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Sudeep Tanwar *Editor*

Fog Computing for Healthcare 4.0 Environments

Technical, Societal, and Future Implications

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Preface

Over the last few decades, we have witnessed various trends in industry standards and applications. For example, Industry 1.0 focused on mechanical engineering and automation, whereas Industry 2.0 focused on electrical energy. The third generation is Industry 3.0, which had telecommunication and information communication technology (ICT) as its core components. However, with the evolution of the Internet of Things (IoT) and cloud computing (CC), the current form of industries, i.e., Industry 4.0, is based on intelligent devices deployment and their usage. Advances in industries allow interaction with billions of objects across the world. According to an industrial survey conducted by Grand View Research, it was confirmed that the revenue obtained from the automobile industry segment was more than 25% in 2016. Also, it was observed that the healthcare sector garnered good revenue, which is more than 15% in 2016. To fulfill the requirements of Industry 4.0, the acceptance of IoT devices is growing at a rapid pace. To make the environment eco- and user-friendly, the healthcare industry needs to be prioritized with respect to service availability (as compared to other industries as mentioned above). Similar to other industries (mechanical, electrical, or civil), the healthcare industry has also developed from 1.0 to 4.0 generation. The healthcare industry is still in its nascent stage as it marked its beginning only in 1970. The efforts were preliminary, and resources were limited; therefore, this stage was termed as Healthcare 1.0. The subsequent gain in the momentum of the information technology (IT) field and in then medical technologies, the development of advanced medical imaging and tracking systems were introduced in the era of Healthcare 2.0. The advent of new and effective treatment methods has started with the intervention of computational methods and data processing systems. In this context, during the period 2006–2015, Healthcare 3.0 became popular due to the use of electronic health records (EHR), an alternative version of patients' data chart. This generation has adopted the EHR to help doctors to get the relevant information on time.

The revolution in Indian healthcare industries with the adoption of artificial intelligence (AI) techniques and the usage of robust communication interface in healthcare systems enable the doctors to analyze the medical data more efficiently to get meaningful insights from it. Such a value-based system enables the healthcare industry to improve the quality of service (QoS) provided with well-informed decisions. Healthcare 4.0 is being considered in the USA, where 90% of the healthcare system has been planned to shift towards a value-based system. In India, it is expected to run the healthcare industry with an estimated budget of 6000 million US$ by 2020. Numbers of healthcare IoT devices are producing a large amount of data at regular intervals; therefore, storage and security of such vast/enormous data are major issues in this environment. Physical data storage in a hospital may not be possible in every situation, so CC, an emerging technology, can handle this situation easily. With high storage capabilities and flexible processing services, CC has considerably expanded the application scenario of wearable medical sensor (WMS)-based systems. Across the globe, investigators and institutions have engaged in developing prototypes to employ WMS-based technologies and services offered by the cloud. Regardless of the multifaceted advantages, the cloud fails to address various issues for the delay sensitive applications:

- In real time, the hindrance in data transfer and processing over the cloud and relay of the outcome back to the user are unacceptable.
- In some cases, just a little delay or lack of application availability due to any reason (power failure, loss of Internet connectivity, cloud failure, etc.) may become life-threatening.

This book is organized into five parts. The first part focuses on the background and preliminaries of fog computing in Healthcare 4.0, which includes six chapters. The second part discusses the enabling technologies for Healthcare 4.0, which has four chapters. The third part illustrates the security and privacy issues with five chapters. The fourth part highlights the resource block for Healthcare 4.0, which has four chapters. Finally, the last part focuses on the next generation health fog analytics for Healthcare 4.0 and has four chapters.

Part I: Background and Preliminaries

The chapter "Adoption of Fog Computing in Healthcare 4.0" presents an introduction to fog computing in the healthcare domain. The major aim of this chapter is to provide a systematic view of the fog computing technology used in Healthcare 4.0. This chapter also gives a comparative study of the different versions of healthcare with current version 4.0. Furthermore, the authors discuss the different researchers' views about the healthcare industry in detail. This chapter also discusses the importance of fog computing in healthcare with some case studies for better understanding in solving health-related issues.

The chapter "Background and Research Challenges for FC for Healthcare 4.0" highlights the background and research challenges of fog computing in Healthcare 4.0, intending to guide the researchers and stakeholders for the overall improvement in the functioning of the healthcare domain. At the end of the chapter, the authors summarize findings to describe the advantages and limitations of existing mechanisms and provide insights into possible research directions.

The chapter "Fog Computing Architectures and Frameworks for Healthcare 4.0" discusses the existing architectures and frameworks available for the healthcare industry. The chapter presents the classification of architectures and frameworks developed for healthcare applications with respect to fog computing. Then, the authors have performed a comparative study of architectures and frameworks based on the issues addressed in them. Along with that, each study was classified on the basis of performance criteria such as low latency, minimum response time, time sensitivity, mobility, scalability, reliability, location awareness, energy efficiency, and power consumption. In the end, the study has been concluded with the future research direction.

The chapter "Importance of Fog Computing in Healthcare 4.0" discusses the relevance of fog computing in the area with its issues and challenges. This chapter focuses on the basics of fog computing, its advantages to the healthcare sector, and details about the features that can be used with it. Then, the security issues of fog computing are also highlighted. Further, a case study is given that provides evidence about the prolific integration of fog computing and IoT.

The chapter "A Comprehensive Overview of Fog Data Processing and Analytics for Healthcare 4.0" highlights the background of fog computing in the healthcare domain with its issues and challenges. This chapter is divided into five major sections, namely architecture of fog data processing and analytics, applications of fog-based data processing and data analysis, data processing algorithms in fog computing and data compression mechanisms, and data analysis mechanisms in fog computing towards Healthcare 4.0. The fog data architecture discusses various layers, namely sensing layer, fog gateway layer, fog-based data processing and data analysis layer, cloud layer, and service layer. Here, the process of sensing of healthcare data, maintenance of data, and various methods to analyze healthcare data are discussed.

The chapter "Data Processing and Analytics in FC for Healthcare 4.0" provides insights about the future of fog computing in healthcare. In the first section of the chapter, the emerging technologies in Healthcare 4.0 and their impact on the healthcare systems are discussed. In the second section, the three-layered fog architecture is discussed. Then, the need for data processing and analysis, along with various stages of data processing, is highlighted. Then, the chapter discusses issues and challenges in fog computing. Finally, the chapter also discusses different use cases involving fog computing.

Part II: Enabling Technologies for Healthcare 4.0

The chapter "Enabling Technologies for Fog Computing in Healthcare 4.0: Challenges and Future Implications" presents an overview of the challenges of Healthcare 4.0. The challenges are regarding the data (data collection and analysis), security and privacy, and e-healthcare services and also present a novel taxonomy of fog computing that can be a better solution to Healthcare 4.0. In the end, the chapter focuses on the future implications of fog computing in Healthcare 4.0.

In the chapter “Healthcare 4.0: A Voyage of Fog Computing With IoT, Cloud Computing, Big Data, and Machine Learning,” the role of IoT, fog computing, and cloud computing has been described along with applications of machine learning and big data that runs on these paradigms. Issues related to cloud computing and motivation behind bringing the fog computing paradigm have also been explained in detail. Several architectures of fog computing are also discussed in this chapter, along with their application and comparison. The application of big data and machine learning modeling has also been explained in the latter part of the chapter. Lastly, case studies related to fog computing, big data, and machine learning in healthcare have been discussed.

The chapter “Fog-IoT Environment in Smart Healthcare: A Case Study for Student Stress Monitoring” provides a case study for student stress monitoring. This chapter proposes a temporal dynamic Bayesian network (TDBN) model to depict the event of stress as conventional or sporadic by readings through physiological means congregated from medicinal devices at the fog layer. It is constructed from four parameters: leaf node confirmations, outstanding tasks at hand, context, and understudy well-being quality. The experimental results aimed at both fog and cloud layers on stress-related datasets that illustrate the usefulness and accuracy of the TDBN model in the proposed system. The final experiments attain an accuracy value of 95.5% and a specificity of 97.3%, compared to the state-of-the-art approaches. At last, Healthcare 4.0 software-based multi-layer fog tools demonstrate their applicability for potential observation and regulation of eHealth.

The chapter “IoT Based Cloud Based Rx Healthcare Expert System” highlights the most up-to-date IoT or fog and cloud-based SMART system proposed and covered in previous literature. The authors propose a comprehensive IoT cloud-based healthcare system capable of monitoring, diagnosis, automatic medication dispensing, interaction between patients and system, interaction of the system with doctors, and interaction of the system with emergency personnel. They also demonstrate a process model of the proposed system. Finally, the chapter discusses the challenges and impact of IoT fog and cloud-based healthcare system.

Part III: Fog-Assisted Security and Privacy for Healthcare 4.0

The chapter “A Secure Fog Computing Architecture for Continuous Health Monitoring” discusses the evolution in IoT, the concept of cloud computing, and related issues. Thereafter, the chapter presents the concept of fog computing along with associated constraints and challenges. Furthermore, it describes the proposed secure fog computing architecture, which is integrating the security aspect in the fog layer. In the proposed architecture, a two-step approach is discussed to maintain the privacy and integrity of health data. The proposed architecture caters to the demand for a secure automated HMS that advocates its widespread deployment in real life.

The chapter “Security and Privacy Issues in Fog Computing for Healthcare 4.0” presents an extensive and organized overview of the security and privacy issues which state the need for security in fog-based medical devices. Different possible attacks and threats are covered with the scenario of the implanted medical device. Security challenges for different segments of fog computing like device, network, and data have been discussed with an in-depth analysis of security challenges, privacy, and trust issues with regard to Healthcare 4.0.

The chapter “Fog-Assisted Data Security and Privacy in Healthcare” explores the field of fog-assisted data security and privacy issues, that is, how patient data can be retrieved for monitoring while reducing the latency and securing the private data of the patient. A pairing-based cryptography technique such as an elliptic curve Diffie–Hellman key agreement protocol and a decoy technique are presented to access and store data more securely along with the help of some cryptographic algorithms. The chapter also includes some of the security issues that may arise in the healthcare sector. Then, the chapter discusses existing resolutions and emergent threats.

The chapter “Data Security and Privacy Functions in Fog Computing for Healthcare 4.0” details the fundamental issues related to the big data health monitoring system by leveraging the fog computing principle at smart gateways, offering advanced network edge techniques and services. Then, a system model for data protection at fog node is proposed. In particular, the chapter presents a case study on electrocardiogram (ECG) as it plays an important role in the diagnosis of many heart diseases. The experimental results show that fog computing helps to reduce encrypt and decrypt time compared to other traditional algorithms, and the information will be transmitted more safely using the proposed approach with less computational overhead.

The chapter “Fog Computing Application for Biometric-Based Secure Access to Healthcare Data” explores the complete design process of a multi-mode biometric-based security layer to provide secure authentication to access healthcare data at the edge devices deployed in hospitals and patients’ smart homes. This chapter discusses the prototype design for authentication of end users of healthcare data and carries out a face recognition experiment for authentication. In the end, a case study is presented and the challenges faced in fog computing implementations in Healthcare 4.0 are discussed.

Part IV: Resource Block and Healthcare 4.0 Applications

The chapter “Efficient Resource Discovery and Sharing Framework for Fog Computing in Healthcare 4.0” describes the challenge and issue of fog computing related to the fog node discovery and utilization of available resources. Then, the chapter describes the proposed frameworks using publish/subscribe and P2P overlays to overcome the problems of resource discovery, sharing, and self-organization.

The proposed networking infrastructure can provide efficient resource sharing, discovery, and self-organization of nodes.

The chapter "Healthcare Using Different Biofeedback for Tension-Type Headache: IoT and Fog-Based Applications in South Asian Context" presents experiments for the treatment of stress. The focus of this study is to compare the impression of electromyography (EMG) biofeedback (BF), and galvanic skin resistance (GSR) and EEG integrated biofeedback on stress due to headache and quality-of-life. EMG biofeedback (BF) and GSR are considered an effective therapy for headaches. In this chapter, the experimental group showed a significant reduction in the level of stress using EMG and GSR biofeedback therapy. Hence, it is concluded that continuous positive thinking has the capacity to reduce stress among students and increase their working performance.

The chapter "Electronic Healthcare System: Mental Disorder Assessment and Intervention with Self-Treatment System Using Rule-based Techniques" facilitates a new version of a quick and practical electronic self-assessment and coping guide called electronic Mental Assessment and Self-Treatment System (e-MAST) for all patients. This system offers patients with three different sets of questionnaires measuring current stress, anxiety, and depressive symptoms generated using rule-based techniques. Besides, the weighted sum method is used to calculate the sum of answers from the patients. It also explores possible life stress domains and self-treatment techniques while awaiting professional help. This system helps to increase the scientific community's awareness of mental health and creates an opportunity to embrace a healthy generation of people. Also, this system can be used at all times, anywhere, and can be of benefit to all towards smart hospital ideas.

The chapter "Breast Cancer Detection Based on Antenna Data Collection and Analysis" presents a simulation of a wearable hexagonal T-shaped microstrip antenna for sensing of breast tumor in an initial development juncture. In this chapter, different distinctiveness of the aerial such as return loss, gain, smith chart, group delay, radiation pattern, and VSWR has been analyzed and observed that the antenna is best suited for breast tumor detection application. From the simulation results, one more application is observed at 1.75 GHz. The proposed work is virtuously dedicated for breast tumor detection, but it can find its application in GPS unit for radar and IoT.

Part V: Next Generation Health Fog Analytics for Healthcare 4.0

The chapter "Yajna and Mantra Science on Healthcare Domain: A Futuristic Scientific Approach with Indian Scenario" presents a deep insight into the impact of yajna and mantra in people's lives. The authors have performed a case study on the impact of Yajna and Mantra science on the healthcare domain considering the Indian scenario. In their case study, the authors took data from different sets of people and analyzed it using big data tools. Also, the authors have used the fog data analytics to find out the impact of Yajna and Mantra science on human health. The proposed study was performed on some patients (men = 4) and (women = 7) with an age range of 44–70 years. The results obtained after undertaking yagyopathy treatment indicated considerable improvement in the healthy lives of individuals.

The chapter "The Interoperability of Fog and IoT in Healthcare Domain: Architecture, Application, and Challenges" discusses the IoT and fog computing, their architecture, their application domains, and their integration and importance in healthcare. A literature survey involving all the works that include fog and IoT is discussed. Case studies involving fog and IoT in healthcare systems are also presented to provide light on how fog and IoT eliminate pressures on healthcare systems that require real-time processing.

The chapter "Application of Fog Computing, Internet of Things, and Blockchain Technology in Healthcare Industry" highlights the amalgamation of fog computing, blockchain, and the Internet of Things (IoT) in healthcare. Fog computing extends the capability of cloud computing that works between the cloud and end user devices called IoT devices to perform operations such as computation, storage, and communication over the Internet. It provides better data storage facilities with real-time access, lower latency, higher response, better fault tolerance, and secure and concealed environment. In IoT, conglomerate devices are interconnected and fragment IoT systems into five layers, such as fog, access, data interface, application, and security layers. To provide better security of the data in the healthcare environment, it discusses blockchain technology and consensus mechanism. This research focuses on the use of technologies for existing patients and normal users and improves the services of the healthcare industry.

The chapter "Social, Ethical, and Regulatory Issues of Fog Computing in Healthcare 4.0 Applications: Discussions and Resolutions" discusses the ethical, legal, and social issues arising with the growth of healthcare data and personal records. Apart from the location of the cloud servers and gateways based on the industry 4.0 architecture, this chapter also provides an integrated model for the adoption of gateways, fog nodes, and IoT devices in their respective areas, with a view of reducing the total installation cost, given maximum request capacity, latency time, devices in use, and reportage area.

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Sudeep Tanwar is an Associate Professor in the Computer Science and Engineering Department at the Institute of Technology, Nirma University, Ahmedabad, Gujarat, India. He is a visiting professor at Jan Wyzykowski University in Polkowice, Poland, and at the University of Pitesti in Pitesti, Romania. He received his B.Tech in 2002 from Kurukshetra University, India, M.Tech (Honors) in 2009 from Guru Gobind Singh Indraprastha University, Delhi, India, and Ph.D. in 2016 with specialization in wireless sensor network. He has authored or coauthored more than 130 technical research papers published in leading journals and conferences from the IEEE, Elsevier, Springer, Wiley, etc. Some of his research findings are published in highly cited journals such as *IEEE Transactions on Vehicular Technology*, *IEEE Transactions on Industrial Informatics, IEEE Transactions on Network Science and Engineering*, *Applied Soft Computing*, *Journal of Network and Computer Application*, *Pervasive and Mobile Computing*, *International Journal of Communication System*, *Telecommunication Systems*, *Computers and Electrical Engineering*, and *IEEE Systems Journal*. He has also edited/authored 10 books with international/national publishers like IET and Springer. He has guided many students leading to M.E./M.Tech and guiding students leading to Ph.D. He is Associate Editor of *IJCS*, Wiley, and *Security and Privacy Journal*, Wiley. His current interest includes wireless sensor networks, fog computing, smart grid, IoT, and blockchain technology. He was invited as guest editor/editorial board member of several international journals, invited as a keynote speaker for many international conferences held in Asia, and invited as Program Chair, Publications Chair, Publicity Chair, and Session Chair in many international conferences held in North America, Europe, Asia, and Africa. He has received best research paper awards from IEEE GLOBECOM 2018, IEEE ICC 2019, and Springer ICRIC-2019.

Part I
Background and Preliminaries

Chapter 1
Adoption of Fog Computing in Healthcare 4.0

Rachna Jain, Meenu Gupta, Anand Nayyar, and Nitika Sharma

1.1 Introduction

With the evolution in industrial technologies, the healthcare industry has also evolved [1]. The current scenario follows industry 4.0, with its focus on intelligent (or smart) devices [2, 3]. Smart devices involving data analytics capabilities empowered with technological advancements such as Machine Learning (ML), Deep Learning (DL) [4], Artificial Intelligence (AI), Big Data Analytics (BDA) [5], IoT, etc. for detection of diseases have become an eminent part of industry 4.0. In today's era, when people are engulfed in their day-to-day busy life, they pay less attention towards their health. Regular medical check-ups are neglected consequently leading to decline in health. Poor health directly affects an individual's efficiency at work. A country's desire for development cannot neglect the well-being of its people, which has a direct impact on the overall growth. The need of the hour is to improve the lifestyle of people by providing them advanced healthcare facilities [6].

Many technologies have evolved to improve the lifestyle of human beings, outsourced through web or network to the people, which may help individuals to get proper diagnosis at less price within short time. From mechanical automation trends

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in industry 1.0 to current trends of deployment of intelligent devices in industry 4.0, many transformations have taken place in healthcare along the way to ease down medical institutional stress and establish a well-organized healthcare environment. The entire process of healthcare transformation has come across many challenges such as maintaining health records, global communication [7, 8], efficient and speedily diagnostic process, etc. Among these challenges, the biggest challenge that has emerged out is the management of the enormous amount of data. Technologies such as BDA, CC, IoT [9], and blockchain [10–13] have joined healthcare 4.0 one after the other to manage the accessibility of data, response time to access data and taking care of security of sensitive data. The latest technology involved is FC, acting as an intermediate between all the above technologies to care of various aspects related to healthcare data. Figure 1.1 shows the trend of FC in healthcare on several research platforms.

Healthcare 4.0 has also incorporated such smart devices bringing a revolution in the sector of healthcare. IoT has enabled these devices to store relevant data for analytics and diagnosis purpose. Data collection has become a significant part of the healthcare sector to diagnose a disease, to examine and to follow up the treatment [14]. The collected data can be used to predict early indications of disease and may provide adequate assistance. It is also functional in providing quality healthcare services in remote areas through enhanced telemedical services. The current technology is extensively using CC technology to store big data [15]. However, processing of the complex healthcare data takes a significant amount of time and also increase cost of speed and bandwidth. The speed cost is tackled by EC approach where different tasks are placed at the edge of the network instead of placing it on cloud. The processing of data on edge devices is called EC. This approach solved the issue of high latency, but in the case of big data [16, 17], a large amount of space is required for storage of data. In this case, enormous storage space used on edge devices makes the overall technology exorbitant. Exercising the complete data computation on edge devices proffers the access of the data to any user possessing access to the device violating security issues. FC was initially designed with the purpose of additional computing resources with increased storage size, which is an extension of CC [18, 19]. Figure 1.2 shows architecture of FC and its attribute [21]. This architecture is divided into three major parts: device layer, fog layer, and cloud layer.

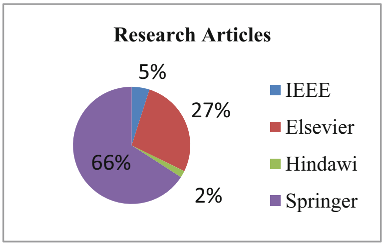

Fig. 1.1 Trend of FC in healthcare 4.0 on different research platforms

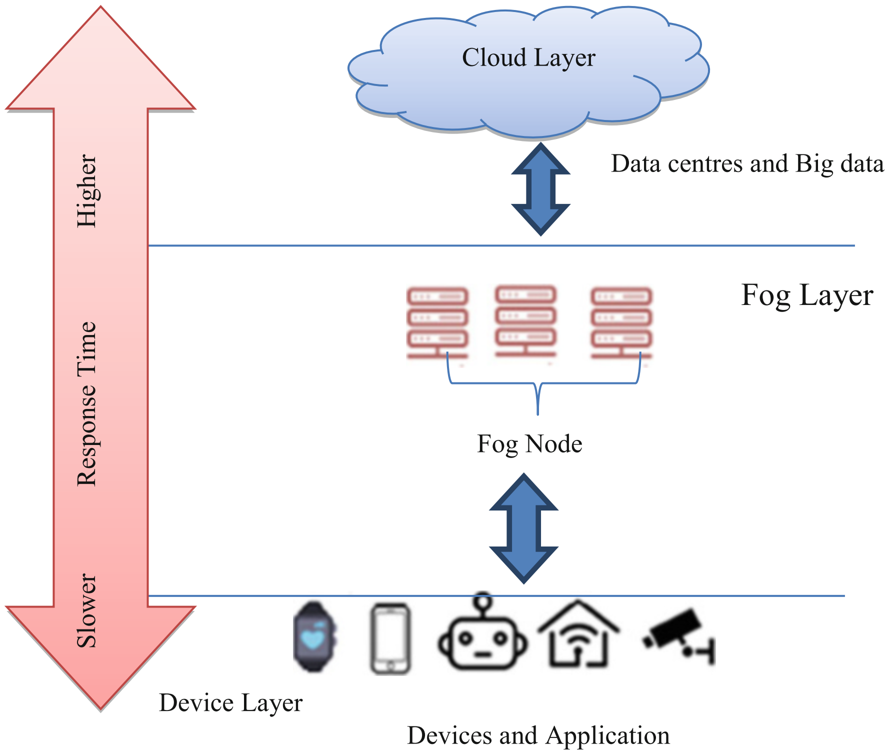

Fig. 1.2 Architecture of FC and its attributes [20]

The device layer works on data visualization, real-time processing, storage of micro data, and embedded system gateways. The fog layer is consisting of fog node which is used for data analysis and reduction. It is connected with device layer (i.e., physical device) for sensing and processing the data. The last layer of this architecture is cloud layer. This layer is used as a data center whose response time is less. A FC framework is distributed over the network with a variety of the different number of devices. These devices universally attached at the terminal of the network to provide adaptable communication, storage services, collaboratively variable and computation. FC gives many advantages in different areas such as real time, low latency, high response time, and especially healthcare applications. It is somewhere in-between the cloud data centers and user devices located at the ground (or at the base level). The topologies of FC are the main characteristics which differentiate it from the other technologies. In FC, the nodes are geographically distributed, perform computations, and provide better storage space and better network services [22]. However, due to high latency and privacy gap in CC, FC came into the picture to solve these health-related issues. In terms of healthcare industry, FC along with IoT came into the picture through which a person can approach a consultant directly. IoT provides a path to people across the world to interact with the respective person for health-related problems, whereas FC send back to the cloud after analyzing the data generated by IoT device.

This chapter mainly focuses on the role of FC in healthcare 4.0. It also gives an overview of different technologies used in healthcare in comparison with current technology. Section 1.2 is an elaborative literature survey. Section 1.3 discusses different types of healthcare versions for providing a better understanding of the role of FC in healthcare version 4.0. However, there are some challenges faced by FC mentioned in Sect. 1.4. Section 1.5 discusses the importance of FC in healthcare. Techniques and technologies used in healthcare industry are discussed in Sects. 1.6 and 1.7, respectively. Section 1.8 gives comparison of FC with other existing technologies. Role of FC in different areas are further elaborated with the help of case studies in Sect. 1.9. The chapter is concluded in Sect. 1.10.

1.2 Literature Survey

The technology has evolved in various fields like home, aerospace, society, and cars. Healthcare is one of the fields which need focus and incorporation of evolving technology as well. Different researchers give different study about healthcare issues and their monitoring method by implementing various techniques and technologies. The studies are considered in this section for a better understanding of the issues and challenges faced in healthcare industries and human beings.

In [23], George et al. discussed the usage of a smartphone as a sensor to keep tracking the health of patients. They used the FC technique for faster analysis about the health of the patients and discussed the advantages of FC over CC in finding health issues of a patient. They considered three types of patients such as critically injured, generally hospitalized, and who need future advice for a regular check-up. They used the IoT application for sensing the data. In result, they concluded that the use of IoT in healthcare with FC gives a significant contribution in providing a better solution for healthcare. Kraemer et al. [24] discussed different use case application for healthcare informatics. They used the FC technique to handle the inventory of application used for a specific task. Further, the author discussed the different types of the task executed by FC at different levels of the network to provide trade-offs with respect to desired need required for healthcare. We can replace In last, authors with Finally, the authors concluded that FC plays a vital role in healthcare application (such as the collection of data, analyzing the data and observation of data in the context of patients, etc.) with computation and it needs to be executed in between sensors and cloud.

Further, in [18], Ahmed et al. gave a study about the various applications of FC in healthcare. They also discussed the different service models of fog such as infrastructure, platform and software service level. This study aimed to help future platform designer in making choices about the features (supported or not supported) and also which application is suitable for their platform and what benefits can be achieved by a platform designer. In [21], Dang et al. have given a study about the different applications, components, and market trend for IoT in healthcare. In this study, they discussed the most promising technology (i.e., CC, big data, etc.) [25] being applied in healthcare industries to provide different policies for e-health regulation. They also discussed how they could assist in health-related problems by using these technologies. Further, they discussed the security issues/risks of the previously designed security model, opportunities, and challenges come in IoT-based healthcare system. In [26], the authors provided an analysis of the role of FC, CC, and IoT in providing uninterrupted services to the end-users. The authors proposed a three-layered healthcare architecture working on real-time data.

Further, in [27], the authors proposed a Mobile Fog Computing (MFC), a smart cooperative strategy to fully utilize social benefits and shun probable problems in rural operations. They initially focused on the drawbacks and challenges faced in moving from cloud platform to fog platform. Then after, they analyzed the design of policy (with example) that comes from a feature comparison perspective, urgent needs, and possible solutions. Further, they evaluate the performance using simulation and validate the results on the basis of two parameters (i.e., round trip time and transmission time). They also discussed the momentous usage of these policies over multiple application categories. For the establishment of policies, they used the timestamp protocol for simplification and implementation procedure. In result, they concluded that the round trip time and transmission time were completely demonstrated when different hop and packet numbers were consumed.

In [28], the authors gave an analysis of the role of FC in healthcare. They also gave the analysis of IoT and CC for their uninterrupted services (when required) to end-user. They also looked for the healthcare industries 3.0, which is hospital-centric. In 3.0, those patients came who suffers from long time sickness and also suffered from multiple hospital visits for their general routine check-ups. This process actually increases the cost of patients in their treatments. This context motivated authors to do work in this area. They discussed how FC and CC could minimize this expenditure of the patients and facilitates in storing the patient's data for fast access. Authors proposed a three-layer medical data collection, storage and distribution architecture in real time. This provides users with insight into the applicability of fog apps and interfaces to existing and future applications in healthcare 4.0 environments.

In [19], Kumari et al. discussed the unique and complex nature of the study of fog results. A comprehensive taxonomy is summarized in a new process model for FDA. This design addresses many research problems, such as availability, scalability, the interaction of fog nodes, nodal coordination, heterogeneity, reliability, and the criteria of Quality of Service (QoS). In the last couple of years, the big data [29, 30] proliferation of intelligent phones, sensors, and IoT has dramatically increased. Creating massive data from these systems ensures that large volumes of information are collected, processed, and analyzed at high frequency with effective results. This paper also concentrated on the evolving intersections of FC and CC technology with particular emphasis on fog-based big data analytics. Through smart cities, health services, satellite imaging, intelligent transport systems, and smart grid, FDA communication provides a wide variety of applications. The FDA is the key to unlock full benefits in modern society from such applications. The paper performed an exhaustive study in FC technology for big data connectivity and analytics with respect to principles related to mainstream CC. In order to carry on this high-priced technology, i.e., FC, they expressed the need to use efficient and efficient algorithms to store and process the data, as indicated from the survey results.

In the questionnaire, they addressed other issues and established a broad taxonomy for the FDA throughout data processing and analysis. Authors have also summarized an advanced level of a process model which for large computing is an extended FDA life cycle. The researchers proposed a new and articulate fog-based remote framework for continuous tracking [31] of safety and prediction of falls in [32]. The system provides remote monitoring of both e-health indicators like glucose, ECG, and the temperature of the body and background information like room temperature, humidity, and air quality. The system offers other specialized capabilities, such as ECG extraction functionality, security, and local centralized shops, by using fog computing on the edge of the network. The findings in the wearable sensor node has shown to function correctly and to be energy efficient, the wearable sensor node. While the node comes with many sensor types, a 1000 mAh lithium battery can run safely up to 157 h per single charge. In fact, they contrasted their findings with other researchers.

This work has explored the viability of RF energy collection as a source for the sensor power supply. Due to its low voltage (0.2–0.3 V), Schottky diodes were used as a rectifying component. The intended frequency range of production is 925 MHz GSM bands. For this purpose, the current work in progress is being carried out by equipping low-threshold transistor linked voltage diodes with mini-solar panels attached to the doors of the transistors. It would help to protect the voltage required for the transistor, allowing the harvesting device more resilient and capable of working even at very low RF signals, −15 dBm, whereas current RF energy collection allows the sensor to work directly in a normal, single scenario, and an effective battery charge recovery system can be used to refill the sensor node and increase its life span. In comparison, the situational sensor nodes and gates can be entirely autonomously operated by a solar power system along with a simple power control tool consisting of a boost converter, a buck converter, and a voltage regulator. In contrast, other than the low cost of manufacturing, lightweight, improved mechanical and thermal properties, the use of elastic wear and printed sensors are being studied concerning rigid non-flexible sensors and are much safer and convenient to track. Table 1.1 gives a comparative study on different researchers view in FC.

In this section, different author's viewpoint about the healthcare system has been discussed. However, due to high latency and privacy gap in CC, FC came into the picture to solve health-related issues. These above studies concluded that FC plays a vital role in the healthcare industry and also improves the e-health care system with the help of additional advantages of FC. It is essential to understand how healthcare has evolved over the years accompanied by emerging industrial trends.

Table 1.1 Comparative study on different researchers view in FC

Authors	Year	Aspect discussed	Description
Ahmed et al. [18]	2019	FC	Detailed review on FC is drawn discussing various taxonomy and its need
Guan et al. [33]	2018	Privacy and security in fog computing	Introduced the challenges in solving privacy and data security in FC
George et al. [23]	2018	FC in conjunction with IoT	Discussed use case of smart phones as health monitoring sensor
Tanwar et al. [34]	2017	Safety management via fog	Implemented an improved safety system for miners where FC layer contributes in dynamic decision-making
Al Faruque and Vatanparvar [35]	2015	Energy management in FC	Implemented prototypes for micro-grid and home management systems

1.3 Generation of Healthcare

The term healthcare means upholding and upgrading the health by improving the diagnostic and treatment methods of disease, prevention of physical injuries, and mental impairments in people [1, 36]. Health industry proposed a different version of healthcare with different functionality. These healthcare versions are discussed below.

1.3.1 Healthcare 1.0

Healthcare 1.0 was the community-based approach that involved one-to-one interaction between the physician and the patient. The technology involvement was restricted only to testing and diagnostic purposes. The medical history of patients was stored either by the doctor or with the patient. The efficiency of the diagnosis and treatment was a dependable factor on experience and medical knowledge of the physician. Healthcare 1.0 can be considered as the classical method of treatment. Figure 1.3 shows patient–doctor interaction in healthcare 1.0. It is simply a combination of some business and science, with a significant emphasis on the art of practicing medicine.

Healthcare 1.0 clearly had some imperfections, such as:

- Treatment involved high cost by the practitioners
- No communication between the physicians
- Unnecessary testing simulates the treatment cost
- Lack of corroborative medical practice

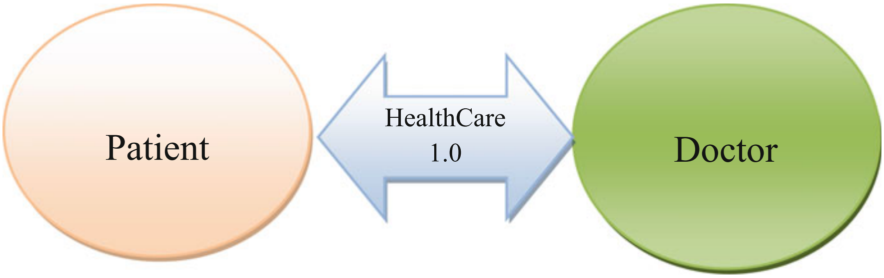

Fig. 1.3 Healthcare 1.0 with patient–doctor direct interaction

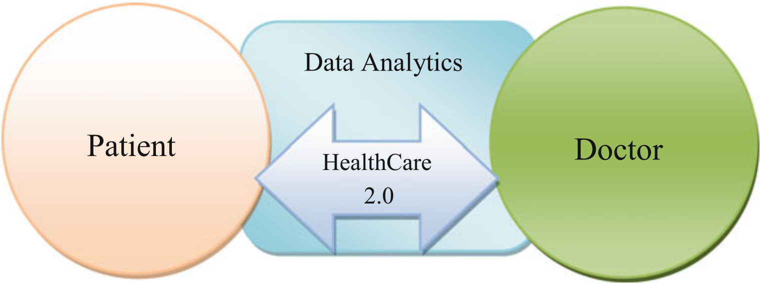

Fig. 1.4 Healthcare 2.0

1.3.2 Healthcare 2.0

The conventional resolution of "Healthcare 2.0" is shown in Fig. 1.4 which focused on technology as a facilitator for care collaboration. It provided the methodical use of social software tools to stimulate cooperation between patients, doctors, caretakers, and other collaborators in health. It focused on enhancing clinical coherence, quality of care, affordability, and fee-for-value. The five major facets of this innovative technology included social networking, substantial patient participation, mediation, collaboration, and public openness. The technology accredited patients to be substantially involved in their own healthcare decisions.

It provided patients with an astounding opportunity to share their Electronic Health Records (EHR) [37] with health professionals and medical researchers. Thus, healthcare 2.0 established a new era of healthcare analytics.

1.3.3 Healthcare 3.0

Healthcare 3.0, also known as Health 3.0, was an initiative to create a value-based model, which was patient-centered to recapture the art of care by recollecting the best parts of healthcare 1.0 and 2.0 [38]. It was a journey that transfigured a system of sick care and vicissitude it to healthcare. The motivation was to lessen the administrative burden and to utilize the capability and experience of the clinicians, by increasing doctor–patient interaction with the incorporation of virtual tools. This initiative redefined healthcare and constructed a system which is empowered instead enslaved by the evidence. Consecutively, medicine is unrestricted by it, provided patients are recognized as unique individuals. Hence, healthcare 3.0 is recognized as an approach that provides comprehensive care for patients. Information and communication [39] technologies played a significant role in healthcare 3.0 through the development of databases and increasing the data efficiency, thus preventing medical related issues.

1.3.4 Healthcare 4.0

Healthcare 4.0 is a successive approach to previous healthcare versions inspired by industry 4.0. It is focused on congregating a patient-oriented system by establishing augmented virtualization and personalized healthcare domain. It is based on sharing patient's records among healthcare professionals through Electronic Health Record (EHR) repositories [40, 41]. The data sharing has enhanced the accessibility of data by doctors at any location. It furthermore facilitates doctors to share their patient's data with their peers for efficient diagnosis and to plan the best possible treatment consequently. Healthcare 4.0 has effectively correlated patients with healthcare organizations through technology. However, data sharing has raised additional challenges such as data security, data ownership, communication protocols, authentication of data, etc. Besides these, the upgraded technology necessitates skill development for it to be used efficiently [6]. Healthcare 4.0 involves several research fields such as robotics surgery, AI, IoT (Internet of Things), CC, Cyber-Physical Systems (CPS), Information Security, healthcare informatics, etc. [42, 43].

It also provides medical assistance through blogs, apps, and websites. Patients are able to connect to medicine suppliers through their websites and get all kind of assistance. The data sharing can take place over the cloud or on LAN connecting multiple patients to multiple doctors or healthcare professionals, as shown in Fig. 1.5.

1.3.5 Comparative Study of Healthcare Industry from 1.0 to 4.0

A quiet revolution is underway in the healthcare industry—both globally and in India—driven by networked E-Health Record systems, AI, real-time data for portable equipment, and improved analytics. In the next few years, the way in which healthcare is delivered and how results are measured will probably change fundamentally. Nonetheless, in order to define the scope, perhaps it would be wise to take a few steps back and understand how this industry has developed and where

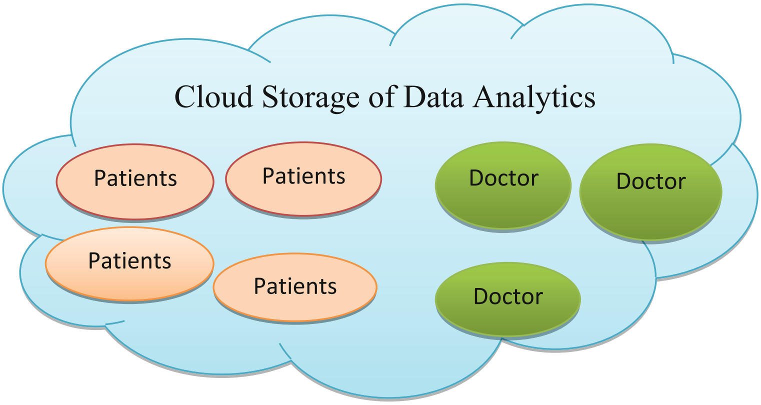

Fig. 1.5 Healthcare 4.0

Table 1.2 Evolution of healthcare industries

Healthcare version	Year	Features
1.0	1970–1990	• In the health sector, MRI and Computerized Axial Tomography (CAT) have been carried out • Modular computing systems have appeared in the health sector
2.0	Next decade and half of 1.0	• Health IT networks continued to network and developed EHRs started to connect with medical imaging, providing a better view for physicians
3.0	2005 onwards	• Genomic data growth, wearables, and implantation development • Health 3.0 was created when these data were combined with the networked EHR programs
4.0	Present era	• All these innovations, combined with the processing of real-time data, were put together. Improved AI use and translucent user interface superimposition • Combined with real-time information collection, increased AI use, and overlay of invisible user interfaces, all of the technologies are being combined

it is based, especially in India before we go to Health 4.0, to understand its different aspects and potential impacts. Table 1.2 has summarized the evolution in healthcare industry.

The growth of the healthcare industry is shown in Fig. 1.6. Any advancement in industrial evolution has concurrently contributed in evolving healthcare industry as well. Mechanical systems and automation was part of healthcare 1.0. The systems

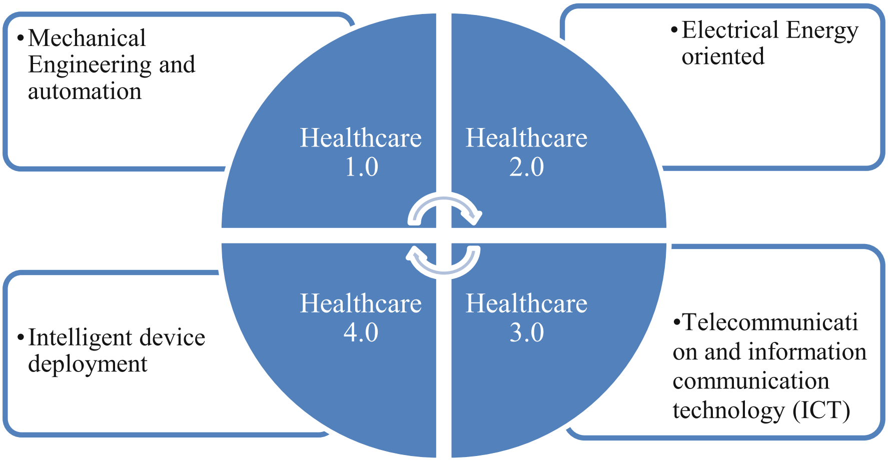

Fig. 1.6 Growth of the healthcare industry from version 1.0 to version 4.0

were enhanced with introduction of electrical energy oriented industrial evolution and involvement of Information Communication Technology (ICT) in versions 2.0 and 3.0, respectively. Healthcare has been made more interactive, faster, and better by deploying intelligent devices in healthcare 4.0.

1.3.6 Classification of FC in Healthcare 4.0

The FC in healthcare is classified in different parts which are followed as:

1.3.6.1 Patients Data Related to Health

The majority of scientists consider this as one of the main components of the healthcare 4.0 environment. Figure 1.7 reveals the proposed FC healthcare 4.0 taxonomy. This group is an organization that uses FC to coordinate current healthcare work [28].

- *Data collection*: The ongoing health surveillance through the use of WLAN and wearable medical equipment is a transformative phase in healthcare. It continues safety monitoring over a wireless network. Biomedical devices, energy efficiency, low-cost electronics, and mobile networks have advanced exponentially and have taken this idea to the fore. Nonetheless, significant challenges and issues still have to be answered. The monitoring systems are the first to collect all information from the human body as they think of continuous medical surveillance [41, 44].

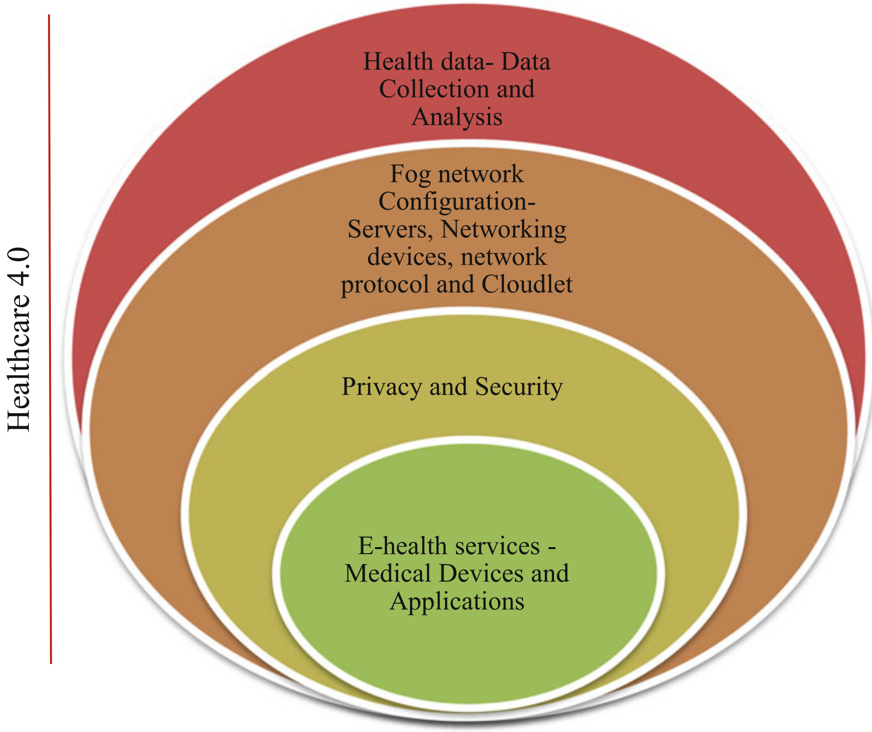

Fig. 1.7 Classification of FC in healthcare 4.0 [28]

- *Data analysis*: There is a considerable difference in long-term continuous monitoring network space and energy needs and the capacities of existing devices. Sample collection systems, compression detection, and anomaly-driven delivery minimize the overhead of wireless communication, encoding, data storage, and authentication [45]. The system should be able to get bio-monitoring from sensor instruments and to send sensed information to portals through a specific wireless communications network, for example, Wi-Fi, in order to monitor the health in real time using global health monitoring systems.

1.3.6.2 Configuration of Node in FC

This requires networking equipment, servers, clouds, and network protocols. Data demand is growing, and the number of sensor devices is bursting. This could be a threat to battery life, contact, and computer power. To cope with all this, Peralta et al. [46] have used an FC method which adds a limited complication of an operational layer between the network and IoT node in message queue telemetry transportation

(MQTT). A Medical Cyber Physical System (MCP) facilitates smart and coherent communication between medical devices and computer entities as the growing drift of health services. Cloud services are usually available in support of MCPSs for storing sensed information from medical devices. Inverse, owing to the complex QoS of MCPS, long-lasting and unreliable links between medical devices and cloud data centers can affect health care services and lost stored information related to patients over network.

1.4 Issue and Challenges in Healthcare

Healthcare is improving and growing with emerging industrial technologies. However, along with the benefits transpire some obligatory challenges. Some of the critical challenges are discussed below:

- *Rise in cost at an untenable rate*: The advanced equipment, services, collection, maintenance and storage of massive data, etc. has accumulated to give rise to an unsustainable cost in healthcare. Healthcare comprises of a substantial segment of physical and financial resources. Rise in cost in healthcare would create an obstruction in the availability of quality in healthcare.
- *The challenge to conception of privacy and ownership of data*: The healthcare websites and search engines collect other non-health-related information from its users. This data is processed and sold to marketing companies which are used for the promotion of products. Customer's profile is private data which becomes accessible to various companies. The personal information thus is at stake [47].
- *Security credentials*: A patient's health information is sensitive data and need not be shared with the rest of the world. Storing data over cloud or edge devices may put this data at risk. Protecting the security credentials of this data is a big challenge in healthcare [48].
- *An extensive amount of complex data*: The health-related data is not only vast but complicated as well. To manage the processing of such voluminous and diverse information becomes strenuous [49].
- *The rapid evolution of science and medicine*: Medicine science experiences rapid changes due to so much research being carried out across different corners of the world. Technology in healthcare has to cope-up with these frequent changes to keep medicine sector at par [50].

1.5 Importance of FC in Healthcare 4.0

Healthcare 4.0 targets services effectively offered by CC and EC. Accessing data on cloud results in inadequate real-time response and non-ignorable delay. Fog computing, on the other hand, is highly consistent as it works on distributed architectures assisting cloud as well as EC [51]. It is an intermediate between a wireless network and wearable medical devices. It gives the provision of larger space interface to edge devices with reduced time delays [28]. It works in conjunction with other technologies to deliver best e-Health services. In other words, it can be said that FC is an amalgamation of telecommunication, sensors, IoT, CC, and big data. Healthcare 4.0 has brought an advanced telemedicine experience to the patients via applications and services [52]. IoT-based medical devices consist of sensors and actuators which interact with cloud, fog, and EC services and provide health data. This dynamic data is highly useful in providing services to patients remotely.

1.6 Techniques Used in the Healthcare Industry

Healthcare industries are more worried about the upcoming health issues faced by a human being, and less awareness about its diagnosis due to lack of time or insufficient resources. In this era of technology or computer era, health industries can do better by providing medical information via the internet and provide e-services to resolve health issues of a person [53]. There are several ways through which the health industry can make human beings aware of health-related issues and their precautions with its remedies. These ways are described below:

1.6.1 Health Awareness to Patients by Sending Direct Email

Health industries are more concerned about their patients' health. They encourage their patients by sending them a direct email (from their patient's database) regarding awareness about some medical conditions. They also remind their patients about appointment procedures or routine health check-up by sending them a direct email. This direct email conversation helps their patients in finding upcoming health fairs where they can participate with their family and also do a practice to a family living in a specific region or ZIP code. This process (sending a direct email) can also help (i.e., patients) in finding the probability of health insurance and Accountability Act regulation in specific medical condition.

1.6.2 Appeal to Specific Segments

New patients can be found by creating a message that appeals to a specific segment in the target market. In general, some people can be convinced by telling them about the benefits of healthcare products and their services. This is especially more convincible to the young adults and helps them to take (or book) an appointment according to the health information technology firm BioMedix. This type of age group person is generally called as Generation X and younger patients who can easily understand the advantages of looking for healthcare on specific medical issues (such as refining their energy level or protecting their kids from getting ill during flu season).

1.6.3 Start Small

BioMedix gives a quote to their patients (who fit into the X generation target market) and is quick to experience buyer's remorse, even with healthcare products. Because of this reason, healthcare industries do not want to push them into a significant risk (like, ask them for significant treatment) they recommend them a small procedure where patients can get more comfortable and able to build their trust in their practices. They also take the initiative for a start small, like a free health fair.

1.6.4 Sharing Healthcare Information at the Social Networking Site

In the present era, the human being is more addicted to social networking sites. This is the easiest and wide area for spreading any information regarding healthcare and reminding them about the current medical issues coming in front of the target market. By the use of health education and awareness in the wellness topic, they can explain different types of medical services and information regarding their products and its offers.

1.7 Technologies Used by Healthcare Industry

Several promising technologies have become part of contemporary healthcare sectors such as AI, data mining (DM) [54, 55], CC, and IoT.

1.7.1 AI in Healthcare

Clinical methods have been re-designed and optimized with the help of AI. The patient data obtained from AI-based clinical methods such as genetics, pathology, imaging, etc. is intelligently integrated to reduce disparity in practice in order to achieve quality and operational efficiency. With the help of AI, medical processes would become more accessible and efficient in managing patient's treatment and would facilitate doctors in making decisions based on medical evidence. AI can succor medical science to find the best possible treatment and assist in lessening the pressure laid on patients to get more accurate with treatments.

1.7.2 DM Techniques in Healthcare

DM has tremendous potential for the healthcare industry to allow health organizations to analytically use data and to recognize incompetence and discrepancies in the system and also suggest best practices that optimize care and minimize the costs [34]. Data mining helps to predict the amount of data required to find adequate methods for unique category of patients. The medical systems are able to build up methods ensuring patients receive pre-eminent care. To develop a model, most common technique used in data mining is classification technique, which classifies bulk data on the basis of pre-classified examples [56]. Eminent classification models implemented in data Mining are decision trees, multilayer perceptron, Naive Bayes [57], ZeroR, KNN (K- Nearest Neighbor), VFI algorithm, etc. Other data-mining approaches likely employed are decision trees, neural networks, clusters, and time series.

1.7.3 CC in Healthcare

CC is re-shaping the way doctors, nurses, clinics, and hospitals deliver optimum cost-effective services to their patients. This transformation is being driven by two factors: the economic importance to minimize the costs and to enhance the quality of healthcare. The cloud has the potential to revolutionize healthcare, rendering it more efficient through a decentralized approach, and enhancing the patient experience by providing services at a significantly lower price. Figure 1.8 shows CC in healthcare.

1.7.4 IoT in Healthcare

The IoT has revolutionized the industry by inter-relating digital devices, machines, computing devices, and people to interact and transfer data over a network without the involvement of human such as wireless sensor networks, building or home automation systems, etc. IoT has been generating an unprecedented volume and variety of data which is stored on the cloud [58]. There are some limitations/challenges in IoT. Immediate action is required in emergency cases; for such situations using cloud for analysis may not be a good choice. FC or EC is a preferred solution [59]. It is one of the most exciting subjects for academics, the public sector, and business. Although conventional internet allows interaction between a variety of small devices and humans, IoT integrates multiple linked

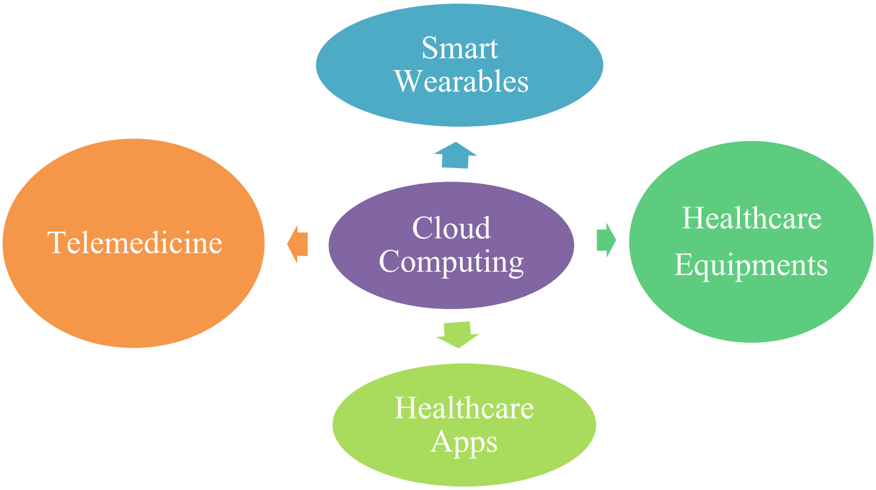

Fig. 1.8 CC in healthcare

"things" into an interconnected, human-free computer intelligence network [60]. The use of information and communication systems and the advancement of wireless communication technology allow patients to receive care in real time [27, 61]. Most detectors and portable devices available can also calculate other physiological parameters of humans such as blood pressure, breathing rate, and heart rate by a single touch. Even though it is still in the early stage of development, companies and industries have quickly taken advantage of IoT technology in their existing systems. They have seen both efficiency enhancements and consumer experience [62]. However, IoT technology integration in the health sector poses several challenges, including data store, data management, data exchange between devices, security [63, 64] and privacy, and unified and uniform access. CC infrastructure is a possible solution to these problems.

1.8 Comparison of FC with Other Existing Technologies in Healthcare

Organizations that heavily depend on data storage and maintenance use technologies such as CC, FC, and EC infrastructures. These technologies enable organizations, including the Industrial Internet of Things (IIoT), to benefit from different computing and data storage tools [60].

The CC system is used throughout the internet to conduct data, processing and manage data on remote servers or devices rather than on a local computer or database. CC provides direct Internet delivery services. The cloud services of any kind, including space, database, applications, devices, network, servers, etc. are supported by cloud [65]. EC takes storage close to the source of the data and does not require distributed cloud servers and other hierarchical structures. Through reducing the distance and time it takes to transmit data to centralized sources, we can increase data transmission speed, efficiency and edge appliances and phones.

FC is a concept that describes how EC operates and allows processors, storage and networking resources to run between terminals and CC data centers. For EC, FC can be used as a jump-off stage. FC offers much more operational flexibility, more in-depth visibility into security control, better data safety, and less operating characteristics [66]. It has an additional edge layer that supports and resembles the cloud and Internet applications. Fog calculation provides primarily low network latency through the availability of immediate reactions when operating with interconnected machines.

The comparison can be made in the following aspects:

- *Latency*: FC primarily operates on the resources stored locally on the computer rather than retrieving remote resources resulting in lower latency issues [67].
- *Capacity*: Storage space available for CC is much more significant as compared to fog computing. A wide range of data can be stored on the cloud. The computations in FC take place at the fog nodes (at the hub of the local area network). Thus, the storage capacity in FC is lesser than cloud but more than edge devices.
- *Bandwidth*: FC reserves a reasonable amount of bandwidth in contrast to CC.
- *Responsiveness*: Response time of CC is lower than the response time of FC as it links both the cloud and the edge platforms.
- *Security*: FC provides with better security as the data is never directly retrieved from the end-users but only from the fog layer proffering advanced security [33, 68].
- *Speed*: The speed of computation is high in FC as compared to other technologies due to minimal data transformations to and from a central server as the data operations, and calculations ensue in the central hub of the device.

The above-discussed comparison of FC with other technologies on various aspects has been summarized in Table 1.3.

Table 1.3 Comparison of FC with other technologies

Features	Cloud	Edge	Fog
Latency	High	Low	Medium
Capacity	High	Low	Medium
Bandwidth	High	Low	Medium
Responsiveness	Low	High	High
Security	High	Very high	High
Speed	Low	High	High
Data sharing	High	Low	Medium

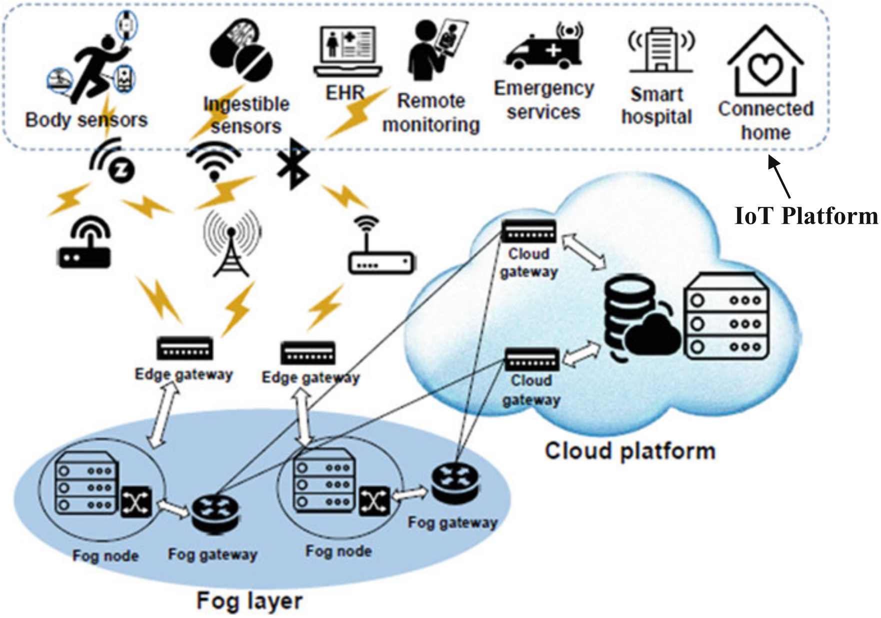

Fig. 1.9 Architecture layer for fog, cloud and IoT platform [21]

The architectural comparison of these technologies has been depicted in Fig. 1.9. Figure 1.9 shows a generic healthcare system that incorporates IoT and cloud technology so that shared medical data and shared infrastructure can be accessed ostentatiously and transparently, delivering on-demand, network-based services and carrying out increasingly needs-consistent operations [69]. Computing resources, including cloud, storage, network, technology, and data analysis, have been distributed by CC over the Internet. It provides quicker delivery, flexible capital, and cost-effectiveness. In fact, the recent transition from hierarchical (cloud) model to distributed (fog) paradigm [70] is headlines. FC conducts edge hardware data analysis so that consumer storage is feasible, data security is enhanced, and prices are reduced. The proliferation of portable devices, AI, and CC mean that the advancement of IoT in the health sector is squarely focused on the revolution of all aspects of human life. IoT reviews published by [52, 71–74] have drawn interested readers to obtain a more detailed and thorough knowledge of various areas of IoT technologies allowed, their current development progress, and the key issues that must be addressed by researchers. In addition, [69, 75] used to gain insights into CC and FC applications with their everyday usage situation. The different problem in the deployment of CC and FC systems with possible future research that need to be done is discussed further.

IoT offers effective technologies for all life facets, for example, smart towns [76], smart roads, waste management, systemic health monitoring, security and emergency services, supply chains, distribution, environmental management [77], and healthcare. Through 2030, 500 billion smartphones, roughly equal to 58 smart devices per person on our planet will be connected, according to a CISCO report. Statist's analysis into IoT markets at the end of 2017 found that by 2020 the aggregate IoT business value is going to hit USD 8.9 trillion and that 7% of the total market value is from the healthcare sector. Due to the incorporation into the healthcare sector of IoT and CC, health professionals will deliver quicker, more effective and optimized healthcare services, leading to the better patient experience. It leads to better healthcare services, enhanced patient experience, and less red tape for health professionals.

1.9 Case Studies

The role of FC in healthcare can be understood through the following case studies. This study covers different aspects of the disease and the milestones achieved to improve healthcare through the development in the industry.

1.9.1 Case Study 1: Impact of Healthcare 4.0 with FC in Rural Areas

In terms of education, rural areas are impoverished. Availability of excellent faculty is the primary concern and issue for good quality of education. With the help of emerging technologies such as fog computing and IoT (Internet of Things), educationist provides an excellent platform for learning and teaching for students as well as teachers to receive real-time video lectures. Moreover, these kinds of methods help them to understand the concepts from baseline, and these idea exchange mediums help them to make their future better. These methods also help them to solve their queries through shared medium and interact with the concerned person without latency. Nevertheless, when we are talking about the awareness for the medical-related problem, rural area people suffer a lot due to the unavailability of well-trained medical staff and lack awareness about medical problems [78, 79]. Sometimes due to financial problems, the local government and the people living in such areas do not have availability of well-trained medical staff in their region. Due to these issues, a human being suffers a lot [27]. People in rural areas have struggled for a long time to sustain access to quality healthcare [80]. The difficulties faced by rural hospitals and other facilities have been recorded in comprehensive literature, and rural Americans are often not equipped with essential health services [81–84]. Such issues in rural areas were exacerbated by various elements: demographic growth, economic stagnation, lack of medical practitioners and other health professionals, a large number of elderly, disabled and under-assured people, as well as high rates of chronic diseases.

1.9.2 Case Study 2: ECG Monitoring Using Healthcare 4.0

Throughout conjunction with body movements, blood glucose plays an important role. For instance, the brain uses glucose only as its source of energy. Nonetheless, this has some severe consequences if the blood glucose rate is high. In the case of low-blood glucose symptoms known as hypoglycemia, for example, heart repolarization can lead to sudden cardiac death. Diabetes can be treated for more extended periods as high blood glucose level is harmful because they can cause heart disease, stroke, cardiac insufficiency, and other aggressive diseases directly or indirectly.

One way of reducing the severe consequences of diabetes and hypoglycemia is to monitor blood glucose levels continuously for real-time reactions like insulin adjustments from the insulin pump. Nevertheless, it is a failure purely to track blood glucose without taking into account other signs or information such as electrocardiography (ECG) and the state of the operation since it has close ties [85]. Hypoglycemia, especially in people over the age of 65, can easily lead to a fall. The effect of dropping is risky in the absence of drop detection [32].

FC can provide healthcare industry advantages particularly, such as diversity assistance, rapid delivery of the request in real time. It is perfect for analyzing and gathering fragmented information. The electronic health surveillance system will be improved by improving FC in smart ways with disseminated storage, integrated real-time alert services, and data mining, all operational on the edge of the network. ECG collection primarily holds a noteworthy function in the treatment of various heart disorders. The different signal components of the ECG were defined in this case study, e.g., PR interval, QT interval, RR interval, P wave, pulse train, and T wave. Such signals have been analyzed using the Cambridge Technology Institute, Beth Israel arrhythmia registry to minimize data, by using a Dynamic Time Warping (DTW) technique. These signals are scanned. This algorithm is used to determine variations in information from time series. Different applications like walking patterns detection, business, finance, and ECG signalling analysis use this algorithm. In fact, by the Euclidean distance, the distance between two points is determined. The distance between the Euclidean series and out-of-phases cannot identify any correlations. DTW method can detect similitude among two sequences, regardless of phase difference and duration of signals. This produces a matrix adjacent to it and determines the shortest path. The ECG data sets were given by the Internet registry on the fog machine. The main objective is to classify arrhythmic ECG bats with QRS-complex measures and the RR interval. ECG signals generate QRS complexes using real-time signal processing. This method of data reduction is built at fog node like Intel Edison in python. The ECG signal of 2500 used in the proposed architecture took around a second processing time at the fog node.

Thus in Fig. 1.10, which is well suited for real-time ECG tracking, the researchers [28] suggested that group structure is illustrated. Alternatively, the GNU zip software is used for compressing ECG time series to compress the data. The compressed files are then forwarded to the cloud. Figure 1.10 shows an increased percentage of

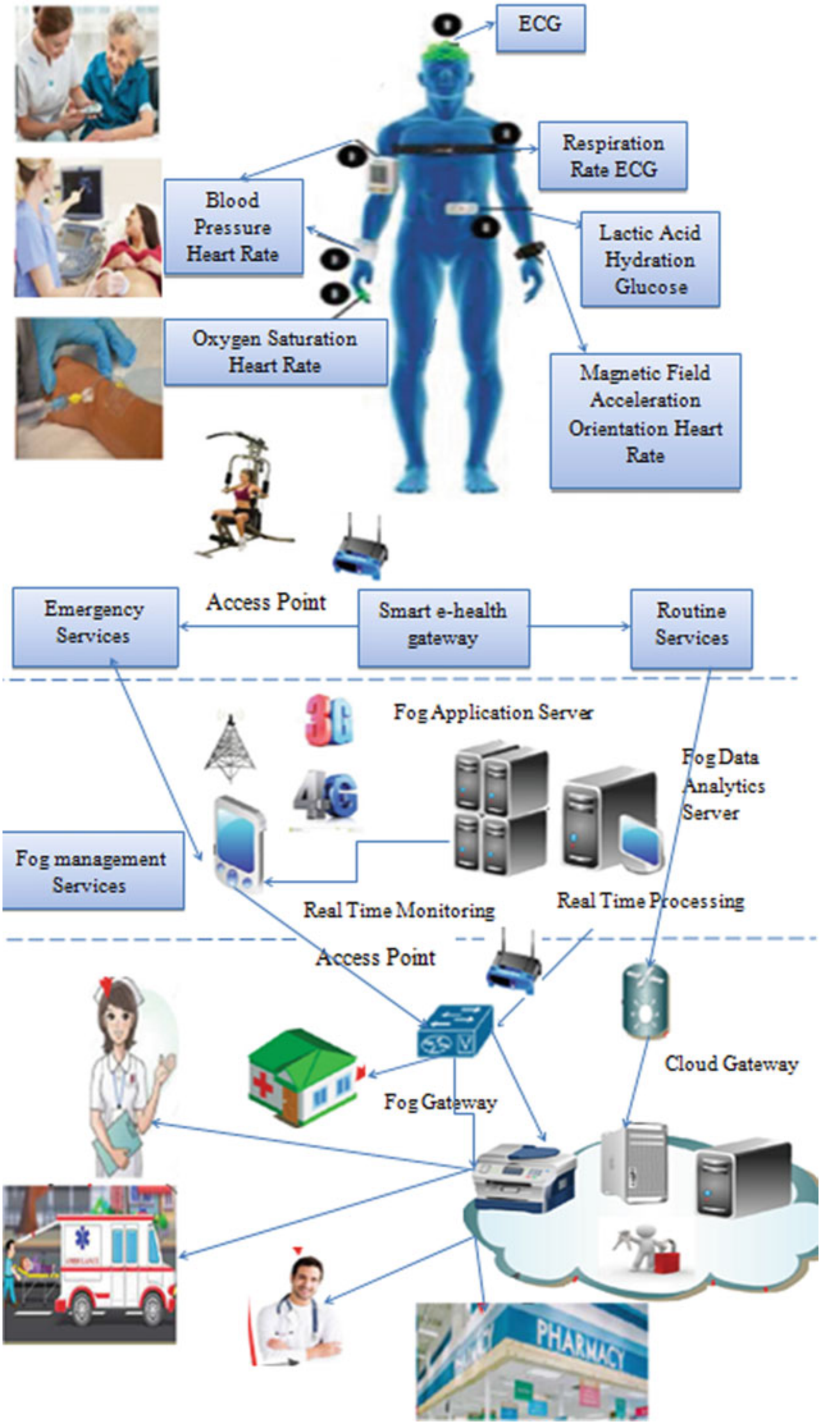

Fig. 1.10 Three-layer FC-based e-health architecture [28]

FC data compression. The DTW displays the ECG time series prototype sent to the internet. In contrast, encoding displays the ECG data compression rate. It helps reduce the time at which the files are executed. ECG signals are further analyzed in intelligent gateways with the practical abstraction of heart rate.

1.9.3 Case Study 3: Smart Grid in Healthcare 4.0

We present a case study on Smart Grid (SG) in order to validate the FDA template of big data analysis. Smart metering/adapter's true value is the application of real-time data, for example, in order to generate real insights into loss control, better demand balancing, and enhanced energy quality and reliability. Not only is data analysis necessary for utilities, but it also allows consumers to make use of essential changes in their usage habits to reduce their average bill price by optimizing their daily use of energy. These analyses helped to investigate on the ground suspicious cases and to find cases of conventional meters defective [86]. When connectivity efficiency in the network grows, the SG provides consumers and providers of energy supplies with justifiable products. It outlines the following [87]: the automated SG framework, the protection of the atmosphere (the decrease of gas emissions and climate change) [88], high-quality and reliable [89], security and privacy, efficient use of assets [35], minimization of energy costs and improvement of the SG QoS [90].

This section discusses the working of the current SG FDA system design in the intelligent home scenario. These requirements are: SG generates power to different traffic, renewable energy supplies produce local heat, and multiple-intelligent home electrical equipment absorbs different amounts of renewable energy. Using a smart meter, the consumer can track and display data about energy consumption [91]. Electrical appliances like an aspirator, air conditioner, washing machine, television, and electric cars consume energy. There are considerably large intelligent homes in an area, and a massive amount of data has to be stored and handled on the fog database of that particular region. Fog servers temporarily retain energy consumption data so that fog servers can respond quickly to customer inquiries. These data are then transferred to the cloud for permanent storage.

This FDA process design allows SG to provide its consumers with detailed information at low latency. It allows clients to assess and track energy consumption per hour/day/week/month/year. A detailed analysis can reveal important personal information. For example, analyses of TV's energy use may disclose hints about whether or not the consumer has their homes or equivalent analyses of dishwasher's power consumption can reveal eating habits. The protection of such private information involves the use of publicly and privately owned security measures. Data is divided between public and private smart meters in the current system model. In contrast, the cloud does not exchange encryption keys, which in effect provides increased protection on the FC. Using local fog servers, customers can safely access accurate energy consumption information [92]. FDA further decreases the time for entry and information search. On the local fog list, the customer can delete private

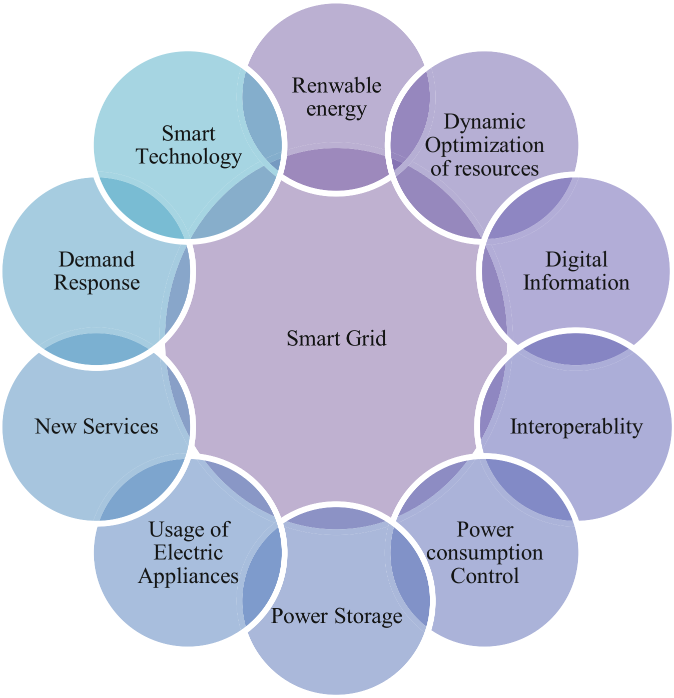

Fig. 1.11 Big data analytics services in smart grid systems

information. FC is essentially a smaller, more efficient version of the CC. When aggregated data stored only on cloud servers [87], SG data storage is growing. Figure 1.11 demonstrates the integration of smart grid deployment of the new FDA system model. In this smart grid, network reflects the different analytical services related to BD.

In the sense of diversity, real-time connectivity, and in particular interoperability, the debate of FDA for IoT system calls for both stockpiling and FDA storage. In these and other areas, accelerated innovation development produces an unprecedented level of enormous amounts of DB. However, current approaches to processing data generated are not sufficient compared to their exponential rate of growth. There are currently very few FDA-related problems with IoT implementations with devices and technology. On the basis of a review of the literature, possible research challenges are described in this chapter which includes the creation of the FDA life cycle system model. Based on the comprehensive literature review, problems and concerns are outlined in Fig. 1.12 that also discuss FDA in IoT applications; the primary research challenges associated with the FDA have been identified.

Fig. 1.12 Research challenges in fog data analytics

1.9.4 Case Study 4: Monitoring of Diabetes Through Healthcare 4.0

A most common and chronic disease is diabetes. It is a metabolic condition with elevated levels of blood sugar, resulting in severe damage of heart, blood vessels, skin, kidneys, and nerves over time. Type 2 kind of diabetes is generally found in adults, when the body becomes resistant to insulin or stops producing sufficient insulin. The occurrence of Type 2 diabetes has increased considerably in all countries in the past three decades.

- *Type 1 diabetes*: It is recognized as the deficiency of insulin production and generally developed during childhood also referred as juvenile diabetes. This type of diabetes requires regular insulin administration. The prevention is not possible since actual cause of this chronic disease is yet unknown. The disease can be acknowledged with the sudden appearing symptoms of weight loss, thirst, constant hunger, fatigue, and increased excretion of urine.

- *Type 2 diabetes*: Inefficient use of insulin by the body results in type 2 diabetes. Type 2 diabetes is mostly due to increased body weight and physical inaction and comprises people with diabetes worldwide. Symptoms of type 2 diabetes can be similar to type 1 diabetes but less severe. Consequently, the condition may be diagnosed when the symptoms have already established with several years of onset. The adults were found to have this type of diabetes until recently however, it is increasingly being observed in children as well. Access to affordable care, including insulin, is vital to survival for people living with diabetes. The international goal is to curb the increase in diabetes by 2025. Diabetes of type 1 with current knowledge cannot be prevented. There are successful strategies to avoid type 2 diabetes. Research is being conducted to prevent complications and premature death caused due to the disease. It involves policies and practices that lead to good health for all in entire communities and within different environments (school, residence, workplace), irrespective of whether they have diabetes, such as regular exercise, healthy eating, cigarette avoidance, blood pressures, and lipid regulation.

  This calls for a government-wide and comprehensive approach, in which the health impact of commerce, agriculture, finance, public communication, education, and urban planning policies are routinely taken into account by all parts—understanding that the health is improved or hindered by policies in these and other fields. All individuals with type 1 diabetes and many with type 2 require medicine to minimize glucose levels in their blood. There should, therefore, be a closer look at access to essential medicines and fundamental technology in a diabetes management discussion. Governments must ensure funding for the management of essential medicines and technologies for the diagnosis. As documented by the WHO reports,

- The number of diabetes patients rose to 422 million in 2014, from 108 million in 1980.
- Among adults aged 18 and over, the worldwide prevalence of diabetes rose from 4.7% in 1980 to 8.5% in 2014.
- Across middle- and low-income economies, the occurrence of diabetes has increased more steadily.
- Blindness, kidney failure, heart attack, stroke, and lower limb amputation are the significant causes of diabetes.
- Estimated deaths from diabetes were 1.6 million in 2016. In 2012, another 2.2 million blood glucose deaths were related.
- Nearly half of all deaths related to blood glucose occur before 70 years of age. World Health Organization reports that in 2016 diabetes was the seventh leading cause of death.
- A healthy diet, physical activity, and maintaining normal body weight are a means of preventing or reducing the development of type 2 diabetes.
- The consequences of diabetes can be treated with diet, physical activity, drugs, regular checking, and complication treatment avoided or delayed.

Fig. 1.13 Smart glucose monitoring systems [27]

Severe diabetes cases can affect other organs, like the kidneys, ears, knees, etc. These cases require regular blood sugar testing. Blood sugar levels may be monitored by random blood sugar test, fasting blood sugar test, and oral glucose tolerance test. Regular visits to hospitals and doctors to track blood sugar levels are not feasible for an individual. Any negligence affects the health of the patient and may lead to serious health issues. Healthcare 4.0 has provided a solution to this problem [20]. Intelligent glucose monitoring systems are introduced to keep regular track of recent and previous records, as shown in Fig. 1.13. Such apps are compact, portable, and compatible with smartphones via mobile applications. These IoT-enabled devices efficiently use FC technology to connect to the nearest hospitals and other health centers. Emergency conditions are adequately addressed by the integration of technology in healthcare 4.0.

1.9.5 Case Study 5: Role of FC in Healthcare 4.0

The primary function of FC is data sharing. The potential uses for data sharing are population health management, genetic studies, chronic disease registries, disease monitoring, and even routine patient care interoperability in the emergency department. Besides clinical and patient-centric application, the data exchange is important to ensure that best practices can be exchanged between healthcare organizations or among other companies such as financial institutions or government institutions.

- *Remote diagnosis*: An increase in patient's engagement with their own health is observed by the doctors due to internet connected wearable health gadgets. This has led to decrease in hospital costs by 16% over the coming 5 years. Online consultations provide enhanced convenience to the patients meeting their demands assured with wearable devices and improved resource efficiency with robotic surgeries. The entire healthcare ecosystem is benefitted with such technological transformation taking place.

- *Large data files storage and accessibility*: Incorporation of FC to operational architectures can facilitate fast and reliable transfer of huge data files of medical imagery, which can improve both accessibility and the quality of care.
- *Web presence of pharmaceuticals*: Several pharmaceutical companies have established their presence on web platforms to provide assistance to patients to find right medication. Through such websites patients are able to keep the track of their regular medicine requirements. These platforms are well maintained and provide detailed description of drugs such as its composition, consuming methods, and side effects. Patients are able to purchase medicines on internet and deliver at their doorstep. The facilities [93] offered by these global pharmaceuticals have largely reduced the complications arising due to allergic drugs. This has helped reduce the burden of treatment on patient and their caretakers by making it possible to identify and timely address the emerging side effects.
- *Wearables*: The fitness gadgets are a proven example in enhancing people's health across the globe. People using these monitoring devices are much more aware of their health habits and are able to take proper measures to maintain good health. These wearable gadgets comprise sensors and fit on wrists or arms. These devices are easy to use and intelligible. Every patient responds differently to same kind of treatment, which makes it necessary to customize treatment as per the patient's need. The Internet of Medical Things (IoMT) have eased doctor's task in identifying right treatment.

Some of the smart medical monitoring devices that have assisted doctors in making medical treatment better are discussed as follows: A device named CYCORE [94] was tested on patients. The ones using this device were observed to have less severe cancer symptoms in contrast to the patients, part of the control group who had weekly visits to the physician without any monitoring device. Another device which is used to monitor a chronic disease, diabetes discussed in case study 4 is Continuous Glucose Monitor (CGM). Readings taken at regular intervals through this device can help monitor blood sugar levels of a diabetic. Smart inhaler technology introduced by Propeller Health has helped asthmatic patients to identify allergens causing asthma symptoms and alerts with the forecast. It also helps to track the exercise of medication used for rescue. Several other monitoring devices are being developed to assist medical treatment and are consistently improving the quality of healthcare.

1.10 Conclusion and Future Scope

This chapter discussed the connotation of FC in amalgamation with healthcare 4.0. FC has emerged as an effective solution to various challenges transpired in healthcare. The study has been carried out with an outline drawn on various technologies used in healthcare in comparison with current technology. Previous versions of healthcare discussed in this chapter provide a better understanding of the role of FC in healthcare version 4.0. Issues and challenges in healthcare have been discussed, followed by technologies employed in the health sector. It was inferred that among all the healthcare versions, healthcare 4.0 is currently working for the best as it facilitates the support for intelligent edge devices. Case studies based on rural areas, ECG monitoring, smart grid, and diabetes handling have also been included in this chapter. FC has been recognized as a well-designed technology for the computation of data comprising the advantages of cloud as well as EC concluded from the comparison with other technologies.

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Chapter 2
Background and Research Challenges for FC for Healthcare 4.0

Shivangi Surati, Sanjay Patel, and Keyur Surati

2.1 Introduction of Fog Computing in Healthcare 4.0

The Industry 4.0 is extended to the "Healthcare 4.0" that leverages the situation where different stakeholders of healthcare domain, *viz. doctors, nurses, hospitals, and patients* are strictly interconnected with the procedure, the technology, and the organization. It is mainly subdivided into two tracks: patient monitoring system and health and fitness monitoring system. The patient monitoring system aims to digitally monitor the patients suffering from the diseases (inside or outside hospital premises) or the patients who have undergone the operations. The health and fitness monitoring system is widely adapted by the healthy community to continuously monitor and take follow-up of their health. This improved healthcare provision is made promising with the use of various healthcare sensors, *viz. wearable sensors (skin sensors, sensors for monitoring heart rate, respiration, pulse, temperature and blood pressure, hemoglobin and glucose monitor, smart watches, motion sensors) and implantable sensors (chemical sensors, glucose and oxygen sensors for diabetics, neural implants, and cochlear implants)* [1, 2]. However, this resulted in the diverse and massive volume of Patient-Generated Health Data (PGHD) having following characteristics and key objectives [3–5]:

- Mobilized due to the mobility of patients
- Geographically distributed and decentralized
- Heterogeneous
- Security and privacy concerned for severe diseases

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- Require real-time (live), fast, accurate, and safe clinical decisions
- Require continuous and timely observations in case of critical patients
- Minimized repetition of investigative testing, imaging, and the past records
- Enhanced medication organization
- Increased implementation of testing and examining requirements and protective health procedures

Due to these characteristics, healthcare became a uniquely challenged domain that raised the major issues to be addressed, *viz. (1) minimum latency time, (2) real-time rapid interaction, (3) infrastructure, resource and network management such that data available to all stakeholders in timely manner, (4) interoperability and scalability, (5) location awareness for the decentralized and distributed data, and (6) security and privacy of patients' data*. Initially, Cloud computing was preferred for the aggregation, storage, analysis, and maintenance of healthcare related data because of its high computation power and storage capability. However, transfer of the data and requests to the centralized Cloud computing model increase the latency time for processing the data and transfer them back to the organizations. Even though there is a rapid upgradation in the computation speed, the network bandwidth becomes bottleneck for the healthcare data as it has not been improved significantly. In healthcare domain, long latency due to delay in the data transfer is not acceptable especially in life threatening situations. For example, during ECG monitoring of patients, the cardiologists assessed the maximum time and delay for which the monitoring process could be paused/obstructed without discomfort of the patients. As per their observations, these readings are 15% and 3 or 4 s, respectively, depending on the patients' condition [6]. Not only that, the patients in the rural areas may suffer because of latency constraints and inadequate infrastructure.

Another limitation of utilizing Cloud computing is dependency on the centralized server located at distant place. Apart from that, the data related to the healthcare domain can be analyzed and decisions can be taken locally, without immediate transfer of data to the Cloud. Later on, only useful data can be transferred to the Cloud storage for further analysis and decision making. Motivated by this, high tech industry companies and academic institutions across the world formed a public-private ecosystem known as OpenFog Consortium. The aim of this consortium is to develop and accelerate Fog computing framework to be utilized even at the base level applications. The fog computing is mainly popular because of its topology where the geographically distributed nodes (fog nodes) perform computation and also provide storage and network services near the edge of the network of the user/application. The infrastructure, resources, and network are managed such that the data are available to all the stakeholders quickly through real-time response using fog nodes (Fig. 2.1). The fog node is any device with computing, storage, and network connectivity, *viz. routers, switches, gateways, embedded servers, and sensing devices*, depending on the specific application and domain.

For the healthcare domain, the aggregation, filtration, storage, analysis, and maintenance of healthcare data are performed using fog computing such that the

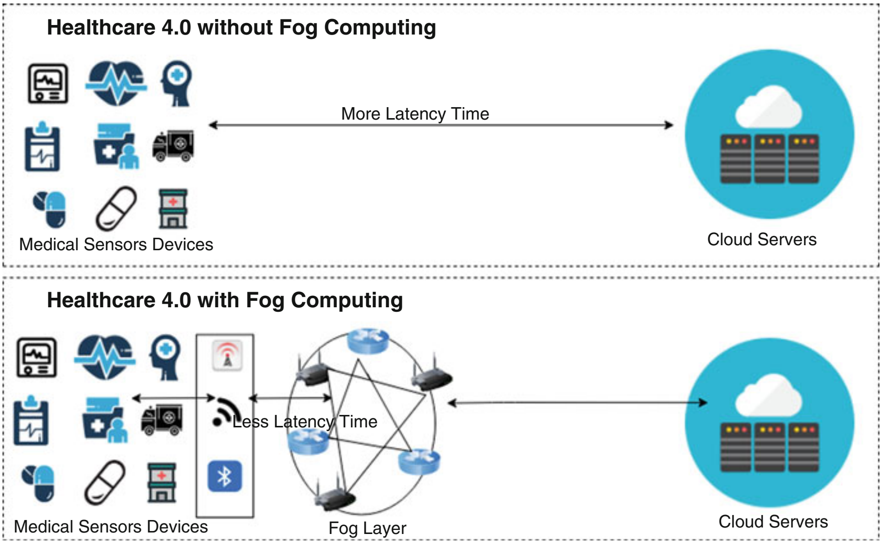

Fig. 2.1 Importance of Fog computing in Healthcare 4.0

data is continuously available, portable, consistent, accurate, scalable, secure, and quickly transferable. The fog computing in the healthcare domain is evolved in the recent years due to the following advantages [7–13]:

1. **Low-latency time, low bandwidth utilization, and low energy consumption:** The fog computing performs the storage and computation locally, i.e. closer to the application devices. This reduces the delay due to the physical distance to transfer the data and the response time to receive the processed data and hence reduces the latency time. In addition, the amount of data to be transferred to the distant data centers is reduced as the computation tasks are performed at local nodes known as fog nodes. Thus, fog computing is prominent due to low bandwidth utilization, especially when network connectivity is limited (rural areas, old-age homes). This decreases the overall cost overheads and energy consumption and is advantageous in case of time-sensitive healthcare emergency as compared to Cloud computing.
2. **Support of heterogeneity and interoperability:** The fog computing supports various types of health sensors and context sensors (static as well as mobile). In addition, it supports technical interoperability (different network interfaces, operating systems and standards) and syntactic and semantic interoperability (different formats of messages, meaning of data and vocabulary, different communication protocols) at fog nodes.
3. **Reduced dependency and provides location awareness:** The use of Cloud computing infrastructure largely depends on the network availability, speed, and connectivity. Poor network connectivity or Cloud/network failure is not acceptable in case of healthcare data and its processing while experiencing

the life threatening scenarios. On the other side, fog computing provides more resiliencies against these issues as real-time and on-line analysis of the healthcare data is controlled at the fog nodes (closer to the healthcare application devices).

4. **Scalability and elasticity:** The applications can be executed by a single fog computing node or by the multiple fog nodes together. This improves scalability and offers elasticity as more fog nodes can be added as and when required by the application.
5. **Decentralized and distributed:** The medical professionals and patients at geographically distributed locations (even at remote and distant locations) can contact each other and send/receive the data quickly. The decentralized architecture of fog computing improves the system reliability and consistency as the data is analyzed locally and the sensory data provides local feedback.
6. **Real-time push alerts/notifications:** The fast computations and reduced latency time result in real-time rapid interaction with the medical professionals. This helps them in taking quick decisions in case of emergency and they can provide high quality care to the patients.
7. **Security and privacy of patients' data:** The data is processed locally at fog nodes and later on, they are transferred to the Cloud servers. Thus, if the patients' data contains any confidential information, then it can be filtered out if it is not essential to store it on Cloud. This considerably improves the privacy and security of medical data. Thus, nation wise, state wise, district wise, or hospital wise secrecy can be maintained by fog computing in healthcare 4.0 only.
8. **Integration of new applications:** Innovative sensor devices and supporting applications are being developed rapidly for improved and continuous monitoring of patients. This often requires simultaneous support of infrastructure and healthcare professionals' expertise for the same. Fog computing supports easy integration of intelligent devices and sensors with the enhanced expertise of stakeholders.
9. **Supports patients' mobility:** The development of the infrastructure and resources for application-oriented limited premises (hospitals of smart buildings) also bounds the patient monitoring area. When patients leave these highly instrumented infrastructures, these motilities should be covered by the computing technology so that the patients do not need to stay for longer. Such transitions between different infrastructures can be managed efficiently by the fog computing resources.
10. Lastly, fog computing improves the automatic supervision of the health of the patients while handling the emergency situations as well. This helps in reducing the manual supervision and pen and paper work.

2.2 Background of Fog Computing in Healthcare 4.0

The evolution of fog computing in Healthcare 4.0, overall view of taxonomy used, and architecture of fog computing in Healthcare 4.0 are discussed in detail in this section.

2.2.1 Evolution and Enablers of HealthCare 4.0

In medical industry, HealthCare is in current trends that includes various key techniques and applicability of IoT and fog computing. The evolution of industry has various stages based on the needs and the issues of the respective era [14].

Industry 1.0 At the end of the eighteenth century, first industrial revolution began with the invention of steam engine and development of railway. The first mechanical system was instantiated by constructing the mechanical weaving loom in this duration.

Industry 2.0 In the starting of the twentieth century, electrical and assembly line triggered the second industrial revolution. This resulted into the mass production that improved the industry.

Industry 3.0 The transition began towards the automation because of evolution of information technology and micro-electronics applications led to third industrial revolution. It prompted the computer or digital revolution in 1960s resulting in main frame, personal computer, and Internet.

Industry 4.0 With the fourth industrial revolution stipulated in twenty-first century, the computer system became more integrated. This evolved various technologies, *viz. automation, identification, computer, network communication, digital manufacturing, production process, production control management, decision making, judgment, sensing, and analysis*. These technologies make an extensive use of sensors, artificial intelligence, machine learning, cyber physical systems, 3D printing, and many more. The healthcare extension of industry 4.0 is termed as Health 4.0.

2.2.2 Taxonomy of View of Fog Computing in Healthcare 4.0

The overall view of the fog computing in Healthcare 4.0 is shown in Fig. 2.2. Beginning with the collection of data, the fog computing in healthcare 4.0 can mainly be elaborated by the data analysis, configuration of fog nodes, service level objectives, and privacy and security concerns [4, 7, 15, 16].

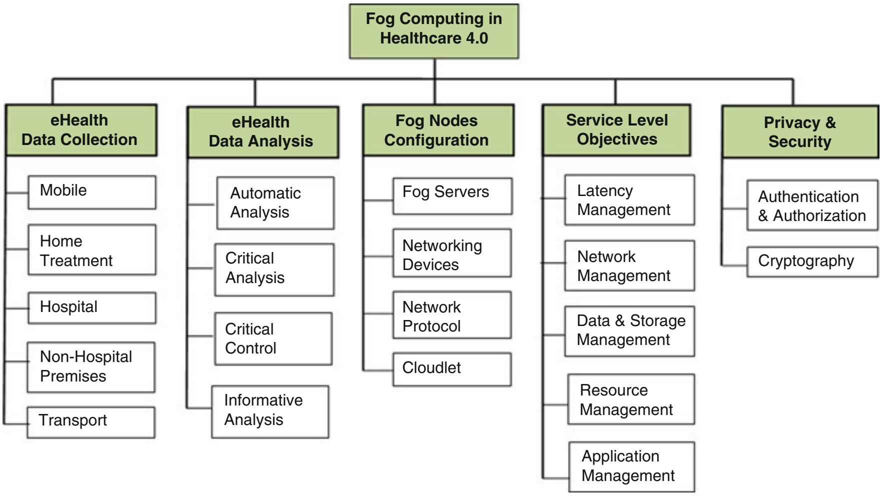

Fig. 2.2 View of Fog computing in Healthcare 4.0

2.2.2.1 eHealth Data Collection

The eHealth data can be collected by the deployment of sensor devices at various locations.

- The mobile phones of the users can be used as base unit and to collect the data of patients, for example, the method to monitor the Chronic Obstructive Pulmonary Disease (COPD) patients.
- The patients' Internet connectivity is often used in home treatment and fog computing is used to process the data, for example, monitoring of patients having Parkinson.
- When data is collected from the hospitals, the devices and infrastructure of hospitals are used, while in non-hospital premises, it is partially shared between professional care and devices from the hospitals and personal devices/connectivity from patients.
- Lastly, the connectivity from the mobile patients during transport (in ambulance or helicopter), the emergency and on-time data is collected from the devices/cellular phones deployed with the patients.

2.2.2.2 eHealth Data Analysis

The collected data must be analyzed so that the health professionals can take the decisions and suggest appropriate line of treatment based on physiological, physical, and mental state of the patients.

- In automatic analysis, the collected data are analyzed automatically using predefined computing process, for example, data of Parkinson's patients.
- However, the data observation for patients' critical conditions and alert/notification generation are required as critical analysis, for example, cardiac monitoring via ECG.
- In critical control, the devices are also controlled apart from alert generation, for example, device for regulation of oxygen supply to the patients.
- Lastly, informative analysis is carried out for health and fitness monitoring system where the data is analyzed for general information about overall health and to take the follow-ups accordingly.

2.2.2.3 Fog Nodes Configuration

The fog node configuration basically includes deployment of fog servers, management of networking devices, network protocols to be used and Cloudlets.

- The decentralized and geographically distributed fog servers are deployed at very common places, viz. parks, shopping malls, bus stands, etc. and can be equipped with storage and computation and communication power. Even base stations or moving vehicles can be configured with such facilities depending on the application requirements.
- The traditional networking devices like routers, switches, gateways, embedded servers, and sensing devices as well as dedicated networking devices like smart eHealth Gateways [8] can participate as fog infrastructure.
- The standard network protocols WiMax, ZigBee, Wi-Fi, 2G/3G/4G/5G can also be used for fog computing in healthcare.
- Cloudlet is located at the edge of the Internet and can be considered as a tiny level of cloud data center. The main motive behind its design is resource-intensive and interactive mobile applications with lower latency and hence it can also be utilized in healthcare data computing.

2.2.2.4 Service Level Objectives

- **Latency Management:** Depending on the healthcare application requirements, the latency thresholds, i.e. the maximum tolerable latency time of a service request are decided for fast transfer rate. The low-latency fog networks are developed to manage latency constraints as a part of latency management and thus to enhance service performance in healthcare, for example iFogStor [17].
- **Network Management:** The network management manages the network related issues, *viz. network congestion, virtualization, connectivity, and communication between end devices and other entities as well as handling mobility of the devices*.
- **Data and Storage Management:** The data and storage management in fog computing is important due to handling of distributed, decentralized, and massive

volume of patient-generated health data. Three main service models, viz. the offloading, the aggregation, and the peer-to-peer model can be used for data storage and workload execution in fog computing [18].

- **Resource Management:** Resource management takes care of participation and management of fog nodes, computation resources, storage resources, and backed-up cloud resources as well as interconnection, interworking, and interoperation between them.
- **Application Management:** It is responsible for managing several applications being executed simultaneously and managing resources between them. For smooth execution of applications, the application management provides required programming platforms, schedules applications, offers scalability, and elasticity and facilitates offloading techniques in case of constrained environments.

2.2.2.5 Privacy and Security

The patients' data are private and contain sensitive information about their health. Hence, privacy and security of these data cannot be neglected during storage and execution of computation tasks at fog nodes or when data are transferred at Cloud servers. The security architecture is proposed for the authorization, authentication, and continuous tracking of mobile and other devices as well as on deployment of new devices and data transfer between them [19]. Also, a security model is proposed that uses the authenticated key agreement protocol in fog computing facility to preserve the privacy of medical big data [20].

2.2.3 The Hierarchical Architecture of Fog Computing in Healthcare 4.0

The hierarchical architecture is improved for fog computing in Healthcare 4.0 that modifies the traditional ways followed by the patients and health professionals [1, 4, 21, 22]. The architecture is divided into three layers, *viz. Terminal or Device layer, Fog layer, and Cloud layer*. The fog layer is intermediate between the patients' generated data and the Cloud layer as shown in Fig. 2.3. Apart from this, the key architectural decisions also consider the positioning of fog nodes, their hierarchical structure and the software and hardware characteristics of the connectivity between them.

2.2.3.1 Terminal or Device Layer

Terminal layer or device layer is established nearby the end devices (sensors) where the applications are in execution. It mainly consists of various mobile phones, IoT

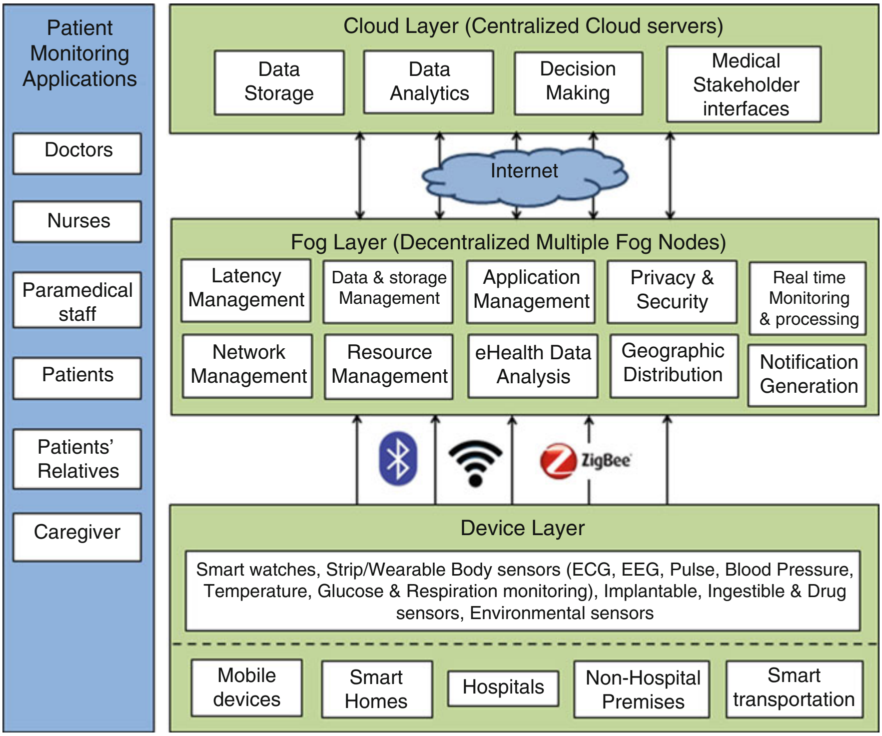

Fig. 2.3 Layered architecture of fog computing in Healthcare 4.0

based medical sensors (wearable health monitoring devices, cameras), and actuators deployed at homes, hospitals or non-hospital premises, and smart transportation that constantly observe the real-time physical conditions of the patients. Two types of medical devices are used to monitor the patients: (1) Physical sensors, generally in the form of wearable devices that track the physical health of the patients, for example, sensors used for ECG monitoring, respiration rate monitoring, pulse, blood pressure and glucose monitoring, etc. (2) Virtual sensors capture the patients' data from one or more physical sensors and use these data for analysis, prediction, remote monitoring, and consultation about patients' health. The eHealth data are collected from these geographically distributed devices and then communicated to the fog layer for storage and computation purpose via wireless or wired communication protocols such as Bluetooth, Wi-Fi, ZigBee, or 6LoWPAN.

2.2.3.2 Fog Layer

The fog layer is an intermediate layer between medical devices and the Cloud. It is a highly virtualized platform consists of dynamic number of low-power and high-performance computing nodes known as fog nodes that are located in the close proximity to the end medical devices. They perform number of services such as storage, management, calculation, and networking services on the patients' data received from the sensor layer. The main characteristics and functionalities of fog layer in Healthcare 4.0 are as follows:

- The healthcare data are context-sensitive and require on-time (with low-latency) analysis and critical decision making (response) based on it. These are addressed efficiently by fog layer with the help of cloud layer, Big data analytics, AI, Machine learning, and other relevant technologies.
- Massive amount of decentralized, streaming, and real-time medical data are sent to the fog layer that distributes them between various fog nodes. They perform protocol conversions and filtering, aggregation, dimensionality reduction, compressing, and formatting of the data to produce efficient results. These results are sent to the health professionals and periodically to the Cloud layer for storage.
- As the healthcare data contain private information about patients, the fog layer also addresses privacy and security concerns of these data.
- The fog layer offers higher bandwidth and reduces network traffic towards Cloud layer. It is enhanced with multi-standard interfaces and these interfaces are well-suited with PAN and wireless sensor network protocols such as Wi-Fi, 3G/4G, radio frequency identification (RFID), ZigBee, IPv6 [23], and wired protocols such as Ethernet.

Thus, fog layer provides all service level objectives, i.e. management of latency, network, data and storage, resource, and applications.

The fog computing architecture for preventive healthcare is proposed in [2], where the communication between device layer and fog layer is implemented by Mesh Layer. It is utilized as first security level by implementing point-to-point connections at run time with the nearby nodes. This architecture increases the security and optimizes the routing; however, this additional layer introduces small, unwanted latencies.

2.2.3.3 Cloud Layer

The Cloud layer provides long-term storage capacities, complex time insensitive processing, and centralized control of healthcare data. It cannot communicate directly with the end devices; hence, it relies on the fog layer for data communication. It consists of Cloud servers that perform long-term, complex and behavior analysis, relationship modeling, long-term pattern recognition, and decision making from the stored data. The data can be accessed by healthcare professionals or patients for billing, record keeping, and future correspondence. It consists of connectivity layer (establishes connection between devices and layers), data management layer (eHealth data is integrated and can be accessed by different stakeholders), and application layer (handles and executes different application services of healthcare).

The Hierarchical fog-assisted Computing architecture for Healthcare (HiCH) is proposed in [24] in which the health data analysis is partitioned into the centralized part (located at Cloud) and the distributed part (running at fog nodes). The remote health monitoring is divided between analytics by fog nodes and decision making by the Cloud along with MAPE-K model. In addition, the closed-loop system management technique is deployed that works based on the context of the patient. This technique is used to experiment the traffic organization to control data communication from the fog to the Cloud.

2.3 Fog Computing in Healthcare 4.0 and the Enabling Technologies

The fog computing in Healthcare 4.0 can be emerged with the other technologies to deal with the challenges in this field [25].

A Software-Defined Networking (SDN) based architecture is proposed in [26] with an aim to provide the security of the concern data. A master-slave concept is used where centralized master controller is located at the Cloud that manages, monitors, and grants a secure communication by authorizing all the components in the loop. It utilizes Sub-master1 controllers which manage secure communication between fog nodes and F2C (Fog to Cloud) and Sub-master2 controllers for data processing at the selected edge devices. Lastly, slaves are IoT devices including end-user mobile devices and fixed sensors. This strategy decreases the authentication delay in fog and Cloud communication that reduces the response time and hence the architecture is beneficial in time-sensitive application such as healthcare.

The challenge of massive amount of medical data storage and its management at fog layer is addressed in [1]. Furthermore, availability of data, negligible delays, interoperability, and privacy issues are also considered for better management of medical records by combining fog computing with blockchain technology. Based on the functional and non-functional requirements, the responsibilities of the architecture are divided between gateway module, patient submodule, stakeholder submodule, and fog nodes module. The blockchain is used in the proposed architecture to provide the privacy of the data at different modules. The fog nodes can carry out authorization process and thus can perform independently and self-contained using this technology. Finally, the case study of improved management of the medical records of a patient in a home-centered healthcare scenario is presented using the proposed architecture.

2.4 Case Studies/Applications

Various case studies are experimented in order to test the performance of fog computing in Healthcare 4.0 [12, 24, 27–35]. Two case studies, *viz. Heart patients monitoring and diabetic patient monitoring* are discussed in detail in this section.

2.4.1 Heart Patients Monitoring

A higher number of heart abnormalities are inferred using the wearable device that is trained with the execution of advanced alert generation algorithms in [30]. The HEART platform is developed that establishes the connection between patient, caregiver, and healthcare professional to make available on-the-spot, consistent, and accurate monitoring of the heart. The patient can receive continuous feedback and reports from the doctors without presence of the caretaker. In addition, real-time and continuous communication between all of them can handle emergency situations efficiently. The proposed heart monitoring scenario can continuously monitor the patient after any heart incident (follow-up) or can be used in case of preventive monitoring and early diagnosis. The first phase is the learning phase of the wearable ECG using normal and abnormal sessions of ECG recordings. After validation of this phase by the healthcare professional, the system enters in training phase that trains the pattern matching engine of the wearable device. Finally, the detection phase analyzes and classifies the signals collected from ECG as per pattern matching and takes decisions as well as sends notifications in case of abnormal events.

To diagnose the data of heart patients, a novel lightweight automatic system based on ensemble deep learning framework HealthFog is proposed in [33]. This framework makes use of fog-enabled IoT devices that efficiently monitor the records of heart patients. The input data of the heart patients are taken from the sensors and HealthFog sends back the results that predict whether the patient is suffering from heart disease or not. The design of it is divided into three modules: (1) data pre-processing module that obtains the patients' data from pulse-oximeters or ECG and pre-processes and extracts the features (age, blood pressure, cholesterol level, blood sugar, etc.) required as input to the deep learning model, (2) ensemble deep learning module for binary classification and prediction (heart disease present or absent) based on the training of deep neural network, (3) the Android application FastHeartTest is developed that allows Gateway as a mediator to communicate with body sensors and worker nodes. The framework achieves high accuracy with low latencies that is tested and validated using FogBus framework.

2.4.2 *Diabetic Patients Monitoring*

To monitor the diabetic patients having cardiovascular diseases, an IoT system assisted by fog is proposed in [34] that analyzes eHealth data of various activities of the patients. The sensor layer is equipped with three types of eHealth sensor nodes (low data rate, high data rate, and hybrid data rate) for collecting body data. The actuator nodes are used in sensor layer to collect and control surrounding environment (temperature, air quality, humidity, time, location, etc.). Fixed or movable smart Gateways are deployed at fog computing layer for advanced fog services such as distributed local storage, data compression, local host with user interface, categorization service, and push notification. Lastly, Cloud layer provides centralized global storage, scalability, data security and performs heavy computation tasks. The proposed algorithms aim to calculate and analyze QT length, fall detection during walk and activity status detection to provide quality of health services.

2.5 Research Challenges of Fog Computing in Healthcare 4.0

The fog computing is widely used for smart utility services, caching and processing, decentralized smart building control, traffic management system, augmented reality, and many more. It faces different types of challenges during implementation and execution of these applications. However, Healthcare 4.0 is the most crucial area due to real-time data analysis and criticality of the decisions to be applied with human lives. Hence, fog computing in Healthcare 4.0 faces the following research challenges [4, 36]:

- **Placement of data:** The geographical distance between the fog nodes and smart end devices may vary from few meters to thousands of kilometers for eHealth applications. Hence, efficient data placement strategies should be proposed to minimize the service latency between these two entities. On the other side, replication of the placed data should be implemented such that it also considers consistency level of these data in fog nodes [17, 37]. Apart from the placement of the data, the selection of the data for local access (in fog layer) or centralized access (Clod layer) limits the access of the data.
- **Data management:** Massive amount of heterogeneous streaming data is collected by fog nodes in monitoring of patients. Values and format of these data may vary as per human body changes, sensor node reading, or surrounding environment, for example, XML format in case of ECG data or image format in case of skin diseases. Thus, the data formats and protocols need to be standardized for appropriate processing and storage of the data.
- **Storage capacity of fog layer:** As compared to Cloud computing, fog nodes have limited storage capacity. Thus, the number of fog nodes may be increased

to process the data that occupies considerable space (image data). In addition, the aggregation of these data and results manipulation also introduce time overhead.

- **Scalability:** With the increased use of IoT devices in healthcare (smart homes, smart hospitals, mobile phones), the fog nodes utilized for small scale data cannot handle processing of real-time, continuous, and distributed data. The large amount of resources in fog layer will increase the overall cost of the infrastructure.
- **Poor network connectivity:** The developing countries and rural areas are still facing the challenges regarding the network setup and connectivity between them. This may limit the performance of fog computing that is not acceptable in time-sensitive healthcare applications.
- **Standardization and regularity affairs:** The medical sensor devices need to be designed and approved as per the healthcare standards (FDA, CMS, or FCC approval). Similarly, to launch IoT eHealth supplies in the marketplace, it must follow a composite multi-agency regulatory constitution before launching.
- **Security and Privacy:** The security and privacy of patients' data as well as doctors' treatments should be maintained at each layer. Due to the belief of keeping the data centralized to maintain its security, the use of decentralized fog computing may degrade.
- **Technical challenges:** The fog node failure or network failure may cause delay in data communication and decision making about life threatening situation of the patient.
- **Training programs for fog in healthcare:** With the development of fog computing technology in Healthcare 4.0, the stakeholders (doctors, nurses, patients, caregivers) should be trained to utilize the facilities provided by fog.
- **Increased cost:** The deployment of the fog layer and connected devices between sensor devices and Cloud layer increases the overall development expenditure. On the other side, the application of fog computing in healthcare improves the health, saves the lives, and increases life expectancy.

Apart from this, based on our observations, the other diagnostic and technical challenges arise in fog computing with Healthcare 4.0 as discussed below:

- The records of patients' data and given treatments can be linked with unique identity number of the patient (Healthcard number). Thus, in future, any other healthcare professional can access the history of the patient and hence minimizing the chances of negligence.
- Data analysis committees are required to be formed for cross verification of the decisions made by the fog computing paradigm. This committee can prevent any system or diagnostic error that occurs and resolves the dispute between healthcare professionals and patients.
- Apart from acceptability of fog computing among the patients and doctors, it may be possible that stakeholders (doctors, patients, or their relatives) challenge the fog computing data/decisions in the consumer court. This type of legal issues between patients, fog computing system, and doctors need to be solved out.

- Robotic surgeries are the future of Healthcare 4.0, hence, fog computing architecture should be compatible with such type of technology.
- As the fog computing nodes are near to the human being, health hazards may happen by the transmission channels.
- Legal permissions from the government for the approval of the system as well as patients' and doctors' consents are required to be taken in order to use this fog computing architecture.
- It is difficult to implement fog computing in Healthcare 4.0 for technologically backward regions. They need to be enhanced to support this architecture.
- Since the concept of cloud itself is complex, the experts believe that the introduction of fog technology would further complicate the architecture and hence create an area of confusion.

2.6 Conclusion

The evolution of fog computing in Healthcare 4.0 (extension of industry 4.0 for healthcare domain) along with the detailed study of the taxonomy and architecture of it is presented in this book chapter. The fog computing is beneficial for healthcare applications due to its features such as reduced latency time, low bandwidth and energy utilization, quick responses, heterogeneity, and scalability. The research challenges while applying the fog computing in Healthcare 4.0 are also discussed so that various organizations or research communities can explore the domain further.

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Chapter 3
Fog Computing Architectures and Frameworks for Healthcare 4.0

Anuja R. Nair and Sudeep Tanwar

3.1 Introduction

With advent of technology, with customer demand getting increased and the longing for cutting edge innovation to further augment advanced technological services, innovative and novel opportunities and challenges are getting emerged in an industry. This transformation endorses novel perspective in context configurations, environments, and motivations that in due course impacts performance of a company. In current era, technical innovations and advancements are increasing genuine significance in many industries such as IT industry, bio-technical industry, automotive industry, and so on. New technologies are being incorporated by these industries which utilize automation and intelligent solutions are outcome of the same. These changes are the antecedents to the growing and evolving changes which leads to a novel industrial revolution, namely "Industry 4.0" [1]. This power of revolution will produce an impact industry-wide.

3.1.1 Industry 4.0

Comparing the evolution of industry standards, Industry 1.0 evolved in eighteenth century focused on mechanization of production and steam power. Industry 2.0 was brought in nineteenth century began with advent of electricity which was followed by Industry 3.0 in twentieth century focusing on manufacturing of electronic devices

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and telecommunication. Lastly, the current evolution, i.e. Industry 4.0 in twenty-first century focusing on intelligent things. It is not only a technical improvement; it is a significant idea that can improve any industry's performance. Interoperability, decentralization, modularity, real-time capabilities, service orientation, and virtualization—these six standards constitute the pillars of Industry 4.0. Developing technologies such as Cyber Physical Systems (CPS), Cloud Computing (CC), Internet of Things (IoT), Internet of Services (IoS), and Artificial Intelligence (AI) drive the fundamental ideologies of Industry 4.0. Figure 3.1 [2] shows four revolutions of industry.

Being a core component of Industry 4.0, IoT [3] has gotten expanded attention from researchers, private users, industry experts, businessmen, etc. It is a network of interconnected devices which are heterogeneous in nature and are addressable and interconnected by means of a communication protocol (mutual). It provides a "smart" environment consisting of sensing devices that are connected by means of this communication protocol sharing data over multiple platforms in order to make an amalgamation between applications so as to generate some meaningful information. With introduction of keyword "smart," Fig. 3.2 [4] shows the various use cases of IoT in current era and also their market shares in Global IoT Sector as taken from Growth Enabler industrial survey [4]. This shows that global IoT market

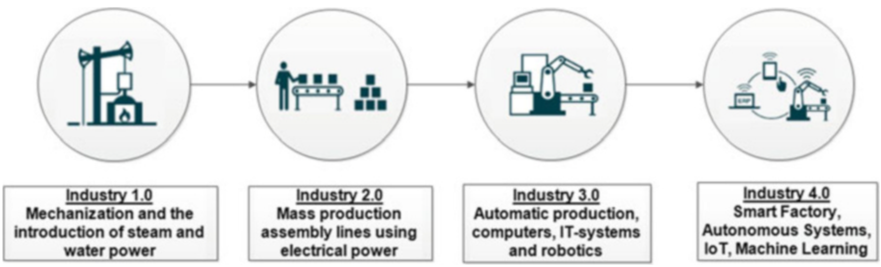


Fig. 3.1 Four industrial revolutions [2]

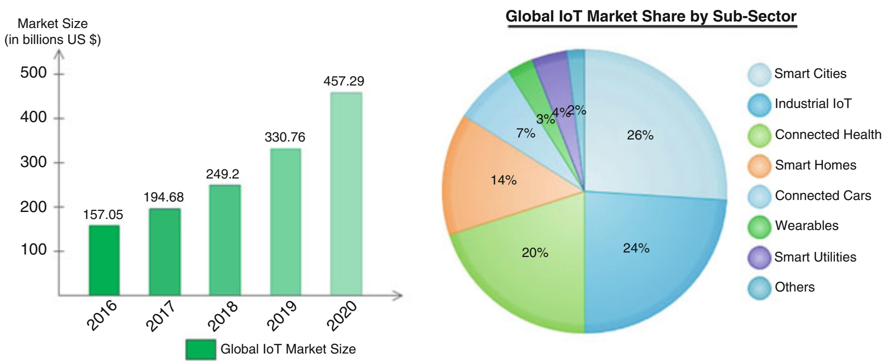


Fig. 3.2 (**a**) Global IoT market share, (**b**) Global IoT market share by sub-segment [4]

share is conquered by major sub-segments which are Smart Cities (26%), Industrial IoT (26%), and Connected Health (20%).

As already learned from Fig. 3.2 [4] that healthcare industry is third largest sub-sector getting affected by advent of Industry 4.0 and IoT, a revolutionary change is also anticipated in healthcare with new opportunities and challenges coming in its way.

3.1.2 Healthcare 4.0

Evolution of Industry 1.0 to Industry 4.0 acts as foundation of evolution of Healthcare 1.0 to Healthcare 4.0. Healthcare 1.0 blossomed in between 1970 and 1990 with an objective improving the efficiency by simple automation to reduce paper work. The limitation of Healthcare 1.0, i.e. stand-alone systems with limited functionality was overcome by Healthcare 2.0 evolved from the year 2000. It witnessed health IT systems getting networked and health data getting generated by means of integration with clinical imaging. Healthcare 3.0 emerged in the duration between 2006 and 2015 with the introduction of Electronic Health Records (EHR) along with emergence of wearables and implantables. EHR helped in storing genomic information of a patient in a digital way. What we are witnessing today is Healthcare 4.0 [5]. All the technologies that are part of Industry 4.0, i.e. computing environments such as cloud, fog, and edge, use of AI, and using invisible user interfaces supports Healthcare 4.0. Figure 3.3 [6] shows correlation between revolution of industry and healthcare. It is not only the improved measure of information that is accessible to doctors; however, the real critical factors here are

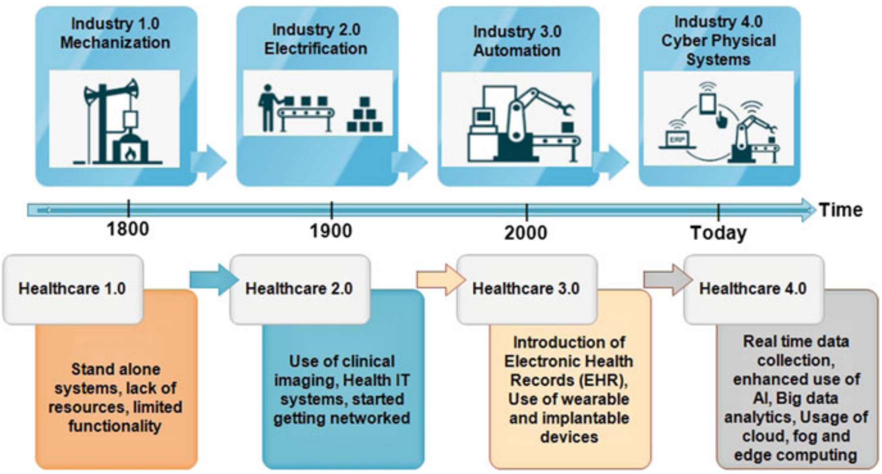


Fig. 3.3 Correlation between industry and healthcare revolution [6]

the capacity to extract bits of data captures and the sharing of this data. Portability of data enables patients and their doctors to get to it anytime anywhere and diagnosis and proper medical responses can be predicted in a timely and innovative manner by means of enhanced analytics. It can pinpoint regions of improvement and empower better decision making.

3.1.3 What Drives Healthcare 4.0 Towards Fog Computing?

Along with a technological revolution brought by IoT services such as storage capabilities, computation resources, high processing, heterogeneity, etc., the sensors being used as a part of IoT are increasing in number and consecutively getting smaller in size, so as to be worn by an individual without hindering everyday activities. These sensors are required because they collect data continuously. One such sensor as stated in BioStamp [7] is of a size of bandaid that can be attached to skin and measures biometric signals. Even contact lenses also provide the facility of sensing biometric characters [8]. In the current era, where people are contact lenses also provide the facility of sensing biometric characters [8]. In the current era, where by means of wearing fitness trackers. All the data gathered by these wearable and implantable devices is of use only if it can derive some insights from it by performing machine learning and data analytics. The accuracy of understanding the insights provided by these devices will exceed the humans, when big data analytics will be used to study the efficacy of medical treatments, accurately identify the patients who are vulnerable to chronic illness, provide treatment options to patients, make sure patients adhere to the treatments given, and optimize the entire process.

Immense amount of data, energy, processing capacity, and memory is generated by the sensors that are wearable and are wireless. Physically storing these data in a hospital is not a possible solution. The data is aggregated from all the sensors and sent to other computing devices for analysis, collection, and storage. Hence, connectivity between these computing devices and communication using a mutual standard protocol also plays a major role. With regard to all the said requirements, cloud computing (CC) [9] can handle the situation easily. Cloud computing offers following benefits [10] to healthcare industry:

(a) *Data storage capacity*: Healthcare industry produces tremendous amount of data which cannot be stored onsite. Health clouds allow storage of data off-site so as to avoid pain of handling physical servers and also help with the cost factor.
(b) *Scalability*: Since, healthcare industry requires services 24/7, cloud handles this requirement by scaling its servers with increasing or decreasing demand of the client. Thus, it fits into the network demands of the client.

(c) *Integration and collaboration*: Clients can easily transfer or share data who are using the same cloud environment. The data can be accessed by anyone who is intended user of that data.
(d) *Provision of AI and machine learning*: Massive amount of data generated requires to be analyzed in an accurate and in a timely manner so that unstructured data can be converted into structured one.

Along with benefits offered by cloud computing, it also brings hazards [10] to healthcare industry listed as below:

(a) *Implementation*: Handling of tasks efficiently requires implementation of a reliant and efficient cloud solution, otherwise, information leaks, business downtime, improper handling of data, etc. will be seen as an outcome of bad implementation.
(b) *Security*: Even though cloud networks provide measures of security that warns and deals for suspicious behavior, still they are not perfect. There have been many cases of security breaches in health information.
(c) *HIPAA Compliance*: Health Insurance Portability and Accountability Act (HIPAA) should be complied by all health cloud solution providers. This includes implying their protocols on security breaches, privacy of patient, law enforcement, and notification of breaches.
(d) *Control and availability*: Since EHR data needs to be available 24/7, hence, measures need to be taken so that when cloud platforms go down from time to time, healthcare professionals are still able to access the data required.

In 2012, announcement of an infrastructure paradigm called *fog computing* [11] was done by Cisco, in order to tackle the issues faced in cloud computing.

3.2 Fog Computing

Fog computing is based on the idea that fog nodes lie somewhere in between ground and cloud/data centers where end user's devices are geographically placed as shown in Fig. 3.4 [12]. A term called *edge computing* is also used synonymously, wherein edge devices are the ones that are end user's devices and the tasks done by the same is part of edge computing. Topology is the important characteristic of fog computing which means the distributed nodes are placed geographically who performs computation and offers network services and storage. It is such a distributed system that the application specific resides on the infrastructure components along with data centers as well as user devices. Theses infrastructure components include routers, gateways, and access points. Fog computing offers the following benefits [13, 14]:

(a) *Privacy*: Propagation of data can be reduced by means of fog computing. Sensitive data can be analyzed at local gateway rather than at a data center that is not in control of the user, so as to ensure privacy of user data.

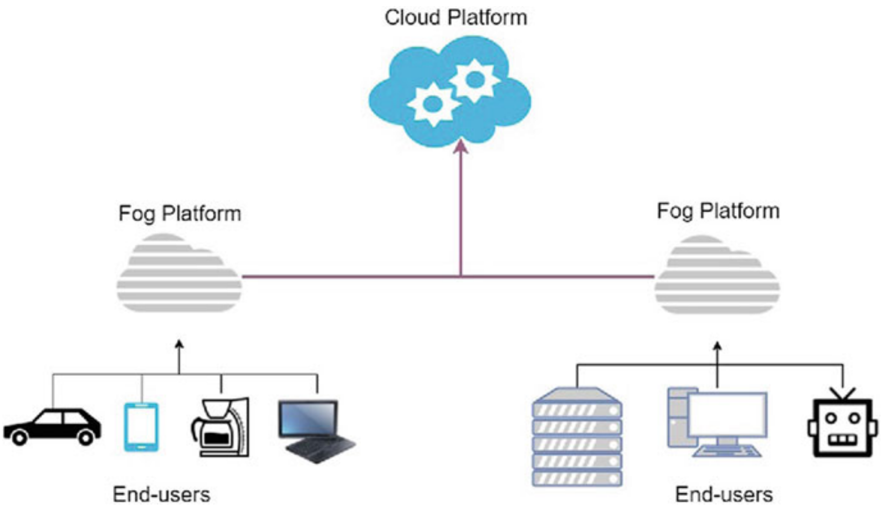


Fig. 3.4 Fog nodes—lies between cloud and ground [12]

(b) *Reduced latency*: Processing devices if placed closer to the devices reduces the latency as physical distance is reduced and response time will be much lesser as compared to when placed on data center.
(c) *Energy efficiency*: Instead of sensors actually working all the time, gateways can act as communication proxies which can handle any request when sensors are on sleep mode and can be processed when sensors wake up. This is how energy efficiency can be improved within sensor devices.
(d) *Bandwidth*: Instead of sending entire data to data center, large chunks of raw data can be processed at fog nodes, so as to reduce the volume of data sent to data center.

3.3 Fog Computing in Healthcare 4.0

Healthcare systems face massive challenges which keep on increasing due to increased population and proned risk to chronic illness.

(a) *Need of remote monitoring*: There is also a demand to maintain high quality care to patients but at the same time demand is to reduce the cost as well. Also, a shortage in efficient nursing staff is also seen in many years. Hence, healthcare industry is shifting to information-centric delivery model where remote monitoring [15] of patients is to be enabled anytime accessibility to the patients increasing the efficiency and reducing the overall cost of healthcare. Currently, much time is squandered in clinics by physically estimating parameters of biometric features and moving the information between systems, regularly including pen and paper. Instead of wasting time in manual supervision, automated supervision can also be an improvement in healthcare.

(b) *Improved procedures in hospitals*: Another challenge is the improvement of procedures inside the clinic. Numerous procedures are arranged physically, and subsequently done successively, of utilizing resources all the more viably. Moreover, sensors will make it less complex to provide precise data about the current status of patient's biometric features. Sensors will likewise give a progressively exact image of patients, as they can catch information ceaselessly and permit a knowledge into expanding assortment of biometric parameters. This will reform diagnostics and treatment.

(c) *Need of preventive care*: Another pattern is the takeoff from reactive treatment, where patients are treated in a medical clinic simply after an incident, towards a progressively preventive medicine [16]. This begins by checking healthy individuals, to keep them out of clinic for as long as could be expected under the circumstances. Also, expanding the potential outcomes to screen patients at home encourages discharging them prior from the clinic. All in all, this implies the fringes between clinic, home, and different purposes of care get progressively obscured: medicinal services happen constantly and all over the place.

The idea of fog computing was intended to fulfil applications which require real-time response with low latency such as healthcare systems [17]. Low latency can affect the performance of services of emergency and health monitoring. It can also delay the response time for sending data to cloud and receiving back instructions from the cloud to the application [18]. The amount of data produced as an outcome of healthcare applications is very large and to process them, fog computing is required rather than limited storage devices and computing resources. Fog computing is widely preferred for healthcare applications as these applications show lower response time, are latency-sensitive, and yield huge volumes of data. Real-time requirements are the need of such applications and hence, in E-health, streaming-based transmissions should be managed [19]. In fact, scalability, elasticity, redundancy can be improved using connected fog nodes forming a fog computing infrastructure [20]. All the issues in healthcare applications cannot be resolved by fog computing unless and until the architecture is not capable to do so. Issues such as low latency, low response time, handling huge amount of data, mobility, scalability, real-time monitoring, reliability, etc. are architecture based. Figure 3.5 [21, 22] shows the architectural layer of fog computing.

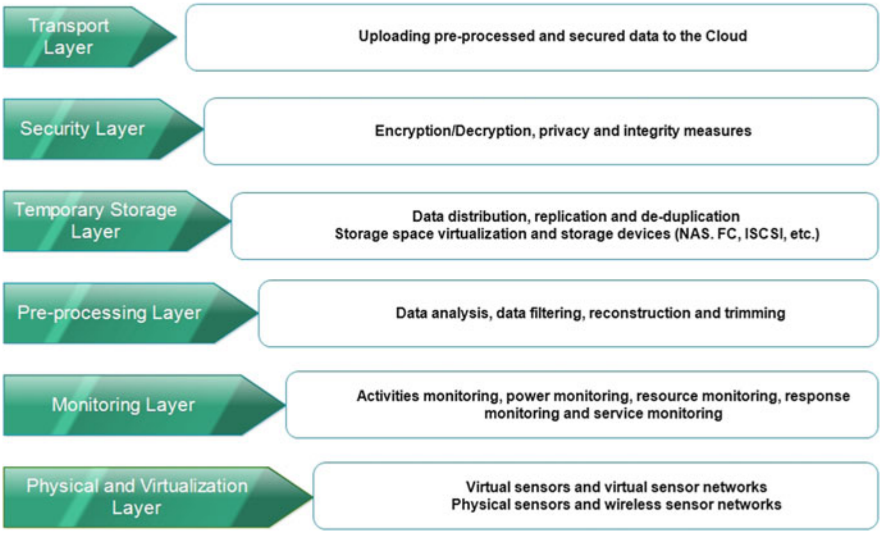


Fig. 3.5 Architectural layer of fog computing [21, 22]

3.4 Classification of Fog Computing in Healthcare 4.0

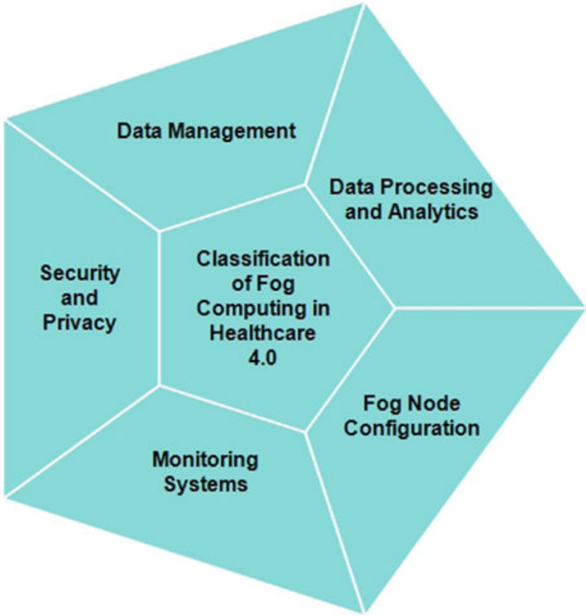
Many researchers have implemented frameworks and proposed architectures for fog computing environment with respect to health applications [23]. These implementations are categorized as the following classification shown in Fig. 3.6.

3.4.1 Data Management

3.4.1.1 Frameworks

Framework for heterogeneous resource sharing [24] is presented to produce optimized utility functions using convex optimization techniques. This framework ensures low latency and high energy efficiency, making it much more feasible to use in mobile cloud. With increasing amount of heterogeneous sensors, their corresponding protocols and data formats need to be efficiently management. In that case, Device Cloud approach is used [25], wherein cloud computing concepts are applied to IoT domain to solve IoT resource management issues. IoT devices are allocated from a shared pool on-demand. Framework [26] that supports exchange of data among healthcare applications and implementation of software tool to support interoperability between cloud and fog platforms by means of integrating with data dissemination protocols in healthcare. It proposes that "out-band" transport is better

Fig. 3.6 Classification of fog computing in healthcare 4.0



than "in-band" transport when done over Wifi with translation of edge data into HL7 standard records.

3.4.1.2 Proposed Architectures

Physical sensors attached to human beings that generate data about incidents requires crowdsourcing [27] to get an insight of emergency situations and also to provide awareness in such situations. The infrastructure consists of large-scale sensing of human population and valuation of data quality, data integration and analytics of heterogeneous data, and performing decision making, giving alternate recommendations. Mobile IoT Federation as a Service—MIFaaS [28] facilitates delay sensitive requests for IoT devices in order to support 5G environments. LTE (Long Term Evaluation) and NB-IoT (Narrowband-IoT) are used in this paper for performance evaluation.

3.4.2 Data Processing and Analytics

3.4.2.1 Frameworks

Nebula [29] is a varied cloud infrastructure that supports computation and storage by means of deploying fog nodes at the edge in order to share resources. It uses

MapReduce framework for computing data-intensive applications taking care of optimizations including computation placement, location-aware data, recovery, and replication. Firework [30] developed to process huge amount of data and cut down volumes of data to be transmitted along with maintaining data integrity and privacy of user's data. It supports big data processing by means of predefined interfaces which exposes virtually shared views of data to the users. These interfaces take form of set of functions and datasets, wherein the functions are privacy preserved and are dataset bounded.

3.4.2.2 Proposed Architectures

Dubey et al. [31] presented a proposed service-oriented architecture whose objective is to process huge data and analyze the same using fog resources with reduced power. This paper presents a low power embedded computer that performs data mining and analytics of data on raw data that is collected from the sensors. It tries to find similar patterns from the collected data. Unique patterns are transmitted, the embedded computer finds clinically relevant information and sends to cloud. In order to perform data processing and analysis and local storage at real time, a smart e-health gateway called UT-GATE was implemented [32]. The gateways were positioned and distributed geographically. Each gateway is responsible for collecting data from the sensors connected to the patient and monitor the same irrespective of the patient's movement or location. Issues like mobility, energy efficiency, performance, reliability, etc. can be resolved using this fog based system. COLLECT—COLLaborative ConText Aware Service Oriented Architecture [33] facilitates context aware data processing by means of a light message broker for integration of heterogeneous IoT context data and making use of enterprise service bus for easy data delivery among agents and participants in system. A three-layer architecture, i.e. Medical device layer, fog layer, and cloud layer [34] that is patient driven for real-time data collection, data processing, data analytics, and data transmission. FIT [35], a low-power fog computing interface, built on previous work, EchoWear, which collects information from smartwatch will now be interconnected to cloud by means of smart gateway. The information collected will be speech data from disordered patients suffering from Parkinson's disease. IoT architecture [36] in order to process and store big data gathered from health sensors. Meta Fog-Redirection (MF-R) and Grouping and Choosing (GC) architecture are the two architectures used in here. MF-R architecture uses Apache HBase and Apache Pig for data collection and big data storage. GC architecture is utilized for integration between fog and cloud. MapReduce is also used in order to predict heart diseases.

3.4.3 Fog Node Configuration

In fog computing, there can be presence of shared fog nodes, fog nodes that work as smart gateways, either shared or individual, cloudlet/foglet, servers, networking devices, etc. These are used to increase the response time. They can work with heterogeneous configurations.

3.4.3.1 Frameworks

In a framework proposed [37] for time-sensitive healthcare applications, users are notified about heart attacks and brain strokes as early as possible. Two algorithms are developed in here. First is used for choosing whether a user is present in overlapping share of fogs. In order to find change in user's position and the shortest path between all the fogs, second algorithm is used. Edge Mesh [38], a software framework distributed all the decision making tasks across the smart gateways as well as shared fog nodes. Difficulty in clustering in radio access points especially when various user requests arrive for services of fog computing is solved by means of multiple user small cell clustering optimization algorithm [39] especially for geographically distributed fog nodes. Rahman et al. [40] presents a mobile edge computing framework that shows location-aware and real-time services when millions of people are mobile. It uses a concept of hybrid cloud at the server side and fog computing nodes at the edge side.

3.4.3.2 Proposed Architectures

Data centered fog computing platform [41] was proposed which scales down processing capability at cloud and keeps it to fog nodes so as to lower the data transmission time between smart objects and cloud. The idea is to bring computing power closer to users from the remote cloud. Cloud4IoT [42] platform supports vertical and horizontal, i.e. roaming and offloading movement of IoT functions by means of Kubernetes cluster so as to solve the challenge of confidentiality of data and performance of connected networks.

3.4.4 Monitoring Systems

3.4.4.1 Frameworks

A computational framework [43] was projected which enables real-time monitoring, performing high computing tasks, sensing of data for making diagnosis and prognosis. It uses wireless sensor networks (WSNs), machine learning, and cloud computing. TILAA [44], a framework for Tactile Internet-based Ambient

Assistance Living in fog environment facilitates posture detection and correction in early stages so as to prevent from falls and backaches. It provides continuous communication feedback between patients and doctors with minimum response time.

3.4.4.2 Proposed Architectures

Remote monitoring with efficiently low cost was exhibited in a fog based monitoring system [45]. In addition, this system is contained with smart gateways and energy-efficient wearable devices or IoT sensors. Moreover, body temperature, respiration rate, and ECG signals are gathered by means of sensors and are sent to gateways wirelessly so as to generate notifications along with an analysis which is automatic. For latency-sensitive healthcare requirements, a fog based architecture was proposed [46]. A programming model was used to manage large-scale geographically distributed application of healthcare. Delivery time of service can be enhanced and retainment of data accuracy and data consistency can take place. A system was designed [47] in order to detect and comprehend the occurrence of Chikungunya Virus (CHV). On cloud server, FCM (Fuzzy-C means) was made practical along with SNA (Social Network Analysis) in order to get a better insight of CHV outbreak. To support ambient assisted living (AAL), continuous patient monitoring system [48] was proposed, wherein Body Area Networks (BANs) are used in order to pass data of movement of patients suffering from neurological diseases to the fog gateways. Also, efficient clustering algorithm is proposed in order to reduce load on the communication infrastructure. HiCH architecture [49] developed for health monitoring systems has two core components. First one is an architecture for executing machine learning based analytics of data and for hierarchical computing. Another is a management technique which is closed loop capable of automatic adjustment with respect to a patient's condition.

3.4.5 Security and Privacy

3.4.5.1 Frameworks

Ahmad et al. [50] presented a fog based healthcare framework that represented security and privacy aspect of healthcare applications by employing fog as an intermediate layer between end devices and cloud. CASB, i.e. Cloud access security broker was used to enhance security at the edge of the network. It used a modular framework design. It was capable of fetching data from multiple places and also applying proper level of cryptographic algorithms. A fog based middleware [51, 52] hosted on fog nodes for collection of patient's health data along with maintaining privacy and confidentiality of their health data, this is done by implementing personal gateways at the side of patient which serves as intermediate node, i.e. fog nodes, rather than storing all the data in a centralized way. In order to prevent DDoS attacks, a certificate based DTLS handshake [53] is implemented for mutual authentication between client and smart e-health gateway. The interaction between medical sensors and client is made secure by ensuring that all the requests from the sensors go directly to the gateway and not to the client. It also condenses load on IoT sensors. AZSPM, a security provisioning model [54] is proposed, wherein it can built by use of dynamically composed atomic security components. There is no rely on certificate authority (CA). By deriving processor clock cycles from execution of service at a hardware platform, authenticity of atomic security components is achieved. Secure communication among participants is ensured by means of generating a session key between participants using tri-party one-round authentication key agreement protocol built on bilinear pairing cryptography [55]. BHEEM: Blockchain based framework [56] proposed for effective storage and preservation of EHR data cryptography [55]. BHEEM: Blockchain based framework [56] proposed for effective storage and clinical decision support system [57] for fog computing is proposed. Real-time monitoring of patients and hybrid privacy-preserving clinical decision support system [57] for fog computing is proposed. Real-time which is secure, design of new secure protocol is proposed.

3.4.5.2 Proposed Architectures

Moosavi et al. [58] proposed an end-to-end security scheme with help of set of interconnected gateways, which scales communication traffic and latency between smart gateways and end users. Use of Blockchain technology is used to improve interoperability between healthcare databases, to improve access to medical records in order to prescribe proper medication to patients, to track the devices etc. The paper [59] also proposes Access Control Policy Algorithm to improve accessibility os data between providers of healthcare. IoT-based health prescription assistant (HPA) [57] gives recommendations to doctors daily. Also, user authentication is provided by means of OpenID standard. After authentication is done, user is provided with SAT—security access token which gives them privileges to access medical IoT devices and their services.

Table 3.1 shows a comparative study of frameworks of fog computing in Healthcare and also the performance metrics each study impacts. Table 3.2 shows a comparative study of proposed architectures of fog computing in Healthcare and also the performance metrics each study impacts. Performance Metrics, i.e. (1) Low Latency and High Bandwidth, (2) Minimum Response Time, (3) Scalability, (4) Reliability, (5) High Mobility, (6) Time-Sensitivity, (7) Energy and Power Efficient, (8) Location Awareness, (9) Cost Effective, (10) Data Availability and Shareability are specified in both the tables.

Table 3.1 Frameworks of fog computing in healthcare

Authors	Issues addressed	Technique used	1	2	3	4	5	6	7	8	9	10
Nishio et al. [24]	Sharing of heterogeneous services such as CPUs, bandwidth, content, etc. and support services between mobile devices	Framework for heterogeneous resource sharing producing optimized service oriented utility functions using convex optimization techniques	✓						✓			
Kliem et al. [25]	Management of increasing amount of heterogeneous sensors, their corresponding protocols and data formats	IoT resource management issues are vindicated by means of Device Cloud approach where cloud computing concepts are applied to IoT domain										✓
Lubamba et al. [26]	Challenge of interoperability between cloud and fog platforms	Exchange of data among healthcare applications facilitated by a framework and implementation of a software tool to support interoperability by means of getting integrated with data dissemination protocols in healthcare										✓
Ryden et al. [29]	Mobility of data gets affected as high computation of data does not support it, reason being centralization of cloud resources, which are inappropriate for deployment of data-intensive applications	Nebula, varied cloud infrastructure that supports computation and storage by means of employing voluntary nodes at the edge in order to share resources								✓		✓
Zhang et al. [30]	Issue of processing huge data along with maintaining data privacy and data integrity of user's data	Firework in order to endorse data privacy along with cutting down the amount of data to be transmitted	✓								✓	
Zohora et al. [37]	For sensitive data such as brain stroke, heart attack, accident, etc., response time is slow	Two algorithms are developed in here. First is used for choosing whether a user is in overlapping share of fogs. In order to find change in position of user and the shortest path between all the fogs, second algorithm is used. This notifies the user in case of time-sensitive issues		✓		✓		✓	✓			

Sahni et al. [38]	Edge devices were not used in decision making	Tasks of decision making are distributed across smart gateways in Edge Mesh (software framework)	✓		✓							✓
Oueis et al. [39]	Difficulty in clustering in radio access points when various user requests for computing services	Formulation of various user small cell clustering optimization algorithm for geographically dispersed fog nodes							✓			
Rahman et al. [40]	Challenges faced for location-awareness, providing real-time services where millions of people are mobile at a time as per time and geographic location.	Framework which uses hybrid of cloud at the server side and computing fog nodes at edge side, capable of delivering real-time, location-aware services	✓				✓			✓		
Aazam et al. [60]	For urgent real-time responses, time-sensitive services are needed	Implementation of Micro Data Center						✓				
Wu et al. [43]	Inefficient monitoring systems for collecting huge amount of data and develop models for prediction for diagnosis and prognosis	Framework developed for real-time monitoring, sensing and performing high computing tasks	✓						✓			
Vora et al. [44]	Monitoring of patients for real-time detection and correction such as posture correction leading to backaches in Ambient Assisted Living (AAL)	TILAA, a framework for Tactile Internet-based Ambient Assistance Living in fog environment	✓	✓					✓		✓	
Ahmad et al. [50]	Security and Privacy	Usage of Cloud access security broker (CASB) to enhance security at the edge of network. Fog as an intermediate layer so as to avoid unnecessary flow of information. Use of homographic encryption										✓

(continued)

Table 3.1 (continued)

Authors	Issues addressed	Technique used	1	2	3	4	5	6	7	8	9	10
Elmisery et al. [51]	Privacy preservation of patient's data	To serve as intermediate nodes, i.e. fog nodes, personal gateways are situated at the patient's side				✓						✓
Rajagopalan et al. [53]	Prevention of DDoS Attack	For mutual authentication between client and Smart e-Health gateway, certificate based DTLS handshake takes place	✓				✓					
Elmisery et al. [52]	Privacy preservation of patient's data	To serve as intermediate fog nodes, personal gateways are situated at the patient's side				✓						✓
Chaudhry et al. [54]	In absence of universal certification authority (CA), security provisioning of health data is a concern	Implementation of Security Provisioning Model (AZSPM)				✓						
Al Hamid et al. [55]	Security Attacks on healthcare cloud	Ensuring secure communication among participants by means of generating a session key between participants using tri-party one-round authentication key agreement protocol built on bilinear pairing cryptography				✓						
Vora et al. [56]	Inefficient balance between data privacy, access to patient's data	BHEEM: Blockchain based framework for effective storage and preservation of EHR data along with maintaining balance between privacy and accessibility of EHR data										✓
J. Vora et al. [61]	Privacy preservation of healthcare records	Proposing blind signatures to ensure the anonymity of identities									✓	
R. Gupta et al. [62]	Issues of security, privacy, and interoperability in existing telesurgery system	HaBiTs, a framework that is blockchain based which is secure and flawless inter-operable telesurgery system based on Smart Contracts										✓
Liu et al. [57]	Leakage of privacy of patient's data to unauthorized parties	Hybrid privacy-preserving clinical decision support system (HPCS)										✓

Table 3.2 Proposed architectures of fog computing in healthcare

Authors	Issues addressed	Technique used	1	2	3	4	5	6	7	8	9	10
Abu-Elkheir et al. [27]	Scarcity of data management platforms in order to predict an emergency situation by processing huge amounts of data	Crowdsourcing human population and their physical sensors that generates data about incidents to get an understanding of emergency situations and also provide awareness in such situations	✓	✓				✓				
Farris et al. [28]	Delay sensitivity in IoT devices	MIFaaS, Mobile IoT Federation as a Service, that facilitates delay sensitive applications for IoT devices to support 5G environments	✓	✓								
Dubey et al. [31]	Collection and analytics of huge raw data collected from sensors	Service-oriented architecture is used. A low power embedded computer finds similar patterns from the collected data, stores unique patterns, and finds out clinically relevant information to send to cloud							✓			
Rahmani et al. [32]	Issues of data processing, data analysis, and local storage in real-time	E-health smart gateway was proposed in which fog computing is used as an intermediary intelligence layer between sensor nodes and cloud. Each gateway is responsible for collecting data from sensors	✓			✓	✓		✓			
Garcia-de-Prado et al. [33]	Context aware data processing	COLLECT—Collaborative Context Aware Service Oriented Architecture						✓				✓
Kumari et al. [34]	Issues of data collection, processing, and transmission	A three-layer architecture that is patient driven for real-time data collection, data processing, and data transmission						✓				
Monteiro et al. [35]	Processing of healthcare clinical speech data	FIT, fog computing interface built on previous work, EchoWear, provides interconnection between cloud and a smartwatch for collecting speech data of patients suffering from Parkinson's disease								✓		

(continued)

Table 3.2 (continued)

Authors	Issues addressed	Technique used	1	2	3	4	5	6	7	8	9	10
Manogaran et al. [36]	Because of increasing density of data, it is tough to analyze big data in order to produce some valuable insight	IoT architecture that processes and stores big data gathered from health sensors. Meta Fog-Redirection (MF-R) and Grouping and Choosing (GC) architecture are used in here	✓	✓								
Li et al. [41]	Data latency between cloud and smart objects	Data centered fog computing platform which scales down processing capability at cloud and keeps it to fog nodes so as to lower the data transmission time between cloud and smart objects	✓	✓								
Dupont et al. [42]	Confidentiality of data is a challenge when number of connected devices are increasing day by day and also impacts performance of the connected networks	Cloud4IoT platform which supports roaming and offloading movement of IoT functions by using Kubernetes cluster							✓			
Gia et al. [45]	Real-time monitoring and ECG analysis	Usage of smart gateways and energy efficient wearable devices. The sensor nodes collect information of body and sends it to gateways wirelessly in order to have notifications and for analysis that is automatic	✓	✓					✓		✓	
Chakraborty et al. [46]	Designing and developing real world data monitoring system	Dynamic fog model using a high level programming language that matches the needs of time-sensitivity which is latency-sensitive, on large scale and is distributed geographically	✓					✓				
Sood et al. [47]	Detect and contain the outbreak of Chikungunya Virus (CHV)	On cloud server, Fuzzy-C means (FCM) was applied along with SNA, Social Network Analysis, in order to get a better insight of CHV outbreak	✓	✓								

Vora et al. [48]	Neurological monitoring which requires real-time processing is time consuming and affects the performance	For ambient assisted living (AAL), continuous patient monitoring proposed using Wireless Body Area Networks (WBANs)	✓	✓				✓				
Tanwar et al. [63]	Monitoring of patients with joint problems to facilitate early detection of arthritis	Architecture using thread protocol and Bayesian classifier to get anomaly detection and achieve reliable communication		✓				✓				
Azimi et al. [49]	Centralized cloud based systems face issues like availability, accuracy, and reliability, also because of outsourcing analytics of data to edge of network because of inadequate computational capability at edge nodes	HiCH architecture provides efficient health monitoring system				✓						
Ali et al. [49]	Monitoring of heart attack patients	Real-time Heart Attack Mobile Detection Service (RHAMDS) to minimize the response time in case of heart attack incidents	✓	✓				✓		✓		
Moosavi et al. [58]	Security for mobile healthcare IoT	End-to-end security scheme using set of interconnected gateways	✓				✓		✓			
Tanwar et al. [59]	Continuous access to patient's private records and securing them	Use of blockchain technology to protect and provide continuous access to patient's private records, also implementation of Access Control Policy Algorithm for improvement of data accessibility between providers of healthcare	✓	✓								✓
Hossain et al. [64]	Security problems and telemedicine requirements	IoT-based health prescription assistant (HPA) which helps doctors by giving recommendations daily and also provides security	✓	✓		✓						✓
He et al. [65]	Challenges of security, safety, unpredictable delays, and high bandwidth requirements	Use of Field Programmable Gate Array (FPGA) technology	✓	✓								

3.5 Conclusion

Fog computing is well-thought-out of as a significant research bearings for numerous reasons in systems of IoT related to healthcare. Research efforts toward this path are under development till now. Be that as it may, appropriate illustrations and limits keep on being viewed as uncertain. By looking into and organizing research efforts, this study means to contribute to such comprehension and information. Henceforth, the study is divided into origin of industry 4.0 and healthcare 4.0, effect of fog computing in healthcare 4.0, frameworks for fog computing in the medicinal services applications, and proposed architectures in fog computing in the medicinal services applications. By genuine scrutinizing and examination of various research articles, more of review data was procured, for instance, the problems, troubles and difficulties, motivation, and points of interest, what's more, recommendations distinguished for future work in fog computing for healthcare applications. Also, frameworks and proposed architectures were compared based on the issues addressed in them and the technique used to address the challenge. Along with that, each study was classified on the basis of performance criteria such as low latency, minimum response time, time-sensitivity, mobility, scalability, reliability, location awareness, energy efficiency, power consumption, etc. All these factors are basic challenges of healthcare applications.

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Chapter 4
Importance of Fog Computing in Healthcare 4.0

Jasleen Kaur, Richa Verma, Nawaf Rasheed Alharbe, Alka Agrawal, and Raees Ahmad Khan

4.1 Introduction

In the present world, where almost every individual finds the Internet as an unavoidable part of their lives, the urge to continuously explore the new dimensions of the existing technologies such as big data, cloud computing, machine learning, etc. is undeniable. The healthcare sector is no exception. It has also got transformed from version 1.0 to the present-day version 4.0. The gradual transition in the different versions of healthcare is shown in Fig. 4.1. The Internet is serving as an ultramodern technology that not only helps in optimizing the entire healthcare system but also enhances patient care. The revolution of Industry 4.0 has already redefined the manufacturing process of the industries [1]. It helps industries in optimizing the processes to increase their productivity. But, in the healthcare sector, where there exist various regulatory concerns, the exact picture of deployment of the Industry 4.0 concepts is still unclear. The incorporation of the concepts of Industry 4.0 into the healthcare sector is not as widespread as it is in other fields. The major principles of Industry 4.0 environment include modularity, virtualization, interoperability, decentralization, real-time responses, and service orientation. The basic idea of Industry 4.0 is driven by various emerging technologies such as big data analytics, machine learning, blockchain, etc. This research endeavor is all about

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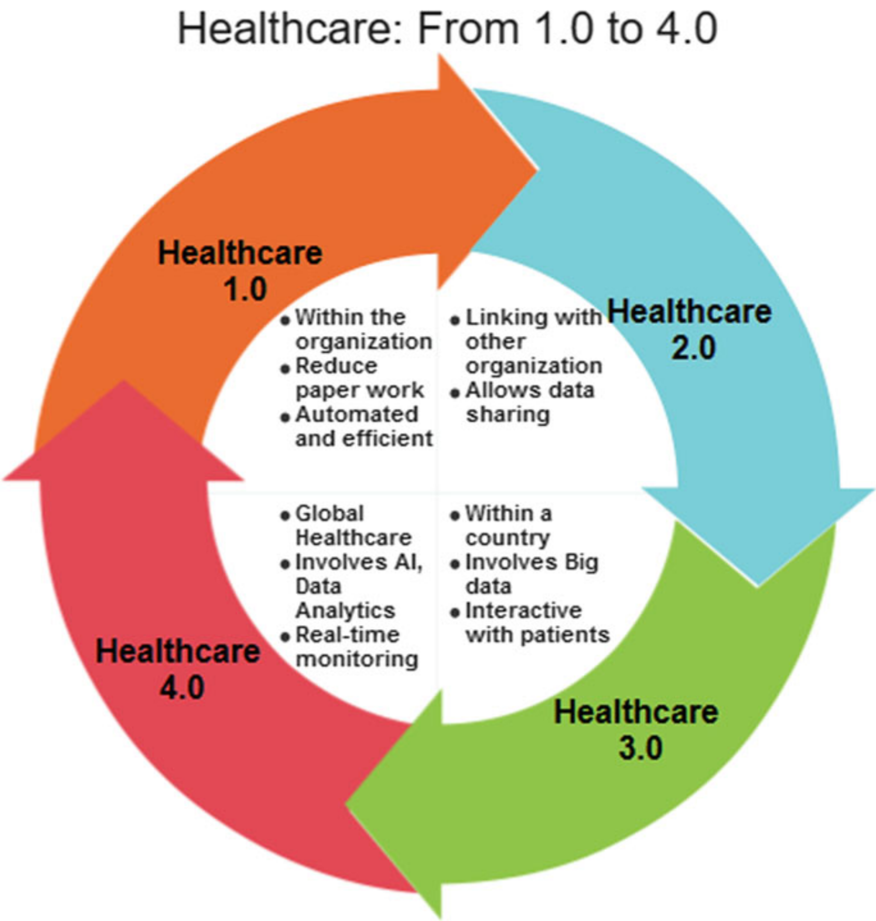

Fig. 4.1 From Healthcare 1.0 to Healthcare 4.0

the transformation of healthcare to the current Healthcare 4.0 version that revolves around the concepts of Industry 4.0.

The main working of Industry 4.0 revolves around the process of data sensed by the sensors and the responses received by the cloud. The data from the sensors travels across the web to the cloud. The cloud analyses the sensed data and notifies the actuator with the response to the received input. This process makes the complete process autonomous and decentralized. The above cycle is repeated the infinite number of times for a given sensor. This repetitive process consumes a large amount of network bandwidth, time and reduces the response time of real-time applications. In the case of latency-sensitive applications where real-time results are required, the concept of cloud computing is not pleasing enough. This led to the emergence of the concept of fog computing. Fog computing is widely described as an extension of the

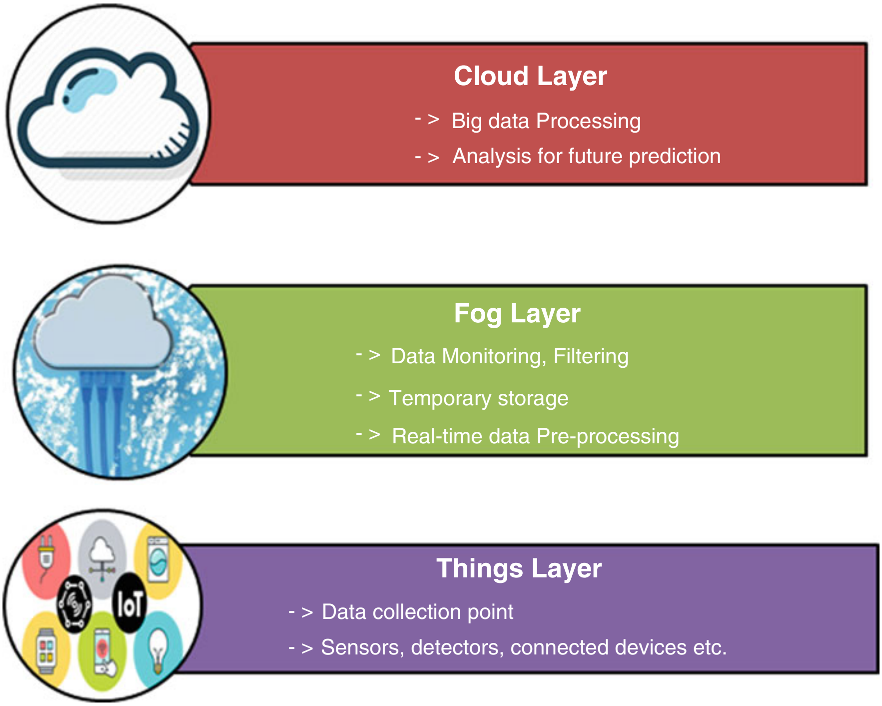

Fig. 4.2 General fog computing architecture

cloud that brings computing, storage, control, and communication closer to the end user [2]. The general positioning of the fog layer in simple cloud architecture is shown in Fig. 4.2.

It is evident from Fig. 4.1 that the fog layer being nearer to the devices performs faster as compared to the cloud for latency-sensitive applications. In the case of healthcare, the responses from the sensors need to be communicated to the required person-in-charge within no time so that the necessary action may be taken. Fog computing proves to be a boon in the case of healthcare as it improves the system response time, minimizes latency, supports mobility, enhances security by keeping data near to the edge, and also improves the network bandwidth. Any irrelevant delay can lead to the loss of life. Therefore, in a critical application such as healthcare, the deployment of fog computing is inevitable. The blockchain technology also provides an edge to the healthcare sector. The basic mainstays such as, decentralization, immutability, and transparency of blockchain technology justifies the competence of its application to this sector [3, 4].

The basic idea behind this contribution is to provide a clear understanding of suitability of fog computing in the healthcare sector and provide insights about its benefits and importance. The rest of the chapter is organized as follows: Section 4.2 is about the need, significance, and issues related to the deployment of fog computing in healthcare 4.0. Section 4.3 explains the architecture of IoT and IoMT. In Sect. 4.4, the authors have described the security at fog level in detail followed by the conclusion as Sect. 4.5.

4.2 Fog Computing in Healthcare 4.0

The area of cloud computing has gained much attention from industry professionals and academia in recent years. This paradigm is serving as a backbone to the modern economy because of its abundant fields of application. Despite its countless benefits, the cloud computing scenario suffers from the issue of high time-delay which is the basic reason for the emergence of fog computing. Fog computing is defined as the extension of cloud that brings storage, communication, processing, and computation to the network edge thereby reducing the network latency [5]. Hence, fog computing is ideal for applications that require very quick or real-time response, especially for the healthcare field. This is evident from the need for urgency in this area. For example, a patient in ICU may be fighting for his life and if the readings from the medical equipment (or, wearables) are not well-timed, we might lose him. Similarly, in emergencies like ECG and blood pressure monitoring or during critical-care monitoring, instant observation of health status plays a vital role in diagnosis and treatment.

Healthcare is one of the distinguished application areas that require real-time and unambiguous results and the introduction of fog computing to this domain has led to a favorable impact. The basic advantage of using such architecture will lead to reduced latency in e-monitoring of patients' health status. It will also reduce the propagation of data to the network, as compared to typical cloud architecture by analyzing sensitive data at the gateway itself. Thus, it will help in better privacy facilities. Data can be stored and analyzed at local servers and thus communicating data centers every time is not mandatory at all. Thus, it conserves network bandwidth. This type of architecture is also scalable in nature, i.e., it can be expanded as and when needed. Thus, it will be apt to say that fog computing is redefining healthcare [6].

4.2.1 Need

As per a report by Markets and Markets in 2017, the IoT healthcare market is expected to boom to $158.07 billion by 2022 [7]. As healthcare is being transformed substantially by the IoT landscape and also provides innumerable benefits to individuals' health, the reliability and efficiency of the plot automatically become crucial. Healthcare is a serious topic that presents even more serious challenges. Today, most parts of the world face various healthcare system issues because of the rise in chronic diseases among the people. The demand to alleviate healthcare costs also exists parallelly. For all such issues, the amalgamation of technology and healthcare comes as the savior. About 76% of doctors believe that technology has the potential to improve healthcare [8]. Technology also allows individuals to take a more active part in monitoring their health. Thus, this merger leads to economic and prompt patient care and satisfaction. Various such requirements of the healthcare 4.0 system are described as follows.

4.2.1.1 Reduced Latency

With reduced latency, doctors can monitor patients remotely in an efficient manner. The fast analysis of the data from wearables can lead to the suggestion of some preventive measures by the experts. Approximately 84% of doctors believe that telehealth is beneficial for their growth [9]. The effective implementation of telehealth requires nominal latency. In rural areas where network infrastructure is not well developed, latency requirements tend to play a major role. In critical situations also, say for ECG, approximately real-time response is needed. This issue is stressed by various researchers, viz. [10–12].

4.2.1.2 Security

Reliability and security are must in critical healthcare as they directly affect the life of a person. This is mainly because of two major reasons. First, for providing privacy to patients' sensitive data that flows across the Internet and second, for preventing tampering or modifications to devices or systems involved. Also, in case of telehealth or remote patient monitoring, the possibility of various security attacks such as Denial of Service (DoS), account hijacking, data loss, etc. [13] exist as the data travels across the web. Thus, presenting a wide attack surface area. The need for security in healthcare is highly emphasized by [14–18].

4.2.1.3 Energy Efficiency

Nowadays, wireless body sensors are being placed on or in the human body to monitor his/her health at any point in time. Therefore, there exists a need to deploy low-power sensors or the ones that work on the principle of energy harvesting. This is a point of serious concern because if the sensors, do not harvest energy or get discharged early then there is no point in their installation. Some sensors even need to be operated for changing batteries. Energy efficiency is stressed by various researchers [19, 20].

4.2.1.4 Interoperability

A patient under intense care is monitored by many medical devices. These devices should be interoperable to improve patient care. This also decreases errors and adverse conditions. The ability to secure and effective exchange of information between the devices may be utilized for storing and interpreting the patient's records and consequently automatically analyzing the patient's condition. Thus, it can be said that interoperability will definitely lead to consistent and quality care and also will create a caring environment that is learning by nature.

4.2.1.5 Bandwidth

The demand for bandwidth is very high in the healthcare sector. From transmitting data from the wearable devices to transferring patient's data for consultation, the major concern is to transfer data as fast as possible. Also, latency and bandwidth are interdependent. This relationship can be well explained by the fact that if there exists high latency, the sender will have to sit idle for long, which will automatically reduce the network throughput, i.e., bandwidth. In this era of digital care or virtual medical care, the dependency on the network has already added up to the intense bandwidth requirements.

4.2.2 Significance

Through the above discussion, it is quite evident that the basic requirements of healthcare and the features of fog computing are a perfect match. Fog computing exists in between the devices and the cloud, therefore provides various benefits concerning typical cloud architecture by bringing the computing nearer to the end-user. The different characteristics of fog computing have been listed below. In this section, the authors analyze various healthcare requirements one by one for different characteristics of fog computing.

4.2.2.1 Solution to Reduced Latency

The overall latency of the system is less as compared to that of the cloud scenario because of the position of the fog layer in the typical fog-cloud architecture. The fog layer is present between the cloud and the devices. The minor/urgent computations are performed at the fog layer itself and thus, overall network latency is reduced. In the case of sensitive healthcare cases, where the life and death of the patient depend upon the response time of the medical devices, fog computing can help by alleviating latency to the minimum.

4.2.2.2 Solution to Security

In comparison to device-cloud architecture, the data is analyzed mostly at the fog level. So, the propagation of the patient's sensitive data is restricted to be transmitted over the Internet. The sensitivity of the data can thus be analyzed at a local server. Therefore, it may be said that the introduction of fog computing to the healthcare sector will surely enhance data privacy.

4.2.2.3 Solution to Energy Efficiency

Energy efficiency is yet another advantage of deploying fog computing to the healthcare industry. There exist many methods that may help in building an energy-efficient system. By data distribution and handing of processes at fog nodes, the traffic on the servers is reduced to some extent and thus making a system that is energy efficient as compared to a typical cloud scenario. Also, during the sensor's sleep mode, the gateways (or, fog nodes) can keep the updates to themselves and update the device when it wakes up.

4.2.2.4 Solution to Interoperability

Interoperability, in the healthcare scenario, is defined as the ability of the medical devices to perform efficiently in consonance with each other. The working of a device should not hamper the performance of the other and vice versa. With most of the jobs being done at a local fog server, the performance of the complete care system is expected to increase.

4.2.2.5 Solution to Bandwidth

As far as the device-cloud architecture is concerned, the number of interactions between cloud and device is way more than in the fog-cloud scenario. It may also be said that the fog layer serves as the filter to the data for processing, analyzing, etc. and the meaningful information is transferred to the cloud. This preprocessing of the data at the local servers reduces the bandwidth consumed and thus increases the overall system efficiency.

4.2.3 Pertinent Issues

As every coin always has two sides, this deployment of fog computing to the healthcare industry also comes with many issues. Some of them are discussed below:

4.2.3.1 Patient Data Management

With the advent of the healthcare 4.0 environment, the sensors collect the patient data and continuously throw it to the local fog servers for the needful. Hence, there is a constant flux of data from the sensors to the fog nodes. The healthcare system has to manage this constant flowing heterogeneous data with a high amount of variety, velocity, and volume. For example, the skin-related sensors generate data in image format while the ECG report is generated in XML. The management of this data is dependent upon the processing ability of the fog node. Another issue that arises in the case of fog computing is the monitoring of the data whether it is to be processed at the fog layer or the cloud.

4.2.3.2 Security and Privacy

The patient data flowing through the fog network is sensitive in nature. As the fog layer is closer to the end user, the attack surface area is more. This increase in attack surface area as compared to cloud architecture may lead to various attacks such as flooding and insider theft. Different types of security issues exist at different layers of the fog-cloud architecture i.e., device layer, fog layer, network layer, and cloud layer.

4.2.3.3 Scalability

Scalability refers to the expansion of the system as per the requirement without intervening in the processing of the existing system. In the healthcare scenario, the system needs to be scaled up to the complete hospital so that the patients can benefit from it from anywhere within the premises via personal smart devices. The basic point that should be stressed upon while addressing this issue is the trust between the devices being added and the existing system. The security checks pose a challenge while considering this issue.

4.2.3.4 Other Issues

In general, the introduction of fog computing to the healthcare industry has led to various serious issues and challenges. One of them is the lack of standardization the healthcare 4.0 at various topics, viz., communication protocols and interfaces (device-fog; fog-cloud). Interoperability is another such issue. The flow of patient data between the different architectural layers should be properly governed. The patient-centric feedback should be properly channeled to make better and more user-friendly medical devices for healthcare 4.0. The involvement of human-factor engineering in the system is expected to make the devices that require minimum or no expert intervention.

4.2.4 Research Gap

In 2014, Fernandez and Pallis [21] stressed the use of IoT to have real information-driven healthcare. Other researchers also projected the growth of the IoT healthcare system as providers of different technical alternatives for the sector [22]. Also, the researchers presented a smart gateway with fog computing to various fields of applications including healthcare [10]. In 2015, fog computing gained much popularity in the healthcare sector. The different approaches applicable at the cloud level, say, Multi eHealth Cloud Service Framework (MeCa) were migrated to fog level to obtain improved results [11]. Various life-threatening activities in the sector, where time plays a major role, started deploying fog computing for better patient care and monitoring. For example, for ECG feature extraction [12], stroke mitigation [23], mild dementia, and chronic obstructive and pulmonary disease [24], etc. Gu et al. [25] proposed low-cost resource management in fog-supported medical cyber-physical systems (FC-MCPS). The authors claim to decrease the overall cost and enhance the Quality of Service (QoS) through two-phase linear programming based heuristic algorithm that addresses the medical data at three levels namely, uploading to user-associated Base Station (BS), transferring to another BS, and then final processing of the patient data takes place.

Right from the introduction of fog computing by Cisco and its widespread usage in diverse fields of applications, this concept continued to help in providing better healthcare facilities in 2016 also. Various fog computing architectures for the healthcare sector were presented [26]. Different use-case scenarios were also discussed toward providing benefits to the sector. Fog computing was also termed as a key-enabler to technology deployment of dependable e-health services [27]. The researchers deployed a fog-based cloud architecture paradigm and experimentally verified the performance of the system [28]. Some also developed devices or systems based on the fog computing technique. Some examples include a medical warning system [29], Fog computing InTerface (FIT) for clinical speech data [30], automatic privacy-aware fog-based middleware for healthcare IoT [31], etc. A framework named Health Fog particularly meant for wellness applications was also developed [32]. The security aspects raised due to the introduction of this concept in the healthcare sector also started getting attention in 2016 [14].

The year 2016 ended with an introduction to the need for security in fog-assisted healthcare. In 2017, the security considerations in the sector gained much momentum. Various studies related to secure healthcare monitoring at fog levels were conducted. Some review studies were conducted that focused on issues, challenges, security aspects, and solutions to the deployment of fog computers in various fields including healthcare [6, 15]. The applications developed for application in the sector also considered security as one of the important aspects. For example, SOA-FOG [16], privacy-aware security model [17], secure architecture for monitoring and alert generation [18], and many more. Some other healthcare frameworks/systems were introduced for chikungunya [33], patient monitoring [19], energy-efficient systems [20], etc.

In 2018, different researches ranging from the ones based on energy efficiency [34], challenges regarding the deployment of fog in healthcare 4.0 [35–37] to the ones based on optimization of ECG monitoring signals [38] and detection and prevention of mosquito-borne diseases [39] were conducted. A similar trend was observed in 2019 too. A fog computing based framework was proposed to help cancer patients [40]. A study based on vulnerability assessment was also conducted in the year to provide assessment against all known vulnerabilities in healthcare environments [41]. Similarly, a blockchain-based fog computing framework was developed for human activity recognition in remote patient monitoring [42]. The researchers have also stressed the use of distributed machine learning as a future research direction [43]. In this regard, some studies have also been conducted that are based on the prediction of dengue [44], fall detection system based on fog computing and neural networks [45], deep learning-based smart system for heart patients [46], etc. A privacy leakage detection scheme for android healthcare devices has also been introduced in 2019 [47].

With the emergence of the fog computing paradigm in 2012, it slowly but steadily has spread its wings to almost every field that requires instantaneous results. In 2014, the researchers introduced the benefits of IoT to the healthcare sector which consequently introduced fog computing to the area. Since then, the benefits of the concept to the healthcare sector were thoroughly explored by the researchers. It has caught the eye of almost every healthcare researcher and marked its presence in the sector; from the development of fog-based wellness applications and health monitoring devices to making them energy efficient and secure as well. In recent times, some researchers have also tried to deploy machine learning and deep learning techniques to predict various diseases such as heart-related issues, cancer, etc. based upon the initial symptoms. Figure 4.3 shows the year-wise work done on fog computing and healthcare.

4.3 IoT for Healthcare

IoT is the concept that implies the use of electronic devices that can accumulate and track data and can feed it to a public or private cloud. The small components of the IoT device act as the data amasser that keeps on transmitting the data as an input for actuation and decision-making. Although this full-grown technology can't impede the population from aging or exterminate chronic diseases it can surely enhance the accessibility of personal health for the public. In the case of several diseases, the early detection of health deterioration is the key to reduce the medical expenses and death rate. According to a study conducted by the Global Burden of Disease 2017 [48], Ischemic heart disease is one of the major life-threatening diseases that is causing most of the mortalities throughout the world. With the advent of IoT, early detection and prediction of diseases are possible in healthcare disciplines. The integration of various techniques such as data acquisition, transmission, and analysis at one end has equipped the IoT-based system to present a smart solution specifically in the field of healthcare.

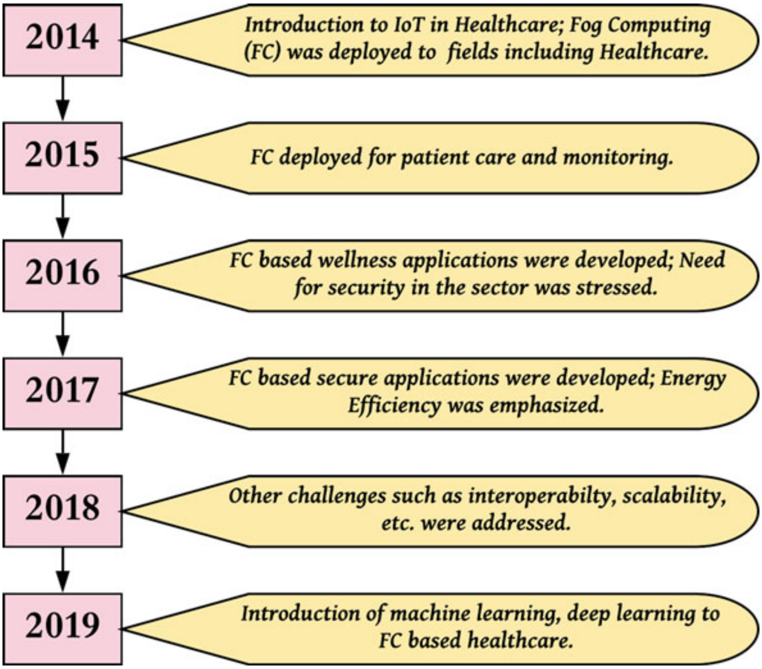

Fig. 4.3 Year-wise categorization of literature on Fog Computing and Healthcare

According to a report by IoT Healthcare Market [49], the overall IoT healthcare market is estimated to increase from 41.22 billion USD in 2017 to 158.07 billion by 2022. In the healthcare sector, IoT can present multiple applications right from patient monitoring, connected imaging, telemedicine, clinical operations, medication management to workflow management of the hospital or a clinic. The foundation mission of IoT is to diminish human interaction or manual intervention and hatch opportunities for improved efficiency and accuracy. This advancement not only improves the health of the patient but also cuts down the time incurred in the necessary preliminary analysis (which is now done with the help of smart devices) and allows physicians to devote that time in amplifying their expertise. It is an advanced facility in which everything is chased and dealt simultaneously while all the data is gathered at a centralized database.

4.3.1 Benefits of IoT in Healthcare

The benefit of IoT in healthcare is beyond question and is undeniable. Most of the IoT-based healthcare applications are designed to gather patient and staff's data and to track authenticate and identify the entities and people. The endless benefits of this

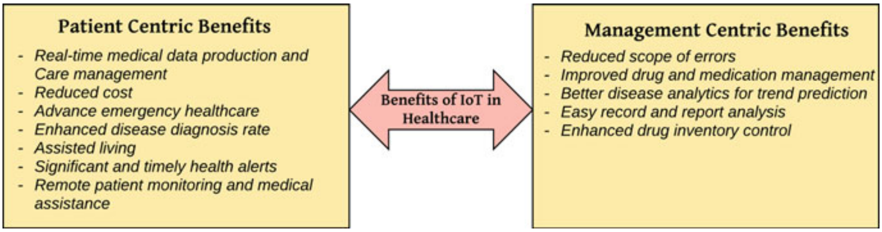

Fig. 4.4 Benefits of IoT in Healthcare

technology have diversified its application in the healthcare sector and prove to be the best fit. The benefits can be classified into two broad categories: patient-centric benefits and management-centric benefits as shown in Fig. 4.4.

4.3.1.1 Patient-Centric

IoT infrastructure for healthcare has a lot to serve patients. The majority of the hospital devices are now equipped with sensors that continuously capture health indicating parameters, including pulse rate, oxygen level, blood pressure, etc. The generated real-time data is then transferred to the layer that is termed as the Fog layer for further classification and processing. IoT helps in better monitoring of the patient activities by generating alerts that can even save the lives of the patients in critical cases. Some benefits of IoT that directly impact patients are

(a) *Real-time medical data production and care management*

IoT devices that appear in the form of smart wearables help in monitoring and recording a patient's health status in a real-time and consistent way. This constant and timely production of data helps doctors to get clear insights about the patient's disease. With the emergence of IoT in the healthcare sector, proper care management can also be done as concurrent data production helps in better implementation of the care management processes.

(b) *Reduced cost*

With the use of IoT and Internet-connected medical devices, the monitoring of the patient can be done in real-time which in turn reduces the overall cost incurred for the visits by doctors. Additionally, these smart wearable devices are integrated with multiple tracking systems that are set up to record different health parameters. Thus, reduces the overall cost of buying separate devices.

(c) *Advance emergency healthcare*

The tracking systems equipped with these smart devices can help in dealing with any emergency caused to the patient by sending alert information to the concerned. In some cases, it can also contact the caregivers or ambulance to take away the patient to the hospital.

(d) *Enhanced disease diagnosis rate*

Connection of IoT-based healthcare solutions with cloud computing has given an edge to the diagnosis of disease. The use of big data and various analysis mechanisms have helped in better identification and understanding of the diseases. This ensures the timely and improved outcome of evidence-based treatment.

(e) *Assisted living*

The present smart IoT-based wearable devices make the patient aware of the various parameters for monitoring the health and their drivers as well. Changing in which aspect of life will affect what part is now well known by the patient. Now the patients are conscious about their health and wellbeing. This leads to device-assisted living for the current population.

(f) *Significant and timely health alerts*

With the emergence of IoT, the real-time generated data can now help the care managers to send alerts by acting on the produced data. Considering this live data certain checks are generated, if the value of some parameter goes beyond the predefined limit the device immediately sends alert and, in some cases, suggests remedies as well.

(g) *Remote patient monitoring and medical assistance*

Remote patient monitoring refers to continuous healthcare. The basic and prime objective of this is to effectively track and manage patient's health condition so that direct action can be taken in case of any emergency.

4.3.1.2 Management Centric

IoT has made things easier for medical management as well. It has facilitated the management not in one domain but nearly in every domain. Right from the patient registration, appointments, report generation to billing things are now so easy to carry out that the management needs not to indulge them in tedious paperwork. All the records are now kept on the cloud that can be accessed from anywhere at any time. Some of the benefits are mentioned below:

(a) *Reduced scope of errors*

Previously, all the work done by the medical staff was almost manual which may lead to some unintentional errors. Now, with the advent of IoT, the majority of the work is automated so, there is less room for errors. The automated workflow integrated with data-driven decisions provides an excellent way of cutting down the scope of errors as well as overall cost.

(b) *Improved drug and medication management*

With IoT, it is meant that proper drug management is taken up considering the health of the patient. The right prescription reaches the right patient is the sole idea behind this. There could be a disastrous situation if a patient is taking the wrong medication because of the negligence of the medical staff. With automation, now it is possible to link-up the patient details, prescriptions, reports, bills, etc. to one registration number. Thus, creating a better operational control over the patient's information and catering them with correct services.

(c) *Better disease analytics for trend prediction*

IoT has shown positive motivation in healthcare analytics. The experts have access to the large volume of the generated data, this helps in analyzing the trends in healthcare for determining particular health condition. With healthcare analytics, the trends for particular diseases prevailing among the population can be traced. Further, early detection and proper medication of the disease are now possible.

(d) *Easy record and report analysis*

All the records now can be put over the cloud and can be accessed from anywhere. There is a central repository of the data which can be accessed and analyzed at any time. This also helps in better analysis and comparative study of the reports which in turn provides improved diagnosis rates of the diseases. IoT and cloud computing have complemented the record-keeping facility due to which old records can also be accessed and analyzed.

(e) *Enhanced drug inventory control*

Automation provides improved inventory control of the drugs. An error-free, complete, and consistent record of the drugs available can now be maintained which provides better assistance while managing the inventory. The orders can be automatically sent to the vendors as and when the stock for the particular drug goes down.

4.3.2 Architecture

The biggest challenge that appears with the emergence of IoT is the complexity. A complete IoT set-up can be thought of having heterogeneous devices that are equipped with sensors that generate data that has to be worked upon to provide some meaningful insight out of it. Keeping all this in mind a structural IoT solution is needed that considers both Physical (sensors, network, etc.) as well as virtual aspects (communication protocols, services, etc.) of the technology. For data-driven IoT application, a basic three-layered architecture is presented in Fig. 4.5 that works right from the data capture phase to decision-making.

The basic IoT architecture for healthcare consists of three main layers says, Data collection layer, Data digitization, and aggregation layer, and Data storage and analysis layer. To deal with complexity, all that data collected from the end devices have to follow the layered architecture. The detailed explanation about each layer is given below.

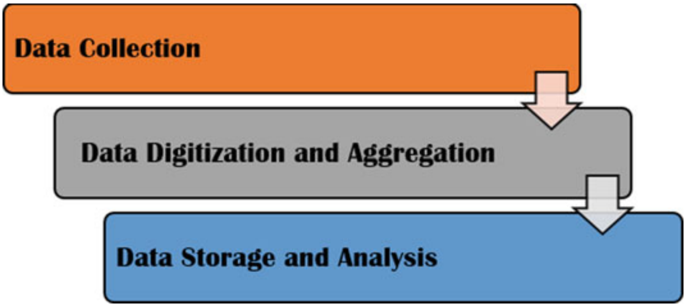

Fig. 4.5 IoT in Healthcare

4.3.2.1 Data Collection Layer

In this phase, the data is collected through various medical sensors (BP machines, Activity trackers, connected inhalers, etc.), detectors, actuators, connected IoT devices, etc. Generally, sensors and actuators are not considered as “smart” devices, but sensors and actuators, when combined with wireless technologies like Zigbee, Bluetooth, etc., can get added processing capability. All the devices that are at ground level and are open for data collection, collect data, and send to the next layer for processing.

4.3.2.2 Data Digitization and Aggregation Layer

The medical data received from the sensors is usually in analog form, which for further processing needs to be converted into digital form and then aggregated. The normalization of the raw data collected through the sensor, scaling, A-to-D conversion occurs at this stage. After the digitization has been done that data is aggregated for further processing.

4.3.2.3 Data Storage and Analysis Layer

After the digitization and aggregation process is complete; the data is checked for any kind of preprocessing and is finally stored on the cloud. Advanced analytics of the medical data is done to provide the correct response to the generated data query for the end user. Data storage with specialized functionality and services for end users and data processing is done at this layer. As per the current IoT era, it will be apt to say that IoT is redefining healthcare. Proper analytics and research may lead to better care, improved treatment, and enhanced patient satisfaction.

4.3.3 Internet of Medical Things (IoMT)

The IoMT is an amalgamation of information technology systems with medical care systems by using networking technologies. The IoMT not only monitor, but also notify and inform the healthcare providers and caregivers with the actual data to take care and identify the medical situation that could unless have been critical. It allows the physicians to transfer medical data over the secure network channel and contact the patients without their physical presence. With the rising rate of chronic diseases, the demand for better treatment options with lower cost becomes the need for the population. Additionally, with the innovation of technologies demand for better healthcare outcomes and efficiencies has also come into the picture. This takes us to a need for a technically equipped medical solution that can deal with the ailment effectively and efficiently.

IoMT can prove to be a boon for elderly people as it can provide them care by using advanced technological developments and can also cut down the additional cost incurred for accessing the conventional medical services. With the help of IoMT, continuous tracing of vital organs such as the heart, lungs, and brain, etc. is now possible. Old aged people generally forget the time and the dose of the medicine; IoMT devices remind them about the medicine and also keep the record of the prescribed medication along with the timeline.

4.4 Securing Healthcare at Fog Level

Healthcare communities have taken up the fact that IoT will serve as an indispensable part soon. The digitizing and streamlining of the health data will facilitate in enhancing the efficiency and effectiveness of the results in a cost-friendly manner. Medical data particularly is very sensitive in nature, loss of which can create a disastrous situation for both patients and the administration. The end IoT devices that act as the data generator needs to be primarily secured. If any IoT device is compromised then it will generate false data that will corrupt the entire network. Data that floats over the fog layer is also vulnerable to various network applicable threats. Malicious insiders, data breach, DDOS, network jamming, etc. are some comment threats that affect the fog layer. In the shadow of the above-mentioned threats, a well-tailored approach is required for this sector to safely navigate and securely get through with this unique field.

4.4.1 Fog Layering

When fog computing came into the picture the basic three-layered IoT architecture evolved and a new layer was added to it, i.e., fog layer which was situated between

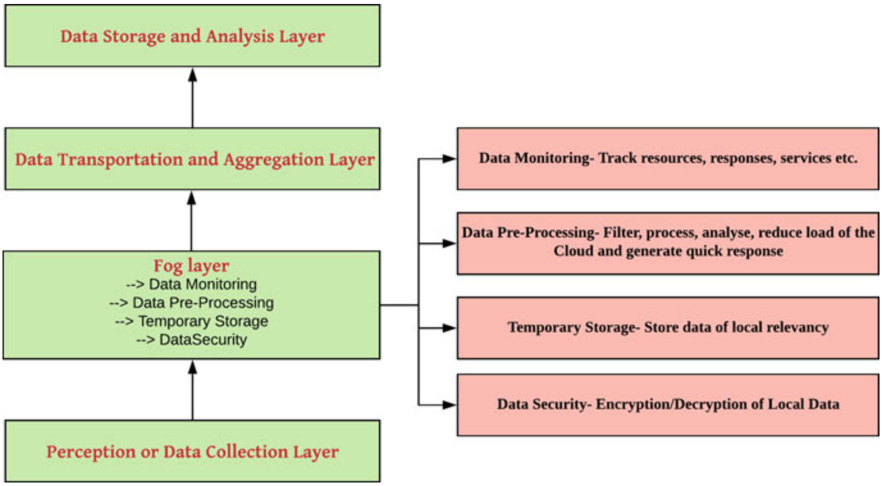

Fig. 4.6 IoT fog-layered architecture

data collection and data aggregation layer. The fog layer was further divided into four phases according to the jobs they perform. Figure 4.6 shows the four-layered fog architecture along with its subphases.

Fog computing is a principle that shifts certain IoT services, like monitoring, temporary storage, preprocessing near to the edge of the network to enable faster local decision-making. In Fog architecture, processing and storage are characteristically done by "fog nodes" or "Smart IoT Gateway," which are laterally connected to other fog nodes. The detailed description of each of the layer is as follows:

4.4.1.1 Perception or Data Collection Layer

This layer could be termed as the physical or perceptual layer that includes sensors, detectors, and integrated IoT devices. This is the ground level both the architectures that collect and transmit the basic element, i.e., data for further processing and action generation.

4.4.1.2 Fog Layer

The applications that are generating data from ground level may sometime require a quick response for triggering the action. In such situations relying only on the cloud could not be a good option. So, an early analysis approach was required that responds promptly and this work can be done by including the Fog layer into the premises. Fog layer acts as an intermediated processing layer that cut off the loopback time incurred in communication to the cloud. Based on different functions fog layer can also be classified into four sublayers:

(a) *Data Monitoring*
This layer keeps track of the power, the response generated, resource accessed, and service availed/offered.
(b) *Data Pre-Processing*
The main aim of this layer is to filter, process, and analyze data in a way to reduce overall latency, burden over the cloud and also subscription from the cloud.
(c) *Temporary Storage*
The data that is of local relevance can be stored. The intermediate data or buffer values can be stored in this layer.
(d) *Data Security*
This layer deals with the security of sensitive data which can be achieved by employing encryption or decryption mechanisms.

4.4.1.3 Data Transportation and Aggregation Layer

This layer can be thought of as a network layer that acts as data gatherers and transmitters. This phase is responsible for transferring the data and acts as the IoT gateway.

4.4.1.4 Data Storage and Analysis Layer

This layer stores the data that are received from the lower layer and analysis on it is performed to provide some useful insights out of it. The analysis is done upon the data to predict future trends, providing business models, work outcomes, etc.

The above fog computing architecture seeks to address the need for the healthcare real-time environment. The added layer attempts to enhance the efficiency, performance, and security of the communication network.

4.4.2 Securing the Layers

The security of the complete healthcare environment is a matter of utmost concern. It should be taken care of that the patient's sensitive data is secured at every moment starting from its generation to its stay at fog level and finally at the cloud level too [36]. This abstruse task of securing the data throughout its journey may be made smooth if we consider the security concerns layer-by-layer, as discussed below:

4.4.2.1 Perception or Data Collection Layer

The data collection layer consists of various sensors that continuously gather the data and send it across to the fog layer. The prevalent attacks at this phase include spoofing, tag cloning, direct connection, etc. To combat such attacks, authentication mechanisms, authorization schemes, access control, etc. should be efficient enough to sense any abnormal behavior. The basic point that should be emphasized while developing a security mechanism for this layer is that it will be deployed on the devices that are energy constrained in nature. So, the mechanism should be lightweight.

4.4.2.2 Fog Layer

This layer is responsible for the data transfer amongst sensors and fog nodes. The most probable attacks at this layer include sinkhole attack, Sybil attack, etc. Various researchers have pointed out the security and privacy issues that exist at this layer, namely, authentication, access control, trust, etc. The security solutions include encryption of data, design, and development of trust mechanisms, access control schemes which are lightweight in nature.

4.4.2.3 Data Transportation and Aggregation Layer

This layer is the network through which the data flows from the fog to the cloud. So, all the security attacks that are possible in the network such as man-in-the-middle attack, flooding, etc. can occur at this layer.

4.4.2.4 Data Storage and Analysis Layer

It is very necessary to tackle the security issues at this layer as the entire patient sensitive data is finally stored here for modeling and predictions. Any tampering to this data may lead to severe repercussions. Attacks such as sniffing, SQL Injection, cross-site scripting (XSS), etc. may occur at this layer.

The integration of Healthcare with Fog computing can be well illustrated with a case study in which health monitoring system is combined with fog computing at gateway level [12]. In this study electrocardiogram (ECG) is selected as it plays major role in identification of many cardiac diseases. The signals (T wave and P wave) generated by ECG are analyzed through smart gateway and prime features are extracted. The result of the experimental analysis reveals that fog computing provides low-latency real-time response and 90% bandwidth efficiency at the network edge.

4.5 Conclusion

Digitalization is the driving force behind the technical advancements in the health-care sector. Now, its job is just not limited to the maintenance of medical records or the enhancement of medical images. Rather, it is leading the world into an era where complete healthcare process including the providers' business is managed and designed by the technology. This advancement is highly affected by the large volume of heterogeneous medical data that is being produced through sensors, wearable's, etc. Healthcare, being a latency-sensitive area, should be designed in such a way that despite the generation of the large volumes of data per second, it does not suffer from any kind of delay as that may cost a life. Considering the requirement of real-time responses, the concept of fog computing is being deployed in the sector. Fog computing, on the one side, has benefited the healthcare industry in many ways; but, on the other hand, it has also raised questions about the privacy of patient's sensitive data by bringing the attack surface closer to the edge. Various other challenges such as data management, scalability, etc., still have some space for exploration. This chapter mainly focuses on the basics of fog computing, its advantages to the healthcare sector and details about the features that can be used with it. Further, a case study is given that provides evidence about the prolific integration of fog computing and IoT.

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Chapter 5
A Comprehensive Overview of Fog Data Processing and Analytics for Healthcare 4.0

Rajalakshmi Krishnamurthi, Dhanalekshmi Gopinathan, and Anand Nayyar

5.1 Introduction

During early year of 1980s there was huge requirement for enhancing the safety in healthcare industry referred as Healthcare 1.0. For next decade of years was generation of Healthcare 2.0, during this the healthcare and medical records were digitized and networking of Electronic Healthcare Records (EHR) was initiated so that better healthcare services can be provided to the patient through network of doctors. Next during Healthcare 3.0, the innovation of wearable devices, body implantable devices, and advancement in genomic research has evolved into tremendous healthcare enhancement in terms of data and networking of medical practitioners. Although Information Communication Technology (ICT) was broadly adopted during Health 3.0, there was no significant improvement in the healthcare industry, due to serious lack of technical interoperability and insufficient healthcare models to handle the diverse technologies. To overcome this, at present Healthcare 4.0 targets to integrate the diverse technologies into a unified model referred as Internet of Things (IoT). Thus, the Healthcare 4.0 aims at the collaboration and convergence with IoT, Fog and Edge Analytics, cloud computing, Artificial Intelligence, Big Data, and Blockchain toward providing better healthcare services.

Healthcare 4.0 together with IoT systems target for the continuous patient health monitoring. In this respect, it requires continuous sensing of human vital

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signals and recording of health data. The sensing of health data is performed through wearable healthcare devices, wireless body area network, and implantable medical devices. It is to be noted that, the complexity of these devices increases in proportional to the convenience provided by these devices in health monitoring. The amount of healthcare data generated has characteristics of voluminous, variety, and velocity. Here, the voluminous refers to huge amount of data collected from different sensor devices. Further, the velocity in terms of different time and space zones of data. Then, the variety refers to different types of sensor devices, which have unique hardware and software specifications. However, the underlying IoT-based healthcare sensor data are resource constrained in terms of battery power, computation capability, memory, storage space, and networking. Hence, the sensor data has to be offloaded to cloud computing platforms. The cloud computing platforms provides service such as storage, software and platform based on pay as per usage strategy. Some of the issues addressed in literature includes various computational tasks with respect to healthcare informatics that can be processed by using the fog and cloud computing. Authors in [1, 2] discussed the potential locations in the Internet of Things where these tasks have been executed. Authors in [3] addressed the tradeoffs to consider when placing computational tasks in the fog computing verses the cloud computing-based healthcare system.

Further, the enormous data that are gathered through healthcare devices has to be made available to doctors in the form useful information and informative data for better and quick medical assistance to the critical patients [4]. Hence, data analytics play vital role to understand the data gathered, analyze hidden patterns of data, and extract the knowledge out of these data through analytical techniques like machine learning, artificial intelligence, and deep learning. However, it is important to observe that, there is need for both real-time data handling as well offline data processing. Cloud computing along with data analytics works perfect for offline analysis and Healthcare 4.0 objectives. It is to be noted that, in cloud-based data analytics, the huge historical data are considered for analysis purpose. Moreover, the cloud computing has its limitations in terms of delay and jitter in networking between IoT healthcare device and remote cloud servers. These constraints of cloud computing need to be overcome by using fog computing. Further, there are several medical applications and emergency situation that requires real-time computation and decision-making based on sensor data. In such scenarios, the fog computing plays vital role in terms of healthcare data analytics. Hence, this chapter targets to provide insight into the fog-based data processing and data analytics (FDPA). This chapter focuses on elaborating the detailed architecture of fog data processing and analytics and also various methods and algorithms that are performed at the fog computing devices with healthcare perspective.

The key contributions of this chapter are to discuss:

- Basic architecture of FDPA based on IoT stack
- Various applications of FDPA
- Various data processing algorithms in FDPA
- Various compression techniques in FDPA

- Various analytical methods in FDPA
- Various challenges in FDPA

This chapter is divided into five major sections. Section 5.2 discusses the basic architecture of FDPA. Section 5.3 discusses the various applications of FDPA. Section 5.4 discusses the data processing methods and algorithm in FDPA. Section 5.5 discusses the various compression techniques in FDPA. Section 5.6 discusses the data analytics mechanism. Section 5.7 discusses various challenges to be handled in fog computing and finally Sect. 5.8 concludes the chapter.

5.2 Architecture of Fog Data Processing and Analytics for Healthcare 4.0

Healthcare 4.0 system targets to present important and valuable data to facilitate effective decision-making by doctors and to enhance value-based services for patients. Specifically, the fog computing vital role in handling real-time data gathering and analysis gathered from IoT healthcare sensor systems. Hence, this section discusses the basic architecture of fog data processing and analytics. Basically, there are five layers in FDPA namely sensor layer, fog gateway layer, fog data processing and analytic layer, cloud layer and service layer as depicted in Fig. 5.1. The details of each layer are discussed further below.

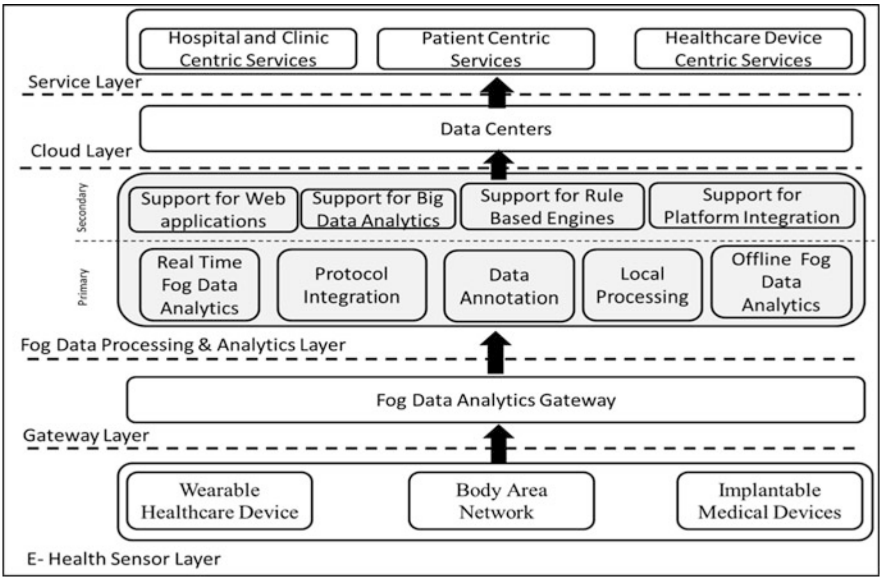


Fig. 5.1 Basic architecture of fog data processing and analytics

5.2.1 Healthcare Sensor Layer

The healthcare sensor layer constitutes of various healthcare devices that can sense the vital body signals of a human. In this technology enriched era, the IoT-based sensors are very popular as these devices can be interconnected through Internet. Basically, there are two main methods of IoT-based healthcare sensing methods namely physical sensing and virtual sensing [1, 5, 6].

5.2.1.1 Physical Sensing

Monitoring of patient health using sensor through wired or wireless devices is part of the healthcare ecosystem. These devices monitor the physical condition, wellness, sudden changes in body signals, etc., of the patients. Some of these physical sensing input devices are blood pressure measuring device, ECG monitor, heart rate detector, glucose level monitor, clinical thermometer, orthopedic sensors, sterilization units, etc.

5.2.1.2 Virtual Sensing

This type of sensing incorporates workstation software applications and mobile-based medical applications related to various healthcare services. Few examples include virtual e-health sensing includes telematics monitoring, telematics consultation, Patient Healthcare Records (PHR), nutrition level monitoring, and clinical reference-based applications.

5.2.2 Fog Gateway Layer

The fog gateway layer consists of two components namely fog gateway devices and the fog gateway data.

5.2.2.1 Fog Gateway Devices

The fog gateway devices are different from IoT edge devices in terms of computing capabilities. Each fog gateway devices control several IoT edge devices. Unlike IoT edge devices, these fog gateway devices are autonomous and capable of performing complex operations. Functions of fog gateway devices include executing short-time complex processes, networking with remote cloud systems, handling personal area networks, resolving addressing schemes within the localized networks, and routing among interconnected fog gate devices. Also, the optimization of resource allocation within fog networks are carried through advanced processors within the fog gateway devices. The fog gateway devices have IoT protocol stack along with support for Internet.

5.2.2.2 Fog Gateway Data

The fog gateways gather different type of sensing data with factors like data set size and various features associated within this healthcare data. These healthcare data are broadly classified as telehealth data and medical Big Data [7–9].

- *Telehealth data*: Telehealth data provide interactive system that connects various healthcare services to the patients. Examples of telehealth data includes video streaming, audio streaming, wireless device communications, and remote patient monitoring. These telehealth services provide patients with right care, under right doctors and at appropriate time. More the increase in demand of medical professionals and increase in the number of available medical professionals can be balanced through telehealth services.
- *Medical Big Data*: In case of medical Big Data, sources of data includes health management claim documents, clinical records, electronic health records, patient observations and reported data, biometric data, the internet networking data, medical imaging, biomarker like protein, DNA, RNA data, and several clinical trials.

The primary challenge of healthcare data is to handle different formats at Edge devices, cloud and service specification. Hence, the fog computing-based data processing provides unified platform to handle the variety of data. Next challenge is to provide high reliable and resolution of data from medical sensor devices obtained from patients or from hospital or from clinical laboratories. Hence, the fog nodes play vital role in collecting, sorting, processing, and exchanging with remote cloud platforms and also maintain these essential characteristics of data such as high reliability and high resolution.

5.2.3 Fog Data Processing and Analytic Layer

The fog data analytics (FDA) is an algorithmic process that tries to give best results using the available computing resources in a constrained environment. FDA allows the organizations such as healthcare and other sectors to process the information at any location that makes sense. They are connected between analytics and the devices are low-latency via fog. The data is not transmitted all the way to cloud to processing. Hence, it does not require much bandwidth. The data is analyzed at the close proximity of its generation.

The objectives of primary fog data processing and analytics are to provide supportive healthcare services such as (1) real-time data processing, (2) offline data

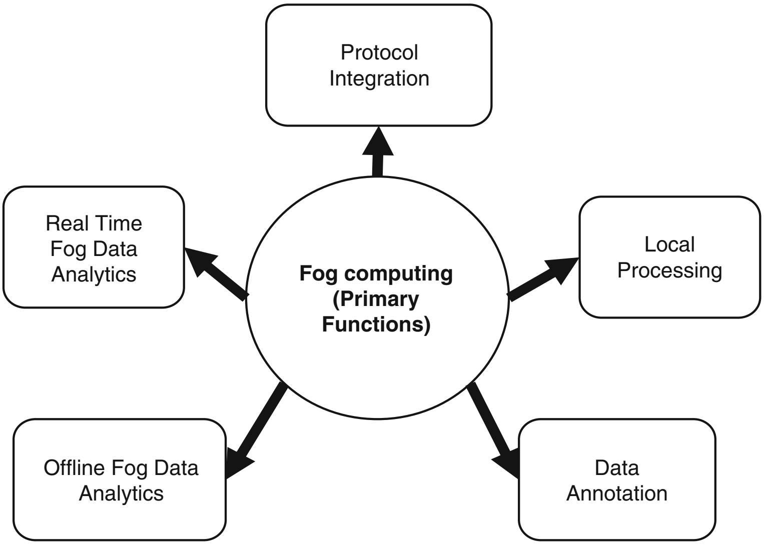


Fig. 5.2 Applications of fog data processing and analysis

offloading, (3) handling messaging protocols, and (4) data annotation [1, 10–12]. These services are further depicted in Fig. 5.2 and explained below.

5.2.3.1 Real-Time Data

The cloud-based IoT data analysis is best suitable for data in rest and for batch processing. However, in healthcare systems, there exists certain requirement to have data analysis and decision-making at real time. Fog data analytics come in to picture for these types of real-time data in motion analysis and decision-making. The fog nodes perform operations like collect, gather, and store the patient's vital healthcare signal data in real time.

5.2.3.2 Messaging Protocols

There different types of messaging protocols at the application layer of IoT. The commonly used messaging protocols are MQTT, CoAP, and XMPP. It is to be noted that, these protocols are different and unique in terms of processing the data packets and messaging mechanism. Hence, it is essential to provide transparent mechanism of messaging protocol irrespective of the underlying application protocol.

5.2.3.3 Data Annotation

Different types of IoT sensors are involved in healthcare. These sensors are typically manufactured under different specifications and standards. The fog node provides platform to integrate these variety of devices as well as data for further processing. Similarly, the EHRs of healthcare are different in formats and standards. In order to handle this, the fog nodes play vital role in integrating, retrieval, and transfer of EHR data transparent to the underlying standards and complexity.

5.2.3.4 Data Offloading into Cloud

The healthcare system has to perform diagnosis in reactive manner over a period of time based on clinical observations of patients. For such cases, the data need to be stored in addition to patient historical data for further analysis. This way, data offload into cloud is required for classification and predictions of disease through heavy computation machine learning algorithms. However, the data offloading required preprocessing like signal moderating, encoding, decoding, compression, data splitting, aggregation, duplication removal, etc. Fog data processing techniques help to resolve such preprocessing problems, and prepare the data suitable for offloading into remote cloud.

5.2.3.5 Short-Time Database

The emergency decision-making such as critical patient monitoring system requires short-time databases and processing of data. In such cases, FDPA provides platform of short-time databases and data analysis. For example, the change in the rhythmic pattern of heart beat needs short-time database, to monitor the sudden changes or arrhythmic pattern of heart beat. Another example is to monitor the invasive insulin monitoring system where the glucose level for particular time duration has to be monitored. In these examples, the storage of short-time data into network expensive remote cloud is not effective. Thus, fog-based data storage for limited time period is a more effective solution.

5.2.3.6 Local Processing

In case of patients in critical care units, the medical decisions are need to be instantaneous and real time in case of emergency. In such cases, the fog-based local processing is a more effective solution. Next, the healthcare sensor device are heterogeneous in terms of both hardware and software functionalities. Hence, fog-based local processing is preferred to perform data format handling before being offloaded into remote cloud.

5.2.4 Cloud Layer of FDPA

The cloud layer performs intense data handling, processing, and analysis operations. The cloud layer consists of public or private network of data centers. The popular cloud platforms are Amazon Web services (AWS), Google cloud, and Microsoft Azure. The cloud data centers are remotely accessed through Internet. The IoT edge and fog devices can communicate with the remote cloud servers effectively using the Internet. The cloud platform provides storage as a service. In this way, cloud platforms along with Big Data and Data analytics can offer tremendous opportunity for handling healthcare services. Particularly in healthcare, huge data are generated through IoT-based healthcare sensor devices. These raw huge healthcare data are needed to be engineered and analyzed for extracting useful information in order to diagnose the patients quickly. Hence, the cloud layer overcomes the difficulty of handling voluminous, variety, and velocity of healthcare data at offline. Also, it is essential to consider the historical data of the patient for better diagnosis of patient. Thus, cloud platform provides efficient means to provide healthcare services to doctors, caretakers, patients, and medical specialists.

5.2.5 Service Layer of FDPA

The services offered as e-health are generally classified as hospital and clinic centric, healthcare devices centric and patient-centric services [1, 2, 13, 14].

5.2.5.1 Hospital and Clinic Centric

Generally, the hospitals incorporate high-end medical facilities and resources to allow patient get admitted, undergo treatment, get surgeries done, and monitor the vital health condition. Further, in recent years, the number of patients visit to hospital is continually increasing. Hence, the role of advance technology in hospital management to meet different requirements of healthcare is inevitable. In case of hospitals, example scenario could be, to perform surgery; it requires smart biomedical machines for real-time monitoring and conducting complex medical procedures. Further, there is need for real-time communication coordination in accessing healthcare records, interpretation among doctors, surgeons, nurses, patients, and family members. Hence, the role of IoT along with enabling technologies likes fog computing are essential to make real-time processing and decision-making. Similarly, clinics and its allied clinical mechanisms are needed to enhance with recent technologies. Example scenarios of application of fog analytics in clinical analysis includes real-time verification of insurance records of patients and intelligent work flow like appointment fixing, remote access, and sharing of lab reports. Farahani et al. [15] discussed several medical services with respect to hospital and clinic services for healthcare system and providing solutions through fog computing. Some of them are smart intensive care units, primary care systems, smart pharmacy systems, connected screening, secure communications, and smart ambulance systems.

5.2.5.2 Healthcare Device Centric

In recent years, the influence of healthcare devices toward consumer affordability and profits are mainly targeted. Also, the healthcare device should have enhanced services and user-friendly models that are capable to embrace patient requirements. Particularly, the real-time monitoring of patient healthcare through inexpensive self-testing devices is intensively researched. The major objectives of the healthcare device centric approach are to analyze the variety of health devices and their connectivity technicalities and difficulties. Next objective is to compare the different connectivity and communication architectures that are suitable for different cases of healthcare. Next, objective is to the transfer of data and further analysis of captured healthcare data along with various performance characteristics such as reliability, privacy and security, less noisy data in real time. Finally, the user-friendly, underlying technology transparent, plug and play and interoperability are needed to focus.

5.2.5.3 Patient Centric

In recent years, there is drastic increase in demand for personal healthcare reports, as patients expect frequent and updated personal health information. Hence, there is huge urge for patient-centric data-driven approach. The fog data processing and analytics provides effective connecting bridge between the patient instantaneous demands, personal healthcare and Electronic healthcare records. Therefore, the primary aim of patient-centric service is to provide services at large scale to improve the responsibility of personal health, propagating contiguous disease and prevention, provide better facilities for healthy results, and achieve greater satisfaction in service of patients.

5.3 Applications of Fog Data Processing and Analytics

The applications of fog data processing and analytics are to provide supportive healthcare services as such in (1) Web-Based Applications, (2) Rule-Based Engines, (3) Big Data Healthcare Analytics, and (4) Platform Integration [15–17] as depicted in Fig. 5.3.

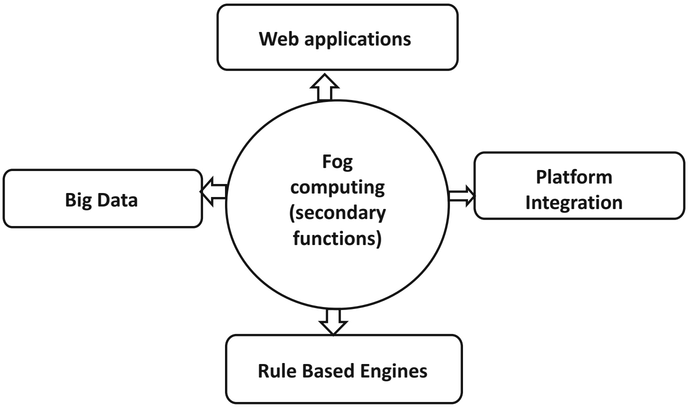


Fig. 5.3 Applications of fog data processing and analysis

5.3.1 Web-Based Applications

In this system the patient and care taker are allowed to use web-enabled user-friendly interface to monitor and manage the different healthcare devices utilized for the patient. The data gathered from various health monitor devices are aggregated at the fog nodes. At this point, the real-time fog data analysis needs to be performed for proactive treatment of patients. Other hand, the fog data can be offloaded to cloud for further data analysis toward diagnosis or treatment for patients. While, in addition to this, the web-based applications provide support features like visualization, and share the data on different platform.

5.3.2 Rule-Based Engines

This system provides various features added to the web-based applications like event generation, alarm system, trigger events, and send notifications. Generally, these rules are based on threshold or complex based on different events and values obtained. In this, fog nodes can perform specific data processing modules based on event monitoring or triggering. For example, the specific temperature threshold measuring and analysis for IoT-based healthcare sensor which involves can be performed on fog nodes.

5.3.3 Big Data Healthcare Analytics

In healthcare analytics, first the healthcare data gathering and then further performing analysis on data in rest. This is significant to identify the essential insight of data and also for necessary action to be taken based on the analysis. In this, the fog nodes play role by capturing various changes in process mechanism and to handle optimization. The fog nodes can modify the data sampling rate and the media resolutions as required.

5.3.4 Platform Integration of Protocols

The platform integration of different message queue application protocols such as MQTT (Message Queuing Transport Telemetry), XMPP (Extensible Messaging and Presence Protocol) and CoAP (Constrained Application Protocol), in order to achieve scalable and flexible IoT systems. For this purpose, the fog-based data encapsulation and data flow monitor play vital role. The IoT sensor data gathered at fog gateways can be further encapsulated according to the egress network protocols.

5.4 Processing Algorithms in Fog Data Processing and Analytics

The data processed by fog computer is time-series data which contains time stamps from wearable sensors. This helps to understand time and type of data collected. In general, the healthcare data collected at fog computer can be speech or ECG or other clinical observations. The services in the fog computer process the raw data obtained from healthcare devices and convert it into relevant data features with respective time stamps. This section explains the methods and algorithms such as Dynamic Time Warping (DTW), and Clinical Speech Processing Chain (CLIP), that are used for analysis of healthcare data on fog computing.

5.4.1 Dynamic Time Warping

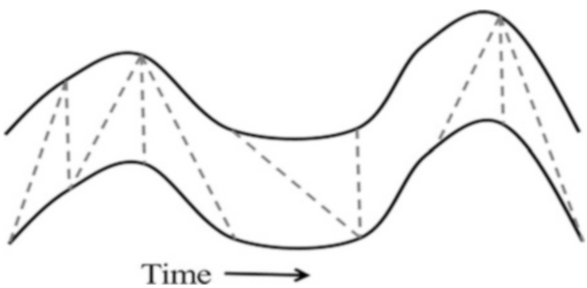
Fog computing (FC) provides benefit to healthcare industry as support by processing real-time application without much delay. The distributed storage and embedded data mining techniques used in the FC enhances the e-health monitoring system. Primarily, ECG feature extraction plays a very important role diagnosis of different cardiac diseases. Heart rate is one of the most important features extracted from ECG as it provides emergency services and diagnoses many diseases. DTW algorithm is for detecting various types of arrhythmic ECG beats. This approach detects the similarity between two series even though signals are out of phase and length. It creates an adjacency matrix and then finds the shortest path through it. In [15] authors have used the DTW distances between the query beat and all the reference beats of the different arrhythmia classes are computed. During the classification process, the minimum each query beat is assigned minimum DTW distance of the reference class. The arrhythmic ECG beats are identified using QRS complex and RR interval measurements. The extraction of QRS complex from the ECG beats are performed at the fog node and the reduced data is sent to the cloud for further processing. The QRS complexes from ECG signals are extracted using real-time signal processing. This data reduction process is developed on fog node. In [18] ECG frames are classified using the DTW algorithm. The DTW computes the distance function to compute the warping path by searching the frame from its end to start. It uses a threshold for DTW matching residual which either classifies an ECG frame or add to a new class. Minimal residual and threshold requirement is used to classify the frame into a category.

The dynamic time warping (DTW) algorithm is widely used for patterns and data mining in time-series data specifically for speech recognition. DTW produces a similarity measure for the time-series signals by realigning them and manages the time distortions in a better way as depicted in Fig. 5.4. In healthcare domain, it is widely used for analysis of ECG and speech signals.

DTW measures the distance between two consecutive time sequences. Let $A[1 \ldots m]$ and $B[1 \ldots n]$ be the two series A and B of length m and n respectively, where A denotes the reference signal and B denotes the test signal. The goal of DTW is to find a mapping path $P = \{(a_1,b_1),(a_2,b_2)\cdots(a_k,b_k)\}$ such that the distance of this warping path $\sum_{i=1}^{k} \mid A(a_i) - B(b_i) \mid$ is minimized subject to following constraints.

(a) Initial boundary conditions are set as $(a_1,b_1) = (1,1)$, $(a_k,b_k) = (m.n)$.
(b) The adjacent nodes of (i,j) in the path are restricted to $(i - 1,j)$, $(i,j - 1)$, $(i - 1, j - 1)$. By doing this, it ensures that the mapping path is obtained as monotonically non-decreasing in its first order and second order arguments. Also, for any given element in A, there would be at least one corresponding element in B, and vice versa.

Fig. 5.4 Dynamic time warping



The optimum path $D(i,j)$ can be found by following equation:

$$D\left(i,\,j\right)=c\left(i,\,j\right)+\mathrm{Min}\left\{\left(\,D\left(i-1,\,j\right),\,D\left(I,\,j-1\right),\,D\left(i-1,\,j-1\right)\right.\right\} \tag{5.1}$$

with $c(i,j)$ denotes the local distance between the reference and query signal.

The distance matrix D of dimension $m \times n$ is constructed by filling the value of start cell $D(1,1)$ by the local distance. Usually, the local distance is calculated as $|A(i) - B(j)|$ for the cell(i,j). Then by using the recursive formula given in Eq. (5.1), the whole matrix is filled one at a time by columns and rows in order. The final distance will be available at the end cell (m,n).

Figure 5.5 shows the wrap path of two signal X and Y. The warp path through the cell $D(i,j)$ denotes that ith point of X is warped with the jth point of time-series Y. The vertical line in the path shows that the one point in time-series X is warped to more than one point in time-series Y while the opposite is true for the horizontal line in the warp path. Hence it is not necessary that time series should have equal length. If X and Y were equal length then the warp path through the matrix would be a straight diagonal line.

The minimum-distance warp path denotes the entry in the last cell (m,n) of the cost matrix. Once the matrix is computed, the warp path must be found from $D(1,1)$ to $D(m,n)$. The warp path is calculated in reverse order starting at $D(m,n)$. It searches the left, down and diagonally to the bottom left cells and selects the smallest value. It is then added to the beginning of the wrap path found so far. Thereafter the search continues from the chosen cell till the start cell $D(1,1)$.

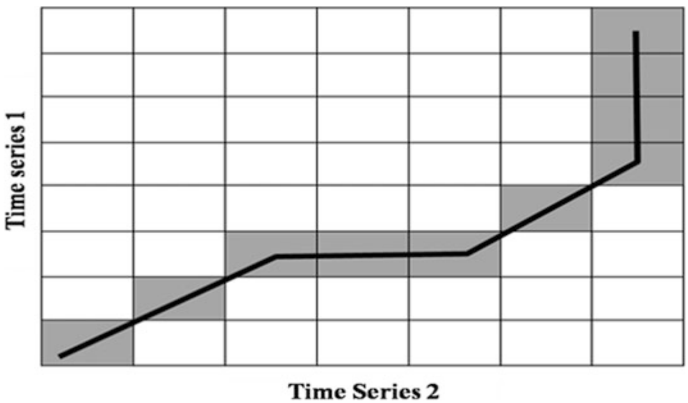


Fig. 5.5 Minimum-distance warp path

5.4.2 *Clinical Speech Processing Chain (CLIP)*

Monteiro et al. [19] discussed that the patients with Parkinson's disease (PD). It represents speech disorder in the patient, who experiences the speech production difficulty associated with Dysarthria. This disorder is due to the impairments in human speech production system such as lips, vocal folds, tongue, and diaphragm associated with speech sensory. The impairment (Dysarthria) mainly depends on which part of the nervous system is affected for the patient. The symptoms include that the patients may face difficulty in understanding the speech; they may have limited movement in lips, tongue, or jaw. It can occur by birth or due to diseases like multiple sclerosis, motor neuron morbidity, cerebral palsy (CP) disorder, Huntington's chorea, Parkinsonism, traumatic brain injury (TBI), mental health issues, stroke, progressive neurological conditions, etc. Speech-language pathologists (SLPs) treat the patients by providing treatment as vocal exercises. The patients need to practice these exercises regularly once they have undergone the treatment in the clinical setting. Monteiro et al. [19] proposed a Fog computing Interface (FIT) for processing different clinical speech data. It is an interface between the smart watch and the cloud. It is designed based on low power embedded system which performs operations such as collect, store, and processes the speech data and then sends the selected speech features to the cloud storage system.

Authors [2, 7] refer the clinical speech processing on cloud as clinical speech processing chain (CLIP). A series of filtering operations are applied on the speech to attain clinically appropriate data for processing like loudness and frequency. The speech data obtained during the speech exercises are stored in the cloud and processed by the cloud. During the processing, the speech data is analyzed by constructing speech Quality Matrix (SQM) and provides the result on a user interface. The SQM are monitored by the SLPs to evaluate the speech quality of the participants by the vocal exercises at home. The CLIP also provides the automatic health reports to the SLPs and patients. This system uses machine learning techniques which provide personalized speech treatment for each patient.

5.5 Compression Techniques in Fog Data Processing and Analytics

The communication channel plays an important role in the area of telemedicine [20]. However, primary concern in the rural areas is the connectivity. Hence, in such areas, the store and forward technique is preferred. Data compression plays a vital role in this scenario. Data compression is an encoding of information in as few bits as possible. The main objective of it is to reduce the resource requirements such as storage, transmission, and processing. It reduces the cost of dealing with data and enable things that otherwise are not possible with available resources. Telemedicine consists of transfer of text, reports, voice, images, and videos from one place to

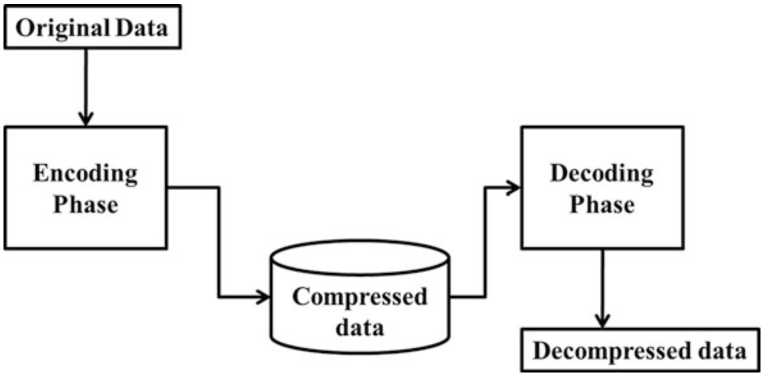


Fig. 5.6 Data compression technique

another. Before sending data to the Cloud, data compression is performed at the Fog processor. Upon receiving the compressed data, the back-end cloud decompresses it before processing. This section explains different types of data compression techniques used at Fog end as depicted in Fig. 5.6.

The two kinds of compression techniques are as follows:

- Lossy compression—This compression eliminates unessential information such as noise and undetectable details. It is very effective for image, video, and audio compression. The data reproduced after decompression will be similar, but not the exact copy of the original data. Compression efficiency can be improved by removing unessential data but it may reduce the quality of the data.
- Lossless compression—It keeps all the information and the data produced after decompression will be the exact copy of the original data. Further, it ensures that essential data is not lost during the compression. However, the redundant data which is removed during compression are added during decompression.

5.5.1 Data Compression Techniques

Data compression techniques can be applied on different kinds of data [21–23]. In some applications such as messaging, browsing etc., the quality of the data is not highly considered. On the other hand, the applications like medical imaging maintaining the data quality is very critical. It is the most important diagnosis performed by doctors as they give information of shape and function of organs of human body. Generally, the medical practitioners use images for diagnosis, together with clinical data information for qualitative and subjective evaluation. Hence, here the data quality cannot be compromised. The images and videos need large amount of bandwidth for communication. Therefore, the size of the image to be sent to the cloud need to compress and reduce the amount of data such that image is accurate and transmitted economically. This compression of data has performed in the fog computer. The general idea of any data compression techniques are to find the repeating patterns in a file and construct a dictionary to represent these patterns as a reference in the dictionary.

The widely used loss-less compression techniques includes Huffman Coding, Lempel-Ziv-Welch (LZW) coding, Run Length Encoding. The lossy compression methods such as JPEG, MPEG uses Huffman coding.

5.5.2 Huffman Coding

In Huffman coding, the symbols which occur more frequently are assigned a shorter code and lesser occurrence of symbols is assigned a longer code. This technique as discussed by authors in [21], a binary tree is created where the leaf node represents the character to be encoded and stored in an array whose size is proportional to the number of symbols.

To illustrate, consider an example of a text file with thirty five alphabets which has only five characters (A, B, C, D, E) with the following occurrences of each letters as—A → 14; B → 7; C → 5; D → 5; E → 4. The text file consumes 280 bits of storage space as ASCII encoding of each letter uses 8-bits to represent. The Huffman tree is constructed starting with the leaf nodes containing the probabilities or frequencies of the symbol. The new internal node is constructed by taking the two nodes with smallest probability. The weight or frequency of the new node is then set to the sum of the weight of its children. This process is repeated recursively on remaining nodes until only one node which is the root of the Huffman tree. The pseudocode for Huffman Code is illustrated in Fig. 5.7.

```
Huffaman (Code)
        Num=|Code|
        Queue=C
        For i=1 to n-1 do
                {
                Construct new node Z;
                Z.left_node=x=MinExtract(Queue)
                Z.right_node=y=MinExtract(Queue)
                Z.freq=x.freq+y.freq
                  Insert_node (Queue,Z)
                }
Return MinExtract(Queue)
```

Fig. 5.7 Pseudocode for Huffman Code

```
Input : Text
Output: Compressed text
Method:
    i → first input character
     While (next character j is read) {
              If j exists in the dictionary
                 Assign i as j
             Else
                 {Insert j to the dictionary
                    Output the existing code for C
                    C=i;
                 }
}
```

Fig. 5.8 Pseudocode for LZW Algorithm

5.5.3 Lempel Ziv Encoding

It is a dictionary-base encoding algorithm. A dictionary is used as a reference to encode the data by this algorithm. Lempel and Ziv in 1978 (LZ78) developed the original version of this encoding method and was further enhanced by Welch in 1984. Hence the algorithm is named as LZW acronym. Figure 5.8 illustrates the pseudocode for LZW Algorithm.

Dictionary-based coding works well when the original data contains more repeated patterns. An index is coded for the pattern in the input sequence. It is then stored in the dictionary. The algorithm starts reading a sequence of symbols and groups into strings. It then converts these strings into codes which takes less space than the strings. LZW begins with a dictionary of 256 characters and code table with 4097 entries.

5.5.4 Joint Photographic Experts Group (JPEG) Image Compression

It is the first international standard in image compression that is widely used today. The main objective of the image compression is to store and transmit the data in an efficient form. It uses the DCT (Discrete Cosine Transform) method for coding transformation. Authors [24] addressed technique of DCT for image compression in healthcare systems. There four basic steps in the JPEG coding are: (1) preprocessing, (2) transformation, (3) quantization, and (4) encoding as depicted

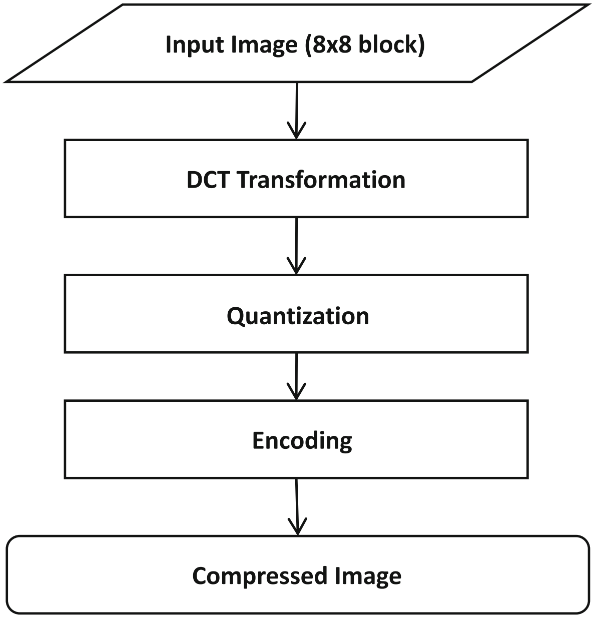


Fig. 5.9 JPEG compression process

in Fig. 5.9. The next section illustrates the four steps considering an image of dimension 160 × 240 pixels.

5.5.4.1 Preprocessing

In this step, the image is partitioned into blocks of size 8 × 8 pixels. For example, consider an image with dimensions as 160 × 240. In preprocessing, this step creates 20 × 30 = 600 blocks. The pixel intensities are ranging from 0 to 255. The last part of the preprocessing step is to find the relative intensities around the central value 0, this is achieved by subtracting 128 from each of the pixel value.

5.5.4.2 Transformation

Basically, JPEG Image Compression Standard is based on the popular technique named Discrete Cosine Transformation (DCT) in order to transform the input image. DCT is applied to each image block where this technique performs conversion of the image information from the spatial domain to the frequency domain as given in the Eq. (5.2).

$$F(u, v) = \text{DCT}(f(I, j)) \tag{5.2}$$

Table 5.1 Quantization Matrix for luminance and chrominance

16	11	10	16	24	40	51	61	17	18	24	47	99	99	99	99
12	12	14	19	26	58	60	55	18	21	26	66	99	99	99	99
14	13	16	24	40	57	69	56	24	26	56	99	99	99	99	99
14	17	22	29	51	87	80	62	47	66	99	99	99	99	99	99
18	22	37	56	68	109	103	77	99	99	99	99	99	99	99	99
24	35	55	64	81	104	113	92	99	99	99	99	99	99	99	99
49	64	78	87	103	121	120	101	99	99	99	99	99	99	99	99
72	92	95	98	112	100	103	99	99	99	99	99	99	99	99	99

Here, $f(i,j)$ represents the pixel intensity with respect to row i and column j, and $F(u,v)$ represents the DCT coefficient in row i and j of the DCT matrix. It is to be noted that, often the signal energy of each image are low frequencies and the upper left corner of the DCT matrix holds these low frequencies. Compression is achieved since the lower right values represent higher frequencies, and are often small enough to be neglected with little visible distortion. The discrete cosine transform (DCT) separates the image into parts with respect to the image's visual quality.

5.5.4.3 Quantization

The predefined quantization matrix of size 8×8 is involved in the process of quantization. Based on each cell value of the quantization matrix, corresponding DCT coefficient is quantized by division operation. This is done to obtain reduced number of bits, which can be used for further encoding each DCT coefficients. Basically, two types of quantization tables are used namely luminance matrix and chrominance matrix. After the DCT matrix is generated, the each obtained coefficient bits are reduced for further encoding. To quantize DCT block, each value is divided by the predefined quantization value, using JPEG algorithm. The resultant real numerical values are rounded off to produce corresponding integer values (Table 5.1).

5.5.4.4 Compression

After quantization, in order to group low frequency coefficients in top of vector a zigzag scan is performed on the resultant matrix. The zigzag scan maps the 8×8 matrix to a 1×64 vector. In the quantized matrix, it performs operation to reduce the huge number of zeros. As a final step, JPEG incorporates Run Length Encoding (RLE) method to compress the bit pattern at the compression phase obtained from zigzag vector.

5.5.5 Wavelet Compression Technique

This technique of compressing images is very essential in the field of telemedicine as its objective is to reduce the bandwidth consumption for transmission for health signal analysis and perform remote diagnosis. Steps involved in image compression as illustrated in Fig. 5.10 are as follows.

Stage 1: Convert the source image into digital signal s represented as string of integer numbers.

Stage 2: Decompose the signal s into progression of wavelet coefficients w.

Stage 3: Modify the wavelet coefficient from one progression w to another progression w' based on thresholds.

Stage 4: Apply quantization to convert w' progression to another progression q.

Stage 5. Compress progression q into e, by using entropy coding.

Wavelet coefficients are modified using thresholding. Thresholding is a method which will modify the wavelet coefficients which are near or equal to zero to a long string of zeros. Through entropy coding, these long strings of values are further stored and sent in less space. The three kinds of thresholds available are hard threshold (THR1) and soft threshold (THR2) and quantile threshold (THR3). In general, THR1 represents near zero value as threshold limit. Generally, THR value represents the median obtained by initial level averaging the absolute coefficient values. THR2 represents threshold obtained by measuring the retained level of energy in terms of percentage. THR3 represents threshold obtained by square root of the THR2 values.

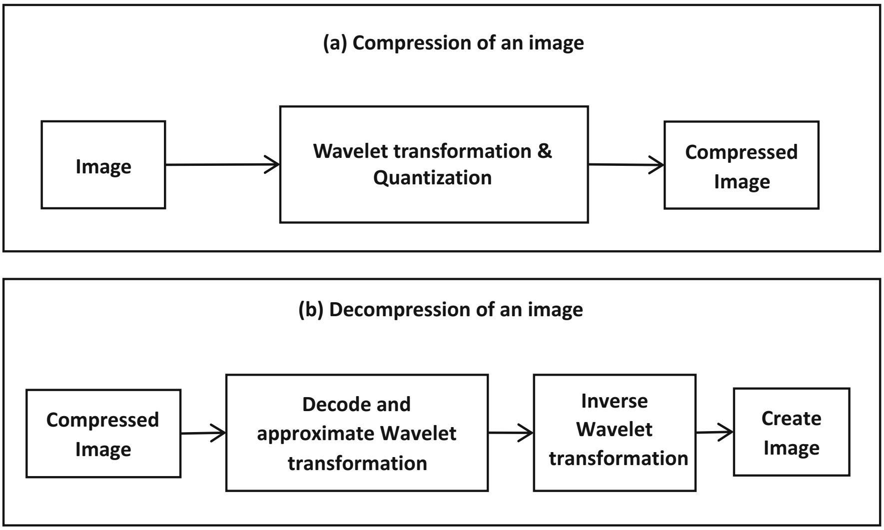


Fig. 5.10 Wavelet compression technique

In general, the lossy compression techniques are not used in the medical imaging scenario. This is due to the reason that, it may be possible that some important clinical information which influence the diagnosis may lose and also to preserve the best quality to image. In general, medical images are represented using Digital Imaging and Communication in Medicine (DICOM) format, deployed by National Electrical Manufactures Association (NEMA) along with American College of Radiology (ACR). It includes all kinds of medicines in the image formats. DICOM format includes a header with patient health status information in two formats namely image and respective image sentience [25, 26]. Hybrid form of compression is required as it contains text and image information.

5.6 Analytical Methods of Fog Data Processing and Analytics

The objectives of fog data analytics to perform real-time critical analysis and knowledge insight from the sensor data gathered from different IoT healthcare devices. Particularly, in healthcare, as discussed in Sect. 5.3, the characteristics data collected from IoT healthcare devices are raw with redundancy, missing values, outlier data, misplace data. On the other hand, the fog data analytics has to provide almost instantaneous knowledge insight about the data at real time. Hence, the issue is to provide tradeoff between data characteristics and knowledgeable information. In this respect, fog data processing bridges this tradeoff through techniques like event processing, state machines, rule-based techniques, data mining, reasoning algorithms, and machine learning algorithms. Thus, the functions of fog data analytics are to identify the typical changes in process and optimization of the entire fog computing operations. In this section, three analytical methodologies namely real-time decisive analysis, real-time content and context analysis, and real data analysis that exists in literature of fog data analytics are discussed. The comparison of different fog data analytics mechanisms in literature are discussed in Table 5.2.

5.6.1 Real-Time Decisive Analysis

In literature, there exist several real-time healthcare decisive analysis systems based on fog data analysis. Authors in [27] addressed the optimization of data sampling data of EGC-based healthcare data. The fog data analytics computation performed feature extraction based on wavelet time-series analysis of ECG device data. The fog data analytics generated location-based data enrichment and notification system at real time. The mobile-based healthcare application was developed using Personal Area Network (PAN) mode. Authors in [28] proposed ECG monitoring system for feature extraction, classification, and detection of signal-based health anomalies and to raise fog node-based alarm locally. Also, the system was able to filter noisy signals using low and high pass filters on received ECG signal and also restricted

Table 5.2 Comparison of fog-based data analytics

Purpose	Details	References, year
Real-time decisive analysis	Optimization of data processing and analysis for ECG data	Krishnamurthi et al. (2019) [25–28]
	Signal-based anomalies in ECG data	Chen and Liu (2016) [14]
	Patient fall detection based on accelerometer	Cao et al. (2015) [12]
	EEG signal-based patient health monitoring	Rotariu et al. (2012) [29]
Real-time control and context analysis	Oxygen level monitoring with context to local environment	Farahani et al. (2018) [15]
	Pacemaker monitoring with context to local environment	Casanova et al. (2019) [13]
	Medical staff monitoring and resource handling by medical staff with context to local environment	Piliouras et al. (2015) [30]
Real-time data analysis	Smart glass-based heart beat monitoring	Constant et al. (2015) [16], Poongodi et al. (2020) [31]
	Smart gloves-based Parkinson disease monitoring	Farahani et al. (2018) [15]
	Smart watch-based heart beat monitoring	Monteiro et al. (2016) [19], Dubey et al. (2015) [17]

wandering baseline signal waves. Further, the system offloaded the result data into remote cloud for historical data analysis.

Authors in [32] proposed the fog data analytics to detect the patient fall based on accelerometer sensor data. Authors in [33] proposed a system for patient vital signal monitoring based on Fog data analytics. Here, capturing of various biometric data and encoding those signals to monitoring any real-time changes within patient's health were determined. Gia [7] discussed real-time data analysis of EEG signal data. The fog data analysis was performed based on discrete wavelet transformation. The classification of signal data was performed using machine learning, and local notification system was also incorporated to alert the patient caretakers.

5.6.2 Real-Time Control and Context Analysis

Authors in [34] proposed the real-time oxygen level monitoring and control system. In this, the level of oxygen supplied along with patient status was appropriately adjusted during treatment. In addition, context analysis based on the local environment data was also performed to improve the patient health condition. Authors in [19] proposed real-time monitoring, analysis, and visualization of pacemaker imbibed within the patient body. The objective of this real-time monitoring and customizing pacemaker was to provide local support system and also capable of updating the various parameters of pacemaker at real time. Authors in [31] proposed medical staff activity monitoring system for the effective utilization of staff resources. For this purpose, the location, medical device usage, time consumption by staff for performing the current operation, planning, collaboration, and availability of medical staff were analyzed.

5.6.3 Real-Time Data Analysis

Authors in [30] presented to achieve high resolution in multimedia data through smart glasses. The smart glass performed continuous real-time monitoring of heart rate. The pulse sensors were used to gather heart rate data. The fog data processing was performed on the gather heart rate data obtained from smart glass. Then fog node performed aggregation of the heart data values. Further, the fog nodes convert the aggregated data into XML data format and offloaded into remote cloud for data analysis. Authors in [29] proposed Smart Gloves for assistive technology-based telemedicine for Parkinson Disease. The smart glove consisted of flex sensor, microcontroller, and Bluetooth low energy communication module. In this, the finger tapping were captured through the flex sensor. Then the fog nodes would compute the frequency, variation, and characteristics of tapping sequence within the Parkinson patient. The peak detection algorithm was proposed to estimate the magnitude of finger tapping recorded at regular interval time.

5.7 Challenges of FDPA

Although the fog computing has shown promising solution for handling real-time data processing in Healthcare 4.0, there are several challenges associated with it. This section discusses some of these challenges such as standardization of protocols, naming and addressing schemes for Fog and edge devices, energy efficiency, and access and security level.

5.7.1 Standardization of Protocols

There are several protocols available at the medium access layer of the IoT stack. These protocols include Zigbee, Bluetooth, WiFi, 4G/LTE, etc. However, there is no unified standardization of these protocols. Each of the medium access protocol is different in terms of data packet handling, data forwarding, and transmission of data. Hence, the fog computing devices need to handle the technical complexity of protocol before performing data processing and data analysis.

5.7.2 Naming and Addressing Schemes

There is huge variety of IoT Healthcare devices available in the market under Healthcare 4.0. These devices are required to adapt the ad hoc fog network formation in the plug and play manner. Hence, naming, addressing, and identification of devices within fog network are essential in healthcare systems. Further, the users must be transparent to the complexity of configuring these devices.

5.7.3 Energy Efficiency

The fog computing devices such as fog gateways, edge devices are limited in energy resources. These devices are mostly operated using battery power. Hence, it is essential while designing and developing any algorithm or processing modules to be energy efficient. The computation time and memory space must be optimized for better and long last functioning of fog devices.

5.7.4 Access and Security Levels

A variety of healthcare devices are used in hospitals, clinic, and personal level. Similarly, these devices are handled by different kinds of people such as doctors, patients, caretakers, nurses, clinical representatives, medical assistants, and family members. Moreover, in the Healthcare 4.0, these devices are interconnected among each other through Internet. Hence, the access level and security level of these devices are at nascent level and yet to be refined and addressed according to the on-demand requirements of customers.

5.8 Conclusion

In recent years, tremendous enhancement in Healthcare 4.0 has been made through emerging technology through the Internet of Things, Cloud computing, Big Data, and AI. However, the limitation of cloud computing restricts to handle real-time computation capability of Healthcare 4.0. Particularly, healthcare systems require real-time data gathering, analysis, and decision-making to provide patient with effective treatment and at the right hour. Hence, fog computing and fog-based data processing and analytics (FDPA) play vital role in Healthcare 4.0. Therefore, this chapter discusses integration IoT along with fog data processing and analytics toward achieving the goals of Healthcare 4.0. First, the chapter presented the basic architecture for FDPA. In this, five different layers namely sensing, fog gateway devices, fog data processing and analytics, cloud and service layers were discussed in detail. Next, the applications of FPDA in Healthcare 4.0 are web-based applications, Big Data analytics, rule-based engines, protocol integration, and local processing. Next, two different data processing methods and algorithm for FDPA were presented namely DTW and CLIP. Followed by, discussion on data compression techniques and image compression techniques. Finally, the fog data analytics based on real-time decisive analysis, real-time control and context analysis, and real-time data analytics were discussed.

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Chapter 6
Data Processing and Analytics in FC for Healthcare 4.0

Khushi Shah, Preet Modi, and Jitendra Bhatia

6.1 Introduction

Health is a prominent aspect of concern to humanity. In the modern age of digitalization, Healthcare is no exception as it gives care for the population. During the past decades, health information technology has experienced an escalation in terms of technological advancements. So doctors, well-being business analysts, and medicinal services executives of this generation need to flourish in such an innovative domain to remain prominent in this profession. There has been a lot of research into Industry 4.0 and its benefits, trends, challenges, and opportunities concerning the healthcare services industry. Real-time results and accurate analysis have now become necessary with the increase in life expectancy [1]. Healthcare system(s) faces enormous challenges like security challenges, latency, demand to reduce costs without compromising high-quality care to patients. Today, technical innovations, and advancements in the healthcare sector are gaining more popularity. The main motive of this chapter is to discuss the need for data processing and data analytics using fog computing in healthcare services.

Various technological trends such as Cloud Computing for rental architecture and fast computations, Telemedicine for remote diagnosis, Artificial Intelligence for efficient data analytics, Natural Language Processing (NLP) for voice-controlled systems, and Augmented Reality/Virtual Reality for better visualizations have enhanced the healthcare generations till date and continue to do so. Figure 6.1 shows the visits per 10,000 patients for primary care and is proof enough to understand the vast set of audience reachable by the improved healthcare generation. The summary of notations used throughout this chapter is shown in Table 6.1.

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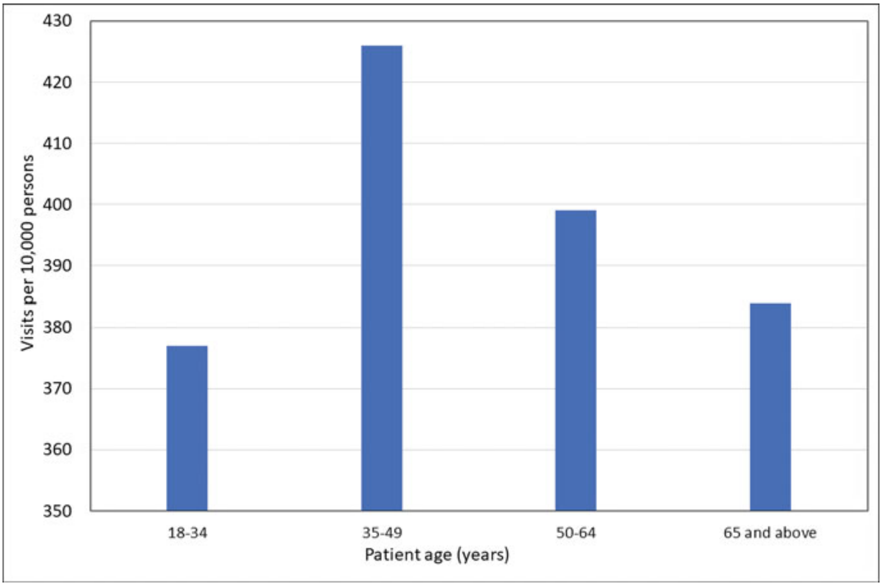

Fig. 6.1 Patients visits for primary care [2]

Through this chapter, we aim to shed light on fog computing, its benefits and disadvantages, and the embedding of fog layer in healthcare industry to construct a three-layered architecture for providing real-time results which is the demand of healthcare industry today. The chapter majorly focuses on the data analysis and data processing in the three-layered architecture using FC and CC.

6.1.1 Transition from Healthcare 1.0 to Healthcare 4.0

Initially, Healthcare was limited to read-only information. The first generation was introduced as a means to access information regarding health over the web. Healthcare 2.0 focused on user/patient-generated content. Healthcare 2.0 amalgamated technology with medical aspects using cloud-based and mobile technologies for providing patients greater control over their health. These technologies revolutionized the Healthcare industry by gathering information and data from around the world. Healthcare 3.0 is based on the basic concept of embedding semantics with data sources. Data could now be shared and reused across applications and communities. This concept is known as the Semantic web. It provides data access to users or patients for personalized-health and electronic health records, thus creating an Open Healthcare information architecture. While Healthcare 3.0 focused on personalized health-related information. Even though both these models generated tons of data, they lacked efficient usage of these data to generate medical record trends. But,

Table 6.1 Summary of notations

Abbreviations	Descriptions
IoT	Internet of Things
CC	Cloud computing
FC	Fog computing
FN	Fog node
SDN	Software-defined network
ML	Machine learning
DL	Deep learning
RF	Random forest
NB	Naive Bayes
SVM	Support vector machine
KNN	K-nearest neighbor
CNN	Convolution neural network
DT	Decision trees
PCA	Principal component analysis
LDA	Linear discriminant analysis
ANN	Artificial neural network
LR	Logistic regression
RL	Reinforcement learning
BT	Boosted tree
BBN	Bayesian belief network
VM	Virtual machine

due to data incompatibility, 3.0 did not prove to be significant enough to support Healthcare for providing real-time solutions. The intention of Healthcare 4.0 is to adopt a portion of the standards of Industry 4.0 by incorporating technologies with IoT for data assortment, expanding the utilization of AI for data analysis, and also utilizing the overlay of a blockchain for patient medical records [3].

6.1.2 Healthcare 4.0

Healthcare 4.0 aims at eradicating the challenges faced by the previous generations by introducing the usage of machine learning (ML) and the Internet of Things (IoT). It majorly focuses on precision medicine. The fourth generation of healthcare amplifies the ability of accurate interpretation, recognizing progressions, and generating actual results and trends [3]. IoT is the network of electronic devices interconnected through the internet, allowing real-time data access from anywhere in the world.

IoT has enabled objects to communicate with each other and generate an enormous amount of data as a result. The primary purpose of including IoT in healthcare is to provide real-time data for patients in critical conditions. It can be

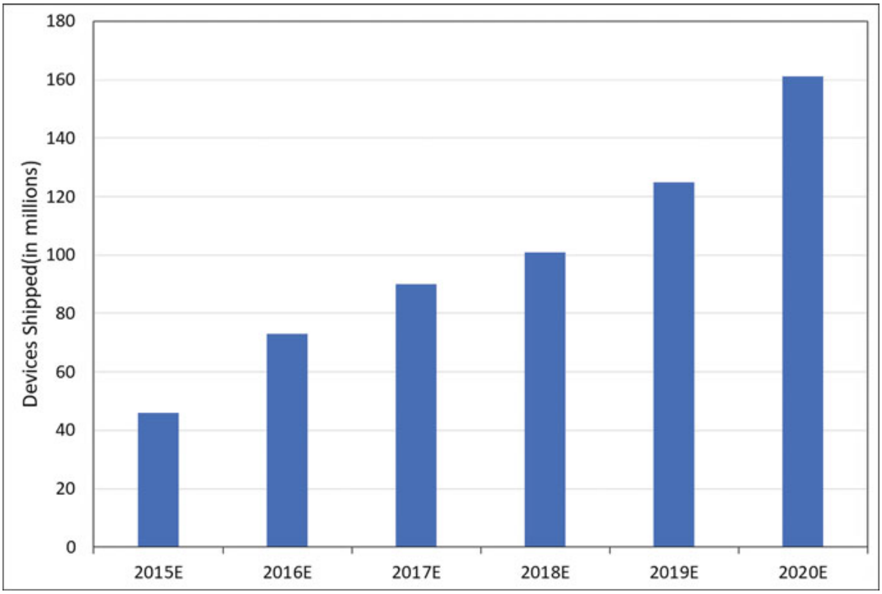

Fig. 6.2 Estimated IoT Healthcare device installed [4]

labeled as self-organizing and self-managing technology. The data generated keeps increasing by the second and is mismanaged and unutilized. Machine learning is a technique enabling the computers to develop notions about the solutions without requiring any human assistance. The mass of data generated from these IoT devices can be transformed into useful information in the form of medical trends with the help of such ML algorithms. Precise and accurate patterns can be obtained from this unstructured data if it is handled properly. Figure 6.2 shows the worldwide installations of IoT healthcare devices, which shows a rapid increase in the devices installed by the end of each year. Approximately 161 million IoT healthcare devices are estimated to be installed by the end of the year 2020. Figure 6.3 shows the fundings for AI/ML Digital health companies per year.

6.1.3 Need for Data Processing and Data Analysis

Data processing and analysis in the healthcare industry promote support decision-making by insight gaining. The data generated from the IoT devices have a lot of information stored within them that needs to be extracted. But at this stage, this data is unstructured and in incomprehensible form, which makes data processing an essential step. The changing landscape of healthcare is creating a massive demand for health data analytics. As indicated by an ongoing Research and Markets report, health data analytics is ready to grow into a $34.27 billion industry

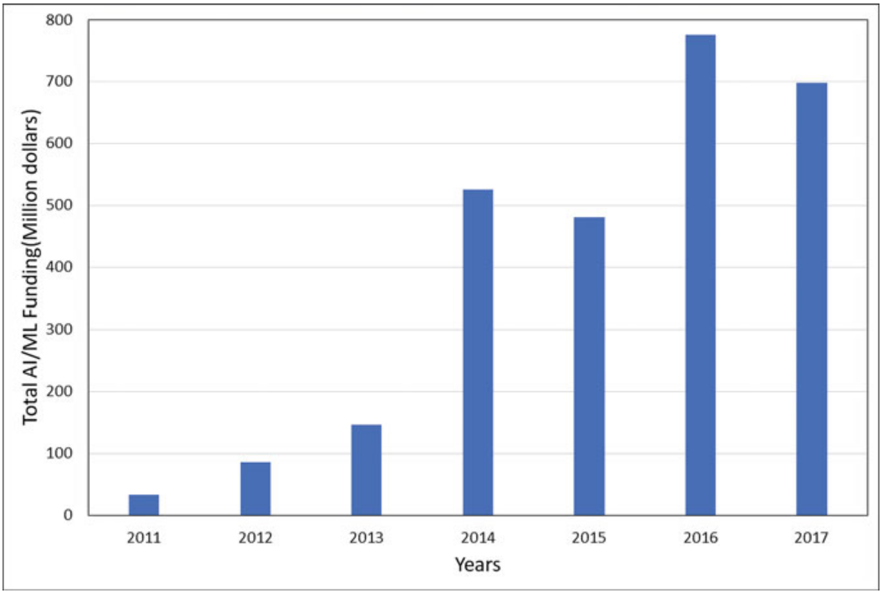

Fig. 6.3 Fundings for AI/ML Digital health companies [5]

before the finish of 2022. From prime areas like behavior of patient, clinical data, and pharmaceuticals, macro- and micro-level healthcare analytics can be done to streamline the operations effectively, improve patient care, and lower the overall costs. Data analysis plays a core function in day-to-day operations as there is a transition in healthcare providers from fee-for-service to value-based care models. It improves performance by delivering data-based quality care, reduces wait time of patients by leveraging scheduling, reduces readmission rate by leveraging predictive analytics that can isolate patients that may be at risk, quality of care is improved by streamlining tedious processes like scheduling appointments, processing of insurance requests, etc.

With the availability of digital data, healthcare data is expected to grow to skyrocket, resulting in HealthCare Big-Data Analytics. Also, data generated from different sources possess different format and structure that needs data processing. There is a need for sophisticated computing infrastructure and efficient data analytics to manage and analyze the data. For this big healthcare data, high-performance computing engines are used for data processing and analysis, generally referred to as cloud computing. Vital information of the patients is sent to the cloud. The information extracted by carrying out data analysis can be used by doctors to diagnose fatal diseases at their initial stages. Through the investigation, insights may be obtained, allowing precise decision-making, refining healthcare systems, saving more lives, and obviating infections.

6.1.4 Enabling Technologies in Healthcare 4.0

Digital health is a paradigm shift, and the use of most advanced cutting-edge solutions results in an effective health care system. Various technological reforms have been implemented in the Healthcare sector that has brought in a major revolution. The following are the already existing technologies that are being implemented in the sector of Healthcare.

AR/VR Augmented reality (AR) is a visualization technique which helps computer in generating virtual objects overlapping with the real world [6]. Virtual reality (VR) depicts the interaction of user with "fake" objects [7]. AR and VR both have most of the usage in the field of Healthcare. The data visualization is the easiest way that can neatly fit the augmented reality into the healthcare system. VR is widely used by young surgeons to master surgical skills on human cloned virtual bodies before directly performing surgery on an actual person. It reduces the risk borne by the non-experienced surgeons [7]. AR is utilized by doctors to make students and patients visualize the ailment in depth for better understanding Fig. 6.4.

Big Data Big Data technology refers to a software utility that is intended to analyze, process, and extract the data from a tremendously complex and huge data sets which the conventional data processing would never manage [9]. The healthcare industry has started to 'digitize' the patients medical records. As a result, the amount of data in the Healthcare sector is increasing by an exponential rate [10]. This data possesses a lot of valuable information that needs to be extracted. Big Data works

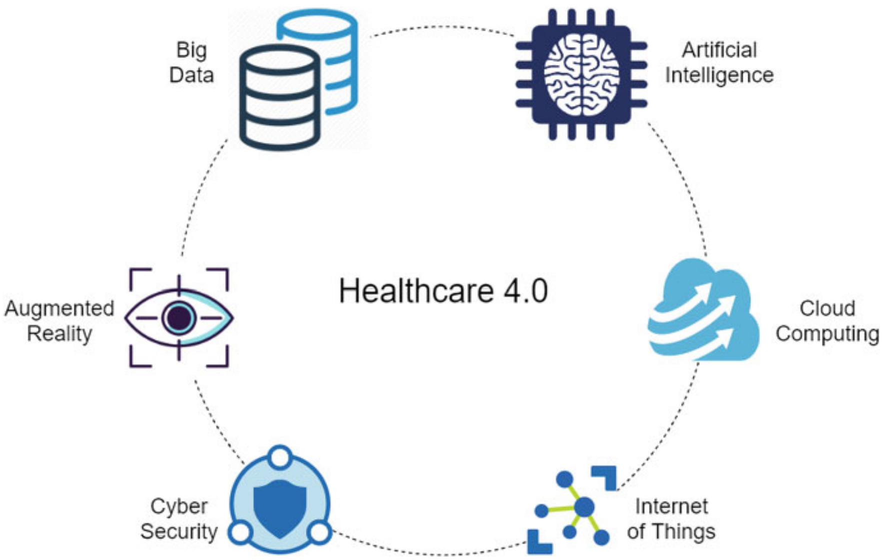

Fig. 6.4 Existing technologies in Healthcare 4.0 [8]

with techniques to extract information from data sets of enormous size. According to International Data Corporation (IDC), healthcare data will reach up to 40ZB of data by the year 2020 [11]. Wang et al. [12] analyzed the usage of Big Data in the healthcare sector and discovered it to be beneficial in a lot of aspects. Following are some of the several benefits of this technology:

– Reduce system redundancy
– Simplify IT management
– Process large number of patient records in seconds
– Shorten the diagnosis time
– Reduce unnecessary treatments
– Increase system efficiency
– Extract hidden information

Cloud Computing It is preferable to use cloud computing instead of buying and maintaining expensive hardware devices for computations. This technology overcomes the problem of users for employing a full-time computation engine, and allows them to rent a high-capacity computation engine for the specified time. In simple words, cloud computing is *pay for what you use*. It refers to the allocation of computer resources as per the demands of the user and charging for the same [13]. The patient's medical health data is sent over the network to a remote cloud server for computations and generations of trends. This process yields beneficial information hidden in the data. Along with all the benefits of this technology, there are some drawbacks which are listed below:

– Cloud servers are located at remote locations, which increases the transmitting time of the data from the data source to the cloud and back, resulting in the inability to produce fast results. Healthcare demands real-time results to act immediately in times of a critical situation. The physical distance between source device and cloud is a hindrance to generating real-time results [14].
– Cloud servers are shared among many different organizations and hence have heavy network traffic. The request/response time in the cloud is quite large. It causes a delay in the computation of the data, which in turn leads to delayed results.

The problem of latency in cloud motivates for a new nearest computing framework that overcomes the above issues for the effective response in real-time health care systems.

6.2 Fog Computing in Healthcare 4.0

The healthcare industry demands real-time results with low latency. Cloud computing fails to provide the features mentioned above due to its remote location and constant high traffic [15]. Fog computing or edge computing is introduced to overcome these issues and produce better results. Fog computing technology facilitates

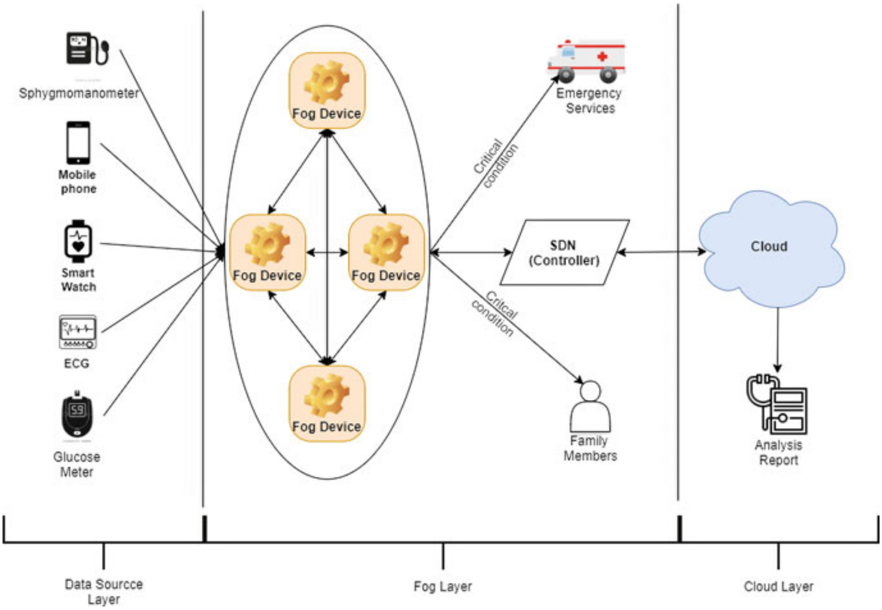

Fig. 6.5 Three-layered architecture [16]

the user by adding fog nodes for providing services of storage, computation, and networking services, intermediating between cloud and end devices.

The main focus of FC remains on getting real-time results. A three-layered architecture as shown in Fig. 6.5 is used to embed fog nodes for faster computations. The three main layers of this architecture are:

1. Data Source
2. Fog Layer
3. Cloud Layer

6.2.1 Data Source

Patients admitted to the hospital are under continuous monitoring by different devices that monitor every health parameter of the human body. Moreover, people have grown alert regarding their health. The gadgets like a smart watch, fitness bands, digital sphygmomanometer, glucose meter, and many such devices are frequently used to keep a check of health in everyday life. The devices from which the patient's health data is generated are data source. Medical data are generated from the patient's body and sent to the fog layer, some of which are mentioned below [17].

Table 6.2 Type and values of data generated

Attributes	Outputs	Description
Heart rate	Numerical value	Heartbeats per minute
Blood pressure	Numerical value	Pressure sensor readings
Diabetes	Numerical value	Amount of glucose in blood in milligrams per deciliters (mg/dL)
Fever	Numerical value	Body temperature in degree Celsius
Respiratory rate	Numerical value	Breaths per second
Gastrointestinal tract	Requisite format	pH, temperature, and pressure measurement in the stomach and intestine through ingestible sensors
Other sensor readings	Requisite format	Values of transcriptome, genome, exposome, metabolome, etc.

- **Clinical Data**—health-related information that is associated with regular patient care like heart rate, blood pressure, sugar level, TSH, gastrointestinal tract, etc.
- **Metabolome**—the total number of the small molecules or intermediaries of metabolism within a cell, tissue, or organism
- **Transcriptome**—the full range of messenger RNA molecules expressed by the genes of an organism
- **Genome**—the set of chromosomes in a micro-organism or each cell of a multicellular organism
- **Exposome**—the measure of external factors like tobacco smoke, pollution, etc.
- **Images**—X-rays, ultrasounds, scans, etc.

This layer has very little to no computation capability and is briefly related to the collection of data only. Table 6.2 shows the types and values of the data generated from the human body.

6.2.2 *Fog Layer*

The fog layer is an intermediate layer between the cloud and the source devices comprise of various high-performance computation nodes called fog nodes [16]. Data from the data source is transferred directly to the FNs. These FNs are authorized to perform all the critical computations on the received data. As a use-case, the authors [18] designed fog based architecture fog nodes to perform critical data analysis and generate results classifying the condition of the patient as benignant or malignant. If the state is classified as malignant by the FN, emergency protocol is followed, which includes alerting the hospital management, informing the emergency contact of the patient, and notifying the doctor in charge to attend the call immediately. The fog nodes are nearer to the source of data generation, which results in faster transmission of data and results, as compared to communications with cloud. To select an optimal fog node for pathway, a better efficient, agile, and reprogrammable network requirement is a prime need.

6.2.2.1 Software-Defined Networking (SDN)

SDN provides the facility to program the network to select an efficient fog node [19] [20]. With SDN, new notions of networking can be created. It drastically simplifies network management and helps in evolution and innovation. SDN decouples the software logic from the hardware to apply new protocols with ease [21]. Embedding SDNs in the three-layered architecture improves the efficiency of the system. SDN can leverage real-time data analysis in IoT based Healthcare due to its central controller and a global view of a network [22, 23].

Data Processing in Fog Computing Data generated from the data source cannot be utilized directly to analyze and produce meaningful results. Data processing converts this unstructured data into the utilizable format. This process is carried out in four steps, the flow of which is shown in Fig. 6.6.

1. **Data Acquisition:** Data acquisition is the process of retrieving data from electronic health records (EHR) and sensors. EHR data consists of the patient's records that include the patient's medical history and previous medical information like diagnoses, lab tests, image data, etc. Proximity sensors are used to monitor their heart rate, breathing rate, blood pressure, and other types of identifiable data. Wearable devices are used for providing cost-effective methods

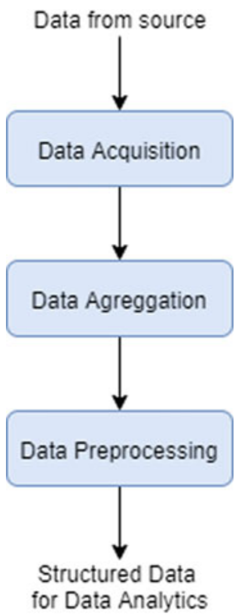

Fig. 6.6 Data processing

for on-site monitoring of these clinical parameters. The data acquisition layer transmits the variables of patient's data to the fog layer with the privacy policy. Data exchanged is encrypted to save it from falling into the hands of malicious users [24].

2. **Data Aggregation:** Data aggregations serve as a noteworthy archetype for wireless routing in sensor networks. Its original idea is to cluster the data from different sources by minimizing the number of transfers and eliminating redundancy. This paradigm focuses on a data-centric approach that aims to find routes from multiple sources to a single destination and to merge redundant data. This entire process ultimately leads to saving of energy. The delay in aggregation depends on the difference between the distances of the multiple source nodes and the sink or the destination node [25].
3. **Data Preprocessing:** Data preprocessing refers to take action before the actual data analysis is done. It can be considered as a basic transformation of real-world data into a set of new data. Analyzing unprocessed data can lead to misleading results due to the errors or noise in the received data. Major aims for data preprocessing are as follows: (1) solving problems that may be a hindrance while performing any analysis on the data, (2) understanding the nature of the data, and (3) extracting required information from the given set of data. Various data processing techniques are used. Few of them are listed in Table 6.3. Data preprocessing is required to solve the problems with data as mentioned below in Table 6.4.
4. **Data Storage and Retrieval:** With the rapid growth in the use of IoT devices, a variety of data to be processed witnesses a quick increase. Effective management and analysis of massive-scale data pose an important and critical challenge in data storage and retrieval. Security is an important aspect while storing data. The

Table 6.3 Data preprocessing techniques [29]

Techniques	Description
Data filtering	Removal of irrelevant features or undesirable data with minimal distortion of the data
Data ordering	Organizing data in proper locations for further retrieval and analysis
Data sampling	Splitting dataset into several parts for training/testing purposes or for evaluating different algorithms through an iterative process of varying sample size
Noise filtration	Removal of noise added by amplifiers or jittering
Data visualization	Extraction of the highly multivariate data involving only the relevant features
Data elimination	Reducing the volume of the data substantially and partially classifying it
Data selection	Clustering similar data into groups
Data fusion	Fusing the readings from different sensors into single parameters that are more informational and create precise results

Table 6.4 Type and values of data generated [29]

Data problem	Description
Corrupt data	Errors caused while transmitting, reading, or writing data to the database have incorrect data values leading to a false analysis of the problem
Noisy data	Large amount of errors in the received data than the actual attributes can lead to false results from analysis
Irrelevant data	Irrelevant data can hinder the learning of algorithms used to generated trends
Missing attributes/missing attribute values	Improper sensor functioning might generate out-of-range data which cannot be processed no matter how sophisticated algorithm is used
Very large data size	The hardware/software available used for data analysis does not always have the capability to process very large amount of data
Small amount of data	Less amount of data can stop the algorithm from converging and generating trends
Numeric/symbolic data	A combination of numeric and symbolic parameters is difficult to deal with
Incompatible data	Data having different formats may not be compatible with the system
Multiple data sources	Data collected from different sources can have different types of parameters and attributes

data of the patients are sensitive and should not fall into the wrong hands. For this purpose, a variety of security techniques like Network Coding, Blockchain are followed [26]. Recent advancements in blockchain technology ensure the security of sensitive data [27]. Ekblaw et al. [28] proposed blockchain technology for security and interoperability of electronic health record (EHR) systems.

6.2.3 Cloud Layer

Cloud computing is an emerging technology to execute enormous-scale and complex computing. It forfeits the need to maintain expensive computing hardware, installation space, and software. The massive influx of healthcare data generation has been observed. Data analysis is the process of inspecting data to discover useful information used to support decision-making [30]. Addressing the analysis of enormous data is an arduous and time-consuming task that requires a large computational infrastructure to ensure accurate data processing and analysis [31]. In this architecture, cloud acts as a data analytics engine and the fog layer classifies data generated from the body as:

(a) *Critical data:* Data, which needs immediate attention of the authorized personnel.
(b) *Non-critical data:* Information containing patient's vital medical records and requires no prompt activity.

Data generated from the source is passed to the fog layer, which, after classifying it as critical or non-critical, sends it to the cloud to train algorithms and generate accurate trends. Both critical and non-critical data are sent to the cloud layer for examining recorded information to predict future events [24].

6.2.4 Role of Machine Learning and Deep Learning in Data Analysis

To analyze this continuously generating data, we need algorithms that can comprehend the information and learn trends on its own. ML and DL algorithms facilitate us with these features and are widely used for the analysis of large amounts of data.

(A) ***Machine Learning:*** Machine learning involves the usage of statistical models to achieve specific goals without explicitly instructing the computer systems [32]. These algorithms are classified into the following categories:

1. *Supervised Learning:* Algorithms that require labeled data in their learning phase are categorized as supervised learning. These algorithms can be used when they have already acquired a dataset with the correct judgment of their medical conditions. For example, The Pima Indians Diabetes dataset where the medical records include vital information like blood pressure, insulin level, age of the patient, etc. and also contains the diagnosis of the patient. LR, SVM, NB, DT, RF, ANN, CNN, etc. are the examples of some state-of-the-art supervised ML algorithms used frequently for healthcare applications.
2. *Unsupervised Learning:* Algorithms that do not require labeled data fall under this category. These algorithms cannot specifically classify the result as yes/no but can classify them in groups. KNN, K-means clustering, PCA, etc. are some examples of some state-of-the-art unsupervised ML algorithms used frequently for healthcare applications.

(B) ***Deep Learning:*** ANN is a connection of nodes known as neurons that vaguely resemble the biological neuron cells. These artificial neurons are interconnected like biological brain cells and possess similar learning capability [33]. An ANN with a lot of hidden layers comprising of a lot of neurons is known as a deep network, and the method to train this network is known as deep learning.

This technique involves a higher number of parameters, which results in obtaining better trends and precise decision boundaries. This technique demands a compute engine with very high computation power and results in a

Table 6.5 Progressive work done using ML and DL algorithms in healthcare

Year	Author	ML algorithms used	Objectives
2016	Gupta et al. [35]	InfoGain, AdaBoost	Chronic disease prediction
2016	Araujo et al. [36]	RF, NB, SVM, KNN	Preauthorization for Healthcare Insurance Providers (HIPs)
2017	Chen et al. [37]	CNN, NB, KNN, DT	To predict diseases from structured and text data
2017	Dolatabadi et al. [38]	PCA, SVM	Normal and coronary artery disease diagnosis using heart rate variability (HRV) and ECG without human intervention
2017	Varathrajan et al. [39]	LDA with enhanced kernel based SVM	To reduce noise and get better pattern recognition with the help of enhanced kernel based SVM
2017	Zhong et al. [40]	DL, NN	Development of a framework to improve health prediction using deep learning paradigms and revised fusion node
2018	Maini et al. [41]	DT, NB, ANN	Cardiovascular disease prediction
2018	Abhinash et al. [42]	SVM, co-relation	For efficient feature selection in large datasets
2018	Kannan et al. [43]	LR, DT, SVM, RF, clustering, anomaly detection, RL	Comparison of different ML algorithms to predict and diagnose coronary disorders by the 14 qualities from UCI Cardiac Datasets
2018	Nijeweme-d'Hollosy et al. [44]	DT, RF, BT	To assist patients with acute low back pain (LBP) to prevent it from transiting to chronic LBP
2018	Ndaba et al. [45]	K-means clustering, KNN	Proposed an enhanced generalized regression neural network (KGRNN) to predict type II diabetes
2018	Nair et al. [46]	Big Data ML	To develop a real-time remote health status prediction system modeled around open source Big Data processing engine
2018	Kim et al. [47]	ANN, LR	To detect risk factors following posterior lumbar spine fusion
2019	Singh et al. [48]	RF	To detect epileptic seizure
2019	Yahyaoui et al. [49]	SVM, RF, CNN	To predict diabetes
2019	Jadhav et al. [50]	SVM, NB	mHealth disease prediction system

model which gives out prediction considering the higher amount of parameters than regular ML algorithms.

Analysis of this data using the methods mentioned above generates trained ML and DL models. These models are sent back to the FNs, which further utilize the analytic trends learned by the cloud computation engine to update the classifier at a regular interval of time [34] (Table 6.5).

6.3 Benefits of Fog Computing

Embedding fog layer in the healthcare systems is proved to be extremely advantageous due to the following benefits offered by fog computing:

1. **Reduced Latency:** In comparison to device-to-cloud architecture, the three-layered architecture involving the fog layer results in reduced latency owing to the less physical distance. Also, intensive computations that take longer time on sensor devices can be performed on the nearest fog nodes [51].
2. **Privacy:** Propagation of data is reduced in fog computing. Due to less transmission of data, the privacy of the patients is improved [51].
3. **Energy Efficiency:** Fog computing improves energy efficiencies in various ways within sensor devices. The length of sleep cycles of sensors can be increased by using gateways as communication proxies. The gateway monitors any updates or requests, and they are acted upon when the sensor device wakes up [51].
4. **Bandwidth:** The volume of data to be sent to the cloud reduces with the involvement of the fog layer as raw data is filtered, analyzed, pre-processed, and compressed. In some cases, fog nodes are capable of answering requests from devices based on cached data, and hence communication with the cloud might not be mandatory [51].
5. **Scalability:** Local computation on FNs reduces the load from centralized resources and can also be expanded, which improves the scalability of the system [51].
6. **Dependability:** The dependability of the system is increased by fog computing. Since the computation is close to the sensor devices, the nodes are slightly dependent on the availability of the connection to a centralized resource [51].
7. **Context:** The FN is the primary node in a network that has enough recapitulation to judge a situation and context of data [51].
8. **Real-time Computation:** Because of proximity of the FNs to the edge devices, it is easier to get real-time results. Small or easy computations can be performed on the FNs and quick results can be provided on the devices in real-time.

6.4 Issues and Challenges in Fog Computing

Despite the abundant benefits of fog computing, there are a few areas of concern that need to be focused. Some of them are listed below.

6.4.1 Authentication

Authentication is an essential aspect for the security of fog computing since the system provides access to front fog nodes to large number of users [52]. Stojmenovic et al. [53] have considered authentication as the main security issue of fog computing at different fog nodes. Balfanz et al. [54] have proposed a secure, cost-friendly, and user-friendly solution to overcome the issue of authentication in the system, having involvement of a physical contact for pre-authentication. The rise in the use of biometric authentication in cloud computing and mobile like face authentication, fingerprint authentication, touch-based authentication can be widely seen. So, employing biometric-based authentication in fog computing is beneficial [55].

6.4.2 Dodgy Fog Node

A fog node or device that appears to be legitimate and coaxes users to connect to it can be known as a dodgy fog node. For example, an administrator in charge of managing the nodes may generate a rogue node rather, causing an insider attack. Once we are connected to this dodgy node, manipulation of all requests arriving and leaving from cloud to end-user and vice versa, tampering user data is possible by the adversary, and quickly, it can further launch attacks. The presence of an illegitimate fog node will be a significant threat to user's data security and privacy [55]. This problem is difficult to deal with due to two main reasons:

- Each situation calls for different trust management schemes since every trust situation is different.
- Dynamic creation and deletion of VM instances make it hard to maintain a list of rogue nodes.

6.4.3 Invasion of Privacy

The breaking of private information, such as user data, saved passwords, or current location, is a possibility when users are using services like cloud computing or IoT, etc. This challenge prevails for taking care of such privacy in fog computing, too, because fog nodes are in the proximity of users. Owing to this reason, they can collect a lot of vulnerable details as compared to the remote cloud. Another major privacy issue is the pattern of use with which a client utilizes the fog services. For example, in smart grid systems, the collection of the meter can disclose household information like the presence of no person at what time, etc., invades the user's privacy. In case a fog client utilizing multiple fog services at various locations, there is a chance of disclosure of tracking the path to the fog nodes, if the fog nodes connive. As long as such a fog client is attached to an object or a person, the location privacy remains at risk [55].

6.4.4 Encroach Detection

Encroach detection techniques are adopted in cloud-based systems to reduce various attacks like insider attacks, flooding attacks, port scanning, attacks, etc. In fog computing, EDS can be deployed on fog systems to detect encroaching or intrusive behavior by overseeing and analyzing log files and user login information. Prevailing challenges also include implementing encroach detection in geo-distributed, massive-scale, high-mobility FC environment to meet the requirement of reduced latency. Due to the outsourced nature of cloud computing, cryptography is used in CC to implement user access control [55].

6.5 Case Study

In this section, we have described various case studies of health care systems in which fog computing is used. The three case studies listed below explain the benefits and proper functioning of the fog layer in the three-layered architecture. They also give insights on why fog computing is better to achieve real-time results.

6.5.1 Fog-Assisted IoT Enabled Health Monitoring Systems

Prabal et al. [18] have proposed a fog-assisted IoT enabled health monitoring systems for patients in smart homes where health data of 67 patients were continuously generated for 30 days to check the validity of their model. In an intelligent communication mechanism, the information related to patient health history can be accessed from the cloud layer. While, in regular communication, the fog node related updates are transmitted to the cloud along with patient details for future requirements. This model follows the three-layered architecture comprising of

- **Data Acquisition Layer:** Timely data retrieval from the IoT devices is performed at this layer. Environmental and physiological parameters are obtained from these devices and sent to the fog layer.
- **Fog Layer:** The parameters obtained from the IoT devices are converted into an appropriate format before sending it to the cloud. The event classification also takes place at this layer, where the data is categorized as normal or abnormal. When parameters have higher values than usual, like high blood pressure or high

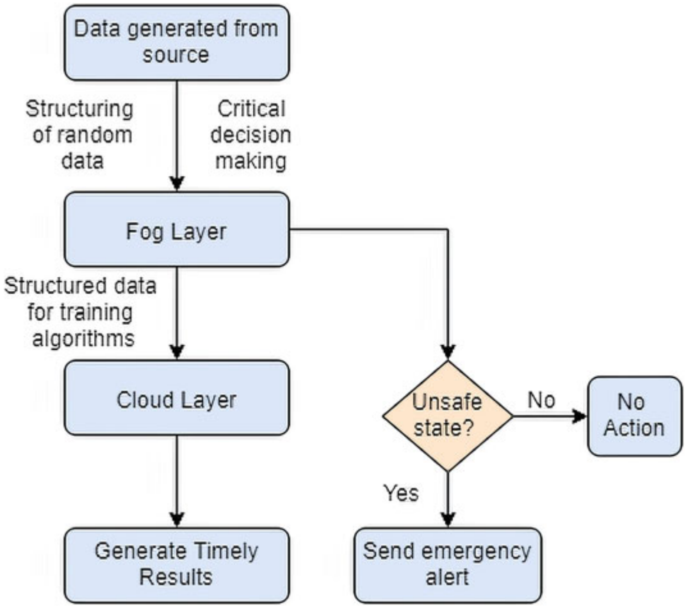

Fig. 6.7 Decision-making in three-layered architecture [18]

glucose level, it is considered to be an abnormal state. The BBN classifier is used to calculate the probability of occurrence of any critical event.

- **Cloud Layer:** This layer focuses on extracting or mining useful data from the fog layer in real-time. The training algorithms are run on this layer using the continuous data generated from the source. The parameters of the data can be classified as SS (Safe state) or US (Unsafe state) for the patients. If it is the US, an emergency alert is sent from the fog layer to the source of data generation. Else, the data is sent to the cloud, and timely results are generated. The decision-making of the model is explained in Fig. 6.7.

6.5.2 Pima Indians Diabetes Set

We used the Pima Indians Diabetes dataset to predict if a person has diabetes or not from various attributes such as BMI, age, blood pressure, glucose level, insulin level, skin thickness, etc. generated from different IoT devices. After data processing, the size of this dataset is reduced to 722. On using different state-of-the-art ML algorithms such as KNN, RF, and LR, the following results were obtained. For the KNN algorithm, an accuracy of 65% with an F1 score as high as 0.72 was received. On using the LR model, we achieved an accuracy of 67% at a learning rate of 0.3 and 800 epochs. On the other hand, with the RF algorithm, the accuracy was boosted up

Table 6.6 ML algorithms

ML algorithms used	Accuracy obtained
KNN	65%
LR	67%
RF	75%

to 75.32% when applied with 100 estimators. It proves that the result of the analysis has a significant dependency on the algorithm chosen for the task. For the same dataset, different algorithms can yield different results. The algorithms that we used and their accuracy obtained are shown in Table 6.6.

6.5.3 Body Edge Architecture

Pace et al. [56] proposed BodyEdge, an architecture concatenating IoT devices network with edge computing to face challenges such as response time, scalability, privacy, etc. [56] followed a three-tier architecture as shown in Fig. 6.7. This system was intended to be used by workers in a factory, athletes, or even patients in the hospital to monitor their health. The architecture comprises of two main components.

1. *BodyEdge Mobile BodyClient (BE-MBC):* The main purpose of BE-MBC is communication between the different IoT devices and the mobile phone where this software will be installed. The other important job is to send the data from these devices to the next component.
2. *BodyEdge Gateway (BE-GTW):* BE-GTW does the task of communication with different edge gateways and public/private clouds. It also has the feature of data management to achieve interoperability and guarantees a certain Quality of Service (QoS) level.

Tests were carried out by comparing different compute engines on the prediction of high-stress conditions on the following users:

1. Workers working in a factory
2. Athletes while training

The results were computed on 3 different platforms: (1) Raspberry Pi3, (2) Nano PC, and (3) Azure cloud. On evaluation, it was noted that for both the scenarios, Azure cloud and Nano PC produced similar results, while Raspberry pi3 lagged. Raspberry pi3 took 1600 ms for 100 factory workers and 3200 ms for 100 athletes (Fig. 6.8).

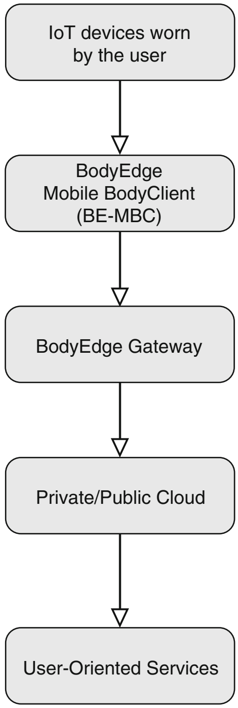

Fig. 6.8 Decision-making in edge based architecture

6.6 Conclusion

The future of healthcare will be driven by digital transformation and data analysis. With the change in healthcare with respect to value-based payment initiatives, examining available data to discover the practices that are most effective aids in cutting costs and improving the health of the mass served by health care institutions. In this chapter, we have provided insights about the future of fog computing in healthcare. In the first section, we have discussed about the emerging technologies in Healthcare 4.0 and their impact on the Healthcare systems. In the second section, we have discussed the three-layered fog architecture. We have also explained the need for data processing and analysis, along with various stages of data processing. Furthermore, issues and challenges in fog computing are discussed. Finally, we discussed different use-cases involving fog computing.

It is quite evident from above that IoT based fog computing is providing more efficient patient-crucial data to the users. Real-time events are monitored at the fog layer for computing event adversities. Delivering the information to the end-user from the cloud layer plays a vital role in managing medical emergencies. A real-time alert generation with event complexity computation further enhances the utility of the healthcare system. The adoption of a fog layer in the healthcare architecture plays a crucial role in achieving real-time results with low latency, and to design a secure network. Along with the advantages of data analysis for present healthcare industry problems, a Health BI solution can also bring scientific and technological advancement for the future.

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Part II
Enabling Technologies for Healthcare 4.0

Chapter 7
Enabling Technologies for Fog Computing in Healthcare 4.0: Challenges and Future Implications

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7.1 Introduction

The healthcare organizations are concerned with the problem of huge chunk of the population growing old and the chronic diseases that is affecting many in various parts of the planet. These circumstances have caused a steep rise in the healthcare expenditure. To get an idea, 7.3 trillion US dollars was spent on healthcare all over the world in 2015, and this amount is expected to reach US$ 8.7 trillion in 2020. As a result, various state-of-the-art solutions have been devised to enhance the reach of the medical services, optimize the treatment procedures in patients, and avert further severities. Sensor-based patient monitoring systems are being used to address these needs and have been able to generate a huge amount of data about the state of the patients on a daily basis. In this case, this data was stored and analyzed using the cloud computing model. But the cloud-based systems could cause communication

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delays in applications and cause disappointment of therapeutic frameworks and lead to wrong diagnosis. Along these lines, fogging is now seen as an alternative to cloud by getting capacities and abilities closer to the apps and information sources and subsequently anticipating postponements. Fog can be utilized to construct progressively powerful therapeutic innovation arrangements.

Given the utilization of fog foundation as a promising model, the topic of making increasingly proficient stockpiling storehouses in the fog layer is still looked with inadequate approaches. Consequently, it is a challenging task to handle health data contained in the fog. Moreover, the differences in the data are important as it can impede the diagnosis depending on their availability and affect the judgement, leading to greater problems in the health of the patients and even to their death.

With the information of patients in the records, privacy becomes a very crucial factor. By introducing an environment for fog computing that is sensitive to the context, they seek to enhance and update the health-based applications. They address the various computational healthcare activities that are executed on the fog layer, internet, and consumer apps and sensors. The safety of the information going through the device will be enhanced because data access is limited because the data need not move between the nodes in the network.

Services provided by the cloud are distributed at various nodes to compensate and decrease the latency time required for the data to move between the endpoints and the cloud. Fog computing is one possible solution in health informatics to seal the path between analytics and sensing. This is a distributed system architectural style where the application-dependent logic exists in both data centers, computers nearest to end users, and in the constituents of infrastructure around them. Gateways, routers, and access points are examples of such network components. The additional technology versatility opens up new ways to address healthcare problems. Better patient flexibility and improved connectivity would allow continuous monitoring as mentioned above, as well as allowing completely new applications, as discussed later. Section 7.2 outlines literature review; the proposed taxonomy and its architecture are defined in Sect. 7.3. Section 7.3 addresses fog's healthcare issues 4.0, and Section 7.4 discusses future consequences.

Nevertheless, a simple cloud to sensor infrastructure is not achievable for many health informatics applications. Regulations do not require patient data to be stored outside the hospital in some situations. Due to safety norms for patients during data center or a network failure, depending completely on data centers located at remote location is not acceptable for some applications. To work in the best way possible, the Internet of Things needs a new medium other than the cloud. Cloud computing cannot be trusted for sensitive tasks although it is very reliable for some purposes. There is a need for a new infrastructure to manage all IoT transactions without unnecessary risks for this reason. Fog computing aims to improve efficacy and decrease the quantity of data needed for analyzing, storage, and processing to be transported to the cloud. While this is mostly done for reasons of efficiency, it can also be done for reasons of safety and compliance. Fog computing is bound to grow significantly in the coming decades. Fog computing is the glue that bonds the sensors to the health analytics systems. This has motivated us to write this manuscript in the area of fog computing.

7.2 Review of Literature

Silva et al. [1] present various works that conducted a state-of-the-art analysis showing why the fog model was implemented in healthcare [1]. This paper describes all kinds of healthcare products generated by fogging, the collection of infections which tend to take place in such arrangements, the approach that was taken, the features that were provided, the inspirations for using fog in the field, and the obstacles that should be looked into to enhance the usage of the model. We also made a distinction between the use of different types of sensors in structures, the most widely accepted infrastructural design, and the standards and concepts applied in the literature studied. Figure 7.1 provides a map of the results of the audit. With the survey, it was noted that the fog layer's administration of restorative data is still an open inquiry [2]. For such a strategy, security and protection are significant highlights and are commonly listed in [3, 4]. In addition to the cloud, storage capabilities form an obstacle, as it has space constraints [5]. The fog-based storage systems must therefore conform to this restriction. In addition, the works reviewed consider the presentation associated with the control of data in applications as the primary motivation for the usage of fog computing in the field of healthcare [6], meanwhile the review [7] certifies the results identified with the absence of healthcare knowledge by the board method in fog, claiming that no proper info is available. Many work deals with Fog's managing max. Job (2017) [8] shows another calculation answerable for the dynamic planning of these sorts of undertakings in vehicular systems. Another estimate is suggested in which partitions information to squares and distributes planning of resources. A management assignment and distribution technology of fog resources are suggested depending on the size of the operation, the completion period, and the capability limit [9]. Then again, the works are not offering answers to boost fog's processing mission. Taking into account the difficulties faced in the present arrangements, we propose a technical solution that tends to address problems of accessibility, execution, interoperability, and security as a way of dealing with them. Sentence means, the large amount of data is required to prove the security using Block Chain. Vora et al. [10] introduced a fog-based patient-assisted living monitoring system (FAAL). BAN Provides the Sensor Nodes, using that kind of sensor nodes, data traces of patient activity (for neurological diseases) are gathered and transmitted through the fog gateways. An effective portioning algorithm for information transfer is implemented in order to reduce the load on the communication infrastructure. The performance of the solution proposed was validated with features such as latency and overloaded data. Tanwar et al. [11], Describes many approaches are explored to strengthen current limitations in healthcare systems using blockchain technology, including frameworks and methods for evaluating the efficiency of such systems,

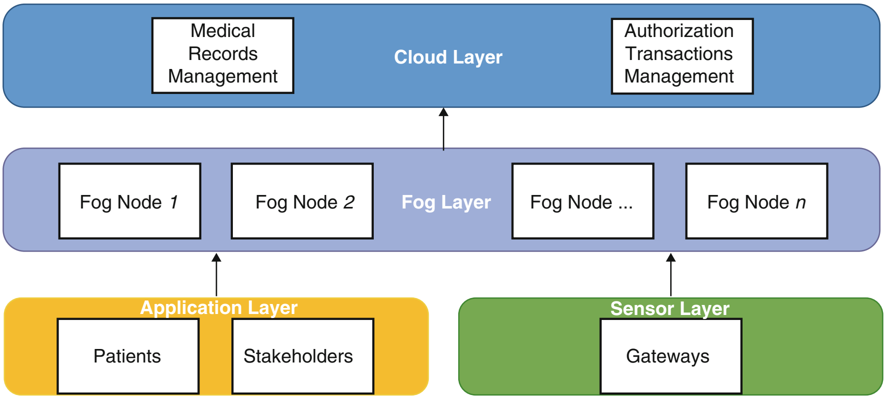

Fig. 7.1 Architectural view of the proposed architecture

such as Hyperledger Fabric, Composer, Docker Container, Hyperledger Caliper, and the Wireshark capture engine. In addition, they propose an algorithm to enhance data reachability among healthcare providers, helping to simulate environments by applying the Hyperledger-based Electronic Healthcare Record (EHR) sharing framework using the chain code principle.

Silva et al. explain the method suggested to better manage the records of patients. This method tries to enhance the reliability and quality of the process by storing a part of patient's information very close to the data source and applications. In addition, by using access control methods, the software guarantees the security of patient data. It also preserves the confidentiality of data by unlinking the identity of the patient from his/her details.

Layered view: The layered view of the planned design is shown in Fig. 7.1. This form of view aids in getting qualities of portability and modifiability to the defending strategy [12]. The layers listed in the technical analysis referred to in Sect. 7.2 and the perspective shown in Fig. 7.1 have been used in the elaboration of this interpretation. It therefore consists of four layers: (1) sensor layer equipped with sensors to monitor the patients; (2) to access and manipulate info from the records of patients and track its usage; (3) to manage and store a subset of information in the records very close to the application. It also receives information from the sensing devices and the systems in the application layer and verifies accessing rights to this information. Figure 7.1: view of the surface of decomposition of the architecture. (4) Cloud Layer: liable for the handling of the total arrangement of patient records, exclusive data on the utilization of data, and logs acceptance given to get to them. Communicating with sensor layer, different sorts of gadgets get distinguished in the lower block of Fig. 7.1. These gadgets screen patients, producing information of medicines administered. Identifying with the application layer, there are frameworks that control the information of patient data and are utilized by patients, doctors, medical attendants, relatives, salvage laborers, emergency clinic staff, and others. Kumari et al. [13] describe that the conventional power grid is substituted by a modern infrastructure based on ICT, known as the smart grid. The devices produce large amounts of information and storing, processing, and analyzing data is a challenging task that varies with volume, speed, and variety. Cloud computing (CC) commonly stores and helps analyze the data generated in a grid framework, which feeds results obtained immediately into several products. Nevertheless, in order to deal with the problems of latency during grid data analysis, fog computing is seen as platform to provide great computing capabilities near the end users.

Paul et al. [14] propose a three-level engineering that utilizes cloud and fog computing to follow setting and latency sensitive health. The tri-levels are distributed computing, fog computing, and sensors that work together. Sensors include wearable and non-wearable devices that are connected to patients such as genius watches, fitness teams, PDAs, and wearable glasses. Parts operating in the edge gadgets are placed on fog layer, body sensors, and cloud. The cloud and the layers of haze can limit the edge gadgets. In setting up delicate controls on healthcare, customized care can be given to every patient. Environment can be described in an alien and characteristic environment. When social insurance exists, internal conditions are influenced by external factors such as the illness that affects the client. Natural sensors can be used to delete a client's external parameters, and biosensors can isolate the inherent environment. All natural and external sensors provide important data that could be used to track medical care for patients. And, depending on the patient's condition, the kind of information that is suitable varies. Subsequently, the haze layer must also complete the setting up of delicate information storage. The schematic chart of the engineering is given in Fig. 7.2. In this setting of delicate healthcare checking frameworks, we guarantee to ensure most goals of healthcare observed and all are altogether cultivated.

These are the devices that capture patient data. Such sensors acquire properties that are both alien and natural. The temperature, location, etc. are the outward attributes. Pulse, blood glucose rate, pulse, etc. are intrinsic characteristics that are gathered by the sensing devices worn by patients. The patient could key in information into their advanced cell, and that information will be made available for preparation at that stage. The sensors' operation is to gather this information and send it to the recording surface of fog. Information is collected and analyzed in this layer. The edge gadgets gathered information and data are broken down in this layer. Huge measurements of constant sensor data are sent to this point. At that point, the fog layer transmits the handling work to various edge gadgets associated with the haze layer, and consequently, gigantic information measurements are broken down. The distribution of the planning work must be done using a realistic estimate of the errand booking. Fog layer deals with several activities which is carried out to perform the evaluation of healthcare. A portion of the observation software executes in the sensing devices that allows for the collection and transmission of information into haze layer. The distributed computing layer handles the system for tracking healthcare on an ongoing basis. Aside from the different levels depicted over, the human services conveyance framework normally comprises of four categories: locale, foundation, clinical division or outpatient facility, and person data progression must be efficiently tracked between these four stages. There are

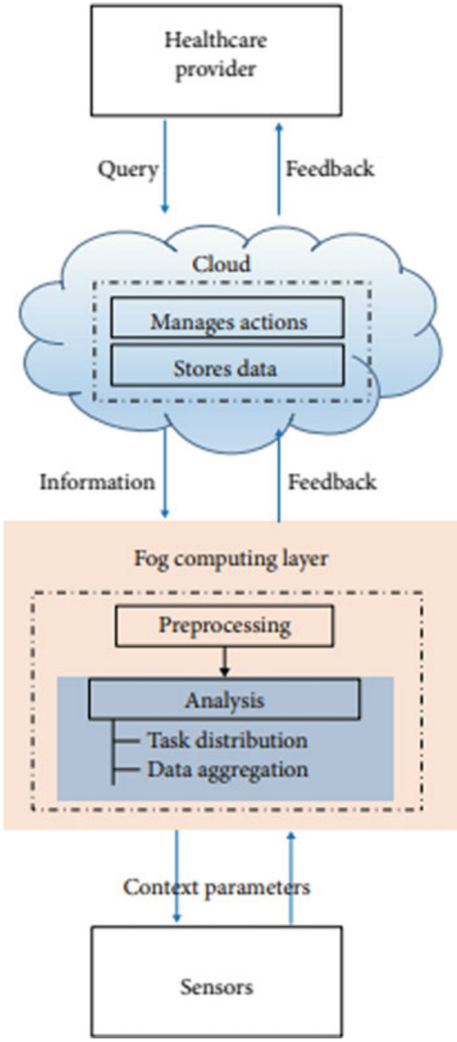

Fig. 7.2 Proposed three-tier architecture

several critical defense and safety issues that need to be tackled subsequently. Kumari et al. [15] describe that they review the role of cloud, fogging, and the web in offering users with continuous on demand service which is aware of the context. Three-layered user initiated model was proposed to collect, analyze, and deliver actual live. It gives the clients knowledge about the application of fog gadgets and pathways for present and to be developed apps in the healthcare 4.0 platform. Ananda et al. [16] propose edge-cloud data analytics architecture; the edge-based cloud model for the investigation of information is shown in Fig. 7.2. Similar edge based system, for example, cell phones, motion displays, and brilliant meters, data from sensor-prepared gadgets is sent to the hubs for further handling.

Unadulterated edge processing frameworks conduct full calculation on the edge hubs, although the operation of the edge-cloud frameworks completes the task-specific calculation nervous and perhaps associates with cloud for mix purposes. Sensors are equipped to perform a high-recurrence inspection: for example, voltage and recurrence devices can store a large number of info every second. The amount of information that needs to be passed along these lines is immense. This leads to high latencies and heavy device traffic when trying to move each of these data to the cloud for planning purposes. In comparison, ML is repetitive and, in some cases, unfeasible with such large data sets. The job of edge hubs in the suggested edge based cloud research technology implemented in Fig. 7.2 is thus to decrease the amount of information transmitted to the cloud and decrease the movement of information; the arrangement proposed here spotlights on information decrease for ML undertakings. Fog computing is used in different healthcare scenarios, one such is arthritis. Tanwar et al. [17] say that specialist's regular joint health monitoring and consultation may aid users having chronic infections. The proportions of qualified surgeons to arthritis patients are small throughout the world. The usage of sensors can provide considerable help to the healthcare industry. Encouraged with such details, we suggest a prototype to monitor the patient's hand gestures. Fog and cloud gateways are used for the generation of real-time response to regular tracking of users with arthritis.

7.3 Proposed Fog Taxonomy (Fig. 7.3)

The tri-tiers are sensor layer, fog computing layer consisting of fog nodes, and include cloud computing layer that operate together. Sensors are wearable or unwearable devices connected to patients. The devices are intelligent watches, smart health bands, mobile phones, glasses, etc. The health monitoring applications will have components running in the fog computing layer. Cloud and fog layers can power the edge devices. Information is going to flow through this three-tiered infrastructure.

This taxonomy consists of different modules, they are as follows.

Sensors Tier: These instruments capture heart patient information. These sensors collect values that are both extrinsic and intrinsic. The temperature, position, and so on are extrinsic characteristics. High and low blood pressure levels, variable glucose levels in the blood, pulse, and so on are the intrinsic characteristics obtained by the wearable sensors of the patient. The client will also be able to enter information into his or her mobile and will then be made available for processing. Sensors play a very important role in collecting the patient data and the data is further processed in the fog layer.

Fog computing layer: Information preprocessing, reduction and productive analysis of the information are the tasks carried out in this layer. This layer is mainly responsible for accumulation of information and data by the smart gadgets

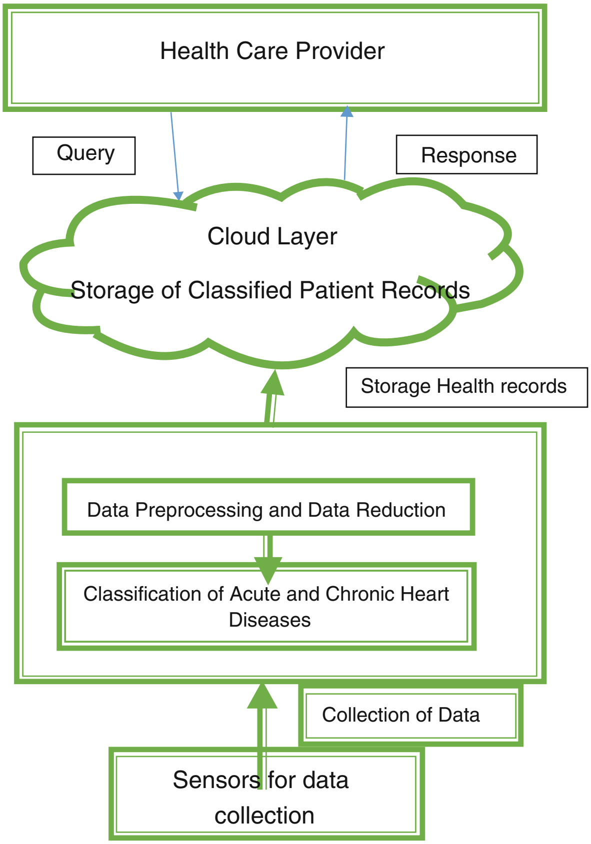

Fig. 7.3 Proposed fog taxonomy for healthcare 4.0

Fig. 7.4 Process involved in fog layer

and is further analyzed. The server activities are carried out in this layer. This layer receives gigantic sums of real-time information from sensors (Fig. 7.4).

Inside the fog layer different modules are there for processing and classification, they are as follows.

7.3.1 Data Cleaning and Normalization

Cleaning the data is identifying missing, wrong, unreliable or irrelevant data pieces and removing, altering or erasing dirty or coarse information afterwards.

Original data is raw and is unprocessed, not complete and is irrelevant noisy data. For example, the databases may contain

- Redundant and obsolete fields.
- The attributes which contains missing values.
- Extreme values called outliers.
- Unsuitable data forms in the dataset which are not suitable for the data mining models.
- Values are out of common sense and are not consistent.

So we can start the data cleaning process first by filling the missing values, which can be done in different ways.

Missing values can be handled carefully and can be replaced by the following:

1. Analyst specifies constant values; then the missing value can be handled by replacing it with the constant.
2. Missing numeric variables in the data set can be replaced with the mean or the missing categorical variables in the data set can be replaced by the mode.
3. Random value which is generated by variables' observed distribution pattern.
4. Analyzing the other characteristics of the record, the imputed values can be substituted.

Then identify the outliers either using graphical method or by using interquartile range (IQR) method.

7.3.1.1 Graphical Method of Identifying the Outliers

These are the values that go against remaining data pattern. The data set contains some errors, which can be termed as outliers. Graphical methods for identifying outliers are histogram and scatter plots (Fig. 7.5).

One elementary robust method to detect the presence of outliers is interquartile range (IQR).

The data set can be divided into four parts called quartiles, which contains 25% of the data.

- Q1 is called first quartile, which is 25th centile.
- Q2 is called second quartile which is 50th centile, which is the median.
- Q3 is called third quartile which is 75th percentile.

The Sentence means that the Variance which is calculated using IQR is better than Standard Deviation. The difference between the first quartile and the second

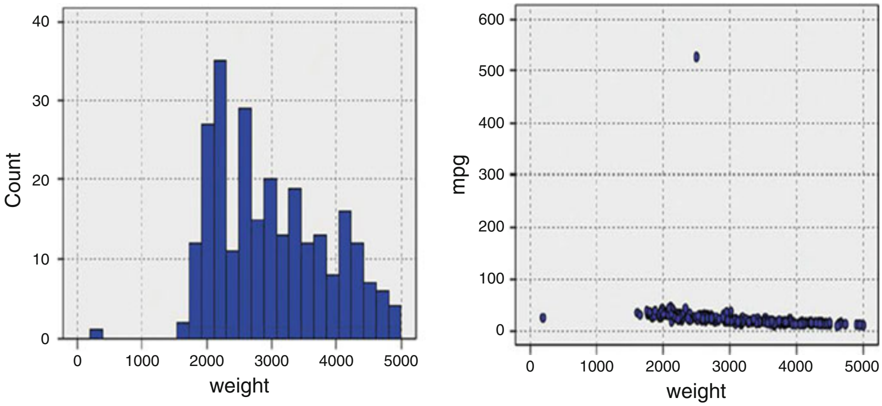

Fig. 7.5 This figure represents the outliers in the data set

quartile is the formula to calculate the interquartile range. This value is used to interpret the spread of the data.

Therefore, a robust outer detection measure is elaborated in the following. The value in the information is an outlier when—is 1.5(IQR) or less than Q1 or—is 1.5(IQR) or greater than Q3.

7.3.1.2 Data Normalization

A large-range attribute should not outweigh small-range attributes. This can be achieved using standardization. Scale all the values, such that it should fall within range, such as 0 to 1.0, an attribute is normalized. Min-max normalization, *Z*-Score, and decimal scaling are different data mining techniques that we use.

Simply put, when there are several attributes or attributes have values on different scales, this can result in poor data models conducting data mining operations. So they are structured to put on the same scale all the attributes.

Min-Max Normalization

Min-max normalization compares how much lower the field value is than the total min(*X*) value, and by the distance measuring this difference. Equation (7.1) represents the min-max normalization formula, which uses minimum and maximum value in the data set.

$$Y_{\mathrm{mm}} = Y - \min(Y)/\mathrm{range}(Y)$$

$$Y_{\mathrm{mm}} = Y - \min(Y)/\max(Y) - \min(Y) \tag{7.1}$$

Z-Score Normalization

Z-score standardization works by the breakdown between the field value and the mean value of the field and by multiplying the distinctness by the normal field value variance. Equation (7.2) represents the *Z*-score normalization formula, which uses standard deviation and mean of the data set.

$$Z\text{-score} = Y - \text{mean}(Y)/\text{SD}(Y) \tag{7.2}$$

Decimal Scaling

In decimal scaling, the standardized value is into -1 and 1, the highest absolute value that is the number of digits is represented by d.

Equation (7.3) represents decimal scaling formula.

$$Y_{\text{decimal}} = Y/10^d \tag{7.3}$$

7.3.2 Data Reduction

When using a large amount of data in data analytics applications, it can produce redundant results. To solve these challenges, we can use methods of data reduction.

Data reduction is the transformation of empirically or experimentally based digital number or alphabetical data into a form that is corrected, ordered, and simplified. Reduced data size is very low in volume and comparatively original, thereby increasing the processing capacity while reducing data handling costs and also minimizing the analysis time.

Techniques for reducing the data can be used to achieve a smaller degree of representation of the data set which is very shorter in size but still includes critical information.

7.3.2.1 Strategies of Data Reduction

1. Data Cube Aggregation

   Many of the tasks concerned with aggregation are operated upon the data during the data cube construction.
2. Dimensionality Reduction

   Identify the redundant attributes and remove those to lessen the quantity of the data set.

3. Data Compression
   Compress the data set using encoding mechanism.
4. Numerosity Reduction
   The data are estimated or replaced by unorthodox set of data in numerosity reduction.
5. Discretization and concept hierarchy generation
   Higher conceptual level data values can be replaced for raw data values.

7.3.3 Efficient Classification Model/Mathematical Model

The following passage explains the reason for choosing the appropriate techniques or algorithms before going into the detailed explanation of the analytical algorithms implemented. A data analytics employee should be aware of the different forms of machine learning algorithms such as supervised learning, unsupervised learning, and reinforcement learning.

Supervised learning refers to learning the program from the examples that provide a marked information. As the name suggests, the system needs a supervisor to train or teach using training data (part of input data correlated with the correct output) and to create a model that is tested using test data (part of input data on which the prediction is made). Supervised learning addresses two categories of algorithms—classification (where the target or output variable is categorical) and regression (where the output or target variable is a continuous value). In the absence of a supervisor, unsupervised learning deals with machine learning as well as with no marked results. Here, the algorithm tends to operate on its own by leveraging information such as accumulating data based on patterns, similarities, and other variations without any data on practice.

Unsupervised learning is about the two categories of algorithms—clustering (determining the basic arrangement in the data) and the rules of association (detecting rules that characterize large portions of the data). Reinforcement learning issues with the computer taking reasonable action in an atmosphere to optimize rewards in an effective situation. This varies from supervised learning because supervised learning makes a decision based on the initial input and the decisions are not dependent on each other while the outcome depends on the current input in reinforcement learning and the subsequent input is learned from the previous output.

Figure 7.6 shows the model construction process. The models can be enhanced if possible, by tweaking the appropriate input values that increases the accuracy. If we take decision trees, provide more accuracy compared to SVM. But SVM examines all the factors for computation and furnishes a best suited model for the input data.

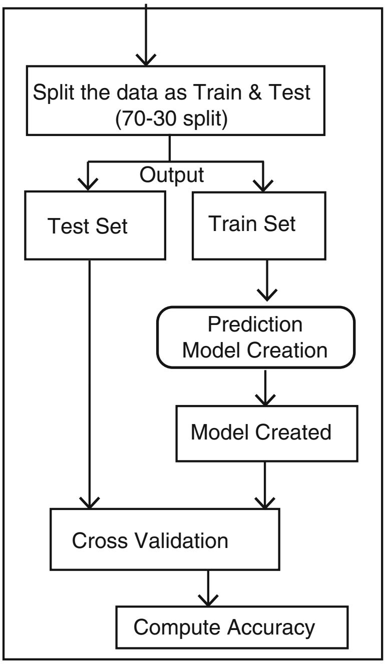

Fig. 7.6 Classification model

7.4 Cloud Layer

Cloud file storage approach is used in this layer to accumulate the data or information in the cloud which offers access to data via sharing the file systems to huge storage (server) and applications. This flexibility makes storage of cloud data perfect for workloads that are depending upon the shared file systems rely. Many classified patient records are stored here.

Storing file data in the cloud delivers advantages in three key areas:

1. Scalability—In spite of the fact that only one out of every odd storing of files in cloud framework can scale up and use all the intensity of the cloud, the most progressive arrangements offer the capacity to begin with the limit and execution that is required immediately and expand the limit as required.
2. Interoperability—Most modern applications require compatibility with shared file resources following the current terminology of the file system. A distinct advantage of cloud file storage systems is that secured set of code can be written to access the files.
3. Budget and Resources—To work with external files, it needs hardware budget, maintaining the resources, electricity, reducing the temperature, and physical space. Cloud data storage allows companies for redistributing technical resources to other initiatives that add business value.

7.5 Healthcare Provider

A healthcare provider is an individual or corporation providing clients with a healthcare service. In other words, you are taken care of by your healthcare provider. We view the history of the patient's heart disease and provide remedies. By the query and answer process, we access the individual information.

7.5.1 Challenges for Fog Computing in Healthcare 4.0

The explanation and examples for the challenges faced in fog are discussed as follows.

7.5.1.1 Privacy and Security

Fog computing can reduce data propagation when compared to the traditional cloud architecture, for example analysis of secured and critical data on a local gateway rather than a data center outside the user's control. This can boost customer data protection; the main security problem is the encryption at various gateways of the devices used in fog computing. IP address of its own should be provided to each appliance. The users access the data/information present in each fog node in a malicious way by creating the fake IP address. To avoid the malicious activities at different levels of the network, a secured intrusion detection system must be used to provide access control.

7.5.1.2 Secure Communications in Fog Computing

The different ways for collecting, analyzing called as processing of data and storing the data are discharged into fog nodes at the fog layer, and security requirements cannot be discharged. The IoT systems need some of the secured and safety measures to be introduced. Communications between IoT devices are considered to take care of the IoT communications security practices in place. IoT devices only communicate with fog nodes when a processing or storage demand needs to be unloaded. Any other activities would not be considered as part of the fog system as they would happen as part of the network.

The manner in which processing and storage specifications are discharged into fog nodes cannot be discharged. Even IoT systems need to meet the minimum security specifications. In context with IOT communication, the devices are required to interact in a secured pattern. The IoT devices interact with the fog layer especially the fog nodes for the fulfillment of data formatting, cleaning and analysis and storing it. Any other operations, as part of the network, would not be considered as part of the fog zone.

Such fog nodes communicate when they are needed to take care of the resources present in the network effectively or to control various activities in the network itself. The planned activities are performed in decentralized manner. The following communications between these devices are to be controlled in the scenario of fog-cloud architecture.

1. The interaction between the IoT devices and fog nodes with one another.
2. The interactions between the fog nodes.

Certain difficulties include reducing the overhead email, taking into account the secured, private space in which the IoT devices run. Communications between fog nodes require end-to-end protection, as multi-hop nodes may not be worthy of trust.

In context with cloud computing, privacy is an important aspect to avoid the data leakage in various aspects such as cloud computing, wireless network, and IoT services. Fog computing also has challenges in maintaining these confidentiality, fog computing protection, and privacy issues as fog nodes are close to end users and can gather more sensitive information than the core network's centralized cloud. Privacy protection strategies have been introduced in many areas.

7.6 Network Management

If SDN or NFV technologies are used, connecting to heterogeneous networks, handling fog nodes, the network, connecting each node will be a burden.

7.6.1 Delay in Computing

The performance or the effectiveness of fog database systems has been reduced due to data processing and resource overuse, causing data computing delays. Data collection must be carried out prior to data processing, planning for resource-limited fog nodes using the priority and flexibility model should be prepared.

7.7 Data Governance

Some cases of fog usage allow local and non-cloud processing of data [18]. This applies in general to medical and financial systems [19]. The introduction of a fog provider [19] adds additional complexities, as connectivity of the fog network from outside the world is a complicated process. The IDC study [20] estimates that by 2020, 44 zeta bytes of data will be produced by individuals, artifacts, and processes. Current holes therefore need to be identified and fixed as a matter of urgency to allow the data owner to monitor and control their information effectively. Therefore, from a regulatory compliance point of view, information management concerning confidentiality and reputation requires [7] has been developed with a consistent SLA framework covering every point of contact and each point of decision within a fog domain process.

7.8 Cybersecurity and Confidentiality

"Technology is a double-edged sword," said Dr. Badlani. He said healthcare is always infatuated with sparkly new toys and popular expressions, for example, cloud innovation, prescient examination, AI, and blockchain. Dr. Badlani said it's basic emergency clinics map for what reason they're putting resources into a specific arrangement, what the development can fix and why past endeavors were not attempting to keep centered and make the most astute speculations. Ben Patel, CIO of the Sinai Health System situated in Chicago, said that the decision of the correct innovation is regularly hampered by administrative weight, confidentiality necessity, and the expanding risk of information ruptures.

A new study by HHS or the media in March 2017 reported that there were 1,519,521 infringed patient records in March, representing an increase in the number of infringed records in January (388,307) and February (206,151) by 155-fold.

The expanding pace of breaks and cyber-attacks has constrained medicinal services associations to consider innovation from a ROI perspective that not just dissects what an organization could pick up from taking care of an issue, yet additionally the potential entanglements it could make, Mr. Patel said. Healthcare associations invest more energy inquiring about how innovation could reveal a medical clinic from a security viewpoint to guarantee that huge ventures do not deliver an expensive protection issue. Therefore, just add value to the best tools by helping medicine practitioners and the governance people to make sense of the different data produced by EMRs, said Mr. Buzachero. The expert commented that the hospitals are in need of "strong AI appendages that will help us make sense of what we got—to work smarter and more effectively."

7.8.1 Choosing the Appropriate Classification Model

Such questions apply to data mining methods and their limitations. Topics such as the sophistication of mining techniques, the variety of available data, field dimensionality, specific research needs (if known), the estimation of discovered information, the use of background knowledge and metadata, data noise management and handling, etc. are all examples that can decide choices in the mining methodology. Of example, different methods of data mining are often useful as different approaches depending on the data at hand can work differently. Therefore, different approaches will suit and answer the consumer's needs differently. Most algorithms take noise-free data for granted. This is, obviously, a solid assumption. A few databases contain abnormalities, invalid or fragmented data, and so on, which can confound, if not misty, the examination procedure and much of the time bargain the unwavering quality of the results. As a result, pre-preparing data (information cleaning and transformation) gets fundamental. It is frequently observed as lost time, however as tedious and disappointing as it might be, information cleaning is one of the most significant strides during the time spent information and knowledge discovery. Information mining strategies ought to have the option to deal with information clamor or inadequate data. The size of the inquiry space is significantly more basic than the size of the information for information mining systems. The width of the search space likewise relies upon the quantity of measurements in the domain space. The search space as a rule develops exponentially as the quantity of dimensions increments. This is called the dimensionality curse. This "curse" so severely affects the quality of some approaches to data mining that it becomes one of the most urgent problems to solve.

There are many artificial intelligence and statistical methods for data analysis and interpretation. Nevertheless, for today's very large data sets in data mining, these techniques have often not been developed. Terabyte sizes are popular. When handling the huge amount of data, the scalability and reliability of data mining issues raises. Using algorithms with exponential and even medium-order polynomial complexity cannot be feasible for data mining. Usually, the norm is linear algorithms. In the same theme, sampling may be used for mining instead of the entire dataset. Nevertheless, problems such as completeness and choice of samples arise. Specific issues in the performance issue are incremental upgrading and parallel programming. If the dataset can be subdivided and the results can be combined later, there is no question that parallelism will help to solve the problem of scale. Incremental updating is necessary to combine parallel mining results or update data mining results as new data become available without the complete data set being re-analyzed.

7.8.2 Future Implications of Fog Computing in Healthcare 4.0

The explanation and examples for the implications on fog computing are discussed here.

7.8.2.1 Migration of Data and Applications

Users and phones are highly mobile in most fog computing situations. Such dynamics should therefore also be accompanied by the services provided. It includes software and data instances to be transferred through various instances of fog. While this is still performed reactively today, we plan to do this proactively based on users and data's expected flexibility and access trends.

Orchestration and Seamless Interplay between Fog and Cloud.

Although fog computing definitely provides many advantages and practical use cases, we still need cloud infrastructure to continuously store and batch big data. Data collected at the edge of the network may be as useful as possible for immediate storage, but also for cloud applications. It is therefore necessary to orchestrate cloud and fog services.

7.8.2.2 Fog Computing Can Help Build Smart Cities

Companies can install smart technology to assist in making decisions or perform tasks that are currently being performed by people. The creation of driverless trucks would reduce the demand for truck drivers as freight could be transported at night, operating on less busy motorways continuously. Driverless technology would mean that freight companies are not limited to comply with safe practices by the statutory number of working hours of a driver.

One example is hospital automation where diffusion pumps used to administer narcotics intravenously store and feedback on prescribed drugs and alert doctors to possible combinations of dangerous drugs.

The benefits may be clear, but companies need to assess the challenges of introducing fog computing and allow time for new work practices to be developed. Organizations need to develop solutions based on the feedback they get from end users, whereas progress in smart city projects such as Chicago's health center will come from people's active involvement in the change process.

Fog computing can come into its own as a viable future innovation when investors are actively involved in the process and when stakeholders and end users can vote on their ideas to create wider societal impact solutions.

7.8.2.3 Nanotechnology, Fog Computing for Healthcare 4.0

Nanotechnology includes a number of emerging technologies that deal with structures with dimensions of less than 100 nm (10.9 meters). When all is said in done, nanotechnology alludes to the advancement of structures that display novel and essentially improved physical, compound and natural properties, marvels and nanoscale-sized procedures. Nanotechnology is regularly associated with biotechnology, IT, and neuroscience and designing when applied to sustenance. All over the place, nanotechnology is found. Since 2005, in excess of 1700 customer items containing nanoparticles have been put available. For instance, titanium dioxide nanoparticles are presently generally utilized in nourishments (particularly biting gum, desserts, and candy), dietary enhancements, and individual consideration items (particularly sunscreens and toothpastes), frequently representing as much as 10% of their weight. Such techniques have interesting implications for medicine. Nanotechnology and fog computing play an important role in healthcare 4.0.

7.8.2.4 Digital Medicine

Digital healthcare provides patient-focused applications and better care. Many digital medical applications are presenting traditional healthcare facts slowly. This examination explores the impacts of advanced well-being innovation on human services sooner rather than later by assessing the impact of innovation used to encourage analysis, restoration, and correspondence among patients and social insurance experts. Three key advancements have been recognized that can possibly make applications that immensely affect social insurance. In the fields of natural language processing, profound learning, and computer generated reality, inventive advancements have been distinguished and talked about, including how wide utilization of these systems can change medicinal services from a patient point of view. This is because of expanded clinical execution, improved patient-social insurance commitment, and low-edge access to human services, regardless of area and time.

7.9 Conclusion

For health monitoring systems, we have suggested a fog computing scheme. Various functionalities or the metrics such as availability and performance enhancement by storing the information nearer to the applications and computers. It is based on the concept of fog computing, providing the functionality of availability and performance by storing the data closer to the applications and computers. Here we discussed some of the challenges of fog computing to prevalent applications for healthcare. Sometimes, IoT devices which are smart are not efficient enough to perform independently, which is why computing tasks need to be discharged. Due to restrictions on reliability, privacy concerns, or regulations, cloud computing is often not a better solution. Therefore, fog computing, with better options to integrate network infrastructure, appears as an appropriate concept to satisfy the healthcare requirements. We proposed an efficient taxonomy including the various layers like fog layer, cloud layer etc., for the healthcare 4.0.

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Chapter 8
Healthcare 4.0: A Voyage of Fog Computing with IOT, Cloud Computing, Big Data, and Machine Learning

Anish Kumar Sarangi, Ambarish Gajendra Mohapatra, Tarini Charan Mishra, and Bright Keswani

8.1 Introduction

There have been industry revolutions throughout the history of engineering starting from Industry 1.0, up until now and have reached Industry 4.0 which is more focused on intelligent devices and smart decision-making capabilities within machines which is reducing human efforts to perform a task with high efficiency, accuracy, and minimum labor and time. Technologies like IoT, artificial intelligence, big data, forms of wireless internet, 5G technologies, use of a schematic database, augmented reality, virtual reality, content-based image retrieval, etc. are forming up the Industry 4.0 standards (I4S). Similarly, healthcare industry also came from Healthcare 1.0 up until 4.0. The initial start of healthcare industry in the late 1970s termed as Healthcare 1.0 has undergone various innovations and changes with the innovation in medical devices and machinery, not to mention the healthcare industry is still in a very nascent stage. However, with AI, machine learning, IoT, cloud services,

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etc. many companies, as well as start-ups, has come forward to bring up various solutions to solve some of the biggest problems faced in healthcare sector. In other words, I4S extension in the healthcare industry forms Healthcare 4.0. It has the potential of vitalizing various processes related to healthcare and making it more personalized.

The recent years have noticed the industrial standards in parallel with healthcare standards. Industry 1.0 started mostly with automation in core mechanical engineering. Industry 2.0 was mostly based on electrical energy. Revolution in telecom technology and information communication technology (ICT) drove Industry 3.0. Finally, the Internet of Things (IoT) and cloud computing (CC) coined the Industry 4.0.

The standards of healthcare are very tightly coupled with the standards of industry. A healthcare industry to be user-friendly must match the services provided by industry standards described above. Being categorized from 1.0 to 4.0 the healthcare industry is still in its emerging stage. Healthcare industry with inadequate resources and capability is termed as Healthcare 1.0. Advancement in Information Technology (IT), medical image processing, and other medical technologies comprised Healthcare 2.0. By this time, the patient data chart was becoming a challenge. The Electronic Health Record (EHR) to maintain data chart became popular and thereby the Healthcare 3.0 was coined. EHR is adopted widely and it is helpful to get the patient information on time.

In a similar context, when the IoT, cloud computing is combined with existing healthcare technologies, it forms Healthcare 4.0. In Healthcare 4.0, huge amount of heterogeneous data are created using many platforms and across various healthcare industries. Big data technologies are used for storage and computations in cloud and fog computing nodes. The technologies such as IoT, big data, cloud computing, and fog computing providing real-time healthcare-related solutions are driving Healthcare 4.0.

Several computing elements, communication devices, biomedical sensors, storage infrastructure, interfaces, and biomedical actuators group up to form Healthcare 4.0 Cyber-Physical System (HCPS) which permits observation and monitoring of patients before, during, and after the treatment, thereby collecting ample of data which would be helpful in collection of data on which data analytics and machine learning can be performed, which enables services to be more personalized. HCPS consists of a biosensor that continuously collects data from the body during the treatment, and sends it to a server where the decision-making algorithm exists. This decision-making algorithm then triggers actuators or biomedical actuators which may vary from a simple alarm to a device that may inject certain medicine into the body with proper dosage. While making a decision, the decision-making algorithm looks into the patient's historical data as well as patients' current data to take a proper decision. Smart healthcare bands and mobile devices can be considered as examples of biomedical sensors that continuously record data from the body.

Healthcare 4.0 brings a collection of data and perform analytics on it to diagnose in real time and predict future events of patients. This would dramatically help healthcare providers to improve their quality of service and portability of data anywhere, anytime. To fulfill this purpose, the conjunction of IoT with big data analytics, fog computing, and cloud computing is important. Let us understand this in nutshell. IoT devices along with body sensors continuously collect a huge amount of data every second which needs to be monitored strongly without any lag. This is where fog computing comes into play and where cloud computing fails. Cloud computing has several issues that are covered later in the chapter, but network lag and data security are two of the huge challenges. This is where fog computing performs way better. The problem of real-time monitoring without any lag is omitted in fog computing where IoT devices send collected data to fog servers via fog gateway. But does this means cloud computing is redundant? No, it doesn't! The reason being, a huge amount of data is collected every day which needs high performance computation infrastructure which would become costly. Hence, performing analytics on big data collected from IoT devices on cloud infrastructure is a wise and cost-effective decision. This is the reason why the conjunction of three big technologies, namely IoT, big data, fog computing, and cloud computing is really important. We will discuss it in detail later on in this chapter.

This chapter focuses basically on the fundamentals of IoT concerning its application in the field of healthcare. Security is a primary challenge in any connected system. Therefore, this chapter summarizes various aspects of the security genre in IoT. Moreover, the current trend of data storing is cloud dependent. Hence, the usage of cloud to store various healthcare data is also depicted in this chapter. In addition to this, this chapter elaborates basic concepts of cloud computing, its types and application. In a similar context, advanced concepts such as telemedicine, telecardiology, and medical imaging are discussed in brief. Primarily, the focus of this chapter is the applicability of fog computing in healthcare. The concept of fog computing is discussed elaborately in this chapter. The architecture discussed on fog computing is cutting edge and the application of fog computing to Healthcare 4.0 is significant. Finally, the Machine Learning (ML) aspect of Healthcare 4.0 using fog computing has been established (Table 8.1).

8.2 IoT in Healthcare

8.2.1 IoT

Term "Internet of Things" was first brought up by AutoID center of Massachusetts Institute of Technology (MIT). Here, "Internet" refers to the ability of devices to communicate and "things" refer to objects with data sensing capability which is not precisely identifiable. Internet of Things can be defined as a paradigm of technology which involves devices having limited computational capabilities but with descent communication capability which can collect data using sensor and can send it to storage using over certain communication channel, thereby enabling end-user or system to monitor certain parameter and trigger certain event concerning the value

Table 8.1 List of abbreviations

Abbreviation	Meaning
I4S	Industry 4.0 Standard
IoT	Internet of Things
BD	Big Data
AI	Artificial Intelligence
FC	Fog Computing
CC	Cloud Computing
HCPS	Healthcare 4.0 Cyber-Physical System
LoRaWAN	LoRa Wide Area Network
LoWPAN	Low energy Wide Personal Area Network
BLE	Bluetooth Low Energy
UWB	Ultra-Wide Band
RFID	Radio Frequency Identification
NFC	Near Field Communication
IaaS	Infrastructure as a Service
PaaS	Platform as a Service
SaaS	Software as a Service
DDoS	Distributed Denial of Service
APIs	Application Programming Interfaces
CPS	Cyber-Physical System
WBAN	Wireless Body Area Network
ECG	Electrocardiogram
EMG	Electromyogram
AR	Augmented Reality
I/O	Input-Output
EMR	Electronic Medical Record
DR	Diabetic Retinopathy
HER	Electronic Health Record
HIS	Hospital Information System
HDFS	Hadoop Distributed File System

collected. This also enables data scientists to perform machine learning models and data analytics to bring up insights into the data and predict future values whenever required. IoT devices have increased exponentially over time. It is expected that more than 18 billion devices will be connected to the internet and contributing to the IoT eco-system across industries like manufacturing, automobiles, healthcare, etc. The ability of connected devices to trigger actions opens up a whole new possibility of efficiency, automation, and convenience. In short, it can be said that IoT devices can collect data, send it to the storage system and even interact with other IoT devices.

Components of IoT can be listed as:

1. Actuators and Sensor: Responsible for the collection of data.
2. Communication Devices: Responsible for wireless transfer of collected data.
3. Microprocessor: Has limited computational capabilities and co-ordinates between sensor and communication devices.

Some characteristic of the Internet of Things is described below:

1. Collecting data and making it available to end-user in real time.
2. It consists of communication devices for wireless transfer of data.
3. Accessibility to collected data from anywhere and anytime.

8.2.2 Role of IoT in Healthcare

Healthcare is one of the most interesting domains of IoT where the quality of service provided by healthcare providers can improve. Some examples of IoT in healthcare include remote monitoring of health, chronic diseases, elderly care, etc. [1]. Some of the early applications of IoT in healthcare include smart beds which gave information about whether the patient is sleeping on the bed or willing to get up. It adjusted its position automatically without needing any nurse intervention. Figure 8.1 shows IoT infrastructural diagram in healthcare.

Healthcare is such a field which is of prior concern for governments and welfare committees around the world who constantly thrive to bring in healthcare services

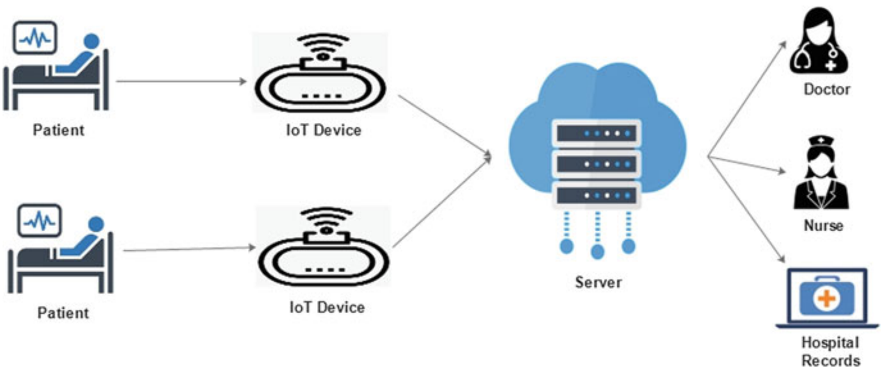

Fig. 8.1 IoT infrastructural architecture in healthcare

to every corner of the area at most affordable way. Some of the best things that IoT is bringing on to the table:

1. Healthcare services are reaching to the most interior corners of the world with the best facilities because of IoT.
2. Transfer of image and video data to specialized centers for special tests is today readily available due to data digitalization and the internet.
3. Instant clinical consultation and life-saving first aids before reaching the hospital.

IoT has enabled data of a particular person readily available at anytime and anywhere, thanks to cloud computing [2] and fog computing paradigm. Devices with limited features can continuously monitor blood pressure, blood sugar, oxygen saturation, electrocardiogram (ECG), electromyogram (EMG), etc. and send the collected data instantly for storage and analysis [3]. To send the collected data, various communication protocols are used. IoT devices have very limited power capabilities, hence various low power, low energy, short-range communication paradigm has been developed. For example, LoWPAN, LoRaWAN, ZigBee, BLE, UWB, RFID, and NFC are some of those communication protocols which help data communication at very low power consumption. To aid this technology, augmented reality is assisting while surgeries and training of medical students [4]. Moreover, health wearables are allowing the collection of health data and assisting people in tracking their health and targets they set for themselves. Smart health bands are an example of medical wearables. This also helps in formulating personalized healthcare services.

Some applications of IoT in healthcare are listed below:

1. Diabetes is a chronic disease which causes due to high or abnormal sugar glucose level in the blood, i.e., very high or very low. This impairs the production of insulin in the body and decreases the sensitivity of cells towards the activity of insulin. High diabetes may result in damage to various organs of the body. Continuous monitoring of blood glucose levels via IoT can help patients to control their diet and take proper medication at the right time.
2. Thirty percent of all deaths occur due to circulatory problems like long QT syndrome, arrhythmia, etc. according to the reports [5]. Hence, it is very important to monitor the ECG data in real time to give maximum information about heart-related measurements like a heartbeat, rate, prolonged QT intervals, etc. which can be done through IoT-enabled technologies. This can help to make vital data readily available with medical staff.
3. One more important aspect to monitor is body temperature. From body temperature, doctors can know if a particular medicine suits a patient or not. Sometimes, it is a very important parameter while determining whether the body is responding to treatments and even the condition of the patient. Real-

time monitoring of body temperature using sensors embedded in TelosB is really helpful.

4. Pulse oximetry can help measure the blood oxygen saturation level continuously. Hence, a combination of pulse oximetry and IoT would make monitoring and triggering alerts for actions easy.

8.2.3 Security of IoT in Healthcare

However, with so many novelties of IoT in healthcare, there are security challenges to it as well which cannot be ignored. Providing security to such a huge amount of data which is ever increasing with continuous generation of data from IoT devices is a big challenge. As mentioned earlier, IoT devices have very limited computational capability. Processing units in these devices cannot perform heavy computation which is what required with traditional security systems. Again, they have very limited storage space which is primarily occupied by the embedded operating system of the processor. Thus, executing complicated security protocols is not possible. Apart from that, most of the devices are connected to the global network of internet provided ISPs (Internet Service Providers) which makes data vulnerable to security breaches and theft. In IoT networks, devices vary from “things” with very low computational capabilities to servers with high computational abilities. Hence, creating a central security framework that can provide security to all the types of devices is a big challenge. Some IoT devices work within their network like ZigBee, LoraWAN, etc. which need to have a separate security arrangement, so that data do not leak out during communication. Again in IoT, multiple network protocols are used for end to end communication which have their strengths and weaknesses. Hence, incorporating a security system into the IoT network becomes complicated. Some IoT networks do not assign IPs to devices in it, which makes complexity even higher.

These security issues are somewhat addressed by the use of blockchain technology in healthcare, which helps in keeping data secure and easily accessible to the stakeholders. Given the sensitivity of healthcare data, permission-based blockchain can help in providing data security to EHRs where the authorization key remains with the data owner. Whatsoever, consistency of data accessibility is very crucial given a critical situation. If data is not made available at such a time, a life-threatening situation may arise for patients. For consistent accessibility of EHR, smart contracts among the parties in the ledger of the blockchain based on predetermined conditions can provide consistent accessibility. Again, parties can change those conditions as well. Cryptographic keys also give control of data to the data owner. Owners generally have a master key which can be given to healthcare professional whenever so needed to unlock the encrypted data. Smart contracts along with cryptographic keys help in restricting the addition of records from unauthorized sources and even remove the possibility of tampering the existing health records. During the addition of EHR in a chain, it provides an opportunity to all the associated parties in the chain to review the record before it is being added to the ledger or chain. In this way, data accuracy is also maintained. Vora et al. [6] have proposed a blockchain-based framework for securing EHR. The proposed framework provides security to EHR as well as provides an efficient way of storage and maintenance of medical records. The framework enables patients to be the sole owner of data. MedChain and MedRec are companies exploring blockchain technology to provide decentralized storage of medical records as well as providing security to patients' data.

8.3 Cloud Computing

It is a paradigm of technology where many remote servers are connected and hosted on the internet which provides storage, computation, and easy accessibility anywhere and anytime to the end-users. The charges of cloud computing infrastructure are generally based on the usage of it. Some features of cloud computing are as mentioned below:

1. It can provide the services to the users over a network like Virtual Private Network (VPN), Wireless-Fidelity (Wifi), Very Small Aperture Terminal (VSAT, Ethernet, Integrated Service Digital Network (ISDN)), Fiber Network, etc. which provides access to information anytime and anywhere.
2. It is scalable vertically and horizontally according to the needs of the user, i.e., it can be upgraded anytime according to the computing needs of the application. This makes cloud computing flexible and affordable for a large number of people to get access to some of the world's best computing devices remotely.
3. Various organizations around the world can share the same infrastructure for their computing needs where they can share services and information with like-minded people and organizations. Due to this sharing, cloud computing becomes affordable for various organizations.
4. The availability of the internet on mobile devices has enabled the usage and accessibility of information even easier. Cloud computing services can also be availed using smartphones, laptops, tablets, etc. This makes cloud computing services, application, and infrastructure easily accessible.

8.3.1 Cloud Computing Service Model

Cloud computing has various service models, namely, Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS) with its availability in private, public, hybrid, and community cloud. Information about the same is mentioned below.

8.3.1.1 Public Cloud

Cloud services provided by the third party over public internet are generally referred to as public cloud. It is available to anyone with internet connectivity starting from an individual to any group or organization. Public clouds generally have unlimited storage and charge users on pay per usage basis. It is sometimes free as well with very limited capabilities. In this model, hosting, ownership, maintenance, and operation completely lie with the third-party service provider. Examples of public cloud are Amazon Elastic Compute Cloud (EC2), IBM's Blue Cloud, Sun Cloud, Google AppEngine, and Windows Azure Services Platform.

8.3.1.2 Community Cloud

The cloud services that are provided to a group or a limited number of users which operated, maintained, and secured either by the members of the group or by third party service provider. The cost associated with the public cloud is generally higher than that of the public cloud but less than the private cloud. The entire cost of setting up the cloud computing environment is shared by participating members or organizations. This kind of cloud is generally used by groups with similar interests.

8.3.1.3 Private Cloud

Cloud services and infrastructure which is exclusively built for a single organization and use of it outside the organization is strictly restricted. It can also be referred to as an enterprise cloud. The IT services and infrastructure related to a private cloud are generally managed internally within the organization; however, external hosted private clouds are also used by many enterprises as it removes the cost and tasks related to maintenance, operation, etc. Private cloud users are generally charged based on data usages like per gigabyte used or terabyte used. Data stored in private cloud can only be accessed by members of the organization. Information and data stored are highly secured and is better than other cloud deployment modes as far as data security is concerned.

8.3.1.4 Hybrid Computing

A hybrid cloud can be defined by merging the features of the private and public clouds. The definition as stated by National Institute of Standards and Technology is "the cloud infrastructure is a composition of two or more distinct cloud infrastructures (private, community, or public) that remain unique entities, but are bound together by standardized or proprietary technology that enables data and application portability." Enterprises use cloud computing to scale up their IT infrastructure by connecting various cloud infrastructures at various geographical locations. Usage optimization, security, data integrity, transfer of risk, and all-time availability are some of the advantages of hybrid computing as compared to cloud computing.

8.3.2 Cloud Computing in Healthcare Application

Technology adoption in healthcare has always been very slow. Traditionally IT services and infrastructure in hospitals have been used for various management systems like information management system, inventory management system, laboratory management system, bill and reimbursement management system, etc. However, due to limited IT infrastructure and high cost associated with it, many of the abovementioned systems have not been implemented in a centralized fashion. In a hospital or any healthcare organization, investment preference is always given on the medical devices rather than on IT infrastructure which is quite logical as well. This is where cloud computing comes in which provides a very cost-effective solution for IT infrastructure. Cloud computing in healthcare is generally used for Infrastructure as a Service that provides a centralized computing and storage space with high availability (HA) and accessibility anywhere and anytime to deploy various functional modules. Some of the applications related to healthcare in the cloud are telemedicine, remote clinical consultation, medical image storage and analysis, clinical research, information exchange, etc. Some of the large applications are mentioned below. Figure 8.2 shows an architectural diagram of healthcare in cloud computing. Figure 8.3 shows the functionalities of cloud computing in healthcare.

8.3.2.1 Telemedicine

Cloud computing allows storage of data on virtual cloud storage which is easily accessible and available anytime and anywhere. This makes it suitable for the storage of patients' data regarding the tests, medicine, and history of treatments which makes it easy for doctors and healthcare professionals to understand the patient better. This also opens off the opportunities for teleconsultation, tele-education, and tele-follow up. Telemedicine consists of features like video-conferencing and storing various data-related health parameters of the patient like heartbeat record, blood glucose level, blood pressure, ECG, X-ray images, etc. This kind of technology enables healthcare to reach even to the remote corners of countries where it is difficult to reach. Typically, using telemedicine software patient health record is sent from the remote location to the cloud data center using an internet connection. This data is then made available to a super-specialist, who then gives appropriate advice to the patient through the software itself from a remote location. This has the potential to enable governments to reach every corner and provide healthcare and cater to the needs.

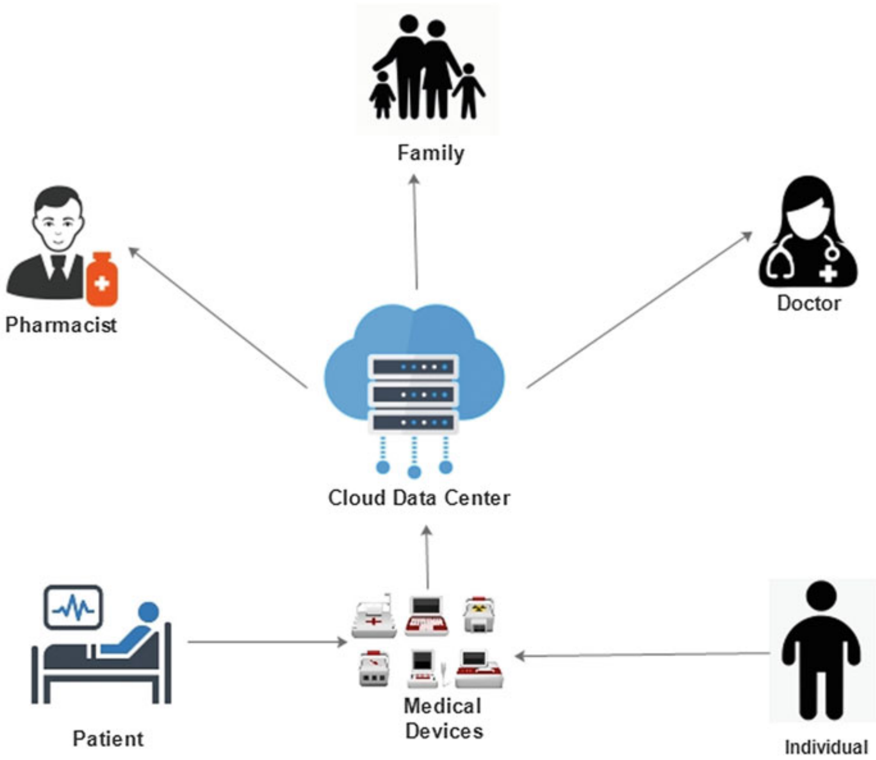

Fig. 8.2 Cloud infrastructural architecture in healthcare showing collection of data from patients and making it available to users and healthcare professionals

8.3.2.2 Telecardiology

The main objective of telecardiology is to storing the ECG data records at central cloud storage which would make interoperability available across hospitals and clinics. This would also allow the cardiologist to access a patient's historical ECG records as well as present ECG records and make an interpretation based on that. This telecardiology platform enables centralized storage of ECG records and interoperability which enhances research work across healthcare providers and gives a unified and centralized teleconsultation platform for patients who seek consultancy and doctors who give it.

8.3.2.3 Research

Research in any domain requires a lot of data on which studies can be based. Hence, making data available for researchers is important. This can be made possible by

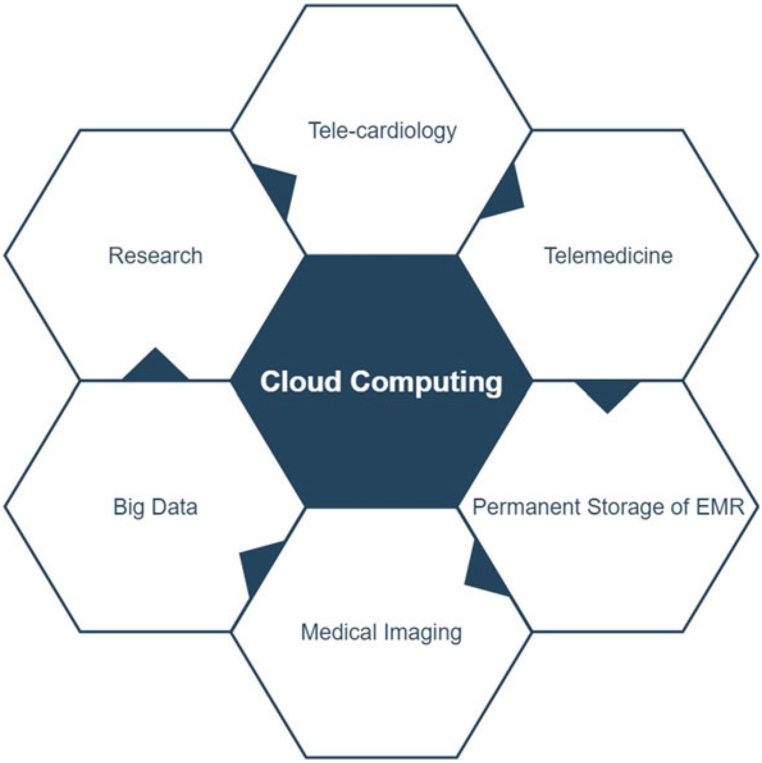

Fig. 8.3 Cloud computing functionalities in healthcare

storing patient data in a central database, making it available to the scholar groups for clinical researchers through a central portal.

8.3.2.4 Big Data

Hospitals and other healthcare providers tend to incline towards cloud storage to avoid the overhead cost of local hardware and storage devices. Cloud storage holds large datasets of genome data, radiological images, and electronic health records, which are of great use for clinical drug trials. Sharing the data with various facilities across various geographical regions without remote cloud storage may delay treatments.

8.3.2.5 Medical Imaging

Medical imaging helps in archiving various images pertaining to patient health in regard to a particular health issue in central cloud data storage. Medical imaging comprises storage, computation, and communication of image. This allows medical images to be shared among a group of doctors or specialists who then give their expert opinion based on their observation.

8.3.3 Security and Protection of Healthcare Data

The above application and benefits come with certain limitations and threats. There is certainly risk associated with data protection and integrity. A lot of sensitive healthcare data is stored in the cloud infrastructure, which makes having strong security protocols mandatory, so that data may not get leaked out. In recent years, data breach has been a major issue for many organizations. Some of the key security challenges are discussed below.

1. Lack of visibility of cloud infrastructure leads to a lack of control over it. Traditionally, cloud and storage infrastructure were present locally within an organization. However, with third parties providing cloud services with public and hybrid cloud infrastructure, the same level of granularity with regard to management and administration is not present. Lack of visibility also creates hindrance in identifying potential security threats and may lead to failure in business.
2. Even though enterprise-grade cloud infrastructure provides better security as compared to private and hybrid cloud, there is still a risk of downtime and data breaches. In public and hybrid cloud downtime and resolution of data breach lies completely in the hands of the third-party cloud service provider. Consequently, organizations have very little control over how many time-critical systems remain offline.
3. Some healthcare facilities may rely on the public and hybrid cloud for their storage and application needs. So, it may lead to heavy dependency of the organization upon the third-party service provider and if some critical service is run on a particular cloud infrastructure, the service provider may force the organization to unpleasant contracts and sometimes retaining contracts. It also becomes difficult for the organization to migrate to different cloud service providers due to the criticality of the services and data associated with it.
4. Distributed Denial of Service attack is one of the most common problems that today cloud service providers are facing. With more critical operations moving to cloud, attacks of this kind force many businesses incur heavy losses. DDoS overloads a server with a lot of requests as a result of which it no longer responds to legitimate requests coming from users. Successful DDoS attacks may render a website useless for hours which may result in a heavy loss in terms of revenue.

5. Hacking is one of the biggest reasons for data breaches in recent years. DDoS are used merely as a distraction when attackers target data stored to steal or delete it. Hence it is very important to secure every network layer including the application layer and providing this kind of security should be the prime focus of any cloud service provider.
6. One of the biggest advantages of cloud computing is that it can be accessed from anywhere and anytime. To make this availability, cloud service providers create a lot of APIs. However, all the APIs provided by vendors are not entirely secure which leaves behind a loophole in the security system. Again, when clients develop an application on top of those APIs, those applications also become vulnerable to data breach and loss. Hence, securing APIs is important for any cloud service provider.

Apart from the above security flaws, there is one more limitation to the cloud computing paradigm when it comes to the implementation of Healthcare 4.0 which is an extension of Industry 4.0 in the healthcare domain. The Healthcare 4.0 demands continuous monitoring of patients using the Cyber-Physical System (CPS) and aids humans through decentralized decision-making algorithms and autonomous actions. This requires flawless, reliable, and lag-free connectivity with decision-making servers, i.e., connectivity between IoT devices, and computing servers should be very fast and reliable as data involved are very sensitive and a minute delay in data reaching the server may cost a life. This is where cloud computing fails as it is highly dependent on Internet or any such connection. This is where fog computing plays a major role in bridging that gap. More about it is discussed in the next section.

8.4 Fog Computing in Healthcare

IoT involves a lot of end devices that continuously generate data with a very high velocity and volume which needs to be stored for monitoring and analysis. In healthcare scenario, IoT infrastructure constitutes wireless body area network which sends various vital signal sensed like ECG, EMG, body temperature, blood glucose level, etc. at most efficient way possible. It can consist of wearable devices and body sensor which records various body parameters and sends it over to storage or computing devices using certain communication protocol running on certain communication device like ZigBee, Wifi, BLE, LoRa, etc. as per the requirement and infrastructural needs. Dashboards and graphs in certain applications help in visualization and monitoring. This paradigm helps in many ways as it has been described in the IoT section. Data storage, computation, and hosting of application are generally done on cloud infrastructure as it is very cost-efficient and provides high storage capability. However, with a huge amount of data being generated at a given point in time, it becomes very difficult to send all the raw data over a network. Again higher the amount of data transmitted over a network higher is the possibility

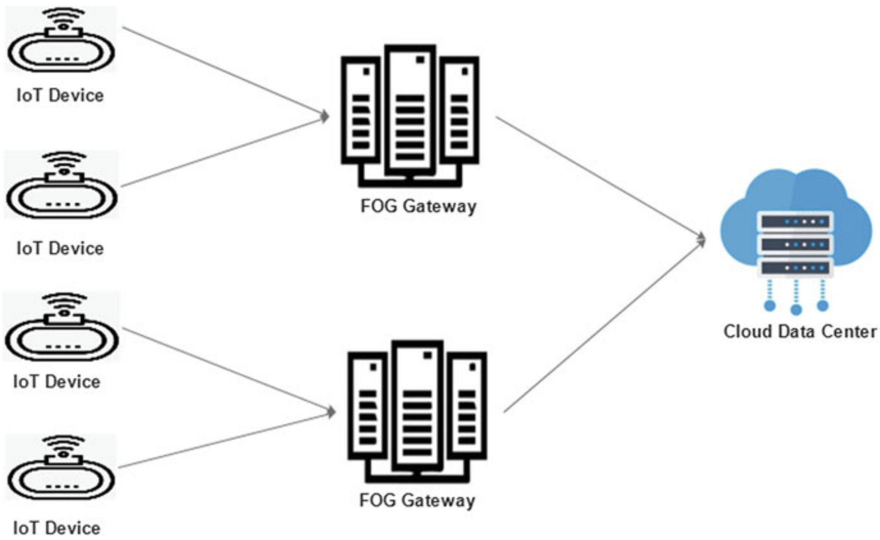

Fig. 8.4 Fog computing paradigm in IoT

of error and data loss which is not permissible in critical situations like while dealing with heart, brain, or any other delicate organ of the body. Apart from that, there is a problem of latency and delay in data transmission which also depends on data volume being transmitted. Hence in these scenarios, quality of service cannot be guaranteed. So all in all, technical challenges like computing capacity, storage, network congestion, cost, etc. have given rise to a new computing paradigm called fog computing. Figure 8.4 shows the fog computing paradigm diagram.

This problem is solved by using an extra layer, otherwise known as the fog computing layer, which would reduce the burden of cloud infrastructure by preprocessing and performing analysis at the edge. This successfully reduces the volume of data that needs to be sent over the network, thereby saving network bandwidth assuring the quality of service. In other words, it can be said that fog computing brings a cloud computing paradigm to the edge and brings its advantages along with it like support for real-time local analysis, low latency in data transmission, edge location, interoperability, awareness of location, etc. Fog computing also allows devices with limited capabilities in terms of communication and computation to interact efficiently with fog servers for data preprocessing and analysis.

Let us take a look at Table 8.2 below to find out a brief comparison between fog computing and the cloud computing paradigm.

Let us understand the comparison mentioned in Table 8.2. Figure 8.4 depicts the fog computing paradigm. In cloud computing, data generated from various sources across an IoT network get stored in a centralized cloud location. This may result in huge data traffic congestion in the internal network, which may become a reason for low response time, traffic jam, and crashes. So, by bringing fog computing the data is

Table 8.2 Comparison between cloud computing and fog computing

Features	Cloud computing	Fog computing
Geographical distribution	Centralized	Distributed
Number of server node	Few	Many
Mobility	Limited	Highly supported
Real-time application	Lagged response	Fast response
Type of connection	Leased line	Wireless
Latency	High	Low
Node location	Internet	Local area network/edge
Client and server distance	Multi-hop	Single hop
Security	Defined by provider	Defined and controlled by end-user
Attack on data	High probability	Less probability
Awareness of location	No	Yes

distributed in the fog nodes, which results in less traffic in a particular server. Again processing the data near to the client reduces response time and thereby latency which is highly required for real-time application. The type of connection dealt in cloud computing is generally leased line as the client has to be connected to the internet to avail any of the functionalities of cloud computing. Apart from that while connecting to the server, client may need to hop from one server to another before reaching the destination server. This again is a reason for high latency in cloud computing, whereas in fog computing, nodes are present locally which can be accessed wireless using Wifi, Bluetooth, etc., and servers can be reached with a single hop. As there is several hops in cloud computing, data may be exposed to threats while en route to the destination server. Again security aspects of cloud computing are primarily handled by the cloud service provider and very little control exists with the client. This increases the risk of data theft. In contrast to that, control of security in server and routers remains with end-user and can be modified, updated, customized or changed as per the requirement.

Having all said, it should not be assumed that fog computing is a substitute for cloud computing, rather it is developed to offload some tasks and assist in the completion of tasks associated with cloud computing. For example, an IoT device measures the temperature of a patient and sends it to the cloud server; however, sending temperature data each second to cloud server would not be required if it is within safe limit. Hence, if aggregation is carried out locally and then that aggregated data is sent to the cloud then it would reduce the data traffic as well as the burden on cloud storage for unnecessarily storing raw data. And this aggregation can be carried out in fog servers or nodes. This is one such example where fog computing complements cloud computing in its operation.

8.4.1 Fog Computing Architecture of Big Data in Healthcare

As discussed, fog computing complements cloud computing. Fog computing is developed to work in a distributed manner and do processing and computations at the edge of the network. Processing and storage of data are near to the users and hence, low latency in services is provided. This is very crucial in services like augmented reality and assistance in surgeries, monitoring of patient's various parameters, etc., where response time requirement is very high without any latency.

Fog computing is a very new domain of technology and does not have any standard architecture. However, many individual researchers have proposed architectures regarding fog computing. One of the very first fog architecture of fog computing was proposed by Bonomi et al. [7]. He defined fog computing as a distributed set of nodes and devices present in between cloud, core network, and various IoT devices and sensors distributed across the network. He also pointed out features of fog computing which distinguished it from cloud computing like low latency, fast response time, higher privacy, location awareness, distributed deployment of nodes, real-time analytics, wireless connectivity, and interoperability with cloud for heavy computation and large storage. Some architectures have proposed where fog layered architecture, hierarchical architecture, fog network architecture, etc.

Azam et al. [8] proposed a six-layer architecture which consisted of virtualization and physical layer, monitoring layer, preprocessing layer, temporary storage layer, security layer, and transport layer. The physical and virtualization layer consisted of things, wireless sensor networks, virtual sensors, and virtual sensor network which are data generators. On top of it is a monitoring layer which monitors the activities of devices present in physical and virtualization layer. It also monitors response, power consumption of "things," services, etc. Above it comes the preprocessing layer where data management like filtering, analysis, aggregation, reconstruction, and trimming takes place. Then comes the temporary storage layer which stores data temporarily after data processing. This is emptied once processed data is pushed to the cloud. And on the top comes security and transport layer which are responsible for data encryption or decryption and uploading the processed data to the cloud.

Luan et al. [9] proposed an architecture where the fog layer is an intermediate layer between cloud and edge devices. The main idea behind this approach was introducing fog servers which would be deployed in the local network and can be accessed by end devices by a single hop. According to his proposition, there can be multiple fog servers present in a particular network and can provide local computation and real-time services to the end-users. For example, helping doctors during surgery by providing real-time AR services without any lag or latency or local monitoring of ECG of a patient and triggering an alarm when encountered with a certain anomaly.

Again, a four-layer architecture was proposed by Akrian et al. [10] which consisted of a data generator layer, fog layer, cloud computing layer, and data consumer layer. The data generator layer consists of devices with limited capabilities that sense and generate information about the environment or a person. In the healthcare context, this layer would be consisting of biomedical sensors like a fitness band, temperature sensor, ECG, etc. which would be continuously generating data regarding the patients. This generated raw data is then forwarded to fog computing layer where a particular fog node is associated with a particular set of sensors for local computation. These devices are generally low power-consuming devices with mid-level computing capabilities. The computing devices perform certain data processing, generate reports and analysis which is required immediately and sends rest of the data to cloud computing layer for long-term behavioral characteristic analysis. Fog layer computation is required for immediate response in certain events like glucose level going below or above the normal value. Cloud computing layer provides centralized computing capability for heavy computation and large data storage. Data consumer layer can be doctors, patients, patient's relatives, or biomedical actuator. Doctors may use it to take necessary steps for patient's wellness. In certain events, actuators may trigger certain actions as well.

Hierarchical fog computing architecture was also proposed by certain researchers. Giang et al. [11] classified devices associated with fog broadly into three categories, namely I/O node, edge node, and compute node. Edge nodes are data producers and receive messages to perform actuation in certain events. I/O nodes are generally responsible for data communication between the edge and compute node and possess a very limited computing capability. Computing nodes possess a certain level of computing capability to offer computation on the data generated. Edge nodes are non-configurable in this architecture; however, IO nodes and compute nodes are dynamically configurable according to the need. Hosseinpour et al. [12] proposed a multi-level hierarchical architecture that consisted of levels starting from zero up to "N" number, where "N" can be any number as per the application requirement. Level 0 consists of sensors generating smart data that encapsulated data capsule which consisted of payload, virtual machine, and metadata of generated raw data. This data is then sent to the nearest fog node for a particular set of sensors which is present in level 1. Level 1 fog gateways are directly connected to the level 0 sensors at one end and level 2 fog nodes at the other. Node at each level has inter-communication capabilities with nodes at other levels and accomplishes tasks of data processing and computation in a distributed manner.

A fog architecture was proposed by Sun and Zhang [13], which was based on the nervous system of humans. They described the brain as a central cloud data center, spinal cord as fog node, and peripheral nerves as distributed sensors. Just as spinal cord acts like a link between peripheral nerves and brain, fog nodes act similarly between the IoT layer and cloud layer of the architecture. Here just like spinal cord, fog devices respond to time-sensitive data and which is most important as far as healthcare is concerned where life of patient is at stake.

To summarize the abovementioned points in context of Healthcare 4.0, fog computing can be majorly divided into big data generation layer, fog computing layer, data consumer layer, and cloud computing layer.

Big data generation layer would be consisting of all the biomedical sensors which would be generating patient's critical conditional data that would be required for monitoring health and taking important decisions in the time of critical conditions. Data would be generated every second and would be sent to the fog computing layer where real-time analysis, data management, and time-critical response would be provided based on analysis on the data using various analytics tools like MapReduce, Apache spark, Apache flume, Apache Pig, etc. which works on commodity hardware in a distributed manner and processes big data most efficiently. Fog computing layer would also be responsible for performing certain aggregation on the data before sending it to the cloud. Biomedical sensors like ECG, EMG, blood glucose sensor, temperature sensor, etc. generate time-series data every second. However, entire raw data need not be pushed to the cloud. Aggregating like finding mean, median, standard deviation, sum, mode, etc. of the data, filtering data, encryption, etc. for a time window based on a requirement can be performed before pushing it to the cloud. Data can also be pushed to the cloud upon certain events as well. More about data management is mentioned later in the chapter. The cloud computing layer would be used for heavy analysis and performing machine learning on the aggregated data which would help find long -term trends and predict long-term health trends of a person. Recommendation engines based on machine learning can be deployed on cloud platform that gives recommendations to the people based on their health data by which they can avoid diseases and remain healthy. Data consumers would be doctors, healthcare professionals, pharmaceutical companies, and patients who can use this data for their benefit in various ways. Brief comparison of various architectures is given in Table 8.3.

8.5 Big Data Management in Fog for Healthcare 4.0

The sole purpose of fog computing is decreasing latency and bringing computation near the edge, so that real-time processing can be done and immediate results can be provided without any delay in response. However, as discussed above, sensors generate a huge amount of data. Some devices like ECG generate data worth of GBs every day. The growing pace of healthcare data will lead to data generated on the scale of zettabytes, which was highlighted by Pramanik et al. [14]. Again, sensors generally produce repetitive redundant data which occupies a lot of storage resources when stored. Those data are also sometimes noisy or useless. So by sending those data to the cloud, there will be network congestion, delay, data loss, errors, etc. Hence, it is extremely necessary to preprocess generated raw data from IoT devices before sending it cloud layer for long-term storage and analysis. IoT devices do not have the capability of preprocessing the data, hence, it is the fog layer that does the work. Moreover, the data which is generated by sensors, if sent directly without any encryption may lead to potential data theft threats. Hence, some encryption is necessary at the fog level before actually sending it over to the cloud via network.

Table 8.3 Brief comparison of various fog architecture

Sl. no.	Author name	Contribution	Remark
1	Bonomi et al.	(i) Defined fog computing as a distributed set of nodes and devices present in between cloud, core network, and various IoT devices and sensors distributed across the network (ii) Pointed out features of fog computing like low latency, fast response time, higher privacy, location awareness, distributed deployment of nodes, real-time analytics, wireless connectivity and its interoperability with cloud for heavy computation and large storage	One of the very first fog architecture of fog computing
2	Azam et al.	Proposed a six-layer architecture which consisted of virtualization and physical layer, monitoring layer, preprocessing layer, temporary storage layer, security layer, and transport layer	
3	Luan et al.	(i) Proposed an architecture where fog layer is an intermediate layer between cloud and edge devices (ii) Fog servers which would be deployed in the local network and can be accessed by end devices by a single hop	Fog servers present in a particular network and can provide local computation and real-time services to the end-users
4	Akrian et al.	Proposed a four-layer architecture consisted of data generator layer, fog layer, cloud computing layer, and data consumer layer	Doctors may use it to take necessary steps for patient's wellness. In certain events, actuators may trigger certain actions
5	Giang et al.	Classified devices associated with fog broadly into three categories, namely I/O node, edge node, and compute node	Implementation of hierarchical fog computing architecture
6	Hosseinpour et al.	Proposed a multi-level hierarchical architecture which consisted of levels starting from zero up to "N" number where "N" can be any number as per the application requirement	Accomplishes tasks of data processing and computation in a distributed manner
7	Sun and Zhang	(i) Described brain as central cloud data center, spinal cord as fog node, and peripheral nerves as distributed sensors (ii) Spinal cord acts like a link between peripheral nerves and brain, fog nodes act similarly between the IoT layer and cloud layer of the architecture	A fog architecture based on nervous system of human
8	S. S. Gill et al.	Proposed a fog-enabled smart healthcare model for heart patients	

S. S. Gill et al. [15] proposed a fog-enabled smart healthcare model for heart patients. In the paper, different layers and their functionalities of the model have been illustrated. The layers in the model are: body area sensor network, IoT devices, fog server, resource manager, and cloud datacenter. Body sensor network comprised of various medical sensors like ECG, EMG, respiratory rate sensor, etc., which senses data and sends it over to IoT device which in turn sends data to the cloud server. Fog server comprises of listener module, security module, message handler, and service broker. Listener module handles connection requests from IoT devices before data transfer happens and security module is responsible to provide secure connection. Message handler handles received patient data and service broker makes patient's data as workload for further processing in cloud. The resource manager consists of resource scheduler and workload manager. The workload manager handles the workload of patient's data and maintains queue based on priority. Resource scheduler is responsible for scheduling cloud resources that have been provisioned for further processing. Cloud centers process a large amount of big data collected from all the patients. Preprocessing of data like filtering, compressing, and encrypting is done using different algorithms. Suitable recommendations for medication and health checkups based on information are provided by healthcare providers and doctors. The patient's data is stored in database for future reference.

As already mentioned earlier, architecture of fog computing can be broadly divided into three layers, namely, device layer, fog layer, and cloud layer. Let us take a look at each of the layers and their functions concerning data management. Figure 8.5 shows functionalities of layers for data management.

8.5.1 Device Layer

This layer primarily is responsible for data acquisition from end devices and sensors and passes it on to upper layers for further processing and decision-making. This layer also receives feedback from above layer for operations and actions. Layer is also responsible for command execution upon receiving it from above layer (fog layer) to trigger actuators for proper actions.

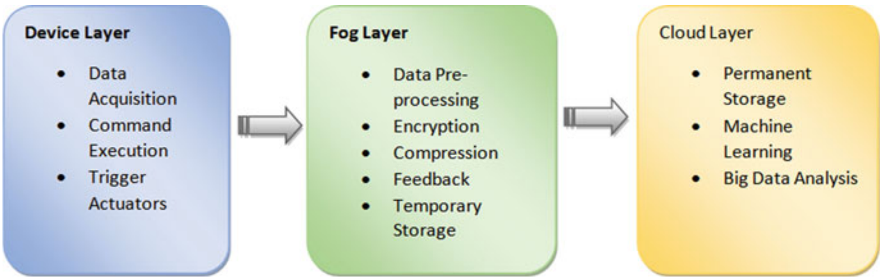

Fig. 8.5 Data management in fog computing

8.5.2 Fog Layer

The data acquired from has characteristics that make it important for proper data preprocessing and management.

- Data are generated in different formats and structure depending on the end device [16].
- Data sensed by sensors are not accurate and uncertain due to misreading, precision issues, etc. [17, 18].
- Unavailability of semantics which makes it easy for machines to understand the data being stored.
- The velocity of data generated by different end devices is different.
- Sensor data are most of the time repetitive and redundant [19]. Hence, storing it all is not wise.
- Raw data, without encryption, may be prone to theft in between the network.

Hence, fog layer is responsible for compression, encryption, temporary storage, and preprocessing of data.

1. **Data preprocessing** involves data cleaning, de-noising, filtering, aggregating, and improving the data quality for temporary storage and pushing the same to cloud layer for permanent storage and long-term analysis. Received data can also be checked against predefined threshold values for alerts and emergency actions. Processing of data may also involve data fusion and edge mining.
2. **Compression** algorithms are applied to the data collected to decrease the load on the network bandwidth while sending it to the cloud layer.
3. **Encryption** algorithms are applied to the data to protect sensitive information from any data theft.
4. **Temporary storage** of data is done for local analysis like aggregations, preprocessing, and lightweight decision-making for an emergency. Once the data is preprocessed and all the necessary local analysis is done, data is pushed to the cloud for permanent storage and data stored in the fog layer is then deleted.
5. **Receives feedback** from cloud and also sends feedback to devices in device layer whenever required to trigger action. The fog layer also sends commands to device layer for execution.

8.5.3 Cloud Layer

This layer is responsible for permanent storage of data and performs long-term analysis on big data in a distributed framework using tools like MapReduce and Spark. Intensive and computationally intensive algorithms are applied to data for feature extraction, data classification, etc. Machine learning models are also applied to data as well to predict various aspects of patients, or to diagnose patient for any ailment with the samples collected. The permanently stored electronic data can also help doctors to go through patient's history which can help them understand patient better while prescribing medicines or treating them. It can also help doctors tracking their patients.

8.6 Big Data Analysis in Healthcare 4.0

As of 2012, amount of healthcare data generated was 500 Petabytes (PB), which is expected to reach around 250,000 PB by 2020 [20]. Looking at the huge volumes of data, data generated can be defined or characterized by volume, velocity, variety, veracity, and value. These are generally called as 5Vs of big data.

- **Volume:** It characterizes high volume of data generated from various sources in healthcare environment like medical records, sensors data, doctors' suggestions, etc. Data is generally in petabytes or terabytes.
- **Velocity:** It refers to the high rate at which data is generated and processed.
- **Variety:** It refers to different types of data generated from different sources in a healthcare environment. It may be structured like CSV, JSON, etc. or unstructured like images, videos, text, etc.
- **Veracity**: It refers to the quality of data and how meaningful it is as far as healthcare functionalities are concerned.
- **Value**: It refers to the worth of information brought to various stake holders and enabling them to taking vital decisions.

Big data is nothing but a process that structures and organizes data characterized by 5Vs and processes to bring out some meaningful insights [21] which help stakeholders and decision-making bodies in various organizations to make data-driven decisions rather than taking intuitive decisions.

This large-scale data produces can be analyzed and modeled and can be used for early diagnosis of diseases such as cancer, processing and quick diagnosis of diseases using medical images and signals, providing personalized medicines and consultation to patient, data analysis on genetic data to understand and prevent genetic diseases by proper prevention and countless many other possibilities. These data include Electronic Health Record (EHR), Hospital Information System (HIS), web data, medical data, omics data, etc. It is worth noting that EHR and HIS have detailed information about diagnosis, demography, test result, genetic data, etc. [22–26].

Various tools realize the big data paradigm and process the data generated. Apache Spark, Apache Flink, Apache Hadoop, Apache Tez, and other tools that can do batch processing or stream processing. Batch processing of data is generally used where real-time analytics is not required, whereas stream processing is done to provide real-time analytics on the go. Apache Kafka is one of the tools providing stream processing of incoming data. Batch processing is generally done on Hadoop infrastructure with tools like spark or Apache Mahout. It is worth noting that spark is capable of both, stream as well as batch processing.

Apache Hadoop is open-source software that facilitates big data processing. Hadoop is composed of four components:

1. **HDFS**: Hadoop Distributed File System which is responsible for the storage of huge volumes of data generated from healthcare eco-system in distributed manner across clusters of computing and storage nodes. It follows a master-slave architecture that is fault-tolerant and can replicate records to provide backup in case of any data loss or failure.
2. **MapReduce**: It is a processing model developed by Google which is based on divide and conquer method. Each dataset is processed by dividing the entire data into sub-datasets and sending it to different clusters for distributed and parallel data processing.
3. **Resource Management (YARN)**: It takes entire infrastructural resource into its management platform and distributes it to the processes, which are called jobs, according to the need and availability. This helps in bringing a distinction between infrastructure models and programming models.

The advantage of using these tools is that it is highly scalable, cost low in terms of hardware, high volume file processing capability, stream processing high volume data, error-tolerant at times of node failure and data locality [27].

As far as Healthcare 4.0 is concerned where a large number of sensors generate huge volumes of data, it is better to store in Hadoop infrastructure as opposed to traditional RDMS which is not horizontally scalable. Again storing data in RDMS would be a costly affair as it requires specialized hardware, whereas Hadoop can be deployed on commodity hardware which is far cheaper as compared to specialized hardware.

Texas Hospital used Hadoop infrastructure for storage of EMR and analysis of the same which enabled to understand that patients require more attention in the 30-day treatment process which reduced their readmission rate from 26 to 21 [28].

Big data is an intelligent approach in analyzing EMR which has the capability of connecting financial, operational, and clinical analytical systems that can give healthcare professionals to provide healthcare seekers with evidence-based consultancies. Evidence-based healthcare uses past clinical health data as well as present health status for diagnosis of patient. Big data has helped in detecting disease and particularly in clinical genomic analysis of HIV [28].

8.7 Machine Learning in Fog-Enabled Healthcare 4.0 Architecture

Machine learning is a form of data analysis where a huge amount of data is used to train a model and find a relation between the dataset collected from various sensors. It also helps in predicting future trends and possibilities of health concerns. It also allows making automated decisions in certain cases. Machine learning along with image recognition is helping to diagnose cancer in minutes which otherwise used to take days by human efforts only. Machine learning has the potential to reduce cost, time, and human effort. Big data along with machine learning in healthcare has numerous applications like helping doctors to prescribe personalized medicines based on patient's past data and his/her body parameters, which is one among many others.

In healthcare context, different sensors are producing different types of data. Some may be structured and others may be unstructured. Structured data make up to 20% of EMR and rest is unstructured. Unstructured data can be reports, discharge notes, audio, video, images, etc. Structured data is something that has a known schema and generally stored in databases in tabular form. It can be series of temperature values, glucose level, blood pressure value, etc.

Several research and innovations have come up in recent years in the field of machine learning in healthcare. Shah labs have been using data mining and machine learning to develop models which can derive data-driven insights, answer clinical questions, tell about effectiveness of medication and treatment, etc. [29] which can help doctor to make decisions faster and better. It is worth mentioning that they have been able to use unstructured data for analysis purpose as most of the healthcare-related data are unstructured.

Google with the help of deep learning has developed a project which can diagnose diabetic retinopathy (DR) which is one of the fastest-growing reasons for blindness. In the past, diagnosis of diabetic retinopathy was done by experts based on the retinal image. In doing so, it used to take a lot of time and at many places qualified experts were not available to diagnose the same. However, using the technique proposed by Google, doctors today can diagnose DR in limited time and resources.

The above analysis mentioned is carried out in cloud servers with high-end resources. In Healthcare 4.0, it is necessary where a doctor accessing cloud reports can get a universal trend and insight into a particular disease rather than getting just local information. However, in certain cases like where sensitivity is very high, and latency is not affordable, models have to make decisions at the edge rather than cloud. Edge AI can be deployed in fog servers which are associated with local sensor network. As a result, important emergency decisions, processing, and insights can be found out at the edge. Dedicated AI processing units have been developed by many companies like MediaTek, Qualcomm, NVidia, etc. These processors can be used in fog servers where machine learning models and data analytic processes can be deployed for local analysis of the received data.

More importantly, it is worth noting that training of machine learning models requires heavy computational resources depending on the type of data and modeling is carried out. For example, deep learning on ECG data, retinal image, etc. requires a high amount of resources as data is back and forward propagated to adjust the weights until error is reduced to least. Hence, training of data should be done in cloud layer as computationally powerful environment is easily accessible at a low cost. However, once the training is done, the trained model can be configured to work on edge devices as well. Just the way speech recognition, driverless cars, etc. work where latency has to be minimum, even less than a second. In deep learning,

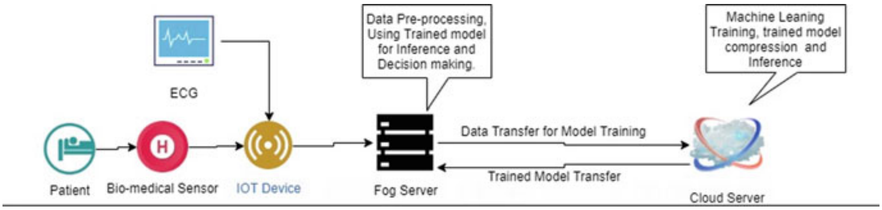

Fig. 8.6 Implementation of machine learning in fog computing with training in cloud datacenter

many neurons are either combined or un-required neurons which do not get activated during inferences are deleted. Pruning of connections of a fully connected trained model with weight less than a given threshold is done and then it is again retrained to adjust the weights of the sparsely connected model. These techniques help in reducing the size of the model in terms of space required and computations required for inference.

Hence in fog-enabled healthcare paradigm, the flow of data, model creation using machine learning and using the model in fog server can be explained and is illustrated in Fig. 8.6. First, the data will be collected from sensors and will be sent to the fog servers using IoT devices. Local decisions, inferences, and data preprocessing as explained before will be done. Then this data will be pushed to cloud where machine learning, big data analytics, and other analysis will be performed. However, trained machine learning models will undergo further compression and pruning process. After model is pruned and made suitable for edge computation, it will be sent back to the fog server where time-sensitive inferences and decisions will be made without any time delay or network dependency. A work flow of data acquisition and machine learning model training and inference at fog server is represented in Fig. 8.6.

8.8 Case Studies

8.8.1 Case Study of ECG Feature Extraction in Fog Gateway

In [30], a case study along with methodology has been presented in extracting features from ECG raw data coming from end nodes connected to ECG machine. ECG feature extraction with very low data latency is highly important as far as patients' health monitoring is concerned. The case study presents smart gateways at fog layer which extracts features from raw ECG data like T-wave, heart rate, P-wave, etc. by using techniques like embedded data mining, distributed storage, notification services, etc. ensuring low latency in response and low bandwidth requirements and high utilization while pushing processed data to the cloud.

The method consists of 3 parts, namely, medical sensor node, smart gateway, and backend. Medical sensors are responsible for transmitting medical data like

EMG, ECG, temperature, location, etc. to the smart gateway via any one of the protocols among ZigBee, Wifi, Bluetooth, and 6LoWPAN. Smart gateway plays the most important role in the architecture which is responsible for connecting sensor nodes with cloud servers. Apart from that, it is responsible for feature extraction from ECG extraction. The backend part consists of cloud servers and services for analysis and real-time visualization.

As described in the above paragraph, smart gateways perform the most important task in the given architecture. It provides fog computing related services. Router supports ZigBee, Wifi, Bluetooth, and 6LoWPAN for communication between sensor nodes and gateway. Apart from that, it supports I2C and SPI for wired communication and a sink for internet service providers. As a whole embedded gateway consists of wireless, wired (I2C and SPI), Ethernet and USB for communication, processor for processing, and external SD card for storage. Gateway consisted of three layers—hardware layer, embedded operating system, and fog computing service layer. Hardware layer forms the middle layer between the physical components and embedded operating system. It receives instructions from operating system to allocate physical resources to services and restricts one service to access a particular physical component. Embedded operating system varies depending on whether used in sink node or gateway node. In sink node, operating system should be compact and lightweight with low hardware requirements, whereas in gateway nodes operating system need not be compact as it needs to support a wide range of software and tools for real-time data transfer to cloud servers and fog computing services. Fog computing services provided at the gateway can be further divided into following services:

1. Database: Database comprises of three parts. One part is called static database which consists of essential static data like user ID, passwords, algorithms required to cater to these functionalities, etc. Second part, which is named as general purpose storage, is used to store huge incoming data and at high data rate to provide fog computing services and graphical user interface. This storage size can be varied according to the requirement. Third part is synchronized storage which stores low data rate incoming data like temperature, humidity, etc. and other temporary environmental data and bio-data, thereby updating data at server.
2. Feature extraction: This is most important part as far as this case study is concerned. ECG feature extraction at fog will help in obtaining latency free insights, monitoring and providing emergency notification to concerned authorities without any delay or dependency on ISP. ECG feature extraction is done in three parts, namely ECG preprocessing, wavelet formation, and ECG extraction. Preprocessing involves filtering techniques like moving average, notch filtering, etc. Wavelet formation is done using fast computation wavelet formation algorithms. Finally, ECG feature extraction is done for extracting different data like S-T segment, P-R interval, Q-T interval, QRS energy, etc. In [30], they have also proposed an algorithm for extracting P-wave, T-wave, and heart rate which is light in terms of computational requirement. Algorithm takes a specified

threshold value of R-wave based on scanned ECG input signal. Formula is given by (8.1) [30].

$$\text{Heat rate} = 60/\left(\text{R} - \text{R interval}\right) \tag{8.1}$$

3. Graphical User-Interface: It is important to visualize the obtained ECG extracted data, patients' details and past test results, doctors' suggestions, etc. which is specific to a specific set of audiences. The visualization is accessed by members by using login ID and password. This helps in restricting certain sensitive data only to doctors, which if revealed to patient may create negative impact.
4. Notification of Abnormality: Notification in real time without any latency should reach concerned healthcare providers during abnormal conditions. This is most important as far as application of fog computing is concerned. The only need why fog computing was brought to picture was to eradicate latency which was faced in cloud computing paradigm. Notification may be generated based on threshold of a particular parameter. Say, heart rate crosses a specified threshold, a message containing heart rate is sent to the concerned healthcare professional who can act appropriately upon receiving warning.
5. Awareness of location: It is one of the characteristics of any fog computing based system. Having awareness about location can help healthcare professional to locate a particular patient in case of emergency quickly to treat her/him in time. Location awareness is done using gateway MAC address. For each corridor a single gateway is created for server on server rooms, thereby giving an idea of physical location.

Smart fog gateway was implemented in [30] using various embedded boards like panda board based on OMAP 4 platform with dual-core ARM cortex A-9 MPCore having a clock speed of more than 1 GHz. For high performance, external SD card of 64 GB was used. Apart from that Arduino with Wifi shield, zigduino, Arduino with Bluetooth HC-05 module was also used for collection and transmission of data to the gateway using various communication protocols like ZigBee, Bluetooth, Wifi, etc. MySQL database is used for storage of data which is required to cater fog computing services. Remote data server is updated using third part tools like xSQL lite database synchronization tool. Graphical user interface was built using JavaScript for frontend page generation, PHP on the backend, and MySQL as the database.

MIT-BIT database was used in the method to obtain ECG raw data upon which ECG feature extraction was performed. ECG data were extracted, stored temporarily in the fog gateway and processed before pushing it to remote cloud server. The benefits in terms of reduced latency of fog computing service data concerning pushing raw ECG data to cloud is shown in Table 8.4 [30]. This shows that sending of processed data reduces the overall data size, which does not burden the network bandwidth while pushing it to cloud. Wifi was used in the comparison below.

Table 8.4 Comparison of latency in sending raw data v/s fog computing service data to cloud

	Raw data		Fog computing			Improvement	
Data rate (Mb/s)	Size (B)	Latency (ms)	Size (B)	Processing (ms)	Transmitting (ms)	Size reduced	Latency reduced
18		106			6.6		>3.5%
12	240,000	152	<15,840	96.3	9.5	>93%	>30.5%
9		213			13.5		>48.5%

8.8.2 Case Studies on Big Data in Healthcare

Penn Signal [31] uses big data and predictive analytics to forecast acute illness using historical datasets even before they occur. They have their data warehouse which contains four billion records of clinical data and two million records being added each day. ETL (Extract Transform Load) technique is used to extract data from data warehouse and is stored in the open-source database MongoDB which is NoSQL database suitable for data science applications. Python programming language is used for extracting data and modeling of machine learning models which is saved after proper training and used in a data stream for inferences in real time. Penn Medicine uses algorithms, machine learning, and threshold values to detect severe sepsis. Machine learning model takes more than 200 variables to predict accurately. This approach has helped Penn Medicine to detect 80% of severe sepsis cases within 30 h of symptoms. Predictive models for detecting heart-related problems are helping Penn State to detect 20% more patients who are more likely to have a cardiac failure and also identifying the group of patient who would have 5 times more possibility of being readmitted to the hospital after cardiac failure. Some other works are presented in Table 8.5.

8.9 Conclusion

Today healthcare-related issues have been in rise due to many factors. Moreover, doctor to patient ratio across the world is very low. Hence, in such a scenario, it has become very important to adopt new technology to provide faster and better quality healthcare service to the seekers. As mentioned earlier in this chapter, fog computing in conjunction with IoT, cloud computing, big data, and machine learning has huge significance in the field of Healthcare 4.0 and making it happen. Fog computing has proved to be a promising technology as far as healthcare is concerned where time sensitivity and data availability at all time are major factors that need to be taken into consideration and these factors have been taken care of by fog computing. However, it is worth mentioning that fog computing is not a substitute for cloud computing rather it supports cloud computing in bringing down various disadvantages of cloud computing which is encountered while using cloud computing alone. Fog computing helps in compressing and extracting useful data from raw data obtained from IoT sensors and devices across the network. This enables effective utilization of network bandwidth and reducing latency while sending data to cloud for long-term computation. Again machine learning and big data analytics are helping healthcare providers to make proper use of their data and enabling them to provide data-driven consultancy to healthcare seekers and patients. Machine learning and big data analytics on complex heterogeneous datasets obtained has helped in predicting various health parameters in advance, including patient's readmission probability. Now, diagnosis of deadly diseases like

Table 8.5 Works of various organization in healthcare using big data

Sl no.	Name of Organization	Purpose and functionality	Technology name
1	John Hopkins University	Uses big data to mine data warehouse, clinical image, genomic data, and EHR to bring up best possible treatment for a patient. Doctors can plan treatment better, thereby providing high quality of service. Radiation oncology predictive model helps in planning radiation-based treatment of patients better [32]	inHealth [32]
2	Carolina healthcare systems	It uses big data to separate patients' EMR based on disease, geography, environment, etc. to create a unique segment upon which predictive analytics can be performed to reduce readmission and using medical emergency department only when it is required. They use Hadoop-based storage which is schema on read as compared to traditional databases which are schema on write which requires data exploration [33]	N.A.
3.	Beth Israel Deaconess Medical Center	It feeds data coming from intensive care unit (ICU) to a custom application that analyzes the risk index of a particular patient based on predictive analytics. It helps in identifying patients prone to deadly complications, blood clotting, dangerous heart rate, etc. They also use predictive and big data analysis to predict about patients' duration of stay and make decisions strategically for expansions [34]	Risk State [34]
4.	University of Pittsburgh Medical Center	Research includes helping clinical healthcare professionals to detect disease outbreaks quickly, helping patients and healthcare seekers to get personalized advice based on their history and genetics data, quick diagnosis of diseases, etc. [35]	N.A.

cancer is done precisely and much faster, before it becomes deadly, due to the analysis of past data over a period of time. Decision-making on healthcare providers part has become easier due to data analytics. However, there are certain challenges to it as well. Different organizations are using their own standard of storing EMR. This makes it difficult while transferring data from one organization to other. Hence, there is a requirement of standardized EMR, thereby enabling healthcare providers across the world to use it. Again, EMRs of patients being very sensitive data which contains many personal information about a particular person, there should be laws which guarantees integrity and ownership of data to patients only. This challenge has somewhat been addressed by blockchain-based EMR system. Again there are challenges to adoption of these technologies by healthcare providers because of high initial investment and variable investments required to run the same, especially in developing and backward countries where considerable amount of funds are utilized in acquiring advanced equipment for treatment of patients. Moreover, proper training needs to be given to healthcare professionals to utilize full potential of Healthcare 4.0. Having said that, these technologies today can save millions of lives with faster diagnosis and data-driven personalized medication and Healthcare 4.0 is making it happen.

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Chapter 9
Fog-IoT Environment in Smart Healthcare: A Case Study for Student Stress Monitoring

Tawseef Ayoub Shaikh and Rashid Ali

9.1 Introduction

Internet of things (IoT) collaborates with the billions of items that utilize the web over the world. In the internet of things period, the healthcare services sector has burgeoned from 1.0 to 4.0 age. The healthcare services 3.0 was clinic driven, where patients enduring sickness undergo a ton because of numerous unnecessary clinic visits for their normal checkups. This, in effect, has delayed the diagnosis of these patients despite an increase in the general use of patient care. Be that as it may, with later innovative headways, for example, fog and cloud computing, these issues are eased with a base capital speculation on figuring and storage identified with information of the patients. Roused by the realities, the examination provides an investigation of the job of fog, cloud computing, as well as the internet of things to offer continuous, setting mindful administrations to the end-clients whenever needed.

Industry 1.0 concentrated on mechanical engineering and mechanization pursued by industry 2.0, which has electrical vitality. The cutting edge comprises industry 3.0 that has media transmission as well as information communication technology (ICT) as its center segments. In any case, as the development of the internet of things (IoT) and cloud computing (CC), the prevalent industries, i.e., industry 4.0, too depends on the astute gadget's deployment as well as its use [1]. Industries' advancement permits association with the billions of devices worldwide, 25% in 2016. Likewise, it is seen that the healthcare services division accumulated great income, which is over 15% in 2016. To satisfy the necessities of industry 4.0, acknowledgment of IoT devices is developing at a very rapid speed, as appeared in

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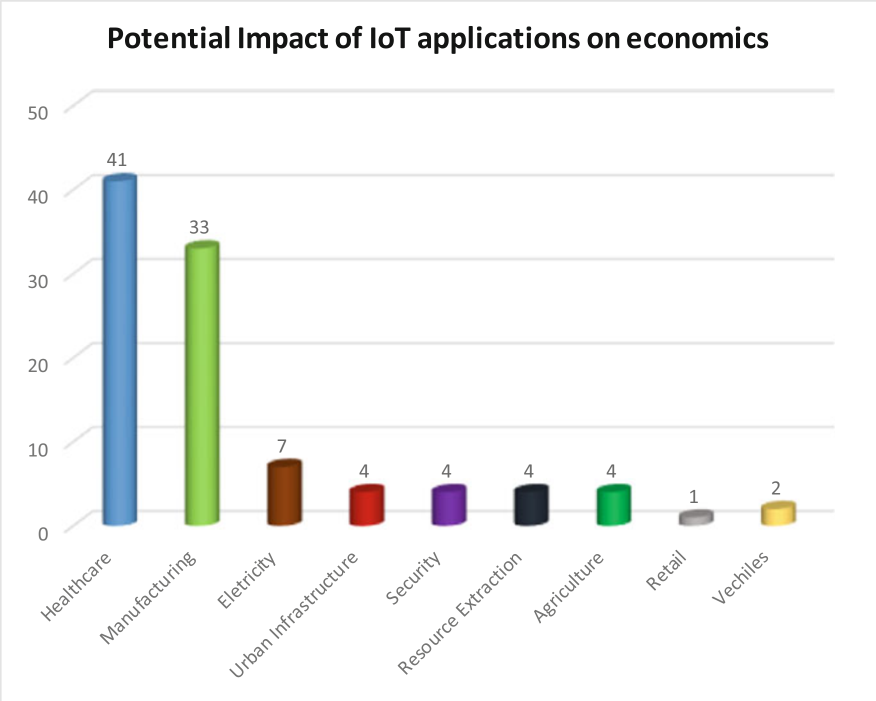


Fig. 9.1 Predicted market share of IoT applications by 2015

Fig. 9.1 [2]. To make the environment easy, the healthcare industry should prioritize the concerned service's availability (in comparison to the industries which are stated above). Like the industries (mechanical, electrical, or civil), the healthcare industry is classified from 1.0 to 4.0 generation. As the industry of healthcare denotes, its emergence in 1970 is still in its expeditious stage. The exertions are fundamental; assets are constrained. Consequently, this stage was named as healthcare 1.0. Results gain in the force of information technology (IT) field and therapeutic advances improvement of cutting edge medicinal imaging and following frameworks, the healthcare 2.0 was conceived.

The appearance of recent as well as compelling medical care techniques has begun with the mediation of computational strategies and information handling frameworks. In this specific circumstance, the period of 2006–2015, healthcare 3.0, got prevalent because of the utilization of electronic health records (EHR), an elective form of the patient's information outline. This age has received the EHR to assist specialists with getting significant data on a schedule. The upheaval in Indian healthcare industries happens by the digitization of healthcare data, which has been begun and is even accessible to the general population for examination purposes. Ministry of Health and Family Welfare (MoH&FW), Government of India (GoI), has set up the National Health Portal (NHP) to give medicinal services related data to the residents of India and to fill in as a solitary purpose of access for united health data [3]. Artificial intelligence (AI), as well as a vigorous communication interface, is involved in the healthcare environment aid specialists that have the capacity of information convenience, valuable and proficient investigative anyplace. Such an esteem-based framework empowers healthcare services to improve the quality of service (QoS) with all-around logical and decisions based results. As 90% of the healthcare substratum intends to turn toward a venerate-based framework in the USA, it makes a platform for the birth of healthcare 4.0. In India, it is vital to speed up with an expected spending plan of 6000 million US$ by 2020. The quantity of healthcare IoT gadgets delivers enormous information at ordinary interims; consequently, stockpiling and security of such tremendous/huge information are the significant issues in this condition. Physical information putting away in a medical clinic may not be conceivable in each circumstance along these lines, and a developing innovation, cloud computing (CC) can deal with the circumstance effectively. Having high stockpiling abilities and adaptable handling administrations, cloud computing has extensively extended the application situation of wearable medicinal sensors (WMS) based frameworks [4]. Over the globe, specialists, as well as organizations, have occupied with creating models to utilize WMS-based innovations and administrations offered by the cloud.

9.1.1 Fog Computing

Fog computing (FC), now and again additionally alluded to as edge computing (EC), mist computing (MC), hazing or cloudlets, broadens the cloud computing (CC) worldview to bring down inactivity, improve area mindfulness, give better help to portability and increment business dexterity. An estimate of near about 50 billion smart devices interconnection by 2020 makes it a necessity for these properties during the age of the internet of things (IoT) (for example, cell phones, tablets, sensors, engines, transfers, and actuators), and the measure of huge data volumes created by these entities is relied upon to develop to around 200 exabytes (200×10^{18} bytes) for every year by 2020 [5]. The center trait of fog computing architecture is that it gives calculation as well as information examination benefits all the more quickly and near the physical devices that produce such information, for example, at the edge of the system and accordingly bypassing the more extensive web (See Fig. 9.2). The production of 1.1 zettabytes (or 89 exabytes) in 2016 to around 2.3 zettabytes (or 194 exabytes) by 2020 is appraised from these data fabricating giants, and data heaps created by production lines, home networks, vehicles, medical clinics, social, and media [5]. Overseeing such measures of data mountains, just as data produced by online life innovations (for example, Facebook, Twitter), is probably the greatest test in which the conventional IoT- and cloud-based designs can't adapt to. The reasons being: the huge scale, assortment, and speed of information regularly known as big data (BD); IoT devices dissimilar makeups; contrasting network conventions; absence of correspondence benchmarks; high

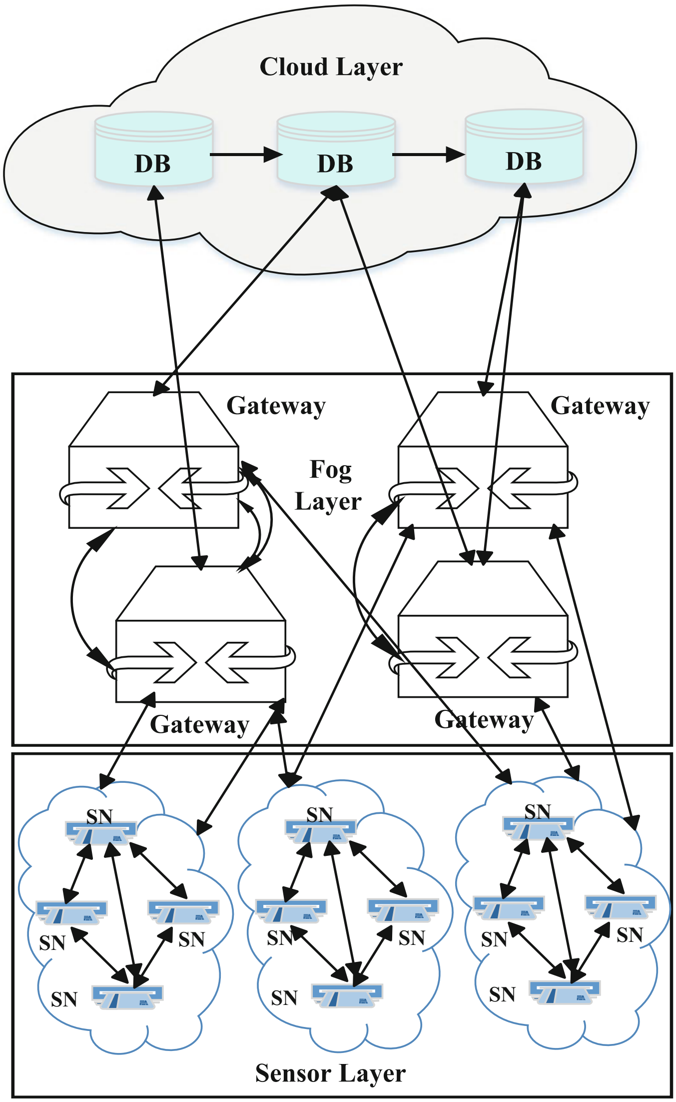


Fig. 9.2 High level based fog overview of IoT

inactivity of the cloud-based conditions and frameworks. One arrangement is to decentralize tasks, the executives, and data examination in the system itself utilizing a conveyed and combined figure model [6]. Cisco gave the name fog computing initially, and the same acts as the hero in this data tsunami age. To provide experiences to end-clients in the materialness of fog devices and entryways in healthcare 4.0 conditions for the present as well as future applications. It plans to push the knowledge, handling, and capacity of information nearer to the verge of the system to give computer-related services all the more promptly as well as close to the interconnected keen things which structure some portion of the IoT. Fog computing sector is at present esteemed at $22.3 million as of 2018 and is relied upon to extend at a touchy rate to develop to around $205 million throughout the following 5 years. Therefore with such an elevated level of availability of brilliant devices, fog processing gives off an impression of being the following enormous thing for the IoT vision.

Despite the way in which there are certain unpretentious variations between these different terms, the terms can be seen as proportionate words on an increasingly elevated level. The word "haze computing" or "edge computing" means that fog structures take a close shot instead of promoting and operating from a concentrated cloud state, as shown in Fig. 9.2. It insinuates setting some understanding, systems, and resources at the edge of the cloud, as opposed to working up channels for cloud storage [6]. Mist computing gives off the impression of being a huge thing for the internet of everything (IoE) [7]. Fog computing is a way of offering measurement and efficiency benefits much faster and closer to an association's physical hardware, for instance at the edge of the cloud network. Fog computing can really be envisioned as a technique for giving organizations even more rapidly yet additionally as a strategy for bypassing the more broad web, the speed of which generally depends on data transmission and bearers. National Institute of Standards and Technology (NIST) Special Publication 800–191 characterizes it as even, physical or virtual world view assets that live between shrewd end gadgets (as most of the part live inside the associations) and conventional NIST Special Publication or associated server farms [8].

The OpenFog consortium [9] decorated the fog computing as flat, structure level designing, which passes on appropriate processing, storage, control, and networking administration tasks closer to the customers along a cloud-to-thing. Hence, it is an outstanding virtualized register which provides benefits between the end gadgets just as the standard cloud computing server ranches the end devices as well as the customary cloud computing server farms [10]. The restriction of fog center points gives diminished inactivity and setting mindfulness because it supports vertically limited torpidity and sensitive applications by giving all-inclusive, versatile, layered, and consolidated framework systems. Software-as-a-Service (SaaS), Platform-as-a-Service (PaaS), and Infrastructure-as-a-Service (IaaS), and fog hubs give an arrangement of the same kinds of administrations as supported by fog computing. Also, fogging design utilizes at least one synergistic end-client customer or close association for edge devices to do a generous measure of correspondence, control, arrangement, estimation, and the board administrations. It is a paradigm that extends the cloud computing services up to the network's edge. It is a model that stretches out the cloud computing services to the verge of the network. The distinctive hallmark is that while cloud conditions may be geologically distant from the organization, often by no means knowing where the cloud-based benefits reside and relying vigorously on the more comprehensive network communication capabilities, fog services are much closer to end-customers, with thick topographical distribution and much better portability help.

Fog computing attributes incorporate the accompanying:

- Context awareness—as the gadgets as well as hubs in the earth have information and comprehension of nature.
- Distribution of geography—as the fog environment circulates geographically, so it assumes a functioning job in the conveyance of high caliber of streaming services.
- Real-time interaction—unlike batch processing, for instance, as is the case of cloud-based applications.
- Remote access organizing—that is progressively suitable for remote detecting gadgets that require time-conveyed examination and correspondence.
- Backing for heterogeneity—as the fog hubs possess varied structure factors, and conveyed in an assortment of disseminated situations.
- Low latency—the familiarity of fog hubs with on-site endpoint gadgets, resulting in a much snappier allocation of time for reaction and investigation.
- Diverse and effective end-client support—as a result of the closeness of edge gadgets to the computer hubs.
- Better help for versatility—given more straightforward correspondence between the fog applications and the cell phones.
- Interoperability compatible and organization stronger—For better matching of products from different sellers and cross-sectional over different spaces.
- Analytics in real time—which is effectively conceivable as a result of ingestion and handling of information near the sources.
- Backing for a wide assortment of mechanical applications—through handling and investigation continuously.

In this chapter, we try to present, first, the different definitions of this growing worldview known as fog computing and explain some of the center parts of fogging; then, we link it to the cloud worldview talking about the constraints and intrinsic problems of cloud conditions and how fogging can theoretically fix a portion of the related issues. We also express the unobtrusive parallels between fog computing and edge computing and suggest a layered way to deal with an image where cloud, fog, and mist computing may precisely be positioned in a wider setting of a cloud-fog-based environment that serves brilliant end-client gadgets in a disseminated IoT state. In the research using a two-stage Temporal Dynamic Bayesian Network (TDBN), a novel IoT-aware student-centered stress observing system to predict student stress index in a specific context is proposed.

9.1.2 Fog and Cloud

Internet of things (IoT) is the primary theoretical basis upon which both cloud and fog computing concepts are founded (Table 9.1). There was always an innovation drive behind the IoT applications with cloud computing. The IoT explains a situation of availability which makes the use of an interplanetary system based on both the

Table 9.1 Fog computing (FG) and cloud computing (CC)

S. no.	Fog computing/Edge computing	Cloud computing
Response time	Milliseconds, sub-seconds	Minutes, days, weeks
Data stockpiling duration	Transient	Months and years
Applications	e.g., M2M	e.g., Data analytics
Abstraction	Functional	Conceptual
Distance (m)	10^2	10^6
Delay (processing + communication) (s)	10^{-3}	10^0
Power (W)	10^2	10^5
Bandwidth (b/s)	10^6	10^8
Access	Mainly wireless	Fixed and wireless
Administration area	Inside the web	At the edge of the system
No. of server nodes	Few	Very large
Distance (client–server)	Various hops	Single hop
Area mindfulness	No	Yes
Backing for portability	Limited	Supported
Location coverage	Local	Global

corresponding personal area network (802.15), the local area network (802.11), the metropolitan area network (802.16), and the wide-area network (802.16) for different assets. Both cloud and fog computing situations need to consider the essential building hindrances that are needed in the planning of dynamic and aggressive conditions of application. A portion of such specialized structure squares are talked about underneath:

- Service-Oriented Architecture (SOA): It includes a library of tried and tested programming applets that can be written to turn into useful applications.
- Extensible Markup Language (XML): This requires the use of identifier labels used to move data of any kind to any given program depending on the Internet.
- Application Programming Interfaces (APIs): These are the special labels that can be used to classify applets relating to the internet.

Fog computing is a system level engineering that integrates storage, processing, and networking with the near end-customer edge computing consortium [11]. Exploiting edge processing, it takes virtualization to another level. The installation of the virtual machines on distant heterogeneous parts is the hallmark of virtualization. Cloud computing focuses to a large extent on making assets available through an essentially related center network, while fog computing focuses on setting up scalable assets/administrations at the edge of the system to enable modern, standardized applications with new developments. The edge innovation case is a business edge switch that benefits traditional switches by working on setting capacity limits, expanding handling speed, etc. [12]. Fog computing is an extension of cloud computing with system structure distinctions where the last one is performed using the system bottom, and the previous one is revised using the system center [12].

A typical comprehension of fog computing is that varied non-different inescapable gadgets impart and can organize among themselves in a situation in which some can execute capacity and handling assignments. Fog computing is executed by utilizing various designs depicted in Table 9.1 below. A traditional understanding of fog computing is that varied, non-different, unavoidable gadgets impart and can organize among themselves in a situation in which some can conduct assignments of ability and handling. Fog computation is achieved using various designs mentioned below in Table 9.1. In a situation where fog computing is used in the handling and change of data at the server point, it diminishes the inactivity of information altogether and encourages consistent data transmission. In a circumstance where fog computing is utilized at the server point in the handling and change of data, it altogether diminishes the information inactivity and encourages the consistent transmission of data. In such a way, the fog server makes inferable dynamically adjustable advancement from the customer devices and characteristics of neighborhood environment to test client experience. Still, the fog server can do details that can be used to improve the web page's rendering and browsing experience.

For fog computing systems, for example, Mobile Cloud Computing (MCC) and Mobile Edge Computing (MEC), the figuring specifications are used synonymously instead. A MEC application case could be a cloud server installed toward the end of a flexible device that performs errors that could not usually be performed in an ordinary setup [13]. The Google Glass, Microsoft HoloLens, and Sony SmartEyeglass are examples of a portion of the well-known products that are based on the conceptualization of fog computing. Fog computing opens the portal to improved capacities regarding the processing of information from large knowledge collections. This handling can accomplish huge information procurement, accumulation, and preprocess, empowering information transportation, and along these lines adjusting registering power. Fog computing also provides various advantages which can be derived from the Internet of Things.

9.1.3 Internet of Things (IoT)

The exponential IoT innovative advances have pulled in consideration of specialists from different instruction disciplines. IoT can cause a significant disturbance in an assortment of fields. As education institutions likewise become a piece of this development, the IoT is probably going to carry huge changes to the education part also. IoT innovation in education can move engagements beyond the classroom for more authentic and relevant learning. Utilizing IoT innovation in the institution, we can associate students around the world, improve grounds security, and above all expansion the proficiency identified with streamlining the everyday tasks of understudies and staff utilizing associated gadgets and radio frequency identification tags (RFID) innovation. Smart devices and intelligent technologies are required in institution space to investigate shrewd learning conditions. Smart devices allude to antiquities, display a few properties of ubiquitous learning (u-learning) that encourage understudy to pick up data on request, available whenever and anyplace. IoT-based wearable innovation as embellishments, for example, glasses, RFID labels on dresses, and other sensor devices in learning conditions shapes a u-learning space. Then again, canny innovations, for example, cloud computing, learning analytics, concentrated on how learning information can be caught, broke down to improve learning just as basic leadership capacities of an institution establishment. Regardless of the differentiation between smart devices and intelligent technologies, they are, in actuality, interrelated on the grounds that information from smart gadgets is dissected utilizing canny advances. For example, the web of things (WoT) and a maximum of the wearable technologies necessitate big data analytics (BDA) to breed significant evidence and afford the user with real-time feedback. In accordance with the internet of things (IoT) vision, these are immediate goods or devices built-in physical things to learn operational skills in artifacts and systems.

The case of restricting IoT implementations to sensors and defining radio frequencies has been misinterpreted in a broad sense. IoT's umbrella includes advanced branches such as ZigBee, EPC, barcode, Wi-Fi, QR codes, IPv4/6, Wi-Fi, pumps, artificial intelligence (AI), sensors, actuators, 4G/5 G social media, robotics, web 3.0, big data analytics, cloud computing, and more. Together with current operating systems such as Windows 16, Linux, SuSE Linux, Macintosh Ubuntu, Android Sun Solaris, Unisys, CP/M, and potential urban operating systems, the IoT applications are even more advanced. Roughly ten billion connected gadgets are expected to become 24 billion by 2020, starting now (Fig. 9.1). Cisco and Ericsson have estimated that 50 billion devices will be the accompanying innovative model with regard to cloud computing before this decade on the web of things (WoT). In human services applications, wireless sensor networks (WSN) have begun assuming a gigantic job in the manner patients are being checked. Remote sensors as remote wearable extras or gadgets are appended to a patient with the end goal that this data can be utilized for the checking procedure. The sensors can be of different structures and sizes as long as they are pertinent to the need. The remote sensor systems create a tremendous measure of information. This information that has been gathered from every one of the gadgets associated with the system might be valuable just as excess. All these phenomenal measures of information can overpower the information, storing frameworks, and information examination applications. The removing of insignificant information must be a setting touchy procedure. Consequently, the sensors would need to send the data gathered to computing gadgets that are fit for performing undertakings of investigation, accumulation, and visualization. Much of the time, every patient requires a high number of sensors, and subsequently, making a foundation devoted to an individual gets wasteful.

Consequently, IoT gives an elective methodology wherein sensor gadgets are utilized in a typical foundation. These sensor gadgets would then be able to advance the information to a cloud server. Sensor devices can use a typical basis to progressively complete their details using institutionalized conventions such as 6LoWPAN over IPv6 [14].

The Internet of Things (IoT) is a self-organizing and scalable system that interfaces certifiable things to the web, allowing them to converse with other relevant elements that provoke the affirmation of another level of ubiquitous organizations as shown in Fig. 9.3 [15]. This IoT definition is not complete as there is a variety of detailed descriptions of the difficulty. The word IoT started to focus on Auto-ID at Massachusetts Institute of Technology (MIT) when Kevin Ashton selected it in 1999 [16]. Nonetheless, the concept of associating gadgets with the web to remotely screen the status that a social event of understudies at Carnegie Mellon University had implemented unparalleled for 1982 when they made sense of how to connect a coke machine to the network and test its status remotely [17]. Innovation in science and technology permits making smaller, more accessible and more snappy figuring contraptions fit to discern nature, confer, and enact remotely, resulting in the extended energy of applying IoT to vast pieces of life, such as smart urban communities, medicinal facilities, and smart homes.

As of now, the IoT is a flexible mix of wearable devices, shrewd vehicles, and canny home systems. Through 2020, the web will be linked to more than 50 billion devices which is normal [18]. Presenting colossal related gadgets requires a flexible design that fits them without undermining the essence of application-requested administration. What's more, a large proportion of Internet-of-things gadgets are resource constraints; properties, for example, processing power, energy, data transmission, and efficiency are uncommon. Such limitations restrict the use situations of these IoT devices used by the organization. For example, it is unlikely that a battery-controlled sensor will be used to connect to the Internet and exchange information about its long-term integration or store readings of a slowly drawn-out time in near memory. In other words, the imperatives create a strategy challenge that molds the IoT development from different perspectives. A portion of these IoT issues is summarized in [19], which compares efforts in each territory. Impressive IoT issues can be eased by extending the cloud computing elements closer to IoT gadgets. Fog computing is such a middle of the road layer that the cloud layer extends.

Remote systems rule the IoT. There are numerous remote conventions, for the most part, custom-fitted for low-control activity, inclusion, or data transmission. For example, as a part of the abovementioned conventions, 6LoWPAN [20], BLE, NarrowBand IoT Protocol (NB-IoT) [21], LoRa [22], and Sigfox [23] occur. The majority of these conventions interface sensor hubs of the fog layer gains admittance to the web. These conventions are normally incongruent to one another. Hence, to adapt this issue, the fog layer gives an extra advantage of going about as an explicable layer among those diverse conventions [24]. A couple of middleware proposals utilizes this layer as an approach to interpret or alter a particular framework or application conventions. The portal in the fog layer likewise can operate inconsequential investigation at the fringe to provide input, direction, as well as notice to the end-clients just like the sensor hubs progressively. Furthermore,

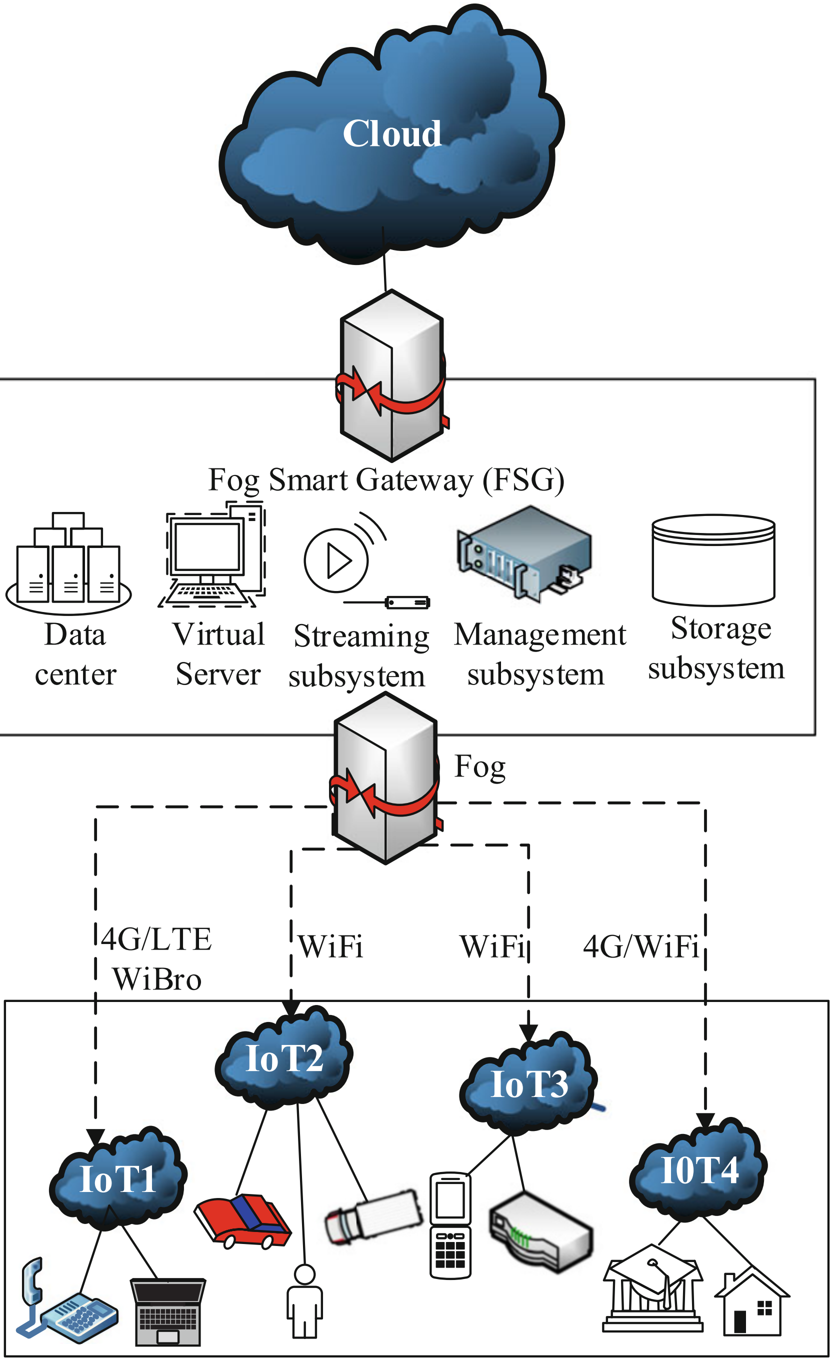


Fig. 9.3 Fog as the middleware between the Internet of Things (IoT) and cloud

the inner association of the fog itself can be orchestrated in a united or progressive manner dependent on utilitarian or area of the associated gadgets.

9.1.4 Our Contributions/Motivations

The invention of new smart sensing tools has amplified the use of the internet of things (IoT), which has resulted in exponential growth in data outputs year after year (YoY). This developmental trend is driven by a focus on space for medical services such as therapeutic sensors, visual sensors, cameras, and remote sensors that drive this technological pattern. In the area of medicinal services, the part expects to consolidate the intermingling of fog computing toward this path. Motivated by the same groundbreaking techniques, our work illustrates the novel paradigm of IoT-aware student-centered stress monitoring to predict student stress index in a specific context.

Below is a summary of the contributions of this chapter.

- In order to classify the stress event as an ordinary or abnormal use on the cloud layer and a two-stage Temporal Dynamic Bayesian Network (TDBN), we adopted the physiological readings gathered from medicinal sensors at the fog layer.
- An algorithm (algorithm 1) is proposed for the generation of stress-oriented datasets at the cloud layer using 25 students associated with the SWELL-KW dataset.
- The stress index is measured on the basis of four criteria, including confirmations of the leaf node, unfinished tasks at hand, meaning and consistency of health understudy.
- After calculating the student's stress index, decisions are taken in the form of an alert generation mechanism with the provision to the caretaker or respondent of time-sensitive information. Experiments are aimed at both fog and cloud layer, which in our proposed framework bear proof of the utility and precision of the TDBN prescient model.

9.2 The Convergence of Fog Computing, IoT, and Healthcare 4.0

The cloud computing market for medicinal services has just come to an abundance of $5.4 billion. To conquer the difficulties of the present healthcare, for example, delay in patient care, the center cloud computing alone is not the best arrangement. Notwithstanding this, healthcare administration and applications accessible straightforwardly on cloud computing do not fulfill the need for the healthcare 4.0 condition. It has its impediments, for example, poor progressively reaction and postponement.

In healthcare, adjournment costs a patient's life, so fog computing has come to play a reasonable role in improving administrations and applications. Fog computing allows high consistency, timely administration while solving challenges, such as delays or jitters, reduces overhead when transferring data to the cloud. It is a distributed level design that enhances the power, computing, and organization of assets along with cloud computing. Fog computing offers three significant advantages, for example, low dormancy, protection, and strength against cloud computing. Thus, the consortium of OpenFog named fog computing as SCALE: Security, Cognition, Agility, Latency, and Efficiency [25]. Among the majority of the analysts, fog computing applications in healthcare 4.0 have geared notoriety pickup, whereby, in comparing with the previous year, a wide range of works on the identification, investigation, conclusion, investigation, and portrayal of illness are suggested. Figure 9.4 shows the scientific taxonomy for fog computing healthcare 4.0. This scientific categorization gives an association of the current works in the healthcare part utilizing fog computing.

Data Accumulation One of healthcare's revolutionary factors is continuous wellness tracking by using wireless body area networks (WBANs) and implantable and wearable medical devices (IWMDs). There are rapid developments in biomedical sensors, low power and minimal effort gadgets, and remote systems that have taken this concept to the edges of the real world. However, significant issues and difficulties are as yet should have been tended to. While discussing nonstop checking of human well-being, the detecting gadgets turn into the primary that gets all information from the human body. The capabilities and facilities of fog computing in the healthcare sector are spoken by Vora et al. [26, 27].

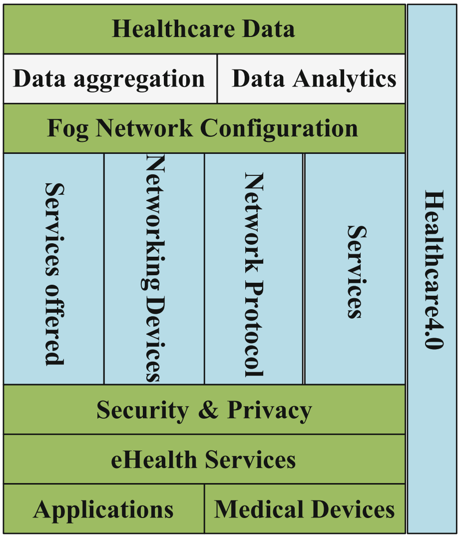


Fig. 9.4 Healthcare 4.0 fog computing taxonomy [70]

Data Investigation There is a significant hole between the need for long haul non-stop ability and vitality to observe the structure and skills among existing gadgets. Information processing, compressive sensing, and anomaly-driven transmission systems reduce the overhead for remote transmission, encryption, data storage, and information validation. The system should be capable of obtaining biosignals from sensor gadgets and sending detected information to the doors using a specific remote correspondence convention, in order to monitor wellness continuously using worldwide well-being observing frameworks, as per example Wi-Fi for starters, the constant information is transferred from that point on to a far-off cloud server for management, commitment, and representation.

Fog Node Arrangement This includes servers, computer scheduling, conferences coordination, and cloudlets. The quantity of detecting gadgets that can be convincing in terms of battery life, connectivity, and computational power is growing. To counter this, Peralta et al. [28] chipped away at message queue telemetry transport (MQTT), an IoT communication convention, using an FC method with low computational complexity in the cloud and IoT hubs core. Since the amplification of healthcare services is floating, a cyber-physical medical system (MCPSs) is engaging in close cooperation between medicinal gadgets and computer products. Cloud assets are routinely shown to process identified restore gadget information to assist MCPSs. Then again, long-postponing and precarious connections are formed between restore gadgets and cloud server farms because of MCPS QoS requests.

Security and Protection Akrivopoulos et al. [29] assessed a working model that gathers electrocardiogram (ECG) that follows from a customized gadget utilizing fog doors for safely sharing them to other approved elements. The model has the capability of sharing patient information freely with their primary care physicians and warn them for emergencies and track their health status. In Mobile Healthcare Social Networks (MHSNs), a cryptographic handshake program occupies a key position for secure communication. He et al. [30], by the name of the cross-domain handshake (CDHS) scenario, provided a unique structure using various graded character-based cryptography for the handshake conspire in MHSNs, which permits coordinating manifestations embedded in MHSNs. The CDHS plan has achieved a reduction in the cost of measurement and correspondence as 18.14% and 5.41% relative to the related handshake plans, respectively.

Privacy The protection of the information upsurge the need for a secure standard framework with proper guidelines and techniques for the healthcare domain. This needed the overburden of communications and safeguarded patient safety. Elmisery et al. [31] proposed a cloud-based healthcare management platform to assess accurate information bits of well-being while safeguarding end-customer security. In addition, Chakraborty et al. [31] showed a large-scale dynamic fog, transmitted geospatially, and touchy dormancy significant level programming model for time-sensitive applications. This paradigm has been designed for knowledge about the pulses. In restorative this knowledge is additional time-touching and controls conditions of life and demise.

***eHealth services*:** In this subsection, a few related components are represented.

Medicinal Gadgets Tasic et al. [32] suggested a cloud-based healthcare system that would incorporate wearable bio-sensors, customized restorative devices, transmitters for the transmission of sensed information, and a server for the transmission of healthcare benefits over the Internet. A therapeutic cloud has a generated framework that speaks to restore devices and sensors, for example, patient to care provider, starting from one hand to the next. The correction of the administration has been finished by a specialist ICT framework, and a medicinal master, if getting a caution for issues during the investigation of sensor information.

Applications Inside the whole rundown of cloud-based healthcare service applications, eHealth attracts excellent consideration because of its basic prerequisites, advancing chances, and social interest. Ramalho et al. [33] propose an all-encompassing multi-eHealth cloud service architecture (MeCa) for the creation of smart eHealth applications and services. The assessment of MeCa demonstrated its ability to execute portable eHealth applications by achieving adequate execution levels for CPU use, network burden, vitality utilization, and future patterns in fog-empowered portable eHealth. Aazam et al. [34], defined as the emergency aid response mobile cloud (E-HAMC) platform, appeared to have an alarming free crisis ready framework. The framework utilized fog computing for crisis ready help. E-HAMC is a Personal Digital Assistants (PDA) based assistance that gives a fast method for informing the fitting crisis managing divisions.

9.2.1 System Architecture of Healthcare IoT

The engineering of the framework gives data on segments, cooperation, as well as the association of the section. This is among key components for the accomplishment of agile scaling as well as execution [35]. In addition, it intends to further reach the utilitarian necessities of application area. Amid ineffectual necessities that compel the framework engineering structure, not many of these are adaptability, ease of use, and execution. The primary difficulties lie in a tremendous quantity of gadgets being associated with the web. Associating more devices causes accessible assets, for example, transmission capacity and processing control, that can be shared with further hubs promoting standard and execution debasement. Notwithstanding, the urgency of the application space causes the debased framework unsatisfactory. Furthermore, a huge extent of these devices is asset compelled. This deficiency of assets adds more plan limitations to the engineering structure.

The introduction of the fog computing layer between the end devices and the cloud adds to a planned move toward IoT-based frameworks while mitigating the previously mentioned difficulties. The fog layer may be utilized to give a broad assortment of administrations in order to help the asset compelled hubs [36]. In a healthcare IoT framework, the architecture outline is as shown in Fig. 9.5, where wearable or implantable sensors and actuators can be the asset-obligated hubs.

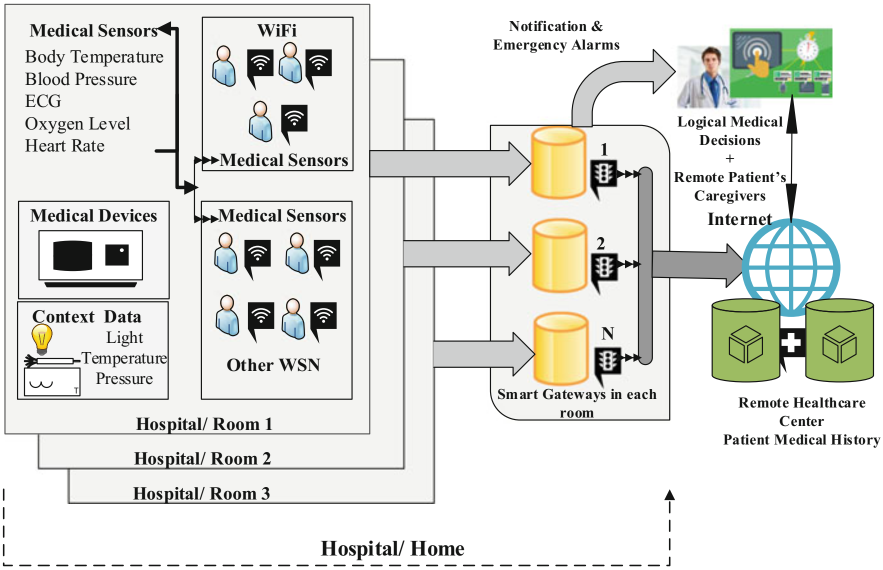


Fig. 9.5 Healthcare IoT framework engineering

The patient may be at home or in an emergency clinic, and the sensors direct the physiological sign estimates to interpret the local entrance to the fog layer. The fog layer has local resources dealing with information, occasions, gadgets, and the system. In the medicinal services situation, this design is made out of the accompanying three primary sections in every layer.

1. **Medical sensors and actuators**: Primarily associated with low-control remote communication conventions, serves to differentiate topic, peruses physiological flag, and works in light of a fog layer order.
2. **Smart e-health gateways**: Dispersed portal system structures a fog layer and serves the basic sensor and actuator arrangement. Generally speaking, it has different junctures that allow different conventions to speak. This has a wide variety of governments, so it is going on as a web scaffold. This is the part's principal focal point.
3. **Cloud stage:** Back-end platform where knowledge continues and partners gain admittance through web or flexible interface into the system.

9.2.2 Case Study I: Health Monitoring

The combination of advancement in sensor innovation, as well as data analysis, encourages the continuously modern monitoring of vital signals for clinical, technical, or relaxation objectives. For monitoring the pulse, circulatory strain, respiratory rate, temperature, blood oxygen immersion, as well as numerous different criteria, cheap sensors might be connected to the body for gathering activities, well-being situations, wellness levels, proficiency of exercises, and sessions of learning. Multibillion Euro showcases the imperative signs checking the twofold digit leading to an increment in the development rates, a lot of speculation cash has filled the segment with the result that increasingly flexible and more affordable sensor gadgets and observing gear will get accessible in the approaching years. Accordingly, information from imperative sign sensors is ample; however, it should be prepared rapidly and productively for interpretation.

9.2.2.1 Early Warning Score

Think about the Early Warning Score (EWS) framework [37], which is a manual device generally utilized in medical clinics to follow the state of patients. It considers the assessment of dangers right off the bat so as to acquire preventive activities, hence it might be characterized as a particular technique of initial discovery to any takeoff from typical rates of specific infections in clinical cases or serologic reactors, observing an example of the populace in danger [38]. Considering five physiological frameworks, as recorded in Table 9.2, hence relegates an outcome somewhere in the scope of 0 and 3 to all of them, with a lower score of significance effective situation. Including independent result provides the EWS result somewhere in the range of 0 and 15, that has exhibited a sensitive indicator for ensuing well-being disintegration as well as ethics [38]. In the recent practice of the medical clinic, EWS is a manual system, however as of late endeavors is made to motorize the estimation as well as EWS count dependent on portable devices detector [39]. Hence, this can lead to a critical bit of leeway that the methodology is not bound to the emergency clinic anything else since prepared medicinal workforce does not need to be available for playing out the estimations. Observing patients constantly at home or during work gets doable. Anzanpour et al. [39] show a mechanized EWS framework with portable detectors, a passage hub that transfers the information of the detector to a server, which registers the result hence makes the appraisal. The detector might be situated in the clinic; hence restorative experts further investigate the information

Table 9.2 Benchmark early admonition scores

Score	3	2	1	0	1	2	3
SPO_2 (%)	<85	85–90	90–95	>95			
Systolic BP (mmHg)	<70	70–81		81–101	101–149	149–169	>169
Breathe rate (per min)		<9		9–14	14–20	20–29	>29
Heart rate (bpm)	<40	40–51	51–60	60–100	100–110	110–129	>129
Body temp. (°C)	<28	28–32	32–35	35–38		38–39.5	>39.5

as well as accept activities when required. Therefore, benefits of this framework are diminished value, expanded solace for the patient, and expanded checking inclusion outside clinics.

The fundamental burdens play as a bother in conveying detectors, existing wire up, as well as a possible value lost in estimations, because of off base connection, free association, flawed detectors as well as tools. In order to sermonize the worries, Gotzinger et al. [40] add the capacity to break down the information dependability and regularity along these lines creating computerized EWS increasingly strong as well as solid. In reality, a universal concern with multiplication detectors associated with IoT in developing aggregate uses as well as spaces is obscure nature of gathered information. Smart sensors display a wide scope of exactness and accuracy, equipment issues, and limited battery limit their lifetime, and the equipment and programming of the preparing and correspondence hardware may remain imperfect and impersonations. Consequently, it is required that a framework like the mechanized EWS examines the nature of the gathered information and monitors meta-data. To this end, Gotzinger et al. [40] portrays an operator-based training system that controls the accuracy and reliability of sensor testing by a large number of collaborating specialists on a few assignments: deliberation, follow-up experience, induction of confidence, and restriction [40]. They exhibit that few regular disappointment conditions in the information accumulation and handling series may be accurately distinguished leading to improvements in the general vigor in EWS framework.

The above strategy is adopted for further innovative works that consolidate self-consciousness, condition cognizance, an awareness technique, as well as adjusting materials allotment schemes. Emphasizing the view of the tangible information and the framework's desire on its condition, a paradigm of its presentation, as well as the crucial parts of the environment has been evolved. Calculating EWS, tactile information is pre-processed along conventional sign preparing calculations to smother commotion and concentrate important highlights. The pre-processing stage offers the upper layers in the handling chain considerable deliberations for the restorative utilization of the crude information. Two approaches are used to modify the principal input data through self-awareness and situation knowledge points. Initial, equivocalness and equilibrium examination recognizes possible blunders during input data. Next an action of the sick is evaluated, as information translation is subject to action design. Framework recognized five diverse action modes: sleep, rest, walk, jog as well as run. Subsequently, considering the estimation error as well as patient movement procedures, the identical translation of information is determined as well as related EWS worth processed.

9.2.3 Case Study II: Patient Safety Monitoring and Training Support

The expenses on medical treatment and old social contemplation have been expanding around the world. Telecare is accepted to repay the decreased customary clinical collaborations and residence nursing. IoT advancements surely provide job within customary telemedicine of chronic ailment organization and ensure patient's well-being at home, empowering new administrations like innovation-assisted rehabilitation. In 2017, the statistical surveying organization Gartner expected that human services related innovations and administrations should have 16% of IoT showcase occupational esteem. Circulated as well as versatile detecting gadgets are appropriate for the improvement of old and extraordinary necessities of patients at residence. As indicated by the Centers for Disease Control and Prevention (CDCP), around 800,000 patients in the USA are hospitalized every year due to tumbledown [41]. On the same page, 25% of the more mature adults in the United States will fall every year. It has also been pointed out that everyday exercises and intellectual and physical well-being can be in a great relation. Certain advanced home telecare frameworks, as of now, give tumbledown recognition usefulness dependent on wearable movement sensors, camera frameworks, and floor sensors [42]. Innovatively today is additionally conceivable to foresee the fragility of old individuals dependent on the activity of daily living (ADL) design examination. In any case, contrasted with ordinary telecare arrangements that intermittently transmit fundamental signs estimation data, the ongoing and trustworthiness prerequisites for such well-being basic telecare arrangements are higher. By traditional home telecare frameworks, the estimations are typically directed two times every day and even by ECG signal estimations, the chronicle bundle does not surpass 50 kB. In this way, until this point, a customary focal server or cloud-based information store for personal health records (PHR) is appropriate The innovative and furthermore security prerequisites for novel home telecare arrangements utilizing certain movement catch or constant activities of daily living (ADL) checking capacities are essentially more grounded which prompts utilization of option—disseminated information preparing models. It might be well assessed that the crude information of the inertial measurement unit (IMU) fits in consequence of the fact that adequately precise human movement or rapid decline following any event 1 kbps. It is easy to comprehend the advantages of disseminated fog-like information handling of constant patient well-being checking arrangements above the one incorporated one.

The burden of the remote server, as well as the correspondence mechanism, can be wholly diminished over nearby information accumulation as well as basic decision-making. In addition, only the meta-information gathered from a clinical point of view, i.e., the number of dynamic hours, the mean measure of development, the standard of rest, and the closeness of novel events such as fall-downs have colossal long stretch consideration worth shielding in PHR. The majority of the unrefined information has a little therapeutic interest, so the security scrutiny increases if the same is moved farther from the private domain. These days cell phones are often utilized as telemedicine doors and remote correspondence is generally utilized. Vast majority of sensors signal, i.e., temperature, conductivity, improvement, and location, as well as light, remote transfer is 100–1000 times more crucial than setting up that motivates local data in the same way. Disseminated fog computing additionally builds steadfastness of remotely arranged frameworks. Today, Bluetooth Low Energy, ANT+, and various standard IEEE 802.15.4 compatible radios are used mainly for organizing the individual region. Because of as far as possible, the continuous information spilling may genuinely influence the unwavering quality of the correspondence. Fog computing decreases such dangers too in light of loosened up prerequisites for the correspondence channel throughout. Significantly more, if the constant basic information preparation is localized, excess correspondence medium, i.e., there can be successful utilization of remote MESH networks.

Hypothetically, it is conceivable to acquire compulsory user action, position, also the falling data outside of one wearable IMU gadget as well as procedure information inside a similar sensor gadget. Present-day IMUs, for the most part, have worked in free fall occasion recognition. The amalgam utilization of straight accelerometer, gyrator, as well as magnetometer information ought to be adequate for dead retribution based development observing. Due to internal blunders of inertial motion sensors, detector combination and elective shrewd home sensors should be used in the test. Human tumbling down can not be accurately detected with inertial sensors and due to nonlinearities of IMUs the creation of dead retribution following is only solid for some meters. Because of the capricious system delays, the portrayed sensor information combination cannot be made in a remote area. In this manner, the combined sensor information, fog-located collection, as well as the conceivable thinking at the entryway gadget is befitting answer for astute residence telecare frameworks in support of ADL investigation as well as peril location. Reablement employing physical exercises will help in expanding the free-living time; therefore in this way, the requirements for costly customary social consideration will diminish. For instance, it has been accounted for total cost reserve funds of 30% in 2–5 years through the training [43]. Be that as it may, the process of reablement itself incorporates trainings that will help humans, and approval of recent aptitudes is exorbitant as well as tedious. Hence the wearable detectors, as well as the IoT gadgets, might empower teletraining, as well as security approval on locally situated working out is normal.

In the near future, remote approval of physical training activities through the home telecare system could be conceivable. Therefore, due to the innovative arrangements, the requirement to visit the clinic or physiotherapists will essentially lessen. For instance, explicit practicing at home is needed at the time of recuperation of the stroke following the joint substitution medical procedures [44]. In the two cases, rather straightforward activities must be performed to maintain a strategic distance from irreversible procedures of joint solidifying. For the preparation viability, certain practicing pace and sufficiency must be saved, which was unrealistic before. Nowadays, with the help of wearable IoT gadgets, the preparation procedure might be very much checked as it provides continuous feedback to the client whether the practicing is precise or not. Integrating such a planning aid device with the aforementioned home telecare system is true, which will properly facilitate out-oriented work supported by the computer. The system will effectively transfer the amount and essence of the preparation exercises conducted to the PHR cloud server where clinicians and physiotherapists can access the data and make more treatment decisions as shown in Fig. 9.5. As with an earlier model of ADL observation, sensor information can be processed locally in the fog to limit the heap of communication channels and spare properties of PHR archive servers. In this particular case, the option of accuracy must be made in the near future. Neighborhood choice help is required to give practicing input continuously, without identifiable delay, and to meet the basic requirements for well-being reliability throughout the information process. It is reasonable to execute preparing evaluation forms in the door gadget which, as a rule, has an adequate measure of the registering power thart access the setting data concerning earth as well as client. Fog based nearby choice help likewise safeguards the client protection since it limits the individual data add up to be transmitted to the remote areas.

9.3 Related Work

The section provides an overview of some of the relevant stress management works as well as IoT-based healthcare tracking.

9.3.1 Stress Monitoring System

An individual health monitoring framework reliant on remote body territory system embracing smart sensors is put forward by Jovanov et al. [45] in 2003. Their remote sensor framework is found very helpful for delayed stress monitoring during unpleasant preparing as well as normalcy in activities. They utilize the heart-rate variability (HRV) parameter to measure and predict pressure resistance during various occasions. In 2008, Suzuki et al. [46] created an original technique to monitor people's worries by promoting autonomous execution through the back seat by using limited 24-GHz microwave radar. Unpleasant sounds bring out the programmed activation through the non-contact assessment of the individual's pulse changeability. The findings of the test indicate that the treatment for older people with cardiovascular problems is very promising. Furthermore, this approach also makes it possible to observe programmed actuation without placing any weight on people's checks. Ayzenberg et al. [47] proposed in 2012 a framework for programmed client's expected and tracking of wireless behavior and stress reactions. Biosensors are used to measure the customer's electrodermal activity. Special programming based on stress recognition is used to evaluate the client's feelings of anxiety.

Stress observing framework named as detecting belt framework is portrayed and executed using wearable devices in the work of Shen et al. [48]. In a texture that speaks with a physiological information procurement unit, different sensors are incorporated. This unit also speaks for investigation with a remote inspection site. The result of the trial indicates that the patient's physiological parameters are very persuasive to verify the structure. This method can also be used as a process of human mental evaluation to examine human heart pressure, cold pressure, as well as warm easement. Tartarisco et al. [49] in 2012 introduced a self-regressive model, a falsified neural network, and fluffy rationale displaying based design for the assessment of the pressure condition of a person. The exhibition of the design is evaluated as far as the grouping of pressure conditions. In 2014, a multilayered stress sensor was designed and developed by Yoon et al. [50]. The multimodal stress sensor is a combination of the sensor for skin temperature, the sensor for skin movement, and the sensor for pulse wave. The wearing of this multimodal stress sensor is therefore measured in terms of the number of gadgets reached, the adaptability of the gadgets, and the skin contact area.

9.3.2 Health Monitoring System Using IoT

Sheng et al. [51] in 2013 presented a brief description of the Internet Engineering Task Force (IETF) convention suite proposed to help IoT. IETF conventions are broken down top to bottom to give better rules, bringing about the effective structure of the correspondence framework. In 2014, Zhou et al. [52] found a pragmatic answer to manage modern assaults, including even hub bargain assault of cloud-helped WBANs. They offered a safe and secure plot to protect key management. This approach defends the blinding technique and the symmetrical key component of blom from an alternative perspective with a changed positive distribution of mysteries. Tsai et al. [53] in 2014 gave a diagram of IoT and latest developments leads to Future IoT (FIoT). Fortino et al. [54] provided Body Area Networks (BANs) with cloud-help in 2014. They focused primarily on the provocations that should be tended to in BAN's progression and executives. In 2015, Chouvarda et al. [55] gave a system to patients experiencing ceaseless infections by acquiring information utilizing associated well-being advances. In 2015, Qin et al. [56] examined the key approaches and best in class discusses IoT initiatives from information-driven viewpoints, including data-centered perspectives, data stream processing, data storage paradigm, complicated events processings, and IoT quest. They also emphasized open research problems related to IoT expertise of executives.

Zhang et al. [57] recognized dark RFID tags in major IoT frameworks in 2016. The creators fundamentally focused on a few conventions to observe obscure labels. They suggested a plan using a bloom filter, which is the distinctive method of proof that eliminates data transmission. The authors in [58] have been given an IoT solution to Information-Centric Networking (ICN). By observing the ongoing trends in the creation of a web base, they explored a potential path toward the benefits of ICN. Wan et al. [59] dissected the Industrial Internet of Things (IIoT) engineering, involving various layers in 2016. They likewise proposed a product characterized IIoT engineering to oversee IoT gadgets and give an interface to data trade. They additionally chose a keen assembling condition for experimentation to give way in actualizing industry 4.0. Similarly, a progressive model for elderly health observing is proposed by Azimi et al. [60] in 2017. In 2017, Ghanavati et al. [61] suggested a Wireless Body Area Network (WBAN) focused on IoT to track the status of patient health. The results show that the IoT-WBAN configuration is effectively beating the WBAN benchmark. Yang et al. [62] proposed another ECG control strategy based on IoT in 2016. ECG information is collected use of wearable control hub as well as legitimately forwarded for further investigation into the cloud layer. The IoT cloud-based model uses HTTP and MQTT conventions to provide timely ECG information to clients. Tests are aimed at sound volunteers to validate the ability of the entire framework. The results show that the device is effective for the continuous collection and display of ECG information. Wu et al. [63] proposed a wearable sensor center with gathering of sun-powered vitality and low-vitality Bluetooth communication allowing the use of an autonomous WBAN. They additionally created an electronic advanced cell application for showing device information as well as fall of patient recognition warning. In conclusion, to deal with dormancy touchy administrations and constant reaction, engineers are creating new IoT-fog-based human services applications [64].

9.4 Proposed Methodology (A Case Study of Fog Computing in Student Stress Monitoring)

The present study offers a new, IoT-centered stress monitoring system for predicting stress in a specific setting. Using physiological readings collected from fog layer therapeutic sensors, the Bayesian Belief Network (BBN) is used to order tension as natural or unusual. For specific parameters related to stress at the cloud layer, anomalous transient basic information that is time-advanced dataset structure is broken down. A Temporary Dynamic Bayesian Network (TDBN) model is developed to assess the stress record of the understudy. The model tracks stress based on four factors, including confirmations of the leaf core, workload, background, and student health characteristics. After processing the understudy stress record, choices for warning generation are made with the release of time-delicate data for monitoring or reacting. Investigations are performed in both the fog and cloud layers that have proof in our proposed structure of the usefulness and precision of classifier BBN and prescient model TDBN.

Table 9.3 Categorization of datasets

Activity set	IoT technology used	Attributes
Visual dataset	Shrewd camera gadgets (wide edge, slender point)	Pupil diameter, mouth openness, squinting recurrence, normal eye conclusion speed, head development, and eyebrow development
Physiological dataset	Savvy wearables, heart sensors, body sensors, EEG screen gadgets	Pulse fluctuation, skin temperature, EEG (stress-related mind waves), expanded perspiring, cool skin, cold hand, and feet, the sentiment of queasiness, tense muscle, and so forth
Behavioral dataset	Kinect SD sensor	Student body posture

9.4.1 Data and Subjects

For the provision of the various stress-related exercises data, body area networks such as physiological, visual as well as conduct sensors installed in IoT can be embedded. The researcher sits in front of the PC screen and responds to his/her errands on the screen. The fundamental parts of information acquisition are sensors such as USB camera, Kinect 3D, and sensors for the body field. Different gadgets used to test worries are listed in Table 9.3. Right off the bat, the physiological parameters gathered utilizing IoT therapeutic gadgets are utilized for grouping at the fog layer. Physiological appreciations obtained through IoT gadgets are grouped utilizing BBN for usual and abnormal stress occasions. The IoT improvement stage of Ubidots [65] is used to give warning to fog layer guardians and relatives. Undergraduate API in Ubidots is followed by understudy sensor readings in python-based grouping calculation (Version 2.7) to tackle the severity of well-being. SWELL learning work (SWELL-KW) dataset [66], eye tracking, and identification dataset [67] are also used for stress display due to the use of criticality as well as the use of both IoT and other information securing strategy. The highlights from the SWELL-KW dataset are shown in Table 9.4. Additionally, these feature-based datasets are replicated to create thousands of records. Records generated from these datasets are stored in the Amazon EC2 cloud which investigates the use of WEKA 3.7 toolbox.

Algorithm 1 portrays the absolute wonder in the understudy domain to build stress datasets. Comparison of the results is obtained from these datasets with various state-of-the-art classification techniques.

Table 9.4 Dataset exploited from SWELL-KW and other parameter values for 25 students (1 h each) [70]

Features	Preprocessed sensor data	Features took under consideration (number of features)
Physiological	Information from restorative sensors (records with readings per 1-min time allotment)	Pulse changeability (2), skin conductance (1)
Facial signs	FaceReader yield (txt logs and records with facial and time-stamped data)	Head direction (3), facial developments (10), feelings (8), eye discovery and following (30-s timestamp window)
Body postures	Joint directions and chest area edges (txt records also, time-stepped data	Distance (1), joint angles (10)

9.4.2 Fog Layer

To order the stress information into various classes, data obtained from the procurement layer is additionally transmitted to the fog layer. As portrayed in the prior area, the heterogeneous properties created from IoT sensors incorporate immediate and roundabout well-being focused traits. Such properties must be aggregated into specific datasets for the internal and external assessment of data, as shown in Table 9.3. In this work, three distinctive datasets are comprehensive to measure the stress parameters of the understudy, within particular the visual dataset, physiological dataset, and the behavioral dataset. Each of these was further clarified in detail.

(a) Visual datasets

This kind of dataset relates to visual confirmations that have been made using visual sensors. Highlights such as eye recognition and follow-up, eye conclusion and development, facial highlights extraction, and facial position extraction take advantage of techniques that appeared in Table 9.3 with the usage of visual devices. Hence the visual devices are implanted in the study's field of action. The visual highlights of each understudy are extricated using wide-point and limited edge video sensors.

(b) Physiological datasets

The dataset of physiology produces knowledge regarding physiological confirmations in an understudy. The understudy body sensor system contains wearable IoT devices, heart sensors, temperature sensors, and EEG monitors. These gadgets are also associated with cell phones that are used as an input for the transmission of information.

(c) Behavioral dataset

Observing understudy conduct depends on body stances during understudy stress conditions. Highlights such as joint coordination and chest area point are separated using Window Kinect SDK. The physiological parameters of understudy caught by IoT gadgets are used as an underlying sign of stress condition. Datasets are arranged using the Bayesian Belief Network (BBN) [68] at the fog layer. Unusual stress occasion characterizes quality-based occasions that can be considered as stress situated and can prompt genuine medical issues. Again, traditional stress opportunity class includes times that have no noticeable impact on stress-related medical conditions. The grouping part of our proposed model is shown in Fig. 9.6. Additionally, the anomalous stress-related property of each class is transferred to the data digging layer for a brief computation of understudy stress appreciation, as explained above. This method is important because it is possible to determine the pressure list at the cloud layer where parameters are physiological results in unusual events. However, for a particular pressure occasion, degree of impact (DOI) is described during the time as the frequency of the stress trait esteems. Furthermore, this DOI is combination of BBN classifier to establish typical stress opportunities as well as strange stress opportunities for further analysis in the fleeting mining segment.

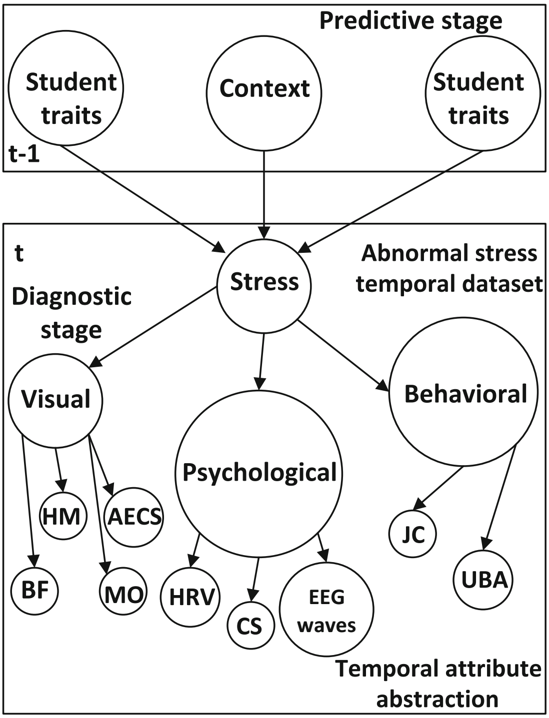
Algorithm 1 Generating stress-oriented dataset at the cloud layer

 # Input: 25 students associated SWELL-KW dataset for stress displaying in student sphere and eye assortment and tracking dataset for **BF** and **AECF** calculation
 # Output: Prognostic stress index

1.	Let **n** be the required number of stress records for each leaf node values initialized with one do
2.	Extract a record from the **SWELL** dataset and a record from eye detection and tracking dataset to generate all leaf node values in a particular context.
3.	Create a new dataset by combining all leaf nodes symptoms for each student during a definite time interval.
4.	Assign a new identification number **S_ID** to the stress database.
5.	If **S_ID** already exists in the database, then discard the record
6.	Else
7.	Add the record to the database
8.	End if
9.	End do

9.4.3 Information Mining Layer

The knowledge mining layer retrieves information from a cloud database associated with different datasets. Different datasets are substituted as transient events, so in our proposed system, mining based on the example of time-setting is needed. The temporal mining technique [69] can be used for the generation of the list to understudy stresses gradually. Fleeting unusual stress datasets are granulated to create a stress list utilizing estimations of various highlights extricated from the leaf hub. The present application situation works in occasion activated mode. In this mode, the essential ongoing examined information is put away at the fog hubs. The fog layer will lead information taking care of procedure by communicating



BF: Blinking frequency
AECS: Average eye closing speed
HM: Head movement
MO: Mouth openness
HRV: Heart rate variability
EEG: Electroencephalography
ST: Skin temperature
CS: Cool skin
JC: Joint coordination
UBA: Upper body angle

Fig. 9.6 Two-layer temporal dynamic Bayesian network model

with other fog hubs and fog information administrations for investigation. The information taking care of procedure thinks about the inspected information of every parameter with the comparing scope of typical qualities which is foreordained by specialists. Heterogeneous information from different medicinal gadgets is changed over into an essential group before characterization. Distinctive datasets are shaped to characterize an occasion into two classes, in particular, typical occasion class and irregular occasion class. To characterize the patient occasion information as strange or ordinary, the Bayesian Belief Network (BBN) classifier is utilized. It takes a shot at the guideline of contingent likelihood and Naıve Bayes arrangement technique. Grounded on the interpretations (R), any incident I will only be classified as normal class (N) and abnormal class (A) if $P(N/R) > P(A/R)$, where $P(A/R)$ depicts the probability of event I having a class A for health data reading . On the same grounds, $P(N/R)$ depicts the probability of an event I has a class (N) if he/she has health data readings (R) which can be interpreted with ease from Bayes Theorem as follows:

$$P\left(\frac{N}{R}\right) = \frac{P\left(\frac{R}{N}\right) P(N)}{P(R)} \tag{9.1}$$

Here $P(R/N)$ is the probability of having a reading (R) when any event happening is calculated with N class. $P(N)$ is the probability of an event having a normal class based on vital health parameters and $P(R)$ is the probability of having health readings (R). Naive Bayes classifier assumes conditional independence of all attributes, which is not possible while dealing with health attributes inpatient healthcare domain. Naive Bayes classifier accepts contingent freedom of conditional independence, which is unimaginable while managing well-being qualities in the persistent medicinal services area. To beat this issue, two-organize Temporal Dynamic Bayesian Model (TDBM model) is viewed as which comprises of a significant arrangement of traits depicted in for right expectation of the occasion.

9.4.4 Prediction Layer

For the present time reason, different elements should be considered in order to measure the understudy's stress index (SI). For example, special treatment is needed for research into mental problems such as depression, anxiety, dementia, bipolar disorder, schizophrenia, and autism. In this way it is possible to use a two-organized Temporal Dynamic Bayesian Model (TDBM model) to transiently analyze the relationship between vulnerable variables. TDBM is also a deterministic paradigm that separates data from one step to the next to evaluate stress factors in fundamental terms. We build a two-organize TDBN paradigm for anticipating feeling of anxiety of an understudy at a specific time case. Stage 1 involves essential characteristics that straightforwardly modify understudy stress file. This stage establishes the prescient piece of the understudy stress figuring area [70].

Definition 1 Many features characterize an SPSR table (student primarily stress relation), (stress $\text{index}_{(t-1)}$) {student wellness attributes, understudy remaining mission, context} to predict the understudy's past stress record—processes the understudy stress file on a previous occasion. Understudy health feature is the recognized element in predicting the list of understudy stresses to which cloud database data can be collected. Student workload determines the student's current activity and context describes the conditions in which an event is scheduled. In the following point, as shown in Fig. 9.6, we infer three hubs from the root node—kid hubs (leaf hubs) of the hub system that portrays the unmistakable highlights that reveal the stress list. Such highlights include the action set, visual information set, clinical dataset, and social dataset that can be quantified to test an understudy for stress reporting. DBN's mixture structure then consolidates the SPSR factors with second-order leaf hub estimates to assess in unmistakable interim time a stress list of an understudy.

Definition A stressed tree is characterized by an anxiety level diagnosis of an understudy. The root center of stress requires three hubs for young people to be relevant, visual, physiological, and social. However, these three kinds of hubs are built from leaf hubs known as proof hubs to generate anxiety for the purpose of the conclusion. The remaining burden on an understudy at a specific time case depends on movement mulled over.

Corollary 1.1 *In the case of a student S_i and an activity a_i in time instance (t), the workload can then be demarcated as $p(w_t(a_i)/w_{t-1})$. Also, student context (c_t) and trait (t_t) are time-invariant, and their values can be derived from the relationship with SPSR.*

At the diagnostic stage, the root node stress index is established on the values c_t, t_t and w_t that can be described as a probabilistic relationship $p(s_t/s_{t-1}, /w_t, c_t, t_t)$. In addition, the leaf node proof at step t can be shown as ρ_t. The student's final stress reading at the time t is calculated by usage of probability $p(s_t/\rho_{1:k})$.

Corollary 1.2 *The current student stress test is based on the values of the leaf node at the time t. The probability $p(s_t/\rho_{1:k})$ is calculated using preceding leaf node evidence and recurrent value generated at the root node in the second stage. Here $\rho_{1:k}$ is the collection of all available evidence for the leaf node at the time . In other words, if $t = 0$, then $p(s_t/\rho_{1:k})$ is degenerated to its prior form $p(s_0)$. Therefore, the stress index of the student is evaluated using Bayes rule:*

$$p\left(s_t/\rho_{1:t}\right) = \frac{p\left(\rho_t/s_t\right) p\left(s_t/\rho_{1:t-1}\right)}{p\left(\rho_t/\rho_{1:t-1}\right)} \tag{9.2}$$

In addition, our proposed TDBN model has a temporary connection to the workload based on student activity. Therefore, the probabilistic value of the workload w_t based on student behavior needs to be modified with time. Hence value is calculated based on the estimation of the total probability $p(w_t) = \sum p(w_t(a_i)/(w_{t-1})p(w_{t-1})$. In addition to this, the student stress probability at step t is calculated by multiplying the probabilistic effects of $p(w_t)$, probability of stress index at step $(t-1)$ is based on the leaf node evidence at time 1 to $t - 1(p(s_t/\rho_{1:k-1}))$, and the probability of stress s_t based on s_{t-1}, w_t, c_t, and t_t evidence.

9.4.5 Decision-Making

Using predictive stage component values determined at the stress root node based on the previous stress index value, decision-making takes its full form in our proposed methodology. The result of $p(s_t/s_{t-1})$ regulates the system to follow if the value of stress reaches a threshold level ψ. Since the probabilistic value is determined on multiplication of four parameters, the weighting factor of every parameter is defined by the methods below.

1. $p(s_t/s_{t-1})$ = (Current stress index − 0.10)/(Balancing factor − 0.10). Thus, the equilibrium variable 1.
2. $p(t_t) = (T.\ V - 0.3)/(W.\ F - 0.3)$. T.V here refers to the Trait Value, and for each student, three conditions are laid down. If the student is very susceptible to

health problems, then $T.\ V = 1$. If the health problems are moderately sensitive, then $T.\ V = 0.7$, and for healthy students $T.\ V = 0.4$. Besides that, for measuring the overall stress value, a weighing factor W.F is taken as 1.2.

3. $p(w_t) = W.\ V/1.67$. It divides the Workload Value (W.V) in three categorizations: High = 1, Average = 0.7, Nominal = 0.4.
4. $p(c_t) = C.\ T \times 0.626$. Here, Context Type (C.T) is taken 0.8 for time pressure, 0.6 for environmental constraints, 0.4 for general context.

Algorithm 2 Alert generation by temporal linking workload with stress node at the cloud layer

Input: Dataset = {Trait ∪ Workload ∪ Context ∪ Visual ∪ Physiological ∪ Behavioral ∪ Performance}.

1.	**Step 1:** Calculate workload on students based on $p(w_t/w_{t-1})$ value
2.	**Step 2:** Produce stress index value at root node expending prior stress index value and workload (w_t), trait (t_t), and context (c_t) values, denoted as $p(s_t/s_{t-1}, w_t, c_t)$
3.	**Step 3:** Leaf node evidence at different instances is computed using $p(p_t/s_t)$ which depends upon the set of all available leaf node evidence during the time I to t
4.	**Step 4:** At the time t and using probability $p(s_t/\rho_{1:t})$, the final stress index is calculated
5.	**Step 5:** If $p(s_t/\rho_{1:t})$ lies in normal stress range, go to step 7, else go to step 6
6.	**Step 6:** Else if $(p(s_t/s_{t-1}, w_t, t_t, c_t) > \alpha)$
7.	**Step 6.1:** Generate alert signal to family members and responder for student real-time health status in education institution premises and transfer the temporal stress attribute evidence from stage 2 to responder for handling medical emergencies if the situation demands
8.	**Step 7:** Repeat step 1, based on the workload detail, after a definite time interval
9.	**Step 8:** Exit

If the $p(s_t/s_{t-1}/w_t, c_t, t_t)$ lies below 0.6, a new stress index of the student at the time t, i.e., $p(s_t/\rho_{1:t})$, is measured after a fixed interval of time. On the other hand, if $p(s_t/s_{t-1}/w_t, c_t, t_t) > 0.6$, then the warning signals will be sent to family members. Here, we set as the standardized threshold value by consulting medical experts to deal with medical emergencies for each student in the stress healthcare setting. In addition, warnings were also sent to the respondent (doctor) to provide the student with healthcare by taking appropriate action using the TDBN model's temporary sensitive information. If the condition is highly critical, a medical emergency provider will be contacted to deal with the medical emergency.

9.5 Results

The exhibition of the proposed framework is broken down from three perspectives. (a) Assess the BBN classifier's periodic arrangement efficiency at the fog layer. (b) Prescient comparison of TDBN model with other best models in the class. (c) Decide the general framework soundness for enormous datasets.

9.5.1 Characterization Effectiveness

Effectiveness of characterization is determined by the validity of propounded order calculation when sorting health-related stress estimates into different fog layer classifications. In order to decide the grouping productivity of the proposed framework, different factual measures are fused. The capacity to classify is determined as per precision, specification, sensitiveness, as well as f-measurement. A rigorous fourfold cross-approval methodology is used to assess the precision and other success metrics for realistic results and to minimize bias. The information generated by Algorithm 2 is divided into fourfolds right off the bat: threefolds are used as training data and onefold is used for the data processing. Hence in this technique, every fold of data is allowed to be as test data, the whole procedure is conducted multiple times, and standard observable results are obtained for different class benchmark classifiers best. The test is formed on the outcome obtained from the hub of the leaf using standard classifiers for various settings of operation.

9.5.1.1 Baseline Classifier

For combine stress into two classifications, a BBN standard classifier is used. Therefore, three classifiers are used for test purposes, to be precise, J48 from decision tree (DT), Random forest (RF) from ensembling strategy, and Support Vector Machine (SVM) from functions gathering. It is essential to refer to here that lone the order model is changed for examination reason as the remainder of the model is kept indistinguishable for definite stress estimation. Results extracted for various classifier models are portrayed in Fig. 9.7.

9.5.1.2 Classifier Result Analysis

Plots in Fig. 9.7a–d outline the examination results for physiological datasets for factual assessment. Given the results of physiological datasets, we may expect that BBN is undeniably more successful as far as empirical evaluation is concerned than other arrangement schemes. The accuracy has been 95.5% in BBN, while different classifiers, in particular, J48, Random forest, and SVM, have accomplished

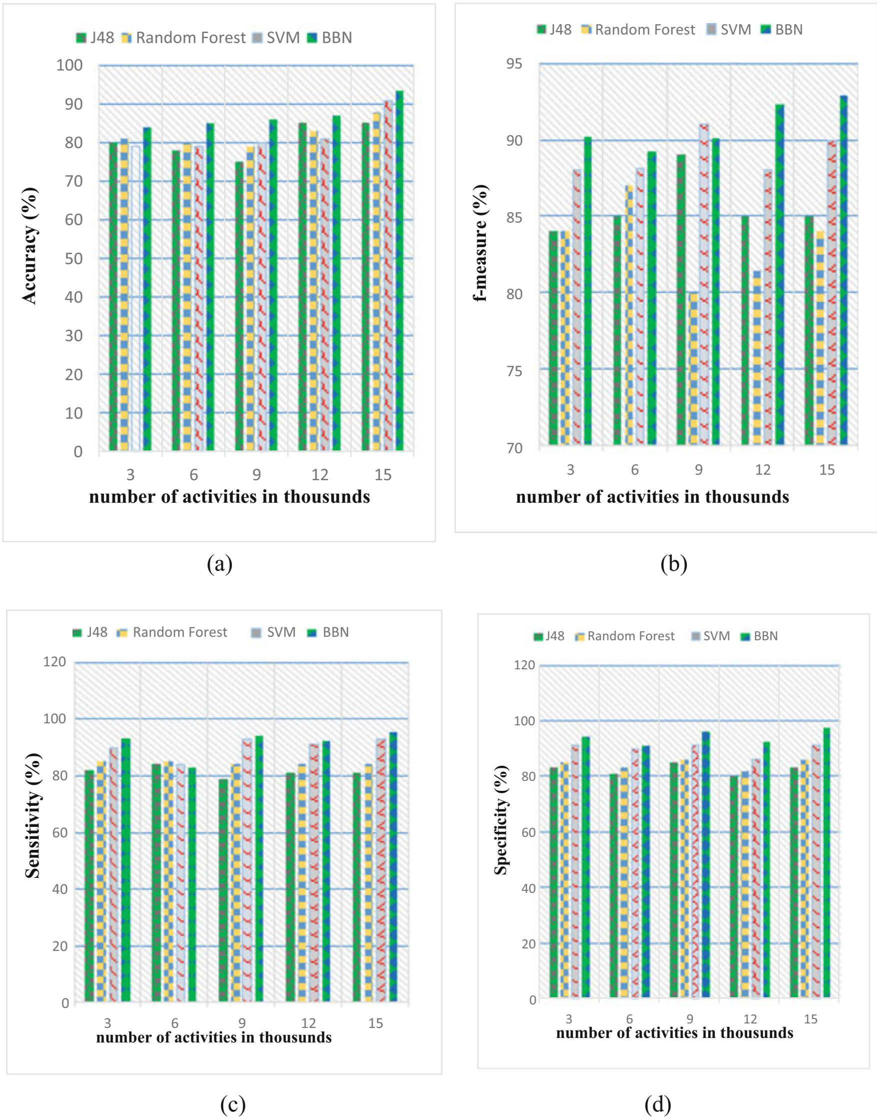


Fig. 9.7 Classification efficiency evaluating results. Physiological dataset: (**a**) Accuracy. (**b**) f-measurement. (**c**) Sensitiveness. (**d**) Specificity

an exactness of 85.2%, 87.9%, and 90.8%, separately. For specificity, we have enlisted 97.3% for BBN, which is higher than those of other best in class classifier models mulled over. Interestingly, if sensitiveness and f-measurement exist, the BBN classifier beats other classifier devices, respectively, with 95.5% and 92.9%.

9.5.2 TDBN Model Prediction Efficiency

Present scientific models may make a proficient contribution by providing perceptions and comprehension of the temporal relationship between relevant ideas. The effectiveness of our proposed framework is predicted to datasets for student stress index for understudy stress list figuring continuously. Since a lot of information is considered for various datasets referenced in Table 9.4, along these lines, it is important to determine the expected model accuracy. An imperative angle is transient mining of diversified datasets before the predictive investigation.

9.5.2.1 Baseline Prediction Models

We contrasted our model with two distinctive best models in the class forecast, in particular, Neural Network [71] and ViSiBiD [71], in order to approve our model. Just the forecast model is modified while during testing, the rest of the system has been kept the equivalent. Different results have been obtained in light of the prescient predictions as indicated in Table 9.5. The TDBN paradigm enlisted a flat-out expectation score of approximately 0.87 with a standard deviation (SD) of 0.08, which is almost superior to other prescient models. TDBN model beats other prescient models for the results of AAE by enlisting an estimate of 0.27 with 0.05 SD. So far as ASE is concerned, in comparison to neural system esteem 1.02 (SD 0.20) and ViSiBiD esteem 0.43 (SD 0.17), the TDBN model shows better performance with esteem 0.25 (SD 0.14).

9.5.3 Overall System Stability

The system protection is evaluated due to the enormous number of datasets necessary in our proposed application. Because an understudy stress file is found using various results of parameters, it becomes necessary to determine the reliability framework for variable estimates of information. The power of the system for Mean Absolute Shift (MAS) is calculated for all intents and purposes. This measure is defined by many registered outcome (A) and the forecast collection of any unregistered outcome (B). There, a little vacillation in MAS is because of distinction

Table 9.5 Exploiting statistical error rates for evaluating TDBN, ViSiBiD, and neural network model

Models	AAE	ASE	Pearson's coefficient
TDBN model	0.27{0.05}	0.25{0.14}	0.87{0.08}
Neural network	0.42{0.08}	1.02{0.20}	0.79{0.12}
ViSiBiD	0.39{0.05}	0.43{0.17}	0.80{0.10}

Table 9.6 Comparison of the proposed method with the state of artworks

Method	Accuracy
Body area network (BAN) [45]	84.25%
Autonomic activation radar [46]	88.33%
Sensing belt system [48]	87.58%
Multilayered stress sensor [50]	90.21%
IoT-aware student-centric stress [70]	92.30%
Deep fog [72]	85.78%
Cloud-centric IoT-based m-healthcare [73]	92.80%
Proposed	95.50%

between prescient stress appreciations and real outcome when the number of datasets increases over time.

If the framework contains high MAS estimates for specific datasets, soundness is low also, the other way around. The MAS calculation (average 0.469) indicates the machine being stabilized regardless of whether dataset quantity is extended and is consequently extremely viable. Also, we evaluated our proposed method with seven states of the artworks, and again, our method led the list in terms of its promised performance (Table 9.6).

9.6 Open Issues and Challenges for Healthcare 4.0

Research problems are numerous, and problems related to the adequate execution of healthcare 4.0 are focused on fog computing. These must be resolved before they can be applied in real time.

9.6.1 Data Management (MD)

The MD acquires tremendous patient information calculation, which experiences enormous big data 5 V's, i.e., value, velocity, volume, veracity, and variety. This is increasingly associated with FN's ability to obtain, store, process, and distribute. As a consequence, information vacillation between fog computing and cloud computing can be seen and should be reviewed by the regulatory system arrangement. In the fog layer (FL), standard conventions and information organizations are necessary to manage the fundamentally disparate information, such as text and image file, from disparate sources, including mobile phones and a smart watch. Smart eHealth portal has to know the right path for the daily movement of information and a desperate demand for information.

9.6.2 Scalability

Information gathering is occurring either from sensors or convenient therapeutic gadgets. The goal of this facility embeds a whole emergency clinic wherein each patient can utilize restorative administrations and can check well-being notices by their cell phones. Healthcare 4.0 spares time for patients to hang tight for consultations, waiting to see the outcome, and offer direct ingress to an unequivocal degree of restorative assets. The healthcare 4.0 could be redisigned for covering whole network or town, which in turn upsurge the improved efficiency, save time, and build a bridge of faith among patients and doctors.

9.6.3 Security and Privacy

The main focal point and end-clients data ought not to be gotten through unapproved organizations. This also poses threats to human health. In the introduction and delivery of healthcare 4.0 throughout real-life clinical applications, security and protection is a significant worry. However, security is required in each layer, for example, Data Layer (DL), Fog Layer (FL), and Cloud Layer (CL) alongside the coordination of such layers.

9.6.4 Standardization, Interoperability, and Guidelines

Till date, healthcare 4.0 lacks the existence of standard principles and guidelines for conventions and interfaces for assorted items and gadgets. To determine this issue, institutionalization endeavors are in demand, for example, a committed association to institutionalize healthcare advancements. It accomplished the constant reaction and settled the uniqueness in the information. Institutionalization ought to consider a wide scope of points, for example, device interfaces, total information interfaces, correspondence convention, and portal interfaces. Like device decent variety issues, there is a wide assortment of conventions for correspondence, for example, Wi-Fi. In this manner, to be interoperable, the Fog Network (FN) ought to perform a fundamental interpretation of convention at various inside layers, for example, message layer, network layers, and data annotation layer of fog layer. Besides, a dynamic logistical system must be framed before healthcare items are accessible in patient's business.

9.6.5 Human-Factors Engineering and Interfaces

E-Health gadget end-clients or partners should be a member of the system community to provide feedback on their solaces and loathes. It makes healthcare 4.0 applications and medical devices for patients easy to understand.

9.7 Conclusion

In this study, numerous difficulties of the healthcare environment 4.0 using creativity throughout fog computing, such as data management, security and privacy, scalability, user interfaces, adaptability, and interoperability, have been discussed. The work in this chapter utilizes the fog computing, cloud computing, internet of things, and machine learning paradigms to propose a computer-aided diagnosis (CAD) method for early and precise students stress monitoring. The given work offers a framework for stress testing that supports five-layer fog cloud-based IoT-based understudy. The fog layer is fused as an oddity viewpoint to characterize the understudy-based stress as a normal or unusual classifier using BBN. The BBN classifier is assisted by the understudy physiological qualities to assess the stress event class. Furthermore, the two-stage TDBN model is used to compellingly assess the stress list. Anomalous spatial computational data, which is a time-improved dataset chain, is broken down in the cloud layer for various stress-related parameter and a two-stage Temporary Dynamic Bayesian Network (TDBN) model is utilized to classify stress as an ordinary or abnormal use of physiological readings obtained from fog layer medicinal sensors. This model measures the stress according to four parameters, in particular, leaf node confirmations, outstanding tasks at hand, context, and understudy well-being quality. In the wake of processing the stress index of the student, choices are taken as a ready mechanism of generation with the liberation of time-sensitiveness data to guardian or respondent.

This engineering can be utilized to plan and convey a patient-driven medicinal information examination framework. Experiments are aimed at both fog and cloud layer, which in our proposed framework bear proof of the utility and precision of the TDBN prescient model. The findings of the correlation dependent on a coefficient indicate that the main factors in assessing the extent of stress are change in heart rate, skin behavior, head movement and twitch of the eyes or average closing speed of the eyes. Although the criteria of conduct indicate a negative relationship with stress a lot of the time, extra leaf hub confirmations can also be combined in future work to determine viable understudy stress file in a particular setting. Also, the TDBN model can be made increasingly convincing by taking into account the intra-dependencies between the confirmations of the leaf hub for each visual, behavioral, and physiological. In conclusion, healthcare 4.0 software-based multi-layer fog tools demonstrate its applicability for potential observation and regulation of eHealth. We would run fog computing in various applications in the future.

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Chapter 10
IoT Cloud Based Rx Healthcare Expert System

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10.1 Introduction

This chapter documents a wide range of proposed and on-market IoT cloud-based healthcare systems. Healthcare is costly for all stakeholders including patients and hospitals. Finding novel methods to decrease healthcare cost in parallel with increasing healthcare quality of service is not an easy task. However, with the advent of new technologies such as IoT, cloud computing, fog computing, and others the process of finding novel methods to decrease healthcare cost is underway. It is a well-known fact that keeping the population healthy is the best way to keeping cost of healthcare down. In addition, early detection of diseases is another method to reduce healthcare cost. The motivation of this work is to integrate the latest technologies for constant monitoring of both healthy and sick individuals at home to reduce hospital visits and hospital patient check-in. This will free hospitals and medical doctors to take care of critical cases only. The contribution in this chapter is to propose a comprehensive IoT cloud and fog based healthcare system that would integrate many of the ideas already existing in previous literature as well as propose the use of neural networks and deep learning in order to predict emergency cases before they occur, conduct early diagnosis, etc. In general, all technologically based systems aim at having a digital medical expert that will monitor patients constantly and monitor their health status as well as taking necessary actions

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including but not limited to calling emergency personnel in case of emergency that occur or predicted to occur. A smart health monitoring, diagnosis, and medication system using IoT, fog, and cloud would alleviate the pressure on hospitals due to crowdedness in hospital care and would reduce the healthcare service delays. In addition, smart health monitoring system either the proposed system in this chapter or those detailed from literature would help reduce medication errors by the doctors, nurses, and pharmacists as all the drugs will be identified and recorded by the medicine dispensing system which is a vital component of a smart health monitoring system. Before smart health monitoring systems can be widely adopted for homecare, the systems must exhibit the ability for continuous health monitoring, timely medication adherence, medication side effect monitoring, emergency health reporting, emergency case prediction and AI based early stage diagnosis and a reporting system for physicians. The comprehensive proposed system in this chapter would be considered the first closed loop IoT healthcare system that allows interaction from both the patient and doctor (two-way communication).

While all systems highlighted in this chapter are a work in progress towards the use of information technology and technology in general for healthcare, the proposed comprehensive system will prove to be unique in all aspects and would allow comprehensive theoretical and practical healthcare of individuals aging from 5 years up to those considered to be elderly. Even though the system can be used for ages less than 5 years old but in that case the system might need more features of parental consent, doctors consent, and other features to cover legal aspects associated with the use of technology to substitute partially or wholly for services usually offered by medical doctors and healthcare providers.

IoT cloud based systems in general not just those dedicated to healthcare will have a huge impact on evolving many sectors to unprecedented levels. The Internet of Things (IoT) has gained its popularity in the global information industry and petroleum exploration industry. The IoT connects all things to an intelligent network for communicating through the devices that senses information according to agreed protocols and for exchanging information. IoT achieves intelligence in locating, managing things, identifying, monitoring, and tracking. It is considered an expansion and extension of Internet-based network, which is the communication expansion from things to things, things to human and human to human. Many objects surrounding people are going to be connected into networks in one way or another in the IoT paradigm. Technologies such as sensor technology, radio frequency identification (RFID), and many other smart technologies will be embedded into numerous application. The evolution of technology including storage, battery capacities, and computing power are now become at relatively low size and low cost. Hence, this helps developing small electronic devices with the capabilities like computing, identification, and communication which can be embedded in other systems, facilities, and devices. In this chapter, we discuss the available systems in previous literature as well as the proposed system with a prototype concept of a complete medical system based on IoT, cloud and fog computing. It consists of several devices and layers that include a portable wearable device with sensors, an automatic medicine dispenser with alarm, cloud-based medical analysis system with accurate short-term and long-term reports for doctors, and an interface for doctor, patient and devices interaction. In addition to lifesaving functions, such as automatic communication with emergency medical personnel in cases when readings indicate a life-threatening situation (using deep learning algorithms) can accurately predict life-threatening symptoms before they actually occur. For example, reading from thousands of patients who suffered a stroke or heart-attack can be accumulated into a database and predict such incidents from reading patients' vitals and predict them before they actually occur, giving more time for medical personnel to arrive to the scene and thus giving more time to perform lifesaving procedures.

Cloud computing is the technology of the available data centers to users over the World Wide Web. The computing capability plus all other related services including but not limited to storage capability in these remote data centers is within the domain of cloud computing. Other services include software, analytics, networking, etc. In this context, the proposed system stores all patients' data to be stored on the cloud in addition to using the cloud computing capabilities to run artificial intelligence algorithms and generating reports. Fog computing is a term created by Cisco Company to refer to the operation of computing, networking, and storage between end devices and cloud computing. Fog computing is also referred to as edge computing. Fog computing is closely related and interrelated with IoT and cloud computing. In this context, the devices such as the wearable device and the medicine dispenser are all end devices connected with the cloud and each of the end devices has processors and storage with communication between them to the operations of computing, networking, and storage which can then be moved to the cloud.

Both cloud computing and fog (edge) computing are vital technologies in the proposed system and similar systems reported in previous literature. It is imperative that the connectivity between devices and between devices and the cloud be always available for the full utilization offered by the proposed system and similar systems. Thus fog computing and cloud computing offer an important piece of the puzzle for systems integrated with IoT that would ease the life of humans in healthcare and all other aspects of living.

10.2 Background

The use of computers and computing to automate, ease, and promote efficient healthcare services has been around since computers and computer programs came to existence. In a paper published in 1980 [1], the authors describe a clinical workstation that supplies patient's medical information to attending nurses. The system is able to collect, process, and display the patient's information including identification, lab results and radiology results, and current medications in addition to supplying the user with the available medical literature databases. In [2], the authors proposed a decision support system for telemedicine using mobile telecommunication platforms. The java-based systems allow practitioners to communicate via the system to consult on patient illnesses and reach to an accurate diagnosis. This would eventually lead to providing better medical care for patients in rural areas.

Current medical information systems are far more advanced, yet in 1980, it was state-of-the-art technology. The concept is utilizing computers in assisting medical personnel in taking vital medical decisions regarding different aspects in the treatment of patients. Even though a lot of research has been done throughout the years with this regard, yet we will mention only a select few in our literature review. In 1994 [3], the authors proposed a system based on machine learning to diagnose a particular medical syndrome called PVM (Prolapse-Mitral-Valve) syndrome. Their system was relatively successful back in that era.

The computing industry since its early beginnings and until today touched on all aspects of the medical field to include Medical Information Systems, Medicine Information Systems, Medical Education, Medical Simulations, etc. As an example, in 2004 [4], the authors proposed the creation of a master table for checking indications and contraindications of medicine from a knowledge base linked with a thesaurus. This was the type of research done at the time though medicine databases have evolved to more technologically advanced levels nowadays. In [2], the authors proposed a decision support system for telemedicine using mobile telecommunication platforms. The java-based systems allows practitioners to communicate via the system to consult on patient illnesses and reach to an accurate diagnosis.

In [5], a study is conducted on certain strategies to reduce medicine preparation errors in neonatal care units. Medicine preparation errors can also possibly happen in a hospital setting. The study indicated that the use of hospital pharmacy services for the preparation of medicine reduces the rate of errors that occur in medicine preparation. In [6], a review paper is presented that discusses the medication errors that might occur including errors in medication administered, failing to adhere to dose time, complying with legal requirements for prescription writing, and various models to monitor medication errors. In [7], the paper discusses the medicine preparation errors in neonatal care units in 10 Spanish neonatal units. The study concluded that calculation errors could be eliminated using protocols based on standard drug concentrations. Thus, the SMART Medication system is an integral part of our proposed comprehensive system because medication is as important as monitoring health condition if not more important especially for elderly patients.

In [8], the design of a terminal solution is proposed for integration of in-home healthcare devices and services towards IoT. The system includes an electronic medication dispenser, which allows electronic interaction with the doctor. However, smart IoT healthcare systems are now moving towards minimal interaction between in-home patients and medical physicians to minimize cost while still providing state-of-the-art quality medical service. Our proposed system provides the required functionalities efficiently, as will be shown in this chapter. In [9], yet another system is proposed to assist elderly patients in identifying their medication and dose using Near Field Communication (NFC) technology. The information is displayed on the elderly patient's smartphone or television prior to medication intake. This system will ensure that elderly patients know what medication they are taking prior to consuming it. In [10], an intuitive IoT-based healthcare system is proposed for elderly patients, which seems to be a theoretical proposal of combining wearable devices, information systems, and interactive interface.

Medicine has had its share of research to utilize the current technologies. In [11], the authors propose a cloud-based system utilizing mobile medical services of Traditional Chinese Medicine (TCM). They developed a medical information system that allows proper scheduling of TCM treatments for patients, verify patient's identity, and remind healthcare providers of the time when treatment should end. Their system also allows communication among healthcare providers within the hospital. In [12], an IoT cloud based wearable ECG monitoring system is proposed in which data collected is uploaded on the cloud and gives the functionality of properly displaying data as well. In [13], the authors propose the use of Inertial Measurement Units (IMU) sensors for IoT-based wearable health monitoring systems. An algorithm is also proposed for such measuring units and the system was found to outperform other systems and does not bind the system to be in any particular position to the patient in order to obtain an accurate measurement. In [14], an IoT-based health monitor is proposed for autistic patients in which brain signals are constantly measured and reported to the caregiver of the autistic patient. In [15], a smart IoT based system is proposed for intensive care unit (ICU) monitoring. The IoT-based system proved more efficient in monitoring patients during their stay in ICU unit. In [16], the authors proposed an IoT cloud based monitoring system for hospitalized patients. Another system named I-CARES is proposed for health diagnosis and medication through wearable IoT-based devise equipped with algorithms to analyze data and assist doctors and physicians in decision-making for early treatment of predicted diseases or sickness [17].

The analysis of medical data is an emerging field and in [18], the authors use data analysis to estimate the success rate of in vitro fertilization (IVF) treatment utilizing a ranking algorithm in particular the RIMARC algorithm. The claim is that their proposed algorithm can be used to accurately estimate the success rate of the IVF treatment. In [19], the authors present a comprehensive review on the utilization of IoT in healthcare systems. Most interesting is the use of big data collected on the cloud for accurate raw data to predict chronic disease in its early stages. In [20], the study presents the opportunities and challenges of health monitoring and management systems using the IoT sensing with cloud processing. The abundance of data measured and uploaded on the cloud makes for a very lucrative data mining and processing algorithms. The concept of using artificial intelligence in the medical field for diagnosis and prediction is abundant in literature, which is already a proven concept theoretically. Researchers have used AI to diagnose and classify diseases such as brain tumors, different types of cancers, Alzheimer, and many other diseases. It is with the use of big data (Large datasets) that can be used to design supervised and unsupervised architectures that could automatically detect and diagnose various diseases [21–25]. It was with the use of data analytics on big data that will someday revolutionize the automation of many processes within the medical field in such a way that will benefit patients and reduce the probability of human error. The AI algorithms can be performed on either the end devices using fog computing or via cloud computing.

This type of research indicates that utilizing IoT cloud based environment is the right path that healthcare is moving towards and indicates that this field of research will evolve healthcare to the next level.

In [26], the authors propose an architecture for secure health application converging big data, IoT, and the cloud. Based on Machine-to-Machine (M2M) communications, the authors propose a converged healthcare architecture designed on Exalead CloudView. In [27], a system is proposed in which patient's data is uploaded on the cloud from different hospitals. Patients own their data on the cloud and give access to only authorized persons to view their data. The system ensures complete privacy and security of the patient's health records. In [28], the authors presented a review paper of all existing systems and algorithms for data privacy and security of patient's data in IoT-based cloud environment. The paper concluded that there is still more research to be done in order to ensure the data privacy and security on the cloud and that the existing systems and algorithms are not adequate to guarantee the security and privacy of data. In [29], another security model is proposed based on attribute-based encryption (ABE) and anonymous attribute based encryption (AABE). Their proposed model achieves compact security in the prime order groups and has many advantages over previous methods, though it has its own disadvantages as well. In [30], the paper reviews and discusses different security attacks towards health systems and proposes different solutions to bridge the security gap. They identified the security vulnerabilities in E-health information systems on the cloud and in IoT. In [31], the authors explore a solution to ensure the security of Electronic Health Records (EHRs) in the cloud environment during transmission of data to the cloud. In addition, they explore the use of biometric images that allow for unified patient identification across cloud-based EHRs and across medical institutions. Extensive research has been done by the research community of the security of EHRs as well as communication security within the healthcare sector, this includes but not limited to the use of biometrics, block chain, blind signatures, and others [31–35]. In addition to security, one of the main challenges of IoT-based health systems is the collection, processing, and analysis of millions of measurements from wireless body area network (WBAN) sensors. In [36], a hybrid periodic-random massive access (HPRMA) scheme for wireless clinical networks is proposed employing ultra-narrow band (UNB). This scheme is able to dynamically adjust the resource allocation for co-existing periodic and random services, in addition, to aligning to requests of differentiated services. In [37], a healthcare smart gateway is proposed to prioritize personal health device (PHD) connections based on their state and requirements. The use of artificial intelligence in healthcare diagnosis is widely researched. In [38], the authors propose a patient monitoring system based on fog computing for ambient assisted living which they dubbed FAAL. Their system uses body area networks to collect data using sensors and then passes the data using the fog gateways. They present the advantages their proposed system has over systems that do not utilize the use of fog computing.

10.3 Proposed System

As can be seen in literature review, the concepts of automated healthcare is well documented and the aspiration of researchers and the industry is clear to produce systems that can automate healthcare and reduce cost for both patients and healthcare providers. In this section, we propose a comprehensive IoT cloud based healthcare system capable of monitoring, diagnosis, automatic medication dispensing, interaction between patients and system, interaction of system with doctors, and interaction of system with emergency personnel. As part of this comprehensive system, we propose the concept of using barcode-based medicine identification so medicine dispensing system can automatically verify the drug for the patient. The complete system also is composed of a health monitor with attached sensors that take different measurements of vitals and other measurements from patients. All data include demographic information, medical history, family history, lab tests, and measurements from devices such as temperature, and blood pressure. All this information will be uploaded to a cloud-based health information system. The health information system is able to compile and view the data from all patients in order to build the smart AI system both using supervised and unsupervised learning. However, each patient data will be secure and only accessible by the patient or the authorized healthcare personnel. The system uses AI for learning from the available database that contains big data. The amount of information compiled from one patient alone is vast and includes the information mentioned previously in addition to MRI scans, X-rays, round the clock measurements from attached sensors. When this information is gathered from a large number of patients, it will definitely fall in the range of the so-called big data. The AI system embedded within the system will be able to use this big data in order to make short-term or long-term predictions and decisions. To better understand what is meant by short term and long term in this system, we provide the following examples: Short-term analysis, when the reading of the patient's vitals are abnormally at dangerous levels, the system will make the decision to call for medical help by informing medical personnel and calling for an ambulance providing the exact GPS location. Long-term analysis example, after the system has big data readings from hundreds, thousands, or even millions of patients who suffered some serious health ailments such as heart stroke, the system will be able to analyze the vitals with different time parameters such as several minutes, half an hour, and several hours before the stroke, and will be able to build a pattern based on AI machine learning to predict heart strokes before they actually happen. This will give enough time for emergency personnel to arrive at the patient's location and provide medical care to either prevent the heart stroke or be prepared to provide medical care to relieve the effects of the stroke and minimize the consequences. Other examples of long time prediction would be for example predicting that a patient would suffer from high blood pressure or diabetes in the near future which would require medical intervention to prevent that from happening. The proposed system also provides a secure interface for electronic health record integration.

Even though this system is designed specifically for home use and with patients that require constant medical monitoring at home, the assumption is that patients will be at home all the time and the communication link between monitor and medicine dispenser is constant. However if the patient leaves home for a short period to visit a doctor, the health monitor equipped with a memory to hold recent data recorded on the home system which will upload copy to the cloud until the patient returns home. The data will be automatically transferred to the medicine dispenser as soon as communication link is established again between patient and system. In addition, if an emergency occurs while the patient is still out, the wearable device will be equipped with internet data and will alert the patient and call for medical help providing GPS location. If Internet service is not available, redundancy is provided by allowing the wearable device to send an SMS message providing coordinates of the location.

Though the initial motivation for designing this system was to relieve constant care for the elderly by medical institutions due to cost and over-crowdedness, yet the final designed system is suitable for patients and healthy adults of all ages and can even be used for young patient as young as 5 years old. However, it can be used by even younger patients but an interface for parents needs to be developed and will be developed in future work. The interface would need to account for legal accountability as well. It is frequent nowadays in which people even in their twenties suffer a sudden stroke that could result in death, yet with this system, lives could be saved by communicating with medical personnel and getting immediate help for the person. Overall, the system would save lives and cost of health by:

1. Encouraging people to lead a healthy life style by giving immediate indications of health status.
2. Detecting health conditions in its early stages where the cost of medical intervention is much lower than late stages of any health condition.
3. By ensuring that people take their full dose of medicine, this will lead to keeping them healthy and reduce cost of healthcare.
4. Constant electronic medical supervision by medical doctors is ensured so that end users stay healthy and reduce the possibility of deteriorating health resulting in costly hospitalization.

Overall as can be seen above, the ultimate goal is to ensure a healthy population which ultimately means a cost benefit to the healthcare industry and national budgets.

Though the above prototype consists of all wired sensors, yet the system is able to integrate wireless sensors as well. The prototype also consists of the most up-to-date sensors which are light enough to allow portability yet too big to allow the design of a brace that consists of embedded sensors and invisible to the people who can see the system user. However, with the advancements in the sensor technology, it is assumed that such a system as proposed in this paper will contain some day only embedded sensors, wireless mini-sensors, or even nano-sensors all sending measurements wirelessly to the wearable unit. When that day comes, the system will not cause any inconvenience to the patients as all embedded nano-sensors will not be visible neither to the patient themselves nor to anyone who sees the system users. The intent of this chapter and prototype is proof of concept and the authors did not do an extensive search on mini- or nano-sensors available commercially nowadays, yet it is presumed that the technology in that field still stands for a lot of improvement. However, the authors acknowledge that the end product would need to integrate sensors and configuration that is comfortable for the end user and allow privacy to the user by having concealed sensors.

The complete system would be a SMART system capable of making judgement and decision set around a certain number of rules and parameters within the medical field. For example, if the SMART dispenser dispenses a fever medicine according to a scheduled dose. This medicine is supposed to take effect within 1–2 h from dose. However, if a measure after 2 h still indicates a high temperature then based on the medical parameters and if medically permitted, the medicine system will dispense an out-of-schedule fever reducer and ensure that the patient takes another dose.

Big data and big data analysis is an established field now and widely used in many systems. The proposed system integrates Bigdata and big data analysis over the cloud. Big data is uploaded on the cloud, the cloud is then equipped with a novel big data analysis algorithms that integrate artificial intelligence able to analyze the measurements, dosage, effects, and side effects of medicine based on patient's short-term and long-term readings.

The cloud contains a dedicated electronic health record system embedded with smart big data analysis algorithms. These algorithms aggregate the data and produce reports for the doctor. The algorithms are also based on machine learning that will be able to segregate attributes of the human body measurements prior to emergency calls and attributes that indicate initial stages of chronic diseases, cancer, or any other health issues. The information is kept secure during transmission to the cloud healthcare system. It is also kept secure while on the cloud and during transmission to the doctor. The success of the prediction for a case depends upon the population size of the measurements and the availability of the assigned annotations to the past cases.

As a whole, the proposed comprehensive system is capable of providing continuous monitoring of a person's health status and ensures timely medicinal dosage scheduling based on real-time patient vitals measurements. Previous literature and their proposed methods to cater to healthcare issues have been analyzed to derive a comprehensive theoretical framework that addresses all shortcomings of systems proposed in previous literature. The system is equipped with the latest technologies including an AI system able to analyze short-term and long-term data to predict and provide early stage diagnostics in addition to diagnosis details to doctors with recommended medicine dosage, frequency, and type.

Figure 10.1 indicated the general process of the proposed system. From the time the patient start the use of the system, the medical information is sent to the cloud to create the patient record and data will then be populated from several different venues including the healthcare providers, the system with integrated sensors, the SMART medicine dispenser, and any other location that contains medical health information on the patient. The AI integrated system starts the analysis of incoming

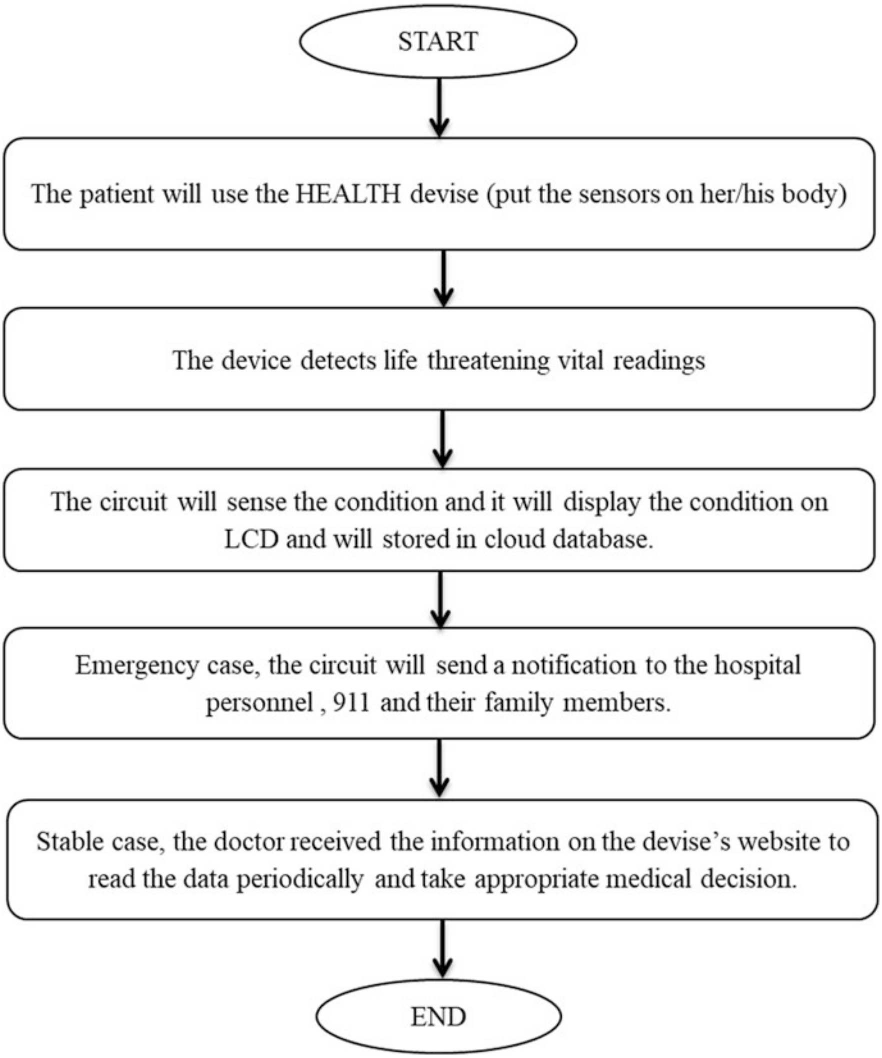

Fig. 10.1 Process model of the proposed system

reading for short-term and long-term predictions. If stable, the patient's charts and reports are periodically sent to the doctor for follow-up and dosage changes if required. If emergency case, the system will call medical personnel to the address of the patient for early immediate intervention of the medical case or early intervention if the health condition is predicted to happen shortly.

Figure 10.2 shows the interface of the proposed system with patient using current technology with the wearable sensors either wired or wireless. This picture is most likely to change in the near future with advance in technology to have nano-wireless

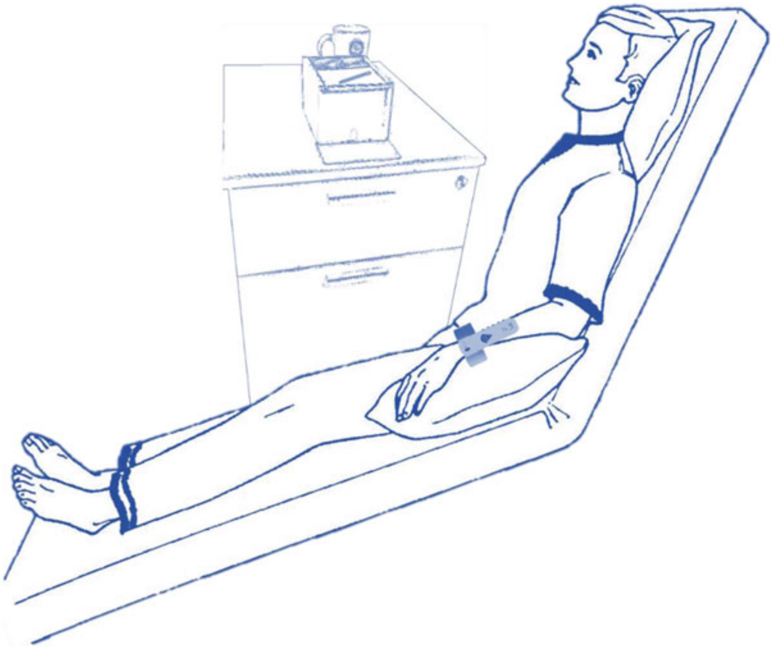

Fig. 10.2 Overall view of the system using current technology

sensors concealed and the patient does not necessarily need to be at home all the time to be connected to the complete system.

10.4 Challenges and Impact of IoT Fog and Cloud Based Healthcare System

The proposed system once a reality and widely adopted will change lives and change the way hospitals and insurance companies operate. It will even have an impact on national budgets as well. However, there are certain challenges before we see such a system in mainstream use. The challenges listed below are some of the obstacles from the point of view of the authors, though we realize that the list might not be comprehensive and that other challenges exist that might not appear in the list. The list of challenges:

1. Development of sensors that may be embedded on wearable devices or embedded within chips that can even be inserted into patients bodies.
2. Medical data in medical health records are really big. With thousands and possibly millions of patient records on the cloud, managing this amount of big data will become a challenge and a possible expensive process.

3. Data security will always remain a challenge due to patient confidentiality laws. Data security in fog computing and cloud computing with information transmitted by IoT devices is still a hot area of research with no optimal solution yet achieved.
4. Identifying symptoms for urgent medical problems such as predicting heart attacks, strokes, etc. has not been done yet and will be a challenge in order to train the artificial intelligence algorithms running on the cloud with possible computing done in edge (fog) computing.
5. Constant communication is a challenge especially in less developed countries. Connection availability is a must when dealing with fog and cloud computing.
6. User acceptance might be a challenge as patients would prefer to have constant hospital care with doctors and nurses (less trust in technology).
7. Keeping cost of such systems affordable to patients or covered by insurance companies.
8. End systems containing the fog portion of computing must be light and less expensive to acquire by patients yet at the same time have high storage and computing capabilities.

However, with all these challenges and if these challenges are overcome, there is a huge positive impact if such a system as the one proposed in this chapter or even some the system detailed from literature review see their way to real-life implementation and wide adoption. The impact as depicted by the authors includes:

1. Constant 24-h healthcare monitoring at portion of a cost of hospitalization and hospital care.
2. SMART devices such as smart pill dispensers to ensure timely medicinal dosages. Taking medicines properly ensures patient's healthy life style.
3. Early prediction of chronic diseases or emergency case which can be a lifesaving function.
4. Already IoT technology includes smart pills (with IoT devices) that can be swallowed to monitor medication in body and take action and decision to warn patients in case of irregularities. Others include moodles for keeping a constant elevated mood for patients and other wearable IoT enabled devices. IoT has and will make an impact on the healthcare profession and industry.
5. Automatic diagnosis, which will relieve pressure on manual diagnosis done by doctors and would also relieve patients from human errors that sometimes occur when diagnosed by medical doctors.
6. COST—Reduce cost of healthcare for all stakeholders.

Due to the uniqueness of the proposed system, a comparison with similar systems cannot be done. As was presented in the literature review, devices that were previously presented were not integrated ones. For example, some worked on medicinal dispensers while others worked on wearable sensor devices and complete systems were rarely proposed, if any. Therefore a comparison could not be done. In addition, healthcare devices proposed including the one proposed in this chapter require special permissions to be tested on humans and thus real-life results could not be presented here as well. We urge the scientific community especially in the healthcare sector to adopt the ideas presented here and obtain approval for human trials.

The connection availability with the cloud might sometimes be hard to maintain constantly; however, the added feature of fog computing with end devices containing their own storage and computing devices that communicate and connect over the WIFI connection ensures that individuals devices stay in contact with each other for any emergency cases that may arise while connection with the cloud is down.

10.5 Conclusion

In this chapter, we have highlighted the most up-to-date IoT or fog and cloud Based SMART system proposed and covered in previous literature. We have also identified shortcoming of existing proposed systems in research, which resulted in proposing a comprehensive IoT and cloud-fog-based healthcare system (CHIPs) that is proven to cover all the shortcoming of existing systems or those listed in literature review. In addition, we presented the proof of concept based on an integrated prototype. Though we have no means for clinical testing of the proposed system, yet, in theory the system which uses technologies that are existing should work the way it is proposed to. Obtaining measurements from wearable sensors, smart pill dispensers, interface, communication, data security, and other functions are already existing in scattered technologies and proven to work as specified. Even fog and cloud based systems and the cloud as such with big data are already in use whether in medical field or other fields. However, cloud-based management systems with big medical data and AI algorithms for short-term and long-term prediction which would have been a privilege to test clinically and using clinical data is not possible and not accessible to the authors. However, the authors have developed artificial neural network algorithms for diagnosis and early diagnosis of certain medical condition in their previous work.

In the near future, we will see either systems as proposed in this chapter or a more advanced version with advanced sensors, mini-medicinal dispensers, constant connection, secure connection, etc. in use and widespread adoption. These advanced versions will be constant health monitors on the go, where patients and individual are not confined to home use only. They can have the system fully working while driving, riding the bus, walking, travelling, and going on with their daily life while being constantly monitored.

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Part III
Fog-assisted Security and Privacy for Healthcare 4.0

Chapter 11
A Secure Fog Computing Architecture for Continuous Health Monitoring

Sanjivani Deokar, Monika Mangla, and Rakhi Akhare

11.1 Introduction

During the past few decades, society has witnessed an unprecedented increase in the magnitude of the Internet. Gone are the days when Internet consisted of only computing devices like computers and mobiles. Nowadays, almost everything like tablets, various wearable devices (fitness bands, sensors, etc.) are connected to the Internet commonly referred to as IoT. According to authors in [1], the IoT is estimated to connect 50 billion such devices by 2020. Authors in [2] explain IoT as interconnection of intelligent and self-configuring nodes interconnected in a global network infrastructure. Basically, IoT comprises of sensors for data acquisition, data storage, and data processing to generate data insight, security, etc. Here, it is important to mention that each connected device in IoT continuously generates data which is forwarded to the servers for processing purposes. Owing to its capability, IoT has observed its significant application in various fields like healthcare, transportation, weather forecasting, smart homes, etc. [3–5]. Among these fields, which have witnessed widespread deployment of IoT, it won't be incorrect if we say that healthcare has been completely revolutionized. The prime factor that advocates widespread employment of IoT in healthcare is its ability to perform accurate and precise monitoring of patients. Moreover, automated monitoring completely eliminates human error from the system, thus yielding optimized performance.

In addition to several favorable factors of IoT, it also bears some limitations. As discussed above, IoT networks consist of monitoring nodes to monitor the patient health. These IoT devices, which monitor the health of patient, have limited storage

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and processing capability. Resultantly these monitored parameters are forwarded to cloud for future storage and processing, known as cloud computing. Thus cloud computing is accepted as a mature technology to address constraints of IoT. Although cloud computing addresses the limitation of IoT devices by introducing cloud for abundant storage and processing, it also poses another challenge of huge data transmission from end devices to cloud.

As discussed above, sensing nodes continuously monitor the patient health and forward the data to cloud. It results into another challenge of requirement of enormous bandwidth to send the data generated from nodes. Requirement of high bandwidth transmission link adds up the cost of system. Another limitation of IoT network is also due to limited storage and computational capability of edge devices. Here, edge devices refer to the sensors and actuators. Owing to limited processing power of connected devices, it raises concern for performance, privacy, and reliability of the network. Another major and most concerning limitation of cloud computing is its latency (response time). In cloud computing, whenever an edge device requests some data, the request is forwarded to the cloud which incurs additional time. Thus, cloud computing suffers from high latency. Due to increased response time, cloud computing loses its candidature for time-sensitive applications.

These limitations of cloud computing are conquered in fog computing. Fog computing addresses these limitations by introducing a virtual layer between edge devices and cloud, known as fog layer. This fog layer consists of multiple fog nodes having substantial capability in terms of storage and processing. Fog layer works on the principle that data should be stored and processed near its generation site. Thus latency of fog computing is substantially reduced which advocates its widespread application in time-sensitive, real-time applications. One such scenario is healthcare which does not have any tolerance for time delay as time delay may turn to be fatal. Authors in this chapter discuss the deployment of fog computing in automated healthcare. Authors present the existing state-of-the-art in this domain. Thereafter, authors in this chapter present a secured architecture for fog computing that primarily addresses the issue of security and data privacy as the health data is considered to be the most personal and confidential data. The subsequent section focuses on cloud computing.

The chapter has been organized as follows: Sect. 11.1 introduces the evolution in technology mainly IoT. Sect. 11.2 is dedicated to background in the domain. It mainly convers cloud computing and fog computing. It focuses on features, challenges, and applications of cloud computing and fog computing. Employment of fog computing in healthcare is presented in Sect. 11.3. Section 11.3 also presents the existing architecture of automated healthcare system that employs fog computing. The proposed architecture is presented in Sect. 11.4. Conclusion and future work is presented in concluding Sect. 11.5.

11.2 Background

Automation in healthcare has witnessed an unmatched evolution. This automation started with invention of sensing devices which could be attached to human body. As the sensing devices are limited, the data is forwarded to cloud for processing, i.e., cloud computing. With time, cloud computing realized some challenges and restrictions, thus limiting its boundaries for employment in health monitoring. These boundaries are widened by evolution in fog computing that addresses the limitations of cloud computing as mentioned earlier. Here, in this section, authors present evolution in the technologies ranging from cloud computing to fog computing mentioning their features and challenges.

11.2.1 Cloud Computing

Cloud computing refers to the scenario where all applications and services are shifted to the Internet [6]. Also, cloud computing addresses the constraints of IoT by providing an unlimited storage capacity and processing power enabling it to implement real-world scenarios. Additionally, distributed computing, virtualization technologies, and parallel computing are some prominent features of cloud computing that makes it a principal choice in future computing [6]. Currently, cloud computing is in its evolving phase. Observing the exuberance in the field of IoT and associated technologies like cloud computing, mobile technologies, etc., it has been termed as the fourth Industrial revolution 4.0 (4IR) [7].

In cloud computing, data, processing capability, storage space, operating system, etc. are considered as service and are shared among users. The general architecture of cloud computing is represented in following Fig. 11.1.

Basically, cloud computing operates on pay-per-user-on-demand mode, thus enabling it to be shared effectively among resources across the Internet. Thus cloud computing significantly enhances the availability of IT resources despite low cost incurred in physical resources. There are several interesting characteristics of cloud computing.

11.2.1.1 Characteristics of Cloud Computing

This subsection presents some prominent characteristics as follows:

Shared Infrastructures Cloud computing provides shared storage, processing capabilities, and physical services among numerous users across the Internet. This shared infrastructure ensures the maximum utilization of available resources using a software model.

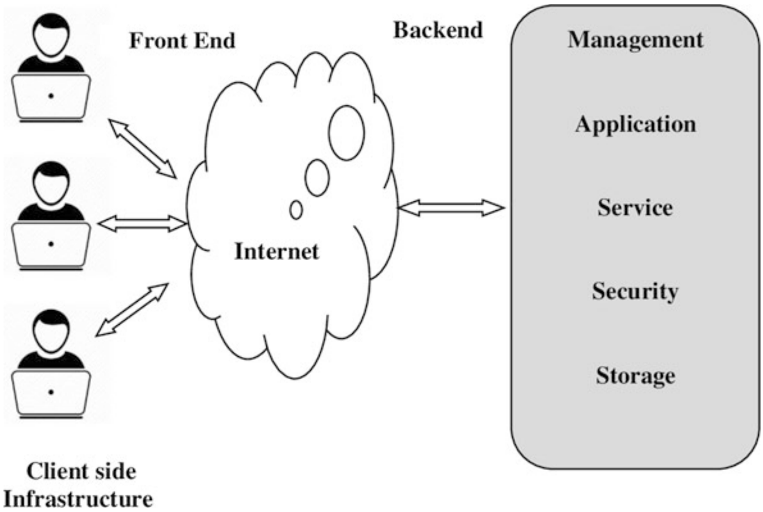

Fig. 11.1 Abstract Model of Cloud computing

Heterogeneous Network Access Accessed from a wide range of devices like laptops, desktops, and mobiles. Deployment of any service in cloud requires everything ranging from business application to latest application on hi-tech devices.

Dynamic Provisioning It allows for services based on dynamic demand of the node in order to optimize the utilization of resources. This is achieved using competent automated software which dynamically expands and contracts the service capability in response to the demand. This dynamic demand provisioning is managed with the help of metering for generating billing information as customers are charged for respective service usage in cloud computing. Thus, cloud computing provides sharing of resources/services without physical deployment at every location while charging the consumers for actual usage. Hence, cloud computing has been accepted as a cost-effective computing technique.

Thus, owing to the above mentioned characteristics and features of cloud computing, it garners several benefits over comparative techniques. The most significant benefit of cloud computing is cost effectiveness due to resource sharing and dynamic metering [6]. Other favorable advantages of cloud computing are scalability, low maintenance, and reliability due to multiple redundant resources.

11.2.1.2 Challenges of Cloud Computing

Although, cloud computing has several supportive characteristics and features, it still has some associated challenges. Here, it is worth mentioning that these challenges may cause slowdown of the system but these challenges can be invalidated with efficient and careful planning.

The first and foremost challenge with cloud computing is privacy and security of data which cannot be compromised at any cost. In order to address the challenge of data privacy, data may be stored within the organization and can be permitted to be used by the cloud. Furthermore, to address the concern of security, efficient encryption methods may be employed. Researchers [8] are trying to devise efficient encryption methods that transfers encrypted bits. Inclusion of encryption and decryption during transfer needs higher bandwidth, causing higher costs. Research is also progressing in the direction of implementing hardware-based security as it is an efficient choice in terms of processing and bandwidth.

Additionally, it necessitates an effective security mechanism between cloud and organization for enhanced security of the data. Requirement of effective security mechanism and centralized computing requires dedicated resources [9], which incurs additional cost. Additionally, centralized processing and storage provide several advantages but it also results into few deterrents. One such deterrent is consumption of huge amount of energy to keep it operational. Another adverse impact of centralized storage is system susceptibility to failure of single point. Moreover, centralized storage and computing causes transfer of sensitive data across a wide geographic distance, thus generating a means of escape for intruders. Furthermore, centralized storage also suffers from transmission bottleneck. According to a computer scientist at the University of California, Berkeley, it takes 45 days to transfer 10 TB data from the Bay Area to Amazon in Seattle using average bandwidth internet link [8]. Consequently, cloud computing has limited application for latency-sensitive applications like robotics, health monitoring, flight control, etc. as all these applications require computation and transfer of very large amount of data [8].

Cloud computing also has challenge of sharing of reputation. Reputation sharing means any illegal activity by a single consumer may adversely affect the other innocent consumers using the same cloud [8]. In case of any malicious activity by any user, all users on the same cloud may get banned. For example, in March 2009, FBI investigated a data center at Dalla as one company was suspected to be involved in some criminal activities. During this investigation, all customers had to suffer prolonged downtime, thus negatively affecting their business.

Another challenge of cloud computing is lack of interfacing standards, which sometimes results into issue of interoperability among clouds. Although various forums are trying to develop open cloud computing interface to address this challenge, this development is still progressing. Another challenge of cloud computing is a requirement of continuous evolution as user requirement keeps on changing. Cloud computing has limited application as it lacks uniform interface to handle different RDBMS simultaneously [8]. Thus, cloud computing is not considered as an efficient choice for data manipulation scenarios. Cloud computing performs poorly during peak load. Moreover, expected behavior cannot be determined as it involves numerous users with fluctuating load of the process [8].

Authors in [9] discuss the changing infrastructure of the cloud in response to the user requirement. Authors in [9] also support for distributed computing far from data centers, thus requiring novel computing architectures catered in future cloud infrastructures. These novel architectures can incorporate some hybrid approaches.

For instance, cloud computing is expected to be employed along with IoT (known as Cloud-IoT) to cater the needs of current and future world. Cloud-IoT is supposed to integrate the strengths of both technologies as Cloud computing and IoT has observed expeditious evolution during the past few decades. This Cloud-IoT compensates for the technical constraints by providing huge capacity and large number of resources. Hence, it provides an effective solution to realize management and use of things (also known as nodes in the network) in the real world.

After comprehending features, limitations, and challenges of cloud computing, it may be understood as a shared infrastructure consisting of shared storage, networks, applications, and servers [10]. Additionally, it allows for data processing to be performed at third-party server, thus giving an economical and scalable solution. There exist several prominent and well-known cloud systems for different applications like Dropbox, Maropost, Amazon Web Services, citizen services, ClearDATA are prevalent cloud systems to provide storage, Marketing, Education, Government, Healthcare services.

11.2.2 Fog Computing

In cloud computing, data is moved to the centralized servers for processing. This data transfer for data processing, data analysis, and data storage used to be a conventional practice during development of Cloud-IoT. Despite its power, cloud computing suffers few limitations in terms of data privacy as data is stored in the shared storage. Data privacy is a prime concern for any organization as it may lead to reputational loss which directly impacts the business. Also, cloud computing suffers data transfer and network latency when connected IoT devices go beyond a certain threshold. Consequently, proliferation of IoT devices necessitated some efficient technology in order to handle the massive amounts of data. This urge for technological development was answered by fog computing [11].

Fog computing overcomes the limitations of cloud computing [12] by placing the physical or virtual resources between conventional data centers and smart devices. Thus it provides a scalable, distributed, and latency-sensitive solution for storage and computation. Hence, fog computing provides significant advantage in terms of reduced latency, reduced data transmission, and minimal network congestion. All these advantages are obtained as a result of bringing data processing closer to its source in comparison to cloud computing [13].

Fog computing has established its competence in the current scenario as a result of its performance in comparison to cloud computing. Here, in fog computing, IoT devices are connected with cloud by processing the IoT data closer to IoT devices [14]. Resultantly, fog computing is competent to address latency and privacy issues in comparison to cloud computing [15]. Additionally, service availability is raised as connected devices do not require connecting to a centralized server to obtain a service.

Fog computing can be summarized to provide following advantages over cloud computing [16]:

1. Fog computing stores the data closer to end user. As a result, fog computing has low latency, thus making it a perfect choice for latency-sensitive applications, e.g., healthcare and robotic motion control.
2. Fog computing drastically minimizes the data transmission for storage, processing, and analysis. According to an estimate by Cisco, 25 billion devices have been connected and this can go up to 50 billion devices by 2020. Considering this huge number of connected devices, it is not advisable to send raw data to the cloud. Hence, fog computing becomes a perfect choice in such scenario as it performs filtering and analysis of data locally, i.e., closer to site of generation.
3. It enjoys enhanced data security over cloud computing.
4. As fog computing processes the data closer to its source, it reduces the processing on cloud. Consequently, fog computing enjoys higher scalability in comparison to cloud computing.

Considering the features of fog computing, it can be understood as decentralized cloud. Here, a large amount of data processing is performed at local user site. Only summarized information is transmitted to cloud, thus reducing the bandwidth requirement by 80%. As a result, fog computing has been accepted as a feasible solution to latency-sensitive high quality applications [16].

Although fog computing has overcome several limitations of cloud computing model, it still suffers some challenges and is therefore under developing phase. Several researchers have proposed various models for fog computing like HealthFog [16–18], which works for healthcare systems. In the literature, it has been noticed that fog computing has observed its widespread employment in HMS as it involves several sensors monitoring vital parameters of the human body. In HMS, sensors collect huge amount of data which is further processed. Thus, cloud computing observes limited application in healthcare further boosting application of fog computing in this domain [19]. Fog computing also handles the privacy requirement of health data. Apart from healthcare, fog computing has also been deployed in the various other domains related to security and reliability.

11.2.2.1 Architecture of Fog Computing

In the literature, fog computing has been occasionally compared with edge computing. However, both differ from each other based on the location of intelligence and computational power. In fog computing and edge computing, intelligence and computational power is placed at fog nodes and edge devices, respectively [20–22]. The abstract architecture of the fog computing can be represented in the following Fig. 11.2.

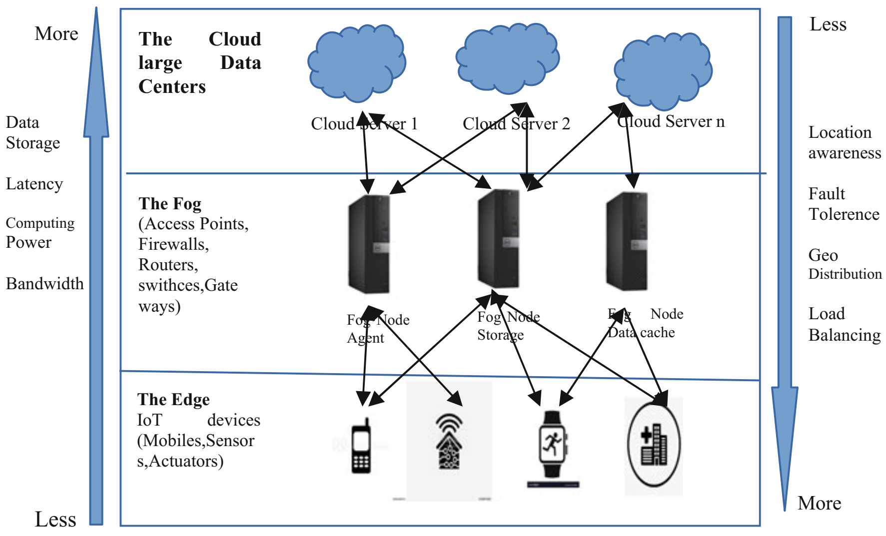

Fig. 11.2 Abstract Model of Fog Architecture

The abstract fog architecture can be understood as a three-layer architecture as shown in Fig. 11.2. Figure 11.2 represents the association among all three layers, viz. The Cloud, The Fog, and the Edge. Here, cloud layer handles all activities related to cloud computing while fog layer comprises of network of interconnected fog nodes. Each fog node acts as centralized storage that handles data collection, communications, data upload, data storage, computation, and management. Additionally, fog nodes have more memory and storage ability to process data from edge devices. These fog nodes may be geographically distributed. Distributed nodes in fog layer outperform cloud computing in terms of latency and computation. Lastly, the edge layer consists of various physical devices like different types of sensors and local data. Each physical device has its own ubiquitous identification, sensing, and communication capacity and is connected to some fog node.

This architecture is advantageous as it eliminates the direct and expensive communication of edge devices with cloud. This transfer takes place through fog layer. Hence, fog layer forms a bridge between cloud and edge layers. The vital characteristics of fog are [15]:

I. Reduced response time (latency)
II. Improved scalability
III. Widespread geographical distribution
IV. Ability to handle heterogeneous devices and data sources
V. Perfect choice for real-time systems

The abstract architecture (Fig. 11.2) of the fog computing can be illustrated in detailed manner as shown in following Fig. 11.3:

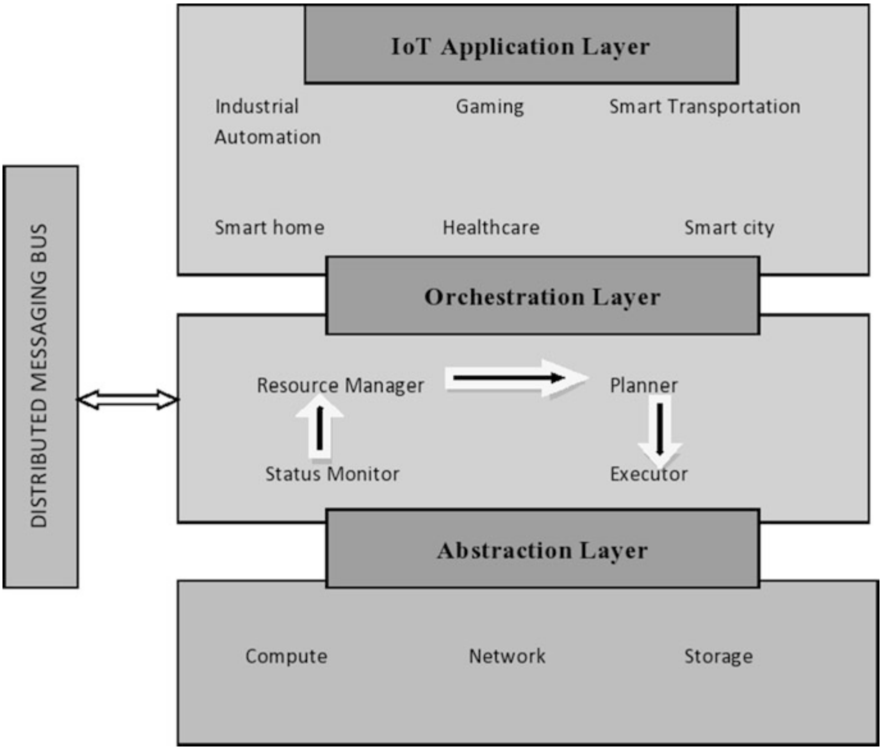

Fig. 11.3 Illustration of Layer-wise functionality of Fog Architecture

The above Fig. 11.3 represents the 3-layer fog architecture [23] as follows:

I. IoT services
II. Orchestration layer and distributed message bus
III. Abstraction layer

As already discussed, fog architecture can be employed in various applications like healthcare, home automation, agriculture, etc. The IoT service can be considered as a channel through which users can access various functionality [24].

Orchestration layer focuses on the allocation and interoperability. Communication takes place through the messaging bus. Hence, it provides dynamic management of fog services through its life cycle. The life cycle basically consists of four parts, viz., probing, analyzing, planning, and execution.

Abstraction layer is dedicated to provide uniformity in heterogeneous infrastructure over diverse application programming interfaces and user interfaces. As a result of 3-layer architecture of fog computing, it provides the following benefits:

1. Reduced data transfer results in consumption of less amount of bandwidth.

2. Reduced data transmission also results in reduction of network traffic, thereby reducing the transmission cost eventually leading to improved quality of service (QoS).
3. Presence of computing at fog level removes a major bottleneck and a perspective site of failure. It also results in higher reliability and fault tolerance.

On the other side, fog architecture also has some associated challenges. Major challenges of fog architecture have been discussed in the following subsection.

11.2.2.2 Challenges of Fog Computing

Although fog computing architecture provides several benefits, it also faces several challenges which hinders its widespread successful deployment. It is evident from the architecture of fog computing that it has distributed and hierarchical structure for storage and data processing resulting into security vulnerability. Therefore, fog architecture primarily suffers few trust and security issues. Following are the major challenges associated with fog computing [25, 26]:

Scalability Billions of IoT devices generate a huge amount of data and therefore require huge amount of resources such as storage and computational capability. Hence, fog architecture should be able to handle this enormous number of resources and capability to respond to them in stipulated time.

Heterogeneity Fog architecture involves devices like sensors, computing powers and storage from different manufacturers. Management of such heterogeneous IoT devices is a major challenge faced by fog computing.

Dynamicity The fog computing architecture needs to handle dynamicity in the environment in terms of evolution, properties, and performance of IoT devices. It may also result due to aging of hardware and software. Hence, fog computing architecture needs to handle dynamic behavior in terms of topological structure reconfiguration and resource allocation [27].

Complexity The heterogeneity in IoT devices from different manufacturers results into enhanced complexity. As a result, it requires particular protocol and hardware which escalates the operational difficulty [27].

Security Although distributed nature of fog computing architecture goes in favor of latency and network traffic, it also results into privacy vulnerability. Resultantly, fog computing has increased security vulnerability than cloud computing. Hence, several researchers have been focusing their research on cryptography and authentication in fog computing [27, 28].

Every fog node works in collaboration with other nodes through message passing. In case of failure to integrate into the network, trust problems arise. Whenever a fog node joins or leaves a network, other nodes need to change their topology. Requirement to change topology further adds up into security issues. In case, if the network contains an infected node, it may infect other nodes as well that results into security crisis in the network. Fog nodes communicate through a network having communication overhead. This communication overhead is discouraging for latency-sensitive applications. Considering the architecture, advantages and disadvantages, and challenges of fog computing, it has observed its application in various significant domains. Basically, fog computing has been accepted as an optimal solution for scenario consisting of Internet-connected devices. Some prominent areas which have realized significant improvement by application of fog computing are as follows:

Smart Cities Fog computing is a perfect choice for development of automated systems like self-driven cars, smart traffic lights, home automation, etc. Fog computing can also be employed for nodes which controls end devices to perform differently [29–32].

IoT and Cyber-physical Systems Fog computing can mainly be used in systems that embed medical devices, connected vehicles, and others. By integrating all these devices with IoT, intelligent medical devices, smart building and automatic robotic system may be developed [29, 33, 34].

Augmented Reality AR has touched new heights as a result of faster, smaller, and ubiquitous devices. AR applications are highly sensitive towards latency as any delay in response time completely damages the user experience [35]. As a result, fog computing has been accepted as a significant technology for implementation of AR.

Healthcare and Activity Tracking Fog computing has also been widely applied in healthcare systems owing to its real-time response property. It can also be employed in critical healthcare as continuous HMS involves numerous sensors, remote storage, and data retrieval at remote site [36, 37].

Authors in this chapter focus on implementation of fog computing in the field of healthcare.

11.3 Fog Computing and Healthcare

The domain of healthcare has been significantly influenced by the evolution and advancement in technology. In addition to several technologies, fog computing has also prominently dominated healthcare. Here, sensors are physically attached to the patient, where sensors continuously monitor and assess health status [38]. Widespread application of fog computing in healthcare system is boosted due to its fast response time as cloud model fails to handle IoT challenges as network bandwidth, latency, etc. Fog computing overcomes the limitations of cloud computing by performing data processing near source. Additionally, it keeps sensitive data within network only which leads to enhanced security.

Here, authors present the advancement in various areas in response to technological innovations in various industries. During the past few decades, there has been tremendous advancement in industry standards. Industry 1.0 mainly witnessed the advancements in mechanical engineering and automation. This was followed by advancement in electrical energy coined as Industry 2.0 [39]. Thereafter, Industry 3.0 mainly focused on telecommunication and information communication technology (ICT). This industry 3.0 also had a short life span due to transcendent advancement in Internet of Things (IoT) and cloud computing (CC). Industry 4.0 mainly focuses on deployment of intelligent devices and their usage [39]. The authors in this chapter mainly focus on transformation in healthcare as a result of advancement in fog computing, i.e. Industry 4.0.

Now it becomes evident that maintaining health data in electronic form started with the inception of Industry 3.0. During Industry 3.0, Electronic Health Record (EHR) was adopted to take decision-making using artificial intelligence. This transformation resulted in well-informed decisions improving the quality of service. Following Industry 3.0, Industry 4.0 is also establishing itself as a promising tool in healthcare. Industry 4.0 mainly utilizes IoT in the healthcare.

According to Industry 4.0, it may not be feasible for each hospital to physically store its patient data. This difficulty is resolved by cloud computing easily which involves shared cloud storage among multiple sites. Evolution in cloud computing propelled its inclusion in daily life in terms of wearable sensors [40]. Inclusion of wearable devices led to requirement for prototype development for cloud. Although cloud computing provided several advantages, it failed to address some vital requirements. Some major hindrances for widespread employment of cloud computing are its huge data transfer and higher latency. Particularly in healthcare, even a minor delay may be life-threatening. Helplessness to tolerate any kind of delay in healthcare led to diminished approval of cloud computing.

In order to address the hindrance of cloud computing, fog computing emerged [41]. In fog computing, the monitored parameters are processed at fog nodes. Processing of data at fog nodes enhances performance in terms of latency and data privacy. Thus, it can be understood as fog computing migrates some tasks of cloud computing data centers to fog nodes. Thus it ensures in-time service delivery by overcoming the limitations of cloud computing, viz. increased network traffic, bottleneck, and delays. All these features of fog computing has encouraged application of fog computing in healthcare.

Resultantly, fog computing has grabbed the attention of researchers as it provides enhanced healthcare service by overcoming the challenges and limitations of healthcare system. Fog computing provides improved service owing to its node configuration. Fog computing architecture basically includes networking devices, protocols, and servers. It is also worth mentioning that HMS has plethora of sensing devices. These sensing devices have limited battery-life and computational capability. This challenge is addressed by the authors in [42] by providing Message Queue Telemetry Transport (MQTT). MQTT is a communication protocol for IoT that provides a less complex layer between cloud and IoT nodes. Hence, fog nodes can provide the required service in real time.

Fog computing provides following services to escalate its widespread application in healthcare.

Sophisticated Assisted Living: Fog based healthcare system is used for monitoring disabled and aging individuals so as to lead a healthier life. For instance, development of smart gloves, smartwatches, and smart wheelchair for disabled people has undergone revolutionary advancement. The US government has observed an increase in the population of aging individuals by application of automated HMS. Also, fog computing based healthcare systems restrain wrong drug prescription as a result of knowledge-based system [43].

mHealth: Moreover, it has led to mobile health (mHealth) which allows patients to access their health-related information through mobile device. Thus it allows patients and medical professionals to have 24 $\times$ 7 access to the database and hence result in the most skillful treatment.

Fog computing also works in the direction of medical implants to restore the normal human functions such as pacemakers and brain simulation system. Moreover, it has also led to the development of various applications. Some of these applications focus on collecting data pertaining to single individual like body temperature, BP monitoring, etc. On the contrary, there are some applications working for a cluster of individual which collect data from individuals using these applications. The collected data is subsequently analyzed to take corrective measures if required.

Although the fog computing architecture has been successfully employed in healthcare system, it has some associated challenges. These challenges need to be addressed for its matured application. Some of these challenges are:

Huge Data Management In HMS, fog computing needs to handle millions of sensing devices generating a plethora of data. Additionally, it involves disparate data in form of text, image, etc. generated from different sources like smartphone, smart watch, etc. Moreover, it also witnesses fluctuation in the data transfer. Hence, a major challenge in the widespread implementation of automated healthcare using fog computing is the ability to handle this massive data. Also, this architecture should be highly scalable so as to enable its implementation at community or city level. Scalable system performs efficiently even if it experiences a profusion of devices. The successful automated HMS should also involve end users to get feedback about user experience in order to create a user-friendly interface. Involvement of the whole community or city is also observed as a challenge.

Another challenge for deployment of automated HMS is inclusion of a variety of products and devices. As a result, it does not have any standard protocols and interfaces creating interoperability issue which requires some centralized organizations to standardize all involved technologies. Apart from devices, it also involves diverse transfer protocol which also needs to be addressed for interoperability. Consequently, it requires an advanced and sophisticated standardization for obtaining interoperability among diverse devices and protocols.

The most significant challenge for automated HMS is security and privacy of health data. Security of health data is also a mandatory requirement from legal perspective and thus a key concern. Any security gap may risk human life. Considering the irreversible impact of security gap, it poses a significant challenge. Various researchers have proposed various architectures to address these challenges. In this chapter, we present the existing hierarchical fog computing architecture (HiCH) for automated HMS [44].

11.3.1 Existing Hierarchical Computing Architecture HiCH

As mentioned above, gateway devices perform local data processing and transfer the data to cloud. Here, various analytics functions are performed at fog layer. The existing HiCH aims to provide the advantages of fog and cloud computing for remote health monitoring. It mainly has two major contributions:

1. HiCH bifurcates the analysis of health data. It analyzes the centralized data in the cloud while fog nodes analyze distributed data. Thus, it involves a hierarchical analysis system where data analysis is spread across multiple tiers. It enables data partitioning between fog and cloud and thus significantly improves availability and response time. HiCH may fail to achieve the desired performance if cloud connectivity is poor. For the same, authors [44] have proposed augmentation of high degree of intelligence at edge devices.
2. HiCH proposes a closed system to manage patient's conditions which involves patients' environment, physical activities, and medical parameters.

The authors in [44] primarily focus on traffic management from fog to cloud. The abstract and generic architecture of HiCH can be represented by Fig. 11.4. This model involves MAPE-K model (Monitor, Analyze, Plan, Execute-Knowledge), fog computing and cloud computing paradigms.

The MAPE-K in abstract model of HiCH is elaborated in the following Fig. 11.5.

Monitoring is the first step in the HiCH architecture. It also bridges the sensors with other units. Thereafter, the data is aggregated and pre-processed in order to eliminate noise. Preprocessing of data also helps in normalization of

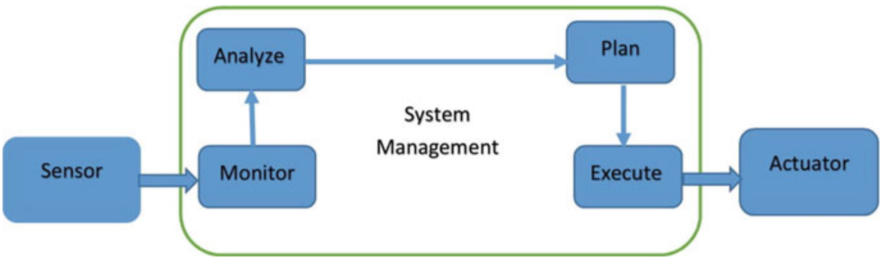

Fig. 11.4 Abstract architecture of HiCH Model

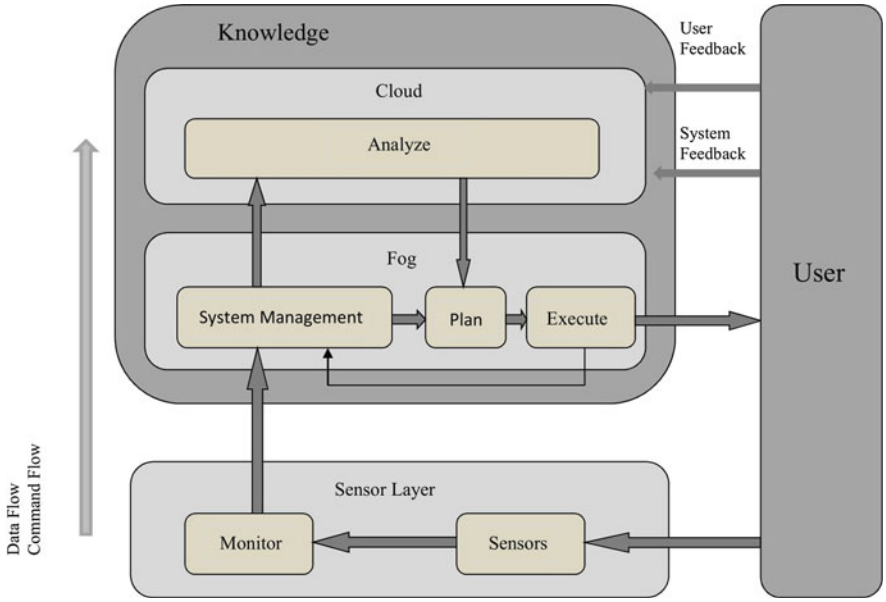

Fig. 11.5 Detailed Illustration of HiCH Model

data. Thereafter, the data is divided into packets which are transmitted to system management.

Analyze step is located in the cloud layer and it performs complex monitoring. It receives the data containing patients' vital parameters from the system management. In analyze, data analytics can be performed using various machine learning algorithms in existence. The derived hypothesis is forwarded to the plan phase.

Plan phase is present in fog layer which is committed to make some decision. The decision is derived based on the hypothesis from analyze phase and data from system management.

Execute is also present in the fog layer and is responsible for guiding system behavior. Execute performs actuation by updating other three parts (Monitor, Analyze, Plan) of the architecture. It informs system management to incorporate changing health conditions of the patient. It also gives a feedback for analyze.

Thereafter, system management is also contained in the fog layer that manages the system configuration. It considers decision from execute phase and determines the current system state. Similarly, there are several architectures for fog computing model in existence proposed by different researchers [45]. However, every architecture has several benefits and associated challenges. As mentioned above, the foremost challenge for automated HMS is privacy and security of health data. It would not be possible to cover all architectures in detail here. Hence, authors present a brief description of various architectures for IoT and Cloud in healthcare domain in form of following Table 11.1.

Table 11.1 Contributions by various researchers on cloud computing and IoT in healthcare

Reference	Contribution
Baker et al. (2017) [46]	• Described basic elements in an IoT healthcare system like sensors • Discussed various types of communication methods • Introduced a framework for healthcare applications
Kraemer et al. (2017) [47]	• Detailed survey of fog computing for healthcare • Analyzed network level that fog computing tasks can be used in
Islam et al. (2017) [48]	• Reviewed applications in IoT in healthcare systems • Reviewed security issue of IoT in healthcare frameworks • Discussed challenges and future directions for IoT in healthcare
Kumari et al. (2018) [39]	• Addressed various opportunities and challenges of fog computing in healthcare • Presented a three-layer healthcare architecture for real-time applications
García et al. (2018) [49]	• Proposed a fog computing-based framework to accelerate the response to mobile patients • Applied proposed framework on a prototype
Farahani et al. (2018) [50]	• Introduced a systematic IoT in e-health ecosystem • Presented challenges and future directions for IoT in e-health • Listed security issues in IoT devices and networks
Ahmadi et al. (2018) [51]	• Described some aspects of IoT architecture in healthcare • Investigated cloud-based architecture role for IoT in healthcare • Discussed critical IoT in healthcare issues and challenges
Mutlag et al. (2019) [52]	• Indicated three fundamental factors to effectively manage resources in cloud-based healthcare systems • Showed limitations of recent methods, systems, and frameworks

After investing the pros and cons of different architectures by various researchers, the authors present an architecture which aims to provide an efficient and reliable system.

11.4 Proposed Architecture

In this chapter, the authors present an architecture that aims to provide a reliable solution to handle the challenge of security and privacy for EHR [53]. In order to present the architecture, we firstly present the various kinds of attack [54]. The major security attacks are as follows [55]:

Sniffing and Spoofing The first and foremost security threat is unauthorized access to the private health data. In sniffing, attacker may simply monitor the communication between two nodes [56]. This eavesdropping of data is not even known to the sender and receiver but attacker gets access to confidential data, thus breaching confidentiality of data. In spoofing, attacker sends fake data in the network by using false identity and obtaining full access to the network [57]. Moreover, attacker may also acquire multiple identities known as Sybil attack. Thus, these attacks attempt to tamper the node and brings the whole network at risk.

Denial of Service (DoS) Attack Attacker floods the devices by replaying packets resulting in collapse of the whole network. In Dos Attack, attacker injects various kinds of packets in the network, e.g., acknowledgement packets, infected code packet, and hello packets. Attack may also result in the packet routing through an unreliable path [58]. Attack may also result in the dropping and/or blocking of selected packets.

As authors have mentioned in Table 11.1, there has been significant work in the field of healthcare using IoT and fog computing. However, the existing architecture lacks aspect of security and privacy of data. In this chapter, authors aim to present an architecture that considers these aspects of data. As discussed previously, that health data needs to be handled privately and securely. But, there can be some common security attacks which may be observed by any system. Any reliable and secure architecture aims to address these threats. An efficient architecture also aims to provide basic principles of network security, viz. Confidentiality, Integrity and Availability (CIA). Also, the authors in this chapter propose an architecture that aims to provide CIA principles of security. The proposed architecture has been illustrated in Fig. 11.6. The proposed architecture maintains privacy of health data by employing authentication of the edge devices ahead of making any request in the network. As these edge devices have limited capability, two different types of authentication mechanism are proposed. Additionally, the proposed architecture provides two-step security. First step maintains the authenticity of the edge device. Second step of the proposed architecture aims to ensure integrity of the message.

In first step, authors propose different authentication mechanisms for different devices based on their computational power. For instance, the edge devices are classified as low power devices (devices having low computational capability, e.g., temperature sensor) and smart devices (devices having low computational capability, e.g., smart watch, mobile). As illustrated in Fig. 11.6, low power devices are authenticated using their device ID registered with the network during network setup. It may be done using some handshaking protocol. On the contrary, smart devices are authenticated using public-private key pair mechanism [59, 60]. The proposed architecture advocates a different authentication mechanism for low power devices as these are incompetent to generate authentication keys.

The authentication of edge devices is followed by secured communication in the network. The authors in the chapter propose implementing Advance Encryption Standard (AES) encryption algorithm as it is a highly sophisticated encryption algorithm [61].

The proposed algorithm largely prevents various security attacks in the network while considering the computational capability of the edge devices. Authentication mechanism between edge devices and gateway ensures that only authorized users

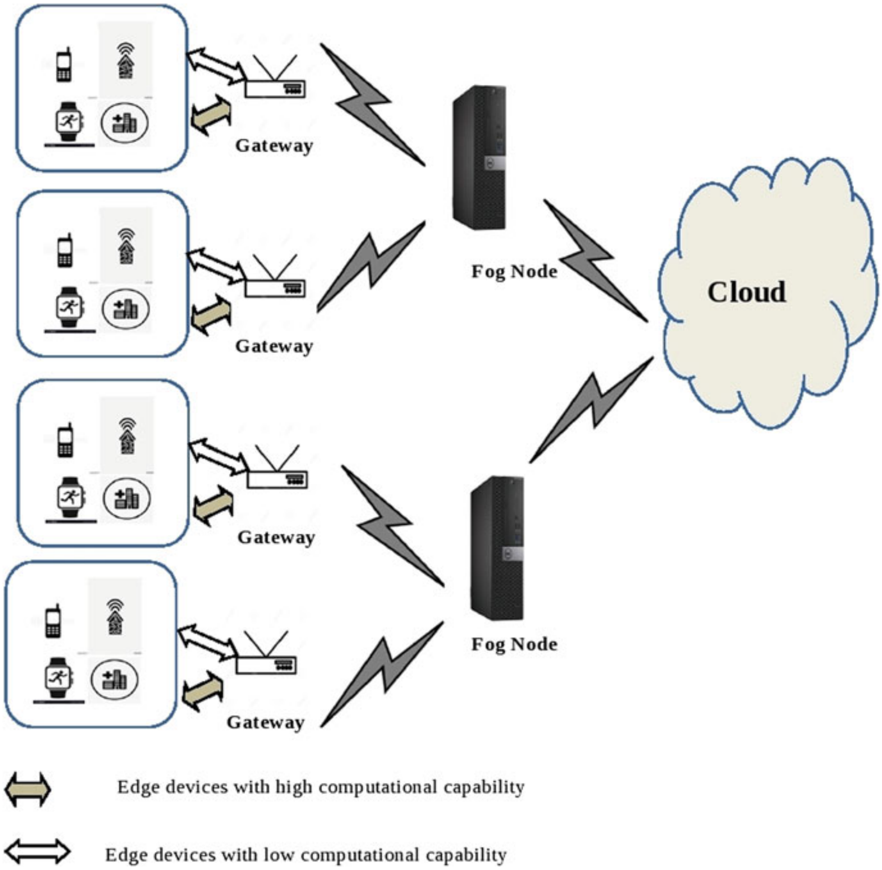

Fig. 11.6 Block Diagram of Proposed Architecture

and devices get access to the network. This authorized access prevents sniffing and spoofing attack. Moreover, it also prevents DoS attack as only the authenticated edge device is able to forward message. Thus, proposed architecture goes beyond the work presented by various researchers as mentioned in Table 11.1. It proposes an architecture which is not vulnerable in terms of security.

However, the proposed architecture does not consider about the load at fog node. In some scenario, fog nodes may be highly imbalanced in terms of computational load [62]. Load unbalancing at fog layer may result into deviation in response time for devices connected to different fog node. This deviation in response time dissuades the user experience. Hence, it is advisable to balance the fog nodes. The proposed architecture can be extended in the direction of load balancing at fog layer.

11.5 Conclusion and Future Work

The chapter focuses on the application of technological development in the field of automated healthcare. The chapter discussed the IoT and its applications in various fields. Several real-life applications of technological development are also discussed. Thereafter, it discusses cloud computing and its benefits. The major advantages of cloud computing are shared storage and processing capability. However, this shared access has a downside that it has higher latency which is not tolerable in many applications. One such real-time application that has zero tolerance in terms of response time is healthcare as a minor delay may result into loss of life. As a result, it requires some technology having real-time response time which is presented by fog computing. The fog computing outperforms cloud computing in terms of latency time and reliability. Hence, it stands enhanced chances of its application in real-time applications like healthcare. Here, the authors propose an architecture that maintains CIA requirement despite limited capability of edge devices.

The proposed architecture is safe from DoS attack as every edge device is authenticated prior to data transfer. For authentication of edge devices, authors propose different mechanism based on computational capability of edge devices. The main contribution of this chapter is this capability-based authentication mechanism. The proposed architecture also ensures secured data communication as it employs end to end encryption. As already mentioned, the proposed architecture focuses on authentication and privacy of data. It prevents the network from security vulnerability.

However, there can be some instances when some fog node is overburdened and thus results into bottleneck. Bottleneck in the network deters its performance. This can be avoided by having some mechanism that guarantees that no fog node is overloaded in the network. Hence, the proposed work can further be extended in terms of load balancing for fog nodes so that QoS is further improved.

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Chapter 12
Security and Privacy Issues in Fog Computing for Healthcare 4.0

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12.1 Introduction

Fog computing bridges the gap between sensors and analytics in healthcare. As it is a distributed system, application-specific logic does not only reside in the cloud or devices but also onto different components of network. For example, gateways, routers access points, and the devices which are placed over the human body. The healthcare 4.0 is more towards using the standard technologies of IT field like cloud computing, machine learning, big data, Fog computing. Such a system maintains medical connectivity globally and gets access to it whenever required. Fog computing is the interworking of different objects. Network connectivity allows this object to communicate and exchange related information which includes sensors, smartphones, smart meters, radio frequency identification, and other such IoT devices that are useful in health applications. This interconnectivity expands the automation of human's daily life. Its decentralized infrastructure utilizes various IoT devices which collaboratively perform different tasks like communication, computation, storage, control, and management. This arises the new challenges in security and privacy issues. The privacy of patient's data is at most a high priority. Also, the transfer of such information, the privacy of data, and accessing information are major issues. Trust issues of Fog nodes arise as Fog computing network is deployed by various nodes of that network which will not be completely trusted as devices are susceptible to different attacks. The Fog devices have constraint storage, computing, and resources and are easy to be hacked. Therefore, different tools and

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protocols are used to secure the communication channel of the device as well as data. Legal and privacy-related issues, lack of transparency, cybersecurity issues are also the most important challenges need to be solved [1].

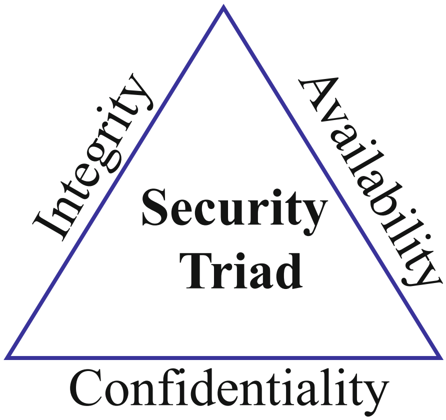
Fog computing incorporates three main components: IoT node, Fog node, and back-end cloud. It is vital to make the transmission secure between all these nodes. Existing privacy and security solution of cloud computing could be applied to some extent but still it has it's specific security challenges due to its features like decentralized infrastructure, mobility support, location awareness, and low latency. Therefore, new methods for securing Fog computing systems have been developed. In this chapter different security issues have been discussed for Fog computing in healthcare 4.0. Security challenges and their solutions have been proposed for each layer of Fog computing. This paper starts with an explanation of basic security issues—confidentiality, integrity, and availability. In addition, basic security architecture also has been discussed. Then different privacy and security threats are discussed based on the e-healthcare system. A pacemaker scenario of the implanted device is taken which illustrates the need for security and privacy in Fog-based IoT device. Different security issues from the perspective of the client, software, hardware, and physician have been discussed. Also, various attacks that can be performed on Fog devices or Fog networking have been discussed. The basic security architecture and network model define the traditional security scheme which states that it cannot be directly utilized for Fog computing. In this chapter Fog security challenges are classified into three sections: the first section introduces the network and service level security challenges, the second section covers the data center level challenges, and the last section covers the device level challenges.

12.2 Security Issues

12.2.1 CIA Triad (Confidentiality, Integrity, and Availability)

1. Confidentiality
   Confidentiality is about protecting private and sensitive information from unauthorized access. In healthcare Fog application securing data is the most important part. Also, data being sent over the Fog networks should not be accessed by unauthorized individuals. With the help of online available tools the attacker may try to capture these data and can gain access. The common ways to avoid this are to include access control, data and file encryption and system permissions (Fig. 12.1).
2. Integrity
   It is designed to protect data from modification or deletion from any unauthorized party. Patient's health-related information is most crucial for any health organization as the diagnosis is made out of such data. While transformation attacker can modify or delete or replay the information which causes a serious impact

Fig. 12.1 CIA triad



on patient's health and health organization too. The primary way to manage this issue is to make use of the hashing technique. There are various algorithms which implement hash function through which we can identify at receiver side that data has been modified or not.

3. Availability
   It is the last component of CIA triad which focuses on the vacancy of system or data when it is needed. Also, the network should be available whenever it is required. The motive behind this is to bring down services to compromise availability. DoS (Denial of Service) attack is an example of this component. The extra security equipment such as Firewall or proxy server can be used to safeguard the system.

12.2.2 Threats

Cloud Security Alliance has identified basic security issues. These issues directly impact onto different layers of Fog-enabled applications [2]. Depends on application security issues may vary. Some of the fundamental problems associated with Fog application in healthcare 4.0 are defined here.

1. Forgery
   Forgery is making fake identities or profiles to mislead end-users. This leads to fake information. Due to this in healthcare, it may lead to an unnecessary diagnosis or wrong prediction.
2. Tampering
   Tampering means modifying (destroying, manipulating, or editing) data by unauthorized users. An attacker may cause harm to the system or it may destroy data. An attacker can intercept the packet and can modify it. As patient's records

are most crucial in healthcare application, dropping or modifying the data may cause serious problems.

3. Sybil
   It is a peer-to-peer network threat in which a Fog node in the network operates multiple identities at the same time [3]. It gains the majority hold of Fog networks to carry out illegal actions. A single node can create and operate as multiple fake identities that affect the genuine user of the system.
4. Jamming
   Jamming jams the communication networks by spreading the bulk of dummy data on the network [4]. It may cause delay or destroying packets of system.
5. Eavesdropping
   Eavesdropping is a technique by which an unauthorized party captures the transmitting packets. It reads the pattern of transmission. This activity does not disrupt normal operation. Sender and receiver are completely unaware that data of the system is intercepted or stolen.
6. DoS (Denial of Service)
   This attack disrupts all the services of users by flooding unwanted requests to a victim node which blocks the route and does not allow to process legitimate requests.
7. Impersonation
   In this attacker pretends the fraud services as Fog services to the end-users. Attacker patiently examines all the fragments of information passing through an insecure medium or residing in the system. A combination of information gives the impersonator to fulfill their purpose. The more information they have, the better they can keep away from detection.

12.2.3 Privacy Issues

Privacy is an extreme problem in Fog computing for the healthcare system as the user's data is involved while collecting, storing, transmitting, and sharing through the medium. Privacy includes four facets, such as identity privacy, data privacy, usage privacy, and location privacy [5].

1. Identity privacy
   In this patient's personal information like name, address, telephone number, health record, disease, a public-key certificate may get a leak on a communication channel [6]. Here privacy of the user is not satisfied. While authentication when user's identities are submitted to Fog nodes it can be easily disclosed.
2. Data privacy
   It is an exposure of user data to unauthorized parties. It may be exposed while information are preserved on Fog nodes or transmitting among two parties. By examining these data attackers can get various information and these data may be used for illegal activities [6].

3. Location privacy
   There are so many massive applications available that collect user's location information. It captures the user's location records to reveal or have a look at the user's moments. It refers to the privacy of the user at the edge of the node. In the healthcare scenario patients or client uses many Fog services through which an attacker can easily know the route of information. Fog client chooses the nearest Fog server which is vulnerable to attacks. It can be preserved through various approaches like identity obstruction [7] as Fog node cannot directly identify the nearest Fog client. Different methods are there to apply this obstruction approach where a third party fake ID generator is used at each end-user. Instead of selecting the nearest location of Fog node it is selected primarily based on a few criteria like reputation, load balance, latency, etc. Due to this Fog node does not get an exact idea about the location of Fog client. But its location can be still traced by intersecting multiple nodes.
4. Usage privacy
   The user utilizes different services of Fog-enabled systems offered by Fog nodes. By compromising this issues attacker might also get utilization patterns of users with which a user makes use of services. For example, by analyzing services of e-health smart meter, users living patterns get disclosed like at what time they are at home, sleeping time, working hours, etc., which results in exposure of user's privacy.

12.2.4 Attacks

An attack is a procedure that involves an attempt to obtain, destroy, alter, remove, implant, or reveal information without having authorized rights. There are so many kinds of attacks emerging day by day. But mainly they are under either class of passive attacks or active attacks.

1. Wormhole attack
   Wormhole nodes make a fake path that is shorter than the original one within the network. This can confuse network routing mechanism and take the shortest fake path. This attack can be easily performed without knowing about the network topology.
2. Selective Forwarding
   Only the selective data packets are transmitted by an attacker and the rest of the packets are dropped [8]. It may lead to degradation of system performance.
3. Route Cache Poisoning
   It involves alteration of routing tables by malicious node. Packets are transmitted through the illegitimate path which leads to a alter or delete or removal of information.

4. Sybil
   It a kind of attack where nodes have a couple of identities over the network. These create confusion and disruption. This creates the chance for a malicious node to operate services of system [9].
5. Sinkhole
   In this malicious node pretends that this is an optimal route to reach the destination node [9]. This node sends fake messages to the initiator node, accordingly after receiving traffic, it alters the routing path. It complicates the topological structure of a network.
6. Hello Flood
   The attacker broadcast a link to all other nodes. An unaware node accepts that link and considers that this received node link is a neighbor node. Now, this unaware node transfers all packets that are actually received by the malicious node. This creates a routing loop within a network [9].
7. Byzantine
   In this, the attacker's aim is to decline network services. The attacker selectively drops packets which create routing loops and forward those packets to the non-optimal path.
8. Attacks Related to Data Privacy
   Generally, attackers are divided into three groups: cloud service providers, hackers, and governments. The cloud service provider has the bulk of the user's data. These data are gained by the service providers to make further analysis and improvement of mechanism. They are authorized to access these data as they have already taken terms and agreements. They use this data for marketing or share this data with another service provider. The agreements do not guarantee data confidentiality nor responsible for any misuse of data. The government can easily access the user's private data as they have legal permission to access. They can ask for such data from the service provider as they are the main source of data. These are meant for surveillance or analysis purpose for the benefit of citizens but if their data source is compromised, then any attacks can be easily performed. Hackers use such data for illegal activities.

12.2.5 Security Issues on the Basis of IoT Device of Healthcare

These security issues can be affected in many ways to healthcare Fog devices. Such issues can be illustrated through the example of pacemakers [10]. Pacemakers are medical devices which implanted in human bodies to monitor the human's heart rate. This device maintains the heart rate of the patient. Such devices fall under the category of healthcare 4.0 which needs the highest safety.

1. Clinical Perspective
   So many medical specialists are using such IoT devices to improve healthcare technology. These devices are implanted into many patients and they would not

believe without such a fully functional IoT device. Such patients need regular basis follow-up by doctor. The trained surgeon or medical practitioner performs program specific to the vendor which communicated with the device through wireless technology. There are technologies where this follow-up process can be made home-based, means patients do not have to come to the hospital on a regular basis, they can monitor from their respective location only. For that data, the module is needed which is located at the patient's location. Once implanted device fits into radio range of module, then contact is established and the nodes communicate with such devices. This information can be viewed by only authorized healthcare professionals.

The failure of such devices leads to a very high impact on human's life. Such failures lead to replacement. This arises high-security concerns in the device level unit. Such failure happened either by manufacturer defect or by an external entity. Remote follow-up can be monitored by an intruder who can perform attacks. Incorrect programming can occur either by error or technical failure or by malicious activity.

2. Risk Assessment
Security issues can be discussed according to CIA triad, which means confidentiality, integrity, and availability. Confidentiality states that data about the patient and the implanted device should be kept secure which could not be understood by any third party. Integrity means the data of IoT devices should not get alter as it results in high severe impacts on patients. Availability deals with the operability of the device. A pacemaker is a wireless device that communicates via the internet or LAN line or sometimes by USB stick. Overview of the pacemaker mechanism is shown in Fig. 12.2 [10].

Tampering or expose of information happens on any device. Like on the internet attack such as man in the middle attack can easily occur if proper

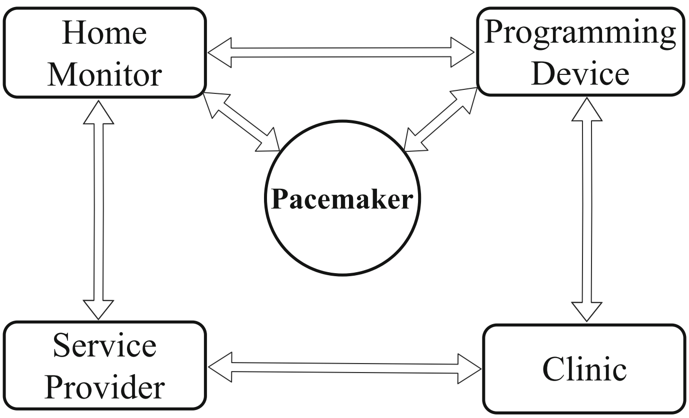


Fig. 12.2 General pacemaker scenario [10]

encryption mechanism is not used. The unsecured wireless medium can easily allow attackers to listen to traffic of network by any other malicious device. Such a malicious device acts as a legitimate user in a medium where DoS attacks also can be easily attempted.

3. Software
   Loopholes or bugs of software are used by a malicious intruder to gain access to the network. Software is uploaded into pacemaker as well as home monitor device and programming device. Software programming device helps to re-program a pacemaker, means it monitors the heart rate of the patient or can change pacemaker rate and processes data obtained from the pacemaker. This communicates with various models of devices. Like software of home, monitor communicates with a pacemaker and upload information regarding the patient to the server. This information can be later accessed by the physician. This needs regular periodic updates of software which minimizes loopholes of the system. If a programming device is compromised, then it may send the wrong parameter what actually being chosen while designing. Likewise, if home monitors are compromised, then it may upload wrong information to the server. This may lead to wrong analysis and computation that further harm the patient. A compromised server may possess such similar threats.
4. Hardware
   Hardware security is as needed as the software of any device. Various attacks like password stealing, login backdoor, privilege access are identified on the system. The various malicious circuits can be installed on the pacemaker as well as home monitoring devices. Malicious hardware mechanism can be installed on the server such as it can reveal or modify the sensitive data which mislead the doctor.
   Security challenges have been increased as such IoT devices have the capability of wireless communication. This includes unauthorized access as well as unauthorized modification of useful information. Device security is at most priority when the wireless network is used. Any intruder can change device configuration or disable any process or remotely run malicious command. The attacker uses compromised programming devices which allow them to access pacemaker and they pretend as a physician and get full rights to change parameters of such IoT device.

12.3 Security Challenges in Fog Computing for Healthcare 4.0

In healthcare applications, any assets like data records, sensors, devices are required to be protected. Compromised assets impact human phycology and can cause permanent loss. Fog IoT devices are resource constraints in terms of less memory, processing power, size limitations, a battery which leads to new level security

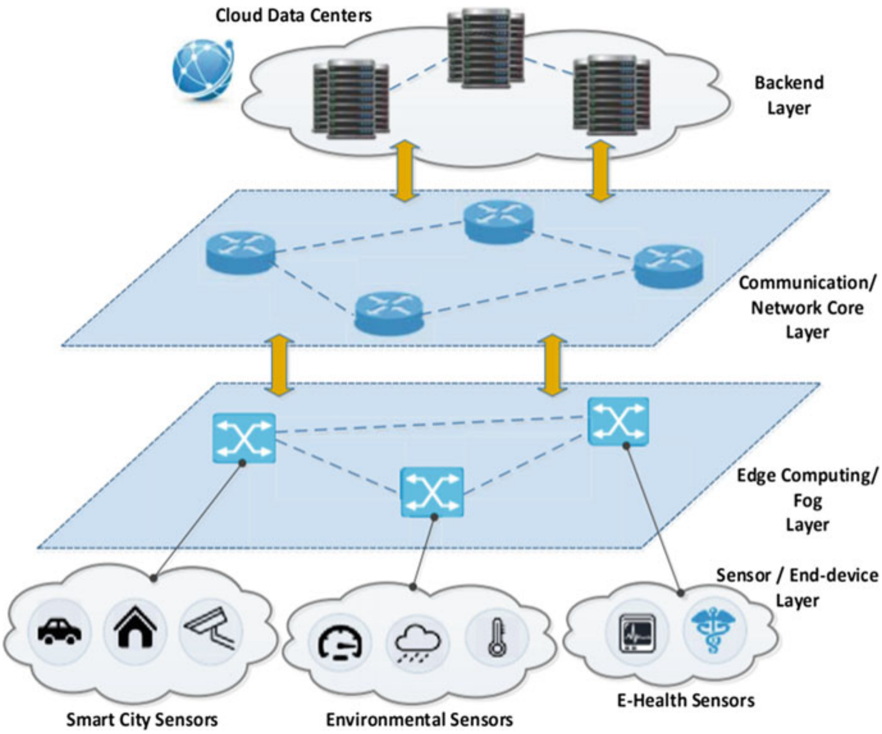


Fig. 12.3 Fog computing architecture [13]

challenges. Such medical devices must prevent unauthorized access but it should not reject legitimate user access at the time of emergency situations. A general security challenge for Fog computing is discussed as follows.

Fog-based architecture is more secure than cloud architecture. There are several reasons which forge more security challenges such as they are less dependent on the internet compared to cloud computing architecture, Fog nodes storage capacity is less complex than cloud and information exchange between the cloud [11]. Which emphasis more security challenges [11]. Fog-enabled system makes use of various networks for interconnecting different Fog nodes or devices such as mobile or wireless device network. This makes them potential targets for any attack [12]. As shown in Fig. 12.3 [13, 14], there are basically three layers of a Fog computing system. Each layer needs different security mechanisms than each other. Cloud computing security mechanism cannot be directly useful to each of these layers as each of the layers has different functionality. Therefore, the analysis of each layer is the most important.

Data centers contain all APIs that provide services to all other nodes which are part of Fog network and other process points like web applications for such reason data center have to be secure as patients' health is at great risk. Fog devices are also vulnerable for attacks as they actively communicate with each other.

Fog security challenges are divided into three classifications:

1. Network and service level security challenges
2. Datacenter level challenges
3. Device level challenges

12.3.1 Security Architecture

Security architecture is a unified secure model design that addresses the potential risk involved in certain scenarios. It specifies when and where to apply security protocols. It defines the relationship between components of a particular system. It is a standardized model, which makes it affordable. It provides different services which ensure that risk management, security policy, and standards, security architecture decision are in real-time applications. It incorporates security phenomena like threats, loopholes. The basic architecture to secure Fog computing mechanism is discussed below.

1. Network Security Model
   The two parties communicate with each other by establishing the path through the Internet between communicating nodes and by the cooperative use of communication protocols. Security becomes a basic need especially when it is desirable to protect the information transmission from an adversary who may introduce different threats.
   As shown in Fig. 12.4 [15], this model has basic four tasks as follows:

   1. Design an algorithm for security-related transmission. This algorithm should be such that the adversary should not gain control over the medium.
   2. Generate secret data used with the chosen algorithms.
   3. Introduce methods for the distribution of secret data.

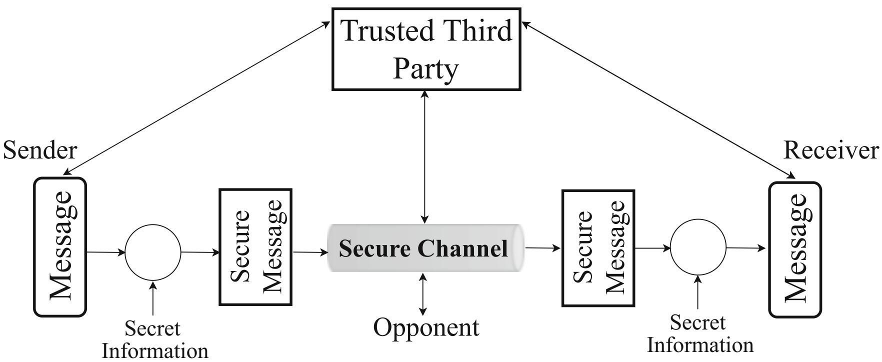


Fig. 12.4 Network security model [15]

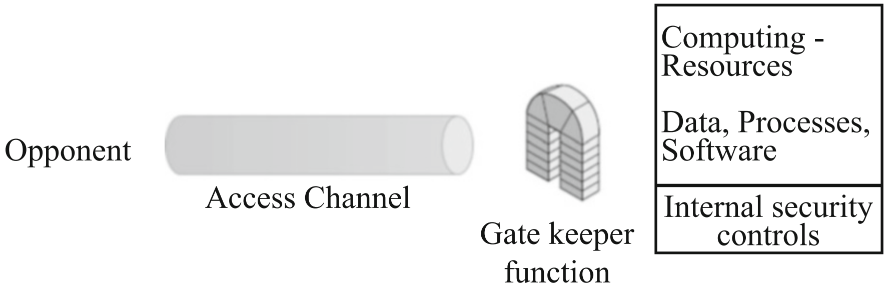


Fig. 12.5 Network access model [15]

4. Specify protocol used by two different parties which make use of the algorithm and secret information to achieve security services.

By achieving these four-task basic security needs can be fulfilled. There are so many different algorithms that are developed for security-related transmission which make use of secret information or key. This key should be as strong as possible as an intruder cannot deduce it. There are different methods for generating such keys. The same key can be used by two communicating parties or two different keys also can be used. Depending upon application two types of methods are used.

A trusted third party is needed for secure transmission. For example, it is responsible for distributing secret information, identify two communicating parties, or arbitrates disputes between the sender and receiver.

By advancing technology security requirements get changing. Other security-related issues are evolving that do not fit into this model. For example, different viruses, worm, hackers may penetrate as legitimate users and harm systems. A basic model for such different situations is illustrated in Fig. 12.5 [15]. Attacks can be introduced into a system that contains unwanted logic which can affect the system. The security mechanism is needed to cope up with such an attack as shown in Fig. 12.5. Gatekeeper authenticates the user. It includes two factor authentication procedures that are designed to deny access from unwanted users or activity. It detects the logic that contains unwanted activity such as malware, virus, worm and rejects another similar kind of attack. Once unwanted users or software gain access another kind of defense line is internal security control that monitors and detects any malicious activity.

12.4 Network and Service Level Challenges

Fog nodes have processing and storage capabilities. While processing and storage request devices interact with Fog nodes. Any other communication happens as a part of the Fog network [12]. Fog nodes interact with each other while managing network resources or the network itself. So, the following communication needs to be addressed to secure the Fog computing system:

1. Communication between devices and Fog nodes
2. Communication between Fog nodes

Fog nodes need to support different protocols such as ZigBee, Wi-Fi, 2G/3G/4G, WiMax, and so on [16]. While the cloud only supports TCP/IP. Fog-enabled system needs to maintain switch network between Fog nodes and cloud or between device and Fog nodes. While this shifting procedure security may compromise. This network needs to be secure by different security protocols.

Fog systems are deployed in a distributed environment. Each Fog server needs to manage a bunch of resources in a different location. Communication and synchronization between these nodes need to maintain security. If one of the Fog nodes is caught to be vulnerable by an attacker it can be compromised and the whole system's efficiency gets decreased. This will directly impact on patient's life at risk.

Data transmission between Fog node has many challenges. It needs to consider connection features. This means how the data get to travel through a medium is a need to specify either via a wireless medium or wired medium. An attacker can easily compromise these vulnerabilities if not properly secured as many tools are available to compromise such vulnerable medium [17].

There are several challenges that need to be addressed:

1. Authentication or identity verification
2. Access control
3. Protocol design
4. Intrusion detection
5. Trust management
6. Privacy-conserving packet forwarding
7. Rouge Fog node detection

12.4.1 Authentication or Identity Verification

Authentication or Identity verification checks for legitimate users or devices within the fog network to use fog-based application. There are many services offered by Fog-based systems. To use the services of Fog-enabled application users or devices must verify their identities in a secure manner. Without a sufficient security guarantee, it is easy for an attacker to target vulnerable services of resources. For example, an attacker may pretend as a valid user to access resources and would also not leave any evidence of their malicious activities. Therefore, authentication services need to be included.

So many authentication schemes are there to provide services to users like username and password, figure detection, or face detection [17, 18]. These schemes do not solve mobility issue of devices. In Fog computing user may travel from one region to another. They connect to different Fog nodes while traveling. If each Fog node performs authentication for accessing the services, then latency may get compromised. To solve this problem cooperative authentication schemes are used. It reduces the authentication overhead and authentication delay for individual users.

12.4.2 Access Control

Access control is the authorization process. Every user or IoT device has the right to access the services. But after gaining access to the system up to what level user or system can utilize the services is a part of the authorization. If there is no authorization architecture, then anyone can access anything and gain control over services and infrastructure. An attacker can easily penetrate into the system. Therefore, authorization mechanism has to be deployed. These include credentials for entities as well as various user factors like trustworthiness, occupation, resource ownership.

Currently, a role-based access control policy [19] is used widely to control access rights to network resources. It is based on the role of the user. Another policy used for authorization is attribute-based access control [20]. It is based on the user's certain attributes. If these attributes satisfy predefined attribute-based policy, then access permission can be granted. Fog computing is a distributed system where it is important to design a distributed access control mechanism. This should support the user's mobility and also device management [21] as a user can access services from any location with any kind of device because the user has multiple devices connected to the internet [22]. Also, the consistency of access policy should be maintained when the user makes use of different devices to access services.

12.4.3 Protocol Design

Real-time services are feasible in Fog computing because IoT devices communicate with Fog nodes in a very short range of communication. Delay of services just not depends only on bandwidth and communication range but also on processing delay of Fog nodes. If Fog nodes perform complex computational operations, then it generates more response delay. IoT devices do not have the capability to compute complex operations or cost too much time to execute them. Therefore, it is better to use lightweight protocol on both the side, IoT device and Fog nodes for performing computational operations.

A variety of security protocols are implemented to offer security and privacy on Fog nodes like authentication and authorization schemes, data encryption, spam detection, digital signature [23]. If they are not efficient enough, then the cost of computational resources increased. To overcome this lightweight cryptography is used. So many schemes have been developed like block ciphers, hash function, MAC (message authentication code), stream cipher to build an efficient and secure end-to-end communication between healthcare devices.

12.4.4 Intrusion Detection

The intrusion detection is introduced to discover malicious activity or policy violations of IoT and Fog nodes. Hole architecture of Fog computing needs to be protected by a defense mechanism. This makes the need to employ intrusion detection for Fog node and IoT devices. Based on the need for security different types of intrusion detection mechanisms like host-based or network-based IDS are used.

A host-based IDS runs on the system and monitors it. For example, it examines system logs, typical fail login, or installation of a back door. For each object IDS keep track of specific attributes like permissions, modification dates, checksum, or size to recognize changes.

Network-based IDS monitors network packets. It examines signs of reconnaissance, DoS attacks malware or viruses, traffic of population of the host, patterns shared between clients. It is useful to detect any attack that is able to penetrate successfully to the Fog computing system. Bayesian network classifier and threat protocol have been developed which provide reliable communication and anomaly detection [24]. This approach is more effective for efficient monitoring compared to traditional cloud based system.

12.4.5 Trust Management

Authentication and access control are not enough to get rid of fake Fog nodes or devices as it is still not guaranteed that all the joining nodes are fully trusted. A Fog node may not blindly trust to neighbor nodes as they may get infected by intruder.

Two basic trust models have been used widely: evidence-based trust model and monitoring based trust model [25]. In evidence-based, there is evidence that proves the trust relationship of Fog nodes like a public key, identity, or any evidence that the user has to prove there trustworthiness. Traditional cryptography was part of an evidence-based trust management scheme. Monitor based trust management is achieved by observing nodes' behavior and its past experience and responses. This trust model can be evaluated by direct evidence or indirect evidence. In direct evidence, trust value is evaluated by examining dropping packets and modifying packets. Forwarded packets are observed with the original packets to identify malicious behavior.

12.4.6 Privacy in Packet Forwarding

Privacy of every packets which are coming from various devices needs to be consistent and private as they carry crucial information. The leakage of privacy should not be compromised as clinical records of any individual play an important role while processing and evaluating.

Many solutions are available to secure packet forwarding like remote data integrity verification, which verifies data integrity. The basic security solution is data encryption before uploading on the network. An atomic proxy cryptography was proposed in which a semi-trusted proxy converts ciphertext without watching the original message using proxy encryption key [26]. Blind signature based secured e-healthcare system has been developed which maintains patient privacy [27]. The main components which are focused in this system are identity, privacy anonymity, and credentials [27].

12.4.7 Rough Fog Node Detection

In Fog computing environment workload is divided into several Fog nodes. This increases efficiency and response time. A Fog node is said to be a rough node when malicious Fog node pretends to be a legitimate node; hence, maintaining data integrity is necessary. Therefore, before any data processing and computation start it is necessary to establish trust management. This requires an authentication protocol.

12.5 Data Center Level Challenges

Data can be collected from various IoT devices and stored at Fog nodes temporarily. Because of this, the data can be readily available for frequent access. This helps to maintain and organize data easily. Data are temporary stored in the Fog nodes. The Fog has different capabilities of data collection, assembling, routing, packet forwarding [28]. It is also capable of simple processing of data and selects the appropriate one depending on the application. Fog node data centers cooperate with each other and also connected with the cloud. It is very important to safeguard data collection and distribution as especially when the health of individuals is a concern [29]. SDN (Software Design Network) is a new latest technology used in data center level that provides centralized control [30]. Large number of data is produced from different sources such as healthcare, financial companies, Internet, etc. [31]. For real-time analysis and to incorporate dimensionality reduction of Big data system PCA (principal component analysis) and SVD (singular value decomposition) are used [32]. There are several challenges which are to be considered at the data center level:

1. Data identification, aggregation, and integrity
2. Secure content distribution
3. Verifiable computation
4. Secure computation

12.5.1 Data Identification, Aggregation, and Integrity

A massive quantity of records have been generated by IoT devices but not all data are useful or meant to be stored on Fog nodes. Before uploading data to the data center their identification, aggregation, and integrity are highly important. Also temporarily maintained data is required to minimize management complexity. Privacy is the utmost need which affects data confidentiality, integrity, and sharing. Distinguishing sensitive information from data is an important task for Fog mechanism. There is mechanism that identifies malicious downloaded data which is based on a blacklist of malicious file hashes [33].

Fog nodes are able to process, modify, and delete useless data and forward it to the cloud. Therefore, determining the honesty of Fog node is difficult. Also due to mobility features, multiple Fog nodes may have user's data. So, to satisfy the integrity of data many possession protocols have been proposed [34, 35]. These protocols guarantee integrity and correctness of data.

Each device collects data from different sources and encrypts it to preserve data privacy. After encryption, it is forwarded to Fog nodes. Then Fog node stores these data depending on the requirement and delivers it to the cloud. During this process, secure data aggregation is crucial to prevent data leakage.

12.5.2 Secure Content Distribution

Secure transferring of data is a basic requirement in Fog computing healthcare. For example, records gathered by IoT devices which are fit into the human body should be shared with family doctors. Sharing of such records with other nodes or devices is a challenging task. For secure transfer, several cryptography schemes have been widely used like proxy re-encryption [36], attribute-based encryption, key aggregate encryption.

Attribute encryption can be used for data security and sharing. In this user's key and ciphertext depend upon attributes. Several schemes have been developed, which can be divided into two parts: key-policy attribute-based encryption [37] and cipher-policy attribute-based encryption [38].

The key aggregate scheme satisfies efficient and secure data sharing through compact keys. The size of the key is independent of ciphertext, no matter how many numbers of ciphertext upload on the server.

12.5.3 Verifiable Computation

Fog computing has computation resources designed for specific computational tasks that produce a result with low latency. This result cannot be fully trusted. This makes a huge concern for the user's as their device does not have that much computation capability to verify it [39]. Cloud has also been connected with Fog nodes in a distributed environment. So correctness verification of result is necessary for users as well as cloud. If there is no mechanism to check the correctness, then the user may not use services offered by Fog nodes.

So many various schemes have been applied to check the correctness of the result. Yao's Garbled Circuits [40, 41] describe a non-interactive outsourcing verifiable computation scheme with fully homomorphic encryption (method of encryption which allows data to be in the encrypted form while it is being analyzed and processed.). Attributes based encryption verifiable computation scheme has been proposed which concerned with the design of public verifiable computation protocol.

12.5.4 Secure Computation

Fog computing is a distributed environment where user's do not have full control over computations. IoT devices expose all collected sensitive information to Fog node and then it executes computation which generates privacy and security concerns. Moreover, if secret key is exposed, then node may pretend as a legitimate user and do everything they want.

Numerous server-aided computations are introduced [42, 43]. Their motto is to reduce the computational time and to keep the records secret from the server. The server-aided verification concept has been introduced which speeds up the verification step of an authentication/signature mechanism [44]. In this method for designing SAV different schemes have been proposed [44]. The security model for a server-aided verification signature has been introduced through which verification of signatures can be performed with less computational cost compared to the original computational algorithm [45]. Moreover, other additional server-aided schemes have been proposed like server-aided encryption [46], server-aided function evaluation [47], server-aided key exchange [48] to speed up computations for users.

12.6 Device Level Challenges

In the Fog computing system, each device has a unique identity, visibility, and task. Not all devices are capable of handling the whole system architecture. All systems of Fog computing are assigned with a specified constraint like computational capabilities, limited power, storage [49]. Thus, Fog nodes send data to the upper layer through gateways for further processing. The system of any environment brings significant privacy and security concerns [50]. The following issues must be considered for securing data at the device level.

1. Confidentiality
2. Lightweight trust management

12.6.1 Confidentiality

System confidentiality means protecting resources from unauthorized access and safeguard data. Existing PKI based system has heavyweight computation and storage. Therefore, it is not effective to apply existing solutions to a Fog-based environment. These solutions are useful in terms of fixed large key size which requires more memory and processing power. They also do not protect systems from insider attacks. Authentication and privacy are basic security requirements for Fog system environments.

1. Authentication
   Fog computing services are offered to huge number of end users via Fog nodes [51]. User-friendly and secure solutions exist to solve authentication issues [50, 51]. In addition, biometric authentication is the most needed technology specifically in the environment of mobile computing, Fog computing [52]. Touch base authentication, fingerprint authentication, face authentication are widely used in this technique [53].
2. Privacy
   Users are more concerned about their private and sensitive information such as personal data, location, or other information while using cloud or Fog based services [51]. IoT user's identities must be protected from getting exposed to the adversary. Group signature or connection anonymization techniques are developed for preserving identity privacy [54]. Fog node collects security data from IoT devices and sensors. Homomorphic or differential privacy can be employed to ensure the privacy of uniform data entries [55]. Several techniques are proposed to obfuscate identity [56]. Different methods are evolving to secure the privacy of the client's location [57].

12.6.2 Lightweight Trust Management

The Fog-based IoT devices should have a certain trust level among them. Authentication plays a crucial role to build trust between Fog-based system. Traditional trust-based routing protocols have different issues like more memory and power consumption [51]. Therefore, there is a need to design a lightweight trust mechanism. Such systems are more effective in identifying malicious nodes or devices [57].

12.6.3 Blockchain Approach

Blockchain is a distributed and decentralized technology which comprises various techniques and services like hash cryptography, immutable ledger, consensus protocol, and P2P networking and mining [58]. It provides great security and privacy in an easy, efficient, and secure manner. It is also implemented as an authorized identity of IoT devices. Its decentralized feature provides great security, authentication, and integrity of data which is communicated between two Fog nodes or between two clients or patients in a confidential manner. Through this technique secure tracking of IoT device transactions made easy.

Blockchain has another feature to deal with authorization of IoT device which provides effective rules for authentication which has less complexity compared to conventional protocol. In this approach, there is no need for third party and still they can securely communicate and perform the execution. Blockchain provides unique GUID and symmetric key pairs to each device of Fog computing which removes key distribution and management process [51]. We can increase the feasibility of lightweight protocol by using this approach as Fog computing has constrained computational and storage capacity. It provides secure communication among different Fog nodes and between layers of Fog computing. It authenticates the identity of the user and ensures the transaction made by the authentic user. It also ensures verifies transaction made by the authentic users. The greatest advantage is there is no single point of failure as copy of records is stored on every device.

There are a few challenges associated with this approach. In Fog computing technology adaptive and lightweight blockchain security solution is needed as it has less storage capacity and computational power. Bitcoin blockchain has latency in terms of latency; therefore, it is not feasible to use bitcoin approach in real-time.

Blockchain and Fog Computing IoT

Fog-based IoT system has great security and privacy issues. A huge number of data or information is produced by interconnected IoT devices which have to be kept confidential. End-to-end security and trust have to be built up. Implementation of blockchain can overcome such problems. Fog computing has a distributed trust and security solution; therefore to build and manage with such solutions, Fog computing uses the blockchain approach [51]. To provide fast services in medical industry FAAL based structure also has been proposed which uses the distributed concept for networking and storage [59]. When a new device is connected to Fog computing system, blockchain architecture provides security to the whole network. It also detects and isolates malicious or compromised node. This provides self-identification and solution of the problems. Data is at the highest priority level in any healthcare IoT system. This technique removes third party intervention. In this regard, blockchain provides the highest security solution. It provides secure storage and transmission through digital signature for more protection and privacy [51]. Also, this can directly transfer data among devices through a time-stamp based method with proper security [60].

To improve system performance and capacity a distributed IoT network architecture consisting of an SDN based network using the blockchain technique is developed [61]. It provides threat prevention, access control, data protection, and other attacks such as ARP spoofing or DDoS (Distributed Denial of service)/DoS(Denial of Service) attack. For authentication, a decentralized authentication mechanism based on a public blockchain is developed which creates a secure virtual zone for secure communication [62]. In healthcare domain records of patient's are crucial as any small change to it puts into a big trouble. To secure such records blockchain based method can be used in which patient has whole control and rights over his records so as to monitor all transactions [63].

A lightweight FC-based hierarchical architecture for IoT is developed that has secure trust management which reduces block management processing time. It provides the solution of lightweight Fog IoT devices with better security privacy. It eliminates overhead with conventional blockchain. A blockchain-based decentralized, infrastructure-independent technique [51] has been developed for securing a patient's or client's location and privacy [64]. It stresses proofs of location, verifies geographic location, and preserves user location privacy. Healthcare data gateway (HDG) is a blockchain-based scheme that is developed to enable the patient to communicate easily and securely [65]. For any financial transaction also this approach provides more security. BloHost framework is proposed for transaction through single unified cryptocurrency [66].

Practical implementation of blockchain based approach has several challenges [67]. Blockchain is replaced with client–server system technology. But FC-based information required less memory and power. Also, increase in number of nodes may degrade the performance of blockchain architecture [68].

12.7 Conclusion

Fog-based IoT devices are prone to different security attacks due to lack of constraint resources and security design of hardware or software. In the healthcare domain technology of Fog computing is widely developing. But securing such medical devices leads to securing human life, health, and well-being. It also includes the protection of health-related information and secures the privacy of those data. Increasing use of the mobile medical application and medical devices that use wireless communication requires a high-security mechanism. In this chapter potential security and privacy challenges for Fog computing in healthcare 4.0 have been discussed. Various security and privacy issues along with their solutions have been discussed. The basic security mechanism is illustrated to state that existing security solutions cannot be directly applied to Fog computing. The medical scenario has been taken to illustrate the challenges and vulnerabilities of the use of Fog-enabled devices in medical applications. New emerging technologies for healthcare application provide an opportunity with security to make the medical field more cost-effective and user beneficial for human well-being. If proper countermeasures are not taken to secure Fog-based IoT device, then misuse of medical data and malware attacks are easy to perform which puts human life in danger.

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Chapter 13
Fog-Assisted Data Security and Privacy in Healthcare

Shweta Kaushik and Amit Sinha

13.1 Introduction

13.1.1 Fog Computing

Fog computing is a stretched version of cloud computing which brings cloud computing near to the client network. The impression behind this migration is to reduce the task of cloud computing's data centers and transfer it towards fog nodes which are nearer to client. Fog computing overcomes the various difficulties faced in cloud environment such as cost expenses, jitter, or delay during data transformation from cloud to client and increases the content delivery on time with more reliability. It helps in enhancing the storage, computation and networking resource availability of cloud computing in any application as data resides near to the client. In general, both of these technologies are applied in the field of IoT, which contains multimedia data and real-time service such as healthcare data, stock market data, bank transaction related data and any real-time data, etc. This inclusion of fog computing with cloud computing brings various benefits in terms of privacy, latency, bandwidth, data security, etc.

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13.1.2 Healthcare

Human services frameworks in many nations face huge challenges that will be increasing continuously because of maturing population and the ascent of incessant infections. Numerous nations likewise experience a developing nursing staff deficiency. Simultaneously, there is an interest to diminish costs while keeping up top notch care to patients. As a result, social insurance industry advances a data driven human services conveyance model. Some portion of this conveyance model empowers remote observing of patients, which prompts expanded availability, quality, effectiveness, and progression of social insurance to patients, and furthermore decreases the general cost of medicinal services.

13.1.3 Fog in Healthcare

The reason for the human services Internet of Things is to make it simpler for patients to remain associated with their suppliers, and for their suppliers to convey responsible, esteem-based consideration to their populaces. Fog computing might be the essential foundation for changing the medicinal services IoT from curiosity to the real world.

So as to achieve this, the healthcare industry must defeat three of its major enormous information hindrances: the test of transforming huge information into perception information, the geological dissemination of suppliers and their absence of interoperability, and the strict patient protection and security decisions that oversee the progression of touchy well-being information.

Fog computing can get around these hindrances by going about as scaled down information preparing focuses that trade information without the requirement for the cloud. Utilizing predefined approval and client conventions, a patient's well-being information could be presented to every gadget through a mutual interface, yet any calculations will just happen where the information begins: at the medical clinic or doctor office that holds the patient record.

The idea is like getting to a portable interpretation of an electronic well-being record from a cell phone. The cell phone does not store any of the patient information itself; however, it allows the client to get to or change data held at an incorporated area, in view of prearranged consents. Notwithstanding quiet produced well-being information, the synergistic condition could likewise coordinate operational and money related information required for improving proficiency and reducing expenses, for example, the GPS area of an emergency clinic possessed tablet, data on the planning of the everyday schedule of a staff part with a RFID tag in her identification, or a caution from a stock sensor that triggers when a significant drug is out of stock. Kumari et al. [1] discussed healthcare basic structure. The possible transition from healthcare 1.0 to healthcare 4.0, discussed by Hathaliya et al. [2], can be explained as discussed in Table 13.1.

Table 13.1 Technology shift from healthcare 1.0 to healthcare 4.0

S. No.	Healthcare 1.0	Healthcare 2.0	Healthcare 3.0	Healthcare 4.0
Purpose	Reduce paper work and improve working efficiency	Improve data sharing and its productivity	Concentrate on centralized server based on patient requirement	Provide real-time solution for healthcare with efficient data tracking
Emphasis	Data automation	Connecting multiple organizations at same floor	Patient interactivity with system	Real-time monitoring of patient data and diagnosis with the help of AI tools
Restrictions	Limited functionalities because of standalone feature	No interaction with patients and data sharing is also limited	Patient data interoperability is very less because of heterogenous data	Patient sensitive record concern as latest technologies are not fully tested and verified
Data sharing	Within an organization	Within a group of related organizations	Within a country	Data is shared globally to support supply chain of healthcare
Technology used	Administrative system and LIMS software	Cloud computing	Big data	IoT, AI

13.1.4 Chapter Contribution

The chapter is divided in following sections viz. introduction, security needs for healthcare, attacks in healthcare, security solution and agreement, possible security solution in fog environment, and a security model using fog computing in healthcare. Each section is divided further into subsections for better clarification and understanding. Section 13.1 explains about the fog environment concept and its need in healthcare applications. This section creates a foundation for the readers. The Sect. 13.2 concentrates on various security needs in healthcare along with possible solution. Possible attacks in healthcare with their solution are described in Sect. 13.3. Sections 13.4, 13.5, and 13.6 tell about the various security solution adopted by the different framework and how much security parameters are solved by them. A security model utilizing fog computing in healthcare is described in Sect. 13.7.

13.2 Security Needs for Healthcare

In last few ages, it has been observed that the utilization of electronic hardware, for example, sensors, for creating computerized social insurance arrangements has

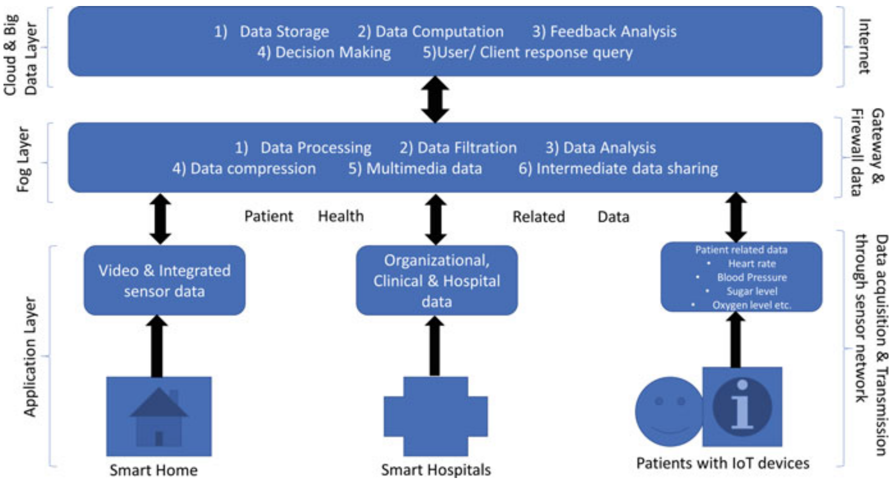

Fig. 13.1 Healthcare framework

gain lots of attentions by the clients. These days, human services applications are not constrained to computerized record possession of different medical information created from patients, specialists, and so forth. Current medicinal services applications center around telemonitoring patients, following their portability, what's more, giving early warnings to specialists and family members if there should arise an occurrence of basic circumstances. This all can be achieved because of the development of Internet of Things (IoT) devices [3] and the utilization of implanted sensors in a patient's body as per [4] and [5]. The general design of the healthcare framework is portrayed in Fig. 13.1. Solid communication, dealing with portability and idleness control also, vitality effective steering is a portion of the issues which should be tended to. Due to the computerized change, there has been a splendid amount of unstructured information like video, images, and also pictures created in the human services field. The medicinal services field has delivered a virtually associated universe of clinical gadgets which constantly convey unstructured, and possibly unbound, information, which is helpless against any occurrence of threats or attack. This information should be transmitted in a channel, which may not additionally be verified. Be that as it may, the physiological information of a person contains profoundly close to home and touchy data. Along these lines, security is an overwhelming need of human services applications, particularly if the arrangements use IoT gadgets furnished with sensors or on the other hand body territory networks. But, when the social insurance arrangements are sent in cloud and fog computing environment, the security concerns are multiplied because of the accompanying reasons:

1. Fog and cloud computing environment data are sent over the customary system figuring so they are powerless against a wide range of security dangers endured by conventional systems.

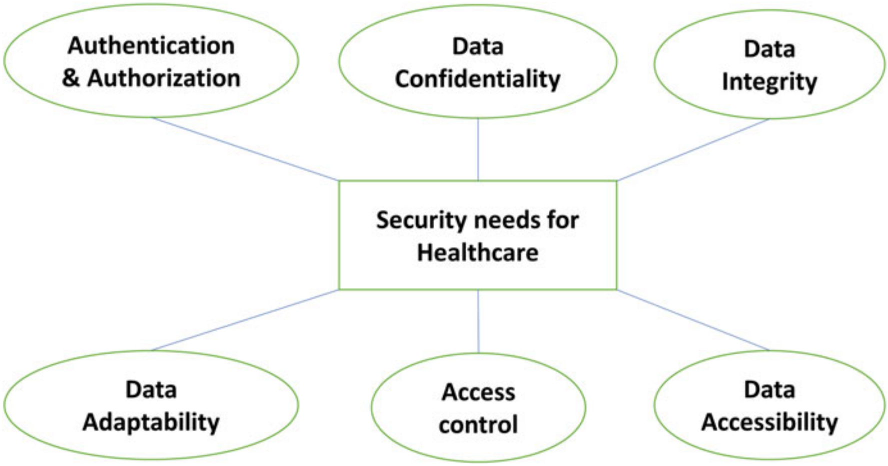

Fig. 13.2 Security needs for healthcare

2. Individual human well-being related information are caught from omnipresent wearable sensors conveyed in IoT gadgets, which are exceptionally adaptable and dynamic in nature.
3. In a large portion of the cases, the correspondence medium through which the information transmits is remote and needs security.
4. The apprehended data from an IP-enabled user device communicated to the desired site may be routed through an unsafe network structure.

Therefore, in order to have a safe and secure virtual cloud network for owner's data there is a need of the following security features for efficient processing of data, as shown in Fig. 13.2:

13.2.1 Data Integrity

This feature is required for assurance that data will not be altered or modified during its transition neither from owner to cloud nor cloud to intended user. In fog-based computing healthcare architecture, all the communication is done though the wireless mode which increases the chances of loss of data integrity during transition. The possible solution to handle this issue can be (i) Cyclic Redundancy Check (CRC)—to identify the erroneous data packet and (ii) Message Authentication Code (MAC)—to verify the data integrity (Table 13.2).

Table 13.2 Security requirements with their possible solutions

S.No.	Security need	Possible solution
1	Integrity	Cyclic redundancy check, message authentication code
2	Data confidentiality	Encryption and decryption
3	Authentication and authorization	MAC protocol
4	Access control	Defining access control mechanism

13.2.2 Data Confidentiality

All the significant health-related sensitive information of each and every patient and individual's data are transmitted over a network path established between the client and specialist organization or service provider. To protect the information in their unique structure and to keep it safe from any middle man attack or leakage, the secrecy of the information is required to be safeguarded against all these attacks. This could be achievable by implying robust encryption and decryption techniques. This utilization of robust encryption and decryption techniques, can be controlled and no attacker can get the entrance to the sensitive information.

13.2.3 Authentication and Authorization

Authentication and authorization features are required to approve the personality of the sender and beneficiary of the health-related sensitive information bundles. Any unapproved access to private restorative data can ruin the whole system. Unapproved access to private information may cause the infusion of some invalid misleading information which may harm the framework. This can be handled by utilizing MAC protocols and define the levels of authenticity of the data along with the user authority, i.e., how much data is accessible by the user.

13.2.4 Data Accessibility

Data accessibility feature guarantees that the health-related sensitive data is administrative empowered through the fog-based framework, uninterruptedly accessible to the approved clients as and when required according to their access criteria. There might be an opportunity or situation arising when the information and administration will be inaccessible at the critical moment because of Denial of Service (DoS) attack. DoS attack can consume lots of transfer speed, kill reaction time, and result in network congestion. Accessibility can be further characterized on the basis of strategies and standards of a framework and assets to be open, usable, and accessible when there is an interest by any authentic client (Kraemer et al. [6], Ye et al. [7]) and at any location in the medicinal services framework. Guaranteeing accessibility feature ensures administration interruptions brought about by equipment disappointments, control disappointment, support work, and framework upgradation.

13.2.5 Access Control

This is the ability to give controlled access to various different resources by approved data owner to the client [8]. It includes three diverse security and protection prerequisites: recognizable or client identity proof, client verification, and its authorization related to particular data. Distinguishing proof is about how to recognize clients. Despite the fact that it is not a reasonable objective of security, it tends to be utilized to impact the way in which a client is verified. It can be based on the client's identity, role, or the attribute it possesses. Confirmation of client's identity gives a surety that the mentioned information get to is authentic. It additionally provides a surety that the correspondence is going on with an approved gathering on the opposite side or client. In the end, the approval procedure chooses which bit of information can be limited to an outside requester dependent on some security approach. It is to be noticed that a proper get to control component could guarantee tolerant protection and furthermore could offer a great balance among accessibility and classification [9, 10] sorts of security objectives.

13.2.6 Data Adaptability

Adaptability empowers an unapproved member who is not on the authorization rundown to get to explicit information in a crisis case to spare the patient's life. Powerlessness or aversion of the get to rules may undermine a patient's life [11].

13.3 Attacks in Healthcare

The various possible attacks in healthcare in fog environment can be depicted as shown in Fig. 13.3:

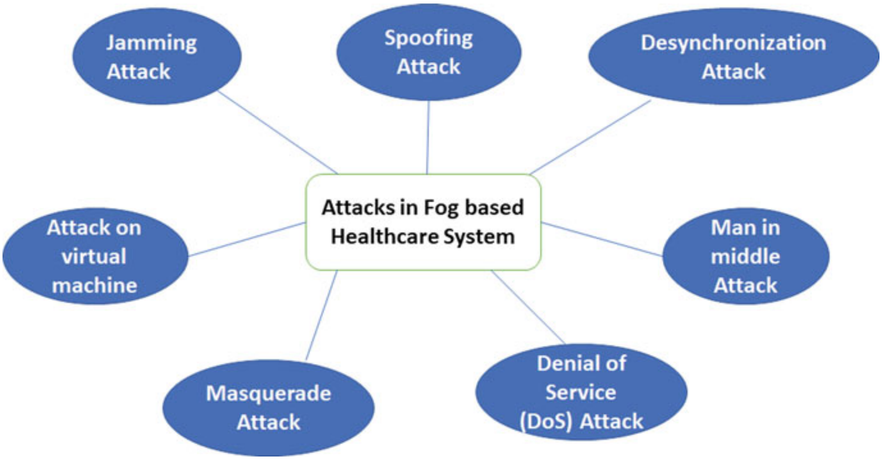

Fig. 13.3 Attacks in Healthcare

13.3.1 Jamming Attack

In jamming attack, the rival alters the substance of the first message by moving radio recurrence flag inside the system or by hindering the message and, as a result, it cannot arrive at the expected collector or client. Radio obstruction attacks are very hard to be handled by the customary security techniques. An attacker can attack the data just by ignoring the medium access convention and persistently sending on a remote system. This attack can be done in two different ways: (1) It is possible that it could be an outer danger model in which jammer or attacker is not a piece of system or (2) it could be an interior danger model in which jammer or attacker has a place with the underlying network. This jammer attack may occur in medicinal services applications by obstruction of the attacker's radio sign with frequencies of the BAN (body region systems) [12].

13.3.2 Spoofing Attack

A fog computing environment where fog devices cooperatively work is progressively inclined to information altering and spoofing attack. Stojmenovic et al. [13] proposed that avoidance techniques could be inherent by utilizing a public key framework (PKI), Diffie–Hellman key exchange protocol, interruption discovery strategies and observing for altered information esteems. In a fog network which stores health-related information, security, execution, and inertness are the significant components to be considered, and instruments like encryption strategies, known as completely homomorphic [14] and to somewhat homomorphic [15] can be utilized to safeguard against information security during information transmission over the network. These strategies combine the functionalities of symmetric and public key encryption calculations along with attribute-based encryption and signature. The homomorphic encryption plans permit doing typical tasks without decoding the information, in this manner decreasing the key conveyance which keeps up information protection and maintains its confidentiality. The possible calculation for homomorphic encryption can be given as:

Algorithm 13.1: Homomorphic Encryption
Input: Encrypted data from various node in fog environment
Output: Secured encrypted data at client/receiver end
BEGIN
Step 1: Let E1 and E2 represent the data collected from fog nodes and sensors in encrypted form from devices at the edges.
Step 2: Apply Homomorphic Additive or Multiplicative (HA/HM) on encrypted data E1 and E2 defined as:

$$\mathrm{HA}\,(\mathrm{E1})\ \Theta\ \mathrm{HA}\,(\mathrm{E2}) = \mathrm{HA}\ \ (\mathrm{E1} + \mathrm{E2}) \tag{1}$$

$$\mathrm{HA}\,(\mathrm{E1})\ \Theta\ \mathrm{HA}\,(\mathrm{E2}) = \mathrm{HA}\ \ (\mathrm{E1} * \mathrm{E2}) \tag{2}$$

where Θ is any mathematical operator.
Step 3: Client receive the data in double encrypted form.
Preparing needs to be done on the information in fog node without decryption of exact message, along these lines saving information classification.

13.3.3 *Desynchronization Attack*

In this type of attack, the malicious attacker alters the message transmitted between sensor hubs by duplicating it commonly by forcing a phony arrangement number to one or the two endpoints in a functioning association; which prompts remote body region systems overpowering the system assets and vitality, consequently making the sensor hubs move the message more than once.

13.3.4 *Man in Middle Attack*

In fog computing environment, there is high possibilities for the occurrence of man-in-the-middle attack. During this attack, fog gadgets filling in as passages may be undermined or substituted by produced gadget or administration. Generally, these attacks can be avoided by utilizing encryption and decoding calculation techniques. Be that as it may, it is hard to ensure correspondence between fog computing nodes and IoT gadgets utilizing the encryption technique. Encryption and decoding strategies consume a lot of time and battery on a cell phone. It is frequently a hazard factor against the QoS (nature of administration) necessity of the medicinal services checking framework in fog communication network.

13.3.5 Denial of Service Attack

A fog computing environment is profoundly defenseless and increasingly inclined to DoS attack. This fog computing environment runs in a conveyed domain, where the data server works in an agreeable and cooperative way. So, it is hard to recognize the underlying foundations of the actual attack. To secure against this DoS attack, network monitoring is done frequently. Intrusion Detection System (IDS) is utilized to protect and to control the strategies. DoS attack on fog network, either from end-clients or outer frameworks, can counteract authentic help use as the system gets immersed. Additionally, all correspondence is remote and henceforth powerless to pantomime, message replay, and message contortion issues. Security from these attacks is huge as human life is included. The most regular method for disposing of such issues is by actualizing solid confirmation and authentication, encoded correspondence, key administration, performs customary evaluation, support private organization and secure steering. Figure 13.4 presents a description of a DoS attack.

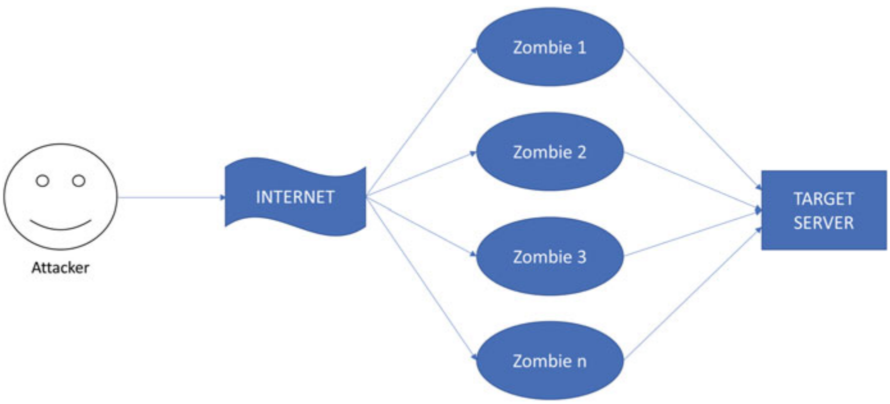

Fig. 13.4 Denial of Service Attack

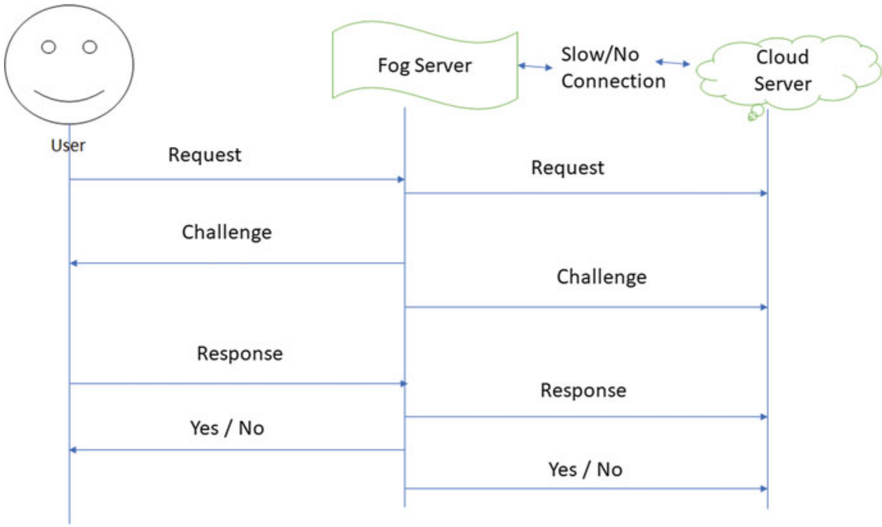

Fig. 13.5 Masquerade attack

13.3.6 Masquerade Attack

A masquerade attack occurs when a noxious fog computing node professes to be a genuine one to trade and gather the information produced by other IoT gadgets for any evil aim or unauthorized access to sensitive data. These kinds of hubs are said to be maverick hubs. Bos et al. [16] presented a cross breed system which can detect the rebel passageways in WiFi-based access systems. Their proposition was intended to give security to the systems from rebel passages, and furthermore in circumstances where the aggressor utilizes redid hardware. A rebel fog node is defenseless to information uprightness and has the capacity to translate client information or give unadulterated information to neighboring hubs. These issues are hard to deal with in IoT and fog environment because of the multifaceted nature in trust the board in different plans. A schematic graph of a masquerade attack is portrayed in Fig. 13.5. A failure in verification and approval between the client and fog server happens only when there is a delicate or broken association between the fog and cloud server. The components to convey verification and approval plans are sent in the cloud server.

13.3.7 Attack on Virtual Machine

The social insurance healthcare related administrations are handled by fog and cloud, are sent in a virtual situation. In the event that the virtual machine is undermined, it can speak with the remainder of the virtual machines having a place with the equivalent physical host. On the off chance that the hypervisor is undermined, it can offer access to the host working framework and the equipment [16, 17]. There is no huge investigation concerning this in the writing, particularly in distributed computing. Wu et al. [18] proposed an entrance control model to forestall virtual machine escape attack in cloud condition. However, this is not tried in fog condition. Harnik et al. brought up some potential side channels that can be found in a customary customer side duplication [19], despite utilizing secure encryption techniques. They proposed customer-side and server-side deduplications depend on an irregular limit. Be that as it may, the possibility of utilizing this in a fog computing environment is yet to be tried. So a legitimate lightweight arrangement observing framework is required to maintain a strategic distance from these attacks in a threatening domain. From the above discourse, the recognizable key focuses which can be drawn in regard to security necessity in medicinal services security conventions can be discussed in short as:

1. All the nodes related to fog/cloud environment have restricted assets as far as preparing power and computational assets. Along these lines, security arrangements ought not be computationally concentrated.
2. Healthcare-based arrangements work with IoT gadget, sensors, and so on. These typically have low battery life. The arrangements ought to be vitality productive and light weight (Table 13.3).

Table 13.3 Possible security attacks with their possible solutions

S. No.	Attack	Possible Threats	Solution
1	Jamming attack	Data integrity, data confidentiality	Network access control protocol, IDS
2	Spoofing attack	Data integrity	Public key-based algorithms, Diffie–Hellman key exchange algorithms, IDS
3	DoS attack	Data availability	Network firewalls, network monitoring system, IDS
4	Masquerade attack	Data integrity, authentication, authorization	Network access control
5	Attack on virtual machine	Data availability and privacy	Network access control
6	Man in middle attack	Data confidentiality and privacy	Data splitting into multiple blocks, strong encryption/decryption

13.4 Security Solution

As described in above sections, the presentation of fog stage practicality between end-clients and the cloud frameworks makes additional opinion for liabilities, which can possibly be abused for malignant exercises [20]. Not only this, like for cloud frameworks, there are also no security standard accreditation and measures characterized for the fog computing environment. Furthermore, it could similarly be articulated that a fog stage:

1. Has moderately slighter believing assets due to their very nature and afterward it is hard to execute a full suite of security arrangements that are capable to distinguish and counteract refined, directed, and appropriated assaults.
2. Is an appealing objective for digital reprobates because of high volumes of material amount and the probability of having the option to obtain touchy information from both cloud what's more, IoT gadgets.
3. Is progressively available in association with cloud environment, depending upon the system design and physical area, which builds the possibility of any attack.

13.5 Security Arrangements

The term security arrangements is accessible to identify and anticipate vindictive assaults on a fog network. The beneath area gives an outline of such frameworks as shown in Fig. 13.6:

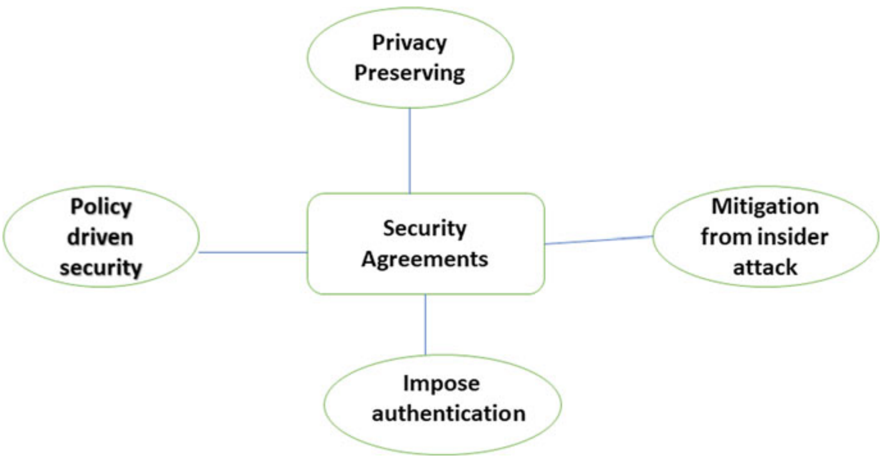

Fig. 13.6 Security Agreements

13.5.1 Privacy Preserving

Previous years' investigation into safeguarding security in sensor-fog networks [21] comprises of the accompanying abridged strides to verify sensor information between end-client gadget and fog arrangement:

1. They gather sensor information and concentrate highlights.
2. Fuzzing of information by embedding Gaussian noise in information at a specific level of change to bring down the opportunity of listening in and sniffing assaults.
3. Isolation by parting information into blocks and rearranging them to dodge Man-in-the-Middle (MITM) assaults.
4. Implementing public key infrastructure for scrambling every datum block.
5. Transmit isolated information to fog node, where information bundles are decoded and re-requested.

The framework additionally incorporates a component decrease capacity for limiting information correspondence with fog nodes to help limit chance. This work is of essentialness as it focused on protecting individual and basic information during transmission. The proposed strategy can be improved by choosing an encryption and key administration calculation, focusing on those that assume a significant job in keeping up the security of information.

13.5.2 Mitigation from Insider Attack

Previous study by Sudha et al. [22] gives an answer for securing information from noxious insiders utilizing parts of fog environment and distributed computing. The aforementioned consolidates conduct profiling and bait ways to deal with moderate security dangers. In the event that any profile displays unusual conduct, for example, the expansion of getting to various archives at uncommon occasions, the framework will label the entrance as suspicious and lump the discrete client. Imitation is a misinformation attack that incorporates counterfeit archives, honey files, honeypots, and different sorts of bedeviling information that can be utilized to distinguish, befuddle, and get the malicious insider. Comparative conduct profiling and bait strategies are utilized in different works [21, 23] to recognize and avert noxious insider threat. The conduct profiling, checking, and client coordinating procedure would not apply any weight on cloud assets and counteract genuine information burglary without uncovering any delicate information. As an additional advantage, these activities will happen on-premise and execute moderately quicker because of low data transfer capacity inactivity.

13.5.3 Policy Driven Security

One previous work proposed a fundamental strategy in which the executive's system strengthen the fog installation to provide the protected communication, share-ability and interchangeability among the client's mentioned benefits. The framework is partitioned into following significant module(s):

1. Policy Decision Engine (PDE) for making a move based on pre-characterized arrangement rules
2. Application Administrator (AA) to oversee fog multi-tenure
3. Policy Resolver (PR) for quality-based verification
4. Policy Repository (PRep) holding rules and approaches
5. Policy Enforcer (PE) to distinguish any errors in approach execution

AA is answerable for characterizing rules and strategies while thinking about various inhabitants, applications, information sharing, and correspondence administrations. At the point when a certain administration demand is produced using a client, it is sent to a PR that recognizes the client dependent on explicit arrangement of characteristics what's more, get to benefits against a mentioned asset. The client traits and their individual consents are put away in a database. PDE takes client data from the PR, removes rules from the PRep, investigates them and upholds through the PE. The eXtensible Access Control Markup Language (XACML) is utilized to make rules and the OpenAZ structure for building PDE. Notwithstanding being in an underlying stage, this approach system can possibly become a vital piece of constant circulated frameworks in future, where there is a solid requirement for understanding the executive's capacities and the resources required in the future.

13.5.4 Impose Authentication

Many research authors explain that the IoT gadgets, particularly in keen frameworks, are inclined to information altering and caricaturing assaults and can further be averted through the assistance of Diffie–Hellman key exchange protocol, public key infrastructure, intrusion location procedures, observing for changed info esteems. Besides, the researchers exhibit the high significance and effect of MITM assault on fog processing by propelling a craftiness assault on video call among 3G and the WLAN clients inside a fog organize. In view of the present condition of verification in fog stage, fog environment is missing thorough validation what's more, secure correspondence conventions according to their particular what's more, necessities. In a fog stage both security what's more, execution factors are considered related, what's more, systems, for example, the encryption technologies identified as completely homomorphic and Fan-Veratrin to some degree homomorphic technique can be utilized to verify the information. This plan comprises of a half and half of symmetric and key encryption calculations, just as different variations of characteristic based on encryption. As per homomorphic encryption grants ordinary activities without decoding the information, the decrease in key dissemination will keep up the protection of information.

13.6 Recommended Security Solutions

As per the various security issues discussed above, this area offers the security information holes which ought to be secured to fabricate a dependable, appropriate and reliable fog stage. Regardless of having enormous potential amount of uses, an absence of security arrangements accessible for fog framework engineers and planners is present. Be that as it may, as cloud registering and many comparative advancements look like the working system of processing, provide a more profound understanding in terms of security dangers and arrangements. Despite the fact that each fog organization has an alternate convention for security prerequisites, application, and affectability, the accompanying subsections give a far-reaching, proficient and material security arrangements, which are accumulated what's more, tried on different frameworks. They can likewise be utilized as conventional best practice rules while building up the fog programming, so the security seems empowered from inside the stage. Table 13.4 exhibits a rundown of the relationship among the accompanying proposed safety arrangements what's more, the twelve classifications of security threats, as shown in Fig. 13.7:

13.7 Security Model Using Fog Techniques for Healthcare

This section will elaborate a model for healthcare in fog environment along with its functionality at each and every step. It accepts as input content in textual form, a therapeutic picture or a medical procedure video as information and furnishes a significant level of security with the assistance of DMD in the fog environment. A client, cloud server, and fog server are diverse three parties associated with the proposed model. The structure of the proposed technique is appeared in Fig. 13.8.

13.7.1 Cloud Server (Centralized)

An Amazon server named as Elastic Compute Cloud (EC2) is utilized as a brought together cloud server. It utilizes open key cryptography to encode information with an open key, for example, a secret key. At the beneficiary side, it utilizes a private key to unscramble the information and get back the actual data. It is highly recommended that we should make use of SSH-2 RSA keys when we dispatch

Table 13.4 Security solutions against threats

Security Solution	Data Encryption	Secured multi-tenancy	Malware protection	Preventing cache attack	Wireless security	Secured vehicular network	Network monitoring
Advance persistent threats					√	√	√
Access control issues		√			√	√	√
Account hijacking		√				√	
Denial of service						√	√
Data breaches	√	√		√	√		√
Data loss	√		√				
Insecure APIs		√	√	√			
System and application vulnerabilities			√	√			
Malicious insider	√	√					√
Insufficient due diligence	√						√
Abuse and nefarious use		√			√		√
Shared technology issue		√	√			√	√

an occurrence. In this undertaking a Linux occurrence with people in general key substance is set in a section inside ".ssh/authorized_keys" for safety.

13.7.2 System Setup

To actualize figuring condition of the proposed system, utilize at least two frameworks, for example, a workstation, cell phones, and so on, are associated with a fog hub/server utilizing IP addresses over the web. This fog hub/server is associated with a cloud server through secure file transfer protocol and bolsters secure key-based

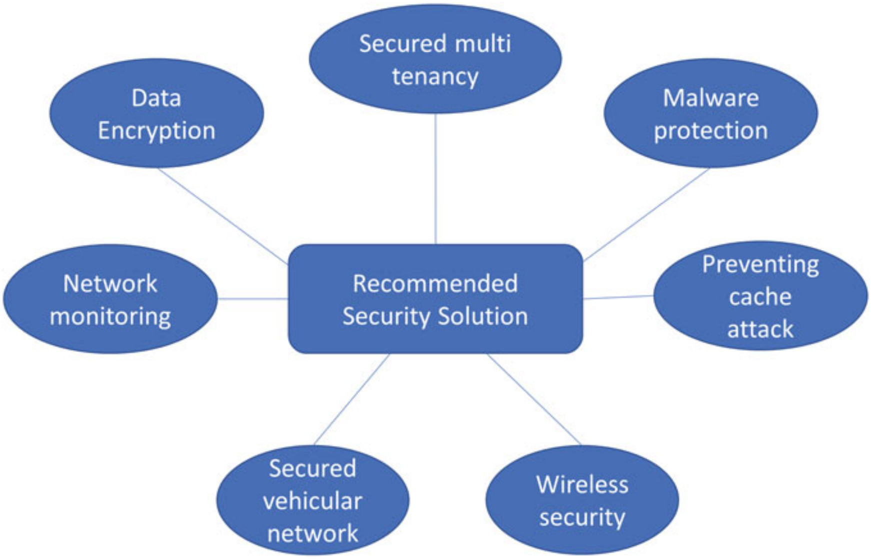

Fig. 13.7 Recommended security solutions

confirmation. File transfer protocol is not so reliable to move business documents on all advanced OS.

An outsider device "Zilla" is utilizing the secure file transfer protocol customer to interface with different PCs. Key-based authentication is finished with secure file transfer protocol, utilizing passwords and SSH keys. In this work, the SSH-2 key-based validation instrument is utilized to spare SSH keys. Zilla has worked in a key administration page to spare keys safely and which enables an association with a remote server naturally. The created task codes are moved to the remote server utilizing this outsider.

13.7.3 Fog Node (Decentralized)

In light of various areas, various gadgets, for example, PCs, server machines, passageways can be set up as fog node or server, which is a decentralized instrument to diminish time delay for information transmission. Fog devices can be claimed by clients or specialist co-ops and can be physically watched, forced, or checked by their associations. Many existing figuring systems depend on focal specialists, which can be costly, wasteful, and tedious handling. This decentralized framework disposes of the requirement for focal expert in registering systems. These fog nodes or server are fit for dealing with the accompanying activities:

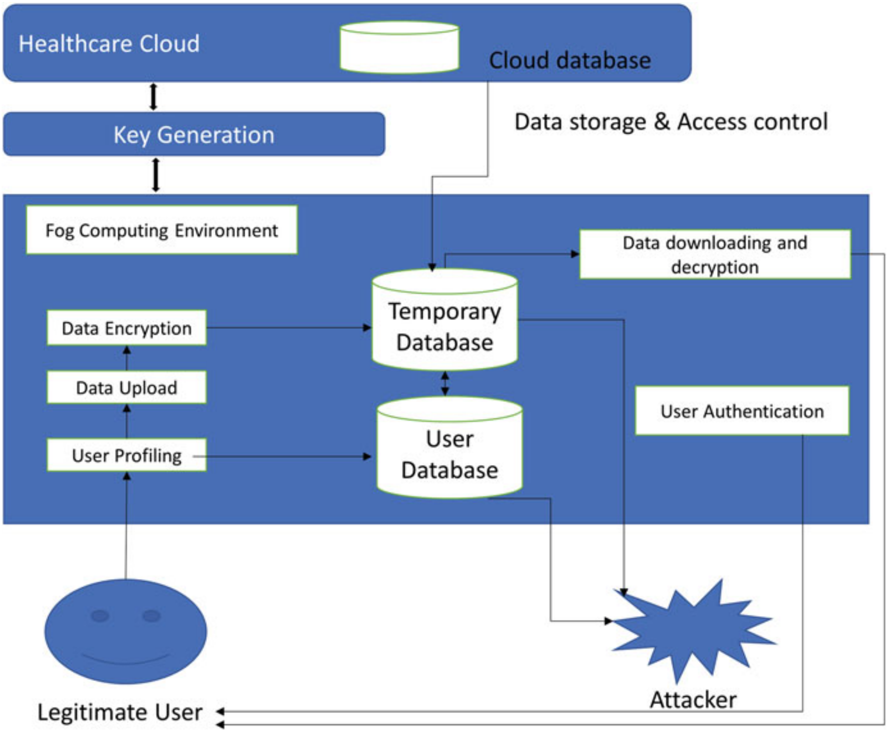

Fig. 13.8 Security model using fog techniques for healthcare

1. Send or get demands with self-assertive tasks to/from other fog gadgets and servers.
2. Procedures information acquired from the end-clients.
3. Send information to the cloud server which requires huge information handling.

13.7.4 Various Modules

1. Client validation and HMAC extraction in the fog server for authenticating the client regarding any data access.
2. Secure Communication for common understanding: Private Key Generator server produces private and open keys utilizing Diffie-Hellman elliptic bend cryptographic technique.
3. Picture Encryption and Decryption: Blowfish calculation is utilized.
4. Distraction Image Creation in the fog while sending an encoded picture to the cloud.
5. V2I Binding Algorithm for Secure Video Files.

13.7.5 HMAC Algorithm

A Hash-based Message Authentication Code calculation is utilized to demonstrate trustworthiness and validation of the message of n-bits length. Here a hash work and a mystery key are utilized to check whether the transferred information adjusted/altered during transition from one node to another or not. Various gatherings will hash the message again themselves with the mystery key. The got and figured hashes will coordinate on the off chance that it is legitimate. The key utilized is a mutual key between parties. We need to cushion zeros on the left half of the mystery key until it becomes n-bits.

HMAC calculation utilizes two goes of calculations to make HMAC code. During first pass, we XOR padded mystery key with the i_pad. The yield got in the above advance is annexed with the plain content at that point apply a safe hash calculation (SHA-512) which produces n-bits yield. At that point during second pass we XOR padded mystery key with the m_pad. The yield acquired is annexed with the yield of the principal pass at that point apply SHA-512.

13.7.6 Client Authentication and HMAC Extraction

In the primary module, half and half client conduct profiling technique is utilized for client profiling, which identifies any abnormal information get to design and to discover whether a client is authentic or not. This module likewise incorporates extraction of HMAC data. At that point join this data in the header part of the information.

The clients are encouraged here to confirm and in this manner, guarantee that solitary substantial clients can get to the application. The cloud clients have some obvious thought of their own when they are getting to administrations. That is, their inclinations, search design, span of access time, sorts of activities, and so on. In addition, they realize the record name that is transferred and its substance. So we have to keep a log record utilizing a half and half client conduct profiling calculation. So that as needs be we can divert the clients to the fake application to evade unapproved get to. This should be possible dependent on the log record subtleties under the accompanying suppositions:

1. Just a limited hunt performed by a genuine client while searching for a specific record.
2. An intruder shows a wide search example to take information since he does not have total mindfulness about the documents and their substance. He needs to open each document to discover fascinating information.

The subsequent parameter to gather client's genuine conduct is their mouse exercises. That is mouse clicks per client session, normal separation went by mouse per session, session time, login time, Macintosh address data for making client profile, and so forth are gathered by the framework to follow client's continuous conduct and this data is utilized to discover authenticitsy by contrasting and the prior examples at whatever point every session starts.

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Chapter 14
Data Security and Privacy Functions in Fog Computing for Healthcare 4.0

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14.1 Introduction

IoT is one of the advanced innovations to provide more benefits to society. The primary objective is to connect people and the real-world physical things through the Internet without human intervention [1] and also to reduce the efforts of humans by collecting the data. IoT uses different types of sensors to gather data from different locations and enables data to be automatically stored or processed depending on the application. The hardware components used in IoT systems include devices such as a remote monitor, control devices, servers, routing devices, and sensors. These devices manage critical tasks and function like system activation, specifications for action. IoT devices are used in many applications. The main challenging characteristics are low computation power, storage, and security. Cloud computing provides the place for aggregation of sensor data and provides the storage access for data analysis. However, data access dependency entirely in the cloud server is not feasible for any situation. Hospital regulations also not allow storing patient data outside the hospital. Patient safety and privacy are affected due to network and data center failures. Healthcare services and applications depend on cloud computing and do not satisfy the need for healthcare 4.0 environment.

One of the possible solutions to solve these issues is by employing computing technology in healthcare. Fog computing provides the on-time service delivery and reduces delay in data transmission. To overcome the issues of IoT, CoT (Cloud of Things) techniques are proposed. In the late 1990s, several professional groups

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strove to build Wireless Personal Area Networks (WPAN) at Massachusetts Institute of Technology. Several information devices are linked to the human body, and electric field sensing was employed to find out the status of the human body. However, the technique is expensive and consumes more power. Besides, the communication system does not satisfy the requirements of the healthcare system, such as flexibility, mobility, and privacy. The Wireless Body Area Network (WBAN) with smaller energy consumption, which in turn improves the lifetime of the network, overcomes these pitfalls. The wireless physiological sensors are used for measuring the medical information of the patient, which is transmitted through a wireless medium to remote users. It is essential to protect the data from attackers. Hence, the sensors are employed for tracking the health status of the patient. The CoT simplifies the flow of data, processing, and integration of complex data processing. The integration of cloud and IoT is used in more applications and brings more advantages. The more IoT devices which are used in the heterogeneous platform is a difficult task to retrieve and store the data in the cloud. Massive amount of data is sensed from different sensors and devices to the cloud, which requires high network bandwidth, and also the processing of the data is also high. The centralized cloud computing is not appropriate for IoT applications, due to poor internet connection and time-sensitive [4]. To overcome the various issues in CoT, fog computing comes into the picture. Fog computing is introduced by Cisco to address most of the challenges in CoT. Fog computing technology combines the study of mobile communications, big consumer data, distributed systems, and micro-clouds. This technology is applied in many fields; one of the critical field is IoT to process and store the data. Like the cloud, the sense data from the IoT devices is stored in the fog devices instead of the cloud. It also provides networking resources, storage, and computation. The main goal of fog computing in IoT is to reduce the amount of storage in the cloud, improve the efficiency, processing, analysis of data, and reduce the traffic in a network. Fog computing enables a different variety of services in different applications for IoT devices [2, 3]. The main goal of fog computing is to reduce the vol. of the data, improve QoS, decrease latency, reduce the security risks, and traffic to cloud servers. IoT applications need a real-time requirement that cannot be fulfilled in traditional cloud computing. So fog computing gives a solution to tackle this problem and provides low-cost resources. Several works have proposed in more applications such as health monitoring systems and vehicle networks by applying fog computing to IoT applications. The applications that run in a sandbox environment but still few security issues may persist in the fog.

Fog computing resources are integrated into access points, router, and network gateways. They perform the task of filtering, aggregation, and temporarily storing data. Fog computing can be performed on a single fog node or several nodes. Electrocardiogram (ECG), electroencephalogram (EEG), and electromyograms (EMG) sensors require more bandwidth for transmission of medical data. The security requirements of healthcare are high. Fog computing nodes can filter data to preserve the privacy of the data and reduce the load of the network. Fog computing leads to more complexity among the devices like sensor nodes and fog computing nodes.

A trust management system is required for the association between the devices for security and privacy of medical information. Unauthorized users should not access end-user information.

14.1.1 *Characteristics of Fog Computing*

Fog computing software is suggested to solve the CoT issues. It is an internet extension, but the IoT software operates closer to the end-users. It has fog nodes, which are shown in Fig. 14.1 as the intermediate between the IoT devices and the cloud. With a network connection, the fog nodes are placed everywhere.

The few characteristics of fog computing can be summarized as follows:

1. Location awareness
2. Scalability
3. Support for mobility
4. Real-time interactions
5. Online analytics
6. Interoperability

The benefits of fog computing are geographical and large-scale distributions, lower operating expense, flexibility, and scalability.

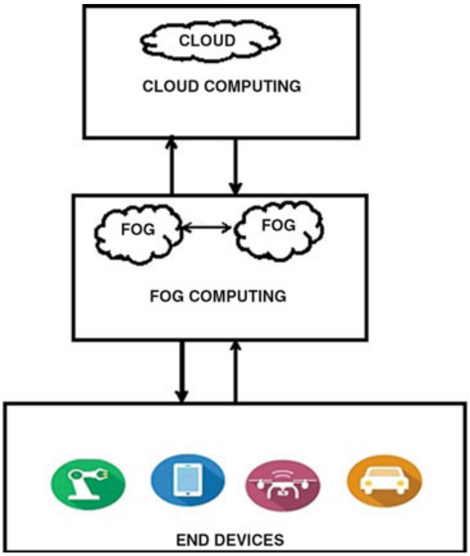

Fig. 14.1 Fog computing enabled IoT

14.1.2 Motivation

Medical information is highly confidential, so anonymity is desired. The patients should also be confident of data privacy. Nonetheless, WBANs adopt the distributive architecture and may undergo data leakage. Incorporating cryptography and access control systems to provide data privacy will address the issue of data leakage. However, establishing security and privacy mechanisms in WBAN is a challenging task due to power or energy constraints. The implementation of safety mechanisms must not affect device performance and efficiency. The above security issues are to be addressed while designing a healthcare application. There are many challenges to be overcome while designing the mechanism for security and privacy of WBAN. Big data is transmitted to networks for the ultimate purpose of remote monitoring by end-users such as caregivers or physicians. Fog computing, therefore, suits these devices perfectly. It is agreed that fog computing is cooperated and integrated with the cloud to improve current IoT applications instead of eliminating or reducing the cloud's position in IoT applications.

14.2 Related Work

Rongxing Lu et al. [1] implemented a lightweight aggregation scheme for data. The LPDA proposed in this paper is characterized by the use of the Chinese remainder theorem to aggregate data from hybrid IoT devices into one, and the use of the one-way hash chain to early execute source authentication at the edge of the network. We studied the overhead communications of LPDA technologically, also carried out extensive tests to determine the computational costs of LPDA and the results show that LPDA is very lightweight and suitable for IoT fog computing.

Ximeng Liu et al. [2] highlight the promise and challenges faced in IoT and fog computing by this emerging area of security and privacy challenges. Also, their publications describe the IoT-fog scenario's further research related to security and privacy concerns. The paper by Xuyun Zhang et al. [3] studied various security and privacy techniques to find the various intrusion detection and prevention techniques on the fog computing environment.

Farouq Aliyua et al. [4] proposed the Man in the Middle (MitM) intrusion detection system, and intrusion prevention system targets the fog sheet. The proposed system uses asymmetric encryption techniques of the Advanced Encryption System (AES), while key authentication is shared using key exchange Diffie–Hellman.

In [5], the authors explored the fog computing environment by combining sensor, cloud, and fog node. It also highlighted the need for various security technologies to configure the stable fog computing environment. Abebe Abeshu Diro et al. [6] proposed the protocol for the Internet of things, which is a more secure and Publish-subscribe a lightweight protocol based on fog computation using elliptic curve cryptography. The usage of a resource is lower, message sizes are reduced, and key lengths are shorter. This scheme provides better scalability. The authors from [7] proposed a new framework for fog computing called PEN. This is low in cost and low powered embedded board with neural computing pin, which is built on smartphones. They developed two prototypes based on the framework to incorporate the visually impaired movement guide. The virtual dog guide system is designed for miniature service, including a robot dog, a wheelchair, model cars, traffic lights, and traffic blockage. The model is a portable full-size guidance device that can be used in a real environment by a visually impaired person. In [8], the authors proposed re-encryption of the proxy based on the ECC. As a lightweight encryption scheme, this research proposed re-encryption of the fog-to-things proxy based on the ECC. The security scheme was evaluated for the efficacy of encryption and decryption runtime, and the expansion of ciphertext throughput. The authors concluded that IoT's lightweight protection mechanisms can be realized by unloading the security features of IoT to fog nodes for resource constraints and using ECC for its smaller message sizes. The authors of [9] proposed the protection of the privacy of publish-subscribe content to achieve privacy and security in the fog computing environment. Using U-FIM, this proposed method will find top-k attributes for every case. By using Laplace and exponential mechanisms, differential privacy can be achieved. Complex attributes are used to match the event of users correctly.

Yinghui Zhang et al. [10] proposed privacy algorithm, data aggregation protection based on the Paillier homomorphism encryption in the world of fog apps. The suggested scheme ensures that the inserted data originates from genuine IoT devices and is not abused or leaked, whether the fog node and the cloud control center are real or not. Many fog sensors failed to do their job, although they will not be affected by data collection from other devices. There is some tolerance of fault due to this proposed method. The authors studied the fog-driven IoT healthcare system in [11], which will concentrate on encryption and key agreement only. So the authors suggested a central agreement protocol, approved by three parties. The new security model was introduced, and a security proof was presented, even providing the security analysis against the attacks. Also evaluated in this paper are communication and computational costs. In [12], it tells about de-duplication in half and half cloud of private information. This technique would restrict the storage of information and the capacity to transmit it. In the paper [13], ProsantaGope et al. have proposed a new privacy-conserving security architecture with the cooperative D2D communication support for the fog computing model. Three lightweight, anonymous authentication protocols (LAAPs) are being built to support the proposed security architecture. The proposed resource-constrained edge system scheme is stable and acceptable. The authors of [14] examined vehicle fog computing on the basis that they built the model that could estimate the potential computing power of a vehicle fog and analyze the effect of the contact range on the capability. Vehicular fog computing computation capacity is also presented by using temporal and spatial distribution. In [15], overall latency of scheduled IoT service requests is minimized in the proposed work. Raafat Aburukba et al. [16] propose adaptive performance and energy awareness for the computational environment.

The suggested approach is tested using the Fog-IoT.IFogSim simulator. In [17], a generic architecture was proposed to deploy fog computing applications and services within a VANET framework. Mobility traces of actual vehicles are used to test the efficiency of the proposed work [18]. Two-step migration algorithm is proposed in the paper entitled: Mobile-aware service chain migration in cloud–fog computing, which will minimize downtime and migration costs [19]. Fog bus is used to develop an application and also allows the users to run multiple processes at a time. So the service providers will share their resources effectively. To access sensitive data, secure operations like encryption, authentication, and blockchain techniques are applied. Characteristics of fog bus are also evaluated based on the existing methods.

Indira et al. [20] proposed the intrusion detection system for VANET. Clustering is done by the grouping of direct-link nodes, which can randomly and impartially select a monitoring node, the Cluster Head (CH). The CH provides security by collecting information from other Cluster Members (CM) and making a database and executing an intrusion detection algorithm on cluster head only instead of running IDS on every VANET Node (VN).

In selective encryption, the authors suggested secure communication between the sensor nodes. The RC6 algorithm is used for selective encryption [21]. Ajitha et al. [22] proposed the smart parking by defining the congested traffic area, monitoring the free slot area, reserving the free slot area, and efficiently allocating it to customers. Natarajan et al. [23] proposed that the current cloud auction system frequently overlooks resource sharing, but does not fulfill the cloud users' provision of dynamic resources.

It uses a static sensor node that collects the accumulated information from different nodes in its Zone of Reference (ZOR) region and transmits this collected information to AUV when entering 3-D ZOR, hence the energy used for transmission [24].

This method senses the amount of energy about a linked node and also takes the highest-energy route to transmit data to the surface location node. In the event that surface position node is occupied with contacts, an update instruction will be given to the successor sub-aquatic neighbor to take a replacement surface position node to avoid data loss [25].

A comparison is made and summarized between different models of data fusion. Nonetheless, it is necessary to develop and enforce an efficient model that supports data decomposition [26]. This system is designed specifically for both security and QoS, insecure system for data aggregation, and iteration filtering algorithm for sensor data validation. If any false data is found, which node should submit the data will be removed by a network will also boost the network's QoS [27].

Healthcare 3.0 was a medical center where patients with long-lasting conditions suffered a great deal from frequent hospital visits during their routine check-ups. This, in turn, increased the coverage of such patients, as well as an increase in overall spending on patient care. Nonetheless, these problems are mitigated with a minimum investment in processing and storage facilities related to patient data for the recent advances in technology such as fog and cloud computing. Motivated by these findings [28] provides an overview of the role of fog computing, cloud computing, and the Internet of Things in delivering uninterrupted context-aware services to end-users as and when required. We propose a three-layer, patient-driven healthcare system for real-time data collection, analysis, and distribution. This offers end-users insights into the applicability of fog tools and gateways in the Healthcare 4.0 framework for current and future applications [29]. The book discusses all aspects of IoT complexity management for Multimedia Big Data Computing (MMBD) applications and offers a comprehensive taxonomy. It also discusses a process model that addresses a number of research issues related to MMBD, such as scalability, usability, performance, heterogeneity, and quality of service (QoS) criteria, providing case studies to prove its application.

The Internet of Things (IoT) has grown significantly in recent times, due to its large number of applications in different areas [30]. IoT affects people's lifestyles significantly. In the IoT market, it is expected to be as big as $2000 billion. Several IoT applications such as smart building, smart home, smart city, and intelligent transportation have recently become popular. Use of blockchain, various transactions, and database records can be efficiently tracked to ensure consistency and predictability in the aforementioned industrial sectors. The open problems and challenges that 5G-enabled IoT poses for blockchain-based industrial automation are also discussed in [31]. Finally, a comparison of current proposals regarding different criteria is given, which allows end-users to select one of the proposals over the others as opposed to their merits.

The current state-of-the-art systems that handle the security of EHRs have made it virtually difficult for patients to access the data. Such systems fail to provide a reasonable balance between data protection, patients, and caregivers having to interact frequently with data. The above problems are solved by blockchain technology [32] because it shares the data in a decentralized and transactional manner. This can be used to protect the healthcare sector's balance between the privacy and transparency of EHRs. In this paper, we suggest a blockchain-based system to store and manage EHRs securely. That also ensures safe and effective access to medical data.

The E-Health cloud model has evolved from the collaboration and expanded sharing of valuable information between various medical facilities, hospital systems, and care providers. The goal of the system [33] is to cut costs and make production processes. Preserving the security of the health record and identity of a patient is one of the major concerns of the cloud-based model. Fear of privacy loss is the major bottleneck for a wider scope of future cloud uses. But [34] needs for that public transport to be effective. Citizens should not have to wait for the bus for a long time without having any idea about when the bus will arrive. Therefore, people should get a seat for the bus. Ensuring that the buses are scheduled and run effectively and reliably is of paramount importance. In fact, the buses are now scheduled as required. But that preparation is done manually in India. In WBAN [35], secure encryption is described in wireless body sensor networks using a compression method. Studied by Kumari et al. [36], the authors discuss and offer an overview of how to handle secure streaming data from different devices. The paper explores the unique nature and challenges of IoT-related MMBD computing.

14.3 Proposed Work

The fog computing system includes IoT network interaction, fog nodes (FN), and cloud storage. Secure data transfer is needed for this environment. Unauthorized fog nodes spread the wrong information to the users and devices. Fog nodes provide services based on the information collected from IoT devices. If false data is injected into the IoT system, the interaction will be disrupted, causing incorrect control center decision. Therefore, during data transmission, a desirable mechanism is needed to protect the data from attackers and filter the false data injected.

The IoT network consists, under our system design, of a set of heterogeneous IoT devices I = {I1, I2, … I N}, fog devices deployed at network edge, control center and trusted authority, as shown in Fig. 14.2. Fog devices are a significant component of fog computing that is installed at the edge of the network. It serves as a conduit between IoT and control center devices. The control center collects all of the information from IoT device and conducts application-based data analysis activity.

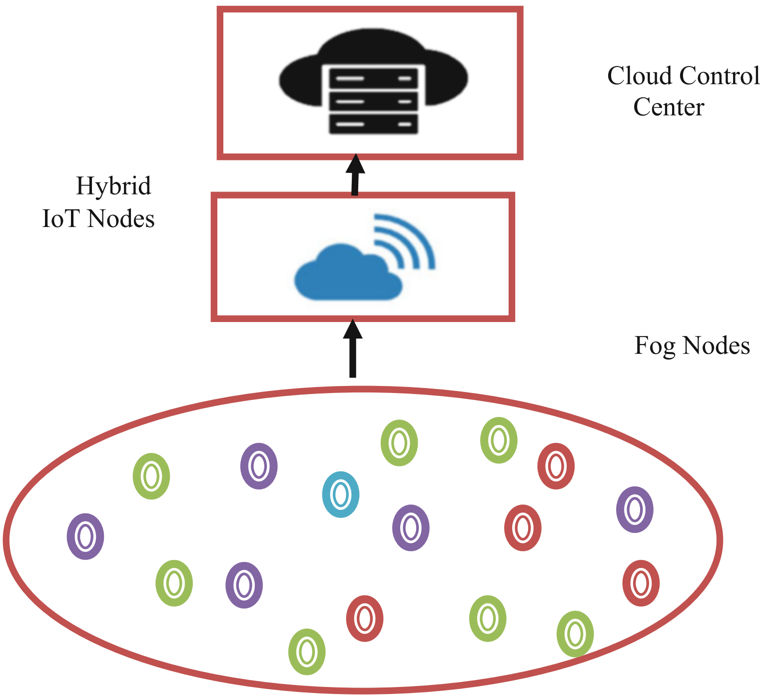

Fig. 14.2 Fog node deployment

Malware can affect control center and fog devices which eavesdrops the IoT data. Intrusion detection and prevention program monitoring the IoT tools, networks, and applications for inappropriate behaviors and any regulation violations.

It is the responsibility of the cloud control center to generate network parameters to register the IoT devices and fog nodes. The control center interacts with the IoT devices through the internet network when the malfunction of an IoT system occurs during the transmission phase, since it is often essential to ensure the aggregation process without affecting the information associated with other users.

In particular, the following objectives should be achieved:

1. To minimize the computation cost and encryption time.
2. To identify the malicious fog node and maintain the integrity of the data.
3. To design the authentication protocol for protecting data transfer between the fog nodes and cloud.
4. To design the lightweight security scheme for data protection.

Figure 14.2 Proposed work flow diagram

The fog devices are responsible for transmitting data packets within their range between the control center and IoT devices, aggregating the data obtained from the complete set of IoT devices, finding failed IoT devices, and reporting the details to the control center to initiate effective countermeasures. Under the abovementioned security model, our goal is to propose a lightweight security scheme for security and privacy in the IoT environment and develop the intrusion detection system for detecting.

14.3.1 Process of Registration

The process of registration consists of IoT device registration and fog device registration. In the initial phase, IoT devices need to register with the aggregation, i.e., fog node for communication. All the hybrid IoT node IDS are stored in the fog node.

Data transmission between biosensors and SH.

Step 1: Forward (J_{Rq}, S_{id}) to FN

Step 2: Wait for approval from FN

Step 3: if (approval = positive)

Step 4: Generate key value using polynomial

Step 5: Encrypt the sensor values using modified TEA algorithm

Step 6: Forward encrypted data S_{id} and MAC to the FN

After the generation of key value, the encryption is performed by using the symmetric key. When an IoT device needs to transfer data to the FN, a D_R along with the SH_{id} and timestamp is sent to the FN. The D_R is verified by the FN and the randomly generated key for data transmission which is provided back to the

SH. We developed key generation and update methods for secure data aggregation among the hybrid IoT nodes. We employ Chebyshev polynomial P to achieve the data aggregation.

$$T_{n+1}(x) = 2xT_n(x) - T_{n-1}(x) \tag{14.1}$$

FN verifies the IoT device ID and sends the polynomial coefficients P to the authorized IoT devices. The x value of the polynomial is substituted by device ID. IoT devices have polynomial coefficients and ID values. When it will need to send the data to the fog node, using Chebyshev polynomial generates the secret key.

$$I_i \rightarrow FN : \{I_{id}\} \tag{14.2}$$

$$FN \rightarrow I_i : \{P\} \tag{14.3}$$

$$I_i \rightarrow FN : \{D_r\, |I_{id}|\, ts\} \tag{14.4}$$

The knowledge about the IoT unit is expressed by M, which is divided into two halves: Left[0] and right[0]. M' represents the ciphertext, which is split into halves left [64] and right [64]. Every half of the plaintext is used to encrypt the other half across 64 processing rounds, and then the ciphertext block is combined to create. The 64 bits of plaintext are split into two types of inputs each having 32 bits. The encryption method can be used with four passkeys. The initial Z input value is moved with 4 bits at first left, and the output is applied with the first passkey, obtained using the critical method of generating polynomials. The polynomial coefficients are generated using the pseudo-random generator. Four passkeys are used for encoding in the encryption process. The key value for first pass can be extracted from the polynomial. Then the main key value of the first pass can be used as a seed point to produce the key value of the second pass.

$$P(x) = a_nX^0 + a_{n-1}X^1 + a_{n-2}X^2 + \ldots.. + a_0X^t \tag{14.5}$$

The next steps are to reuse the initial z input value to undergo a 5-bit right-shift and store the result in the memory afterwards. The key is broken into four 32-bit blocks, k[0] to k[3]. In addition, the XOR and AND operations are used. Furthermore, the dual shift operation achieves regular mixing of all plaintext and main bits. A simple key schedule is used for both encryption and decryption, and the four 32-bit blocks of the key for each step are combined in exactly the same way. The magic constant is used when measuring the key.

For ith cycle

$$\text{Left}[i] = \text{left}[i-1] + F(\text{Right}[I-1], \text{key}[0,1], \text{delta}[i]) \quad (14.6)$$

$$\text{Right}[i] = \text{Right}[i-1] + F(\text{Left}[i-1], \text{key}[2,3], \text{delta}[i]) \quad (14.7)$$

14.3.2 Fog Device Registration

In the privacy-preserving scheme in fog computing, the control center collects the data from the associated fog devices in a specific time period. The control center sends the request for data collection. In the key generation process, the following procedures are involved here.

Step 1: The FN generates two big prime numbers p and q.
Step 2: Calculates N = p.q.
Step 3: FN generates randomly an invertible matrix.
Step 4: FN calculates the inverse of K.
Step 5: Secret key is calculated from K and inverse of KK $_{sk=\left(k_1, k^{-1.}_{1,K,K^{-1}}\right)}$.

Cloud storage is unconfident, and unreliable computations over encrypted data can be incorrect. On the aggregated data, addition and multiplication were performed in fully homomorphic encryption. The chosen-ciphertext fully homomorphic encryption scheme is provided in this section with the following parts: system initialization, data collection, reporting derived from IoT devices, data aggregation. Let M be room for post. The CC FHE is described as:

Gen (1α): A randomized algorithm which outputs a public key, secret key pair (P_k, S_k)
Enc (μ,P_k): A randomized algorithm which outputs a ciphertext M'
Dec (M',S_k): An algorithm that outputs a message $\mu \varepsilon$ M.
Eval (M',C): An algorithm that takes a collection of ciphertexts (M'_i) and circuit to be evaluated C and outputs an evaluated ciphertext M'_{eval}.

14.4 Performance Analysis

The performance of enhanced tiny encryption algorithm is verified by analyzing and comparing its security and efficiency with other existing algorithms. The key size used in the algorithm is 128 bits. Files of different sizes like 0.25 KB, 0.50 KB, 0.81 KB, 1.5 kB, 5.5 KB, and 6.9 KB have been taken as input, and it has been transmitted using 128 bit key from the sensor to the fog. The encryption and decryption time is less compared to other existing algorithms, and the data has been transferred more securely using the algorithm (Table 14.1).

Table 14.1 Encryption time for a key size of 128 bits from STF

File Size(in kilobytes)	RC4	XTEA	ETEA
0.25	0.041	0.082	0.035
0.50	0.091	0.182	0.089
0.81	0.118	0.256	0.101
1.5	0.200	0.399	0.189
5.5	0.781	1.423	0.653
6.9	0.888	1.658	0.799

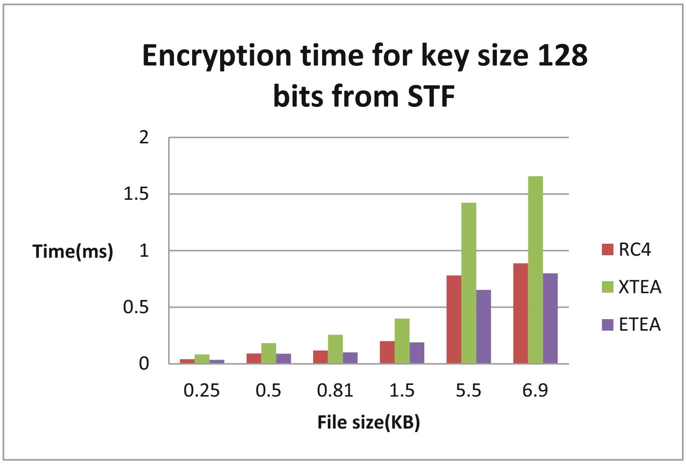

Fig. 14.3 File Size vs. Encryption time for STF

Table 14.2 Decryption time for a key size of 128 bits from STF

File Size(in kilobytes)	RC4	XTEA	ETEA
0.25	0.039	0.079	0.031
0.50	0.089	0.172	0.083
0.81	0.112	0.250	0.100
1.5	0.198	0.391	0.187
5.5	0.777	1.420	0.644
6.9	0.883	1.654	0.781

From the above table, the enhanced tiny encryption algorithm has taken less time compared to the existing algorithm. For the file size, 0.25 KB RC4 is 0.006 ms higher than enhanced tiny encryption algorithm, and the extended tiny encryption algorithm is 0.047 ms higher than the proposed algorithm. Similarly, for the file size of 6.9 KB, the enhanced tiny encryption algorithm takes .009 ms less than RC4 for the encryption and takes 0.859 ms less time compared to the extended tiny encryption algorithm. Figure 14.3 shows the encryption time analysis.

Similarly, the decryption time to transfer the file from the sensor to the fog environment using the enhanced tiny encryption algorithm has been calculated and compared with the existing algorithm (Table 14.2).

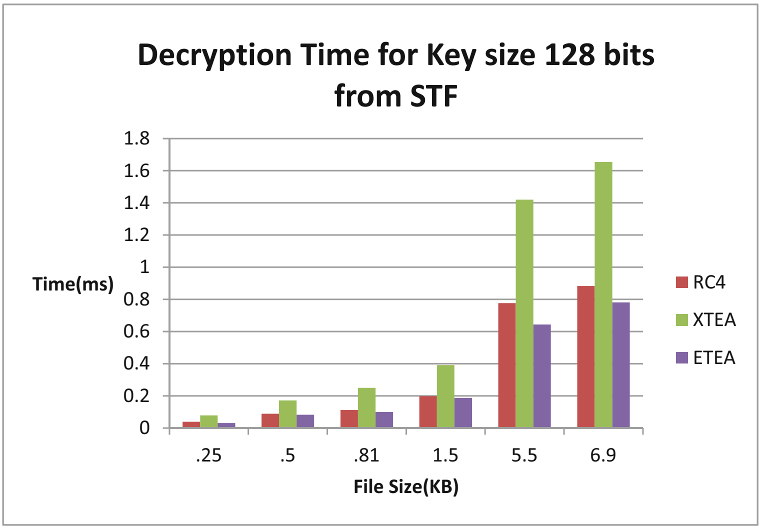

Fig. 14.4 File size vs. Decryption Time for STF

Table 14.3 Encryption time for a key size of 128 bits from FTC

File Size(in kilobytes)	RC4	XTEA	OFHE
0.25	0.080	0.167	0.071
0.50	0.149	0.234	0.134
0.81	0.289	0.456	0.231
1.5	0.432	0.856	0.412
5.5	2.854	4.879	2.653
6.9	3.456	6.675	2.799

From the above table, the enhanced tiny encryption algorithm has taken less time for decryption compared to the existing algorithm. For the file size, 0.25 KB RC4 is 0.007 ms higher than enhanced tiny encryption algorithm, and the extended tiny encryption algorithm is 0.048 ms higher than the proposed algorithm. Similarly, for the file size of 6.9 KB, the enhanced tiny encryption algorithm takes.102 ms less than RC4 for the decryption and takes 0.873 ms less time compared to the extended tiny encryption algorithm. Figure 14.4 shows the decryption time analysis.

The data has been transferred from the fog to the cloud using an optimized, fully homomorphic encryption scheme. The time taken for the encryption and decryption of the file is very less compared to the existing algorithm (Table 14.3).

From the above table, the optimized, fully homomorphic encryption algorithm has taken less time compared to the existing algorithm. For the file size, 0.25 KB RC4 is 0.015 ms higher than the optimized fully homomorphic encryption algorithm, and the extended tiny encryption algorithm is 0.096 ms higher than the proposed algorithm. Similarly, for the file size of 6.9 KB, the optimized, fully homomorphic encryption algorithm takes .657 ms less than RC4 for the encryption

Table 14.4 Decryption time for a key size of 128 bits from FTC

File Size(in kilobytes)	RC4	XTEA	OFHE
0.25	0.079	0.151	0.051
0.50	0.138	0.222	0.120
0.81	0.281	0.399	0.220
1.5	0.411	0.801	0.390
5.5	2.671	4.567	2.451
6.9	3.001	6.423	2.387

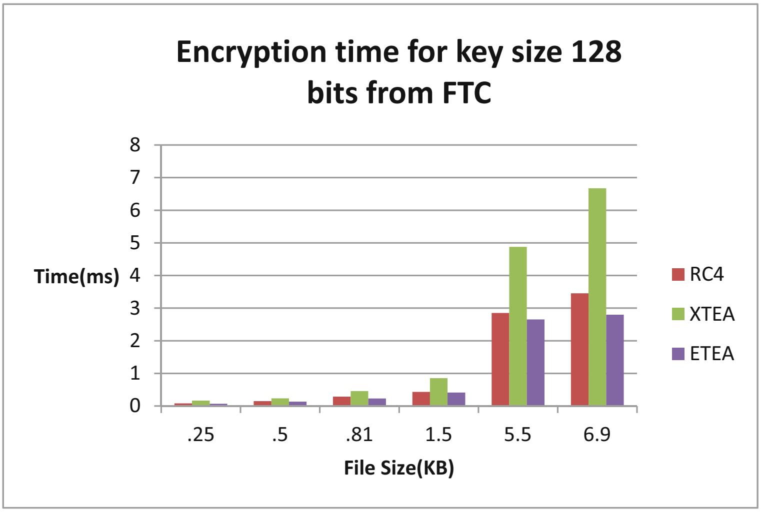

Fig. 14.5 File size vs. Encryption time for FTC

and takes 3.876 ms less time compared to the extended tiny encryption algorithm (Table 14.4 and Fig. 14.5).

From the above table, the optimized, fully homomorphic encryption algorithm has taken less time for decryption compared to the existing algorithm. For the file size, 0.25 KB RC4 is 0.028 ms higher than the optimized fully homomorphic encryption algorithm, and the extended tiny encryption algorithm is 0.100 ms higher than the proposed algorithm. Similarly, for the file size of 6.9 KB, the optimized fully homomorphic encryption algorithm takes .614 ms less than RC4 for the decryption and takes 4.036 ms less time compared to the extended tiny encryption algorithm (Fig. 14.6).

The measurement measures used in the proposed study are the overhead contact and the detection rate. The proposed system's misbehavior detection detects and classifies all nodes correctly, as the system sorts the data in increasing order and compares the data provided with each other to detect the false data. The suggested node is used to detect misbehavior. The comparative methods may lead to a decrease in the detection rate as they are focused on tracking the actions after the data or

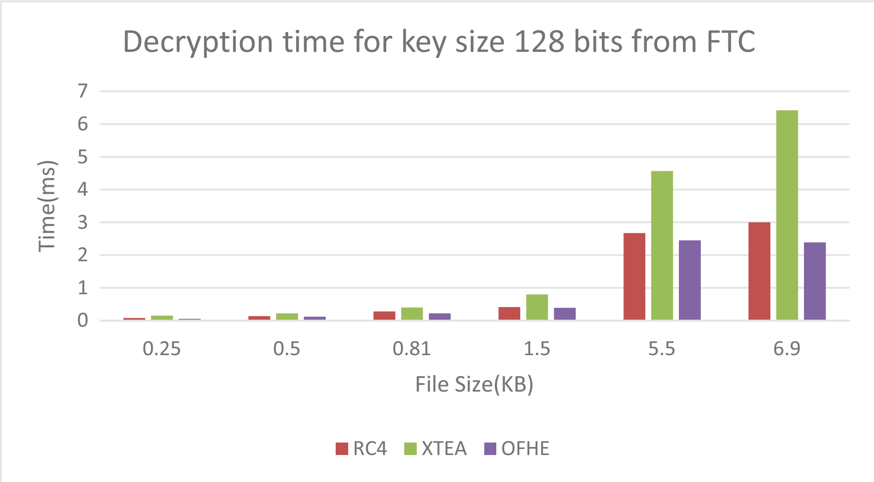

Fig. 14.6 File size vs. Decryption time for FTC

Table 14.5 Number of attackers

Percentage of Attackers	Existing System	XT	OFHE
5	88	100	100
10	88	100	100
15	80	99	99.7
20	79	97	98
25	75	95	96
30	70	90	93
35	65	88	90
40	60	86	88

Table 14.6 Number of devices

Number of IoT Devices	Existing System	XT	OFHE
200	0.7	0.3	0.3
400	0.8	0.5	0.55
600	0.88	0.5	0.6
800	0.9	0.6	0.65
1000	0.95	0.65	0.7

reputation scores are given, while the proposed method provides a high detection rate as it compares the data supplied from the current system (Tables 14.5 and 14.6; Figs. 14.7 and 14.8).

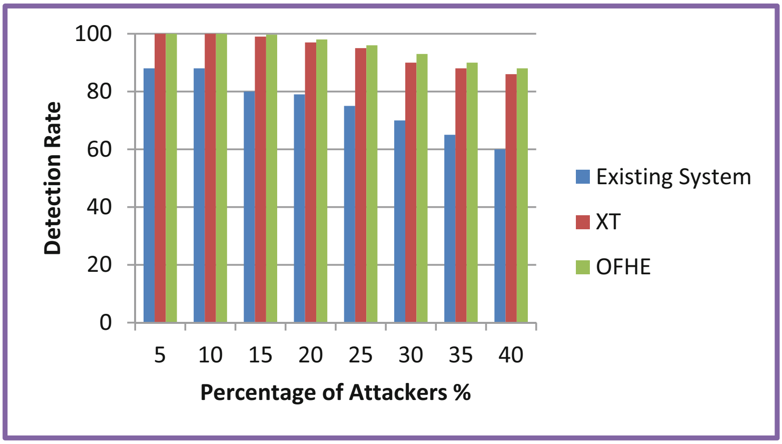

Fig. 14.7 Detection rate

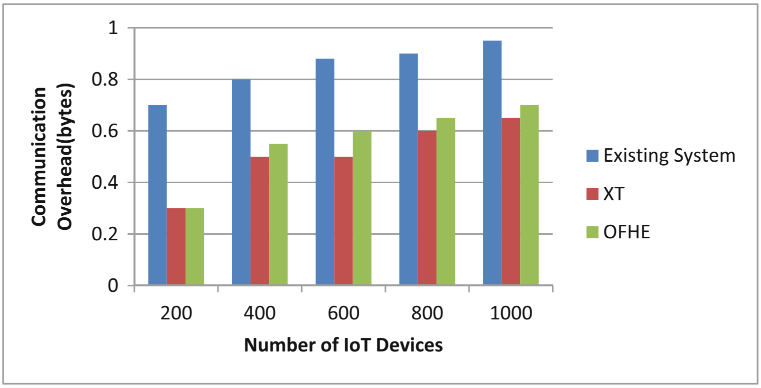

Fig. 14.8 Communications overhead

14.5 Conclusion

The time of encryption and decryption is less than that of other current algorithms, and the data was transmitted more efficiently using the algorithm. The proposed system's misbehavior identification identifies and classifies all nodes correctly, as the system sorts the data in increasing order and compares the data provided with each other to identify the false data. The data was moved from the fog to the cloud using a fully homomorphic encryption scheme optimized. The time taken for the encryption and decryption of the file is very less compared to the existing algorithm.

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Chapter 15
Fog Computing Application for Biometric-Based Secure Access to Healthcare Data

Sreekantha Desai Karanam, Shashank Shetty, and Kurup U. G. Nithin

15.1 Introduction

Healthcare 4.0 industry standards promote a patient-centric healthcare service delivery at his doorsteps. Fog computing paradigm leverages us to deploy the power of cloud computing at the edge devices in IoT networks to leverage cost-effective communication, storage, and computations. “Fog computing is a term created by Cisco that refers to extending cloud computing to the edge of an enterprise’s network.”

“Fog Computing also is known as Edge Computing or fogging facilitates the operation of computing, storage, and networking services between end devices and cloud computing data centers.” Edge computing also enables security, mobility, privacy, network bandwidth, and low latency features in IoT networks. These features are essential to design a real-time healthcare management system. A biometric security system ensures secure and perfect access to a system compared to alphanumeric-based passwords in the digital world. Biometric security can be further strengthened by adopting multi-model authentication. In the IoT domain, every edge device will have a unique network address assigned by the IPV6 system. Only the authorized end-users can access and control these edge devices to access IoT-enabled services protecting their privacy. These edge devices provide secure access for authenticated users through a biometric mechanism by verifying their digital credentials in real time. This secure access mechanism can also be made context-aware to understand user-specific requirements. High-security systems can

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implement a combination of fingerprint, face recognition, and iris scanning to assure the highest safety and privacy for authentication of the end-users.

15.1.1 Evolution of Technological Shift from Healthcare 1.0 to Healthcare 4.0 Standards

The major focus of Healthcare 1.0 is to reduce the manual and paperwork to enhance productivity. Healthcare 2.0 focused on data processing and sharing with organizations. Healthcare 3.0 introduced patient-oriented IT solutions, while healthcare 4.0 objective was to provide real-time tracking of patient conditions and provide on-site medical assistance. Healthcare 1.0 has progressed from the computerization of healthcare data processing to real-time, on-site patient healthcare diagnostics and context-aware AI-based solutions. The healthcare data/information sharing is initiated within the hospitals and extended to the cluster of healthcare providers across the country. Healthcare 4.0 promotes healthcare data sharing across the globe conforming to technical and statutory standards. The technologies for Healthcare 1.0 were information technology solutions for hospital administration, extended to Electronic Data Interchange (EDI), cloud computing, big data, big data analytics, fog computing, IoT, Electronic Medical Records (EMR), wearable devices, block chain, and artificial intelligence technologies. Today the major challenges faced in Healthcare 4.0 are interoperability, conforming technical standards and ensuring privacy, security, and confidentiality of data as per prevailing statutory framework [38].

15.1.2 Fog Computing for Enhancing Biometric Security

The edge computing helps us to solve the difficulties connected with safety and confidentiality of biometric signatures by improving security and privacy of critical patient information. The intrinsic properties of fog computing permit additional advantages of computing features which are essential for ensuring the privacy and security-sensitive data access by computing important data at the fog nodes and transmitting the secure and encoded data to cloud after processing.

15.2 Review of Recent Related Literature

Researchers have carried out an extensive survey of research papers on healthcare 4.0, fog and cloud computing applications from Springier and Elsevier publications since the year 2007. The findings are revealed in the following discussion. A healthcare 4.0 architecture having three processing layers based on fog computing was presented [1]. This architecture is used to implement an analysis of patient-centric healthcare data. Two case studies were presented to confirm the effectiveness of this system. It is mandatory to assure the security and confidentiality of data on the health of a patient by law. In healthcare domain, providing secure access to information is the most critical aspect.

The biometric features are used for authentication of end-users of health data, since these personal features will not be forgotten, hired, purchased and also are very hard to duplicate [2]. Ensuring data security in pathology labs is most crucial in the design of smart medical systems [3]. The generation of a binary string of varying length of bits, corresponding to the range of patient heart beat rate to incorporate quality and security features in Wireless Body Sensor Networks (WBSN) using Random Binary Sequences (RBS) generation method is called adaptive computing. A protocol based on the Squared Secure Biometric Authentication (SSBA) metric is used in a cloud platform. This protocol protects the confidentiality of the critical data and ensures a safe identity in the cloud computing infrastructure [4]. Governments are promoting unique biometrics-based identification for their citizens for authentication purposes to provides passport services, driving license, voter cards, and public and social applications.

The demand is to develop a robust, secure and cost-effective authorization system to protect privacy using multi-model biometric signatures [5]. After the successful implementation of One Time Passwords (OTP), the application of biometrics that is cancelable is highly recommended instead of conventional biometrics to promote secure and private data sharing. Today cancelable or revocable biometric methods are employed as these are more accurate and increase the privacy of data [5, 6]. Considering biometric signatures and stored specimen templates as public data in the authentication process leads to a weak security level, since the server stores the original template and can be tampered by malicious hackers. This biometrics sketch can be encoded as a binary string of constant size and saved in a tamper-proof smart card to ensure better authentication. The suggestions on implementation of Broadband Remote Access (BRA) systems to ensure a two-factor authentication system to store additional data in a tamper-proof smart card as a second factor were made by the authors [7].

A simple security protocol for securing the privacy of the data having cost-effective packet transmission with three stages was proposed [8]. In the first stage, the attacks are detected to eradicate the intruder attacks such as Wormhole, Sybil, and Sinkhole. In the second stage, data is classified and ranked using WPM based on its sensitivity and sends the nascent data to the MNS. In the last stage, an enhanced Elliptic Curve Cryptography (ECC) would provide secure authentication services between the interconnected end-users.

This method achieves the Packet Delivery Ratio (PDR) of 97%. The hardware implementation of biometric-based authentication is very secure and withstands regular attacks. This model was tested in real time and is applicable in many domains [9]. The evaluation of the effectiveness of security to counter the wolf attack was computed using WAP (Wolf Attack Probability). The attacker in the wolf attack tries to differentiate a user without knowing the user's biometric signature. The WAP provides the least level of security for the biometric authentication system [10].

Ensuring the identity, privacy, and anonymity in a transaction using unique biometric signatures are critical challenges. This protocol assumes that a secure sketch and biometric signature template are publicly available entities. An end-user need not have to save their private information and record data at the user's sensors level [11]. Designing of various models for integrating biometrics with smart cards like On-Card Biometric Comparison, Store-on-Card, System-on-Card, and Work-sharing procedure is experimented. These models are still in the design phase. Each of these models is designed with a specific objective having pros and cons.

The authors discussed e-passports and Electronic Spanish National ID Card [12]. The design of security systems is carried out using hardware and software co-design and it is also cost-effective [13]. This system identification is designed considering the mobility of smart interconnected devices in ad-hoc networks. Application of pi-calculus and the ProVerif verification tools are used in the design of biometric authentication using Chen, Pearson, and Vamvakas (CPV) 02 protocol [14]. The results have demonstrated that this protocol is effective, secure, and also correct [15].

The study is carried out on user's behavioral patterns, keystroke dynamics, and texting of SMS messages, which are used as inputs for a multi-mode biometric method in cell phones. The experimental results have revealed that these multi-mode profiles can uniquely identify a user with high accuracy. A user authentication protocol was designed using IBE (Identity Based Encryption) mechanism which provides high security and improves WSNs authentication [16]. The proposal on sensor forge resilience: liveness sensors and age-dependent sensors were explored to check the feasibility of designing duplicate sensors to prevent forgeries of original sensors [17].

A random orthonormal biometric remote authentication model which is not susceptible to counter advanced attack in an open network was designed [18]. This model applies the user's biometric signatures along with other authentication factors to attain higher security levels. A protocol that is not anonymous is to be designed to implement the services of anonymous and un-linkable for various types of intruders [19]. This protocol is efficient in processing, ensuring security and provides extended services. The bio-keys captured from different subjects are quite random and unique to secure the Internet of Medical Things (IoMT) [20]. These bio-keys are applied in medical data encryption to decrease resource requirements. The results showed that this mechanism reduces the economics of healthcare services and ensures safe medical data transfer between end-users and service providers. A new authentication scheme for a cloud server was proposed [21]. Experimental results of a security analysis performed on this model reveal that this proposed scheme performs computationally and economically better. The symmetric cryptography protocol shares end-to-end secret data between the nodes having restricted resources of any particular remote entity [22]. The evaluation of this protocol showed that it is safe, secure and saves the cost of energy.

The proposal to permit an authenticated end-user to change the passwords and biometric signatures without consulting the authorized administrator was presented [23]. This proposal also gives a revocation policy to terminate the misbehaving nodes in a network. The analysis of security aspects of this policy is carried out using Burrows Abadi Needham (BAN) logic and random oracle model using the popular Real-Or-Random model. The results derived from the Automated Validation of Internet Security Protocols and Applications (AVISPA) tool revealed that this model is tolerant to man in middle attacks. The proposal on the "Anonymous Privacy-Preserving scheme with Authentication (APPA)" to IoT fog enabled model is device-oriented [24]. Authors realized a multiple layered device authentication using certification by pseudonym and anonymity. This scheme enables independent update of certificate by SDs and pseudonym ensuring the confidentiality of data sensed.

Cloud-based biometric authentication system BAMHealthCloud was discussed [25]. A dedicated component of this system takes care of the security aspect. ALGO Health Security check was performed on this model and results were found satisfactory. The development of a secure healthcare framework is compatible with cloud and mobiles platforms [26]. This framework considers security at inter-sensor communication and patient's data levels. This system employs multi-mode biometrics signatures for inter-sensor communication through public keys. Evaluation of this system showed that it is a feasible solution for future cellular healthcare systems. System architecture based on smart e-health gateways with distribution to verify the end-user's authentication is proposed [27]. This method decreases the workload on the medical sensors ensuring good security. This architecture depends on Datagram Transport Layer Security (DTLS) handshake protocol which is certificate-based. Analysis of security of this architecture reveals that it is highly secure and also tolerant to Denial of Service Attack (DoS) attacks. A low weight protocol having many features for remote end-user authentication was proposed [28]. This protocol facilitates end-users to register using a gateway node in an IoT environment.

After registration users can interconnect to the required sensor nodes through IoT devices to avail every service directly. This protocol has less weight since it is unidirectional and perceptual hash mathematical and XOR functions. This protocol is less intensive in computing and hence very much suitable for the IoT environment, where the capacities of resources are limited. The authors have analyzed the security features using AVISPA tool to discover that it can tolerate various security breaches. This protocol mainly concentrates on providing features such as privacy, security, and integrity of the applications deployed in the cloud environment. These applications are typically implemented on virtual machines enabling trusted computing pools [29].

The Authenticated Key Agreement Protocol (AKAP) scheme for providing security to remote users ECC in mobile client and server environments was presented [30]. The authors discussed the security features of a random oracle model with Elliptic Curve Discrete Logarithm Problem (ECDLP) and Curve Decisional

Diffie-Hellman Problem (CDHP). Analyzing security features showed that this scheme is tolerant of security threats.

The performance also revealed that this scheme is computationally less intensive and has less communication cost compared to other schemes. A secure protocol having a key establishment mechanism with mutual authentication in IoT-enabled WSNs with better performance was designed [31]. The cryptanalysis conducted on this protocol using the BAN logic model revealed that it tolerates various security threats. A biometric template model for generating a biometric certificate for user authentication was proposed [32]. This mechanism resists the users from generating or extracting the other user's biometric digital key pairs legally. This model enables only the authenticated users to generate the keys. A quantitative analysis of security features of Context Aware Security by Hierarchical Multilevel Architectures (CASHMA), a multi-model biometric authentication system using ADversary VIew Security Evaluation (ADVISE) formalism was carried out [33].

Authors studied the human factors that become threats for the authentication of biometric systems [34]. FaceFirst is a tool to generate a completely automatic, easy to use, face recognition system. This tool sends a message whenever a captured face sample matches a face template stored in a database. The tool works in low-resolution environments and enables real-time operations [35].

15.2.1 Literature on Iris Recognition based Biometric Security

The colored circular section in the human eye is called iris and this can be seen with the normal eye. Iris is comprised of muscles that modify the pupil's size and also controls the quantity of light coming into the eye. Quantity of melatonin pigment contributes to various colors in the formation of iris of humans. The iris muscle foldings covering the ring generate a structure giving a greater level of detail. The creation process of muscle structure is stochastic and it will not follow any specific rules to govern the formation of structure in a human's eye. This muscle structure once created remains permanent throughout the life of the person. Each person's iris is unique and has a distinct pattern for each eye. These properties are considered for individual recognition. A high-quality digital camera can scan the details of iris muscle structures. The iris recognition system uses near-infrared (NIR: 700–900 nm) radiation to capture iris structure. The iris recognition software is installed in a dedicated system to get efficiency and security purposes. A camera captures the image of this structure of iris muscles and its quality is improved by the image enhancement procedures. Every iris formation is unique even the two iris of a person are not identical and there are variations in iris of twins also [36, 37].

This improved image is processed by the recognition system to identify the distinct features to create a biometric template. Matching the sample current iris data with this stored iris template confirms the identity of the person under consideration. Iris recognition offers minimum cost of implementation with high security and user-friendliness. Iris recognition has been implemented by border control agencies of the United Arab Emirates at border security checkpoints. All the foreign travelers with visitor visas have to undergo an iris recognition system for entry into UAE. CANPASS Air program based on iris recognition is operational in several Canadian airports.

Aadhaar, a citizen identification system from the government of India's program is the unique method, where the biometric signatures are extensively used for citizen identification and linked to all public services. Iris identification of a person using iris is very effective in many applications.

15.2.2 Literature on Retina Recognition based Biometric Security

The neural cells constitute a tissue of a thin layer in the eye called the retina. The retina is situated inside of the human eye. The system of blood vessels carrying blood to this thin layered tissue is represented by a specific structure, which serves as a unique identification of a person. The structure of blood vessels is considered distinct for every person. A special device is needed to capture this structure.

The high cost of usage and highly invasive nature of retina recognition makes its less popular personal identification method and is only applied in highly secure implementations such as defense and war fields. The infrared light having low energy is used to capture the retinal patterns. The blood capillaries pass infrared light and other tissues reflect this light. This reflected light is sensed and the image is formed by the retina recognition system. This image is processed to create a retina template representing the person's retina signature. This retina image capturing process is called biometric enrollment. The person's identification may be proved by capturing a new retinal sample and comparing it against the enrolled retina template. Many government agencies like NASA, CIA, FBI, etc. are using retinal recognition for personal identification purposes. Ensuring the privacy of data, precise authentication, and anonymity of end-users identity is very critical in healthcare domain. A framework for providing data abstraction with anonymity of end-user is proposed using a paradigm named anonymous credentials. This framework is implemented using blind signatures [39]. The survey on methods of processing and storage of data in fog environment was carried out. This survey revealed the various challenges and complications in carrying out fog data analytics. Authors have designed a prototype to manage various parameters like ease of access, scaling, communications and collaboration among the nodes, and non-homogeneity. The functioning of this prototype has been explained using two cases [40].

15.2.3 Statutory Requirements for Protecting the Patient Data

15.2.3.1 International Statutory Requirements

"Health Insurance Portability and Accountability ACT (HIPAA)" Standards are developed by US. Department of Health and Human Services (HHS) to assure the security and privacy of data and securing specific health information. The HIPAA privacy rules and national regulations are designed to protect patient data and other personal health data privacy of health programs, healthcare providers and healthcare clearing centers. These entities share medical data to offer online healthcare facilities. The objective of these standards is to establish mandatory precautions to secure patient medical health data privacy.

They define terms for usage, sharing, and disclosing of patient data after taking patient approval. These national regulations enable the patient to exercise their rights over their health data records. The HIPPA security rule enforces proper administration, infrastructural and technological precautions to guarantee the privacy, unity, and safety of digitally secured health data [38].

HIPAA standards compliant business companies which are consuming delicate and secured health data should enforce these standards in infrastructure, networks, safety, regulations and operations [41, 42]. China has also enforced many laws and regulations for protecting healthcare data. The written consent of the patient is mandatory for collecting, using, and sharing the medical and personal data. The recent Cybersecurity Law enacted on May 1, 2017 prohibits the people of China from using digital technologies to breach the privacy of patients and collect personal information unlawfully. European Union (EU) has enacted General Data Protection Regulation (GDPR) from 25th May 2018. This act prohibits any company from gathering and processing medical data from EU or non-EU residents. Japan has established Protection of Personal Information (APPI) act from 30th May 2017 [41].

15.2.3.2 Statutory Requirements for Healthcare Data Security in India

Govt. of India, Ministry of Health and Family Welfare is working on Digital Information Security in Healthcare Act (DISHA). DISHA provides security, privacy, standardization, and confidentiality for electronic health data. The aim is to set up a National Digital Health Authority to exchange information related to health. National Health Policy leverages National Health Information Network to share Aadhaar mapped health records electronically. At present, Indian data privacy laws are not planned for protecting the medical data. The section 43A of the Information Technology Act, 2000 enforces general reasonable security practices, procedures for sharing personal data which is sensitive [43, 44].

15.2.4 Consolidated Summary of Review of Literature

Authors have carried out the comparative study of all surveyed research papers and highlighted the various methods, results, and applications of biometric-based authentication systems as shown in Table 15.1.

15.2.5 Findings from Review of Literature

Authors after a survey of recent literature have discovered that many diverse methods and protocols are used for authentication using multi-model biometric techniques. The implementation using software, hardware using IoT microprocessor boards in real time and experimentation was discussed in very few instances of multi-model biometric signatures concerning Healthcare 4.0 standards. This research gap has motivated researchers to research this area of authentication in the healthcare 4.0 domain.

Authors found that biometric security systems have been successfully implemented in banks, passports, visa offices, and many organizations. The collaboration with KSHEMA Medical Colleges of Nitte Deemed to be University was planned for successful implementation of this prototype. The authors have carried out the experiments in labs and involving their staff and students for biometric signatures.

15.3 Proposed User Authentication System

The main objective of this chapter is to design a patient unique identification system for secure access to patient healthcare data. Authors aimed at developing a hybrid security mechanism at the edge devices to protect healthcare data from intruders. Online home-based healthcare services are provided by smart hospitals to patients at their homes. Patients shall enroll in accessing online healthcare solutions from hospitals. The patients can avail of healthcare monitoring and consultancy services from their smart home. The health conditions of the patient are recorded and monitored by these smart wearable medical healthcare devices.

The wearable medical devices will sense abnormal patient's health conditions and send mobile notifications to the patient caregiver's mobiles and hospital authorities instantly. The patient's healthcare data is private and sensitive, so furnishing security and ensuring the confidentiality of this healthcare data is very critical. Patient's data needs to be accessed only by authenticated doctors and hospitals securely, to the extent permitted by law.

Any violations in securing the privacy of healthcare data lead to breaching of statutory obligations. This paper proposed a biometric authentication model to verify that only authenticated users are accessing the data.

Table 15.1 Consolidated Summary of Review Papers

Ref. No	Methodology Applied	Findings and Results	Areas of Application
1.	Healthcare 4.0 architecture	Doctors can make intelligent healthcare decisions in case of emergency in real time	Patient-centric medical data analysis systems
2.	Biometric features and fast identity standards	Physiological biometrics are more stable than behavioral biometrics	Smart medical systems
3.	Uniqueness and randomness RBSs, is measured using metrics of hamming distances	This method is threefold faster for heart rate	This method has significance for real-time and intelligent healthcare devices.
4.	Homomorphic encryption scheme	Protects the confidentiality of the critical data and ensures the safe identity	The biometric authentication process in the cloud environment
5.	Multi-model biometric signatures	Promotes secure and private data sharing	Passport services, driving license, voter cards, public and social applications
6.	Cancelable or revocable biometric scheme	It has a minimal equal error rate compared with those of the state-of-the-art techniques.	Suitable for IoT environments
7.	Biometrics sketch is encoded as a binary string	Better authentication.	Tamper-proof smart card
8.	Designed a model to detect Sybil, sinkhole, and wormhole attacks under different conditions.	Data packets delivery ratio is 97% and cost-effective packet transmission	Ambulatory care unit for healthcare
9.	Hardware implementation of biometric-based authentication	Very secure and withstands regular attacks	Applicable in many security domains
10.	Secure sketch and biometric signature template	Finger vein pattern algorithm to detect wolf attacks	Secure biometric authentication systems

11.	Specially designed architecture and security prototype for biometric authentication policies	An end-user neither registers nor stores any private data at the client sensor	Identity privacy and transaction anonymity applications
12.	System-on-card, store-on-card, on-card comparing biometric data and sharing	The biometric data and processes are protected using security methods	e-passports and electronic Spanish national ID card
13.	Interconnected security architecture for the system of smart devices	Cost-effective, viable secure system for smart devices that is 35% quicker and 5% increased load efficiency	A security framework for security systems
14.	Pi-calculus and the ProVerif tool	CPV02 biometric authentication protocol, is effective, secure and are also correct	Online banking
15.	Behavior-based biometric methods for SMS texting actions and communications	Matching fusion will improve the classification accuracy by 8%	Create a reliable biometric security system
16.	IBE mechanism WSNs authentication	This protocol for authenticating a user has better security features	Applicable in high-security wire fewer sensor networks
17.	Liveness sensors, age-dependent sensors	Accuracy depends on applied unforgeability and sensing technologies	Forge-resilient secure biometric systems
18.	Unsusceptible biometric-based remote authentication model	Countering advanced attacks in open network	Complex computations are decreased without losing accuracy in biometric systems
19.	An attribute-based non-anonymous and fully anonymous scheme	Performance comparison of this scheme with other similar schemes revealed its out-performance	Appropriate for usage in resource-constrained devices
20.	Secure it, ECG data from 40 healthy patients are collected and public data set, i.e., physionet	The outcome of the study revealed that this method reduces process time and power consumption	Real-time healthcare applications

(continued)

Table 15.2 (continued)

Ref. No	Methodology Applied	Findings and Results	Areas of Application
21.	Sensing of patient heartbeats through ECG signals using wearable healthcare devices. Design of biometric security frames for devices with resource constraints	The outcome of the study revealed that this method reduces process time and power consumption	This biometric security design has business importance and relevant to society real-life healthcare domain
22	Symmetric cryptography protocol	Safe, secure and saves the cost of energy.	Scheme performs computationally and economically better
23	Authenticating users using ECC in wireless sensor networks in the healthcare domain	Facilitates better security Revoking stolen or lost cards and effective security code words and updating the biometric data. Dynamically adding sensor nodes	e-authentication protocol using wireless sensor networks
24	Anonymous privacy-preserving scheme with authentication (APPA)	Model is tolerant to replay and man in the middle attacks	Confidentiality in sensed data can be ensured
25.	Biometric authentication system BAMHealthCloud	BAMHealthCloud provides 0.12 EER, 0.98 sensitivity, 0.95 specificity	BAMHealthCloud, a biometric authentication system for educational healthcare, defense, and banking sectors
26	Secure healthcare framework which is compatible with cloud and mobiles. Security of inter-sensor communication	This framework is feasible future cell phone-based healthcare applications	A ubiquitous and cloud-based security framework for wearable healthcare solutions
27	Multi-mode biometrics signatures in distributed smart e-health gateways	Facilitates important security features, measures using extremely efficient key creation methods	A feasible solution for future cellular healthcare systems
28	DTLS handshake certificate-based protocol	Highly secure and also tolerant of DoS attacks	Intruder detection systems
29	Perceptual hash mathematical functions and XOR instructions	Less intensive in computing and hence very much suitable for IoT environment	Virtual machines and enabling trusted computing pools

30	AKAP scheme for providing security to remote users ECC in mobile client and server environments	The scheme is tolerant of security threats, computationally less intensive	Mobile client-server environments
31	Key establishment for mutual authentication in IoT	Cryptanalysis reveals that this technique has improved performance and also tolerates many security attacks	Secure data sharing protocol cloud computing applications
32	BAN logic model	Tolerates various security threats.	The fingerprint data is used in Aadhaar card ID, criminals identification cards ID, and access control cards
33	Digital key creation and extraction technique which are biometric-based	One can't lawfully create or pull out other users' digital biometric key pairs	Biometric authentication systems
34	A multi-mode biometric authentication system CASHMA's security assessment	The security features are assessed with 0.1 confidence interval and 99% confidence level	Biometric authentication systems
35	FaceFirst is a tool for face recognition	Support vector machine	Face recognition systems
36, 37.	Iris recognition system	Iris recognition is noninvasive and cost of operations is low, user's attention and consent are essential	CANPASS air program is operational in several Canadian airports. The United Arab Emirates at border security checkpoints

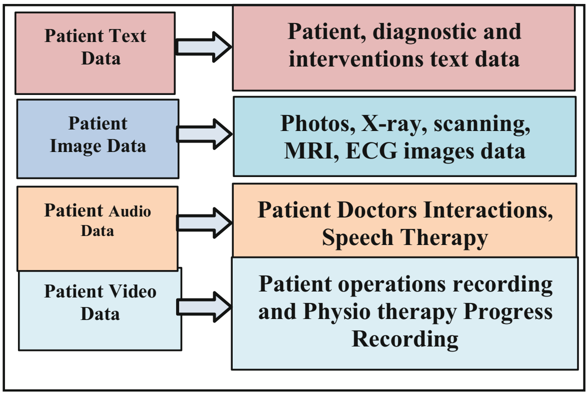

Fig. 15.1 Patient data types

Authorized doctors can access these patient wearable devices for accessing recorded healthcare data. After carrying out remote diagnosis, the doctors can also interact and advise patients in real time.

15.3.1 Proposed Methodology

Authors proposed a fog computing based biometric solution for authentication of end-users to access patient's healthcare data. This healthcare data is managed in a database mounted on the smart home server. Only authenticated end-users can access this data. The healthcare data is multimedia data, and the patient's details such as name, address, and contacts comprise text data. The x-rays, ECG, and scan reports are the image data. The patient's and doctors' interactions and speech theory progress of patients are audio data. The video data consists of a recording of the operations, the progress of physiotherapy exercises, etc. The health data types and examples are shown in Fig. 15.1.

15.3.2 Stakeholders of Healthcare Data

The patient healthcare data would be used by different stakeholders as shown in Fig. 15.2 for various purposes.

- The patient keeps track of his/her healthcare data for personal information and monitoring purposes.
- Doctors would like to access the patient data for diagnosis, intervention, and progress tracking purposes.

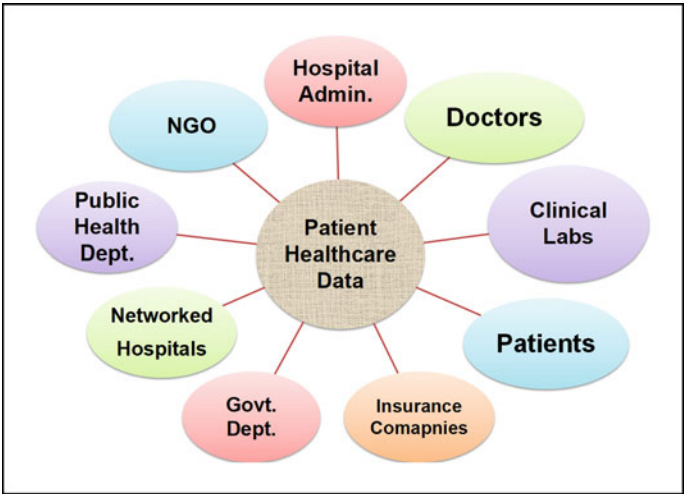

Fig. 15.2 Stakeholders of healthcare data

- Clinical or pathology labs would like to access the health data for analysis and reporting to doctors and patients.
- Hospital administration also accesses the patient's data for billing.
- Govt. authorities also access the patient's healthcare data for planning and reporting purposes.
- The insurance company also accesses the healthcare data for processing the insurance claims.

15.3.3 Architecture of Proposed User Authentication System

The authors have designed a layered architecture for providing authentication to access the patient healthcare data securely as shown in Fig. 15.3.

15.3.3.1 Patient Data Layer

The patient is residing in his smart home or lying on smart bed when she/he is not feel well. This patient health condition data is the innermost core layer in the architecture (Fig. 15.3), where data is captured by the wearable medical devices attached to the patient's body or smart bed.

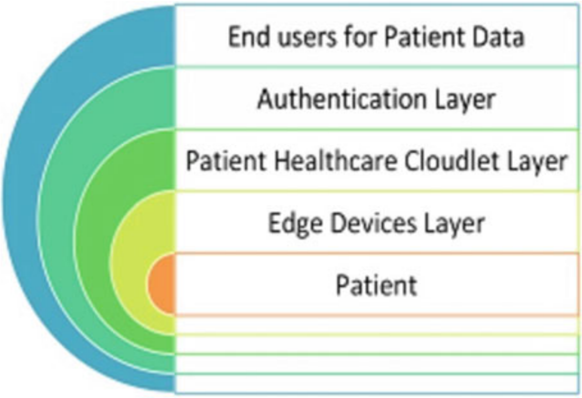

Fig. 15.3 Layered architecture

15.3.3.2 Edge Device Layer

The various health data capturing wearable medical devices are attached to the patient body. These devices monitor the patient body conditions and record health data continuously. Wearable medical devices are configured to send notifications to patients, caregiver's mobiles, and hospitals where a patient has enrolled in case of a medical emergency.

15.3.3.3 Patient Cloudlet Layer

The health data captured is stored securely either in the patient's mobile that plays the role of secure storage edge space or cloudlet. This proposed system can also be configured in such a way that the healthcare data can also be stored in the cloudlet space dedicated to the smart home server of the patient.

15.3.3.4 Authentication Layer

The patient healthcare data needs to be shared by different end-users for different purposes. Ensuring that only authorized users will access patient data to the extent required and permitted by law is most important. In this context, authentication of healthcare data plays a very important role.

The authors have designed a multi-mode biometric authentication system prototype for protecting this data.

The user's authentication is provided by capturing text based on username and password, a biometric image of the fingerprint, face recognition, and iris recognition depending on the data type and significance of data that needs to be accessed.

15.3.3.5 End-User Layers

The end-users of data are discussed and shown in Fig. 15.2 who can access the healthcare data of the patient by proving their identity. The authentication requirements for accessing the data varies on the criticality and type of data. The text data is least critical and hence less secure, while image data and video data have increasing levels of criticality and security.

15.3.4 The Block Diagram for End-User Authentication

The biometric authentication system block diagram is organized and nested blocks as shown in Fig. 15.4.

15.3.4.1 Patient Smart Home Block

The innermost block is the patient smart home block which has four sub-blocks. The patient sub-block comprises a patient with wearable medical devices. The edge devices sub-block is to pre-process the captured data. The authentication sub-block is to verify the identity of users and authenticate the user's access.

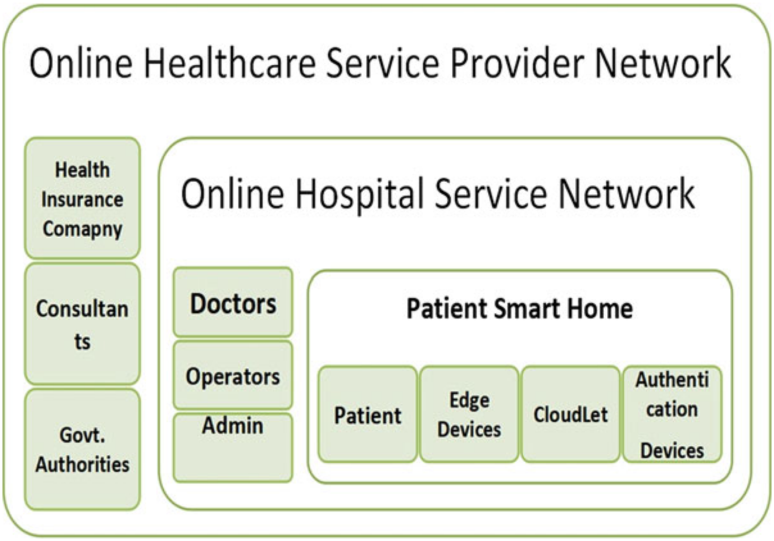

Fig. 15.4 Block diagram of an authentication

15.3.4.2 Hospital Online Services Block

The patients and old age people of smart homes have to enroll in accessing online services with smart hospitals. The enrolled patients are provided with online healthcare and consultancy services. The patients are connected to the hospital through their medical wearable devices. Only authenticated doctors can monitor and diagnose the patients online. The access to patient's data and interactions with health professionals is secured by the proper authentication mechanism. Hospitals have to identify themselves with user code to sign in to patient data account. The authorized doctors and medical professionals can retrieve the patient data to the extent they are allowed to access after verification of their authentication.

15.3.4.3 Healthcare Services Providers

The insurance authorities, consultants, and Govt. authorities would also require to access the patient healthcare data. These bodies can access patient data after providing proper authentication online.

15.3.5 Safety and Privacy Levels of Data

The privacy and security of health data can be ensured by proper authentication using biometric signatures. The authors proposed distinct levels of security for various types of data as shown in Figs. 15.5, 15.6, and 15.7. Text passwords and user names represent the lowest level of security. Images and video recordings require the highest level of security features.

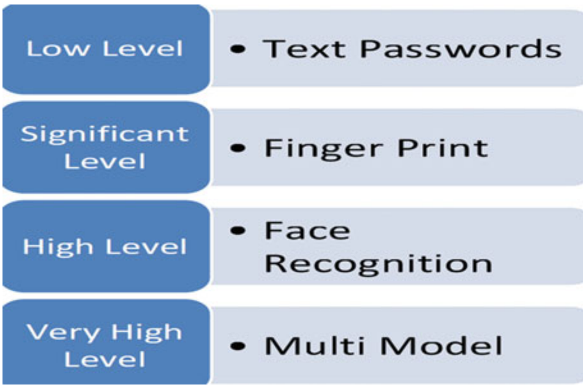

Fig. 15.5 Security levels and data types

Fig. 15.6 Security levels, biometric signatures

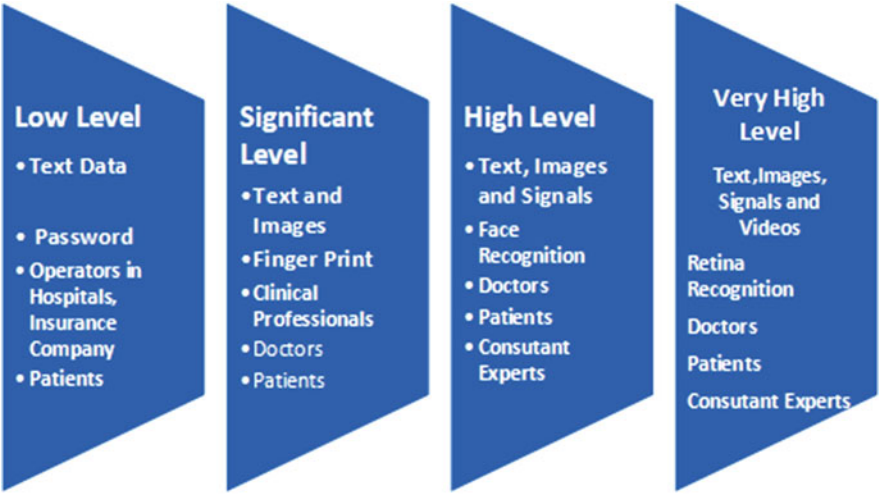

Fig. 15.7 Integrated security levels, biometric signatures and end-users

15.3.6 End-Users Enrollment Procedure for Authentication Purposes

15.3.6.1 Patient Enrollment

The hospital would broadcast the information on available online services through their website. Patients shall register/enroll for accessing online healthcare services on the website of the hospital. The patient's fingerprint, face recognition, and retina signatures are captured during patient registration.

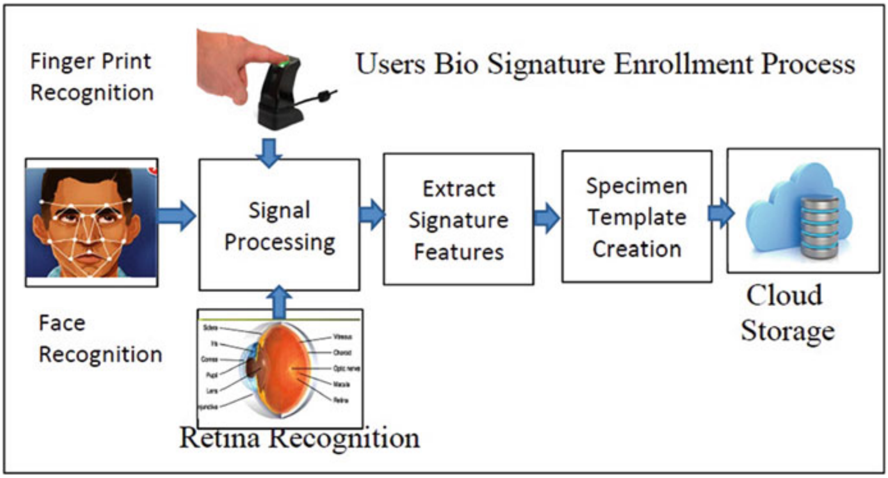

Fig. 15.8 Users biometric enrollment

15.3.6.2 Hospital Authentication

Hospitals will assign a unique identification code for patients who have enrolled in online healthcare services. The hospital staff authentication codes and biometric signatures are securely stored in patient smart spaces also. These authentication codes are cross-checked and confirmed at the patient's location before providing access to the patient's health data.

Fog computing has a very significant role in authenticating end-user identity to ensure that authorized users are accessing the data. End-user's biosignatures are captured by fingerprint readers, face recognition and iris reader devices during the enrollment process. These are images pre-processed and transformed into a standard template with unique identification code and stored in the signature database in edge devices after encryption and compression as shown in Fig. 15.8.

15.3.6.3 End-User Authentication Procedure

The end-users who would like to access patient data need to identify themselves by providing their bioauthentication depending on the type and extent of data to be accessed. These biosignatures captured from end-users are pre-processed. The extracted features of the biosignature are matched with that of enrolled end-user stored signatures. The system compares all the features of user specimen signature with a stored template; if the exact match is found, then only the end-user is allowed to proceed; otherwise, user's data access request will be rejected. If authentication is successful, the user will be able to proceed with data access. The entire process is depicted in Fig. 15.9. The fog and cloud architecture for securing the patient data is shown in Fig. 15.10.

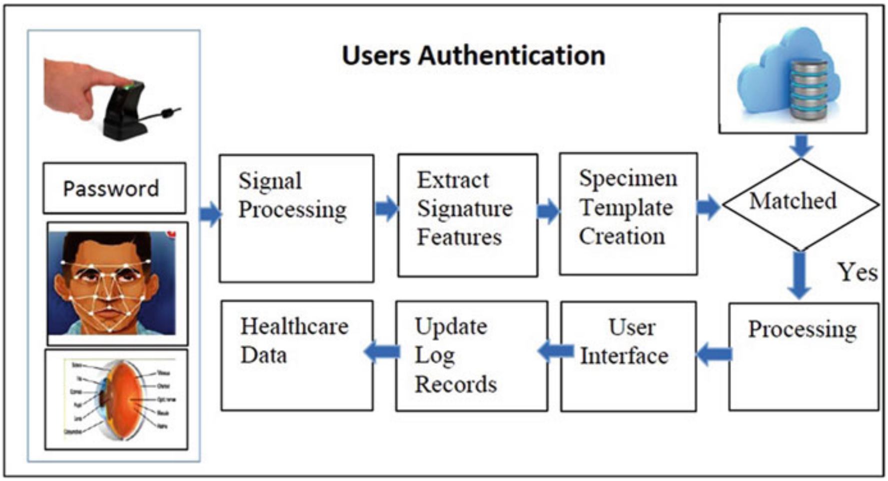

Fig. 15.9 Authentication verification process flow

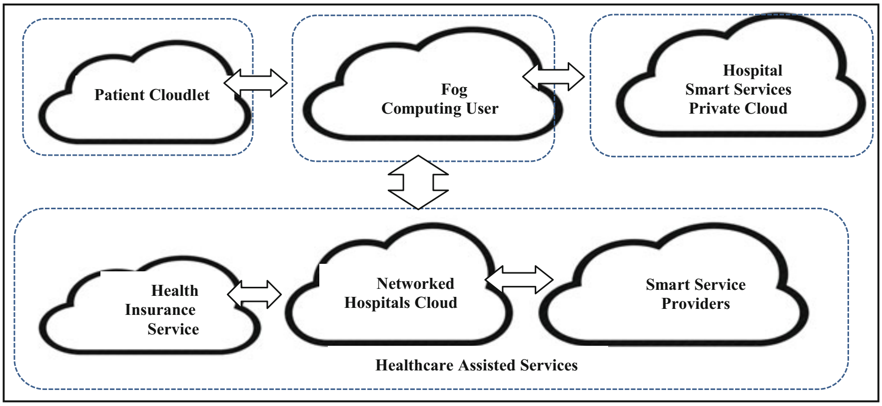

Fig. 15.10 Fog and cloud architecture diagram for securing patient data

15.3.6.4 Summary of Step-by-Step Procedure for Authentication

1. Hospitals publishing their smart healthcare online services
2. Patients subscribing for online smart healthcare services
3. Patient biometric enrollment process (finger, face, and iris signatures registration) for authentication purposes
4. Doctors and medical staff authentication for accessing the patient data
5. Patient registering their medical insurance company representatives and their authentication
6. Hospital admin registration and authentication to access the patient data

7. Govt. Public health representatives registration with hospitals for accessing the patient data
8. Patient's registration with networked smart hospitals to share patient healthcare data
9. Registration of patient's IoT smart home service providers for secure healthcare data transmission
10. Registration and authentication of diagnostic labs for patient's medical test data

15.4 Implementation of Proposed Methodology

The authors have designed an experimental prototype setup for verifying the authentication of users using a face recognition technique shown in Fig. 15.11. A web portal is designed to enroll users. Users use this portal for enrollment to services as shown in Fig. 15.12. Raspberry Pi-3 and Pi camera are interfaced with this web portal. The portal is developed in PHP and implemented Haar-cascade face recognition for security purposes. The user's face is exposed to Pi cameras during the enrollment process. This system is trained to recognize the end-user's face. The face recognition algorithms extract the features of the end-user's face and prepare a specimen template.

During the testing phase when users are exposed to Pi camera the sample face features are compared with stored sample face features. If the correct match is found, then user face recognition is successful and the user is permitted to access the patient health data, otherwise, the user is denied access to the data. The screenshots of registered user recognition and display of user names are shown in Fig. 15.13.

The unregistered users not recognized are shown in Fig. 15.14. An alert message and image of the unrecognized user are sent to the administrator as shown in Fig. 15.15. To improve the accuracy of the recognition, maximum three testing attempts are provided for the users for authentication. If more than three attempts are made, then the notification is sent to system administration along with the sample of the captured image and other details. Researchers are working on the user

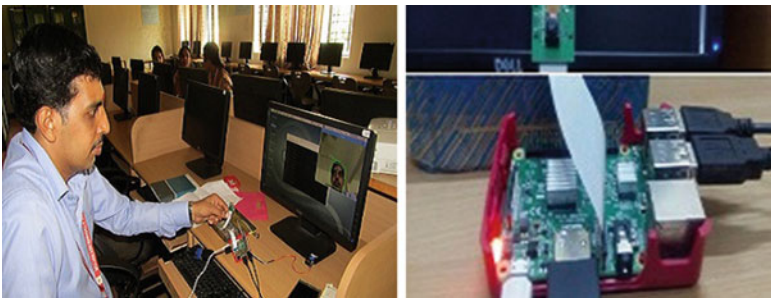

Fig. 15.11 The experimental setup for face recognition

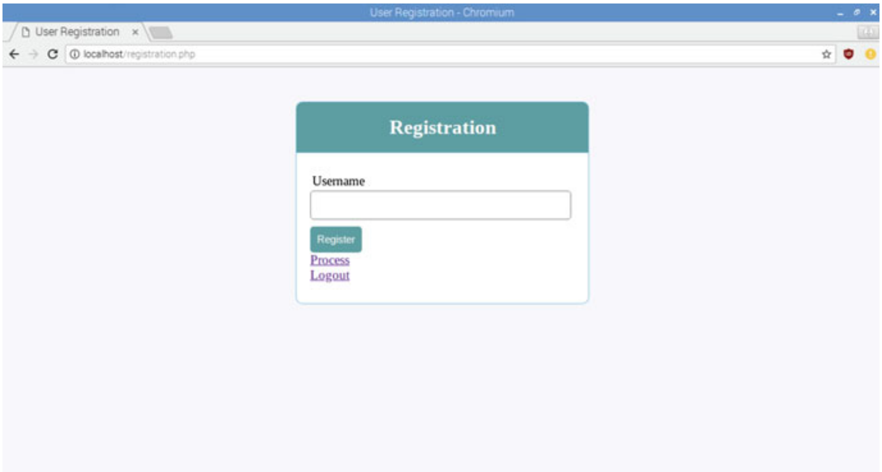

Fig. 15.12 User registration into portal

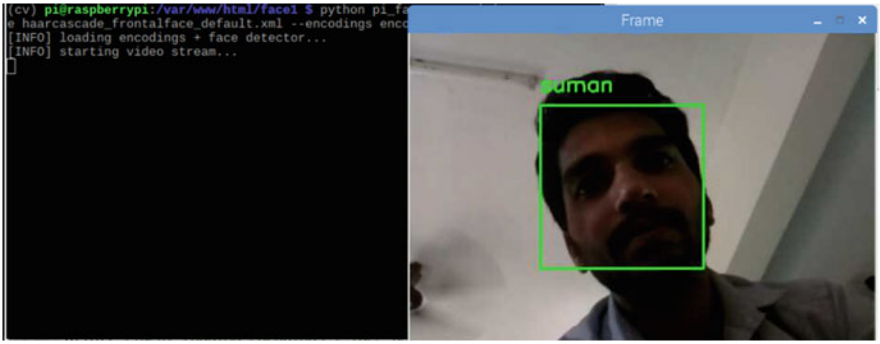

Fig. 15.13 User recognition

authentication process using fingerprint and iris signature recognition on similar lines of face recognition.

15.4.1 Conducting Experiments and Result Discussion

This authentication prototype is tested using the staff and students in our department as users. The authors used a Raspberry Pi camera for capturing the face images of end-users. Authors have selected end-users with different age groups, gender, and categories. Ninety end-user’s biometric signatures were captured in this training process. For each end-user, five face sample images with slightly different postures are captured and stored in the edge device. At the testing phase randomly users

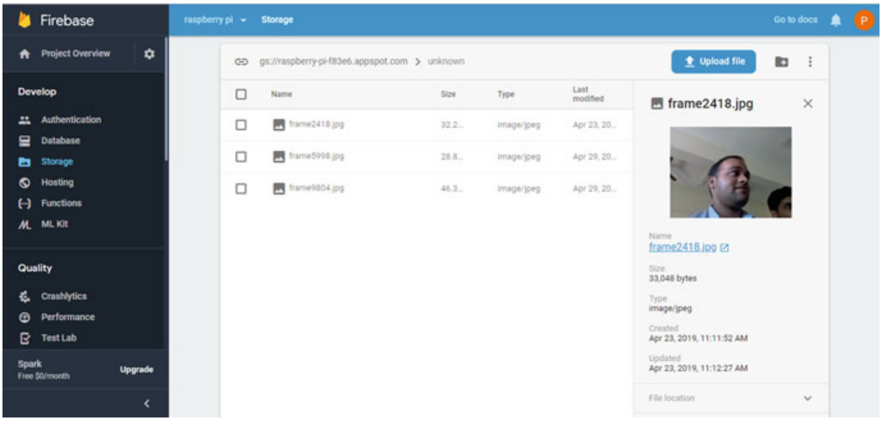

Fig. 15.14 Unknown user recognition

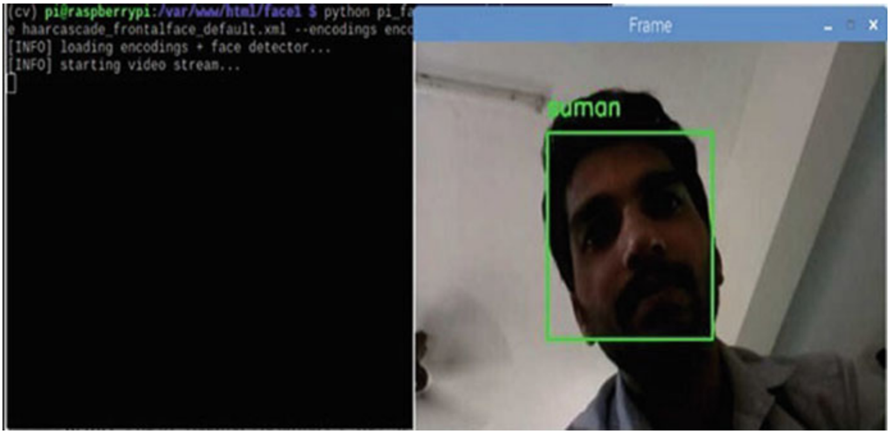

Fig. 15.15 Alert to system administer

Table 15.2 Data set samples and results recorded

Persons Type	Female	Age	Male	Age	Accuracy in %
Lab instructors	8	25–30	15	30–35	95
Faculties	12	28–35	15	28–40	96
Students	20	19–21	20	19–21	97

are called for face recognition. This system could recognize their faces accurately. The face recognition accuracy achieved is about 95% and above. Authors are experimenting with fingerprint and iris recognition modules and would like to integrate all biometric signatures into one system. The details of the sample data set and results in correct recognition are shown in Table 15.2.

Authors have experimented with a set of users in the department and found that the system gives satisfactory recognition results of about 95% accuracy.

15.4.2 *Case Study and Challenges Faced in Fog Computing Implementations in Healthcare 4.0*

The patient is residing in his smart home or lying in the smart bed. The wearable medical devices attached to his/her body will sense and transmit data about the health conditions of the patient to edge device. The edge devices may be the smart phone or any edge device with fog computing capability in the patient vicinity. This edge device will process the data received from wearable devices and if any heath data values are abnormal and critical then notifications will be sent to smart hospitals authorities where patient has enrolled for smart services.

The doctors of smart hospitals can access the patient's wearable devices data after verifying their proper authentication. The edge will transmit the data to smart hospitals. The hospital authorities will call the patient/caregiver and explain the conditions of health and advice course of actions to be followed by the patient. This patient heath data is also shared with clinical laboratories for further investigation and accessing the patient data remotely with proper authentication.

Healthcare 4.0 facilitates remote monitoring of heath conditions of the patient with human interventions. Patient can be altered and advised about medication by the medical professional remotely through smart technologies.

The challenges in implementation are the following:

1. Optimizing the cost of healthcare
2. Infrastructure limitations to support real-time operations
3. Building trust in patients on smart healthcare services
4. Managing the interoperability of devices in fog and IoT network domains
5. Compliance with healthcare regulatory standards
6. Providing fool proof authentication mechanisms
7. Managing and sharing healthcare big data with high security and flexibility

15.5 Conclusions

Healthcare 4.0 standards leverage online health data sharing across the globe conforming to technical and statutory standards. Healthcare 4.0 paradigm promotes a patient-centric healthcare service delivery at his doorstep. The foolproof authentication mechanism is essential to prevent any intrusions into the healthcare systems. Authors have carried out the comparative study of all surveyed research papers and highlighted the various methods, results, and applications of biometric-based authentications systems. A biometric security system is adopted to ensure secure access to a system. Biometric security can be further strengthened by adopting multi-model authentication. This paper discussed national and international status of healthcare data protection acts and tools used for biometric authentication. Authors have discussed the prototype design for authentication of end-users of healthcare data and carried out a face recognition experiment for authentication. The authors have designed a layered architecture for providing authentication to access the patient healthcare data securely. Authors have experimented with a set of users and demonstrated satisfactory recognition results.

Future Scope Authors are collaborating with Nitte (Deemed to be) University and KS Hegde Medical Academy, Mangalore, Karnataka for real-time patient data management and data analytics. Authors are planning to implement this system in the AB Shetty Dental College since authors have developed a web portal to capture patient data which is being implemented in this hospital.

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Part IV
Resource-block and Healthcare 4.0 Applications

Chapter 16
Efficient Resource Discovery and Sharing Framework for Fog Computing in Healthcare 4.0

Nitin Shukla and Charu Gandhi

16.1 Introduction

With the introduction of Healthcare 4.0 standards in healthcare industry, a number of growing technologies like Internet of Things (IoT), analysis of large medical data sets, artificial intelligence (AI), robotics, continuous data sensing, cloud computing, and real-time actuators are combined together to create digital healthcare products, technologies, services, and enterprises. This shift in healthcare industry requires various applications which meet the dynamic demands of the industry. It involves procuring and developing well-equipped, efficient, and cost-effective solutions to the problem of healthcare industry. These technologies are leading towards revolutionized healthcare systems enabling them to provide real-time support to patients aiming at early prediction and prevention of diseases. This will help the doctors to enable cost-effective, preemptive, and pro-active treatment to the patients.

In the present scenario, the healthcare applications and devices are using sensors which accumulate their data on clouds. This architecture is constrained in terms of delay imposed while communicating data from sensors to cloud. The cost to store large amount of data on cloud-based storage is also high. Further, the data associated with these healthcare applications may be time-critical and private to the patient and the hospital. In most cases, one would not prefer to store this private health data to a third-party cloud service provider. Additionally, a network failure or congestion may discontinue the communication between sensors and cloud services which may risk a patient's life. A number of researches carried in [12, 34–36] have already considered issues related to security of private health data. These problems

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associated with cloud-based data analysis of health data can be easily tackled with fog computing. Fog computing allows analysis of patient's data in a distributed manner and closer to the sensor nodes.

Fog acts as an interface between IoT sensors/actuators and cloud services. It utilizes the edge devices/networking devices having limited resources which restricts them to analyze large data sets and may add to the processing time. To overcome this challenge, we need to have a distributed data processing architecture where complex jobs are divided into simpler ones to reduce the processing time and efficiently analyze the data received. Fog computing also brings the data processing applications residing at cloud centers to the edge devices to provide lower latency. To perform initial processing over the sensed data, fog computing brings a complete or partial set of cloud services to the edge/fog devices. As these devices are resource constraints, it is not possible that every fog device is able to render the complete services. Hence, it is considered that a single cloud-based service or API may be located at a single edge device or it may be distributed among different devices. This placement of services ensures prompt data analysis/processing at these nearby nodes.

With the introduction of fog computing in health-industry, we can provide health data analysis at a faster pace which may further be used to take prompt actions. It can also help in reducing the amount of data being stored at the cloud devices by providing an initial filter to the data produced by the sensors. There are a number of different health sensors which require different data analysis services. At present, discovery and management of a fog node, with required services and computational resources, is a time consuming task. Further, as the edge devices are volunteer nodes their active time cannot be guaranteed. This may cause absence of a service as the edge devices may get down demanding a self-reorganization infrastructure. These problems need to be addressed for improving the efficiency of data analysis using fog computing. These problems related to resource discovery and management can be solved by using event-based publish/subscribe systems and distributed hash table (DHT)-based peer-to-peer (P2P) overlays.

Event-based publish/subscribe systems have a number of characteristics to meet scalability and flexibility requirements. A publish/subscribe system consists of three general components: *publisher, subscriber*, and *event notification service* or *broker*. The publisher observes the happening of an event and communicates that event to the broker. Subscribers can register with the broker by showing their interest in some specific class of events. The broker disseminates the events published by publisher to the interested subscribers asynchronously. Use of an intermediate broker introduces decoupling between other components in these systems. The publishers and subscribers are completely decoupled in time, space, and synchronization [7]. This decoupling makes the system flexible as the publishers need not to interact with each subscriber individually and subscriber is not required to check for new events periodically. These systems are also flexible as a publisher for one or more events can be a subscriber for other events and vice versa. All these facilities provided by publish/subscribe systems make these systems suitable for flexible, large-scale, and many-to-many interactions.

The publish/subscribe system can be divided broadly into two categories depending on the way a publisher publishes and a subscriber subscribes. These two categories are *topic-based* and *content-based*. In a topic-based system, the publisher publishes events to a specific topic which are maintained at the broker. The subscribers also show their interest by applying a filter for a particular topic or a group of topics. The broker, after receiving an event under a specific topic, notifies all the subscribers registered to that topic only. In content-based publish/subscribe, events are not classified on the basis of predefined topics but according to the properties or attributes of the event itself. Here, the subscriber specifies filters using attribute-value pair and comparison operators like $=, !=, \leq, \geq, or, and, not$, etc. The events conforming to these filters are disseminated to the intended subscribers.

A number of publish/subscribe implementation architectures are proposed in the literature. These are *centralized, distributed*, and *peer-to-peer*. Centralized solutions propose a centralized broker for event dissemination. However, it suffers from intrinsic scalability issues with increase in number of events. Distributed infrastructure overcomes the scalability problems of centralized approach. It is suitable for fast and efficient delivery of transient data. The third alternative, peer-to-peer infrastructure provides greater flexibility, scalability, and modularity. Here, the peers are used to store the subscriptions and route the events to the intended subscribers.

Peer-to-peer (P2P) overlay networks are better alternatives for large-scale applications due to their flexible and scalable nature. Principles of peer-to-peer (P2P) systems can be applied to mobile networks. P2P systems consider all nodes equal and facilitate resource among these nodes directly. This provides robustness to the system, as failure of one node will not affect others. In addition, P2P networks have the property of handling the dynamic nature of users and are cost-effective due to resource sharing. Peer-to-peer networks can be categorized as structured and unstructured systems. Kaaza [16] and Gnutella [24] are examples of unstructured peer-to-peer systems which suffer from performance issues. Structured peer-to-peer networks generally use distributed hash tables (DHTs), having exceptional load balancing, search efficiency, low overhead, and fault tolerance under high network dynamics. So, DHT is considered as a better alternative over which publish–subscribe system can be implemented. Examples of popular DHT-based peer-to-peer systems are Content Addressable Networks (CAN) [23], Chord [28], Pastry [25], and Tapestry [39].

Traditional publish/subscribe systems are restricted to application layer implementations. There are many challenges to these systems like lack of self-organization, absence of efficient matching algorithms, and scaling issues. These inherent issues can be solved by implementing publish/subscribe system over a P2P overlay network. Some implementations of DHT-based publish–subscribe systems are available in literature like PastryStrings [1], Scribe [26], Meghdoot [9], and Hermes [21]. All these use different DHTs for publish–subscribe applications.

In this chapter, we propose a publish/subscribe and DHT-based fog-computing architecture, which provides efficient resource sharing to analyze the sensor data. Further, Sect. 16.2 of this chapter provides details about the background technologies. The proposed architecture for efficient resource sharing and utilization is presented 16.3. Finally, Sect. 16.4 concludes the chapter and provides research directions.

16.2 Background Technologies

Development of an efficient resource sharing and utilization architecture requires various underlying technologies like fog computing, publish/subscribe systems, and P2P overlays. These technologies and their prominent challenges are as follows.

16.2.1 Fog Computing

With continuous increase in the number of IoT devices around us, it is not always possible to send all the data to the cloud. Additionally, transmitting the sensed data to the cloud for analysis and result computation adds extra latency and operational cost to the system. This may affect the performance in case of time-critical applications. Fog computing solves these problems by extending the cloud facilities near to the IoT devices.

Cisco [3] defined fog computing as, *"Fog Computing is a highly virtualized platform that provides compute, storage, and networking services between end devices and traditional Cloud Computing Data Centers, typically, but not exclusively located at the edge of network."* In fog computing, devices like edge devices, networking devices, and other intermediate devices having some computational capabilities are considered as fog nodes. These fog nodes have limited resources. Therefore, the cloud services may further be distributed as micro-services among these nodes. Thus, they perform the required data analysis in a distributed manner. Additionally, fog nodes are in close proximity to the sensors, which reduces the latency to a further extent.

Fog computing was initially proposed by Cisco in [3]. Later, many research contributions like [2, 11, 15, 17–19, 22, 29, 33, 38] have proposed architecture, applications, issues, challenges, and research directions for fog computing. In [33], the authors present a detailed definition of fog. It also discusses the relationship of fog computing with technologies like sensor networks, P2P networks, network virtualization, and cloud. The authors in [2] provide state of the art of fog computing. This review also discusses architecture, characteristics, benefits of fog computing. It provides various challenges for integrating IoT with fog. A resource allocation framework for fog computing is proposed in [17]. It considers privacy and fault tolerance issues in relation with fog computing. Further, they proposed and evaluated a genetic algorithm-based solution to create a fault tolerant system. In [11], various research problems and issues have been discussed. It also suggests a flexible software architecture, WM-FOG to deal with these challenges. The authors in [38] designed and implemented a prototype fog computing system. They have also evaluated this system and discussed the open challenges identified. A detailed survey of fog computing including the issues related to resource allocation, fault tolerance, scheduling is described in [19]. It also presents the simulation tools and micro-services available for fog computing.

16.2.1.1 Fog Computing Architecture

Fog computing framework is a 3 layer architecture as depicted in Fig. 16.1. It consists of the following layers:

- **IoT Sensor Layer:** This is the lowest layer of a fog computing framework. This layer can also be considered as data acquisition layer. All the IoT sensors are located in this layer. These sensors capture data from their environment, which is transmitted continuously to the fog computing layer using different data link layer protocols.
- **Fog Computing Layer:** This layer is the most important layer in this framework. It acts as an interface between the topmost cloud layer and the lowest IoT layer. In addition to this, fog computing layer consists of several devices ranging from servers, routers, switches, access points, end devices, etc., participating in analysis and filtering of data. These devices, often called as fog nodes, have limited computation, storage, and networking capabilities and are located nearby the sensors which capture data. The fog nodes are initially configured with cloud services, so that they can provide services to the lower layer. Depending upon their configuration, these nodes process the incoming data and send the results back to the IoT actuators with necessary actions. They also filter out the irrelevant data before sending the important information to the cloud. This way they reduce the storage requirements at the cloud and also enhance the bandwidth utilization.
- **Cloud Layer:** This layer is responsible to store and process filtered data for historical analysis. The data filtered from the fog computing layer is sent to this layer for further storage and analysis. Further, the cloud layer is also responsible for updating or adding any service to the fog nodes. It communicates with fog computing layer using Internet.

16.2.1.2 Benefits of Fog Computing

- **Low Latency:** Fog nodes are present in close proximity to IoT sensors. Hence, they provide lower latency and better response time.
- **Secure:** These nodes are present within the boundaries of an organization where the data is being captured. So, they follow all the policies and security frameworks implemented within the organization.

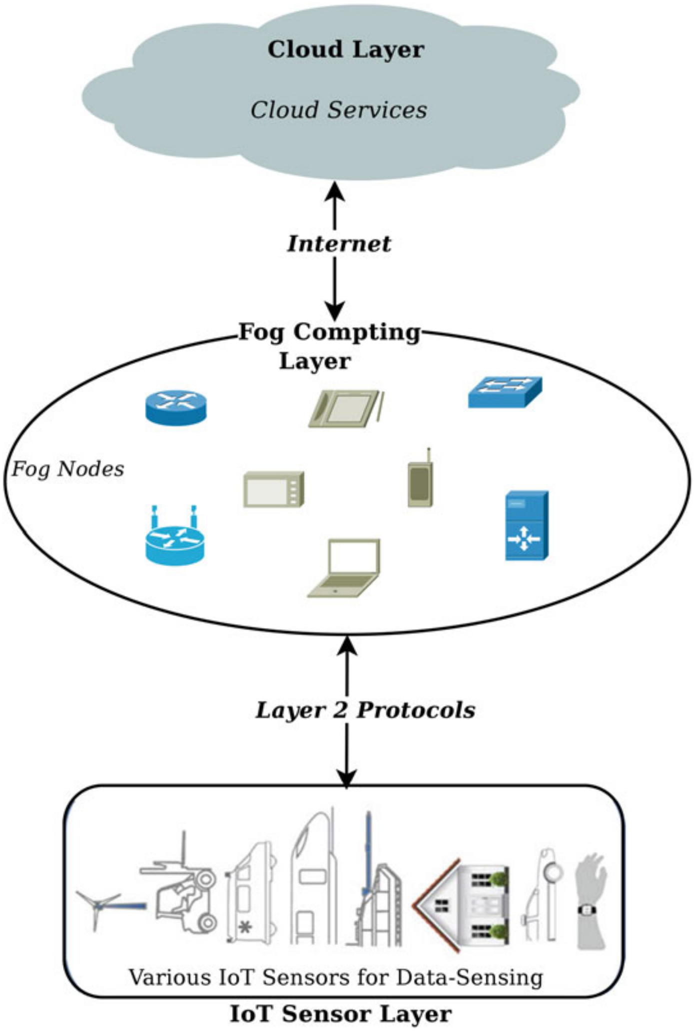

Fig. 16.1 Fog computing layered architecture

- **Less Expensive:** These nodes are normal networking or edge devices, which are already present to carry out technology related tasks. So, there is no need to procure dedicated resources for fog computing.
- **Optimal Bandwidth Usage:** As these nodes perform initial filtering over the captured data on the basis of rules defined, they trim a large amount of data to be sent to the cloud, lowering the bandwidth consumption.

16.2.1.3 Issues with Fog Computing Framework

The presence of fog computing layer between the IoT layer and cloud layer has a number of benefits over direct interaction between these two layers. However, the fog computing layer has certain challenges which need to be considered for efficiency.

- **Resource Discovery:** As the fog nodes have limited computational, storage, and networking capabilities, it is important to discover a fog node with sufficient resources required to process the data.
- **Resource Sharing:** A single fog node may not be able to process a job. So, the job needs to be distributed among nodes having micro-services required to process the data.
- **Self-Organization:** These nodes can be volunteer nodes having indefinite activity time. These nodes may also be mobile in nature. This does not guarantee the availability of these nodes all the time. So, if a node leaves or joins the system, the system may be able to self-organize itself.

16.2.2 Publish/Subscribe Communication

Publish/subscribe systems are designed to overcome the flexibility and scalability needs of a generic client/server paradigm. The components of a publish/subscribe system are decoupled in nature. There are three basic elements in an event-based publish/subscribe system: *publishers, subscribers*, and *event notification service (ENS)* or *broker*. In such systems, the publisher identifies the occurrence of an event. It then informs the event notification service about the event with its meta-data. Subscribers are those users who wish to get notified for the event. They register themselves with the broker by showing their interest in a specific event or a group of events. Broker, after receiving the event information from the publisher, matches it with the interest of subscribers. The notifications matching with the interests are then communicated to subscriber by the broker.

In dynamic topologies, it is not sure that which entity is present at what time for producing or using the information. Publish/subscribe system provides this decoupling and deals with non-determinism by introducing the broker as middleware between the publisher and the subscriber. It provides three types of decoupling between producers and consumers: *time, space*, and *synchronization*. Time decoupling allows the publisher to publish the event when subscriber is inactive and subscribers can receive the notifications, already published, when publisher(s) are inactive. So, both the entities need not to be active at the same time, in order to participate in the interaction.

Space decoupling, on the other hand, enables a publisher to publish an event to the broker without knowing about the intended subscribers. In the same way consumers receive notifications from the ENS without having information about the producer(s) of that event. So, in this type of decoupling the producer and consumer are totally unaware of each other. In synchronization decoupling, publishers are not required to wait for any message from the subscriber for publishing events. Further, subscribers are not required to query/poll the broker for any new notification. These event notifications are pushed by the broker asynchronously even if subscriber is performing some activity. The event publication and notification are not interleaved actions and thus these actions do not occur in a synchronous manner.

These three decoupling allow publish/subscribe systems to design large-scale distributed applications. This communication paradigm is also suitable for highly dynamic and asynchronous communication scenarios. Figure 16.2 depicts the key differences between the three decoupling.

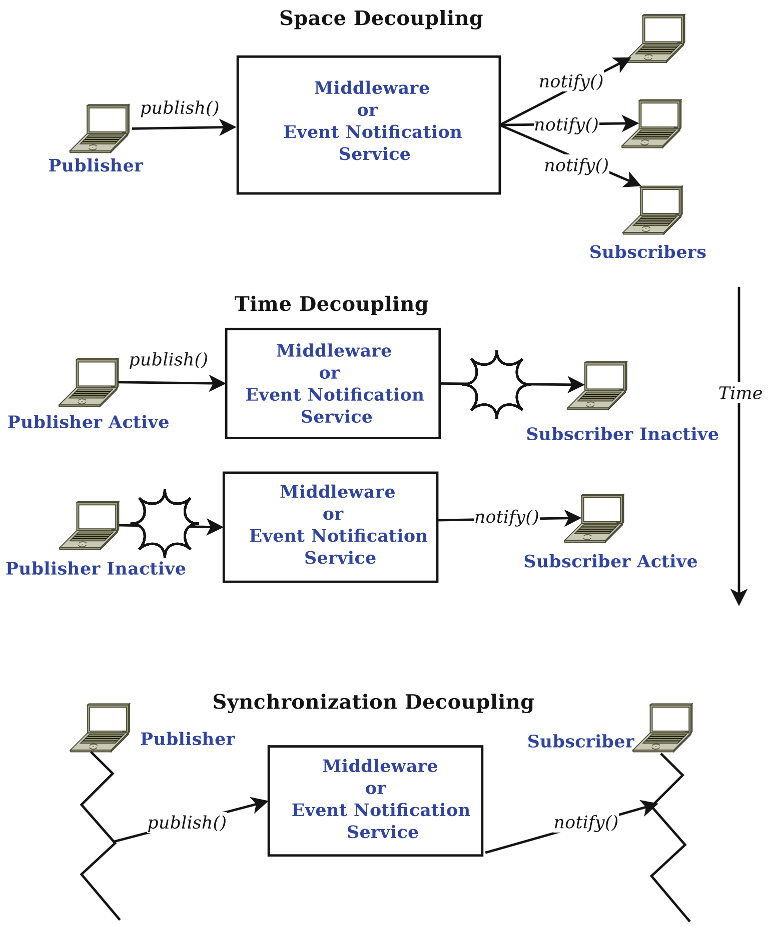

Fig. 16.2 Time, space, and synchronization decoupling

16.2.2.1 Classification of Publish/Subscribe Systems

Publish/subscribe systems are generally classified into two main categories:

- **Topic-Based:** In this scheme, subscribers register their subscriptions in the form of some predefined topics. Topics can be considered as interest sets based on different attributes. The subscribers, based on their interests, can subscribe to one or more topics. Publisher also publishes the event, based on its meta-data, into a specific topic. As soon as a publication arrives for a topic, all the subscribers receive a notification from the broker. Figure 16.3 demonstrates the general topic-based publish/subscribe system.

  Topics are proven to be efficient for implementation also, as the events published are statically analyzed for a matching topic. It uses multicast protocols for communicating the notifications to the subscribers. Every topic available in the broker can be subscribed by a group of subscribers sharing a common interest. Thus, multicast groups are created at the broker. Every topic is mapped to a multicast group. Topic-based publish/subscribe is restricted to limited expressiveness. Here the subscriber needs to have a fine-grained subscription but it needs to register to a topic which is coarse-grained in nature. Due to this, the subscriber often receives notification for those events also which are out of his interest boundaries.
- **Content-Based:** It is a more generic scheme when compared to the previous topic-based scheme. It provides more flexibility to analyze new messages and

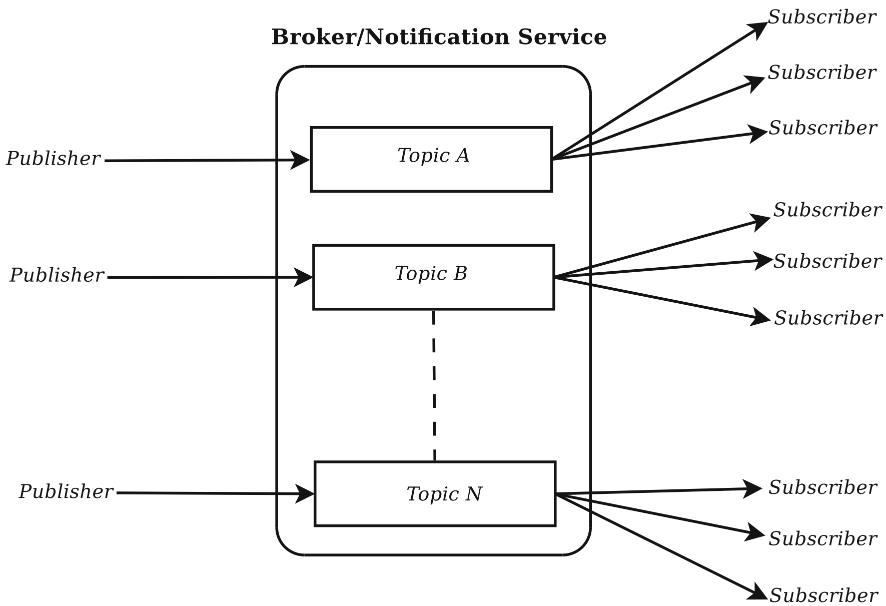

Fig. 16.3 Topic-based publish/subscribe system

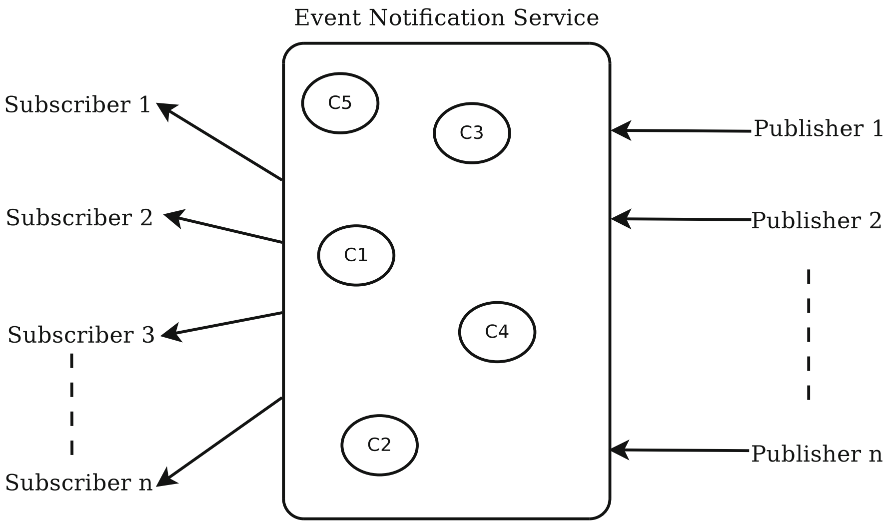

Fig. 16.4 Content-based publish/subscribe system

match them to the already stored subscriptions available at the broker. The events are published according to the properties or attributes of the event itself. The broker analyzes the incoming publications one by one and matches the messages with the already available subscriptions. This scheme is therefore considered as message-by-message approach. The messages are filtered on the basis of their content. This functionality of content-based publish/subscribe systems allows greater flexibility in comparison to the topic-based scheme. Users can subscribe by using special subscription languages. Subscriber can use different subscription patterns to subscribe with the broker. Operators usually used in such subscription languages are $=, ! =, \leq, \geq, or, and, not$. The basic working of a content-based system is shown in Fig. 16.4.

The working of content-based scheme makes it inappropriate for filtering plain text. It is rather suitable for predicates-based filtering. The subscription patterns are then matched and notified to the subscribers. The content-based implementation is more complex when compared to the topic-based scheme. These systems are more expressive in nature but at the same time they introduce extra cost for matching publication to the complex subscription patters defined by subscribers. With increase in number of publications and subscription, a centralized content-based system may fail to address an increase in communication and computation demands. The effect of this scalability over content-based systems can be reduced by incorporating effective matching algorithms.

16.2.2.2 Publish/Subscribe Architectures

- **Centralized:** An event system with a centralized server topology relies upon a single event server to broker between publishers and subscribers. The publisher publish the events to a centralized broker. This broker then notifies the subscribers for the subscribed events. Broadcast and multicast network is an effective way to specify many-to-many communication with low-latency and high performance due to the small delays caused by the protocols at routers and switches. Even then also, centralized system suffers from two more problems: *efficient multicasting* and *efficient matching*. The unavailability of efficient matching affects a publication to match with huge subscriptions on a single broker by imposing delay in event matching and thus notifications are delayed. In general, inefficient multicasting may affect the system when event notification systems or brokers are connected to low speed WAN located in low proximity with the publishers and subscribers. It also affects the performance of the system when the numbers of events, publishers, and subscribers are very large. In both cases, brokers having subscribers showing a common interest for an event should be entitled to the dissemination of that reported event.
- **Distributed:** Distributed publish/subscribe systems have a network of brokers to efficiently match and notify events. In these systems, brokers share active subscriptions and published events to ensure that each subscriber receives the updates they are interested in irrespective of the broker they are linked to. The routing algorithms implemented in the broker network determine how subscriptions and updates are shared. Advanced routing algorithms in particular are used to reduce the number of subscription messages that need to be exchanged by using similarities between subscription filters. In addition, the shared subscriptions determine the subscribers and brokers where the notifications are to be forwarded.

  In this architecture, the distributed brokers can communicate with each other using application and/or transport layer protocols. The broker topology can be formed in hierarchical manner where they are arranged in tree-like structure. The hierarchical placement of brokers is a fixed architecture which cannot adapt with dynamic nature of the communication. The brokers placed near root or at top of the hierarchy may experience higher loads in comparison to brokers at lower levels which may affect the performance of the system.
- **Peer-to-Peer (P2P):** A P2P overlay infrastructure uses application-level protocols for disseminating information. It consists of a set of hosts where each host has a unique identifier generated by consistent hashing scheme. It can exchange information with one or more hosts using their hashed identifier. This P2P infrastructures are self-organizing in nature which poses great advantage in a large-scale environment. The self-organizing property of P2P systems allows them to retain consistency in the network while a host leaves or joins the system. Overlay network is an efficient solution for deploying a large-scale data dissemination system. Due to this characteristics, multiple systems have been developed like Pastry [25], Chord [28], Tapestry [39], or CAN [23].

A publish/subscribe system can utilize the self-organization capabilities using overlay network for its implementation. The publish/subscribe communication can be performed by providing interfaces with the help of underlying overlay. Dynamic behavior of the communication partners can also be inherited from the overlay network structure. Scribe [26] is a topic-based and Hermes [21] is a content-based P2P-based publish/subscribe system.

Considering all the aspects of publish/subscribe systems, potential concerns for the efficiency of these systems are:

1. Absence of self-organization to deal with dynamic nature of network.
2. Expressive-filters are important in terms of publish/subscribe communication. However, processing of these complex filters is done by brokers. This poses extra delay by lengthening the end-to-end path. Consequently, large-scale implementation of content-based systems is still suffering with inefficiency.

16.2.3 Peer-to-Peer (P2P) Overlays

P2P computing and networking is identified as an important development of large-scale distributed systems for evolution and advancement of Internet. Such systems have stimulated an increase in interest and research in this context. Such structures restructure the Internet away from the client–server paradigm to one where a client is also a server, offering more liberty and power to individuals.

A number of P2P systems have proven their effectiveness and economic potential for applications affecting millions of users. Much work has been conducted to formalize the findings and strengthen them. A lot of research have been carried out to develop P2P applications to enable the use of volunteer end-hosts for data exchange. Several P2P systems like Napster [6], Gnutella [24], Kazaa [16], Chord [28], Pastry [25], CAN [23], etc. have been designed and developed.

Further, the growth of wireless communication and mobile computing technologies has led to change in topologies quite often. These topologies consist of mobile nodes which operate independently over existing fixed communication infrastructure. Nodes communicate using wireless links and depend upon intermediate nodes to forward the messages. To cope up with the issues related to movement of nodes, decentralized communication P2P systems can be used. These systems have a number of features to support efficient communication in dynamic topologies.

16.2.3.1 Introduction to P2P Overlays

- **Overlay Network:** An overlay network, as shown in Fig. 16.5, *"is a virtual network of nodes and logical links that is built on top of an existing network in order to deploy a network service that is not available in the existing network"* [28]. Internet also acts as an overlay using telephone network as underlying

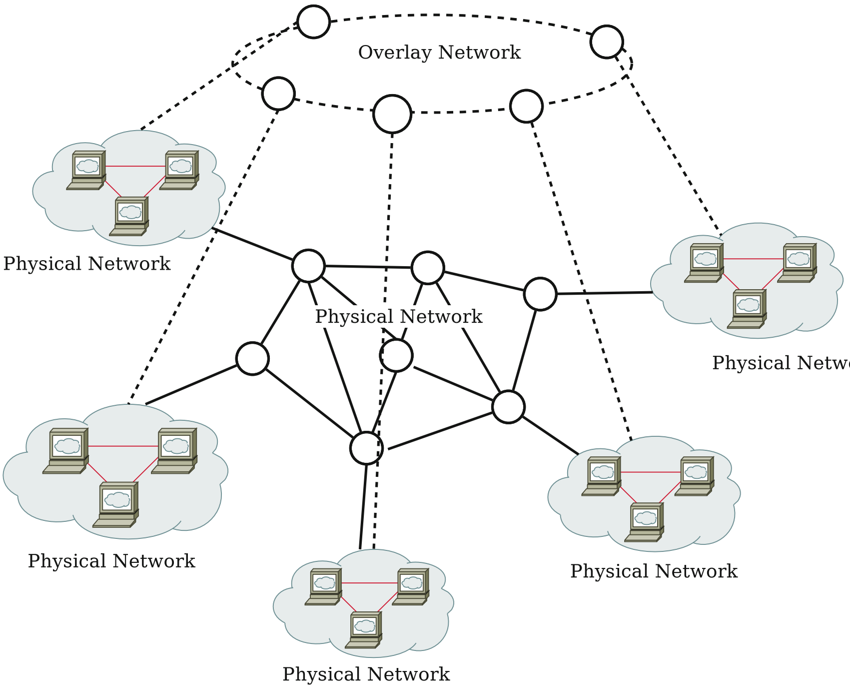

Fig. 16.5 Overlay network

infrastructure. Distributed computing environments such as P2P networks, cloud computing, and even client/server applications depend on overlay networks running over the Internet.

- **Peer-to-Peer Network:** A peer-to-peer (P2P) network is a self-organizing, decentralized, and distributed network of nodes in which every node shares its own resources and services with nodes available in the system. A P2P network is an overlay itself (over TCP/IP), and the terms overlay and P2P network can be used interchangeably. These networks generally share resources like data, computation, storage, network capabilities, etc. Any node can look for a resource that may be possibly available with any other node in the network. P2P file sharing is the most popular service among all P2P systems. This service can run on a user's computer and allow sharing of files with other peer nodes in the network. P2P networking enables nodes to directly communicate with each other. The major characteristics of P2P networks are self-organization, resource sharing, symmetric communication, distributed resources, and distributed control.

16.2.3.2 Classification of P2P Overlays

In any P2P network, the peers must have some knowledge about the existence of other peers. The method by which this knowledge can be acquired and maintained over the course of time can be implemented in two ways and therefore, there are two types of peer-to-peer networks: unstructured and structured. The early public P2P networks, like Gnutella, Kaaza, etc. are unstructured. Afterwards, more sophisticated structured algorithms like Chord [28], Content Addressable Networks (CAN) [23], Pastry [25], Tapestry [39], etc. were developed.

- **Unstructured P2P Overlays:** In unstructured P2P network [4], a node solely depends on its neighboring nodes for message delivery to other nodes. The message is forwarded to destination either by using flooding techniques or by random walk. The routing paths are also random in nature as there is no concrete routing information from source to destination. This limits the performance of the overlay as the resource discovery may be delayed or it may not be found at all. However, these overlays are capable of performing complex searches and low joining/leaving overhead of nodes.
- **Structured P2P Overlays:** In structured P2P network [4], deterministic routing information is maintained in a distributed manner by all the participating peers. Each peer maintains its own local routing table. This enables these overlays to search for a resource in minimal lookups. Further, the peers exchange periodic messages with each other to handle the churn.

  Structured P2P overlays use consistent hashing scheme to address the peers and the resources. A hashed identifier is calculated for both the node in the overlay and the resource available. Resource information is then stored at the peer having closest identifier to the resource. Thus every active peer in the overlay holds a subset of information about the resources available in the network. This makes structured overlays suitable for large-scale systems with proper load balancing and self-organizing nature.

16.3 Publish/Subscribe and DHT-Based P2P Framework for Fog Computing

With the advent of fog computing and its flexibility and evolution of Healthcare 4.0 standards, a number of researchers in academia and industry have proposed its application in healthcare industry. The authors in [5, 8, 13, 14, 20, 27, 30, 31, 37] have applied fog computing framework for different use-cases in healthcare industry. In [20], the authors present a three-tier fog computing architecture for latency-sensitive healthcare application. It also implements the proposed system using iFogSim [10] and compared it with use of cloud computing. An inventory of health related tasks is identified in [13]. It also identifies the network nodes which can be utilized as fog nodes for computational purpose. In [14], the authors have presented a detailed discussion for available opportunities and challenges for application of fog computing in Healthcare 4.0. The research proposes a three-tier architecture for fog computing in healthcare. It presents two case studies to show the relevance of the proposed architecture. A deep-learning-based fog-computing healthcare framework known as HealthFog is proposed in [31], for analysis of heart diseases. It is deployed using FogBus [32] and evaluated on the basis of various parameters. In [8], the authors present an ECG feature extraction template. It implements different fog computing services for efficient analysis of ECG data. Further, [5] presents FAST, a fog computing-based healthcare system to monitor the fall of a patient for stroke mitigation. It uses integrated fog and cloud services to identify the fall of a stroke patient.

All these research contributions provide deep insight for application of fog computing in healthcare industry. Further, our proposal is also benefited from the ideas presented in these researches. We aim to contribute further by reducing the latency for resource discovery and sharing for processing the health data at fog nodes.

In this section, we propose to use two networking infrastructures to create an overlay of the physical fog nodes for providing efficient resource discovery. A basic architecture of fog computing-based framework for healthcare is shown in Fig. 16.6. This shows the presence of a fog controller at the fog computing layer. Fog controller can be used as a device responsible to receive the data from the underlying sensor layer. After, it has received the job, it then finds a suitable fog node or a set of fog nodes to carry out necessary analysis over the data. Finally, the results will

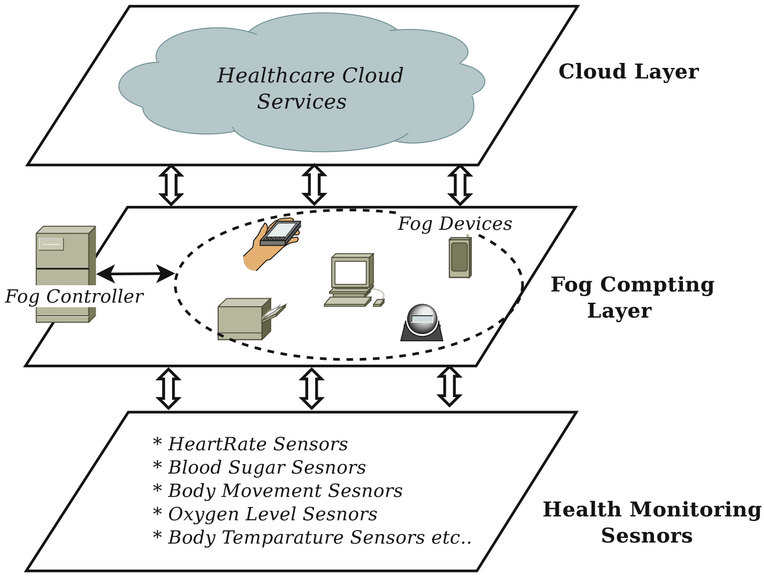

Fig. 16.6 Proposed fog computing architecture for healthcare 4.0

be communicated directly to the actuators available at the sensor layer or filtered data may be sent to the cloud layer for further storage or processing. Our proposed network framework uses two communication paradigms: publish/subscribe and P2P overlays.

16.3.1 PubSub-Based Fog-Computing Framework

Firstly, we propose the use of publish/subscribe-based communication paradigm for efficient resource discovery and job allocation. An architecture of this proposal is presented in Fig. 16.7. We have focused on the use of a fog controller acting as an event notification service/broker for fog nodes. In this framework, the fog controller may be replicated to develop a fault tolerant system.

In this framework, the fog nodes subscribe with their available resources and services/micro-services with the fog controller. Additionally, the sensors acting as publisher publish their sensed data to the fog controller. The fog controller is programmed to identify the type of service and resources required, based on the sensor publishing the data. As soon as a publication is available with the controller, it discovers a fog node subscription matching the requirements of the publication. The fog controller, after discovering a fog node(subscriber), notifies the node with

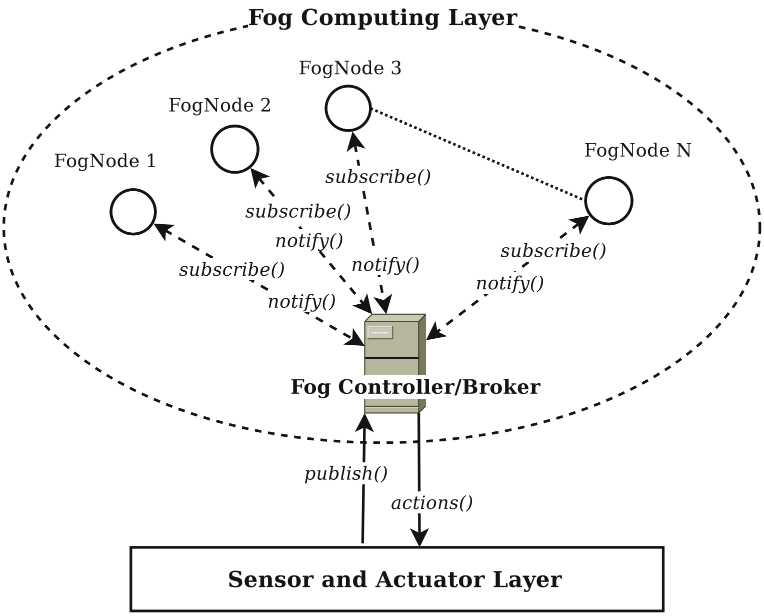

Fig. 16.7 Resource discovery using publish/subscribe

the published job. The job is assigned to the fog node by the fog controller. It also marks the fog node as busy in its subscriber list.

The use of publish/subscribe communication paradigm helps the controller to discover a fog node with required capabilities. However, a single fog node may not be capable to serve a job. Additionally, publish/subscribe paradigm may not be able to address the leaving and joining nature of the fog nodes. These two challenges can be addressed by using DHT-based P2P framework as defined.

16.3.2 DHT-Based P2P Framework for Fog Computing

A DHT-based P2P overlay of fog nodes will help the fog computing layer to deal with leaving and joining of the volunteer fog nodes. It also helps in enabling resource sharing to perform computation of large jobs. Chord [28] is used as an example of DHT-based P2P system to explain the same. A framework for DHT-based P2P overlay is shown in Fig. 16.8. This figure shows that irrespective of the physical connections of the fog nodes, an overlay is formed. The fog nodes are placed on the overlay in sequence of their *n-bit* hash values calculated by their unique identifiers (e.g., *ip address, mac address*, etc.).

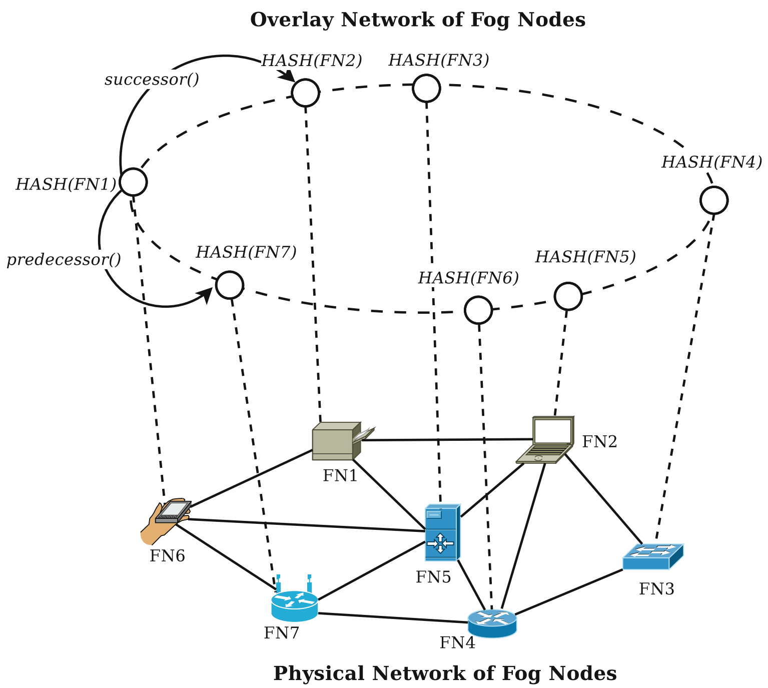

Fig. 16.8 DHT-based P2P overlay of fog nodes

To enable self-organization in DHTs all the nodes in the overlay maintain the following pointers:

- *successor:* A successor pointer holds the information of the active node just ahead of the node in the overlay.
- *predecessor:* A predecessor pointer holds the information of the active node just behind the node in the overlay.

A node in the overlay also replicates its stored data on its successor nodes to maintain data availability in case of it leaving the network. The pointers are periodically looked-up to maintain the consistency in the overlay. As soon as a node leaves the overlay, its successor node and its predecessor node update their pointers. When a node joins the network, its hash value is calculated using its unique identifiers. Based on the hash value calculated, the node is placed at an appropriate location in the overlay. After the placement is done, the nodes preceding and succeeding it in the overlay update their *successor* and *predecessor* pointers so as to incorporate the new node entries. In this way, a DHT helps in self-organization of the overlay network maintaining the data-consistency.

The DHT uses consistent hashing scheme to calculate a *n-bit* hash identifier for a node to place it on the overlay. The same hashing scheme is used to store the data or service. In this framework, we propose that the micro-services required on the fog nodes are hashed on the basis of their meta-data. The resultant hash value is then used to locate an active node in the overlay with closest hash value. The micro-service is then stored on that fog node. Further, all the nodes in the overlay maintain a data structure known as *finger table*, consisting of *n-entries*. Each entry maintains a pointer to a node. This entry helps to identify a resource available on a fog node active in the overlay. This finger table based scheme will enable faster look-up to identify a node with services available to execute in a distributed manner.

16.4 Conclusion

Healthcare 4.0 introduces a shift in healthcare industry from traditional processes to technology-based decisions. This shift aims to use technologies available to provide better experience to the patient. A number of IoT-based sensors are used to capture health data of a patient continuously. Initially this data was sent to cloud-based data centers for processing. This scheme was affected with the latency, privacy, and cost issues. With the introduction of fog computing, the issues related to cloud-based data processing have been solved. Further, fog computing has its own challenges related to the discovery and utilization of available resources. The proposed frameworks using publish/subscribe and P2P overlays overcome the problems of resource discovery, sharing, and self-organization. The two proposals can be integrated to provide an efficient network framework for resource discovery, sharing, and self-organization. The publish/subscribe communication paradigm will cater to the demand to discover a node efficiently. Further, the DHT supports self-organization of the P2P overlay and efficient resource sharing among the participating peers.

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Chapter 17
Healthcare Using Different Biofeedback for Tension-Type Headache: IoT and Fog Based Applications in South Asian Context

Rohit Rastogi, D. K. Chaturvedi, Santosh Satya, and Navneet Arora

17.1 Introduction

IoT helps us to connect each other, i.e., it is known as a smart connecting thing (a sort of Universal Global Neural Network in cloud). It comprises of smart connecting machine with other machine, object, and a lot more. IoT helps us in a way that the machine should judge on its own and can interact or judge some future information. Its data is being stored in the form of cloud which is being taken properly, so that data cannot be misguided by someone. In the modern era, the volume of sample or raw data has increased at a rapid rate. This data may be used for evaluation in many fields. Big data refers to huge sets of data which are also large enough in terms of variety and velocity. Due to this, it becomes more difficult to handle, organize, store, process, and manipulate such data using traditional techniques of storage and processing (Kumari et al. [42]).

This chapter poses the facts and figures that big data currently possesses latest method of implementation named as data analytics and it is a dynamic and trending

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field in today's information era, modern data processing techniques are required to handle above issues of this ever growing raw or sample data.

The chapter incorporates the stress issue, especially TTH (tension-type headache) is a serious problem in today's world. Now every person in this world is facing headache and stress-related problems in daily life. To measure the stress level, the authors have introduced the concept of EEG, EMG, and GSR biofeedback. In case of TTH, human is in a state in which one experiences pain like a physical weight or a tight band around one's head. It can generally last for some days or can even continue for long. TTH is different from migraine as it can be affected due to everyday activities, which is not in the case of TTH. More than half of the world experiences TTH in one form or the other. It has been called by different names over the years, for example tension headache, muscle contraction, etc. Many biofeedback experiments are being conducted to reduce this tension so our team has conducted an experiment where we have collected data on the study of the people; we have studied their tension level and helped them to cure it (Tanwar et al. [43, 44]).

Development in the field of technology is growing with fast pace, mainly the IoT (Internet of Things), i.e., it is usually called as the internet. It is an interface between machine-to-machine, machine-to-human, machine-to-infrastructure as well as machine-to-environment.

The chapter demonstrates that how the fog computing provide benefits such as low latency, allowing instruction processing to take place at the edge of the network, etc. Fog system consists of three-level architecture. It has three levels: The cloud level, the fog level, and the IoT/end-users level. It has effective role in application of TTH cure through biofeedback (Mittal et al. [45]; Mistry et al. [46]).

The chapter explains the drastic paradigm shift from Healthcare 1.0 to Healthcare 4.0 which is bringing a 180 degree shift in current scenario. Different sensor based devices like EEG, EMG, and GSR can be effectively used for this purpose.

17.1.1 IoT

It is a technology that has made the non-connectivity appliance a connectivity appliance. The appliances that contain technology help us to communicate with human and technology. Let us take some example: the GPS is the latest technology that is inbuilt in car to help the driver to make it easy to travel within the road, i.e., it is that technology in which we require internet-based technique (Rubin [1]).

17.1.1.1 History of IoT

IoT has evolved when the major language is not famous on that day such as machine language, commodity analysis, etc. Nowadays, automation, control system, and wireless sensor networks that are connected to the internet help to make us easier to do work.

Kevin Ashton in 1999 was first who coined the term IoT, i.e., Internet of Things. But in earlier the concept of IoT was purposed in Carnegie Mellon University in 1982 that works on the concept of network smart devices (Vora et al. [47]).

Nowadays technology is increasing day by day like CISCO is introducing new technology and in the future, the technology will replace every human work with this technology (Rubin et al. [1]).

17.1.1.2 Applications

The application of IoT is usually bifurcated among infrastructure, industry, commercial and consumer spaces. Many technologies have been evolved in this field, some are described below.

17.1.2 Smart Home

It is a future upcoming home in this world. These technologies include the theory of automation. This includes smart lighting, smart lock system, smart kitchen, even we have wireless technology to which we can speak like GOOGLE assistance, Amazon echo, SIRI in apple IOS, and many other. This technology helps to make our work easier and make an interactive home design that helps and attracts the other. This technology is basically helping to upgrade our system. Many companies are now being evolving nowadays like APPLE, SAMSUNG, LENOVO, etc. (Rubin et al. [1]; Patel et al. [49]).

17.1.3 IoT in Medical- and Healthcare

IoT helps in the medical field to make our future bright, for example major technology has been evolved in this field such as a pacemaker. With the help of IoT, we can create digitalized healthcare facilities; we can connect to medical resources easily and can get medical facilities easier (Tanwar et al. [50]).

Devices enabled with IoT services are applicable for remote health monitoring and especially in emergency notification facilities. They may help us in blood pressure and heart rate monitors and latest gadgets like pacemakers to monitor specialized implants.

Nowadays, smart beds can be seen in the medical facilities that are another feature of IoT. A doctor can interrogate their patient with the help of video call from far away from the place, even the nurses can be appointed through internet facilities. A 2015 Goldman Sachs reported that by increasing revenue and decreasing cost, gadgets being used for healthcare devices in the USA are helping to save nearly $300 billion in annual expenditures in the health sector.

Moreover, a special monitoring sensor is being set up in the parks, shop, medical shops, hospitals, etc. to ensure the medical healthcare of the people. These sensors are being connected to a database system that acts as a collection server and information is gathered out. These are the methods by which, scientists are researching on actions of human being and their development day by day.

Machines are being built on the bases of application on IoT that help the doctor to study properly to their patients and collect and store data in the form of big data that is a subclass of IoT. Many types of research are being done by collecting the data from the sensor. Chronic Disease control and their prevention is wisely taken care by IoT in healthcare and it is playing a fundamental role. Mighty wireless connections have proved remote monitoring a reality; this fast connectivity has made easy the application of recording of subject data and analysis of complex algorithms on it (Rubin et al. [1]).

17.1.3.1 Future Perspective of IoT

With the base of IoT wireless design has been made which can enhance our technology and made our work easier. Much wireless technology has been developed and these technologies have been categorized in three ways, i.e., short-, medium-, and long-range wireless.

- Short-Range Wireless—With short frequency and applied for home purpose.
- Near-Field Communication (NFC)—Protocols making capable communication of two devices in four-centimeter range.
- Radio-Frequency Identification (RFID)—Tags are embedded into items and they are applied on field to retrieve the data.
- Wi-Fi—Devices communicate through a shared access point or directly between individual devices. LAN-based method on the IEEE 802.11 standard.
- Medium-Range Wireless—For company purpose (Tanwar et al. [52]).
- Long-Range Wireless—Establish connect within a country, state, etc. (Rastogi et al. [2]).

17.1.3.2 Concluding Remarks for IoT

IoT is a very useful technology in every field because it plays a crucial role in every field. In the field of medical, it is very important and by this, we can help the people and save them even they are suffering from TTH, stress, or any other disease.

1. Low-Power Wide-Area Networking (LPWAN)—Wireless network, allows low data rate communication in long range, decreases power and cost for transmission. Available LPWAN technologies and protocols: LoRaWan, Sigfox, NB-IoT, Weightless

2. Very Small Aperture Terminal (VSAT)—Uses small dish antennas for narrow-band and broadband data with satellite communication technology

17.1.4 Big Data

The large collection of data is referred to as big data which are very much big and highly complex to process for commonly used data processing software. It consists of data sets which are too large to be stored, organized, integrated, managed, and processed within a certain elapsed time by common software (Fumal et al. [3]).

Characteristics There are major four characteristics of big data, namely volume, variety, velocity, and veracity. Volume is the quantity of the data which is to be stored and which determines whether a data set is large enough to be considered big data or not. The nature and type of generated data are known as variety, whereas the processing speed of data and its generation to handle a specific need is called velocity. Veracity characterizes the quality and value of the available data (Fumal et al. [3]).

17.1.4.1 Applications of Big Data

Healthcare

Big data finds a major application in the healthcare industry. Nowadays, in major hospitals and large healthcare centers, there is a huge influx of patients suffering from a wide variety of ailments. Thus, the doctors rely more on the patient's clinical health record which means gathering a huge amount of data and that too for different patients. This is not possible with the help of traditional data processing and storing software. Hence, big data comes into the picture (Kumari et al. [53]; Vora et al. [54]).

Predictive analysis is an important result of big data which ensures the patient's quality care and safety. It helps the doctors to give the right prescriptions to their patients keeping their medical histories in mind. Analytics can also be used by the medical researchers to observe the recovery rates of various cancer patients which may help them to find the treatments that have the highest rates of success. As the number of patients' increases, the volume of medical records also increases which stems the need of adopting a new approach called Electronic Health Records (EHRs) that organizes this data and makes it easier to have access to such data. Various real-time monitoring systems and tools are offered by many healthcare centers to their patients like new wearable sensors which keep track of the patient's health trends right at their home, which will reduce the patient's visits to the clinics (Chaturvedi et al. [4]).

Media and Entertainment

The media and entertainment sector is rapidly developing day by day. The development brings about the creation of new content and an improvement in marketing and distribution. Many actionable points of action are provided by big data about thousands of individuals which are collected through various different data mining activities. Big data helps this sector by:

- Considering the needs and requirements of the audience
- Being open to optimization
- Consumer targeting for advertisement and marketing purposes
- New content development and content monetization (Boureau et al. [5])

Government

In government processes, the same sets of data are used again and again across multiple platforms. Big data allows this and also offers cost innovation and productivity, thus allowing different departments to work together in association. As the government works in almost all the important sectors, the role of big data increases. Some major areas include:

- Crime Prevention and Prediction: Real-time analytics systems can be used by the police and intelligence departments to observe and track crime patterns and criminal behavior.
- Weather Forecasting: Large amount of data at every instance of each day by using high-end sensors and then use this information to predict the forecast for coming instances of time as used by NOAA (Kumari et al. [55]; Tanwar et al. [56]).
- Tax Fraud Identification: Tax organizations can use big data to identify suspicious behavior and multiple or duplicate identities.
- Drug Evaluation: Big data can be used to access large amounts of data and help in the evaluation of treatment and drugs and thus save millions of dollars for pharmaceutical companies.
- Traffic Optimization: The real-time traffic data collected from sensors, GPS navigators, CCTV cameras, etc. can be used to solve the traffic problems in dense or congested areas by adjusting transportation routes accordingly (Chaturvedi et al. [4]; Boureau et al. [5]).

17.1.5 Relation between IoT and Big Data

The quantity of gadgets interjoined to the internet is growing day by day at a rapid rate. These devices will obviously generate a huge amount of data which will increase in quantity with the number of devices. This data will need to be stored, organized, and processed and hence, big data comes into the picture (Gupta et al. [57, 58]).

17.1.5.1 Role of Big Data in IoT

In a big data system, a heavy quantity of unorganized data is generated by IoT devices and stored. Then this data can be processed or organized accordingly. Analysis of this data can be done using tools like Spark or Hadoop, Map-Reduce. This data needs the light fastening speed of analysis as it is collected through the internet (Vora et al. [59]).

17.1.5.2 Interdependency between Big Data and IoT

Big Data and IoT are not only mutually dependent but also hugely impact each other. As the number of IoT devices will increase, the demand for big data services will also increase gradually. This is because as the quantity of the generated data increases, traditional storage technology will be pushed to its limits, and the demand for big data, which is a more advanced and developed data storage technology, will increase drastically. Therefore, more and more organizations will update, develop, and work on their big data storage systems (Arora et al. [6]).

17.1.5.3 Big Data Tools

For storage and analysis of the big data, there are few intelligent applications which are advanced tools, very easy to use and getting popular in today's scenario. Some of the main tools are described as below.

Microsoft HD Insight

Big data solution by Microsoft, using Azure Blob storage as the default file system, provides high availability with low cost.

Big Data in Excel

MS Excel can be used to access big data. MS Excel 2013 has a feature which allows the user to access the stored data in a Hadoop platform.

Presto

Open source query engine, developed by Facebook, used to handle large amounts of data, not works on Map-Reduce data and can quickly retrieve data.

PolyBase

Works on SQL Server 2012 Parallel Data Warehouse (PDW), accesses the data stored in PDW, an appliance for data warehousing to process any related data and provide connectivity with Hadoop as well (Haynes et al. [7]).

17.1.6 Big Data Security

It is a term used for all measures and techniques to secure the data and all the data analysis processes. The threats to data can include information thefts which can endanger critical and confidential information stored online. There are several ways to implement data security. One simple way is encryption. Encrypted data is useless to any third party as long as it does not have the key to access it. Data stays protected during both input and output processes. Another way of securing the data is by building a strong firewall, which acts as strong data filters and avoids any external sources or third parties (Rastogi et al. [8]).

17.1.7 Fog Computing

Carla et al. [36] experimented in their research that fog computing is introduced to tackle problems like connectivity between end devices and cloud storage, high latency, to situate components of application over multiple clouds separately, overhead of latency induced by inter-cloud communications, and many more. Fog layer is formed by single or more fog domains which in turn are formed by fog nodes. IoT layer is formed by two domains, end-user devices and IoT devices (Mouradian et al. [41]).

17.1.8 TTH (Tension-Type Headache)

TTH stands for tension-type headache. It is a condition of the body in which one experiences ache/pain like a physical weight or a tight band around your head. It can generally last for some days or can even continue long. TTH is different from migraine as it can be affected due to everyday activities, which is not in the case of TTH.

Tension-type headache arises due to
- Constant stress
- Incomplete sleep
- Anxiety

- Depression
- Emotional Disturbance

More than half of the world experiences TTH in one form or the other. It has been called by different names over the years, for example tension headache, muscle contraction, etc. (Cassel [9]).

It is not accompanied by nausea or vomiting and is also not affected by physical factors. Thus one will continue to do his daily task without even knowing if he is suffering from such headache or not. It also does not have any visual disturbances. The pain in TTH spreads all over the head, unlike migraine which pains only on a particular side of your head. Symptoms of TTH include:

- The feeling of pressure across the forehead
- Aching head all over the area
- Tenderness of head and neck muscles, etc. (Cassel et al. [9])

TTH can be divided into two main types: Chronic and Episodic.

17.1.8.1 Episodic Tension Headaches

They can last from 30 min to about a week. It can also vary from 15 days in a month to about 3 months. It can also become chronic. One can have migraines if episodic headaches occur frequently.

17.1.8.2 Chronic Tension Headaches

If the headache lasts for 15–20 days out of a month continuing for about 3 months, it becomes chronic. It occurs early in the morning and its symptoms include poor appetite, restlessness, lack of concentration, and depression.

TTH varies in intensity, duration, and location. Use of alcohol, stress, caffeine, cold, dental problem, eye strain, excessive smoking, tiredness, etc. are the triggers of tension headaches. However, one must remember they are not a brain disease. An individual may suffer from this TTH in any age group; however, they are normal in adult age and older teens. It generally runs in families and is common in women. Earlier reports which show the occurrence of tension-type headaches are given below:

This graph shows various countries in which episodic TTH and chronic TTH are experienced by the people whether it is man or women. Around 71% and 3% people in Denmark are suffering, 39% and 2.5% in Germany and around 38.3% and 2.2% all are suffering by this disease. Also defining the different factors contributing primarily for TTH and extending to suicidal tendency (Ref. Fig. 17.1).

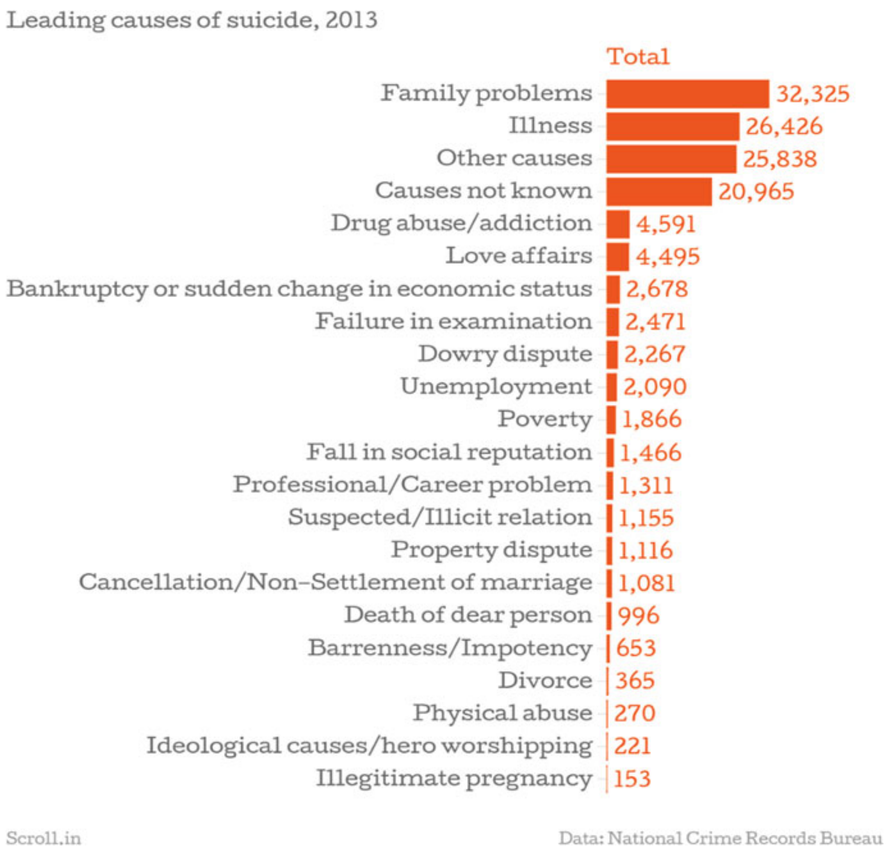

Fig. 17.1 The different factors contributing primarily for TTH and extending to suicidal tendency (Boureau et al. [5])

17.1.8.3 Treatment

Massaging scalp, temples, or bottom of your neck can help to relieve pain in a headache.

Over the countries, painkillers such as ibuprofen, aspirin, paracetamol, and naproxen are mostly used by patients suffering from TTH. These painkillers are used when the condition of headache becomes uncontrollable and interferes with your physical activities. However, the treatment of TTH can vary according to the symptoms and triggers causing it.

Taking painkillers more than thrice a weak can be harmful and thus avoided by the patient. An individual is suggested to be in relaxation stage and tension free to avoid TTH. It is also suggested by experts to have a full sleep of 7–8 h a day in order to be away from headaches. Another way is the use of tricyclic antidepressants. If your headache is caused due to psychological factors, it may be hard to tackle.

It is then advised to see a counselor or psychotherapist. If home remedies do not work, then medical assistance may be needed by the doctor. Consumption of a high quantity of acetaminophen can damage the liver. The heavy dose of analgesics like ibuprofen or aspirin can disturb one's stomach or damage the kidneys too.

17.1.8.4 When to Seek Medical Emergency?

One must seek a medical emergency if

- Loss of balance, vision, speech, etc. occurs.
- The headache starts suddenly and becomes uncontrollable.
- Headache accompanied by high fever.
- Headache pattern changes.
- Medicines fail.
- One has side effects from medicines such as pale skin, rashes, depression, nausea, vomiting, cramps, and dry mouth.
- One is pregnant.

One needs to learn to keep balance among alternative therapy with no-drug consumption, using right and necessary medications only and nurturing healthy habits. It is not necessary that one is having TTH only whenever headache happens. There may be sufficient chances of brain tumor or rupture of a weakened blood vessel also known as an aneurysm in heavy TTH cases. One might also face headaches after a severe head injury. Protecting your head from such injuries is very important. Tension headaches are very common and it marks the QoL and efficiency and productivity in the job along with life satisfaction. Such kind of aches checks an individual from active participation in different activities. One may need to take a break from the job and be at home or even if one goes to work it may make your work impaired (Satya, et al. [10]; Wenk-Sormaz et al. [11]).

17.1.8.5 Preventions

Biofeedback Training

It is used to check some predefined body responses in a constrained environment to decrease the pain. Some important body indications are used as parameters like muscle tension, heart rate, and blood pressure.

Cognitive Behavioral Therapy

The method supports individual to learn how to handle stress and helps to shorten the frequency and severity of one's headaches.

Other Relaxation Techniques

It includes effective alternative therapies like deep breathing, yoga, meditation, progressive muscle relaxation, etc.

As per different studies and reports, it has been found and established that TTH is directly correlated with demographical conditions, social culture across the region as per age, the gender of individual, and stats analysis of data assessment. Large range of risk factors, new researches in genetic and neurobiological research have given a clear insight and in-depth know-how for TTH.

A majority of people with TTH do not seek medical attention thus it has been proven to be difficult to completely diagnose the exact effects, causes, and preventions of TTH. Even adults with new bodily changes are likely to go through TTH. This report thus proves that further research is very necessary on this particular topic and must be done by the medical associations (Carlson et al. [12]).

17.1.9 Biofeedback Therapy

Biofeedback therapy is the process of collecting knowledge about the different psychological functions using some specific instruments. The major objective is to control and manipulate these functions. Some of these controllable functions or processes are important body functions like skin conductance, brainwaves, heart rate, pain perception, and muscle tone. It may also be used to rectify psychological changes related to altering emotions, thoughts, and human behavior. This therapy is useful for treating migraines and headaches (Chauhan et al. [13]).

17.1.9.1 History of Biofeedback Therapy

The concept of homeostasis, i.e., the tendency of the body to stay hold in the inner environment, was introduced by Claude Bernard in the year 1865. It was shown by J.R. Tarchanoff in the year 1885 that the voluntary control of the heart rate could be precisely direct without changing the breathing rate. The voluntary control of the responsible muscle which wriggles the ear was studied by J.H. Blair in the year 1901. He discovered that this skill was learned by the subjects by inhibiting interfering muscles and by the demonstration of the self-regulation of the skeletal muscles. Conscious efforts were made by Alexander Graham Bell who used two devices, the phonautograph invented by Edouard-Leon Scott and a manometric flame, where he tried best to enable a deaf to speak. A theory was developed by mathematician, Norbert Wiener proposing that control of systems is possible by monitoring their results. The popular word “biofeedback” was given feedback of Wiener in the conference in Santa Monica in 1969. As a result, the Bio-Feedback Research Society was founded that allowed isolated researchers to collaborate with each other and it popularized the term “biofeedback” as well (Chauhan et al. [13]).

17.1.9.2 Biofeedback and TTH

It is a non-pharmacologic, majorly used to treat the stress and headache and tension-type headache. The key factors of efficiency, specificity, and treatment moderators are measured by the meta-analysis of biofeedback for TTH.

It is suggested that biofeedback is a good exercise for overcoming headache, mainly tension-type headache. Many studies have been carried out for biofeedback for the treatment of TTH and migraine. It was revealed that out of the last three months, at least four patients had been armed by this particular technique to cure headache.

Nowadays, the rate of headache and migraine disease is been increased upto 6 to 12. Mean patient age, where reported, ranged from 10.3 to 66.7 years (overall mean 35.9 years). The proportion of female patients varied from 43 to 100% (overall 71%). Duration of TTH varied from 1.2 to 42.4 years (overall mean 13.9 years) (Chaturvedi et al. [14]).

Many techniques were used to survey this problem, one of the techniques is electromyography feedback (EMG-FB). Many factors have been observed for making the survey like temperature feedback, galvanic skin response feedback, and electroencephalography feedback. Many teenagers in this world are facing this problem a lot and they all are unaware of this technique. Biofeedback techniques are simply cured of TTH and other headache problem.

17.1.9.3 Biofeedback Application in Headache

Biofeedback is a technique where our body is carried out by an electrical sensor to be monitored and symptoms are recorded. It monitors the activities that are not able to recognize by our physical body.

Biofeedback takes many measurements of the important human body parameters like heart rate, blood pressure, brain waves, skin temperature, anxiety, breathing rate, etc. This helps us recognized that what inner problem our body is facing and we are not able to cure that in time.

By this treatment, we are able to cure our headache and other problem like anxiety, high blood pressure, etc. But in today world TTH, i.e., tension-type headache, is the main problem that every single person in the present generation is facing day by day. So it is a simple technique to cure headache. By doing many physical activities instead of consuming medicines can be a better way and via biofeedback, a person is also not affected by another side problems.

17.1.9.4 Social Impact and Records of TTH as per Gender and Age

TTH though is not very harmful as it is present in the majority of the population. But to be true there are various social impacts of TTH. They can be described as below:

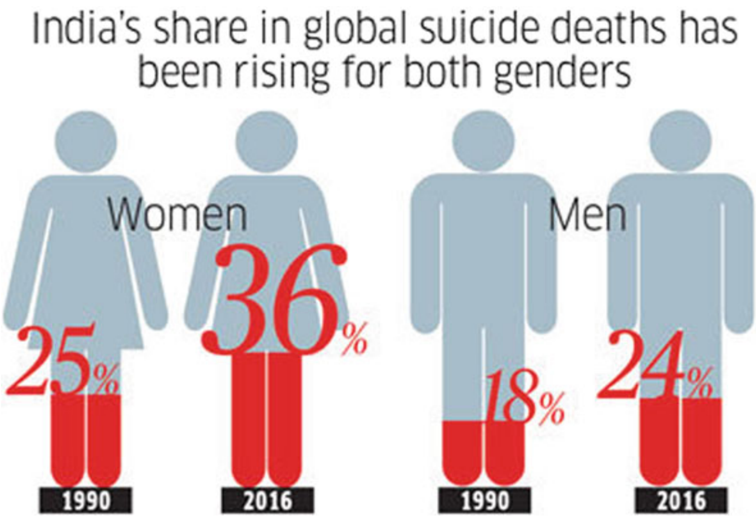

Fig. 17.2 Representation of impact of TTH on age between male and female (Haynes et al. [7])

- It can result in a lack of concentration at work.
- One may not be able to go to work due to this and constantly stay unhappy.
- It can also lead to anger and disturbed state of mind leading to unhealthy relationships with others.
- One may not be able to spend quality time with friends and family.
- The person suffering TTH may stay in depression and anxiousness for a prolonged period of time.
- The person will find it difficult to stay socially active (Figs. 17.2 and 17.3).

17.1.10 Mental Health

17.1.10.1 Importance of Mental Health, Stress, and Emotional Needs and Significance of Study

From ages, human has always been in search of peace. From 5000 B.C. to till date in the first quarter of the twenty-first century, from a long time, man has developed many methods for recreation, entertainment, and synergy. As much as the lifestyle went on hectic, the population was increasing, limited resources of earth were not enough for all. To grab more and more resources, the natural lifestyle vanished and the human race was collectively gripped into a materialistic culture and accumulating tendency with the consumerist lifestyle.

It generated a mass of stress and consequently clashes, disharmony, anxiety, depression and in extreme situation, the suicidal tendency. To meet these issues, the

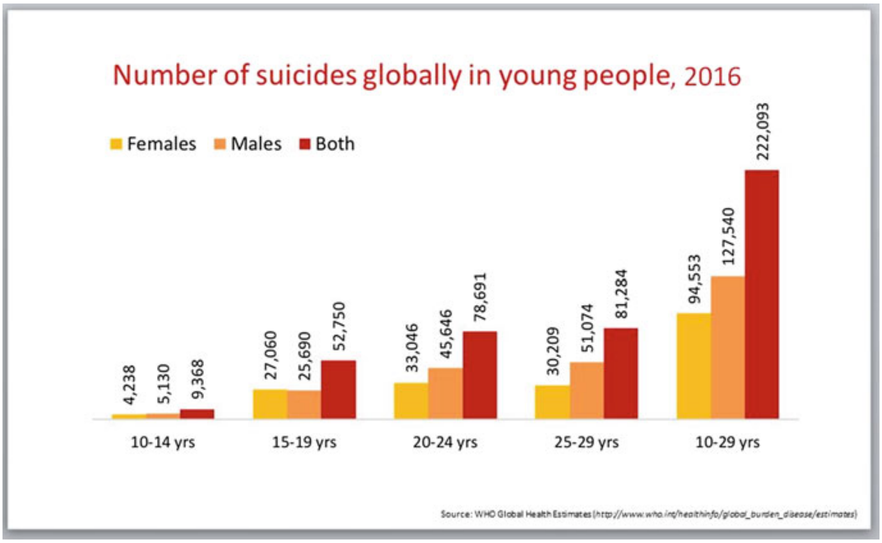

Fig. 17.3 Prevalence of different annals of suicides globally in young people (Journal of Neurology & Neuroscience)

psychiatrist, psychologist, and social analysts did in-depth studies in their own ways and they found many alternative methods and treatments for the same. In recent studies of this century, it has been well established that most of the human body diseases and abnormality are psychosomatically generated. In this research, the scholar has tried best the recent method(s) of alternative therapy like biofeedback which is getting popular due to their ease of applicability and no side effects on human brain and body (Satya et al. [15]).

The biofeedback therapies have been popular for long for the treatment of various mental challenges, stress, and chronic headache like tension-type headache. Stress due to tension-type headache is a very frequent occurrence in all our lives. A TTH symptom experienced for long by an individual with no relief or with increased frequency, it is termed as distress. Weakened cognitive and physiological control is due to TTH originated stress and results in performance reduction. It can lead to symptoms like headache, gastrointestinal disturbances, elevated blood pressure, chest pain, insomnia, peptic ulcers, sexual dysfunction, skin ailments, etc. (Satya et al. [15]).

Life may be divided into four major stages such as kid-life, childhood, adolescence, and adulthood, where the third one is having a transition and transformation. The dis balance of increasing Harmon, their all kind of growth or loss in the body leads to disturbance in physical, mental balance and mental piece is compromised in lack of right guidance and care.

In this crucial time, mostly the teenagers lose their mental balance, get violent and are unable to handle the pressure from peer, friends, parents, and society. In opposition to this, those parents who rightly care about their youngsters and treat them friendly behave sympathetically, less suffer from these issues in their families.

Major emotions of an individual are fear, anger, love, jealousy, guilt, and worries. Wise people handle them carefully and stop the cycle within them instead of spreading them. They enjoy their family relations, office work, and social relations and treat them as their duty. So in this research work, the author team tried to find the impact of positive ideas on mood states of personality for mental health (anxiety, stress, depression, aggression, fatigue, guilt, extraversion, and arousal on the students and technocrats of our institutes) (DSVV and ABES Engineering College, Ghaziabad) (Rastogi et al. [16]; Scott et al. [17]).

17.1.10.2 Mental Health Introduction

Mental health has been always the prime concern of intellectuals, behavioral scientists, and social study makers. Nowadays, it is of a prime concern and happiness index has been considered as an integral part of the progress of any country. Less work has been experimented in the South Asian region regarding mental health. Its correlation with social parameters of age, gender defined by connotates the behavior, perception and feelings that determines a person's overall level of self-effectiveness, happiness and excellence of functioning as an individual (Sharma et al. [18]).

WHO has also accepted the fact and reframed its definition of complete health as individual mental, physical, social, and spiritual wellbeing is termed as complete health.

Therefore has found a balance in his or her social, emotional, and psychological areas of life (John M. Grohol, Psy.D) and (Haddock et al. [19]).

In 2007, WHO has stated, mental health is about: the feeling for ourselves, others and our demands from life. It has also stated the difference between mental ill-health and illness. It states that mental unfitness vanishes the chance of potentials and causes serious problems.

In the case of mental issues, recovery/management may be ensured in the form of counseling or psychotherapy, drug treatment, and lifestyle changes. Stats says that approximately 25% of the people in the UK have mental health problems during their lives, whereas the USA is said to have the highest incidence of people diagnosed with mental health (Arora et al. [20]; Vyas et al. [21]).

17.1.10.3 Factors Affecting Mental Health

According to Joel L. Young M.D., there are nine main symptoms or components that challenge to individual's mental health—daily exercise and social activity level, smoking, diet pattern, physical activity in form of bodily work, abuse or misbehave, social and community activities in residence, relationships with peer and office mates, practice of meditation and other relaxation techniques, use of alternative therapies and priority to healthy sleep (Rastogi et al. [22]; McCrory et al. [23]).

17.1.10.4 Problems and Needs of Adolescents

On the basis of age, group adolescence is categorized into (20–26)years of age or according to early principles (13–18) years that mainly depends on physical growth and development. Physical, emotional, social, and intellectual development are four major types. Following needs and life goals appear to be a source of many emotional problems of adolescents. Need for social status, acceptance and security, independence, adventure, self-support, and belongingness. Adjustment to personal appearance, physical and psychological changes, use of alcohol and drugs, need of heterosexual relations, and a theory of life (Saini et al. [24]; Turk et al. [25]).

17.1.11 Biofeedback with EEG Instrument (Earlier Experiments)

Biofeedback is a method of neurotherapy, a forward-moving regression, and self-controlled relaxation technique to handle the stress and TTH (Wenk-Sormaz et al. [11]). It helps subject to know the current stress level and to handle them.

The biofeedback is an alternative popular therapy used for QoL and strengthens adjustment skills. Found that silent meditation, yoga, and Indian spiritual exercises have a very deep effect on the subconscious of the patient and refine their ill personality factors. In their research recruited 20 mediation practitioners for 10 days meditative therapy process and established the high reported concentration, confidence, and peace of mind. They also reported the decrement in the negative emotions and ill effects as compared to the non-experimental control group. They also witnessed less demotivating components and reduced rumination.

17.1.12 Sensor Modalities

Three popular standard organizations responsible for controlling and marking the biofeedback process, therapy, symptoms, and effects are AAPB, BCIA, and ISNR. They unanimously reached the common definition of biofeedback in 2008: Biofeedback is a process to make capable an individual to learn to alter physiological activity to strengthen the purposes rectifying the health and performance. There are very high accurate instruments to record physiological activity through body functions. As time passes, these alterations can sustain without rapid use of an instrument (Rastogi et al. [16]).

17.1.13 Types of Biofeedback

17.1.13.1 Electroencephalography (EEG)

It is an electrophysiological monitoring technique which is used to track the brain's electrical activity. EEG is generally non-invasive, electrodes are placed along the scalp, although sometimes invasive electrodes may be used too. Brain neurons have an ionic current which is measured by voltage fluctuations. It is generally used to diagnose epilepsy. It can also be used to diagnose coma, brain death, sleep disorders, encephalopathy, depth of anesthesia, stroke, tumors, and other brain disorders (Rastogi et al. [16]).

17.1.13.2 Electrocardiography (ECG)

The process of generating an electrocardiogram, electrodes are placed on the skin, is called electrocardiography (ECG). Small electrical changes produced as a result of the cardiac muscle polarization and depolarization during each heartbeat are detected by these electrodes. Inadequate artery blood flow, electrolyte disturbances, and numerous cardiac abnormalities can result in changes in the normal ECG pattern.

17.1.13.3 Electromyography (EMG)

The electrodiagnostic technique used to track and evaluate the electrical activity of the skeletal muscles is known as electromyography (EMG). It is carried out by using an instrument known as electromyography, which generates a record called electromyogram. The electric potential produced by the electrically or neurologically activated muscle cells is detected by the electromyography. Upon evaluation and analysis, to analyze the biomechanics of human and animal movement, these signals can be used to detect recruitment order, medical abnormalities, or activation level (Sharma et al. [18]).

17.1.13.4 Galvanic Skin Response (GSR)

The Features and characteristics of our body where rapid variations on the electrical attributes of skin are measured have been proved to be very important biofeedback indicators. The gadget to record this feature is called Galvanic Skin Response (GSR). The resistance of the skin changes as per nature of the sweat glands in the individual's skin. Skin conductance indicates physiological or psychological arousal. If the sympathetic nervous system gets aroused, then sweat gland activity increases, which results in the increase of skin conductance. Skin conductance measures sympathetic and emotional responses. Recent studies show that there is

Fig. 17.4 Experiment using biofeedback machines

much more about GSR than meets the eye, and further research and study is going on this field. It is also known as electrodermal activity (EDA), electrodermal response (EDR), skin conductance, psycho galvanic reflex (PGR), etc. (Haddock et al. [19]; Vora et al. [59]; Tanwar et al. [60, 61]).

Electrical characteristic of the skin of the human body is measured under electrodermal activity (EDA). EDA has also been known as skin conductance, galvanic skin response (GSR), electrodermal response (EDR), psycho galvanic reflex (PGR), skin conductance response (SCR), sympathetic skin response (SSR), and skin conductance level (SCL) (Rastogi et al. [22]).

At subconscious state, the cognitive and emotional level of human behavior is modulated by an autonomous way for the sympathetic activity of skin conductance. So it helps to get the right evaluation of autonomous emotional regulation. Fingers, palms, soles of feet, and other human extremities exhibit various bio-electrical phenomena (McCrory et al. [23], Figs. 17.4 and 17.5).

17.1.14 Stress

17.1.14.1 Models of Stress (Headache)

Three models are in practice to medically define the stress which is described as below:

- General adaptation syndrome (Figs. 17.6 and 17.7), stages—alarm, resistance
- Exhaustion: Selye eustress and distress (Table 17.1)
- Lazarus: Cognitive appraisal model (Vora et al. [63]; Vora et al. [64]; Yadav et al. [35])

Fig. 17.5 Recording of biofeedback data

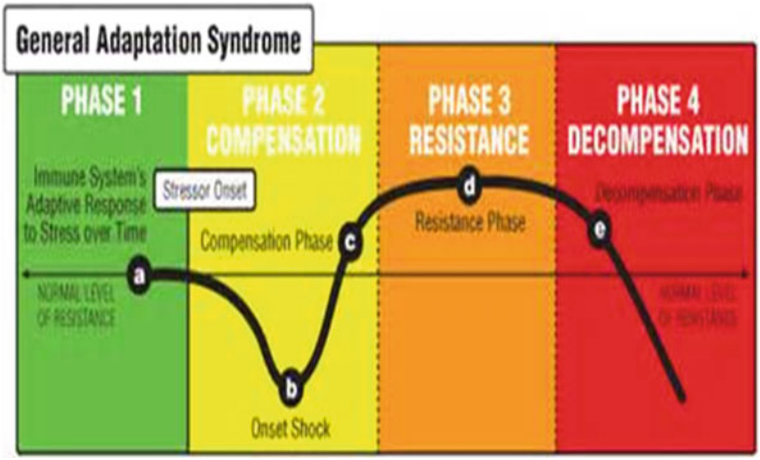

Fig. 17.6 Phases of Stress [20]

17.2 Literature Review

Tension-type headache has been sought as foremost common sort of headache and has been found to occur on average three quarter of final population. They will vary from the occasional gentle headache to daily disabling headaches in some cases. Tension-type headaches are known by varied names over the years, together with cephalalgia, contraction headache, psychomyogenic headache, stress headache, standard headache, essential headache, disorder headache, and mental

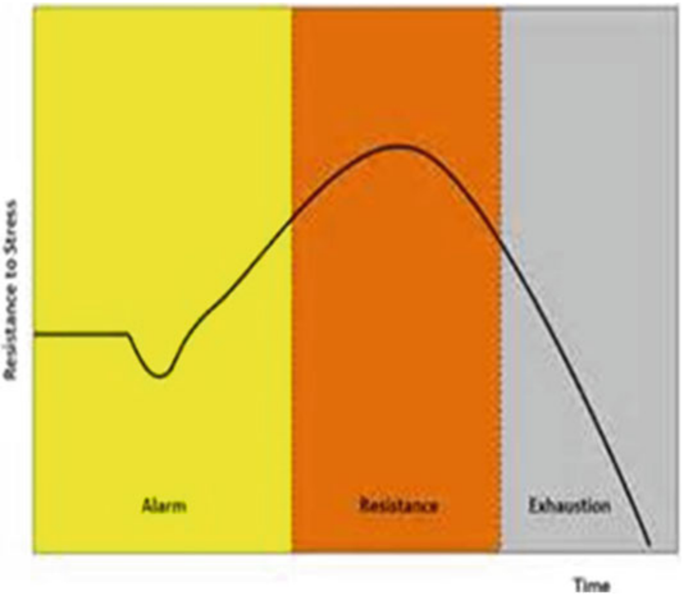

Fig. 17.7 Graphical updates for stress [20]

Table 17.1 Primary and secondary variables of EMG-GSR biofeedback process (Haynes et al. [7])

Variables	EMG	GSR	Control
Average frequency of headache per week	56	55.9	25.8
Average intensity of headache per week	58.2	56.3	46.5
Average duration of headache per week	75.7	63.6	49
SF-36 physical scores	25	26	21
SF-36 mental scores	25.1	19.5	21.7
SF-36 Total scores	28.5	30.5	21.7

headache. Of these names, solely "tension headaches" remains fairly off times used. As you'll be able to see from the names that tension-type headache has been better-known by, it had been at just the once thought that the explanation for tension-type headache was primarily psychological, caused by the mind or emotions. There have currently been studies that powerfully recommend a physical (neurobiological) cause (McCrory et al. [23]).

Tension-type headache is broken down into three types:

- Infrequent episodic type tension-type headache: one or fewer episodes per month.
- Frequent episodic type tension-type headache: more than one, but fewer than 15 episodes per month for three or more months.

- Chronic tension-type headache: more than 15 episodes per month for three or more months. There may be mild nausea with this type of tension-type headache (Tanwar et al. [65, 66, 68]; Zanella et al. [31]; Lee, et al. [32]).

  Today, the technology is dynamic and bringing paradigm shift in United States to develop a cultured technical world. The rising role of ICT has created an outsized impact on global process, activities and functioning. It enhances the quality of care, can increase the patient security and data protection and reduces operational and body value.
- The telecommunication devices are a great deal of user friendly and used by an outsized population around the world that have reduced the communication gap to a zero level. Therefore, accessibility to information has become an easy pattern through ICT and collectively, people have noticed a great deal of relaxation when they are availing these services.
- Biofeedback could be a mind-body technique that involves victimization visual or sensory system feedback to realize management over involuntary bodily functions. This could embody gaining voluntary management over such things as vital sign, muscle tension, blood flow, pain perception, and pressure. This method involves being connected to a tool with sensors that give feedback concerning specific aspects of your body.

Types of Biofeedback
- Breathing
- Heart rate
- Galvanic skin response
- Blood pressure
- Skin temperature
- Brain waves (Bansal et al. [26]; Kropotov et al. [27, 76]; Millea et al. [28])

EMG
- Electromyography (EMG) is a process to assess the health of muscles and therefore the nerve cells (motor neurons) that manage them play a crucial role. EMG results will reveal nerve dysfunction, muscle dysfunction, or issues with nerve-to-muscle signal transmission.

GSR
- GSR in Biofeedback: The galvanic skin response (GSR) feedback instrument measures skin conduction from the fingers and/or palms. ... GSR phenomenon feedback has been employed in the treatment of excessive sweating (hyperhidrosis) and connected medicine conditions, and for relaxing and desensitization training.

EEG
- An Electroencephalogram (EEG) is a device that detects electrical activity in one's brain. For this, a little treatment is done where metal discs (electrodes) are hooked up to one's scalp. Your brain cells communicate via electrical impulses and area unit active all the time, even once you are asleep. This activity shows up as wavy lines on EEG recording.

- An EEG is one of the main diagnostic tests for epilepsy. An EEG can also play a role in diagnosing other brain disorders.
- (Arora et al. [6]; Carlson [12]). Visual EMG-BF has been used less compared to auditory feedback15 (Mullaly et al. [29]; Crystal et al. [30]).

17.2.1 Emotional Fulfillment

In the theory of self-actualization, Maslow in 1954 has given a hierarchy of human needs which are psychological, safety, belonging, love, esteem needs, and need of self-actualization.

Murray in his studies proposed 12 physical needs and 28 psychological needs. Among them, 20 important needs are as follows: dominance, sentience, deference, exhibition, autonomy, play, aggression, affiliation, abasement, rejection, achievement, succorance, sex, nurturance, avoidance, ham avoidance, dependence, order, counteraction, understanding (Verma et al. [68]; Binder et al. [33]).

17.2.2 Background and Purpose of Our Study

We are going to use S-36 questions set for the stress analysis of any individual and after the analysis of the stress report of user we are going to suggest some prevention and control measures as per need.

The Short Form Health Survey is a 36-item, patient-reported survey of patient health. The SF-36 is a measure of health status and an abbreviated variant of it, the SF-6D, is commonly used in health economics as a variable in the quality-adjusted life year calculation to determine the cost-effectiveness of a health treatment. The original SF-36 stemmed from the Medical Outcome Study, MOS, which was conducted by the RAND Corporation. Since then a group of researchers from the original study released a commercial version of SF-36 while the original SF-36 is available in public domain license free from RAND. A shorter version is the SF-12. If having only adequate physical and mental health summary scores is of interest, "then the SF12 may be the instrument of choice."

17.2.3 Intervention on Experimental Study Conducted

When all the candidates are divided into three groups, all the candidates are informed about the treatment that is going to be tested upon them. They were given biofeedback training in a separated room of Hardwar research laboratory, which had very low lighting and negligible external noise so that they could remain in a relaxation state. All candidates underwent respective (EMG/GSR) BF training for 20 min per session for 07 sessions (Turk et al. [25]; Kropotov et al. [27, 76]).

17.3 Methodology and Collection of Data

17.3.1 Universe and Sample

This study will be a randomized single-blinded controlled prospective study. We shall select a no. of recruited subject say n, where (f females and m males) will be randomly allocated to seven groups and will be receiving this biofeedback therapy. All the psycho challenged cases living in Uttarakhand and NCR region (Delhi, Meerut, Ghaziabad, Faridabad, Gurugram, Modinagar, and Muradnagar) will be the universe of study. The college-going students and technocrats of different giant MNCs will be understudy.

A control group of around 100–150 persons will be chosen and for carrying out this work the methodology employed shall be as follows:

- Literature survey.
- Identification of the location (cluster near the region of National Capital Region (NCR) Zone) and perform the study of different given parameters of the psychosomatic disorders due to life deregulation which disturbs one's complete health.
- Development of a model of biofeedback-based experiments which will be performed at Research Labs and Scientific Spirituality Centers of Dev Sanskriti VishwaVidyalaya, Hardwar and Patanjali Research Foundations, Uttarakhand.
- Experimental investigation of mental and spiritual health will be on various medical parameters.
- We will apply some spiritual techniques as per the symptoms observed, suitable to the patient as per his/ her age, diet, culture, and habits.
- Data analysis of the comparative study of both EMG and GSR machines with various spiritual techniques (guided meditations) will be applied over the patients and their performance.
- Analysis of the results obtained and verification of the efficiency of the technique and suggesting appropriate one will be done in a repeated process in case the method doesn't work.
- Impact of the result obtained on the society, the employee, company/college, and environment.
- 25% area (approximately 25 wards) out of 103 wards will be selected as samples purposively.

In the present study, samples of 95 adolescents are selected from ABESEC, Ghaziabad and DSVV Hardwar of graduation. Among this sample, 55 are from urban area, i.e., Lalquan, and 50 are from rural area, i.e., near to Pilkhua township in Ghaziabad (Singh et al. [39]; Gulati et al. [40]).

17.4 Result and Discussions

17.4.1 Experiments and Results

17.4.1.1 Hypothesis

There is a significant effect of biofeedback-based self-guided meditation on mental health and stress management (headache). There is a significant increase in the level of stress management (TTH) and emotional needs by meditation practices. The hypotheses which proved true by this experiment are as below.

- There is no significant difference in the mental health of adolescents due to meditation and therapy by EEG, GSR and EMG integrated audio-visual biofeedback.
- There is no significant relationship between mental health and stress relief practices.

17.4.1.2 Variables in the Study

Independent variable—EEG inputs, Audio-visual EMG and GSR biofeedback therapy, mindful meditation, spiritual attitude

Dependent variable—Stress management, tension-type headache, mental health of adolescents

17.4.2 Experiments with Audio-Visual EMG and GSR

Graphs were plotted in Anaconda Framework with the help of python programming.

Analysis (Fig. 17.8): SF-36 test was applied on different subjects who experienced the audio-visual EMG therapy and graph shows the SF-36 scores of 27 patients over the period of starting point, 30 days, 90 days, 180 days, and 365 days, from the bar graph it is observed that the relative scores of all the patients have been increased.

Analysis (Fig. 17.9): The above graph shows the SF-36 scores of 28 patients which gave audio-visual GSR therapy for 10 sessions each of 15 mins. And records were taken over the period of starting point, 30 days, 90 days, 180 days, and 365 days. From the graph, we may conclude that the relative scores of all the patients have been increased, so it validates the utility of therapy.

Analysis (Fig. 17.10): 27 other subjects chosen for non-experiment group and their SF-36 scores were recorded but it has been observed over the period of baseline, 1 month, 3 months, 6 months, and 1 year. From the graph, it is observed that the above scores increased.

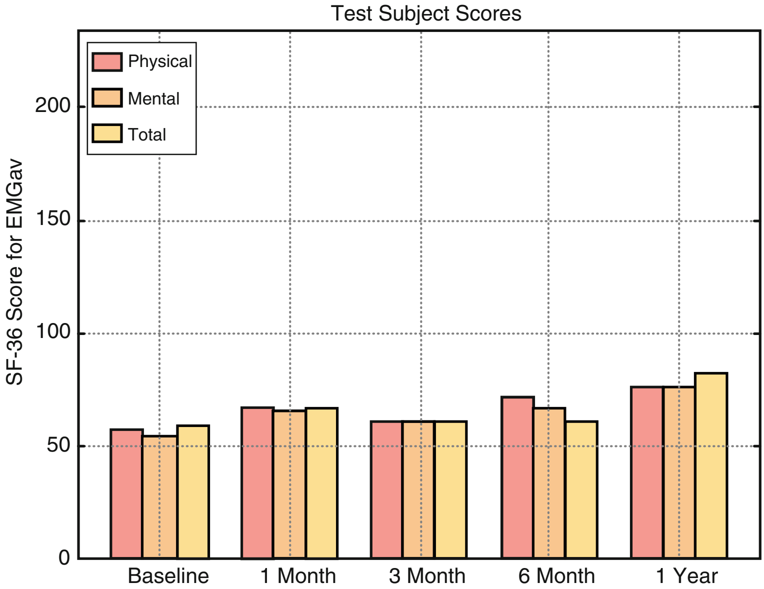

Fig. 17.8 The graph shows the SF-36 scores of 27 patients over the period of starting point, 30 days, 90 days, 180 days, and 365 days with EMGav therapy

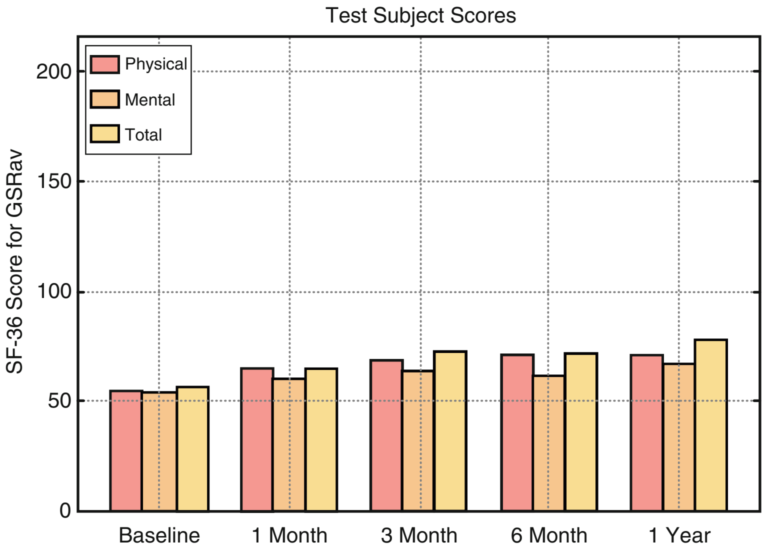

Fig. 17.9 The graph shows the SF-36 scores of 28 patients which were given audio-visual GSR therapy for 10 sessions each of 15 min

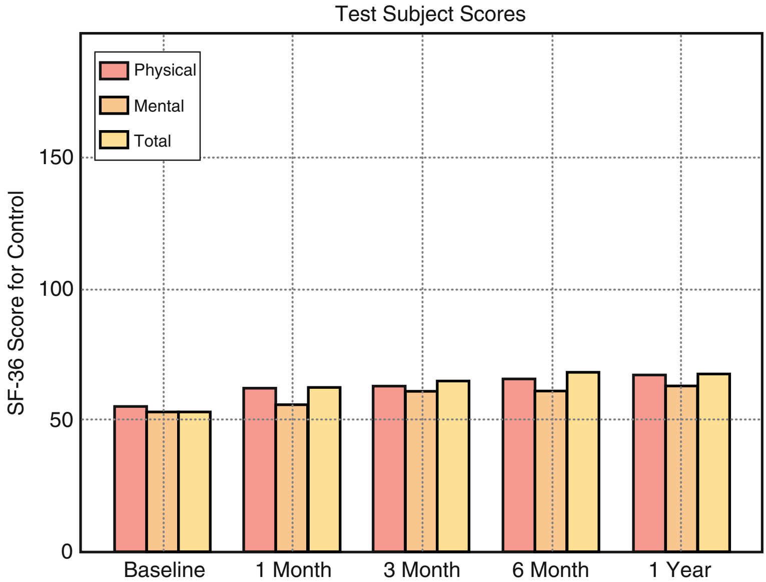

Fig. 17.10 SF-36 scores of 27 subjects chosen for non-experiment (control) group were recorded over a period of baseline

From all of the 3 bar graphs, simultaneous observations may be made that relatively EMG and GSR group has experienced more growth than the control group in their physical, mental, and total scores than the control group. BFB therapy application has shown a significant reduction in stress (TTH).

In EMG, physical scores were constant around for 6 months and gradually increased in the next half. In GSR, physical scores kept on varying to increment continuously. In EMG, mental scores were continuously increasing. In GSR, physical scores kept on increasing continuously. Total scores in both were under fluctuation and varying but increasing timely.

Analysis (Fig. 17.11): The above line graph shows the relation between physical scores of audio-visual EMG, GSR, control categories over the period of a starting point, 30 days, 90 days, 180 days, and 365 days. From the graphs, it is clear that the physical scores of EMG and GSR were better than have increased over the period of time. Initially, the GSR superseded the EMG therapy up to around 6 months but in the next half, EMG therapy showed significant increment over GSR and control groups.

Analysis (Fig. 17.12): The line graph showing the relation between mental scores of audio-visual EMG, GSR, control categories over the time period of baseline, 1 month, 3 months, 6 months, 1 year. From the very starting point, the EMG therapy showed the drastic increment continuously over GSR and control groups in the overall experiment period.

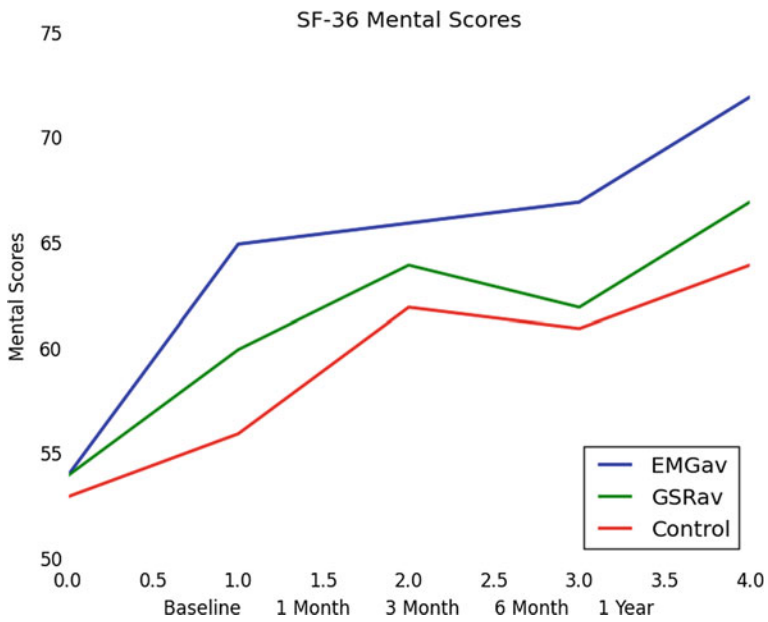

Fig. 17.11 The line graph shows the relationship between physical scores of audio-visual EMG, GSR, control categories over the period of the starting point, 30 days, 90 days, 180 days, and 365 days

Analysis (Fig. 17.13): In an overall score of EMG, GSR, and control categories, we found that initially GSR and EMG were competing but in the latter half, EMG showed a clear win over GSR technique in dealing with the stress issue of subjects.

Analysis (Fig. 17.14): The above line graph shows the relation between average frequency of headache for audio-visual EMG category over the period of starting point, 30 days, 90 days, 180 days, and 365 days. From the graphs, it is clear that the frequency of EMG and GSR were decreased over the period of time.

Analysis (Fig. 17.15): The above line graph shows the relation between average frequency of headache for audio-visual GSR category over the period of starting point, 30 days, 90 days, 180 days, and 365 days. From the graphs, it is clear that the frequency of EMG and GSR were decreased over the period of time.

Analysis (Fig. 17.16): The above line graph shows the relation between average frequency of headache for control category over the period of starting point, 30 days, 90 days, 180 days, and 365 days. From the graphs, it is clear that the frequency of EMG and GSR were decreased over the period of time. On the other hand, their control groups do show such results.

Analysis (Fig. 17.17): The following graph shows the score of REMG and VAS of 51 patients. The X-axis shows the score of VAG and REMG score is shown on Y-axis. The X-axis also shows the serial number of patients. The graph shows the

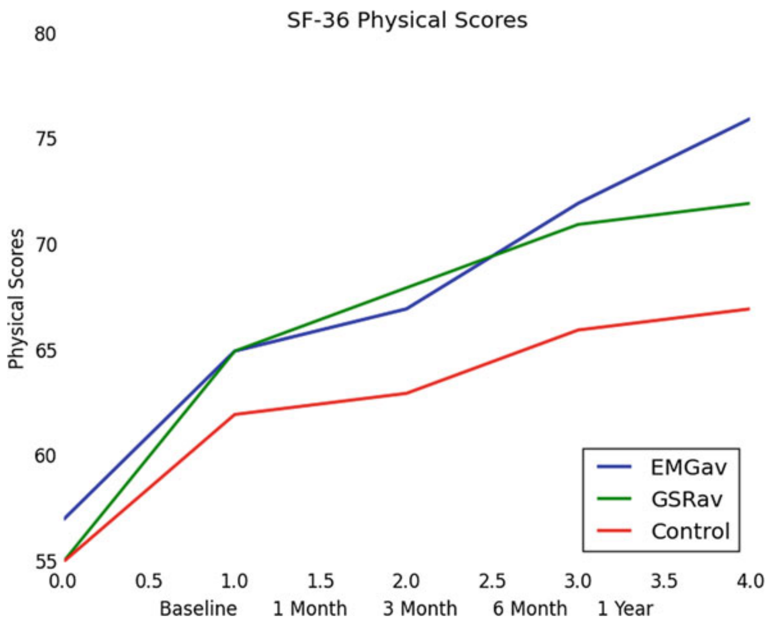

Fig. 17.12 Graph showing the relation between mental scores of audio-visual EMG, GSR, control categories over the time period of baseline, 1 month, 3 months, 6 months, 1 year

fluctuating records of different patients with respect to their relative EMG scores and visual analog score of headache intensity on a scale of 10.

17.4.3 Experiments and Discussion with EEG with Fog Computing

Analysis (Figs. 17.18 and 17.19): The waves are categorized majorly into four types, i.e., alpha, beta, gamma, and theta. Alpha waves are considered to be the best while theta to be the worst. The coolest form of waves is the alpha waves which are considered to be released during the meditation process (as per Tables 17.2 and 17.3).

Our experiment focussed onto measure the alpha waves before and after meditation and also considering the use of EEG for the same. The EEG machine we have done the experiment is 32-channel and the 64-channel could not be used because it was costly. Observations were recorded with and without EEG machine and for pre- and post-meditation.

The initial experiment was for a group of 13 subjects of different genders. The readings for alpha waves without using EEG were 3.4, 4.6, 2.9, 4.3, and so on while for after using EEG were 5.9, 5.6, and so on, respectively. We then calculated the

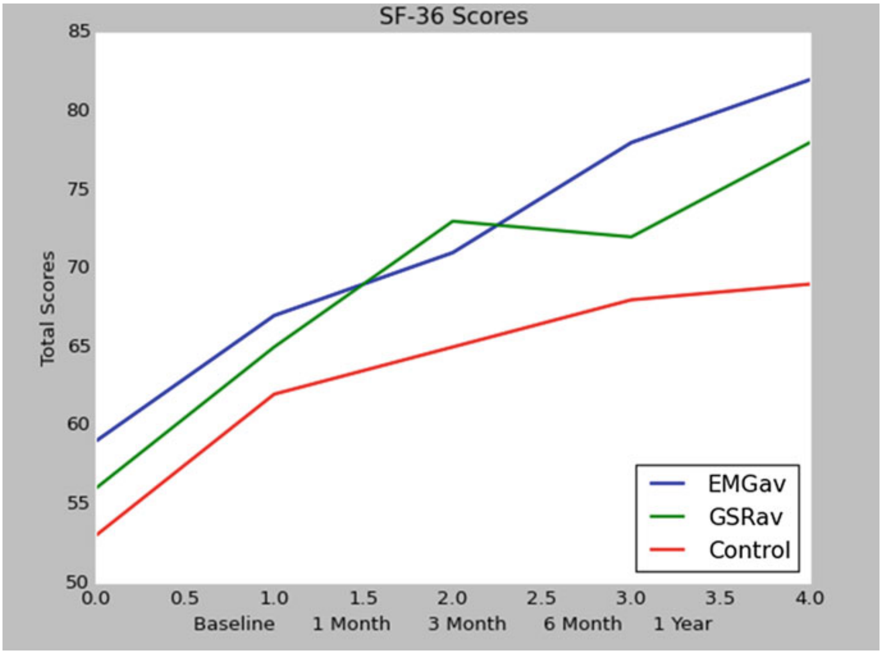

Fig. 17.13 Shows the overall score of EMG, GSR, and control categories

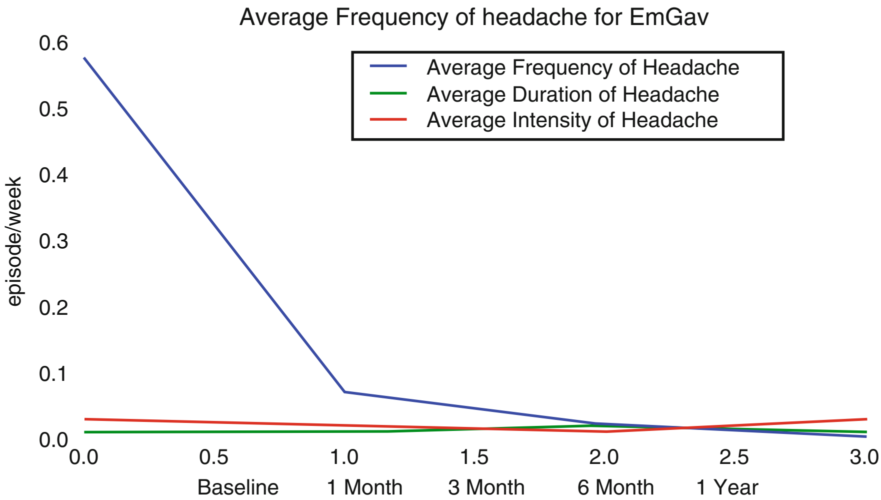

Fig. 17.14 Above the line, the graph shows the relation between the average frequency of headache for audio-visual EMG category over the period of starting point, 30 days, 90 days, 180 days, and 365 days

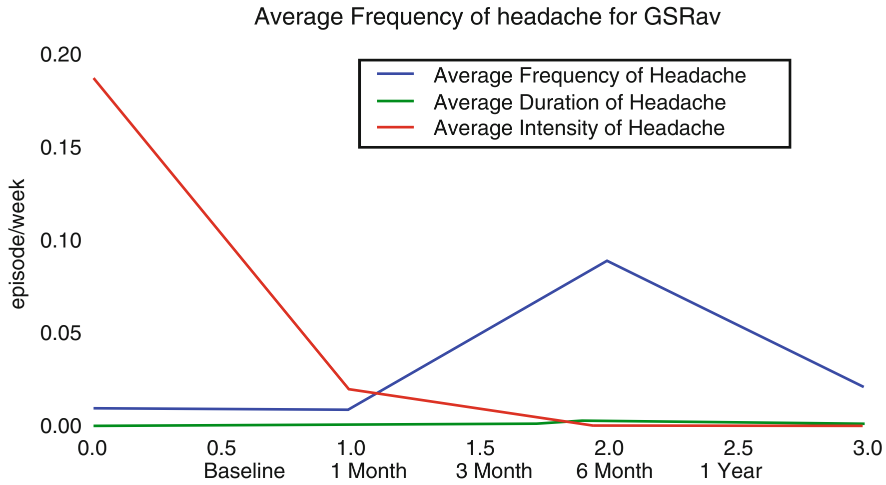

Fig. 17.15 The line graph shows the relation between the average frequency of headache for audio-visual GSR category over the period of starting point, 30 days, 90 days, 180 days, and 365 days

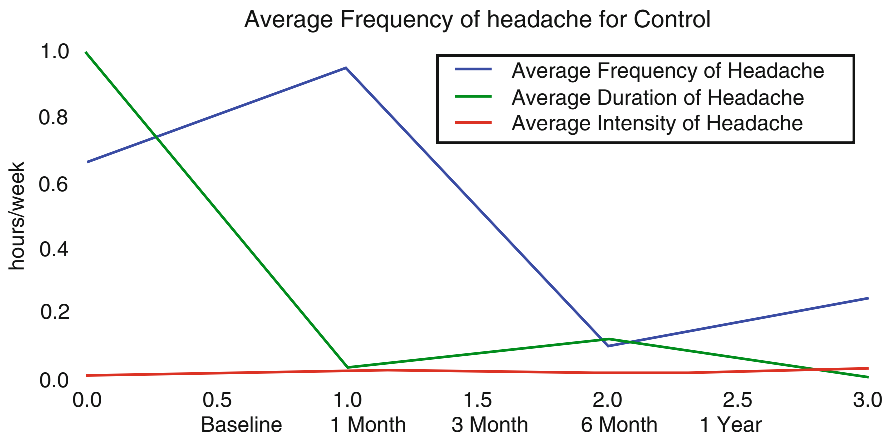

Fig. 17.16 The line graph shows the relation between the average frequency of headache for control category over the period of starting point, 30 days, 90 days, 180 days, and 365 days

standard derivative and the rank relation coefficient for the two values and concluded that they are very less correlated (0.18).The values of SD1 and SD2 were 0.53 and 1.06, respectively. Also, the test conducted results in a t-value of 12.6.

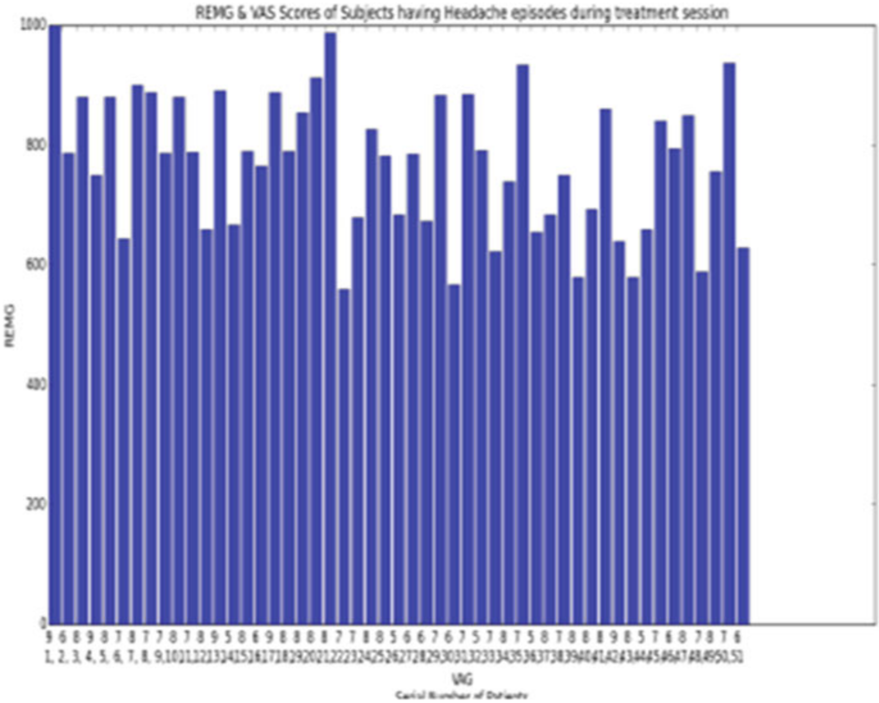

Fig. 17.17 The graph shows the score of REMG and VAS of 51 patients

17.4.3.1 Experiment 2: Graphs using Fog Computing

Analysis (Figs. 17.20 and 17.21):

The same experiment was repeated for another 18 subjects for pre- and post-stress relief exercises. The observations were recorded as they were previously done. The alpha waves measured for before experiment were recorded to be 5.17, 4.13, 6, 7.37, and so on. The observations were, however, this time divided based on gender and also a combined observation was recorded. The readings were different for some subjects while the same for some subjects and differed for each subject. The value of SD1 and SD2 for combined data was recorded to be 1.02 and 1.62, respectively. The rank correlation coefficient was 0.52. However, a very low value of T was recorded, i.e., 0.01. The study could be better experimented using 64-channel EEG but due to some limitations, we were unable to do so. The 64-channel EEG machine is costly and can be used for a large sample of data (Tables 17.4 and 17.5)

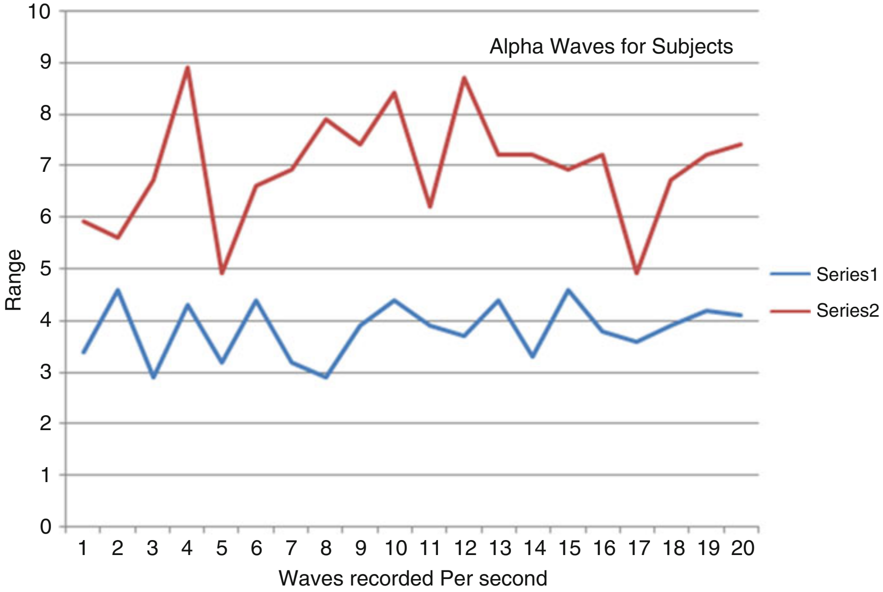

Fig. 17.18 The graph shows the alpha waves for some subjects recorded within a particular interval of time

17.4.4 The Discussion on Quality of Life

Since in the duration of 1 year, only 22 subjects participated fully so we are considering only them. Increasing stress levels in people nowadays are creating higher tension levels, which ultimately results in chronic headaches. One of the most prominent headaches is Tension-Type Headache (TTH) creating unendurable mental disorders. Main life events such as divorce, surgery, and loss of close relatives, family members inculcate major negative effects. Such events in the previous year have been considered related to the persistence of headache.

The main aim of our research is to study the effects of tension-type headache using biofeedback therapies on various modes such as audio modes, visual modes, and audio-visual modes. The experiment was conducted on 90 people, out of whom 78 people remain till the end of medical treatment. In 78 people, 46 were females and 32 were males and it was recorded that females had higher levels of headaches in younger ages. The groups were randomly allocated for Galvanic Skin Resistance (GSR) therapies and the other one was a control group (the group which was not under any type of allopathic or other medications). Except for control group, other groups were treated in a session for 20 min in isolated chambers. The results were recorded over a specific period of time say 1 month, 6 months, or 12 months.

In this study, authors have also tried their best to check the effect of TTH over age and gender. TTH is one of harmful headache, is produced by stress, and may

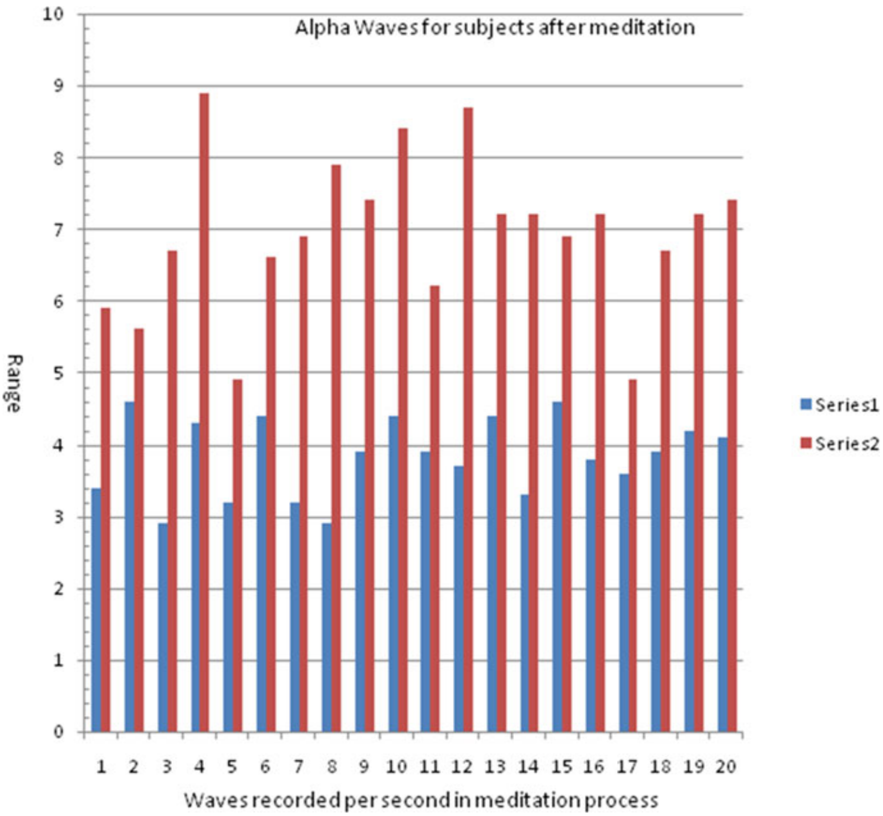

Fig. 17.19 The graph shows the alpha waves of subjects recorded after meditation

Table 17.2 EEG recordings data in the first experiment

M1	3.84
M2	6.94
R	0.18
SDx	0.53
S	1.06
SED	0.25
t-value	12.6

start at any stage of life. Subjects usually suffer from two types of TTH, i.e., for a short time and for a long time. When subjects suffer from a long time, then it affects both mind and body. So, one may check at which age it started and how gender is affected by this problem.

Table 17.3 EEG recordings data in the first experiment

Before experiment reading						After experiment reading					
Name	Pre	Post	Alpha Waves/sec..X	x = X-M1	x^2	Pre	Post	Alpha Waves/sec..Y	y = Y-M2	y2	X*Y
Raj	10	34	3.4	−0.44	0.189225	10	59	5.9	−1.04	1.0816	0.452
Radha	10	46	4.6	0.77	0.585225	10	56	5.6	−1.34	1.7956	−1.03
Monika	10	29	2.9	−0.94	0.874225	10	67	6.7	−0.24	0.0576	0.224
Harish	10	43	4.3	0.47	0.216225	10	89	8.9	1.96	3.8416	0.911
Ganga	10	32	3.2	−0.64	0.403225	10	49	4.9	−2.04	4.1616	1.295
Mradul	10	44	4.4	0.57	0.319225	10	66	6.6	−0.34	0.1156	−0.19
Mukesh	10	32	3.2	−0.64	0.403225	10	69	6.9	−0.04	0.0016	0.025
Savitri	10	29	2.9	−0.94	0.874225	10	79	7.9	0.96	0.9216	−0.9
Jaya	10	39	3.9	0.06	0.004225	10	74	7.4	0.46	0.2116	0.03
Rekha	10	44	4.4	0.57	0.319225	10	84	8.4	1.46	2.1316	0.825
Poornima	10	39	3.9	0.06	0.004225	10	62	6.2	−0.74	0.5476	−0.05
Manoj	10	37	3.7	−0.14	0.018225	10	87	8.7	1.76	3.0976	−0.24
Mukul	10	44	4.4	0.57	0.319225	10	72	7.2	0.26	0.0676	0.147
Suresh	10	33	3.3	−0.54	0.286225	10	72	7.2	0.26	0.0676	−0.14
Savita	10	46	4.6	0.77	0.585225	10	69	6.9	−0.04	0.0016	−0.03
Anmol	10	38	3.8	−0.04	0.001225	10	72	7.2	0.26	0.0676	−0.01
Mradul	10	36	3.6	−0.24	0.055225	10	49	4.9	−2.04	4.1616	0.479
Veerendra	10	39	3.9	0.06	0.004225	10	67	6.7	−0.24	0.0576	−0.02
Akhilesh	10	42	4.2	0.37	0.133225	10	72	7.2	0.26	0.0676	0.095
Nupur	10	41	4.1	0.27	0.070225	10	74	7.4	0.46	0.2116	0.122
Sum			76.7	Ex	5.6655			138.8	Ey	22.668	2.012
M1			3.835		0.283275		M2	6.94		1.1334	
SD1					0.532236		SD2			1.0646	

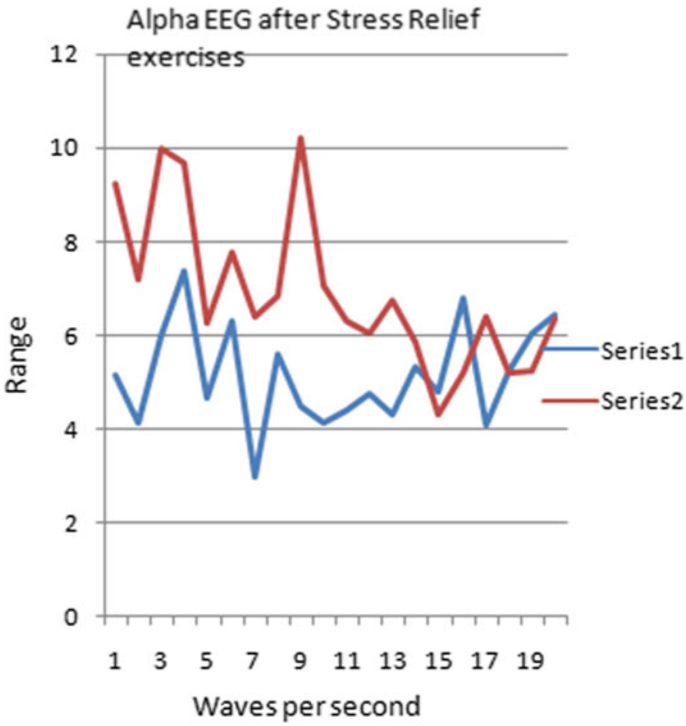

Fig. 17.20 The graph shows the alpha EEG for subjects recorded after stress relief exercises

17.5 Novelties in this Research Work

Till date the field of Tension-type headache (stress) was less covered area, this time specially a systematic study has been conducted to show the effect of other than medication therapies like BFB therapy and comparing the results of EMG and GSR techniques for the effect of positive thinking to manage daily life stress and increase the capacity of problem-solving. The study also shows the betterment of biofeedback mechanism in a long duration of 1 year, subsequently recorded the SF-36 scores in 4 quarters and ignites the path of alternative medication techniques to overcome stress, anxiety, and depression-like psycho challenges. That means we can use this term commonly but stress is not so easy to explain. Stress is a word means to draw tight and has been used to describe hardship, affliction, force, pressures, strain, or strong effort. There are two higher mental processes. Problem-solving has been conceived by psychologists as the discovery of correct response to a problem or situation that is new and difficult for the individual. But decision-making refers to the selection of a correct response, out of several correct responses already brought out and had been found that as people are getting older and older their problem-solving ability is reducing. The paper has shown a clear path to find the relation

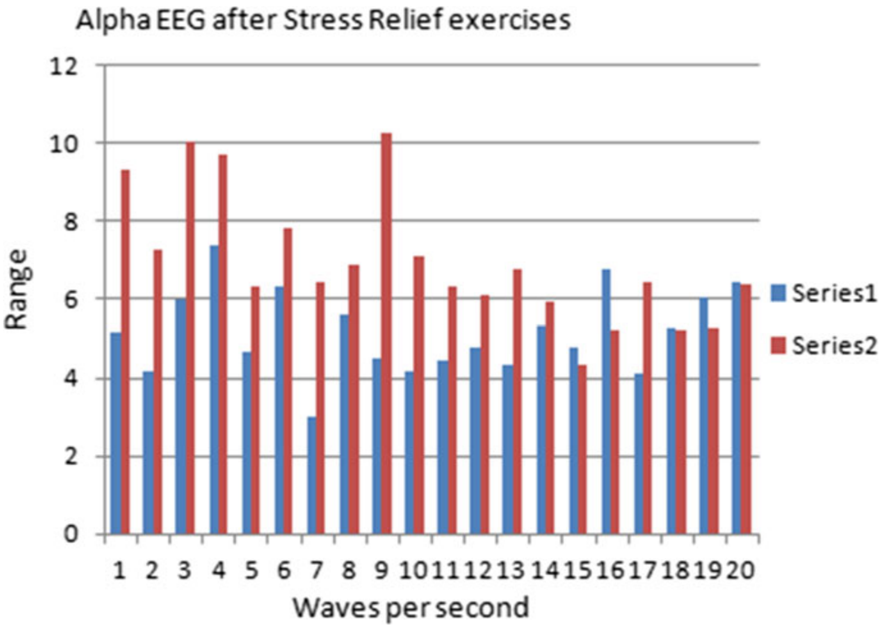

Fig. 17.21 Bar graph showing alpha EEG after for subjects after stress relief exercises

of stress (headache), problem-solving, decision-making, and physical and mental well-being of an individual.

17.6 Future Scope, Limitations, and Possible Applications

Stress is a central concept for understanding both life and evolution. All creatures face threats to homeostasis, which must be met with adaptive responses. Our future as individuals and as a species depends on our ability to adapt to potent stressors. At a societal level, we face a lack of institutional resources, pestilence, war, and international terrorism that has reached our shores. At an individual level, we live with the insecurities of our daily existence including job stress, marital stress, and unsafe schools and neighborhoods. These are not an entirely new condition as, in the last century alone, the world suffered from instances of mass starvation, genocide, revolutions, civil wars, major infectious disease epidemics, two world wars, and a pernicious cold war that threatened the world order. Although we have chosen not to focus on these global threats in this paper, they do provide the backdrop for our consideration of the relationship between stress and health.

Table 17.4 Second experiment readings data on EEG

Alpha EEG for combined Before Experiment Reading								Alpha EEG for combined After Experiment Reading					
Name	Age	Sex	Pre	Post	Alpha Waves/sec..X	x = X-M1	x^2	Pre	Post	Alpha Waves/sec..Y	y = Y-M2	y2	X*Y
Rakhi	23	F	10	51.7	5.17	0.04	1.600E-03	10	92.7	9.27	2.25	5.0625	0.09
Anamika	24	F	10	41.3	4.13	−1	1.000E+00	10	72.3	7.23	0.21	0.0441	−0.21
Sanjeev	23	M	10	60	6	0.87	7.569E-01	10	100.3	10.03	3.01	9.0601	2.6187
Sudha	25	F	10	73.7	7.37	2.24	5.018E+00	10	97	9.7	2.68	7.1824	6.0032
Ankita	26	F	10	46.7	4.67	−0.46	2.116E-01	10	63	6.3	−0.72	0.5184	0.3312
Satyendra	24	M	10	63	6.3	1.17	1.369E+00	10	78	7.8	0.78	0.6084	0.9126
Sumit	21	M	10	29.7	2.97	−2.16	4.666E+00	10	64	6.4	−0.62	0.3844	1.3392
Jitendra	22	M	10	56	5.6	0.47	2.209E-01	10	68.7	6.87	−0.15	0.0225	−0.0705
Chhaya	22	F	10	44.7	4.47	−0.66	4.356E-01	10	102.3	10.23	3.21	10.3041	−2.1186
Aneeta	24	F	10	41.3	4.13	−1	1.000E+00	10	70.7	7.07	0.05	0.0025	−0.05
Shobheet	32	M	10	44	4.4	−0.73	5.329E-01	10	63.3	6.33	−0.69	0.4761	0.5037
Ajeet	25	M	10	47.3	4.73	−0.4	1.600E-01	10	60.7	6.07	−0.95	0.9025	0.38
Swati	24	F	10	43	4.3	−0.83	6.889E-01	10	67.7	6.77	−0.25	0.0625	0.2075
Naveen	24	M	10	53.3	5.33	0.2	4.000E-02	10	59	5.9	−1.12	1.2544	−0.224
Meenakshi	23	F	10	47.7	4.77	−0.36	1.296E-01	10	43.3	4.33	−2.69	7.2361	0.9684
Anshu	21	M	10	67.7	6.77	1.64	2.690E+00	10	52	5.2	−1.82	3.3124	−2.9848
Surakhsha	21	M	10	40.7	4.07	−1.06	1.124E+00	10	64.3	6.43	−0.59	0.3481	0.6254
Sheela	24	M	10	52.3	5.23	0.1	1.000E-02	10	52	5.2	−1.82	3.3124	−0.182
Asif	24	M	10	60.3	6.03	0.9	8.100E-01	10	52.7	5.27	−1.75	3.0625	−1.575
Sameer	26	M	10	64.3	6.43	1.3	1.690E+00	10	63.5	6.35	−0.67	0.4489	−0.871
Sum					102.87	Ex				138.75	Ey		5.694
M1					5.134		M2			7.02			0.2847
						SD1	1.02				SD2	1.62	

Table 17.5 Second experiment gender based readings on EEG

Alpha EEG-Combine		Alpha EEG—For Male		Alpha EEG—For Female	
M1	5.134	M1	4.98	M1	5.28
M2	7.02	M2	5.94	M2	4.73
N	20	N	10	N	10
R	0.52	r	0.24	R	0.71
SDx	1.02	SDx	0.87	SDx	1.26
SDy	1.62	SDy	0.79	SDy	1.55
SEMx	0.24	SEMx	0.29	SEMx	0.42
SEMy	0.37	SEMy	0.26	SEMy	0.52
SED	0.108	SED	0.115	SED	0.14
t-value	0.01	t-value	8.42	t-value	20.16
Sig	0.01	Sig	0.01	Sig	0.01

17.6.1 Limitation

There have been several studies regarding TTH and use of IoT in such field but the studies have been limited merely to writings. The solution to TTH and its perfect cure is not yet found. With such a high prevalence rate, it becomes a necessity for researchers to have a discussion over this topic and come to a final conclusion rather than relating to its symptoms and their cures. Thus important information must be deprived to plan the optimal treatment for TTH patients.

17.6.2 Significance

This study covers all possible aspects of TTH, IoT and big data and their applications to the field of a medical study. It is done in a very short period of time but covers. As a large area of population suffers from TTH thus it becomes a necessity to have a worthy and fruitful discussion and research on this topic. Topics like the causes, effects, cures, biofeedback therapies, future scope, etc. have all been covered by the researchers but its effective application is yet to come. These studies will prove to be useful at the time of its application. This study needs to be done on a large scale in order to prove useful and bring out a solution (Srivatava et al. [71]; Tanwar et al. [72]).

Fog computing which is also known as fog networking is a system architecture that uses edge devices (devices which provides a point to enter into enterprise and to the core network of service providers) to carry out computation, storage, and communication locally. It can be perceived both in big data structures and large cloud systems. It consists of a control and a data plane. It also supports IoT concept. Both fog computing and cloud computing provide application, storage, and data to their users. However, fog computing has a larger geographical distribution and has a closer juxtaposition to end users. Fog computing helps in providing the facilities for operation of storage, networking and computing services between end devices and cloud computing data centers (Bodhkhe et al. [73]).

17.7 Conclusions

From the above experimentation, we may conclude that EEG, audio-visual EMG-BF and GSR-BF are effective in the treatment of stress (TTH), with facts of EMG-BF being better and efficient than GSR-BF. In this study, the experimental group showed a significant reduction in the level of stress. Hence it can be proved by EMG and GSR biofeedback therapy and it can be easily concluded that continuous positive thinking has the capacity to reduce stress among students and increase their working performance (Kaneria et al. [74]) and (Vora et al. [75]).

In EMG and GSR, a prophylactic is a treatment used to prevent diseases from occurring. Prevention is better than cure; these treatments work on this principle. They are used to prevent something from happening, for example, a prophylactic hepatitis vaccine prevents the patient from getting hepatitis. These are also called antidepressants as they help to reduce headaches. Results show that there is a significant effect of the GSR therapy on the prophylactic treatment.

Fog computing is useful measure to analyze this scenario. Mist and edge computing also give efficient results but in closed environment and constrained system, the fog computing provides reliable results.

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Chapter 18
Electronic Healthcare System: Mental Disorder Assessment and Intervention with Self-Treatment Using Rule-Based Techniques

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18.1 Introduction

One of the biggest concern among public nowadays is mental health problems [1]. Mental health is a health problem that relates to how people react, think, behave, interact, and feel toward other people. On the other hand, it can be classified as a loss of feeling of enjoyment, happiness, and interest; moreover, having a low mood in congesting with behavior, cognitive, and emotional symptoms [1]. Besides, mental illness also can be classified as brain disorder due to genetic and environmental factors based on The National Institute for Mental Health (NIMH) [2]. Vos et al. [3] highlights that one of the main disease burdens worldwide is mental health problems. Not only the person who suffers from mental health is affected but it will affect their family and friends as well. Roughly 25% of European people have faced this mental health problem at least once in their lifetime. Other investigations found out that Australians are also facing this mental health problem. It is estimated that around one in five Australians aged 16–85 years' experience a mental disorder

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at some time in their lives [3]. Thus, we can summarize that mental health signifies not only a massive economic, psychological, and burden, but also increase the risk of bodily afflictions to society [3].

Another definition of mental health from The World Health Organization is “a state of normal well-being where they can stabilize their normal and stress life and having a great and productive work among the community.” The teenager can develop mental health disorders as early as 14 years old. Despite this knowledge, we can say that mental health is a serious health problem that continues to develop among our children. This problem will become worse if parents neglect their children and ignore them. As we can see, children who have mental health problems are among the students that are always having difficulties in school, higher rates in suicide, homeless, school drop-out, and involved with the juvenile cases [4]. The National Institute for Mental Health in 2016 investigated that only 19.7 million over 44.7 million adults received treatments on mental health [5]. The individual that has healthy mental, meaning that this person has an ability to control their emotion, good manner and behavior, great social, cultural, economic, and clean environment. This person usually has a happy lifestyle, works in good condition, and has good community social support. Based on Nebhinani and Kuppili [4], people who faced mental health problem are suffering of lacking in care, facing prolong the lifetime and impacting their illness. This is added with poor working conditions that also lead to mental health problems [5]. To worsen this, around a decade ago monitoring was only on subjective clinical self-reporting but the current monitoring of mental disorders depends on a decent model [6].

Therefore, fog computing (FC) is introduced to overcome the challenges of today’s healthcare problems. The idea of FC is coming from cloud computing (CC) and internet of things (IoT) devices. The benefit of FC is in term of on-time service delivery with high consistency. FC also overcomes the difficulties such as jitters or as-delays, and high-cost transmitting information to the cloud [7]. FC can transmit the information acts from the centralized cloud storage to the end user. FC brings the quality of real-time application cloud services at the edge itself with low latency and transmission delay. Moreover, the FC server facilitates their own local computation and data processing, where significantly reduces the delay transmission, latency, and communication overhead. Besides, the benefit of FC server is it can provide mobility support to process real-time data and location awareness [8]. The importance of FC server is it can transmit the requested data from the sensors using wireless communication channel for mobile phone users. Mobile devices help influence people’s health status using a new and better style and motivate people to have a healthy lifestyle. Mobile technologies nowadays are coped with lots of information on health that helps to monitor personal health via online apps anywhere and anytime they want. These mobile devices help in easier accessing of the health data and give a channel to communicate with the physician. Besides, useful to increase a privacy setting among users and doctors where they can choose whether they want to have just a type chat with the doctor or via face app. Thus, it contributes to a lifelong record on mental health status among patients and physician; besides, it can continuously monitor of an individual’s psychological and physiological states. The emergence of communication and information technologies in healthcare interventions may be able to reduce the high-cost healthcare services. Hence, reduce time and improve paperless communication (upgrading the health services).

Motivated with recent technological advancements in FC, this chapter aims to develop a new version of online system on electronic Mental Assessment and Self-Treatment System (e-MAST) for all mental health patients. This system focuses on early diagnosis on mental disorders problem and self-stress treatment using three different tests which is a stress, depression, and anxiety test. Three different questionnaires are transformed into the IF-THEN rules (adopted from McShane and Glinow [9]) before transforming it into a system. This system is developed using Xampp, NetBeans, Sublimes and the languages are used PHP, HTML, Javascript CSS, and MySQL software. Besides, this system enables users to have a free and quick self-mental health treatment depending on their level of mental healthiness. These self-treatments are divided into three treatments which are physical, spiritual, and psychological treatment. Besides, it also provides online chatting with a qualified doctor. FC in e-MAST helps people to become more efficient, can connect anytime and anywhere through world wide web. They have free ability to search and access any urgent information. Besides, can gather data timeless and places using devices such as smartphones or tablets. Through their smartphones and gadgets, there are lots of intelligent sensors such as heart sensors, humidity, accelerometer, temperature, and many more to retrieve any information and data on user environment and activities [10]. Therefore, this develops system for mental health problem using current intelligent devices is seen in line with the FC nature and initiate public on the mental disorders problem awareness.

The important thing about this system is it must cover two main aspects. The first aspect is on the assessment accuracy on the patient's mental status and to avoid error and mistakes. The second aspect is to determine the accuracy of the identity situations experienced by the patient in their daily routine. Thus, it will improve the effect on diagnosis and self-treatment therapy. Thus, the whole of the chapter is arranged as follows: Sect. 18.2 focuses on preliminaries and related research on e-MAST problems. Section 18.3 constructs the system construction and list out all the three test questionnaires. Section 18.4 focuses on computational implementation and features of the system. Lastly, conclude with the results and discussion in Sect. 18.5.

18.2 Preliminaries and Related Research

Section 18.2 begins by laying out the related research on mental health problems and electronic mental health problems; then continues with the explanations of each previous research on mental health including objective, method, and result explanation. Furthermore, some theory on electronic mental health is discussed briefly.

18.2.1 Related Work on Mental Health

Many researchers concentrate on the various mental health problems from different angles. The assessment, diagnosis, and treatment on mental health problems have been increased and enhanced by clinical detection and diagnosis over the past 30 years ago. This is added by numerous publications and research on mental health disorders has been done so far, besides, plus with the development of specialized diagnostic instruments [11]. For example, Foley and Woollard [12] prepared a report to support the Topol Review. The findings are based on a series of an expert one-to-one interviews, five expert focus groups, and purposely literature to find the new technologies that can renovate mental healthcare over the next 20 years. Cullen [13] adopted a broad definition of e-Mental health as *technology-supported provision of mental health services and supports.* Relevant technologies include telecommunications (phone, video, online); online and computer-based programs; mobile apps; virtual reality; gaming; social media; data analytics; and many more. The report organizes and discusses the field around a number of important application domains. These have relevance across the different components of the overall mental healthcare and support ecosystem, including formal mental health services, third sector and peer support organizations, and self-help activity by people with mental health issues. Besides, Werbeloff et al. [14] used Electronic Health Records (EHRs) for mental health care services. This study has the potential to evaluate large-scale projects using the proposed EHRs based secondary mental healthcare in real-world clinical populations. These reports investigated the concerned on digital technology social media were exacerbating feelings of depression and anxiety, leading to cyberbullying, disturbing sleep patterns, and distorting body image among teachers, youngster, and parents [15].

Teles et al. [16] presented SituMan software to develop a MoodBuster a mobile application for self-assessment toward depression. Zamri et al. [17] developed a system on mental disorder diagnosis and stress self-treatment where it offers three different sets of questions on stress, depression, and anxiety. Then, Knickman et al. [18] improved the accessed mental health and substance disorder to become more effective care for people. The way they improved it by using a fragmented care system, where this system focuses on overlooks key questions on how to enhance productivity and life satisfaction and delivering a specific set of services. Then, Bakker et al. [19] proposed a mobile-based mental health application that has a set of clear, practical, and evidence-based recommendations instead of no guide to developing a mental health application. This research is to guide the future development of the mental health application by integrating all the recommendations based on research across diverse fields into a single mental health application. This research is to provide more functionality and base the system to publishing trial-based experimental validation of the apps. It is also to optimize all the included features in the order that are not optimized. This system used mobile phones as a platform that are used by over half of the human population.

Next, Bradford and Rickwood [20] measure 129 young people's views among 12–25 years of age across Australia via qualitative interviews on their thought about the electronic psychosocial assessment tool; moreover, also tested with similar interviews on e-tools toward the different demographic group of young people. Royal Australian College of General Practitioners [21] explored a variety of applications for e-mental health interferences. This e-mental health interferences can be used for avoidance or early intrusion, adjunctive treatment first-line treatment, and as a tool for deteriorating prevention. Next, Bouchard et al. [22] investigated an overview of e-Mental health in Canada, and its opportunity to transform this e-Mental health into a system. Besides, we discussed future e-Mental system barriers, recommendations for current and future use in Canada. Meanwhile, López-robledo [23] identified possible benefits and barriers of an Electronic Medical Record (EMR) for a Mental Health Clinic, and offer recommendations to ensure more benefits and higher expansion of the system. Moreover, Government [24] planned for the next e-Mental Health Strategy phase of growth, where they listed out all the sets of vision for the future path to solving these mental health issues. This report explained how e-mental health can be imbedded into the broader primary mental health care system. This report also focused on the development of e-mental health care systems as well as offering high-quality services to consumers. Next, Donker et al. [25] investigated the effects of mental health symptoms on mental health apps. The main purpose of Donker et al. [25] 's research is to increase the effectiveness of the usability of the mental health apps.

Next, Deziel et al. [26] studied mental health problems among undergraduate Engineering students in a Canadian university using a data mining study. Besides, we created and collected a survey on Canadian Mental Health Association guidelines using classification and regression algorithms. Kroenke [27] used three sets of questionnaires, which were PHQ-9, GAD-7 and PHQ-15 for a systematic review on anxiety and depressive symptom. Purposely, to diagnose five different types of mental disorders in medical populations. Besides, Richardson et al. [28] applied the PHQ-9 to examine the level of depression on mental health patient. Butler et al. [29] integrated mental health services into primary care settings or primary health care for the patient in United States. This service combined with the health Information Technology (IT) for reimbursement structures program within the United States. Lastly, Postel et al. [30] presented a Randomized Controlled Trials (RCTs), recommended by Cochrane Back Review Group for assessing the methodological quality control on e-therapy for mental health problems.

This subsection successfully revised thoroughly on previous mental health problems, including the technology in mental health care. The list summary of them is listed as in Table 18.1:

Next, Sect 18.2.2 demonstrates how FC is so crucial for the healthcare 4.0 environment. Further explanation of all the concepts and methods are described in the next subsection.

Table 18.1 Comparison on mental health's work

No.	Author	Year	System	Description
1.	Foley and Woollard	2019	Topol Review	Find the new technologies that can renovate mental healthcare over the next 20 years
2.	Cullen	2018	e-Mental health	Technology-supported provision of mental health services and supports
3.	Werbeloff et al.	2018	Electronic Health Records (EHRs)	Evaluate the large-scale projects using the proposed EHRs-based secondary mental healthcare in real-world clinical populations
4.	Teles et al.	2017	MoodBuster	SituMan software to develop a MoodBuster, a mobile application for self-assessment toward depression
5.	Zamri et al.	2017	e-Mast	A system on mental disorder diagnosis and stress self-treatment where it offers three different sets of questions on stress, depression, and anxiety
6.	Bakker et al.	2016	A mobile-based mental health application	Guide the future development of the mental health application by integrating all the recommendations based on research across diverse fields into a single mental health application
7.	Knickman et al.	2016	Fragmented care system	Improved the accessed mental health and substance disorder to become more effective care for people
8.	Bradford and Rickwood	2015	Electronic psychosocial assessment tool	Measure 129 young people's views among 12–25 years of age across Australia via qualitative interviews on their thought about the electronic psychosocial assessment tool
9.	Royal Australian College of General Practitioners	2015	e-Mental health interferences	Explored a variety of applications for e-mental health interferences. This e-mental health interferences can be used for avoidance or early intrusion, adjunctive first-line treatment, and as a tool for deteriorating prevention
10.	Bouchard et al.	2014	e-Mental health in Canada	Discussed on future e-Mental system barriers, recommendations for current and future use in Canada
11.	López-robledo et al.	2014	Electronic Medical Record (EMR)	Mental Health Clinic, and offer recommendations to ensure more benefits and higher expansion of the system
12.	Government	n.d.	e-Mental Health Strategy	Listed out all the sets of vision for the future path to solving these mental health issues
13.	Deziel et al.	2013	Mental health problems	Mental health problems among undergraduate Engineering students in a Canadian university using a data mining study
14.	Donker et al.	2013	Mental health apps	Investigated the effects of mental health symptoms
15.	Kroenke et al.	2010	Mental health system	Three sets of questionnaires which were PHQ-9, GAD-7, and PHQ-15 for a systematic review on anxiety and depressive symptom diagnose five different types of mental disorders in medical populations

18.2.2 Related Work on Healthcare 4.0 Environment with Fog Computing

Due to the complicated and complex nature of the mental health problems, the requirement to develop a precise model of solving mental health is vital and has received significant attention from researchers worldwide. Thus, much research has proposed a variety of methods with different approaches to deal with the uncertainty that occurs during the model development and evaluation process. Such as Mistry et al. [31] presented a survey for Healthcare 4.0, Smart Home, Smart Agriculture, Smart City, Supply chain management and Autonomous vehicles on having 5G-enabled IoT as a backbone for blockchain-based industrial automation. Tanwar et al. [32] improved data accessibility for healthcare providers, assisted the simulation of environments using the Hyperledger-based electronic healthcare record (EHR) sharing system that uses the concept of a chain code for an Access Control Policy Algorithm. Performance metrics in blockchain networks, such as latency, throughput, Round Trip Time (RTT) have also been optimized for achieving enhanced results. Kaneriya et al. [33] investigated the precise medical condition of sleep apnea to propose a health manager directive system. This system reduced the apnea severity in a patient using a Probabilistic Markov model (PMM) for the healthy lifestyle schedule. Alzubi et al. [34] minimized the classification time for an integrated Newton–Raphsons Maximum Likelihood and Minimum Redundancy (MLMR) model; then, minimized the false-positive rate to improve the cancer disease diagnosis accuracy using the Boosted Weighted Optimized Neural Network Ensemble Classification algorithm. This algorithm proved that the proposed approach achieves an accurate prediction, reduced delay in comparison to the conventional techniques, and a better false-positive rate.

Tanwar et al., [35] proposed a cloud gateway for real-time response generation and fog to track the patient's hand movements on human arthritis. To achieve reliable communication and anomaly detection, the thread protocol and Bayesian network classifiers have been included in the proposed architecture. Using an OMNet++ simulator, a dataset of 431 patients with arthritis is taken in real time. Observations show that the packet delivery rate is enhanced by 25–35%, the response time is reduced by 20–30%, and the packet delivery ratio is improved by 15–20%, in comparison to not using the fog and thread protocol. Gupta et al. [36] proposed a new framework for security to achieve with immutability and interoperability by Smart Contracts (SCs) named as HaBiTs (blockchain-based secure and flawless inter-operable telesurgery). SC is a piece of code written in solidity or other blockchain specific languages was used to eliminate the need for an intermediary for data sharing and establish the trust between all the parties connected through blockchain. Then, it highlighted how they are mitigated with the usage of the proposed HaBiTs framework and some issues of the traditional telesurgery system. Gupta et al. [37] proposed two different communication channels which are 5G-enabled TI and traditional network based telesurgery, besides, discussed on successfully executed tele slanting heart surgery in telesurgery. The analysis showed that the network backbone has higher reliability in comparison to the existing system and faster response time to the proposed of architecture with TI.

Hathaliya et al. [38] proposed a secure access to the patients' electronic health record (EHR) from the database repository using a biometric-based authentication scheme and then validated it using the Automated Validation of Internet Security Protocols and Applications (AVISPA) tool. For example, Kumari et al. [7] offered uninterrupted context—ware services to the end users as and we required based on an analysis of the role of fog computing, cloud computing, and Internet of things. This research proposed a real-time data collection, processing and transmission using a three-layer patient-driven Healthcare architecture. Besides, Vora et al. [39] identified the identity of a patient and preserved the privacy of the patient's health record using an E-Health cloud paradigm-based cloud-based paradigm. This E-Health system used an adaptive and flexible approach through an authentication scheme that meets anonymity to hold the privacy of the patients. Vora et al. [40] managed the access control mechanism of patients' data using ARCANA for the AT&T scheme. The mechanism used different authorization techniques for encrypting of medical data for the proper data access regulation. This may increase the large-scale usability and impact the trust of the users in the E-health paradigm. Vora et al. [41] proposed a FC-based patient monitoring system for ambient-assisted living (FAAL). Sensor nodes using body area networks (BANs) were used to trace the data movement of the patients (for neurological diseases) and passed it using the fog gateways. Further explanation is summarized as Table 18.2.

18.3 System Construction

This chapter comprises of two main sections. Firstly, we discuss the conceptual model of the engine. In this conceptual model, all development phases such as initial planning, planning, requirements, analysis and design, implementation, testing, and evaluations will be described in detail. Then, the main characteristics of the model, including the selection of the software and system to be developed, are outlined in step-by-step systematic procedures.

18.3.1 Conceptual Model of the Engine

The cyclic software development process is an incremental and iterative development model. It is more flexible in creating the design, implementation, testing, and analysis activities. All the development disciplines such as design, analysis, requirements, etc. are included in each steps and iterations. Besides, each iteration offers a well-defined set of objectives and produces from an initial working implementation until the final of the system. Each successive iteration is evolved

Table 18.2 Summary on FC for Healthcare 4.0

No.	Author	Year	Description
1.	Misty et al.	2020	presented a survey for Healthcare 4.0, Smart Home, Smart Agriculture, Smart City, Supply chain management and Autonomous vehicles on having 5G-enabled IoT as a backbone for blockchain-based industrial automation
2.	Tanwar et al.	2020	improved data accessibility for healthcare providers, assisted the simulation of environments using the Hyperledger-based electronic healthcare record (EHR) sharing system that uses the concept of a chain code for an Access Control Policy Algorithm
3.	Kaneriya et al.	2019	investigated the precise medical condition of sleep apnea to propose a health manager directive system. This system reduced the apnea severity in a patient using a Probabilistic Markov model (PMM) for the healthy lifestyle schedule
4.	Alzubi et al.	2019	minimized the classification time for an integrated Newton–Raphsons Maximum Likelihood and Minimum Redundancy (MLMR) model
5.	Tanwar et al.	2019	proposed a cloud gateways for real-time response generation and fog to track the patient's hand movements on human arthritis
6.	Gupta et al.	2019	proposed a new framework for security to achieve with immutability and interoperability by Smart Contracts (SCs) named as HaBiTs (blockchain-based secure and flawless inter-operable telesurgery)
7.	Gupta et al.	2019	proposed two different communication channels which are 5G-enabled TI and traditional network based telesurgery
8.	Hathaliya et al.	2019	proposed a secure access to the patients' electronic health record (EHR) from the database repository using a biometric-based authentication scheme
9.	Kumari et al.	2018	offered uninterrupted context-ware services to the end users as and we required based on an analysis of the role of fog computing, cloud computing, and Internet of things
10.	Vora et al.	2018	identified the identity of a patient and preserved the privacy of the patient's health record using an E-Health cloud paradigm-based cloud-based paradigm
11.	Vora et al.	2018	managed the access control mechanism of patients data using ARCANA for the AT&T scheme
12.	Vora et al.	2017	proposed a FC-based patient monitoring system for ambient assisted living (FAAL)

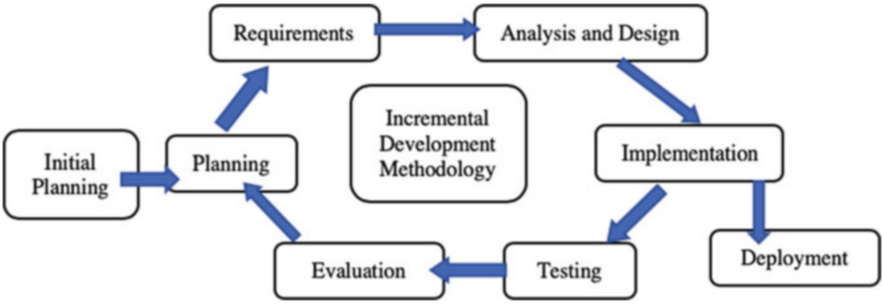


Fig. 18.1 Conceptual model of the engine

and refined until the final product is completed. Thus, the full conceptual model of this engine is illustrated as Fig. 18.1.

Every development phase will be implemented into systems from initial planning, planning, requirement, analysis and design, implementation, testing, evaluation and lastly, the deployment phase as in Fig. 18.1.

The phase starts with brainstorming the ideas of current problems and system requests in the **Initial Planning Phase**. Then continue the discussion with the supervisor to choose a project to be implemented. Literature reviews with the existing similar system are studied to find the problems of the systems.

The title has been confirmed including the details of the project within the **Planning Phase**. In this phase, all the activities will be planned according to the given period to complete the system, starting with brainstorming ideas and proposed the title of the project until the system is completely developed.

The analysis of user and system requirements (in the **Requirement Phase**) are identified in this phase. Several of journals and interviews with mental health patients are reviewed to get more information about mental health disorders.

For the **Analysis and Design Phase**, we identified the design of the system and developed a prototype based on the functionalities that will be built when once planning and requirement phase is completed. In this phase, the process of applying the concept of the rule also will be implemented.

The **Implementation Phase** is also known as the code generation phase. The system is divided into several sub-modules. The actual implementation and coding for each sub-modules now begin according to the user and system requirements. The system will build using PHP language and MySQL as the database platform. User interfaces are also included in the phases as they are important in delivering information and messages to the user.

For the **Testing Phase**, all sub-modules are integrated into a system and undergo integration and system testing to ensure they function properly as a whole system and locate any potential bugs or issues. The user interface will be checked to ensure they are connected to the database and appropriate with the system.

When the system has successfully passed the testing, the product can be delivered to the customer for their use in the **Evaluation Phase**. But if the system needs to be modified, we need to revisit the analysis phase and redo some of the work done in subsequent phases.

18.3.2 Construction of the System

This section focuses on the construction of the mental disorders and stress self-treatment system. Every single installation comes with the system's design, system's planning, system's implementation, and system's achievement. Initial plan is one of the important phases before the development phase. Then, user identification will be analyzed in the requirement phase.

Next, focus is on the development of a prototype of the system, based on the functionalities from the analyze and design phase. The rule-based technique is applied in this phase. Data for each rule are presented based on the McShane and Glinow [11] study. Every single rule for three tests which are stress, depression, and anxiety are transformed into the IF-THEN rules. These rules are in line with the medical expert assistance. Each single rule will be transformed into coding using the programming tools.

Example of the IF-THEN rules code is stated as follows:

IF a_i is M_i and a_j is M_j THEN S_{r}.

There are two parts in expressing the rules, the IF part and THEN part. The IF part is called an antecedent or condition part. The THEN part is called the consequent or conclusion part. The rule can be one rule or multiple rules. For the multiple rules, AND and OR are used as the combination operator for multiple rules. Example of one rule and multiple rules are elaborated as follows:

IF antecedent THEN consequent.
IF antecedent 1 OR antecedent 2. OR antecedent N THEN consequent.
IF antecedent 1 AND a antecedent 2. AND antecedent N THEN consequent.

18.3.2.1 Stress Test

This subsection focuses on the stress tests for the proposed system. Fourteen questions regarding stress were adopted from McShane and Glinow [11]. These questions were transformed into the IF-THEN rules and can generate the level of stress. The list of items are stated as follows:

R1: In the last month, how often have you been upset because of something that happened unexpectedly?
R2: In the last month, how often have you felt that you were unable to control the essential things in your life?
R3: In the last month, how often have you felt nervous and stressed?

R4: In the last month, how often have you felt confident about your ability to handle your personal problems?
R5: In the last month, how often have you felt that thing was going in your way?
R6: In the last month, how often have you found that you could not cope with all the things that you had to do?
R7: In the last month, how often have you been able to control irritations in your life?
R8: In the last month, how often have you felt that you were on top of things?
R9: In the last month, how often have you been angered because of things that were outside your control?
R10: In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?

From the system, user needs to choose and press the button based on their experience facing this stressful situation. There are five different answers such as 0: never; 1: almost never; 2: sometimes; 3: fairly often; and 4: very often.

Let's take on one example of the stress test rule.

IF

R1 is 2 and R2 is 1 and R3 is 3 and R4 is 4 and R5 is 1 and R6 is 2 and R7 is 3 and R8 is 3 and R9 is 1 and R10 is 1.

THEN

Your Score is 13 which is referred to moderate stress.

There are three different score level which is starting from 0 till 56, where:

0–19: Low stress
20–39: Moderate stress
40–56: High stress

The score level can be calculated using a weighted sum method. If there are *M* alternative and *N* criteria then, the best alternative is the one that satisfies the maximization case of the following expression:

That is the total value of each alternative is equal to the sum of the products given. This study chose the weighted sum method due to the precise and accurate results of the test.

18.3.2.2 Depression Test

Next, this subsection focuses on the depression tests. These nine questions of anxiety test also adopted from McShane and Glinow [11]. The list of questions is stated as follows:

R1: Little interest or pleasure in doing things . . .
R2: Feeling down, depressed, or hopeless . . .
R3: Trouble falling or staying asleep, or sleeping too much . . .
R4: Feeling tired or having little energy . . .
R5: Poor appetite or overeating . . .

R6: Feeling bad about yourself or that you are a failure or have let yourself or family down . . .
R7: Trouble concentrating on things, such as reading the newspaper or watching television . . .
R8: Moving or speaking so slowly that other people could have noticed? Or the opposite where being so fidgety or restless that you have been moving around a lot more than usual . . .
R9: Thoughts that you would be better off dead of hurting yourself in some way . . .

Thus, the users need to choose among four answers which are:

0: Not at all; 1: Several days; 2: More than half days; 3: Nearly every day

Thus, the rules for anxiety test level will be:
IF
R1 is 4 and R2 is 3 and R3 is 4 and R4 is 2 and R5 is 3 and R6 is 4 and R7 is 4 and R8 is 3 and R9 is 3.
THEN
The result is 21 which is Severe Depression.
There are five different score levels which are starting from 0 till 27, where:

0–4: Minimal or none depression
5–9: Mild depression
10–14: Moderate depression
15–19: Moderately severe depression
20–27: Severe depression

The score level can be calculated using weighted sum method. If there are *M* alternative and *N* criteria then, the best alternative is the one that satisfies the maximization case of the following expression:

That is the total value of each alternative is equal to the sum of the products given.
This study chose the weighted sum method due to the precise and accurate results of the test.

18.3.2.3 Anxiety Test

Next, this subsection focuses on anxiety tests. Let us take one example for anxiety tests. We used seven questions of anxiety test taken from McShane and Glinow [11]. The list of questions is stated as follows:

R1: Feeling nervous, anxious, or on edge . . .
R2: Not being able to stop or control worrying . . .
R3: Worrying too much about different things . . .
R4: Trouble relaxing . . .
R5: Being so restless that it is hard to sit still . . .
R6: Becoming easily annoyed or irritable . . .

R7: Feeling afraid as if something awful might happen...

Thus, the users need to choose among four answers which are;

0: Not at all; 1: Several days; 2: More than half days; 3: Nearly every day

Thus, the rules for stress test level will be:
IF
R1 is 2 and R2 is 1 and R3 is 1 and R4 is 2 and R5 is 3 and R6 is 3 and R7 is 2.
THEN
The result is 14 which is moderate stress.
There are three different score level which are:

5–9: Mild Anxiety
10–14: Moderate Anxiety
>15: Severe Anxiety

The score level can be calculated using weighted sum method. If there are *M* alternative and *N* criteria then, the best alternative is the one that satisfies the maximization case of the following expression:

That is the total value of each alternative is equal to the sum of the products given.
This study chose the weighted sum method due to the precise and accurate results of the test.

The inference process manipulates the knowledge base to deduce information requested by the user and carries out the reasoning required by the expert system to reach a solution. It links the rules given in the knowledge base with the facts store in the database. For example, if the results turn out to be no depression, thus system concludes the user has a happy life and healthy. However, the system suggests the patient for further treatment at the hospital via a doctor's suggestion if the results turn out to be moderate stress. Therefore, Fig. 18.2 shows the framework for the whole system.

In this section, we have discussed the system construction of the study. This system construction is used for utilization the conceptual model of the engine. The construction technique is introduced with a detailed procedure includes all three tests which are stress, depression, and anxiety test. Finally, conclude with the framework for the whole system.

18.4 Computational Implementation and Features

Once the users set the initial specification, system testing and validation is used to check the efficiency of the system function ability. The phase for system testing and the phase for system validation are one of the important stages to ensure that this system performs well in all time and free from error. Some of the errors always occur during the process of the system are such as debugging, successful link, logic errors,

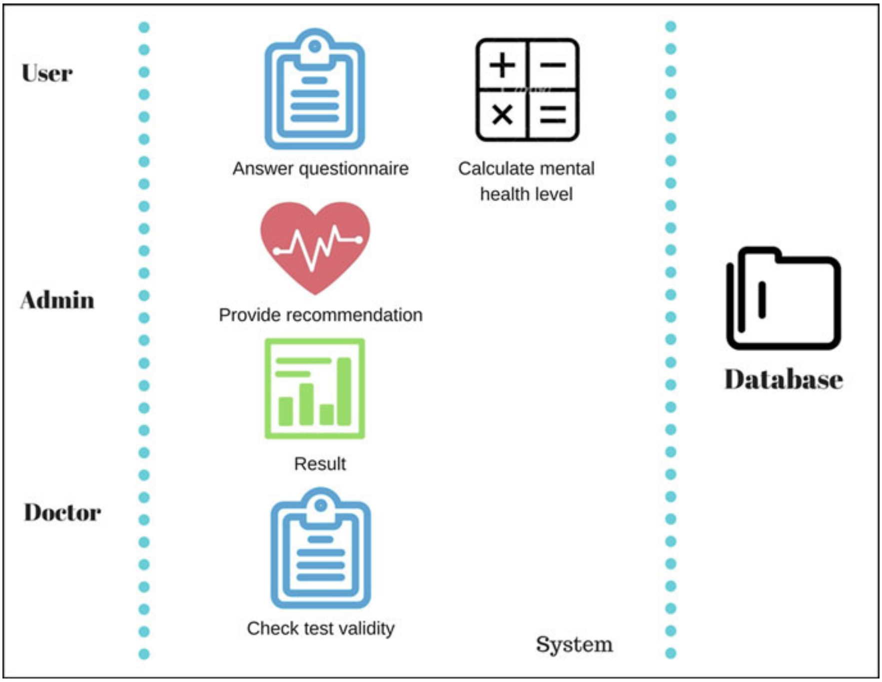


Fig. 18.2 Framework for the whole system

rules checking and many more. Therefore, this section focused on experimental evaluations on mental health and self-treatment system.

18.4.1 Experimental Evaluations

This section outlines the steps carried out to verify and check the function ability for the proposed system. The flow of the proposed system is discussed step-by-step in this section.

System implementation is the construction of the system and the delivery of it into production. The interfaces and user manual of the system are explained and included in this section.

Figure 18.3 states the front page for this system. Some information about this system is provided on the front page. Besides, it provides with general information on mental health disorder. On the other hand, there are also three different buttons for register, login and free treatment button.

Once the login button is clicked, they will proceed to the second page. Figure 18.4 shows the login page for this system. First of all, the user needs to login once they registered. If not registered yet, they will proceed to the registration page. This

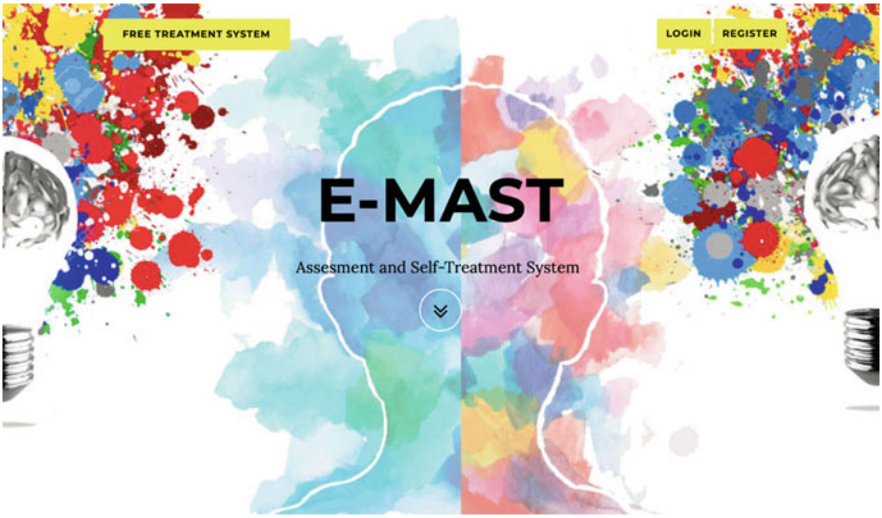


Fig. 18.3 Front page of the system

Fig. 18.4 Login page of the system

login button is also provided for admin and doctor to login to their page. The systems only accept the registered email and password to login to each page.

In the registration interface, users are required to fill up the form regarding their personal details. The registration consists of name, gender, age, email, password, secret question, question answer, height (m), weight (kg), systolic (upper), diastolic

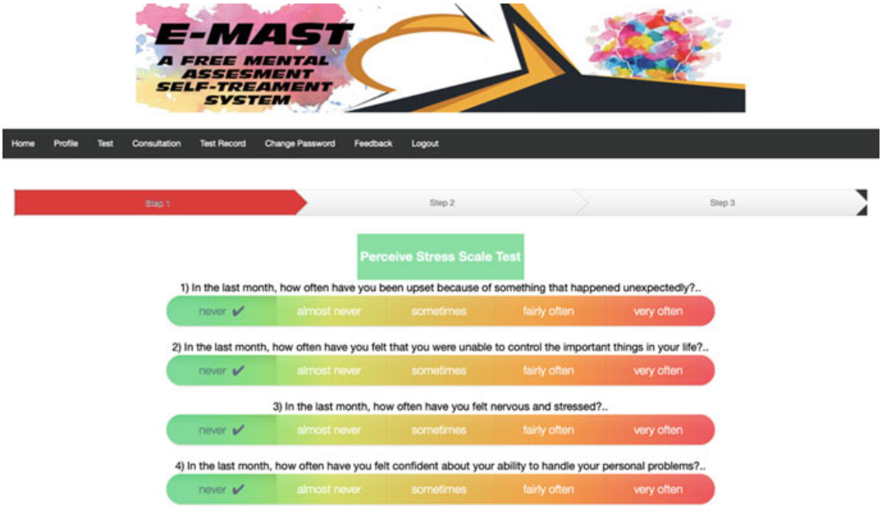


Fig. 18.5 Test page of the system

(below), and activity form. Users must enter the form correctly as the system only allows a required format for each form. The text field of the name only allows characters and text fields for password requires user to enter characters and numbers. The system shows a pop-up message to inform they have successfully registered in this system. Next, the user can proceed to the login process.

Figure 18.5 offers three tests for this system on this page. Stress, anxiety, and depression are the main three test highlights in this system. The user is required to click the radio button for each question. Once all the questions are well answered, they need to make sure every question is well answered before they press the submit button.

Once they press the submit button, the system will automatically calculate the results. The score will turn out on the next page with the full result analysis. This result will come with the level of mental health status and the recommendation for every user (refer Fig. 18.6).

Every detail result for each user will be recorded as in Fig. 18.7. On this page, type of test taken, score, level of illness, a recommendation from the doctor, and the date on which the test is taken are listed in detail. User can track their present and past records. They can monitor their results and health status every month.

The consultation page (refer to Figs. 18.8 and 18.9) is a place where users can have a chit chat with the doctor. Here we call this page as an online consultation page. After they took their examination, before they went to the hospital, they can have a quick consultation with the doctor. The doctor will suggest either they need to be referred to the hospital or just a self-treatment.

Apart from the test score page, this system also recorded and summarized the results of the test for all users. The doctor and admin can view all the users' results

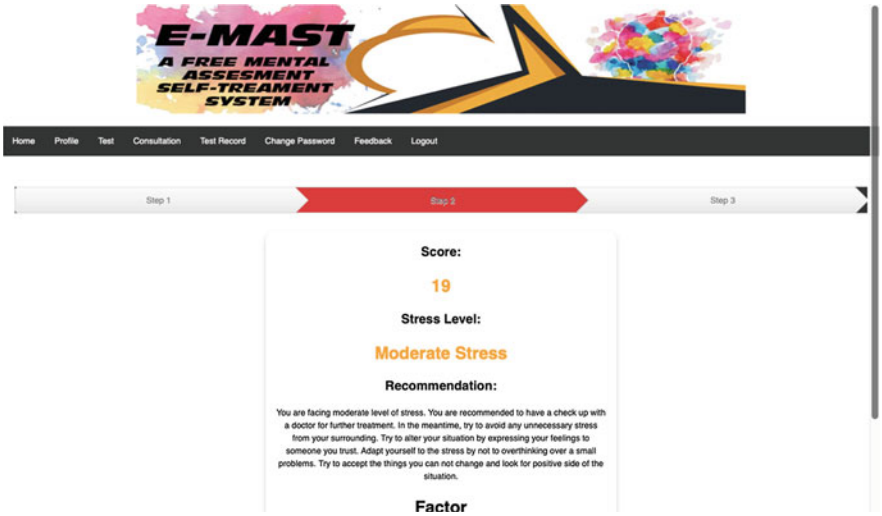


Fig. 18.6 Score page of the system

Fig. 18.7 Test record page

as in Fig. 18.10. There are three different pages for the results of stress statistics (Fig. 18.10a), anxiety statistics (Fig. 18.10b), and depression statistics (Fig. 18.10c). Each level of the test is represented by a percentage (Fig. 18.10). Figure shows the total number of tests and their level of portion.

Aside from statistics for each test, doctor and admin also can view the factors that affected users' test statistics. From here, they can conclude that the most users

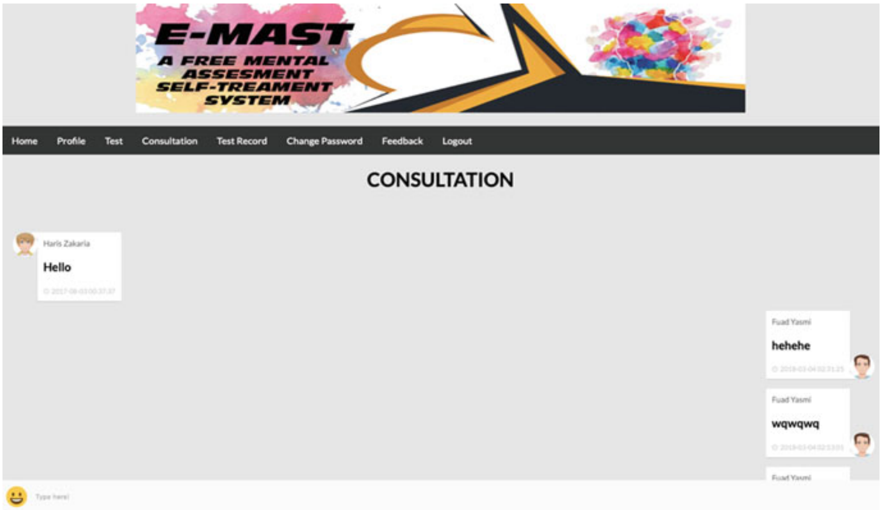


Fig. 18.8 The consultation page

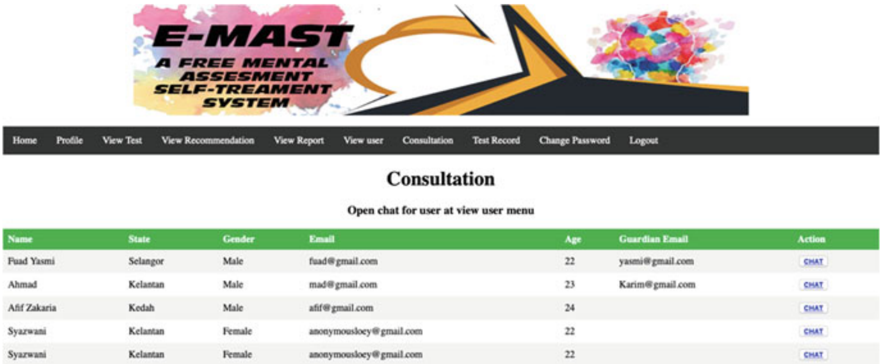


Fig. 18.9 Consultation page

are having stress due to education. From here also, they will know which users are in education stress (Fig. 18.11).

Once a user registered through this system, it will keep all the information in a view users' page. In this page, data about users' names, users' age, users' gender, users' country, users' email will be listed. If a user updates his or her profile, this page will automatically update their list of data (Fig. 18.12).

Lastly, to achieve system efficiency, this system offers a page for system usability. On this page, users are free to comment or give their marks on how efficient this system is. From here, this will allow the admin to modify and upgrade this system into more stable and user-friendly system (Fig. 18.13).

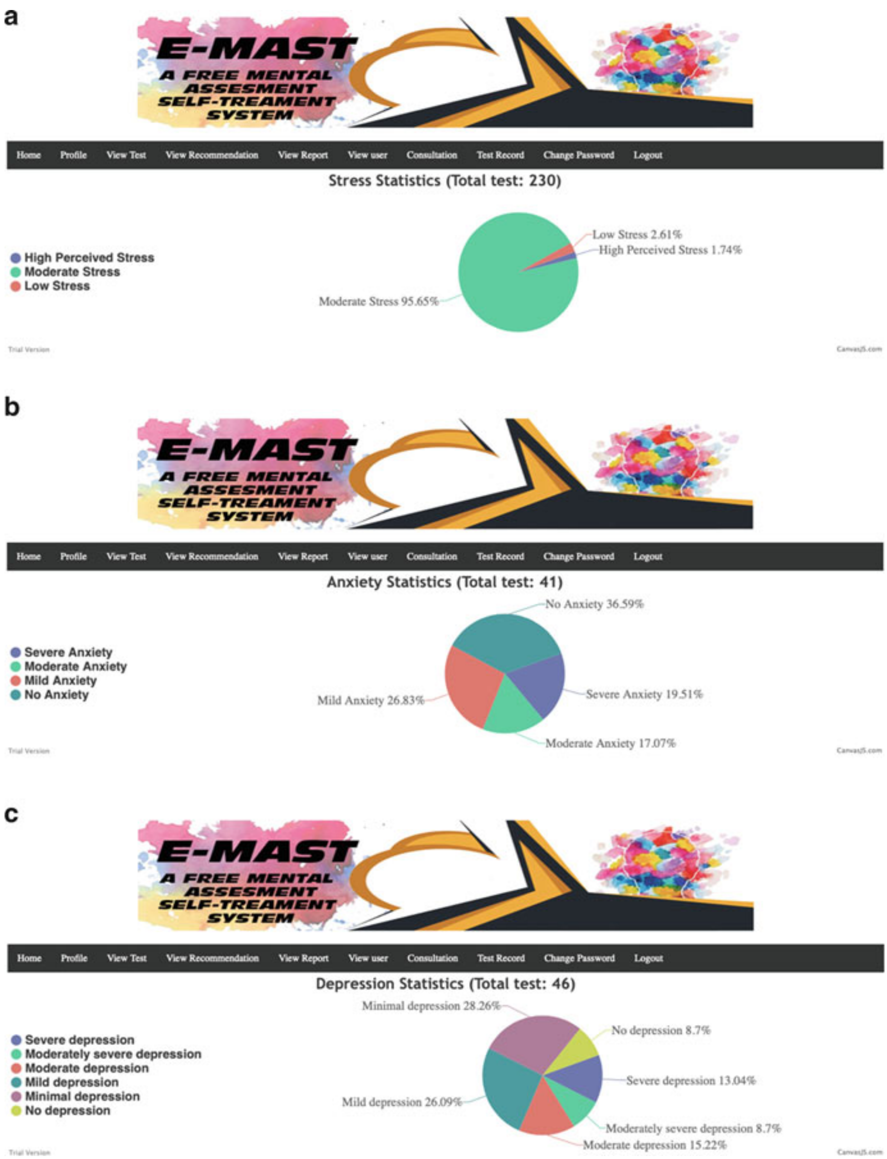


Fig. 18.10 (**a**) Report stress page. (**b**) Report anxiety page. (**c**) Report depression page

18.4.2 Test Cases

After system construction and implementation, there is a condition to determine whether this system is satisfied and works smoothly and correctly. Thus we need a test case. The test case is the process of finding the problems in the requirement

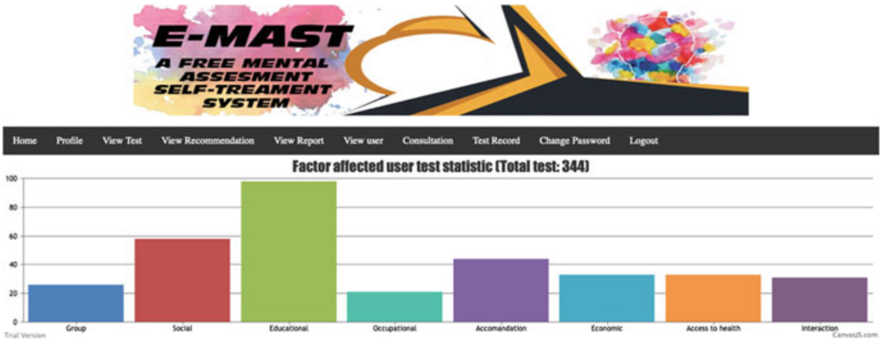
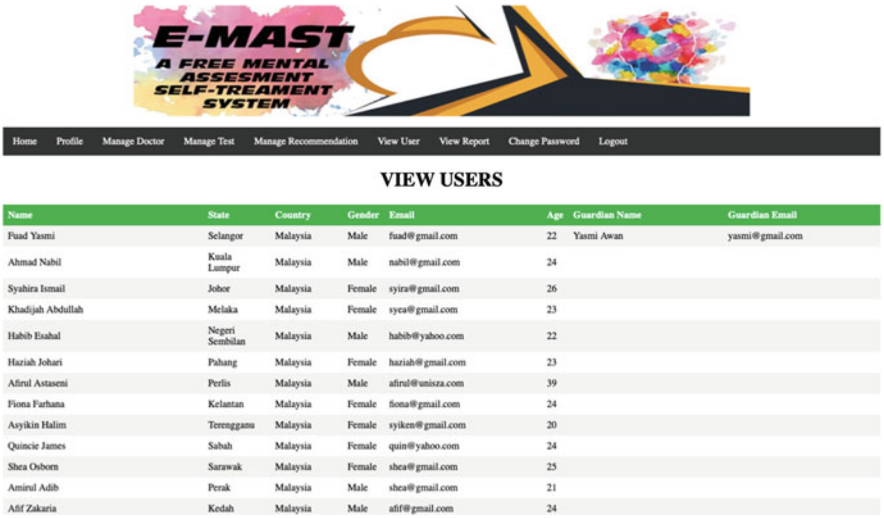


Fig. 18.11 Report factor page



Name	State	Country	Gender	Email	Age	Guardian Name	Guardian Email
Fuad Yasmi	Selangor	Malaysia	Male	fuad@gmail.com	22	Yasmi Awan	yasmi@gmail.com
Ahmad Nabil	Kuala Lumpur	Malaysia	Male	nabil@gmail.com	24		
Syahira Ismail	Johor	Malaysia	Female	syira@gmail.com	26		
Khadijah Abdullah	Melaka	Malaysia	Female	syea@gmail.com	23		
Habib Esahal	Negeri Sembilan	Malaysia	Male	habib@yahoo.com	22		
Haziah Johari	Pahang	Malaysia	Female	haziah@gmail.com	23		
Afirul Astaseni	Perlis	Malaysia	Male	afirul@unisza.com	39		
Fiona Farhana	Kelantan	Malaysia	Female	fiona@gmail.com	24		
Asyikin Halim	Terengganu	Malaysia	Female	syiken@gmail.com	20		
Quincie James	Sabah	Malaysia	Female	quin@yahoo.com	24		
Shea Osborn	Sarawak	Malaysia	Female	shea@gmail.com	25		
Amirul Adib	Perak	Malaysia	Male	shea@gmail.com	21		
Afif Zakaria	Kedah	Malaysia	Male	afif@gmail.com	24		

Fig. 18.12 Statistics of the users' page

or design of an application. This section shows step-by-step all the test cases that require in this system. The first test case starts with the login test case. Table 18.3 shows the flow of the test case for fail login.

18.4.2.1 Test Case for Login

Precondition:

The user must register first in the database for accessing the data.

Postcondition:

The information of the user is registered.

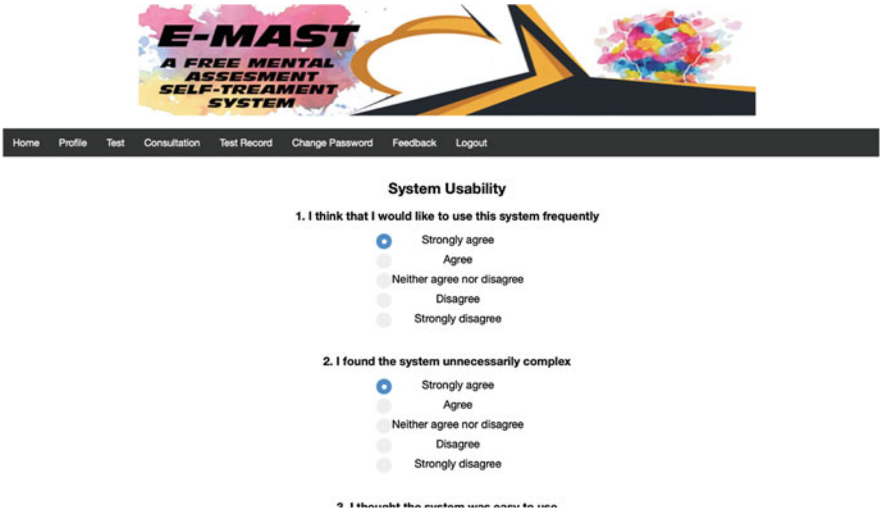


Fig. 18.13 System usability page

Table 18.3 Test case fail login

Step	Action	Expected response	Pass/fail	Comment
1	Fill "email" field	Validate the field	Pass	Default after logging in
2	Fill "password" field	Validate the field	Pass	Invalid password will not be allowed access
3	Click "login" button	Login to homepage	Pass	Invalid user ID/password will remain in the same page

Table 18.4 Test case update user profile

Step	Action	Expected response	Pass/fail	Comment
1	Edit information in the text box	Able to edit the information	Pass	–
2	Click the "Update" button	The information is updated	Pass	–

18.4.2.2 Test Case for Update User Profile

Next is the test case for update the user profile. Table 18.4 shows two steps to update the user profile's test case.

Precondition:
The user must login to the system to access this system.

Postcondition:
The information of the user is updated.

Table 18.5 Test case assessment test

Step	Action	Expected response	Pass/fail	Comment
1	User click on the test	The list of question is display	Pass	–
2	User click on the answer radio button	The answer is able to be clicked	Pass	–
3	User click on the submit button	The page display score, recommendation	Pass	–

Table 18.6 Test case consultation

Step	Action	Expected response	Pass/fail	Comment
1	User click on the consultation menu	The chat message is displayed	Pass	–
2	User write in the text box	The text box is able to write text	Pass	–
3	User click on the Send button	The page inserts the text into the chat messages	Pass	–

Table 18.7 Test case view report

Step	Action	Expected response	Pass/fail	Comment
1	Click on "view report" menu	Display all graph report	Pass	–

18.4.2.3 Test Case for Assessment Test

Precondition:
The user must login to the system to access this system (Table 18.5).
Postcondition:
The detail of the test is displayed.

18.4.2.4 Test Case for Consultation

Precondition:
The user and doctor must login to the system to access this system (Table 18.6).
Postcondition:
The chat is updated and displayed by the time stamp.

18.4.2.5 Test Case for View Report

Precondition:
The user must login to the system to access this system (Table 18.7)
Postcondition:
The graph of results will be displayed.

For telemedicine, the information can be gathered using the subsequent contextual analysis. This contextual analysis has a system for handling, transporting, and gathering the information. The response time of application can be decreased via suitable approach in contextual analysis. This section discusses on how FC can provide benefits to the e-MAST system. FC provides real-time application processing without delay and support heterogeneity for Healthcare Industries. FC is seen suited for collection of nodes and scattered data analytic. FC helps to enhance the electronic health monitoring system at smart gateways using real-time notification service, embedded data mining, and distributed storage at the edge of network. FC is in line with the e-MAST where its role is to diagnose an early recognition and detect the mental health students. Three different mental health problems that can be diagnosed are depression, anxiety, and stress. These diagnoses are calculated using the Rule-based Technique approach. Rule-based technique can be used to manipulate knowledge and store to interpret the mental health information is a useful way. It involves a human-crafted or curated rule set. This technique is used by several applications such as health, environment, business, finance, and many more. The mental health datasets are provided to the fog computer using an Internet-based database. The user will answer all three sets of questionnaires, and these questionnaires are stored in one database. The major goal is to diagnose early prediction on mental health status in each user. Three sets of questionnaires are stress, depression, and anxiety. The concept of FC for e-MAST is seen as a smart way in providing advanced approach and technique such as embedded notification service, distributed storage, and mental health data; besides, demonstrate the effectiveness of FC in the mental health system in terms of low-latency mental health data processing, early prediction, and chatting services using communication protocols. Our test results show that FC is a wireless, data analytics, intelligent, low power and offers efficient service of electronic mental health interventions. Besides, it enables new online services that have low latency, mobility, the strong presence of streaming, and real-time applications.

18.5 Results and Discussions

In this chapter, we describe an e-MAST based FC for augmenting mental health detecting system. This system was used to diagnose early prediction on a mental health test. There were three tests offered in this system which were stress, depression, and anxiety test. These three tests came with a different score that generally defined low, mild, moderate, and severe mental problems. Once e-MAST receives the amount of users data (by taking the test), these data are monitored by the administrative setup of the system and the data fluctuation can be seen on the FC. These data follow the data format, standard protocols, urgent data request, and aware of appropriate routing for routine data transfer. Data collection was designed to collect the data from a portable devices or computer such as hand phone or tablet. This e-MAST system covered the entire hospital, where every patient can use the medical services, check their health status updates by their smartphones. Besides, this system also offered a self-treatment analysis. The patient who was diagnosed by low and mild can used this self-treatment analysis. This self-treatment focused on physical treatment, spiritual treatment, and psychological treatment. While a patient who was diagnosed with moderate and severe scores was suggested to make an appointment with the psychologist directly. They also can have a personal chit chat session with the doctor on the consultation page. Besides, this system also provided with a recommendation from the doctor. There was also a page for patients and doctors to keep track of their previous mental health tests. This system helps user to early diagnosed their mental health problems, and at the same time, give the awareness to them for early recovery. The system usability test was provided to all users as a part of the system team to give positive or negative feedback on the system. This system usability test helps to create user-friendly interfaces and patient-centric medical devices for the future health system. On the other hand, successfully implemented FC services including notification service at the edge of network, distributed storage, and embedded mental health data. This e-MAST system is seen to reduce the high-cost healthcare services while at the same time, can reduce time and improve paperless communication (improving access to health services). e-MAST saves users time to wait for appointments, wait-time for results, and provide straight access to a certain level of medical resources. Besides, it gives benefit to a smart hospital to have a saving quality time, efficiency improvement, and building trust between patients and medical staff.

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Chapter 19
Breast Cancer Detection Based on Antenna Data Collection and Analysis

Suraj Kumar, Manisha Gupta, and Arun Kumar

19.1 Introduction

In the event that we think back, it transformed into the numerous years among 1970–1990 that saw the development of particular IT structures inside the social insurance industry [1–3]. This period ought to be suitably known as Health 1.0. All through the next decade and a portion of, wellbeing IT structures started getting organized and EHRs that were being produced started getting incorporated with logical imaging, giving medicinal specialists a superior frame of mind [4–6]. This became Health 2.0. The decade from 2005 onward observed the advancement of genomic data, the rise of wearables and implantables. The mix of this information alongside arranged EHR frameworks saw the development of Health 3.0. Health care 4.0 is the meeting up of every one of these advances combined with constant information assortment, expanded utilization of AI, and an overlay of imperceptible UIs. The emphasis on a joint effort, rationality, and the union will make social insurance increasingly prescient and customized [7, 8]. Breast malignant neoplastic disease is one of the most common disease where breast tissue becomes larger unrestrained. The incidents of the breast cancer is increasing so rapidly so as the death rate from the disease. The increased cure rate can be attributed to effective medical and surgical treatments. Also, early detection of breast cancer plays an important role. Invasive and noninvasive breast tumors are the kind of breast tumor. In noninvasive, ducts fill in the cancer cells, likewise known as Ductal carcinoma in situ. In invasive

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tumor, cancer tissues break through the canal wall and a central fatty area of the chest. Breast cancer stages are usually known as T-N-M classification. T is the size of primary tumor, N involves lymph node, and M addresses any cancer beyond the breast and lymph nodes [9]. It is calculated that more than 2.1 million peoples are diagnosed with the breast tumor at each year and it is one of the main reasons of cancer-related deaths especially among the women [10]. The key techniques to find the breast tumor [11], mammogram, breast ultrasound, biopsy, and breast magnetic resonance imagery (MRI) [12], have certain drawbacks such as difficult to key out the breast tumor in the initial phase, performance is poor for dense breast, rays used during detection may put down some tissue, costly and difficult to identify the tumor located under arm. The size of breast cancer detected by annual mammogram is small in comparison to the dimension of tumor found by first mammogram. The finding of breast tumor in the early stage of development gives 100% of survival [13]. This circumstance motivated to researchers and academicians to design an efficient technique to get the breast tumor in an initial stage of development. Microwave imaging plays an important character to understand the physical and the sensual dimension of human cells. The correct diagnosis of breast tumor through microwave imaging can overcome the mechanical challenges of scanning. The scanning antenna generates a real-time multiple data, which makes it easy for a physician to identify the breast cancer in an early phase of development [14, 15]. Antenna is a device, acts as an important role in wireless communication, medical applications, image processing, and so on. Different types of antenna such as loop, horn, dipole, slot, mono pole can be utilized. But microstrip antenna is better than any other in terms of antenna dimension, cost, performance [16].In this study, we have simulated hexagonal T-shaped microstrip Arial with polyester as a fabric. The large spectrum of the UWB motivates to design the proposed antenna at 3–10 GHz and it offers an appropriate agreement between the recommended emission of the signal into the breast cell and the suitability outcome of imaging quality.

19.2 Related Works

In this segment, the literature based on the diagnosis of breast tumor by aerial are shown. In this work [17], the authors implemented a rectangular microstrip patch antenna with $\varepsilon_r = 4.4$ to identify the breast tumor. The simulation result shows a comparison between the current density (J), electric and magnetic field for normal breast tissue and tumor breast cell. Nevertheless, it is observed that breast cell with tumor show higher value of the electric field, magnetic field, and surface current density (J). The authors presented a square-shaped UWB aerial to detect the breast tumor [18]. The projected aerial is characterized at 3.1 and 12.1 GHz. The obtained graph reveals that the higher value of SAR signifies the tumor in the chest. Overall, good performance in the suggested aerial for breast cancer detection was accomplished. In this work [19], wearable hexagonal antenna with Jean material ($\varepsilon_r = 1.7$) characterized at 2.45 GHz is designed to detect a tumor in breast tissue.

Table 19.1 Related work on cancer detection

References	Antenna	Spectrum range	Applications
[23]	Wearable conformal antenna arrays	4.97–11.73 GHz	Breast tumor
[24]	Circular patch	ISM	Skin cancer
[25]	T-Shaped antenna	2.45 GHz	Breast tumor
[26]	Flexible-software antenna	ISM	Breast tumor
[27]	Multi-ring slots	ISM	Breast tumor
[28]	Monopole slot	15–17 GHz	Breast tumor
[29]	Vivaldi antenna	–	Breast and skin cancer
[30]	Wearable microstrip patch antenna	ISM	Breast tumor
[31]	Compact side slotted directional antenna	1.54–7 GHz	Breast tumors
[32]	Omni-direction monopole antenna	2.95–14.27 GHz	Imaging system
[33]	Cross-vivaldi antenna	2.2–5.4 GHz	Breast Tumor
[34]	UWB antenna	2.96–10.68 GHz	Breast tumor
[35]	Microstrip antenna	4.23–11.71 GHz	Breast tumor
[36]	Microwave antenna	2–8 GHz	Breast tumor

The obtained analysis indicates that the operation of the performance aerial is more beneficial as compared to the existing antenna design. In this work [20], circular antenna is presented to detect a tumor in breast cell. A comparison between five different antennas based on several parameters is taken out to distinguish the best aerial for breast tumor detection. In this work [21], breast tumor is detected by designing a slot antenna characterized at the spectrum range of 3.1–12.1 GHZ. The S parameters and gain of -10 and 6.2 dB is observed. In this work [22], wideband antenna is presented to diagnose the breast tumor. The experimental analysis reveals that the proposed aerial has high-quality execution to identify the breast cancer in the former phase. The other cancer detection works are tabulated in Table 19.1.

19.3 Current Techniques for Breast Cancer Detection

19.3.1 Mammogram

A mammogram is an x-beam image of the breast. It inclines to be used to check for breast malignancy in women who bear no signs or side effects of the illness. It can likewise be utilized on the off chance that you have an irregularity or other indication of breast disease [37]. Screening mammography is the kind of mammogram that checks you when you have no side effects and manifestations. It can help lessen the number of passings from breast malignant growth among women aged 40–70 [38]. Nevertheless, it can likewise have disadvantages. Mammograms can once in a while discover something that looks anomalous yet isn't malignant growth. This prompts further testing and can cause tension. Now and then mammograms can miss malignant growth when it is there. It likewise opens to radiation [39]. One should converse with primary care physician about the advantages and downsides of mammograms. Together, you can choose when to begin and how frequently to have a mammogram. Mammograms are likewise prescribed for more young women who have indications of breast malignant growth or who have a high danger of the ailment. When you have a mammogram, you need to remain before an x-beam machine. The individual who takes the x-beams puts your breast between two plastic plates. The plates press your breast and make it level. This might be awkward however, it gets a reasonable picture. The composed report of mammogram results inside 30 days [40].

19.3.2 MRI

MRI utilizes attractive fields to make a picture of the breast. Breast MRI is utilized in breast malignancy screening for women at higher than normal hazards. It's likewise now and then utilized in breast malignancy conclusion and arranging. Screening with mammography in addition to breast MRI isn't suggested for women at normal danger of breast malignant growth [41]. Breast MRI is more obtrusive than mammography in light of the fact that a difference operator (gadolinium) is given by vein (through an IV) before the methodology. In uncommon cases, women can have a response to the difference operator (become familiar with gadolinium underneath). Breast MRI has more false-positive outcomes than mammography [42]. A false-positive outcome mistakenly reports a woman has breast malignant growth when she doesn't have breast disease. False-positive outcomes must be checked to make certain there's no breast disease. Follow-up tests, and at times a biopsy, are expected to check a bogus positive outcome. Some MRI focuses don't have the uncommon magnets expected to do a MRI of the breast or don't have radiologists exceptionally prepared to peruse breast MRIs. Breast MRI is costly and not constantly secured by protection [43, 44].

19.3.3 Ultrasound

Breast ultrasound is an imaging test that utilizes sound waves to take a gander at within your breasts. It can help your medicinal services supplier discover breast issues [45]. It additionally gives you medicinal services supplier a chance to perceive how well blood is streaming to the territories in your breasts. This test is frequently utilized when a change has been seen on a mammogram or when a change is felt, however doesn't appear on a mammogram [46]. The social insurance supplier moves a wand-like gadget brought with a transducer over your skin to make the pictures of your breasts [47]. The transducer conveys sound waves that skip off your breast tissue. The sound waves are too piercing for you to hear. The transducer at that point grabs the ricocheted sound waves. These are made into photos of your breasts. Ultrasound might be utilized for especially thick breast tissue, pregnancy, younger women below age 25 [48].

19.4 Antenna Design

The hexagonal T-shaped microstrip antenna at 1.75 and 4.04 GHz is simulated and studied by using HFSS. The principal intend of the proposed design is to detect a breast tumor in a proficient manner. The proportion of the aerial is $40 \times 40 \times 1.6\ \text{mm}^3$. The polyester material is utilized with $\varepsilon_r = 3.2$ and the stature of the material is 1.6 mm. The structure of the aerial is indicated in Fig. 19.1. The specification of the recommended aerial is given in Table 19.2.

The dimension of the presented work is dogged by utilizing the equations.

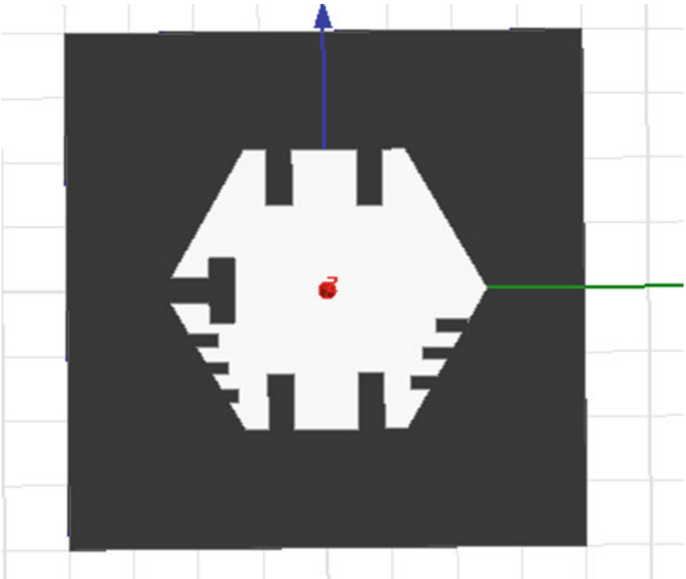


Fig. 19.1 Proposed antenna

Table 19.2 Antenna specifications

S.No	Specifications	Dimension
1.	Sub width (W)	80 mm
2.	Sub length (i)	80 mm
3.	Gnd ($W \times L$)	80×80 mm^2
4.	Patch height (H)	25 mm
5.	Coaxial feed line height (h)	5 mm

Step 1: The width is given as:

$$w = \frac{c}{2 f_{\mathrm{r}} \sqrt{\frac{\varepsilon_{\mathrm{r}}+1}{2}}} \tag{19.1}$$

F_{r} is the resonating frequency, C is the velocity of light, ε_{r} is the relative permittivity of the polyester cloth.

Step 2: The length of the antenna:

$$L_{\mathrm{eff}} = \frac{C}{2 f_{\mathrm{r}} \sqrt{\varepsilon_{\mathrm{r}} \pi}} \tag{19.2}$$

Step 3: The extension of antenna length is:

$$\Delta l = \frac{0.412h \left(\varepsilon_{\mathrm{eff}} + 0.3\right) \left(\frac{w}{h} + 0.264\right)}{\left(\varepsilon_{\mathrm{eff}} + 0.258\right) \left(\frac{w}{h} + 0.8\right)} \tag{19.3}$$

Step 4: The patch length of the proposed antenna is:

$$L_{\mathrm{eff}} - 2\Delta l \tag{19.4}$$

The ANSYS HFSS reproduction suite comprises of an extensive arrangement of solvers to address different electromagnetic issues extending in detail and scale from uninvolved IC parts to amazingly enormous scale EM investigations, for example, car radar scenes for ADAS frameworks. Its dependable programmed versatile work refinement gives a possibility to contemplate on the arrangement as contrasting to investing power deciding and building the finest work [41]. This robotization and ensured exactness separates HFSS from all other EM test systems, which require manual client control and various answers for guarantee that the created work is appropriate and precise [42]. With ANSYS HFSS, the material science characterizes the work as opposed to the work characterizing the physical science. ANSYS HFSS is the head EM device for R&D and virtual plan prototyping. It decreases configuration process duration and lifts your item's unwavering quality and execution. HFSS and CST are 3 D EM test systems dependent on various computational methods. HFSS depends on Finite Element Method (FEM), which is progressively exact for structuring receiving wires while CST depends on Finite Integration in Technique (FIT) and is additionally prominent among radio wire fashioners because of its simplicity in reproductions. Anyway, consequences of both the test systems are not same because of various computational strategies included [43–45]. HFSS results are near trial results with more knowledge in the structure accessible. Promotions are utilized for circuit co reenactments where dynamic parts are additionally included. It may be very well utilized for planar radio wires also and depends on MoM (Method of Moment).

19.5 Simulation Results

The proposed work is simulated by HFSS simulator. Various parameters are analyzed to obtain optimized results. The results obtained during the simulation are discussed below.

19.5.1 Return Loss

It determines the fall of energy in the wave emulated by a cessation in the antenna. It means, greater the *s* parameter, maximum energy will transfer to the load. The return loss is −20, −38 dB at 1.75 and 4.04 GHz, as shown in Fig. 19.2.

19.5.2 VSWR (Voltage Standing Wave Ratio)

It determines the standing wave established in the antenna as a consequence of dissemblance. The range of VSWR 1 and 2 means a small amount of power is emulated from the aerial. In this work, the VSWR is 1.22 and 1.02 at 1.75 and 4.04 GHz, as indicated in Fig. 19.3.

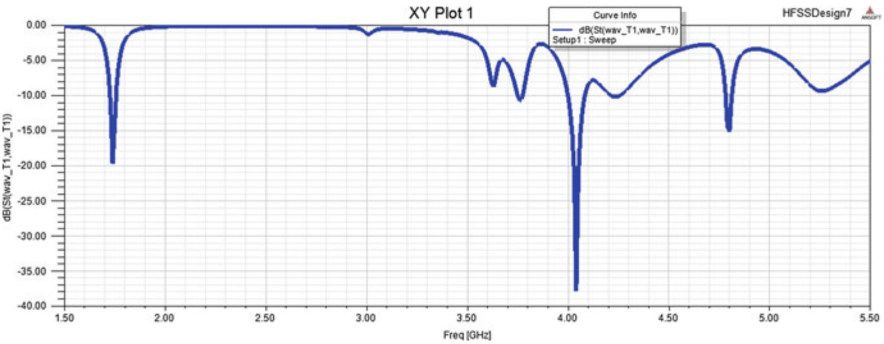


Fig. 19.2 Return loss

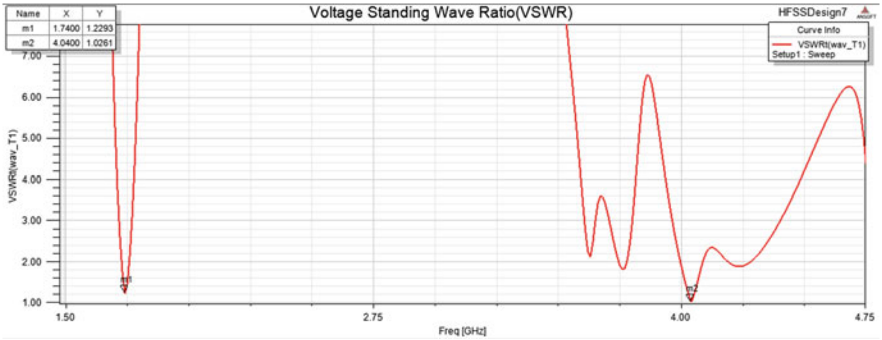


Fig. 19.3 VSWR

19.5.3 Gain

It defines the degree to which an aerial concentrates the radiated wave in a given path as compared with the reference aerial. The gain of 4.06 and 6.57 dB is obtained at 1.75 and 4.04 GHz, indicated by Fig. 19.4a, b.

19.5.4 Group Delay

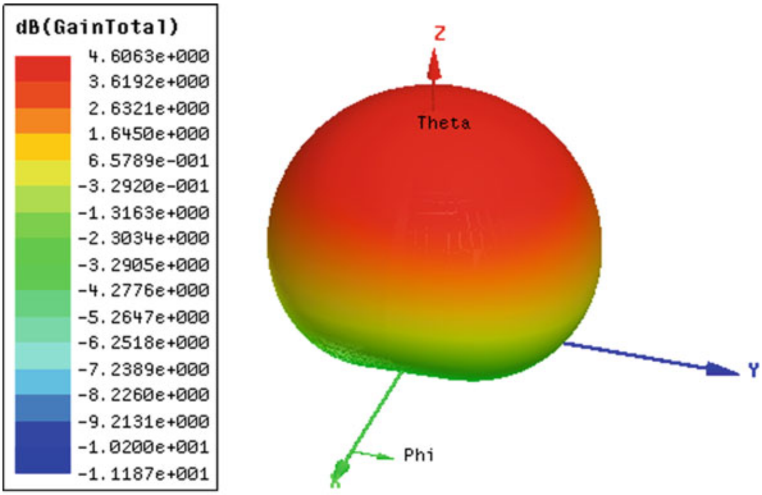
It is a proportion of phase noise. It is the legitimate travel time of a wave through an antenna under test as an element of recurrence. When determining delay, it is essential to indicate the gap utilized for the estimation. The group delay is shown in Fig. 19.5.

19.5.5 Axial Ratio

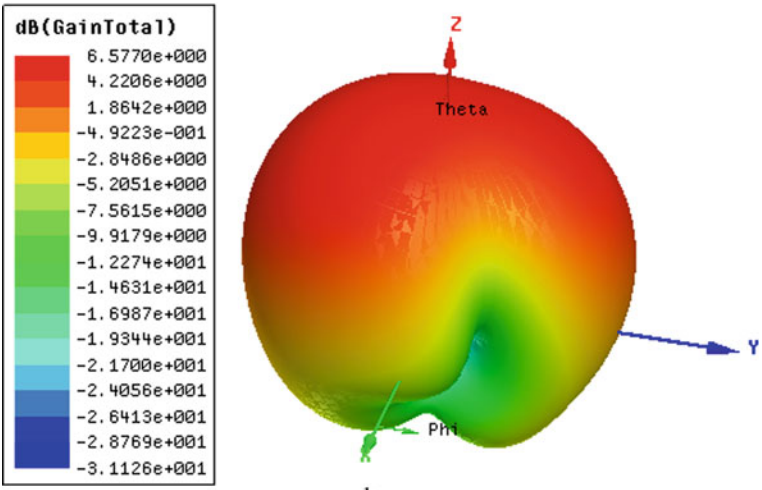
The rate of change of trivial and dominant axis of the emission pattern is known as axial ratio. For circular polarization, it means a circle, having identical axis. The axial ratio is shown in Fig. 19.6.

19.5.6 Radiation Pattern

The azimuth and altitude angle characterized the radiation pattern. Hence, it is experiential in 3-D. The radiation pattern is obtained at 1.75 and 4.5 GHz is given in Fig. 19.7a, b.



a



b

Fig. 19.4 Gain (**a**) 1.75 GHz and (**b**) 4.5 GHz

19.5.7 Surface Current Distribution (J)

The J is obtained at 1.75 and 4.04 GHz, given in Fig. 19.8a, b. At 1.75 GHz. It is experiential that, the current circulation of the breast tumor is high as compared to the normal breast tissue. In Fig. 19.8a, it is seen that the current is distributed in the entire antenna. In Fig. 19.8b, the current division is more on the pinnacle and the base of the patch.

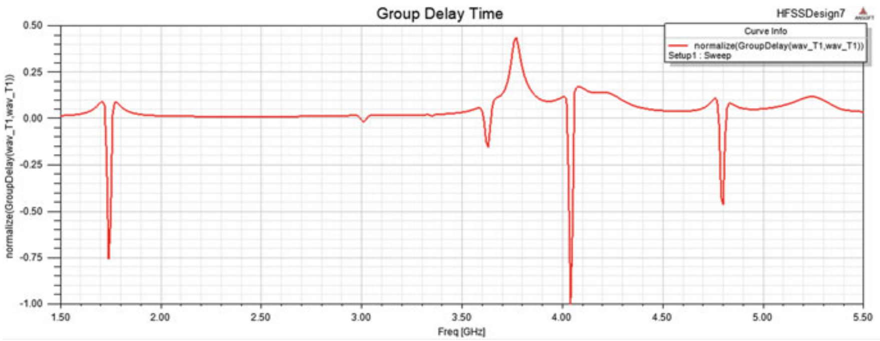


Fig. 19.5 Group delay

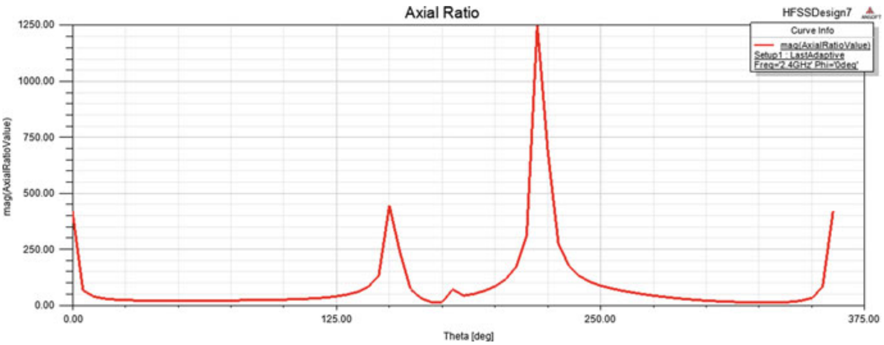


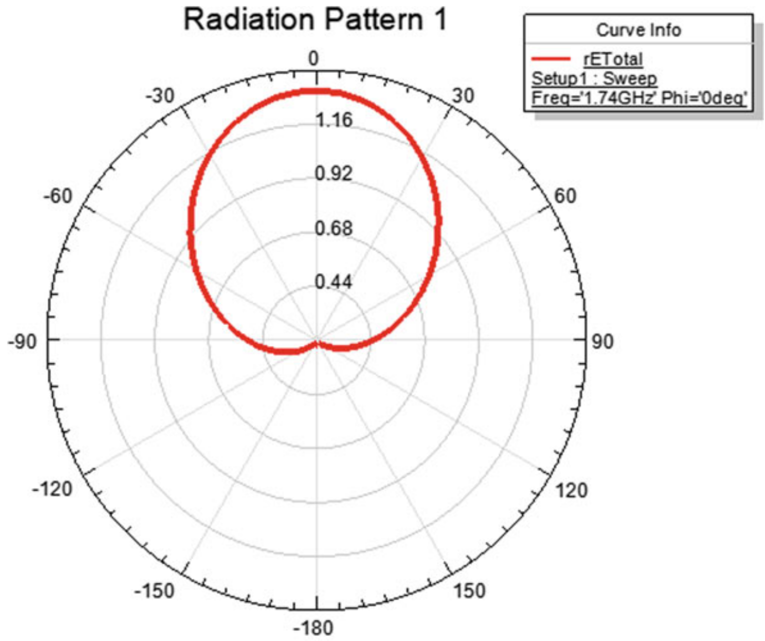
Fig. 19.6 Axial ratio

19.5.8 Smith Chart

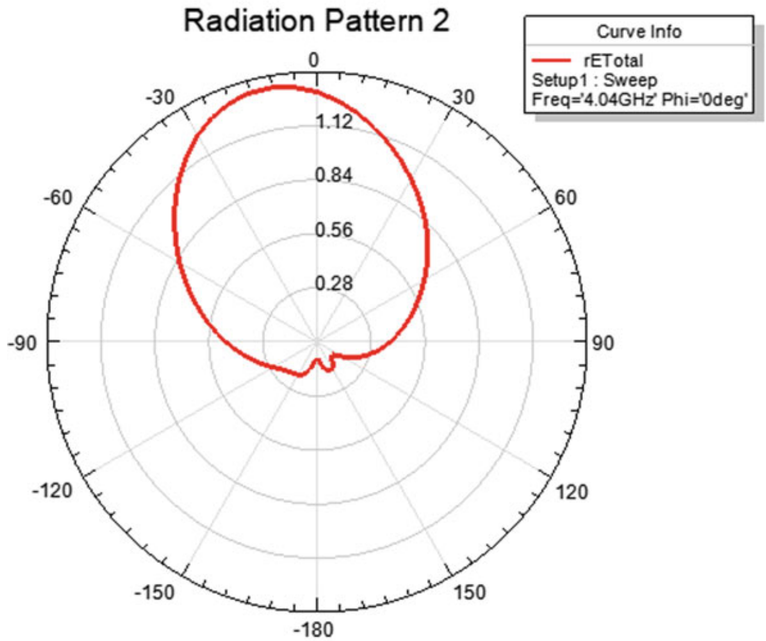
The smith chart of the projected aerial is shown in Fig. 19.9. It is utilized to demonstrate authentic aerial impedance. It can also be useful to analyze the transmission lines by evaluating it on VNA.

19.6 Fog Computing Analysis

Fog computing can be used to detect the tumor by considering several processes given in Fig. 19.10.



a



b

Fig. 19.7 Radiation pattern (**a**) 1.75 Hz and (**b**) 4.5 GHz

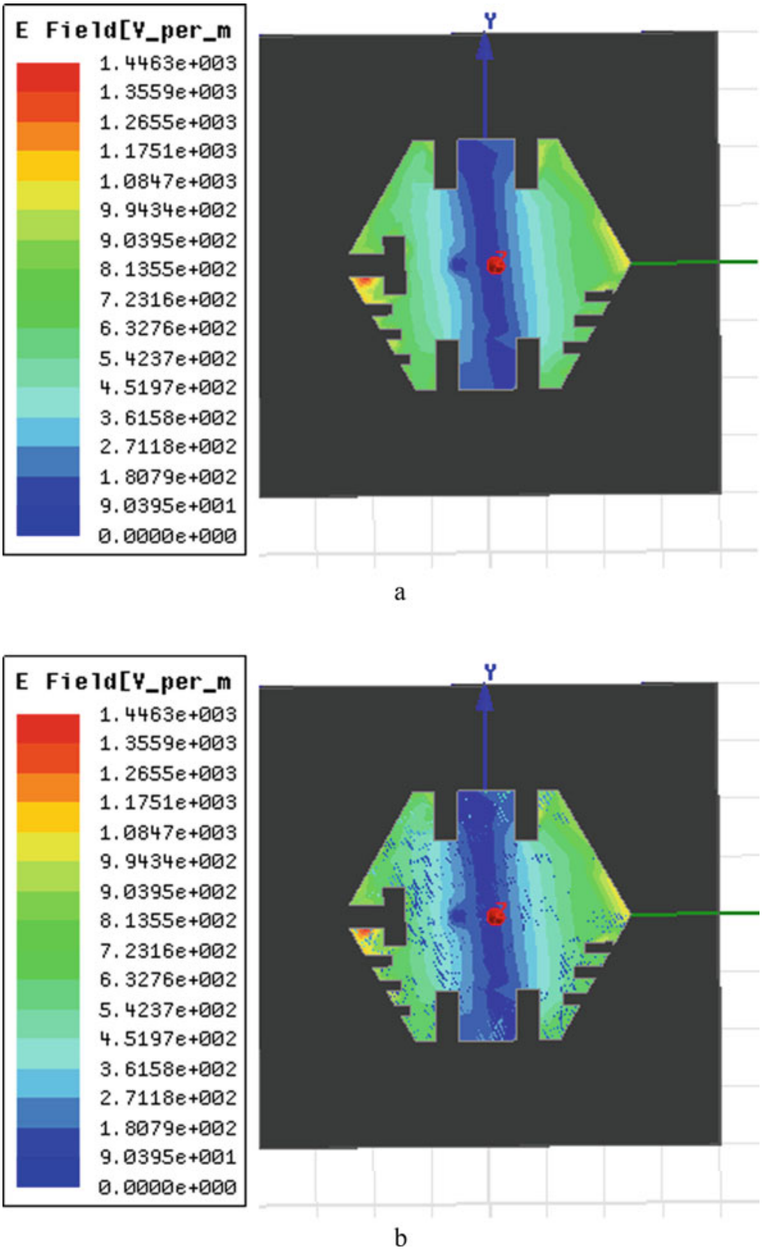


Fig. 19.8 (**a**, **b**) Surface current density

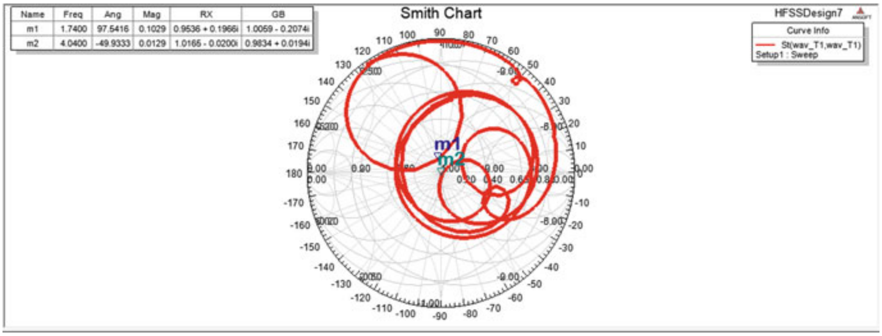


Fig. 19.9 Smith Chart

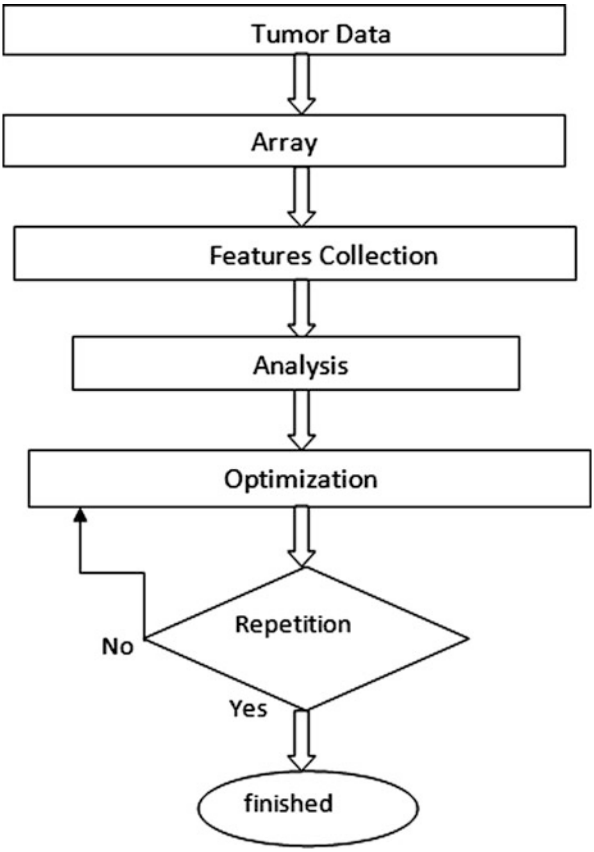


Fig. 19.10 Modeling of breast tumor using fog computing

Table 19.3 Tabular results

S.No	Parameters	Value
1.	Antenna dimension	$40 \times 40 \times 1.6\ mm^3$
2.	Spectrum	1.75 and 4.05 GHz
3.	Return loss	−28 and −38 dB
4	Gain	4.06 and 6.57 dB
5	Axial Ratio	1
6.	VSWR	1.22 and 1.02
7.	Applications	Breast cancer and GPS for radar communication

19.7 Conclusion

In this work, we have simulated a wearable hexagonal T-shaped microstrip antenna for sensing of breast tumor in an initial development juncture. In this work, we have analyzed the different distinctiveness of the aerial such as return loss, gain, smith chart, group delay, radiation pattern, VSWR and observed that the antenna is best suited for breast tumor detection application. From the simulation results, one more application is observed at 1.75 GHz. The proposed work is virtuously dedicated for breast tumor detection, but it can find its application in GPS unit for radar and IoT. The result of the proposed antenna is tabulated in Table 19.3.

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Part V
Next Generation Health Fog Analytics for Healthcare 4.0

Chapter 20
Yajna and Mantra Science on Healthcare Domain: A Futuristic Scientific Approach with Indian Scenario

Rohit Rastogi, Mamta Saxena, D. K. Chaturvedi, Muskan Maheshwari, Priyanshi Garg, Muskan Gupta, Rajat Shrivastava, Mukund Rastogi, and Harshit Gupta

20.1 Introduction

20.1.1 Health Issues and Challenges in Global Scenario

Colin D. Mathers and Dejan Loncar experimented in their research the three models which are simple and project the trends of future health records. The name of each model is Optimistic, Baseline, and Pessimistic. In all the models, the distribution of death shows huge shift of causes from communicable, perinatal and maternal to non-communicable disease. The risk of deaths for humans of age less than 5 years falls nearly by 50% in baseline scenario between 2002 and 2030. Rise from 2.8 million to 6.5 million from 2002 to 2030 is found in global HIV/AIDS trends. Many more results have been estimated from this study in order to help organizations such as WHO to plan their health policies accordingly [1] (as per Fig. 20.1).

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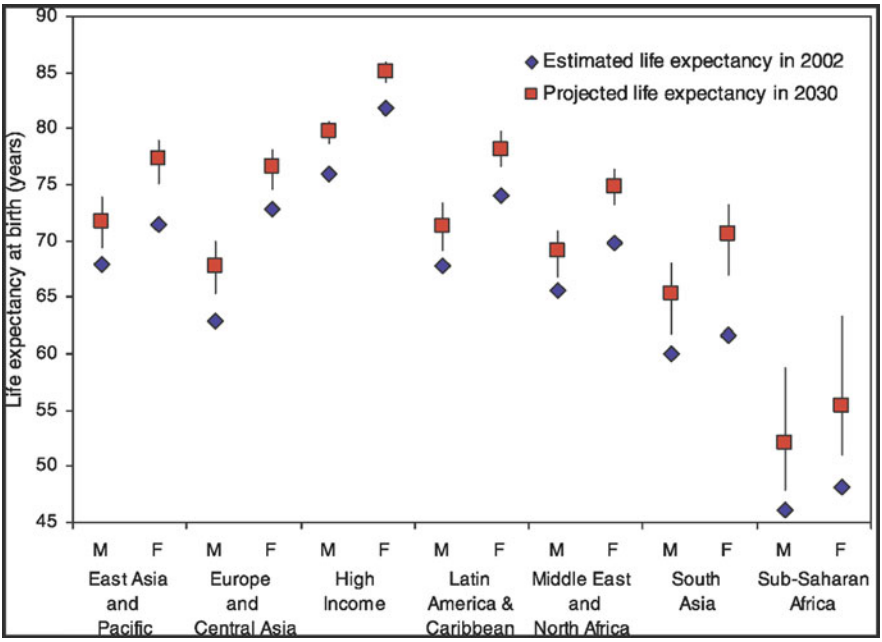


Fig. 20.1 Estimated and projected life expectancy [1]

20.1.2 Healthcare 4.0

Zhibo Pang, Geng Yang, RidhaKhedri, Yuan-Ting Zhang experimented in their research that after taking this initiative, there happens significantly important progress in the direction of ideal vision of 8-P's of healthcare. These 8 P's include Predictive, Participatory, Preventive, Patient-centered, Pre-emptive, Precision, Personalized, and Persuasive healthcare. In this, Persuasive and Preventive Healthcare is achieved by installing smart and unobtrusive sensors in human body as well as in ambient environments through digitalization of living entity especially before that gets sick. Personalized and Personal Healthcare can be achieved by linking all the genic and healthcare data of an individual with the guaranteed privacy preservation in order to make it more precise. Patients are also provided with seamless consolidation of flows of patient and full scheduling and optimization of healthcare process. A primary change by this initiative in healthcare system is the shift of the paradigm design in a loop which is small to large, single to a multi and open to close one [2, 3, 9].

20.1.3 Big Data and IoT

IoT and Big Data, both are continuously moving through the technical world for a time quite now and become a necessity for all of us. Internet of Things (IoT) refers to a unit of physical objects or devices that are connected through internet. “Things” in IoT refers to collection and transferring of data over the internet without taking the help of intercession and embedded technology. Big Data refers to the large set of unstructured, semi-structured, or structured data and inspect them to know about the trends of business. IoT and Big Data are related in such a way that IoT is used to collect the large amount of data and then Big Data analyze this data with the help of connected devices to initiate the improvement of decision-making [4, 6].

Mohsen Marjani, Fariza Nasaruddin, Abdullah Gani, Ahmad karim, Ibrahim Abaker Targio Hashem, Aisha Siddiqa, IbrarYakoob experimented in their research that use of Big Data is rapidly increasing in IoT field as IoT has a main feature of “connected things.” The requirement to adopt the concept of Big Data in IoT is engrossing the data. The Big Data and IoT are interdependent and are developing jointly. The use of IoT increases the amount of data not only in quantity but also in category, hence the application of concept of Big Data is necessary. The applications of Big Data and IoT together is interactivity of devices such as CCTV cameras, traffic lights, home devices, and then generate large amount of data with different formats. Some upcoming opportunities in this field are e-commerce, healthcare, smart cities, etc. Some issues also need to be resolved such as privacy, integration, visualization, etc. [5, 8, 9] (as per Fig. 20.2).

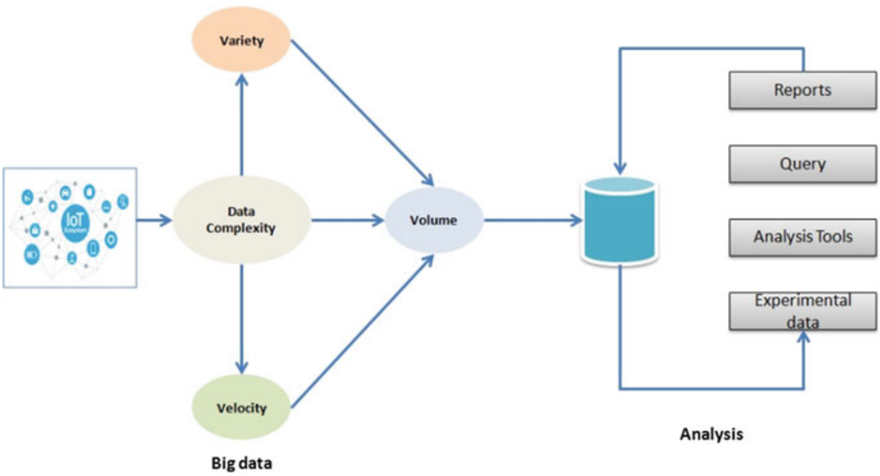


Fig. 20.2 IoT Big Data processing [5]

20.1.4 Fog Computing

Carla Mouradian, Diala Naboulsi, Sami Yangui, Roch H. Glitho, Monique J. Morrow, Paul A. Polakos experimented in their research that fog computing is introduced to tackle problems like connectivity between end devices and cloud storage, high-latency, to situate components of application over multiple clouds separately, overhead of latency induced by intercloud communications and many more. Fog computing provide benefits such as low latency, allowing instruction processing to take place at the edge of the network, etc. Fog system consists of three-level architecture. It has three levels: The cloud level, the fog level, and the IoT/end-user level. Fog layer is formed by single or more fog domains which in turn are formed by fog nodes. IoT layer is formed by two domains, end-user devices and IoT devices [7, 14, 15] (as per Fig. 20.3).

20.1.5 Yajna and Mantra Science

Yagya Science works on the principle of Yagya. Yagya is basically performed by the great rishi-munis in their caves. Not only the saints but also some men, citizens whether rich or poor all do Yagya at that time. They all had respect and faith in Yagya. They spent at least one-third of their lives doing Yagya. At that time people

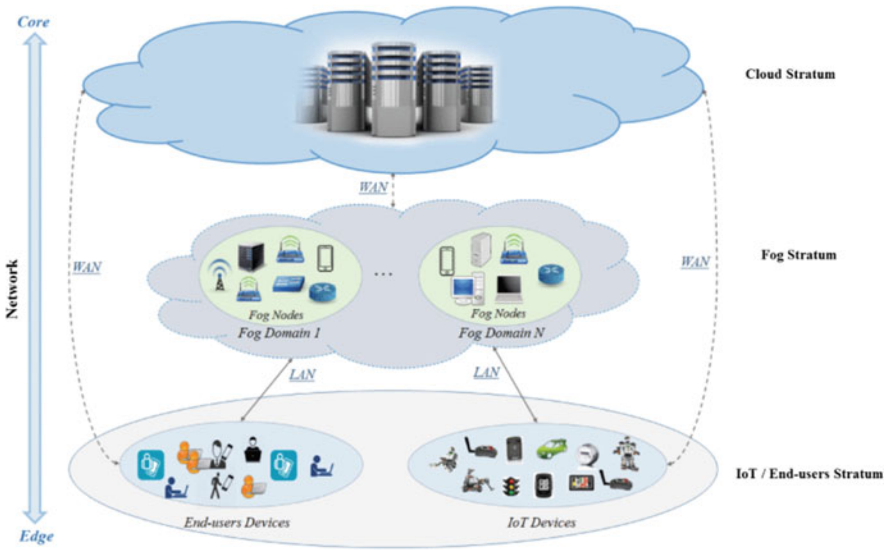


Fig. 20.3 The fog system [7]

believed that, Yagya is very essential for refinement of human life from animal instincts to Brahmin's.

Yagya promotes happiness and a healthy life. The different methods of performing Yagya were discovered by rishi-munis based on their understanding of Yagya in ancient age. But nowadays everyone forgets about Yagya, and what are its benefits and purpose.

There are two basic energy systems in the physical world: heat and sound. In Yagya practice, two energies, the heat of Yagya fire, the sound of Gayatri and other mantras are combined to provide the desired physical, psychological, and mental benefits [10].

20.1.5.1 Ancient Vedic Tradition and Yajna

Ghanshyam Singh Thakur experimented in his research that during some research, history witnessed that in prehistoric times, humans searched for fire for their needs so that they could cook food. After research of fire, humans evolved over time and started worshiping fire. Such acts featured the Yajnas of the Vedic period. It appears that such acts were performed to obtain divine powers and strength from deities. Duty is imposed on people of different sections of society to study Vedas. Along with making sacrifices, it is also said that if anyone wants, the performance of sacrifice is very important to fulfill his wish and this desire is nothing more than to secure a place in the divine abode-Heaven. Yajnas make personal, national, and temporal welfare possible. No basic purpose can be left behind the Yajnas and that is to maintain an environment free from all types of pollution and to maintain ecological balance [11, 16, 18].

20.1.5.2 Technical Aspects of Mantra and Yajna Therapies

The potential outcomes of treatment of mental illnesses by Yajna are much progressively alluring. Conclusion and treatment of mental issue is still in innovation. There is neither one of the wells set up clinical guides, nor any perceived treatment of illnesses like mental issues, psychosis, schizophrenia, sorrow, stress, and so forth. Then again, mental ailment is more serious than physical maladies. Yagnopathy can likewise offer an answer for this difficult issue. Nature around where Yajna is being performed and the fiery debris delivered in the tank has been discovered helpful in recuperating the sensory system, asthma, mental disorders, skin allergies, etc. Analysis of ash has indicated that this includes some elements that calm and soothe the mind [19, 22].

20.1.5.3 Purity and Significance of These Therapies

Different Yajnas are performed to woo different deities. Rudra Yagya is for Shiva, Lakshmi Homam is for prosperity, Vishnu Yagya is for Vishnu, and Ganpati Homam is for Ganesha. Navgraha Grihama is similar to Vastu Griha, usually done to overcome the ill effects of the purchase of a new house or bad times in life. All these things show the significance of Yajna and lead to Hinduism to superiority. As the holy smoke from Yajna enters our house, it does not only erase all bad influences and negativity from our house. But it also brings peace, happiness, prosperity, health, and satisfaction [2, 24].

Pt. Shriram Sharma Acharya ji experimented in his research that more than purification of air it is more prudent to purify the atmosphere of the world. The environment affects every corner of our personality and therefore its development, this, in turn, gives a positive full direction to our preceding thinking process. If we analyze the situation of today's generation deeply then it is found that more than physical diseases it is bad mental habits such as drug addiction, criminal tendencies, malaise anger, wrong thinking, hate, and stressful life that hurts more. The urine sugar level of some exceptional diabetic patients was likewise watched as absolutely missing and the degree of glucose was decreased typically soon after half a month of every day agnihotra. When Yajna therapy is presented in a very compact form all over the world, it will help to overcome mental stress and physical disease on a large scale [10].

20.2 Healthcare 4.0 with Fog Computing on Inhaling Therapies

20.2.1 Implications, Significance, and Impacts on Global Health Scenario

Fog computing (fogging) is a process that uses edge devices for all sort of communication, storage, and computations. Healthcare 4.0 has the potential to visualize and extend the healthcare-related processes very easily. Fog computing and Healthcare 4.0 together are used for patient monitoring. It is very helpful in the cases where the patient lives in a remote area. Fog computing is helpful in collection of patient's data from edge devices, to connect multiple devices to a network, and sending all data and to process all the data in a very less time. Healthcare 4.0 with fog computing has many applications and it will be very successful as it can be predicted by various case studies [6, 12].

Sudeep Tanwar, Aparna Kumari, Neeraj Kumar, and Sudhanshu Tyagi experimented in their research that healthcare industry has travelled a path from 1.0 to 4.0. With recent advancement like cloud and fog computing, the health problems have become less severe with less capital investment on computing. It has also minimized the storage facility related to data of patients. The first priority needs to be given to the healthcare industry. Fog computing helps in data collection and data analysis. Information can be gathered for telemedicine; it has been seen in many cases. The objective of a project of TCS named TCS robust FC was that it facilitates real-time remote patient monitoring. It was very helpful and flexible for patients [2, 14, 16].

20.2.2 Big Data and Computational Analysis

The process of modeling and inspecting data in order to achieve useful information, supportive decision-making, and conclusions is called data analysis. In today's highly technical and advanced world, data analysis plays a very important role in making decisions in order to handle such Big Data effectively and efficiently. There are many free softwares available for data analysis. Some of them are DevInfo, Orange, PAW, Pandas, etc. (as per Fig. 20.4) [18, 19].

D.P. Acharya and Kauser Ahmed P experimented in their research that everyday a very large amount of large data is generated through IOT and cloud computing. So it is necessary to analyze that data to extract knowledge from it. This is why Big Data and computational analysis is the latest area of research. The challenges faced by big analytics of data in the field of healthcare are classified into four categories, i.e.,

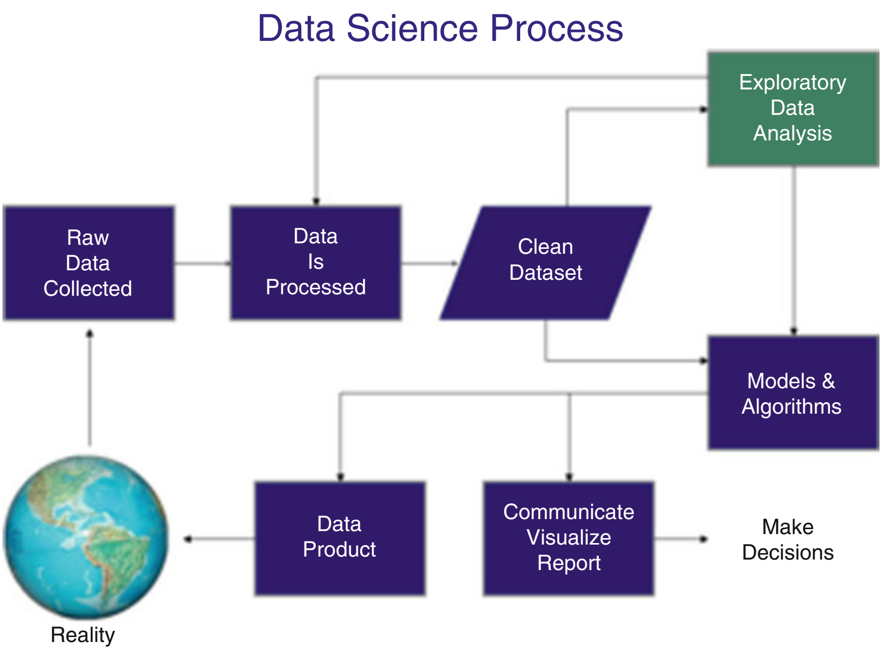


Fig. 20.4 Data science process flowchart from Doing Data Science, by [17]

data storage and analysis, scalability and visualization of data, knowledge discovery and computational complexities, and information security. The various techniques used for data analysis is intelligent analysis, machine learning, cloud computing, data mining, and data stream processing. There is a need to pay attention to these techniques, as these are the future of technology. We need to invent new technology so that Big Data can be analyzed effectively and efficiently [17].

20.2.3 Effect of Yajna and Mantra on Human Health

Rahul Raveendran Nair experimented in his research that one should take care of his/her health as if health is good then only person will be able to do work. In today's world, everyday a new disease is taking birth. So technology should also work in same manner as to cope up with this issue. The Yagopathy has proved beneficial in maintaining human health. The purpose behind the practice of agnihotra yajna is "letting incessant flow of energy (LIFE)" through our meridian lines. This is the most easiest way of curing people. It is actually the Indian tradition and culture. The yajna helps in the betterment of human health as the ahuties that are given to sacrificial fire has very good advantages that can improve the health of humans without the use of any harmful chemical [20, 27, 29].

20.2.4 Pattern Classification in Study

Pattern is everything around in this computerized world. Either a Pattern can be seen physically or it tends to be watched scientifically by applying calculations. Pattern Classification is the way toward perceiving designs by utilizing AI calculation. Pattern Classification can be characterized as the order of information dependent on learning previously picked up or on measurable data extracted from patterns or potentially their portrayal. One of the significant parts of the Pattern Classification is its application potential. Some significant examples of Pattern Classification are Multimedia Document Recognition (MDR), Speaker Identification, Speech Recognition, etc. Medicinal and healthcare area is a major industry these days. Picture-based medicinal finding is one of the significant help territories in this sector. Different Artificial Intelligence systems, for example, artificial neural systems and fuzzy logic are utilized for arrangement issues in the territory of medical examination [30, 31].

Priyanka Mahajan experimented in her research that Pattern Classification as a field developed essentially during the 1960s. It is an interdisciplinary subject, covering advancements in the zones of restorative, engineering, Artificial Intelligence, software engineering, psychology, and physiology, among others. Person has regular insight thus can perceive patterns. Pattern Classification is the examination of how machines can watch the earth, make sense of how to perceive instances of eagerness from their experience, and choose sound and reasonable decisions about the Patterns. Clinical Decision Support System (CDSS) was one of the essential productive employments of AI, focusing basically on the finding of a patient's condition given his indications and measurable information. Work on CDSS for helpful investigation began in the mid-1970s with Mycin3-a standard based ace structure for identifying illnesses [23].

20.2.5 Use of ML and AI

There is continuous research and progress in the medical field when it occurs to medicine. Now with the help of ML algorithms, personalized medicine, and predictive patients have taken another step toward curing diseases. The ML-based software can accelerate development for these serious diseases of the brain. Some researchers are working earnestly to find a cure for cancer with the help of Yagya and Mantra science [31–33].

Ki-Jo Kim and LLias Tagkopoulos experimented on their research that ML is the field of computer science that aims to build forecasting models from data. It uses algorithms, methods, and procedures to uncover latent associations within data and creates descriptive, prescriptive, or prescriptive tools that exploit those associations. It is generally agreed that DL, subfield of ML, is more recent that is a mathematically concentrated algorithm grabbing complex relationships within data. In medical practice, ML and AI tools can help clinicians better understand a disease and precisely evaluate the status of patients, based on high-performance molecular and imaging techniques, which exhibit the diversity and complexity of diseases. To sum up, ML and AI helps us to find the cure of various diseases [25].

20.3 Problem Solving Environments, Complex Systems

20.3.1 Swarm Intelligence Techniques

Chellamuthu Gunavathi, Kandasamy Premalatha experimented in their research that swarm intelligence techniques have a wide range of benefits in many fields. In bioinformatics field, it is used in the feature selection of cancer classification. In feature selection, informative genes are selected from the thousands genes of microarray. These informative genes are classified by swarm intelligence techniques such as Particle swarm optimization (PSO), Cuckoo search (CS), Shuffled frog leaping (SFL) algorithm, and Shuffled frog leaping with L\'evy light (SELLF) [26] (as per Fig. 20.5).

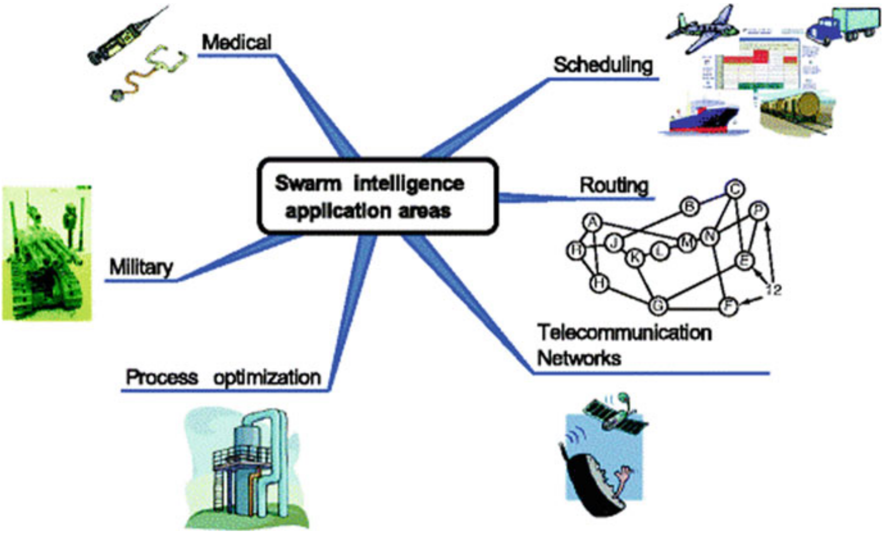


Fig. 20.5 Applications of swarm intelligence in various fields [26]

20.3.2 Pattern Classification

Pinaki Ray, Greg Patian, Aparna Srinivasan, David Rodbard, and David Price experimented in their research that pattern recognition can find applications in various fields. One of its applications in healthcare is that the diabetes management process requires large number of measurements of glucose concentration and other physiological parameters such as glycemia in patient's blood. So, Pattern Classification helps in providing dosing pattern, a pattern of hypoglycemia, a pattern of hyperglycemia, and variability pattern of blood glucose. After analyzing all these patterns, warning message is displayed on the device to ensure whether the person is suffering from diabetes or not to guide the patient about managing diabetes [4].

20.3.3 Advanced Numerical Computation and Optimization

Stanislav Makhanov, Weerachai Antaipaiboon experimented in their research new optimization algorithms, which is designed will help very much in the field of new advancements. The book introduces the reader to the fundamental issues involved in the path of advanced numerical computation and optimization. This technique will also be very helpful in the field of Yagyopathy. New innovations in this field are welcome. It will be very beneficial and one should do research in this field as it is the future [8].

The study of algorithms that use numerical approximation for the problems of mathematical analysis is called numerical analysis. ADVANCED NUMERICAL

COMPUTATION AND OPTIMIZATION finds work in all field of life including medical sciences and engineering [34–38].

20.3.4 Quantum Inspired Soft Computing

Soft Computing deals with using several intelligent tools and method in the form of evolutionary computation, neural networks, and fuzzy logic to solve problem of real world and provide necessary solutions. It has evolved as an efficient way of handling complex and real world problem taking record from various parameters and using complex algorithm. The computing involves analyzing different quantum multilayer neural network and sends the data to complex algorithms, which further filters them to give the required result. In case of “Yagya and Mantra Therapy,” the soft computing methods are also used to analyze different neural network containing details about diseases. It can build treatment for the disease based on data set and previous instances.

The research work of Siddhartha Bhattacharyya on the use of soft computing for analysis and processing of Binary Image gives the idea of use of Neural Network in the form of quantum multilevel architecture. The system takes the advantage that it does not require any previous information for processing the image [15, 39, 40].

The same architecture can be used for “Yagya and Mantra Therapy.” If a system encounters a new type of disease, whose diagnosis is not mentioned in the system, then with the help of quantum computing it can automatically form a diagnosis. This will reduce the work of a doctor when some unknown disease is encountered by the system [41, 42].

20.3.5 Applications and Experience with Deployed Systems

The “Yagya and Mantra Therapy” is capable to treating very serious and deadly disease by simply going “Yagya.” The fume emerging from the Yagya helps to heal the patient from disease. In order to test the “Yagya and Mantra therapy,” many experiments have been conducted by different scholars at different times. One such was measurement of air quality index [43, 44].

Delhi is infamous as the most polluted city in the world in term of air quality index. In a research, it is also found that inhaling in Delhi is equivalent to smoking ten cigarettes a day. To solve this problem and to improve the air quality index some scientists conducted a “Yagya” at different places of the Delhi. Before performing the “Yagya,” the air quality index of the place was measured. Then “Yagya” was conducted at that place. When the air quality index was measured after the “Yagya,” it was found that there was a considerable decrease in the amount of SO_3, SO_4, and NO in the air. Thus the “Yagya and Mantra therapy” can be a powerful tool to improve the air quality index of the cities.

Similar result was found when the same "Yagya" was conducted in different parts of the India. The result was encouraging and proved the usefulness of the "Yagya and Mantra Therapy" as one of the powerful methods which can revolutionize the world in future [46, 47].

20.3.6 Learning Classifier System

Learning classifier systems (LCS) are a prototype of rule-based machine learning methods. It includes discovery component and learning component. John H. Holmesa Pier, Luca Lanzib, Wolfgang, Stolzmannc Stewart, W. Wilson experimented in their research that they exploit evolutionary computation and reinforcement learning. Its aim is to develop a set of condition-action rules that represent a target task. It is complicated during 1900s. It learns by interacting with an environment. It receives a feedback in the form of numerical reward. There are three arguments that support LCS—adaptively, generalization, and scalability. It has always been viewed as adaptive systems. They are capable of online learning in rapidly changing situation by exploiting their genetic algorithm [24, 45] (as per Fig. 20.6).

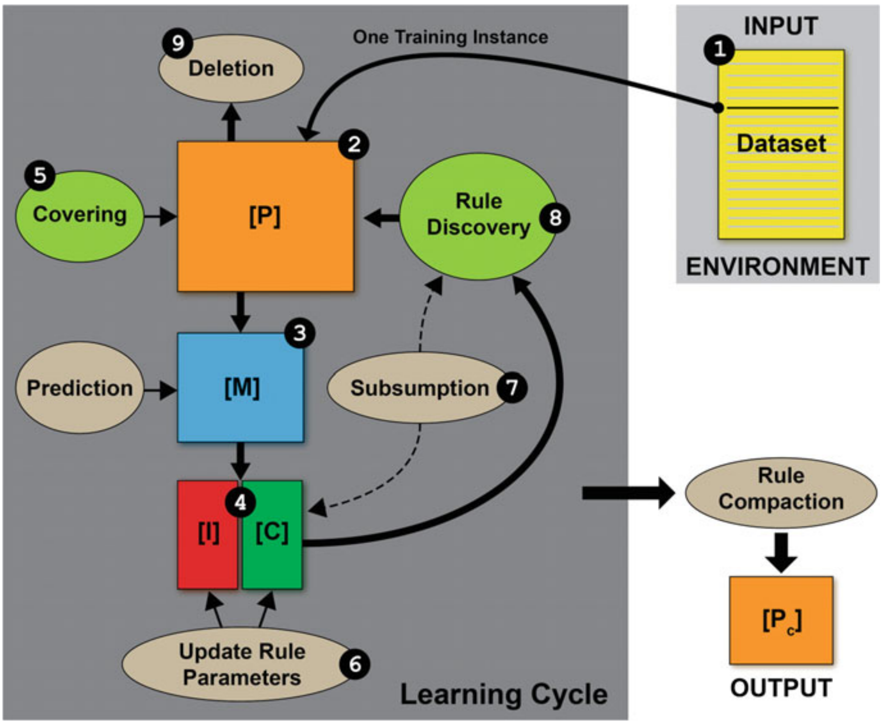


Fig. 20.6 Learning classifier system cycle

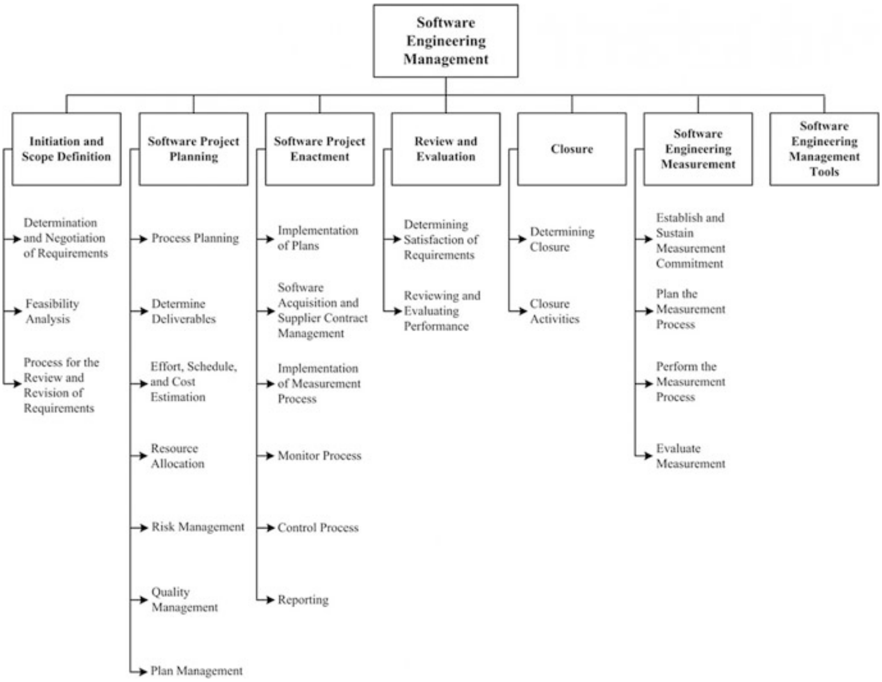


Fig. 20.7 Configuration of software engineering system [28]

20.3.7 Software Engineering and Management

L. Glassa I. Vesseyb 1V. Ramesh found in their work that Software Engineering (SE) is an emerging discipline and there are well-defined trends that indicate an increasing level of maturity. Its purpose is to provide popular characterization of bounds of the software engineer discipline and to provide topical access to the Body of Knowledge supporting that discipline. The field of Software Engineering was done primarily for academic purpose. The field of SE research is focused in research methods. SE research is mainly focused on systems/software technical matters. In other words, it mainly focused on how to build systems, how to formulate better ways to build systems, and how to analyze or implement promising new concepts [28] (as per Fig. 20.7).

20.4 Literature Survey

According to Estrelz Vania and his colleagues, the Cloud Computing, Big Data, IoT, and Wireless Internet Forms, 5G Technology, Encryption, Semantic Database Usage (DB), and Industry 4.0 Standard (I4S) Technology for Automation and

Data Exchange with Augmented Reality Design (ARD) has much scope to do in healthcare applications along with content-based image recovery (CBIR). The healthcare format called Health 4.0. They explained this research on Health 4.0 and the potential to extend, virtualize, and activate new processes related to healthcare, such as home care, cosmetic drugs, personal, and telemedicine. Then convert them into information services.

In the future, these services can virtualize multiple levels of virtual care, device connectivity, and transfer to personalized medicine. The Cyber-Physical Health 4.0 (HCPS) system includes several types of computers, communications, storage, interfaces, biosensors, and bio-stimulants. The HCPS paradigm makes it possible to monitor the actual process as well as monitoring patients before, during, and after surgery using biosensors. In addition, HCPS includes bioreactors that perform targeted interventions, along with other new solutions for deploying PM.

Estrelz Vania has revealed that sensor detectors detect critical external and internal conditions of the patient and send these signals to a decision-making unit (DMU). Mobile and wearable devices are examples of devices that contain biosensors. After receiving the DMU signal, it can be compared with the patient's medical history and followed by a series of procedures to address specific situations depending on the protocol. Part of the task of automating mitigation is a biological stimulus that can vary from a stimulus to the remote release of certain elements into a capsule in the patient's body. Health-related programs when used in conjunction with CBIR System Scan, it provides access to multimedia and multi-mode image information to aid in patient diagnosis and medical decisions.

According to the author, the National Health Service is currently working with patients and medical teams to enhance the transfer of treatment from hospital to home without interrupting outpatient services, Big Data analysis, and easy integration of healthcare professional expertise and smart devices. However, rigorous testing to reach the level of automation of progress, interdisciplinary discussions, robust rules/protocols, inventory of new technology impacts on patients, and undeniable medical technology initiatives is not required.

Gia, T.N. and other researchers have clearly described that the rapid development of IoT has been reported connections support many smart devices with sensors and seamless data exchange between them, so data analysis and data storage platforms such as cloud computing are requireMohammad.

According to her, health is one of the IoT application areas that has great interest in industry, research community, and public sector. The development of IoT and cloud computing has improved patient safety, staff satisfaction, and operational efficiency in the medical industry.

They showed through experiments that FC plays an important role in supporting smart gateways. It also demonstrates the role of fog computing in healthcare, and in 2017, a smart healthcare port was built for fog computing modules. More specifically, the author focuses on regulating the connection from the home gate to the hospital gate.

Finally, to prove the effectiveness of adding a fog layer to the framework, he said, a fog calculation was proposed based on early detection of chronic disease system. In 2016, a healthcare framework called Health Fog was introduced.

In the proposed framework, fog computing technology is deployed to connect the user layer to the cloud layer. They focused on improving and resolving EMR privacy issues. Second, cloud-based security software was added to Health Fog to enhance system security. In recent years, healthcare programs have shifted from cloud computing to fog computing.

Mutlag, Ammar has described the geographically distributed cloud computing architecture and various heterogeneous devices are widely used at the end of networks to provide flexible services, computing, and storage. Fog computing has many advantages and is well suited for applications where real time, high response time, and low latency are particularly important, especially for healthcare programs.

He described the purpose of this study is to present a systematic literature review of fog computing. Technology and previous analysis in the field of IoT care systems. Motivation, limitations faced by researchers, and suggestions for improving key areas of research are provided by analysts.

They used the following methods in their research work: In this method, all studies conducted a systematic study of healthcare fog calculations. In addition, four Web of Science (WoS) databases from 2007 to 2017, Science Direct, IEEE Xplore, and Scopus digital libraries application, and performance were used to analyze the architecture.

They obtained findings based on inclusion and exclusion criteria, and a total of 99 articles on fog calculation in the health program were selected using various methods. Classification results fall into three main categories: frameworks and models, systems (executive or architecture), reviews, surveys.

He explained that the fog computing program is suitable for health applications that require real time, low latency, and high response time. All these studies show that resource sharing can improve containment infrastructure, reduce latency, improve scalability, distributed processing, improve security, fault tolerance, and improve privacy. Lessons: Countless computing lessons are possible.

Cloud computing is undoubtedly delayed compared to cloud computing. Researchers have shown that the ratio of simulation and experiment guarantees a significant reduction in latency. That is very important for IoT health systems because of real-time needs.

He concluded that the scope of research on fog calculations in healthcare programs is different, but in most cases they are equally important. The review concludes that research capabilities are highlighted and additional research areas are expanded and created.

The paper “Medical Internet of Things and Big Data in Healthcare” has written by Dimiter V. Dimitrov, MD. According to their many technologies, it can reduce the overall cost of preventing or managing chronic disease. These include devices that consistently monitor health indicators, devices that monitor self-medication, or devices that track real-time health data when performing self-tests. With the advent of high-speed Internet access and smartphones, many patients use mobile apps to manage different health needs. These mobile devices and applications are now increasingly used in medicine and medicine over the Internet of Things (mIoT). This article examines Big Data in the healthcare field.

They used the following approach: mIoT improves the emergence of new business models and business process changes, increased productivity, cost containment, and customer experience. The authors conclude that today's wearable and mobile applications support fitness, health education, symptom tracking, and disease management, and coordination of co-care. All platform analytics can increase the relevance of data interpretation and reduce the time that end users spend collecting data output. Information from the world of Big Data analytics disrupts healthcare, business processes, and real-time decisions [48].

Eventually, they draw conclusions and a new class of personal preventive health educators has appeared. These workers have the ability to interpret and understand health and welfare data. Help clients avoid chronic illness and diet, improve cognitive function, improve mental health, and overall life. These roles will become increasingly important as the world population grows.

20.5 Methodology

20.5.1 Instruments Required

To develop such expert system, we need some software tools. First, we need Programming Languages, which are problem oriented and symbol manipulated such as FORTRAN, PASCAL, LISP, PROLOG, etc. We use problem-oriented language as they have certain features for performing mathematical, scientific, algebraic, and statistical solutions. Second, we also need Knowledge Engineering languages, which are used to debug the expert system. Third, we need system building aids, which help in designing the expert system. And at last, we need Tool Support Environment Facilities, which helps in making each tool more user friendly and more efficient to work. These all components are illustrated with the help of a diagram (as per Fig. 20.8).

20.5.2 Experimental Setup of an Expert System

While we are doing the experiment for Pollution Checking, we have done Yagya on the places on crossroads. We have taken the reading before doing yagya and then after doing yagya. Then with the help of checkers and testers we installed, we are able to compare the pollution level.

Mamta Saxena, Sushil Kumar Sharma, Sulochana Muralidharan, Vijay Beriwal, Rohit Rastogi, Parul Singhal, Vishal Sharma, Utkarsh Sanga experimented in their

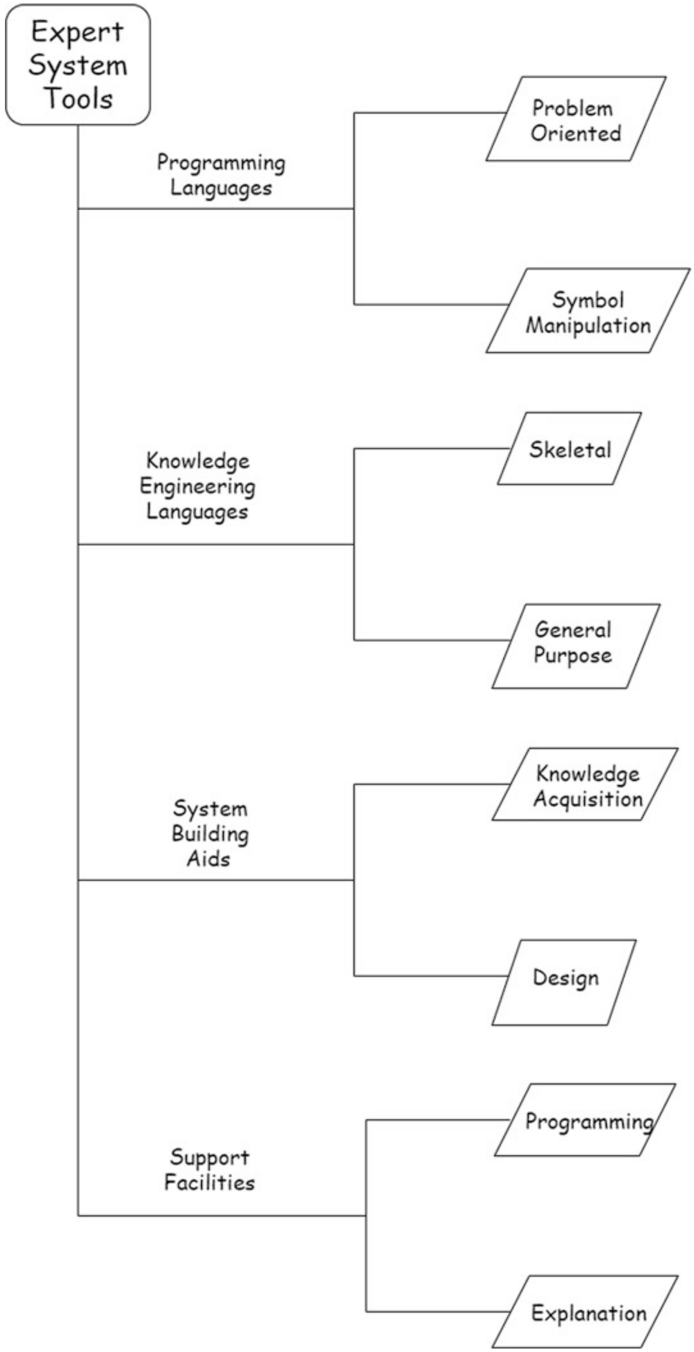


Fig. 20.8 Tools required for expert system

research that while we are performing the experiment on patients suffering with diabetes, we have performed yagya in all its three Sessions i.e., Pre-Yagya Therapy Session, Main-Yagya Therapy Session, and Post-Yagya Therapy Session in a close environment. In Pre-Yagya Therapy Session, all requisites of therapy like CHS and SHS, Utensils, Flowers, etc. are prepared. In Main-Yagya Therapy Session, yagya is performed with some Vedic mantras with Ahutis of Cow ghee and mixture of CHS and SHS in 2:1. In Post-Yagya Therapy, Patients are advised to do meditation, breathing exercises, and yogasan in the same close environment in order to inhale the fumes of the yagya. Then the patients are advised to perform this daily at their homes and have also prescribed with healthy diet pattern and they are also advised not to take any processed meal, potatoes, packed juices etc. During this analysis, the Body weight, Fasting Blood Glucose Level (FBS), Post Prandial Glucose Level (PPBS), HbAlc Level, and their overall general health assessment are recorded periodically [21].

20.5.3 Parameters and Factors under Study

Pt. SHRIRAM SHARMA ACHARYA experimented in his research hematological parameters like Hb, TRBC, Platelets, RBC delicacy, and so forth. Biological modifications like those in the degrees of blood urea, creatinine, sugar, SGPT, cholesterol, SGOT, and so forth are assessed. Moreover, the immunological alterations close to the stages of neutralization and inherent non-susceptibility of specific pathogenic guilty living beings is studied. Yajnopathy helps drug addicts to regain their hankering for drugs while Yajnopathy evacuates negative thoughts of stereotyping and through adoration and empathy persuades them for constructive strategy. All restorative psycho developments have ignored a daily junkie's command. Yajnopathy is another expectation in this field [13].

20.6 Results and Discussions

20.6.1 Results, Interpretation, and Analysis on Healthcare Experiments

Yagyopathy Shivir was conducted in Navchetna vistar Kendra Durgapura, Yagyopathy Research Centre, 43 Srijinagar, Durgapura, Jaipur, Rajasthan 302,018, nckdurgapura@gmail.com, in May 2019 and following results were found for different experiments on different subjects suffering with various physical problems.

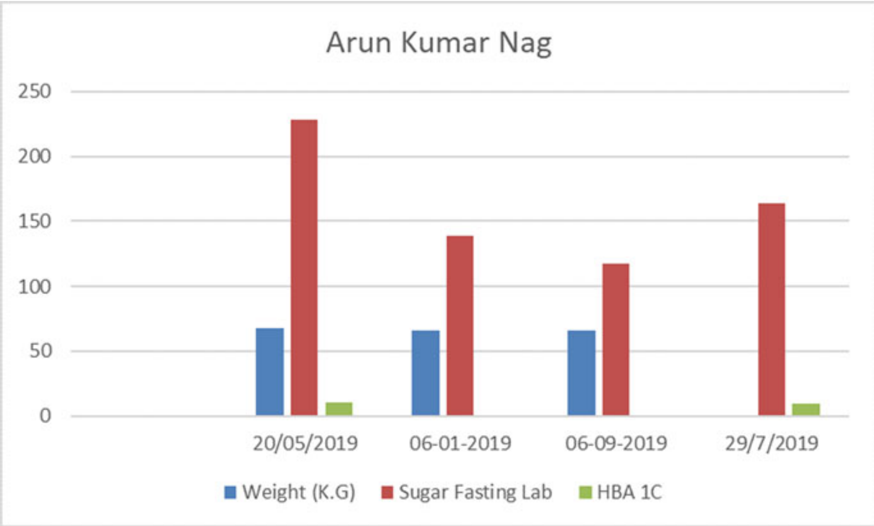


Fig. 20.9 Graphical presentation of details of individual subject obtained from Yagyopathy Camps in 2018 and 2019

20.6.2 Asthma-Related Experiments

Asthma/Allergy-Patient Description—Symptoms were checked on day 1, and after 10, 30, and 60 days.

Data were recorded under date, weight, B.P., other records, limb dysfunction/extreme tiredness or weakness, inhaling problem while lying, unable to breathe deeply, sneezing, cold, restlessness, breathlessness, and other issues.

20.6.2.1 Case Study 1 (as per Fig. 20.9)

Patient Name-Mr. Arun Kr. Nag

Address-52, Soorya Nagar, Taro ki Koot

DOB-08-01-1952

Problem-Diabetes, Type-2 since 12 years

Experimental Results

Date	Weight (kg)	Time	BP/pulse	Sugar fasting		Sugar PP		HBA 1C
				Lab	Glucometer	Lab	Glucometer	
20/05/2019	67.4	M	136/82/82	228				10.1
06-01-19	66.00			138.8				
06-09-19					117			

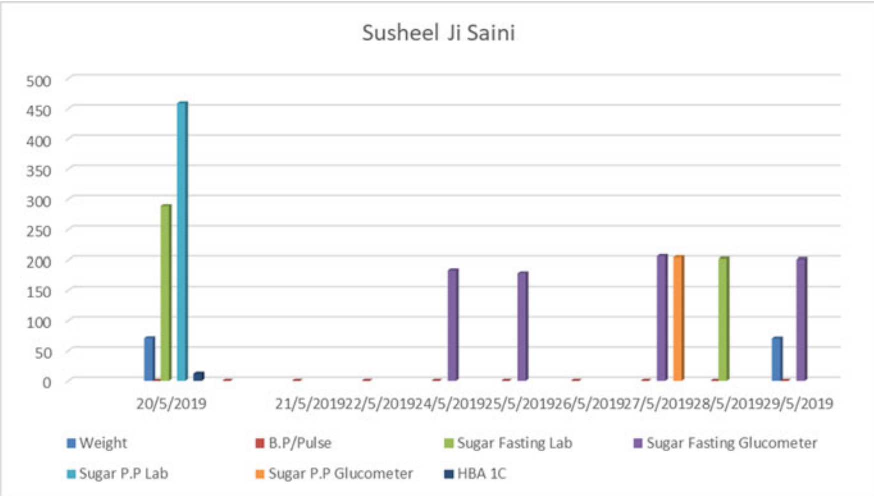


Fig. 20.10 Graphical Presentation of Details of individual Subject obtained from Yagyopathy Camps in 2018 and 2019

20.6.2.2 Case Study 2 (as per Fig. 20.10)

Patient Name-Susheela ji Soni
Address-Prathviraj Nagar, Maharani Farm
DOB-13/5/1963
Problem-Diabetes from 6 years, so pain in knees, Depression
Experimental Results

				Sugar fasting		Sugar PP		
Date	Weight	Time	BP/pulse	Lab	Glucometer	Lab	Glucometer	HBA 1C
20/5/2019	70.6	M	130/76/80	288.5		458.6		11.9
		E	123/75/85					
21/5/2019			146/86/84					
22/5/2019			124/75/99					
24/5/2019			119/72/87		183			
25/5/2019			130/79/89		178			
26/5/2019			128/78/94					
27/5/2019			113/73/88		206		204	
28/5/2019			120/75/87	202				
29/5/2019	70.10		123/78/83		201			

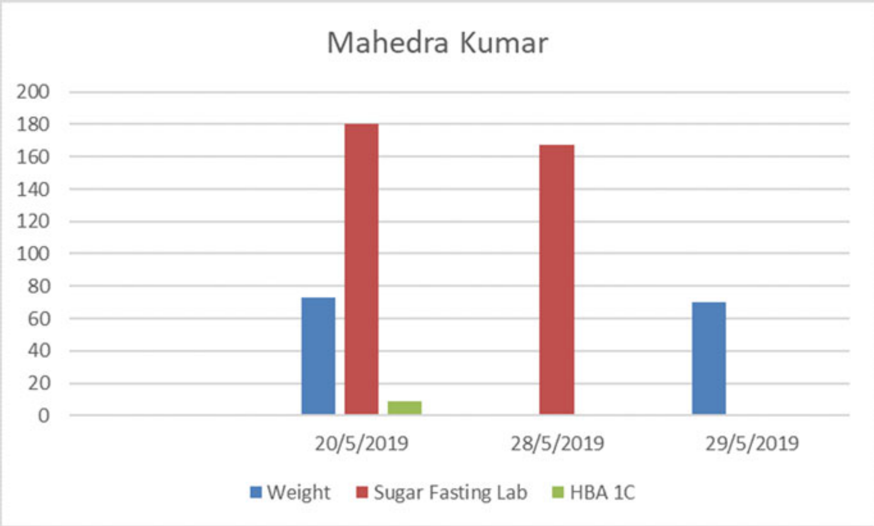


Fig. 20.11 Graphical presentation of details of individual subject obtained from Yagyopathy Camps in 2018 and 2019

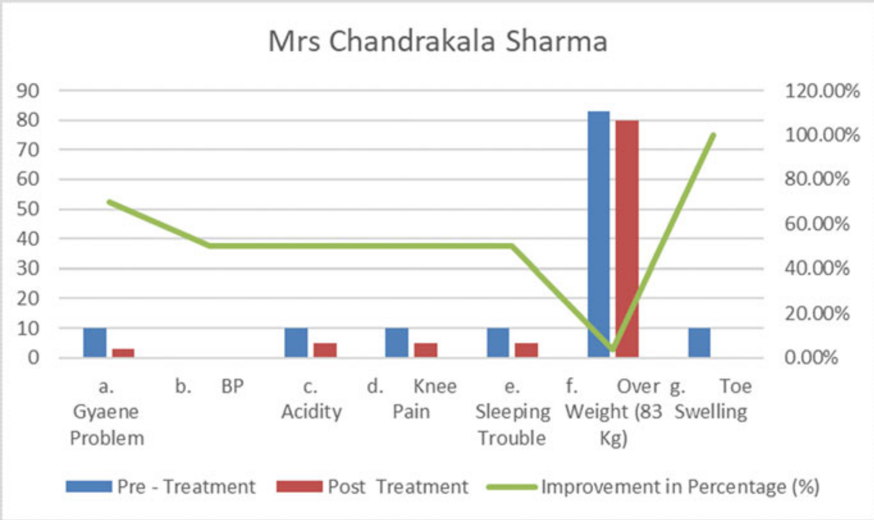
20.6.2.3 Case Study 3 (as per Fig. 20.11)

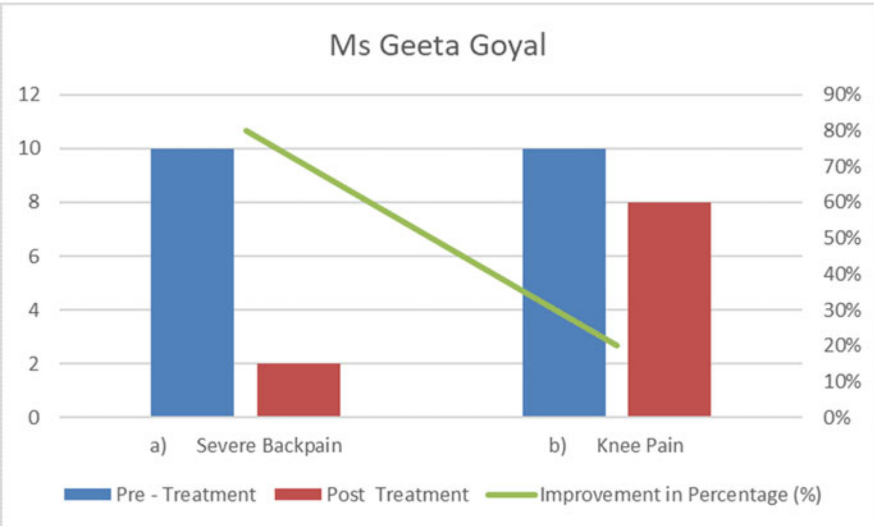
Patient Name-Mr. Mahendra Kumar
Address-31 A Ashok Vihar, Mansarovar
DOB-27-05-1977
Problem-Diabetes from 2 to 3 years
Experimental Results

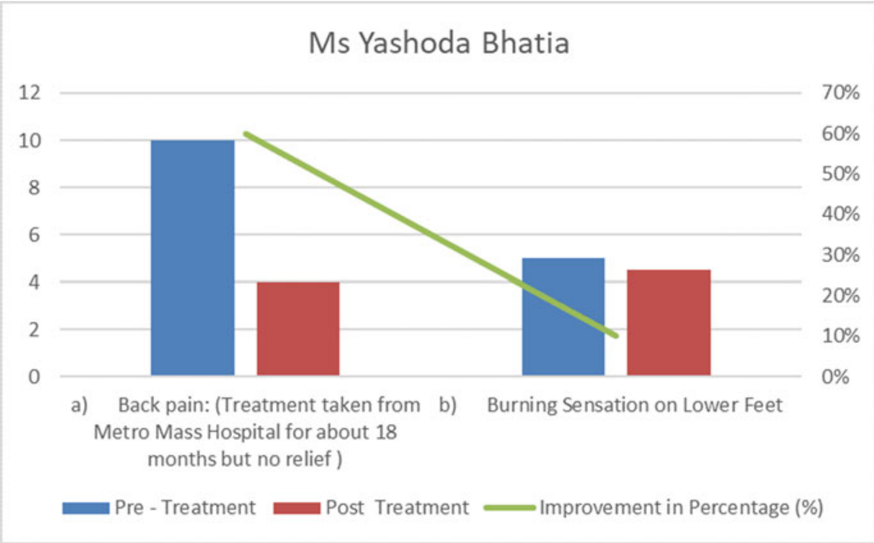
Date	Weight	Time	BP/pulse	Sugar fasting		Sugar PP		HBA 1C
				Lab	Glucometer	Lab	Glucometer	
20/5/2019	73		137/87/90	180.3				9.2
28/5/2019			111/69/83	167				
29/5/2019	70		105/72/96					

20.6.2.4 Case Study 4 (as per Fig. 20.12a–d)

YAGYOPATHY SHIVIR 3: Joints Pain
DURATION: 20–29 MAY 2019 (10 Days).
Experimental Results







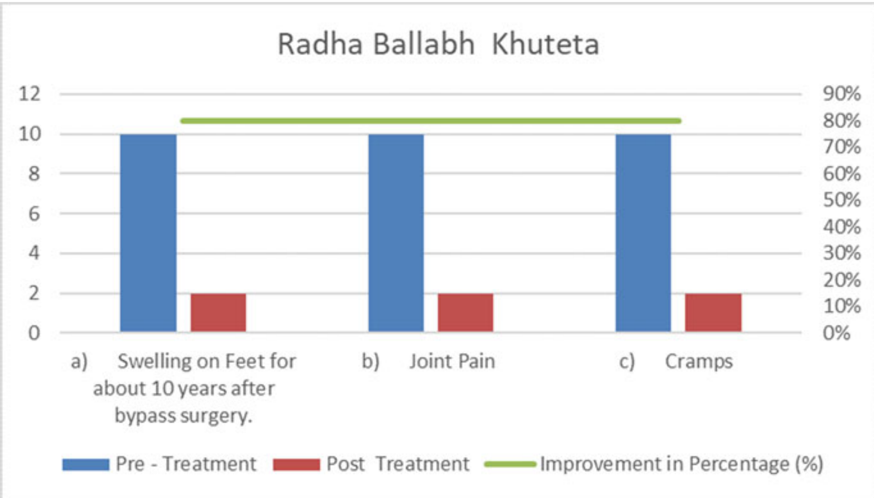


Fig. 20.12 Graphical Presentation of Details of individual Subject obtained from Yagyopathy Camps in 2018 and 2019

Name of patient	Age	Disease/problem particulars	Pretreatment	Post treatment	Improvement in percentage (%)
Mrs Chandrakala Sharma	71 years	(a) Gynaec problem	10	3	(a) 70%
		(b) BP			(b) 50%
		(c) Acidity	10	5	(c) 50%
		(d) Knee pain	10	5	(d) 50%
		(e) Sleeping trouble	10	5	(e) 50%
		(f) Over weight (83 kg)	83 kg	80 kg	(f) 80 kg (−3 kg)
		(g) Toe swelling	10	0	(g) 100% relief
Geeta Goyal	59 years	(a) Severe backpain (long treatment taken at EHCC hospital, Narayana hospital and Fortis hospital but no relief)	10	2	(a) During the camp, patient got relief of 80% in back pain (b) Relief by 20% in knee pain
		(b) Knee pain	10	8	
Yashoda Bhatia	64 years	(a) Back pain: (treatment taken from Metro Mass Hospital for about 18 months but no relief)	10	4	(a) 60% relief in backpain
		(b) Burning sensation on lower feet	5	4.5	(b) 10% relief in burning sensation on lower feet

Name of patient	Age	Disease/problem particulars	Pretreatment	Post treatment	Improvement in percentage (%)
Radha Ballabh Khuteta	75 years	(a) Swelling on feet for about 10 years after bypass surgery	10	2	(a) 80% relief in swelling
		(b) Joint pain	10	2	(b) 80% relief in joint pain
		(c) Cramps	10	2	(c) 80% relief in cramps
Panna lal Soni	64 years	(a) Problem in deep breathing (heart problem underwent three heart attacks)	10	5	(a) Now very much comfortable in deep breathing
		(b) Heart efficiency 25%			(b) Feeling 80% relief and energetic

Note: Grading 10 being worst and 0 being best or absence of Problem

20.6.2.5 Case Study 5 (as per Fig. 20.13)

Chetna Kendra Noida Evaluation Done On 11th May 2019

S. no.	Name of patients	Gender/ weight	Fasting blood sugar		FBST prandial blood sugar		Improvement in other symptoms
			BT	AT	BT	AT	
1	Mr. Anil Mishra	M/68 years	200	88	400–450	261	Improvements in all sections
2	Smt. Geeta Mishra	F/56 years	300	183	400	272	Improvement in knee pain and body weight
3	Shri J.P.N. Upadhaya	M/60 years	180	117.5	220	259	Positive thoughts have increased
4	Mrs. Shakumbals gupta	F/53 years	RBS-160	112.3	RBS-160	102.3	Improvement in energy level
5	Mr. O.P. Yadav	M/44 years	RBS-136	128	RBS-136	210	Improvement in chronic constipation

S. no.	Name of patients	Gender/ weight	Fasting blood sugar		FBST prandial blood sugar		Improvement in other symptoms
			BT	AT	BT	AT	
6	Mrs. Pramila Saxena	F/69 years	100	136	166	220	Improvement in blood sugar
7	Mr. D.D. Gupta	F/44 years	RBS-155	151	RBS-155	219	Improvement in body weight from 93kgs to 88.2
8	Smt. Anandi Devi	F/56 years	RBS-213	137.6	RBS-213	325.4	
9	Smt. Renu Bala Singh	F/38 years	RBS-324	213.7	RBS-324	275.4	Improvement in body weight from 65.3to 64.1
10	Smt. Neelam	F/70 years	RBS-154	106	RBS-154	125	Positive thinking has increased
11	Shri. Kedarnath Ji	M	RBS-135	117	RBS-135	127	160/85–130/75

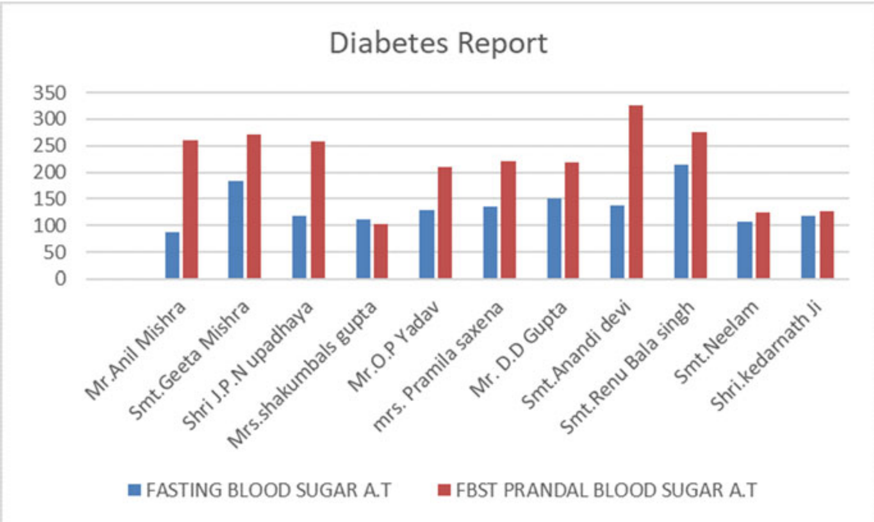


Fig. 20.13 Graphical Presentation of Details of individual Subject obtained from Yagyopathy Camps in 2018 and 2019

20.7 Novelty in Our Work

The yagya and Mantra therapy is a completely different form of treatment from those which we have today. The treatment method today involves eating up of medicines, which are made from different chemicals and in some cases have found to have ill-effects in our body if taken for a long period. Some methods of treatment prevalent today are based on injecting some medicines in the body of the patient by means of injection or other pins. The homeopathy method of treatment also requires eating of chemicals though they are given in mix with sugar balls. This method of treatment is slow and requires long time to cure a patient. Also the disease first rises to its maximum level and then start to cure in this method of treatment. The ayurvedic method of treatment, which has roots in ancient Indian heritage, is also a popular method of treatment especially in villages and now is also becoming popular in cities. But this method also requires eating of spices and other useful and healthy natural products. These products are mostly bitter and therefore patients don't prefer the ayurvedic Method. The "Yagya and Mantra therapy" is a completely different method of treatment.

20.8 Recommendations

Two persons of importance were lost to complications of diabetes. Similar was the story of Smt Sushma Swaraj with diabetes, renal failure, transplant, and myocardial infarction.

Water dilutes the energy of that high pressure and makes it tolerable for humans. After sacrificing it again, in the hands of fire, the disgusting mantra is again re-invoked and the soul is mixed with the flow of hands and then it is broken again by fire and then sniffed quickly.

Due to which that subtle energy gets mixed in the breath and then reaches the lungs from there and reaches the whole body and makes the iron particles of the blood wave and emit energy. This communicates a type of current.

If you will see this water with a krillion photo camera, then you will be able to notice easy light rays.

There are two reasons behind not recommending drinking this water directly:

All human beings presently are not capable enough to digest high-energy matter. If that person is not of the seeker level then you will not be able to handle this power. Now it is a very difficult task to check the status of the former seeker. Therefore, it is best that the method of mixing it in natural life should be taken with olfaction.

20.9 Future Scope, Limitations, and Applications of Yagya and Mantra Therapy

20.9.1 Future Scope

Yagya (agni-Yagya) is not only a great process for cleansing the environment, but also as a powerful medicine against various physical and mental illnesses and mental disorders, used with the right choice of wood and mortar You can also. Proper selection of mantras and modes, timing, etc., promise a good health program. Vascular disorders are widely used to treat mental disorders and psychological problems, apart from dramatic physical and medical uses such as environmental cleanup, treatment of bodily illness, and improvement of vitality and physical ability.

The range of mental illness is invisible, but much wider and more serious than any physical illness. Almost the whole human society suffers from these forms in some way. More than 90% of the causes of physical illness are also at the hidden edge of the patient's heart. Confusion, hallucinations, fear, suspicion, anger, excitement, and strange attitudes are common mental disorders that are common to most of us.

If left unchecked increases stability and silence and makes another person normal or semi-crazy. Depression, insomnia, and a variety of psychologically confusing and painful things are more painful than physical pain. Accidie, Abulia, Forgetfulness, Dullness, Inefficiency, etc. are other types of mental illnesses that lead to suffering such as poverty, backwards, insults, negligence, and insults.

Important sublimated elements and herbal medicines inhaled in Yagya first reach the brain, then reach the lungs and other parts. Therefore, it has the effect of directly healing diseases and complexities born from the brain. The body absorbs the heat of the sacrificial fire and breathes the vapors of the sublimated herbs through the skin pores and breathing. This increases the level of free radicals—when it reaches antioxidants, negative ions, and the brain and nerves, it removes the main cause of mental tension.

Specific energy flows with goby sharks and precise mantras range from headache, migraine, cold to mental movement pit, intellectual disability, depression, insomnia, intolerance, epilepsy, schizophrenia, and various illnesses until then, there are important therapeutic effects on various disorders and diseases.

These experiments were conducted with Central Pollution Control Committee (CPCB).

Aromatherapy: Aromatherapy is a complete treatment using natural herbal extracts to enhance health and well-being; sometimes called essential oil therapy.

Homatherapy: Homa is a Sanskrit word that is used as a synonym for Yajunya. Yajunya is the technical term for Vedic Science and Biosciences and refers to the process of removing harmful atmospheric conditions through the Fire Department.

20.9.2 Limitations

We used the following instrument during our research work: Aurameter, Human energy meter, Chakra energy meter, Consciousness, Happiness Index and Spiritual Index Checker were very costly and highly time taking accuracy.

This study should be done with a large sample size and randomized controlled design using some strong tool.

After havan there is a jump of another 4000–8000 Bovis. But after drinking Ghritavghranam, the energy is increased instantly by at least 30,000 Bovis which is stupendous.

The energy in tap water is 13,000 Bovis, fresh fruits is around 13,000–20,000 Bovis, most of the bakery products it is negative. Cooked and refrigerated vegetables when fresh range between 8000 and 11,000 but it is said if two days old they have negative energy.

Energy in hot milk tea was found to be extremely negative.

Energy in my house in my bedroom where Prof. Rohit Rastogi et al., do daily havan, used to be 24,000 Bovis and after Chandrayaan, it is between 28,000 and 31,000 Bovis.

Energy in water kept in havan, is 18,000 after havan and in Ghritavghranam is very high. Any guess how much it would be?.

20.9.3 Applications

It eliminates their vulgar instincts, satanic desires, weaknesses, and other mental weaknesses-erotic feelings, excitement, anger, jealousy, hatred, fear, anxiety, craving, tension, etc., and calms your mind. Along with this sophistication, there is a compensatory physical energy that lifts and shapes the spiritual body, develops a distinct personality, and stimulates hidden talent and radiance.

Therefore, Yagyopathy is done using Sadakas and seems to provide yatis an elixir experience for health.

This pilot study suggests that Gayatri mantra recitation and Om recitation is effective yoga-based mantra to improve selective attention in diabetic patient immediately after practice. Results obtained after undertaking yagyopathy treatment once a day for approximately 2 1/2 months indicated considerable improvement in lung function parameters.

Results can be further improved with increasing treatment doses to twice a day.

Gurudev Pt. Shriram Sharma Acharya, the spiritual scientist and rishi of our times, had pioneered reinvestigating this lost science in the modern laboratories.

He named this world-famous Yagia-based health treatment “yagyopathy” and established a specialized laboratory at the Forensic Center of Haridwar Research Center in Chanticuni.

20.10 Conclusion

Deep Yagya has a surprisingly practical application, minimal ritual ease of use, and stimulating influences, and Yagya training has a huge impact on the areas of subtle thoughts and emotions.

Yagya-fire is a scientific way of using matter for energy and spreading its potential and positive effects on the surrounding atmosphere.

The impact on Mantra Shakti's unparalleled empathy is important. The special syntactic syntax of the Mantra and Vedic paradigm stems from deeper research (by Rishi) on the sounds of gross and subliminal sounds, music and deeper knowledge of consciousness.

A stunning blend of precise mantras, yoga energy, and great Yajaka's self-determination in the Yagya process creates a wonderful furnace. This evil melts the evil and evaporates it.

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Chapter 21
The Interoperability of Fog and IoT in Healthcare Domain: Architecture, Application, and Challenges

Karandeep Kaur and Harsh Kumar Verma

21.1 Introduction

The great technological advances and expeditious growth in the physical objects being added to the Internet continuously have become the reason for the emergence of the term "Internet of Things" (IoT). IoT has connected the two different worlds, i.e., real and virtual worlds together in a single environment. This integration of the two worlds is made possible by using physical objects, intelligent sensors, gateways, routers, actuators, and Radio Frequency Identification Tags (RFID) attached in objects. IoT is having a great impact on different aspects of day-to-day life. The effects of IoT will be visible in all the fields around us either commercial or domestic fields. According to CISCO, by 2020 the intelligent devices on the Internet will exceed up to 50 billion.

On browsing the Internet, many definitions of the Internet of Things (IoT) have been traced. So this shows that there is a great interest in the research community in IoT issues. As discussed by the National Institute of Standards and Technology (NIST), IoT is a concept that has storage, computational, processing, data sensing, and networking facilities and has important components due to which it can interact with the physical world. As new "Things" are continuously being connected to the Internet at greater speed, a big new system is being generated. This huge system of networks needs to be maintained, properly processed, more computation facilities, storage capacities, privacy, and security facilities are required. For such an increasing demand for storage and processing, external resources are required to meet the requirements. However, these external resources may not be geographically always available where and when required. Here the cloud computing can be used

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to meet the requirements. Nevertheless, unfortunately, the design and infrastructure specifications, low-latency requirements, and real-time analytics make the cloud computing infeasible for many applications. Here fog computing plays an important role in fulfilling these requirements, which cannot be made by the cloud. Fog computing provides a decentralized approach to process and computes the data, by using various fog nodes that are distributed geographically, unlike the cloud. The concept of everlasting increase in devices in the IoT networks is also handled by fog computing. It handles all the managing, computing, and storage tasks very smartly with very less processing time, lesser delays, quick, and efficient responses. According to the application, integration of fog computing with the cloud computing can be more beneficial to provide long-time reliable services. Fog computing did not purely replace the cloud computing but can be preferred where traditional services and functionalities of the cloud are not sufficient. These two technologies can work in hand in hand taking advantage of each other. As only intelligent combinations of computation, storage, resources, and communications can be handled to the requirements of IoT.

21.1.1 Motivation and Contribution

Many application domains use the advantageous features of fog computing and IoT. The real motivation of using fog computing in healthcare is it reduces the number of delays, long processing times, increases the efficiency and reliability of the system by producing quick responses by making quick decisions. It involves edge devices to preprocess and filter the data before it reaches to the cloud pretending as the middleman between the cloud and end user. Due to which the utilization of resources can be very appropriately be performed by fog making it a perfect solution for real-time monitoring. Using fog in real-time systems especially healthcare, privacy, and security issues are also solved. All of the patients involved in these automated healthcare systems are those who might obviously don't want their information or medical status or their condition to be distributed or tampered by third person or party involved. Thus, using fog computing also helps to maintain their private information regarding their health and continuous surveillance by cameras at their own places or even at hospitals. Along with advantageous features like privacy, security, lesser delays, quick responses, distributed data, and many more features are also available.

This chapter provided an overview of IoT and fog computing. A clear understanding of the architecture of IoT and fog is provided. Along with that, light is thrown to applications of both IoT and fog. This chapter discusses how IoT and fog can be used in healthcare and what importance they have in healthcare, which is a major contribution to this chapter. Further challenges and future scope of fog are also discussed providing a clear idea to researchers of problems faced by fog environment, which need to be handled.

The rest of the chapter is described as follows. Section 21.2 covers the survey of researches in the field of IoT, the cloud, healthcare, and fog. Section 21.3 describes the architecture and applications of IoT. Section 21.4 covers the architecture and applications of fog computing. Section 21.5 discusses the concept of IoT in healthcare. Section 21.6 describes the concept of fog computing in healthcare. Section 21.7 discusses the integration of IoT and fog computing in the area of healthcare and further Sect. 21.8 concludes the paper and discusses future trends.

21.2 Literature Survey

Over the last decade, a lot of research is dedicated to the healthcare sector. Out of all those, some of the contributions have been described below.

Baker et al. [1] proposed a model of smart healthcare using IoT. Here the authors presented all the research areas related to healthcare and along with that strengths and weaknesses are evaluated. The proposed model is evaluated for its suitability for IoT healthcare systems including wearable sensors. The proposed model can be used as a general model for healthcare systems. The model presented here can monitor chronic conditions like hypertension. Data collected from all the sensors used by patients, either wearable or sensors in smartphones, are passed to the base station to process the data for an emergency. In case of any emergency, an alert is created and passed to concerned authorities like specialists, doctors, or family members. The collected data is then passed to the cloud where storage is provided. Cloud provides secure and permanent storage, machine learning techniques, preprocessing, and classification.

Ahmad et al. [2] designed a framework named "health fog," where he implemented fog computing in the healthcare system to provide a healthy lifestyle. The cloud and users at the end have fog computing treated as an intermediate layer between them. The concept of health fog is introduced to reduce extra communication cost. To increase data privacy and security within the system "The cloud Access Security Broker (CASB)" is designed. This health fog framework can collect data from multiple sources and then provide a proper level of security and privacy techniques to make it more secure than only using the cloud [47]. Here, three levels of architecture are presented where system entities are presented as the first layer, fog computing as a second layer, and end users at the top layer. All the data collection, preprocessing, and CASB are provided at the fog layer [45, 46].

Gope et al. [3] proposed a healthcare system using a body sensor network (BSN) based on IoT highlighting security as the author believed that it is the most crucial part of any system. All of the security requirements like data privacy, integrity, authentication, and secure localization for IoT-based healthcare systems are discussed. A secure model discussing all its subparts (subsection) is proposed. Different biosensors like Electrocardiogram (ECG), Electromyography (EMG), Electroencephalogram (EEG), and Blood Pressure (BP) are carried by the patient. In case of emergency, Local Processing Unit (LPU) generates alerts, which are sent to Body Sensor Network (BSN) care servers, concerned people, and local physician according to health status. The authors proposed authentication protocols to be used in the BSN care system, for implementing security. Along with that performance, analysis is done with the existing healthcare system.

Cahya et al. [4] proposed an architecture to monitor heart rate (HR) of a person by wearable devices (or sensors) especially for patients traveling in an ambulance. After measuring the data from wearable devices like HR and interbeat intervals, it is then transmitted using access points to a centralized data processor using communication networks. Here heartbeat and BP sensor are present on smartwatch Samsung gear S3 (a wearable device) and the Structured Query Language (My SQL5) database is used to store data created by sensors. A heart attack detection algorithm is suggested to be made in the future by using medical data.

Kaplan et al. [5] presented different fatigue detection techniques in driver based on visual features like eye blinking, yawning, facial expression and nonvisual features like wearable sensors (physiological parameters), vehicle parameters, etc. A smartphone system design is also presented describing the whole working of the driver safety system. Here data is collected by using several sensors and in case of emergency, alerts in terms of call or messages are sent to alert the driver. It also describes the dissemination of information for driver's behavior, which uses intelligent transport systems.

Jeong et al. [6] proposed a vehicle-based healthcare service model by imploying implantable devices. This model provides healthcare services to patients inside the vehicle, which is having IoT devices installed in them. This model is especially for emergency situations where the patient suffers from any sudden healthcare situation and is not able to address its situation. The health of the patient is passed to a healthcare service model for immediate first aid services. The proposed model has higher communication strength, higher network efficiency, and lesser overhead in IoT devices.

Javier et al. [7] developed an approach for drowsiness detection systems. This system combines data from two sources i.e., data coming from the inertial measurement unit (IMU) sensor and data from the EEG electrode. This system is capable of classifying drowsiness into five classes. After the classification, the system was tested on a low-powered platform based on programming. Results show that the architecture proposed provides high-energy improvements.

Gangli et al. [8] designed and implemented a driver drowsiness detection system known as "Brain–Machine Interface system (BMI)." Here EEG and head movement based on gyroscope is used to performing detection of drowsiness. For early detection and management of drowsiness, Transcranial Direct Current Stimulation (TDCS) is used along with EEG. Bluetooth is installed inside this BMI system, which communicates with wearable devices and smartwatch. TDCS generates a minimal amount of current after some intervals to alert drivers while driving. Support Vector Machine (SVM) is used for classification.

Chowdhury et al. [9] discussed the various novel and effective methods to identify drowsiness among drivers. These include three methods known as vehicles based, behavioral based, and physiological based. Further physiological signals are mainly focused on areas of drowsiness detection among drivers. All of the approaches under the category of drowsiness detection of physiological signals are discussed, along with their advantages and limitations.

Choi et al. [10] proposed a wearable device-based system that monitors stress, fatigue, and drowsiness of a driver. In this system, motion and physiological information regarding the state of the driver is used. As the signals collected from wearable devices contain noises due to which preprocessing techniques are applied to distinguish valid signals. Further, SVM is applied for classification. Based on this classification, threes states i.e., normal, stressed, fatigued (drowsy state) are discussed. Authors remarked that using the wearable sensors (or devices) makes detection of drowsy states easier.

Abdi et al. [11] proposed a driver information system, combining deep learning and Vehicular Adhoc Network, together to provide traffic safety. Here deep learning-based detection approaches are presented which is used to identify and recognize road obstacles and complex traffic situations. New AR-HUD (Augmented Reality Head-Up Displays) are used to create real-time interactive animations.

Sun et al. [12] proposed the concept of the collaboration of smart wearables and intelligent vehicles (Smart WeVe). Along with the development of the Smart WeVe model, its characteristics and challenges are also discussed. Communication architecture is proposed for WeVe which is using a hub for communication. The author discussed various challenges for the integration in which requirements for the communication systems, mobility of human beings and vehicles, and proper communication technology are ahead among all. The model proposed has a hub placed in between the internal and external WeVe environments. The wearable sensors and information dissemination can be connected to each other through a common interface. This chapter also presents various different application scenarios that can be raised in the domain of integration of wearables and vehicles. Along with that, many challenges are discussed.

Ahmad et al. [13] proposed architecture for Vehicular Cloud Network (VCN). In VCN, vehicles, and infrastructure in region (range) are merged with the clouds that are traditionally available so as to form the different range of applications. The VCN proposed has three levels depicted as Vehicular Cloud (VC), Infrastructure Cloud (IC), and Back End Cloud (BEC). VC has different resources like storage, computation, and vehicles, which are shared among different vehicles. Vehicle to Vehicle (V2V) communication is performed in this layer. IC has Road Side Units (RSU). Vehicles send their requests for services to RSU. After all this, BEC is finally the largest cloud that existed traditionally in the vehicular environment. A large number of resources and services are provided by this cloud so that vehicles can store their data and can perform computations. Along with the architecture, various applications and threats in vehicular cloud networking are discussed.

Oliver et al. [14] presented a real-time monitoring system having wearable sensors. The system constantly measures SpO2 (blood oxygen level), HR, and physiological signals. After the data gathering, analysis of data is done. Proper implementation of this health gear system is performed using a SpO2 to monitor pulse and oxygen levels. Two different algorithms are also described and evaluated to detect the event of sleep apnea [60].

Jin et al. [15] proposed medicine technology for the detection and prevention of cardiovascular diseases (CVD). This technology is able to monitor and record ECG signals and generating a summary report on cardiac health due to which abnormalities are detected and classified in one place. Along with that Artificial Neural Network (ANN), the technique is proposed. This classifying technique can combine all information regarding the medical status and ECG, to learn about the physiological condition of the user. Smartphones used in the system are properly trained to adapt the user's medical status so that CVD classification results are achieved accurately and along with this better ECG feature extraction is performed.

Leijdekkeres et al. [16] proposed an application for self-testing heart attack for smartphones. The person (or victim) without any intervention from medical practitioners can detect whether he is having chances of a heart attack or not. With the help of sensors i.e., ECG and mobile phones, the user's status is recorded which on further analysis detects heart attack. In case of emergency detected, emergency services are contacted automatically, the current location of user and ambulance services are provided.

Pandian et al. [17] developed a physiological monitoring system using wearable sensors, which is a washable T-shirt known as "smart vest." All of these wearable sensors attached to the T-shirt are connected to a central preprocessing unit so that all the physiological data is sent to the central unit for continuous monitoring. This system has a wearable T-shirt, which is comfortable to wear along with that data processing and remote monitoring can also be done with greater efficiency and ease. ECG, photoplethysmogram (PPG), body temperature, BP, HR, and galvanic skin responses are the physiological signals that are monitored. The signals are recorded and transmitted to the monitoring system and clinical validation of data is also presented (Table 21.1).

21.3 Architecture and Application of IoT

21.3.1 Architecture of Internet of Things

IEEE proposed a project directly related to IoT [19], which defines an architecture of IoT [20, 21], accelerates the growth of the IoT market, and increases transparency. The architecture proposed has three layers and defined as the application layer as topmost layer, networking and data communication layer as an intermediate layer, and sensing as the bottommost layer [22] as shown in Fig. 21.1.

- In the architecture, the sensing layer at the bottom of the architecture has all the hardware components like sensors, RFIDs [23], actuators, etc. This layer actually associates "Things to the Internet" [24].

Table 21.1 Comparative analysis of healthcare systems

S. no.	Author/year	Scope of the study	Signals measured/technologies used	Purpose of the study	Description
1.	Baker et al. 2017 [1]	IoT and healthcare	Pulse rate, respiratory rate, body temperature, BP, etc.	The generic model proposed for IoT healthcare systems	– Machine learning-enabled the cloud used for data processing – Short- and long-range communication technologies discussed – Wearable sensors discussed
2.	Ahmad et al. 2016 [2]	Health fog	Data collection interface to collect physiological information from the smart environment	Framework including fog in health applications	– Fog layer introduced within the cloud and end users – Reduce extra communication cost – Increases data privacy and security
3.	Gope et al. 2016 [3]	BSN care	ECG, EMG, BP	BSN based secure healthcare system	– Authentication protocols are proposed for BSN care system for implementing security
4.	Cahya et al. 2018 [4]	Wearables and vehicles	HR, interbeat intervals, and BP	HR-based monitoring system using wearable sensors	– Architecture to monitor HR by using wearable sensors
5.	Kaplan et al. 2015 [5]	Wearables and vehicular communication	Describes various visual and nonvisual techniques for driver fatigue	Safe driving by dissemination of driver behavior via car to car (C2C) communication	– A smartphone system design of driver safety system – Describes dissemination techniques for driver's behavior using intelligent transport systems
6.	Jeong et al. 2016 [6]	Vehicles and implantable devices	Implantable devices, heart rate sensors, smart shoes, smart band	Vehicle-based healthcare model	– For the emergency situations when patient is not able to address the situation – Higher communication strength, higher network efficiency, and lesser overhead in IoT devices

(continued)

Table 21.1 (continued)

S. no.	Author/year	Scope of the study	Signals measured/technologies used	Purpose of the study	Description
7.	Balandong et al. 2018 [18]	Sleep detection	EEG electrodes	Sleep detection system	– Review of measures used in the drowsiness detection system – Multiclass sleepiness classification techniques
8.	Kartsch et al. 2018 [7]	Sleep detection and wearables	EEG electrodes (alpha waves)	Drowsiness detection in wearable systems	– IMU sensor combined with EEG – Five different levels of drowsiness detected – High energy improvements
9.	Gangli et al. 2018 [8]	Sleep detection and wearables	EEG and TDCS	BMI for drowsiness detection	– BMI to perform sensing and processing tasks – TDCS used, managing drowsiness of driver at earlier stages – SVM automatically classifies the level of drowsiness
10.	Chowdhury et al. 2018 [9]	Sleep detection and wearables	Physiological signals focused	Discusses sensor and features to be used in drowsiness detection	– Three methods vehicles based, behavioral based and physiological based are explained with their advantages and limitations
11.	Choi et al. 2018 [10]	Sleep detection and wearables	PPG, GSR, body temperature and acceleration	Driver's stress, fatigue, and drowsiness detection system	– Three states i.e., normal, stressed, fatigued (drowsy state) – SVM is applied
12.	Abdi et al. 2017 [11]	Intelligent transportation systems	AR-HUD approach	Safe vehicle systems	AR-HUD approach creates real-time traffic animations
13.	Sun et al. 2017 [12]	Smart wearables, intelligent vehicles	ECG, smartwatch, motion sensors	Model smart WeVe	Hub-centric communication architecture is proposed

14.	Ahmad et al. 2015 [13]	VCN	VCN	VCN merges vehicles with the cloud	– Three levels of architecture are discussed i.e., VC, IC, and BEC – Various applications and threats in VCN are discussed
15.	Oliver et al. 2006 [14]	Wearables, sleep detection	Blood oxygen level and pulse	Real-time wearable sensor system for monitoring, visualizing, and analyzing physiologic signals	– Real-time system – Two different algorithms also described and evaluated to detect the event of sleep apnea
16.	Jin et al. 2009 [15]	Wearables, healthcare	ECG, heartbeat	Medicine technology for detection and prevention of cardiovascular diseases	– Detection and classification of abnormalities at one place – ANN artificial neural network technique – Smartphones used
17.	Leijdekkers et al. 2007 [16]	Physiological sensors, healthcare	ECG, BP, oximeter	Self-testing heart attack for smartphones application	– Ambulance services are contacted automatically in case of emergency – Current location determined
18.	Pandian et al. 2007 [17]	Wearable sensors, healthcare	ECG, PPG, temperature, BP, heart rate	Washable shirt wearable physiological monitoring system	Data processing and remote monitoring can be done with greater efficiency and ease

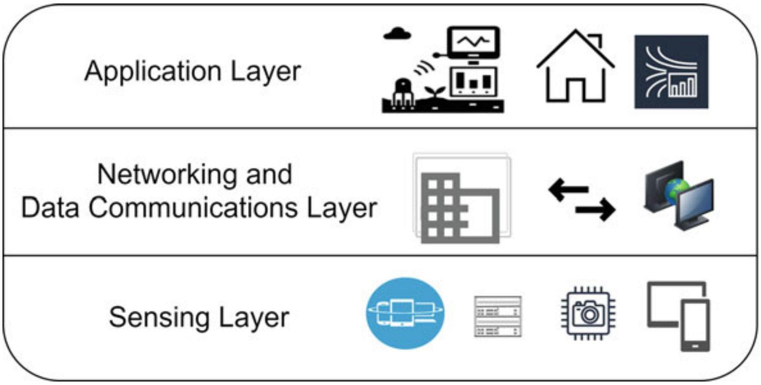

Fig. 21.1 Architecture of IoT

- The middle layer depicted as the networking and data communication layer provides all the networking functionalities like data transmission and detection of various routes for transmission, etc.
- The layer present at the top level is known as the application layer has various application domains contained in it like smart city, smart transportation, smart healthcare, etc.

This architecture is used as a common platform of IoT, which is based on technological changes and many kinds of researches proposed so far [25].

21.3.2 Applications of Internet of Things

Due to the high potentialities of IoT, it is being used in almost all domains [26] as presented in Fig. 21.2. These domains are remodeling the lives of a common man and are changing every environment like our homes, offices, vehicles, exercising areas, and many more [27, 28].

Many applications areas are discussed below:

- *People tracking*: To trace anything including human beings, animals, plants, etc., is easy by using RFID tags, which can be embedded in any of the IoT devices [29].
- *Smart surroundings*: Smart surroundings are those where data exchange with the surroundings is possible. Environment sensors and ambient sensors are used to monitor and transmit data to and from our surroundings. These sensors include ambient sensors, temperature sensors, oxygen sensors, humidity sensors, pressure sensors, etc. Smart cities, smart transportation, smart vehicles, smart agriculture, etc. are part of smart surroundings [30].

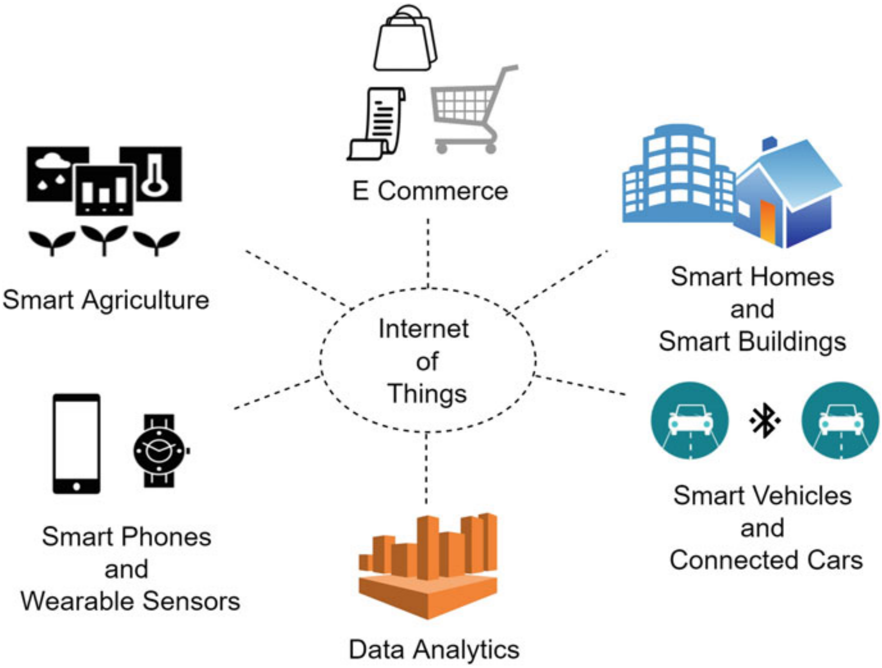

Fig. 21.2 Applications of IoT

- *Smart agriculture:* Smart agriculture involves automatic soil testing, automatic content measurement in soil and water level measurement, etc. Using IoT in agriculture helps to take decisions regarding seeds bowing, production rates, prevention of weeds, and many more [31].
- *Traffic monitoring*: Smart traffic monitoring is a major part of the smart city projects [32]. Traffic monitoring involves smart parking, smart toll systems, congestion control, and communication between vehicles [33, 67].
- *Smart healthcare*: Healthcare is a major research area of the Internet of things [44, 68–70]. Smart healthcare involves taking care of patients at hospitals or at homes on a continuous basis, which involves monitoring of infants, old ages citizens, and pregnant women. This can be achieved by acquiring different sensors like wearables and physiological sensors on the bodies or using smartphones, etc. that can provide continuous surveillance of patients present anywhere [34]. In case of emergency, concerned doctors and family members can be informed [35].

21.4 Architecture and Applications of FOG

21.4.1 Architecture of FOG

Fog computing architecture provides computations, storage, and communication using end devices (or fog nodes). The fog computing architecture has multiple layers as presented in Fig. 21.3. Each layer has its own functionalities and responsibilities.

The functionalities/tasks of each layer are described as

- *IoT sensor layer*

  The bottommost layer is the sensor layer. This layer comprises of all the physical sensors or "Things" used for various applications and is closer to the end users. These sensors are a source of data that is supplied to the application for further processing. They are distributed geographically at different locations and perform sensing tasks by sensing the environment around them and transmitting the observed values to the layers above for further processing and storage. Various IoT devices (or sensors), mobile phones, RFIDs, actuators and smart vehicles, etc. are part of this layer.

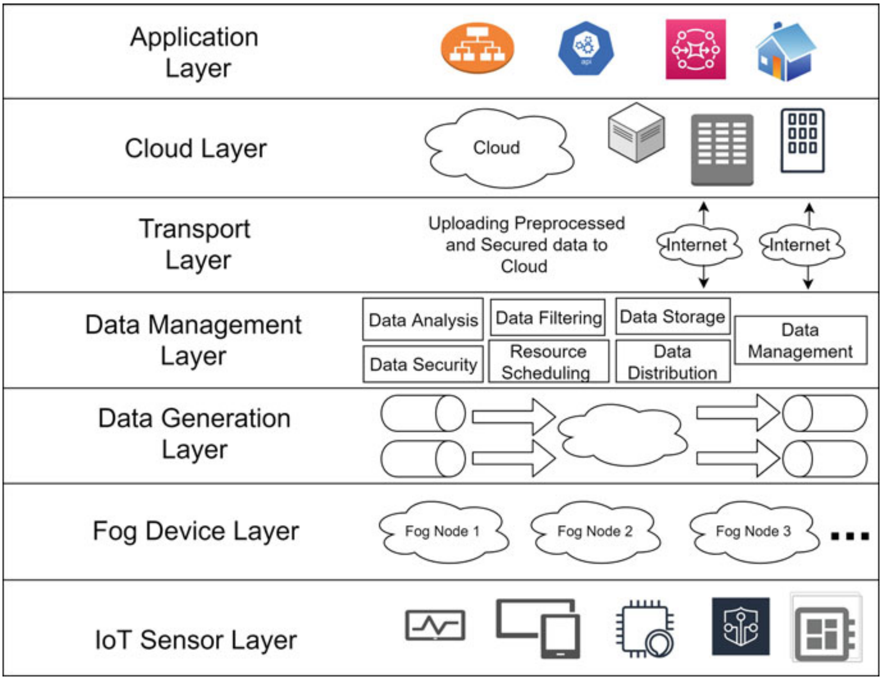

Fig. 21.3 Fog computing architecture

- *Fog layer*

  This layer has fog nodes required in fog computing like gateways, routers, switches, fog server stations, access points, base stations, etc. Gateways are the devices that connect the end users' sensors to the network. The edge nodes are present in between the sensors and the cloud and are very well distributed. The nature of these fog devices is either stationary or moving at some locations. The devices present at the sensor layer and the cloud layer can easily connect to these fog devices, which have computing, transmitting, and preprocessing; data storage is also provided at a temporary basis. Application based on low latency, real-time processing can perform their tasks efficiently with the help of this fog layer.
- *Data generation layer*

  This layer contains all the streams of data that are generated by IoT devices (or sensors). Data streams are actually sequences of values being generated by devices. These data streams can be raw data directly generated from devices and sensors or they can be processed data being generated from applications to gateways for further processing [48–52].
- *Data management layer*

  This layer provides management and preprocessing of data generated from sensors or end devices. This layer collects data from the IoT sensor layer and provides data analysis, filtering, data monitoring, data distribution, resource management, scheduling, security, privacy, and temporary storage facilities. After all preprocessing tasks, data is sent to the cloud and no longer stored at local servers, and then data is removed from servers as it is no longer required [53].
- *Transport layer*

  The transport layer is performed uploading the preprocessed and secured data to the cloud via the Internet, so that the cloud can provide more services [54, 56].
- *The cloud layer*

  All of the cloud computing services are provided in this layer. It includes high quality and high-performance servers along with storage facilities. The cloud has more strong computing and strong data processing techniques than fog computing. The tasks of complex computation, complex processing, permanent storage, on-demand services, etc., are provided by this layer [55].
- *Application layer*

  On the top, IoT applications layer is present comprising of various IoT applications like smart home, smart inventory, smart healthcare, e-commerce, smart building, smart agriculture and data analytics, etc., which uses facilities of fog and the cloud for performing their intended tasks. Fog computing supports all real-time applications and low-latency applications where the job has to be done efficiently and in lesser delays [57–59].

21.4.2 Applications of FOG

Fog supports real-time applications that require quick processing and quick responses with lesser delays. Fog computing can be applied in various application areas. Some of them are discussed below.

- *Healthcare*

  Healthcare is a field that is attracted by most researchers. It has also opted in the field of fog computing, health monitoring, emergency detection, and diagnosis of a critical problem are some works that are proposed by researchers. With the help of fog computing, the patient in problem can take care of his health on its own. Data collected from sensors are collected and processed by fog nodes. All of the computations regarding the detection of disease or monitoring of health are done with these fog nodes. Fog computing provides complete automation in the field of healthcare monitoring [68, 70]. Here the real-time processing is performed by fog, only metadata is stored and further sent to the cloud. Some of the research based on healthcare is done like fall detection where fall monitoring among patients after brain attack (stroke) is done. It is a fog-based system where analysis is done by splitting the task in all the fog nodes present, thus decreasing delays. Another work is also performed where daily activity monitoring is done which provided a smart home environment where intelligent sensing and monitoring of the patient's activity is done.
- *Smart and intelligent environments*

  Fog computing has become a very important part of smart and intelligent environments. Fog nodes are used to preprocess, handle, compute, analyze, and manage data used and generated in these environments. For example, in smart home environments devices manufactured from different vendors has to join together at one platform to perform common tasks. Fog computing is a medium that makes this integration possible. The tasks of low latency, computation, storage, and real-time processing are held and controlled by fog. If suppose lock monitoring is handled by fog computing and any wrong person tries to enter the home, these wrong attempts are monitored by the environment and which the owner of the house and police are reported immediately.
- *Fog and VANETS*

  Fog is being used by researchers in the field of vehicular adhoc networks (VANETS) in connected cars and autonomous vehicles. Here fog nodes are used as an intermediate to pass information or retrieve the information from or to vehicle. Smart traffic lights can also be a part of fog and VANETS. These lights detect the presence of cars, pedestrians, and even bikers. With the sensors, traffic light can also communicate with vehicles and send emergency signals if required. Connected cars and self-monitoring trains are also part of the intelligent transportation system.

- *Visual surveillance systems*

  Cameras present in public areas, buildings, parking lots, and at private premises, cover video surveillance of all these areas. So data generated from devices is sent to the cloud for processing; along with that privacy and security issues need to be resolved [61, 62]. Fog computing handles all of the data collection, performs real-time processing, and handles latency issues created.

21.5 IoT in Healthcare

IoT is widely accepted as a key to eliminating the problems of healthcare-based systems [1]. IoT has made many contributions in the healthcare sector like heart status monitoring, Parkinson disease detection, drowsiness detection, and detecting chronic diseases such as high blood pressures, diabetes, and rehabilitation after physical injury.

A model is presented in Fig. 21.4 [1]. The first part of the model collects data from various sensors to detect respiratory rate, pulse rate, and falls in the elderly, etc. After that data collected is passed to the central node and from the central node is then passed to the base station. This base station processes the data after all the preprocessing. Finally, in case of emergency, the processed information is passed to medical practitioners, specialists, nurses, and family members. These contributions of healthcare models have aided in monitoring the progress of patient's health by continuous monitoring.

To provide monitoring of patients continuously in the healthcare system wearable sensors can be a perfect solution. These wearable sensors can be worn by patients anytime and anywhere which helps to trace emergency situations. These wearable sensors can be used for detecting patterns in gait detection and tracking general activity levels. Along with wearable sensors, vision-based technologies (i.e., cameras) can be used to monitor the progress of patients suffering from the disease.

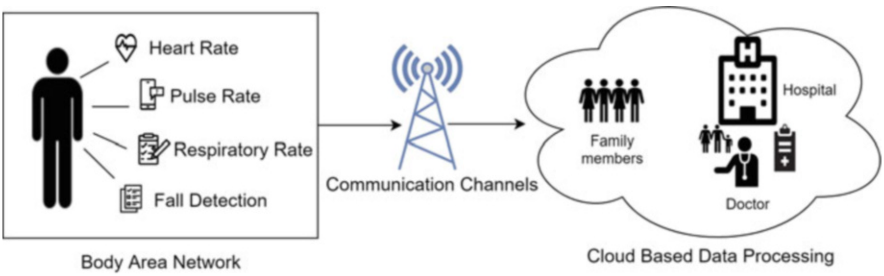

Fig. 21.4 The architecture of healthcare in IoT [23]

21.5.1 Wearable Sensors in Healthcare

Technological platforms are playing a major role in diagnosis and treatment [36]. Monitoring of patient's health is performed in many different ways; such as medical equipment used by doctors, huge machines like ECG machines, etc., or sensors like environment sensors, vision-based sensors, and wearable sensors. Out of all these, wearable sensor technology can be used in healthcare systems because of their small size, portability, ease of use, and efficiency [64]. Wearable sensors have not only become the part of the healthcare system but along with that they are widely used in various domains like

- Detection of neurological disorders like Parkinson's disease.
- Measuring parameters like pulse rate, HR, body temperature, ECG, EMG, EEG, SpO_2, PPG [37].
- Fall detection in elder people [38, 39].
- Dietary monitoring to take care of the dietary habits of the person [40].
- Activity monitoring to report all the abnormal activities performed by the person [41].

A central node (also referred to as a base node) receives the data from all the sensors and processes all this information to for decision-making, to figure out the health status of a patient [42]. In case of emergency detected, an alarm in the form of the warning message is sent to the base station so that immediate assistance can be provided to patients. Along with that, alerts are communicated to family members and caretakers whenever the patient needs assistance. This will help doctors, clinical personnel's to remotely monitor their patient and be alerted at the emergency situations to make a medical decision regarding their health.

Due to high technological advances in areas of the Internet of Things the trends of wearable sensors are also changing. Implantable devices have come into the market to reshape clinical workflow for the management of chronic diseases. Implantable devices can detect critical events with more accuracy as they are placed inside the body [43].

Along with the pros of wearable technology, it has many challenges to be taken care of before these systems can be used on a large scale. Technology barriers like security and privacy should be considered and resolved.

21.6 FOG in Healthcare

Healthcare in fog comprises the services of all IoT, fog computing, and the cloud computing as one unit [65]. The healthcare sector using fog integrates almost all sectors like logistics, insurance, hospitals, pharmaceuticals, and pharmacy in one place as described in Fig. 21.5. All of these can work hand in hand [66].

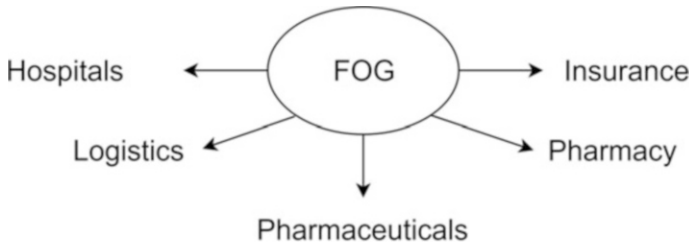

Fig. 21.5 Fog integration with all health sectors

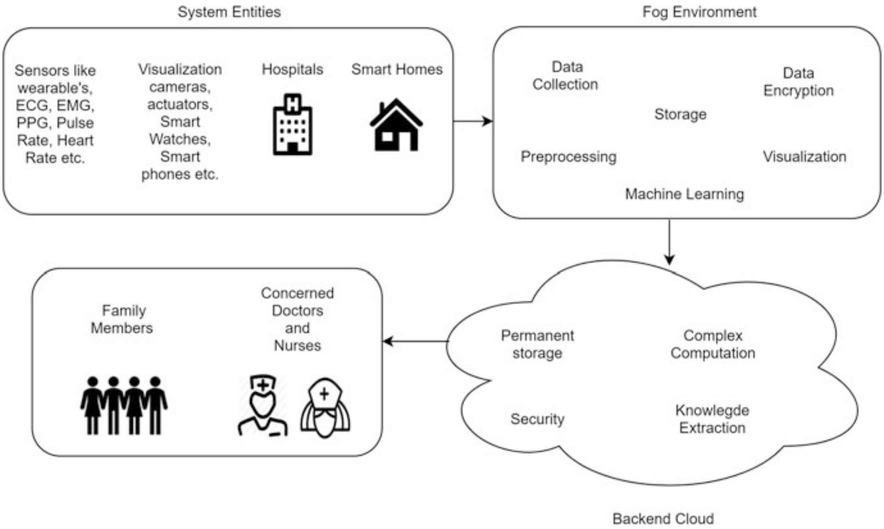

Fig. 21.6 The framework of fog in healthcare

The framework of fog in healthcare is presented in Fig. 21.6. This framework has four units integrating and working as a single environment. System entities, fog environment, backend cloud, and end users (family members, concerned doctors, and nurses) are the units of the framework described below.

- *System entities*

  System entities are actually the source of data, used for managing and making decisions. All the physiological data is generated by wearable sensors, being carried by the patient (or person). These include smartwatches, smartphones, and wearable sensors for monitoring ECG, EMG, EEG, PPG, heart rate, pulse rate, fall detection, etc. This section includes data generated from 24/7 surveillance cameras and actuators present on smart buildings, smart parking lots, and traffic areas. These surveillance systems generate data on a continuous basis. These are actually real-time systems that require low-latency processing. Smart hospitals and smart homes also generate health-related data like data from old age patients, pregnant women, infants, and patients in hospitals.

- *Fog environments*

  Data from all system entities are then passed to fog environments for further computations and preprocessing. Data is collected from all the sources i.e., devices, sensors, and buildings and then preprocessed. Preprocessing involves machine learning, classification, simple computations, decision-making, and visualization of data gathered. Along with this, privacy and security by encryption techniques are also handled by fog devices. All of this metadata cannot be stored on a permanent basis on these fog nodes as only less space is provided by fog (edge) devices [63].
- *Backend the cloud*

  The data after preprocessing and decision-making about the emergency condition at the fog layer is passed to the cloud. The cloud provides all the back end facilities like high-level security, further complex computations, high-level (extended) processing on metadata, and data storage on a permanent basis. Further data analytics can be performed at the cloud to extract even more knowledge from historical data.
- *End users*

  After all the processing made at fog unit, the emergency information or decision made are passed to concerned doctors, nurses, and family members. So that emergency can be communicated to the right people and patient state can be handled immediately, saving precious lives.

21.7 Integration of IoT and Fog in Healthcare

Healthcare involves data collected from sensors that increase the amount of data, due to which the cloud becomes an important part of these healthcare systems. The demand for storing and preprocessing of data in healthcare models is increasing. The machine learning algorithm is also considered as an important part as data collected has to be mined and classified before taking any decision regarding its health.

The cloud is able to provide all the computing, storage, processing services but still, there are some cons due to which the cloud is not preferred in healthcare services. Data collected from sensors has to be passed to the cloud using some communication network and then the results are sent back. Due to this back and forth mechanism communication delays are raised. These delays are very critical to be handled in the healthcare systems as it involves the emergency information of the patient, which has to be handled without such delays. So due to this, the concept of fog computing is introduced.

Some of the researchers proposed the framework for health fog [2]. In these frameworks, fog computing the layer between the users and the cloud. The concept of health fog is introduced not just to reduce extra communication cost but also to increase data privacy and security. The health fog framework can collect data from different sensors by providing security and privacy techniques making it more secure than only using the cloud.

21.7.1 Case Study

There are many scenarios where enabling fog computing reduces many issues like latency, privacy, improves decision-making, scalability, and quick responses. Some scenarios are presented below that enables fog computing in a specific area of healthcare.

21.7.1.1 Fall Monitoring

A fog-based system is designed to monitor falls among people [1]. Fall detection is done using magnitude values of acceleration along with filtering techniques. A u-fall architecture is designed that uses smartphones for fall monitoring among people using acceleration sensors placed in them. Data is captured using smartphones and sent to the cloud using the Internet for preprocessing and analysis through the Internet.

The end cloud and smartphone work in a collaborative manner and result after analysis whether fall is detected or not is passed after collaboration as it increases accuracy and false alarms are reduced. Before data is sent to the cloud, fog is used to distribute data equally so as to provide proper utilization of resources in the network. The system is divided into three parts i.e., front end, communication module, and back end module.

Front end module:

This module is actually running inside a smartphone that has an RSS detector, ADL filter, and alarms as its subunits. RSS detector is responsible for running an algorithm based on thresholding. It calculates the root sum of squares of values of acceleration magnitude. Based on thresholding i.e., lower fall threshold (LFT), which indicates free fall i.e., value between 0 g and 1 g and upper fall threshold (UFT), indicates the impact of fall if the value is 3 g or higher.

ADL Filter: RSS detector is not able to find all as activities of daily living (ADL) i.e., fall-like activities come into the way. So filtering these activities is also an important task, which can also be done by thresholding.

Communication module: next follows is the communication module that acts as a communication interface between the front end and back end. It helps to communicate data from mobile sensors to the cloud or to send results back to the smartphone.

Backend module: Data processing is performed at the backend system too so that the accuracy of fall detection is increased and the rate of fall detection is decreased. Orientation filtering is performed by the cloud as a backend server at a data preprocessor. The acceleration readings collected from smartphones are passed to this preprocessor. Along with that nonlinear analyzer is present that has the same task of ADL filtration as performed at the front end.

This system is able to achieve high sensitivity, specificity, high efficiency, and effectiveness i.e., almost fall events are detected and the rate of false alarms is very low, as some events were carried at the fog devices (smartphones) and other at the cloud devices.

21.7.1.2 Detection of Hypertension Attack

Hypertension is a disease that needs to be detected and monitored on time, as it leads to serious cerebrovascular attacks, CVD, and failure in kidneys. Such detection of hypertension attacks using BP can be done by involving fog computing, which helps to predict different stages of hypertension using sensors and afterward, ANN can be applied to anticipate the level of risk. Fog not only helps to detect stages of hypertension but also send continuous messages of fluctuation of BP to users to detect emergency situation earlier. After the detection, data are sent to the cloud for sharing it with domain experts to find patterns in diagnosis. This system comprises three subsystems i.e., IoT-based user system, health fog system, and the cloud system. The IoT-based user system is actually the real source of data required for detection of hypertension. Different datasets are used that provide data like systolic blood pressure (SBP), diastolic blood pressure (DBP), etc. The health fog system is responsible for the preprocessing, classification, and analysis of results. After data collection, alert or emergency messages are sent to end users or doctors. As data collected from sensors has a lot of parameters, granularity of data is very important to choose only required parameters for hypertension attack detection. Further classification of hypertension is performed into four stages i.e., normal, prehypertension, stage 1 hypertension, and stage2 hypertension by using threshold values of SBP and DBP. After that assessment of risk is detected based on artificial neural network by considering attributes like heartbeat, heart, and lung disease. If any kind of emergency is found, alerts are generated by this fog layer to doctors and family members. The cloud module present in this module is responsible for providing storage so that the history of the patient records is saved, which helps to perform further analysis. The whole system receives high sensitivity, specificity, coverage, and precision and delays are very less due to the use of fog in the entire system as compared to only the cloud detection system and manual monitoring.

21.8 Conclusion and Future Trends

This chapter discusses the concepts of IoT and fog computing in areas of healthcare. Architecture and application areas of IoT and fog are presented. The importance of IoT and fog computing is discussed. The integration of fog and IoT plays an important role in eliminating pressure on real-time systems. Framework for fog computing in healthcare is presented; discussing all its subparts is discussed. The case study is also discussed to give a clear understanding of how fog and IoT are actually implemented in healthcare systems. As healthcare is a part of real-time applications that requires very lesser delays and quick responses, fog computing is a promising approach for satisfying these requirements very well. Along with all the facilities and new opportunities of fog computing it suffers from a lot of challenges like security, privacy, resource sharing, resource scheduling issues, proper standardization, and fog platform implementation.

21.8.1 Challenges

- *Security*

  As fog environment consists of many devices, sensors are geographically distributed and not under the supervision of anyone. Proper security measures must be applied for providing a proper check on all gadgets present within the system. As fog devices or end nodes are the main components of these systems, which provide all the services to an end user, proper trust on these devices should be guaranteed.
- *Privacy*

  Not only healthcare domains, but in all domains, privacy is really an important issue that needs to be considered. Fog-based system is involved with a lot of data, which needs to be kept private. For example, in the case of the healthcare system, medical data of the patient is stored and maintained by the system. This medical data is actually about the medical condition of a person or from some critical illness or disease. Even some systems have vision-based data also that involves cameras and some are location-based. Patients are not really comfortable to share their comfort zone, their locations, their disease, or medications with anyone else. So this type of information should not be accessed by anyone as this information is private and can be used in wrong ways. Encryption can also be a method that can be used so that information can be stored in an encrypted manner to ensure controlled access of information. So even if data is leaked, it is in encrypted form.
- *Scalability*

  As more and more devices, sensors, fog nodes need to be attached to the real-time system, scalability is an issue that needs to be resolved. More mechanisms for handling large number of nodes are required including their processing, computation, and storage.
- *Management of resources*

  Now resources available for devices being attached are still a problem as traditional servers are still the part of systems to provide resource facilities to devices being attached. Many resource management techniques are already available. But smart and intelligent management techniques are still required in a fog-based system that handles resource demand of the real-time application.

- *Failure issues*
  Devices involved within the system like sensors, cameras, gateways, routers may also fail. This failure can impact the whole system let it be sensors, cameras, gateways, routers (i.e., fog nodes). The data continuously taken from them are also adversely affected by such a great loss. This failure is more critical as all devices are geographically distributed. So handling such failures is really a challenge in fog-based systems.
- *Computation related delays*
  Fog computing is preferred than cloud computing, due to its feature of quick responses and lesser delays. But due to complex computations and time-consuming processing, more delays are created within the system. So these computation delays need to be handled seriously.

These issues can be chosen as a future research area by researchers so that fog can be accepted widely in all areas. Some more future directions are discussed below.

21.8.2 Future Trends

- *Security*
  Fog is a widely distributed environment and it involves real-time processing of data and generating results. New security algorithms, schemes, and protocols should be executed in this environment to ensure integrity, consistency of data within the system. Trust and quality of service (QoS) on the system should not be challenged, which is largely affected by these security measures.
- *New interfaces*
  Fog is collaborating with many existing techniques, hardware and software. But still, there are many interfaces that are needed to be redesigned or recreated. These new interfaces will allow collaboration with almost all hardware and software and thus can have added features due to which reliability is guaranteed.
- *Communication issues*
  As a key point of fog computing is lesser delays, communication is an issue that needs to be taken into account very seriously. Different communications and collaboration are provided with fog system between different entities like communication between fog and the cloud servers, communication between various fog nodes, etc. Data transmission schemes applied for communication is traditional and faces some challenges. There is a great need to adapt to new policies, new features that can improve data communication among entities. If data transmission within these ends is done efficiently, the efficiency and performance of the whole system are improved.
- *Standardization*
  Fog computing is still an emerging area, it still requires proper standardization. Proper standards and protocols must be there so that different ranges

of devices, systems can be easily deployed, and issues of interoperability are resolved.

- *Integration of multiple domains*

  Fog computing is applied to almost all areas. But still, there are some areas which have not taken advantage of fog computing. Increasing the scope of fog in various new areas is important but along with that integration of domains in fog computing platform is still a challenge that has not been accepted. As in some applications end to end service is required, which is only possible if multiple domains are integrated. Providing a standard interface, integrating multiple domains together is a need.

- *Fog virtualization*

  For a proper fog-based environment, many actions have to be taken that involve sensing of the environment around using sensors, processing of information, taking relevant decisions based on data, and triggering results if required. So lot of resources are required for this purpose. As the devices involved in the fog environments have a minimal number of resources, virtualization is a very important task that needs to be done. Lightweight virtualization can be applied to meet the demand for resources.

The real-time and low-latency feature of fog and IoT infrastructures can help to open new opportunities for network operators, which can lead to the creation of new business models.

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Chapter 22
Application of Fog Computing, Internet of Things, and Blockchain Technology in Healthcare Industry

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22.1 Introduction

The healthcare industry is one of the fastest-growing industries in the world. We can see the healthcare sector as a multidimensional entity that is dealing with various sectors like the education sector, manufacturing sector, pharmaceutical sector, banking sector, travel industry, IT industry, etc. The healthcare sector is running fully functionally by government, semi-government, and private govern bodies. By running under these types of centralized bodies, healthcare provides services to the patients as well as regular people. Healthcare industry supports in creating job opportunities in IT as well as non-IT sectors, promoting research and development for the development of new innovative products and services, empowering education sector by providing equal support, enlarging businesses for manufacturer of medical equipment's and medicine manufacturer, helps telemedicine manufacturer, medical insurance providers, travel industry, etc. Nowadays, healthcare industry proving ample amount of healthcare facilities to the patients like fast and effective treatment, posttreatment examination, regular health checkup updates, detailed health, and diet plans, easier insurance claim, clearance support, etc. For non-patients, the healthcare industry provides pre-examination or prognosis reports, regular health checkup updates, health and diet plans, etc. By discussing this, we can say that the healthcare sector is a huge sector which creates vast number of opportunities for everyone like educators, researcher, manufacturer, IT expert, doctors, etc. We are discussing the sectors and related stakeholders affected by the healthcare industry as shown in the Fig. 22.1.

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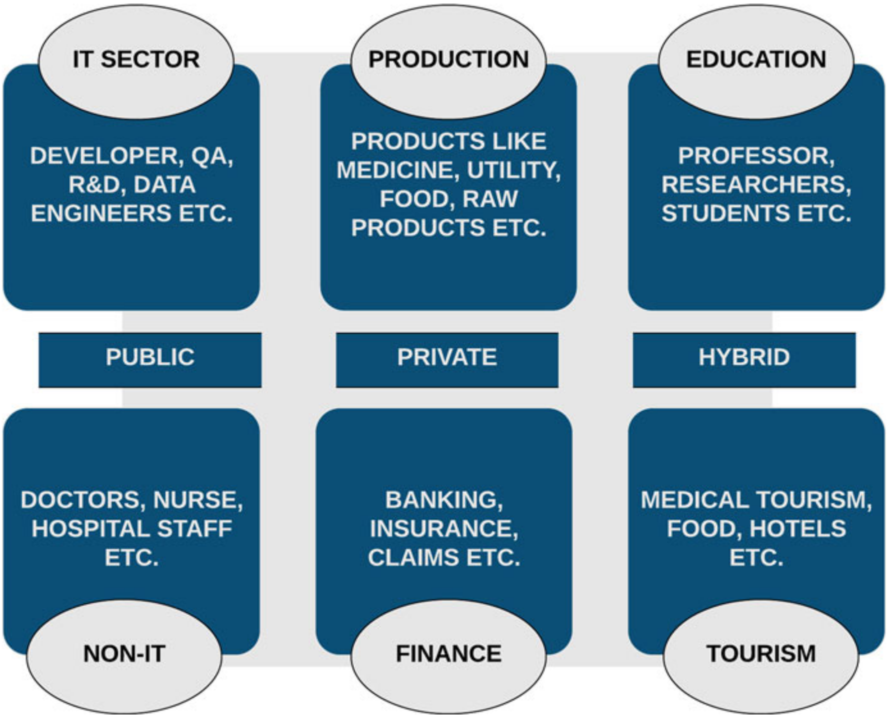

Fig. 22.1 Healthcare sector

By introducing technology in healthcare, the healthcare sector creates magical changes. Like before, healthcare sector following the traditional methodology of work but as the world changes its dimension, it requires serious change. Fog computing and the Internet of things are the perfect solution for healthcare. These technologies are not only beneficial for the healthcare sector but also dropping a hard-core impact on people who are related to the sector like doctors, hospital staff, patients, manufacturers, etc. These technologies are helpful to give a significant impact on people whether they are doctors, patients, or normal people. In incorporation of technologies like fog computing and the Internet of things with healthcare provides profits like:

- It helps to reduce the cost of the treatment, traveling, hospitality cost, etc. for the patients.
- It helps to increase the reachability of doctors as well as patients.
- It helps the manufacturers like a drug, equipment, other amenities, etc.
- It helps to increase the employment ratio.
- It helps small and big business bodies.
- It helps to improve other sectors like tourism, education, defense, food, entertainment, etc.

By seeing these profits of the involvement of technology in the healthcare sector, we surely say that these are helpful for developing any nation bigger and better in terms of services and revenue generation.

22.1.1 Healthcare Empowering Sectors

22.1.1.1 IT Sector

Nowadays, healthcare industry is working very closely with the IT sector. As technologies are growing at faster rate and changes every day by introducing a new mechanism of problem-solving and strategy planning, it is very important for any sector to improve its services by using such technologies. Researcher Brettlecker discussed the term "e-health" in which researcher suggested the provision of providing health services to the people through the Internet and also discussed the "mobile healthcare" [1]. In recent days, we have seen technologies like fog computing, cloud computing, Internet of things, blockchain, data science, etc. By using IT applications and solutions like healthcare mobile applications, telemedicine, telehealth, improving patient care by developing smart and intelligent devices, electronic medical records, digitization of health data, latest operating techniques, etc., healthcare industry is achieving its maximum outcomes.

22.1.1.2 Manufacturing Sector

In any sector, manufacturing and manufacturer are the ones who get the benefitted most whether they are making small products or large-scale products. In the manufacturing sector, healthcare promoting manufacturers who are into the making of medical equipment, drug manufacturing, and other supportive amenities sectors like glass, plastics sector manufacturers. We have seen that benefits from the diagnostic industry, the pharmaceutical industry are increasing more than 10–20% in recent years and the total gross impact of that sector individually still growing. This sector is one of the profitable sectors among the other discussed sectors.

22.1.1.3 Education Sector

In the education sector, healthcare is promoting quality research by collaborating with medical colleges, association with professors and students, etc. the healthcare sector is encouraging researchers and scientists for the innovation of new medical devices, new medicines and new methodologies for the treatment. In recent years, we have seen that almost every medical field they own the new set of the methodology of treatment. This will help while increasing social awareness and development programs in society.

22.1.1.4 Tourism Sector

Healthcare promotes medical tourism by encapsulating hotels and the food and beverage industry. The term “medical-tourism” sounds very weird. Most of the time people cannot understand the importance of the tourism sector but if you see the medical facilities across you then most probably you will find that there is huge number of people who are traveling from one place to another place just to get the proper medication either for them or their families. Another side of the wall is that they become a part of the travel industry and food industry. Researcher Milicia Z. and Jeremy Snyder, discussed about the medical tourism and the importance of medical tourism to increase the income of the healthcare sector and potential challenges of traditional medical services provided by the healthcare sector [2, 3].

22.1.1.5 Banking Sector

The healthcare industry provides a good amount of benefits to banking sectors. The role of a bank in the healthcare industry is to provide medical insurance to people. The banking sector targets people, hospitals for the betterment of their future like in people’s perspective they provide medical cover in case of the medical problems and in hospital perspective they provide loan facilities to them to extend their services. The role of technology comes because banks and hospitals are dealing with huge amounts of data. Fog computing and the Internet of things used to store those data safely and access the data as per the requirement of the user. In the research by Investopedia, US-based website since 1999, presented research on banks and their investment, and how a bank generates revenue in health sector [4].

22.1.1.6 Non-IT Sector

In the healthcare industry, there are almost 50% people who are coming from a nontechnical background like doctors, nurses, ward boys, hospital staff, accounts staff, maintenance staff, management staff, security staff, etc. but still in some context, they have a working knowledge of technical products and technologies like doctors are completely unaware of the internal knowledge of medical equipments but they are trained to use it. Same for accounts staff they are using accounting softwares, security staff uses security devices such as different types of detectors, cameras, weapons, etc. Now, to store the data of different groups, fog computing provides a storage space and IoT provides smoother access over the IoT devices. This sector is dealing with different shades and manages everything in which improve the services of healthcare so, we can say that the role of the non-IT sector is equally important as the IT sector in the healthcare industry.

22.1.2 Aspects of Technology in Healthcare Sector

In the healthcare sector, we are using technologies such as fog computing and the Internet of things in conglomerate fashion for both patients and non-patients. As we all know that cloud technology is a kind of centralized technology for storing data and as per the user's requirements, it provides the data to the users. To extend this technology a little further, we are using fog computing which is a decentralized technology. While incorporating fog computing with the Internet of things, it is very useful in every step of processing of the healthcare sector for patients and non-patients. These technologies will help patients during the treatment process like verifying patient documents quickly, will help if patients need to operate remotely. Document verification is required for the patient and hospitals so that they can provide better services to the patients in the future. It is very crucial in terms of hospital business policy and management. There are few other important sides of technologies where it plays critical roles like remote monitoring of patients, hassle free claiming procedures, storing patients' records to provide better services to them in future and for further case studies for researchers. In the recent research, researchers are more focusing toward the use of technology in healthcare sector whether cloud, fog, blockchain, Internet of things, etc.

22.1.3 Literature Review

In recent years focus in healthcare sector has drifted toward faster, more customized, more specific at home diagnosis of any disorder or sickness of any person. These demands have caused issues like security of patients' data, authorized access of data, latency issues, real-time processing of huge amount of data and maintenance of availability of data. Such challenges can be solved via: Fog Computing, Internet of Things, and Blockchain Technology such as: In [5], Fatema Tuz Zohora, Md. Rezwanur Rahman Khan, proposed a framework for time-sensitive events like accidents, heart strokes, etc. They formed an architecture that used IOT devices and sensors to know about the person's health at that particular moment followed by a layer of fog computing to process it and use cloud to fetch relevant data. The model responds to the end user within minutes. In [6] Corentin Dupont, Raffaele Giaffreda focused on the problem of data confidentiality in Internet of Things and presented a platform Cloud4Iot for both horizontal and vertical migration of IOT methods. In [7] Jayneel Vora, Sudeep Tanwar used fog computing to help patients with ambient-assisted living. They record the movement of patients and pass the data to fog gateways for neurological diseases. In [8] PengZhang helps in clinical decision-making by efficient exchange of information. He used blockchain technology to produce a FHIRchain to meet standards for clinical data sharing [9] and proposed a security scheme to communication, by adding a smart gateway along with a fog layer to facilitate fast processing. In [10] Octavian Fratu, presented the regulations followed for healthcare in Romanian culture for dementia and pulmonary diseases. It mainly focuses on ambient-assisted living. In [11] presents a scheme of off-chain consortium algorithm for medical decision-making in a collaborative manner. It includes the maintenance of privacy of patients' personal data. In [12] X. Liu, R. H. Deng proposes a framework for clinical decision support system while maintaining privacy. It uses light weight data- mining techniques to analyze the patients' condition and provide support in real time. It used fog computing for processing before moving on to cloud. In [13] Yu Cao, Peng Huo proposed a system for fall detection to mitigate strokes in daily life. They did this by first making a fall detection algorithm and then employing it to with the help of fog computing to provide real-time service. In [14] Mahmoud, Mukhtar et al. showed how fog computing can help in cloud of things. It reviews the most suitable fog-enabled COT system and proposes an energy saving strategy for placing tasks on fog devices. In [15] Islam, Naveed et al. proposed to solve challenges in e-healthcare system and remotely monitoring the patients. It combats the major issue of security in interconnected devices via Internet. The authors propose an activity monitoring framework at remote places to improve accuracy in activity classification with fog computing-based block chain architecture. In [16] Kumar, Priyan Malarvizhi et al. proposes a new classifier algorithm using fuzzy logic to solve severe medical problems. It uses IOT to help online application healthcare system and cloud computing for secured storage and retrieval. In [17] Tuli, Shreshth et al. proposed a new framework that is named as FogBus. This framework uses fog computing, Internet of things, and blockchain technology to combat the limitation in healthcare system in modern times that are security, platform independence, latency, and resource management.

Researcher A. Kumari, spotlighted the issues in healthcare sector while performing operations such as data collection in real time, processing of data, and transmission. Researchers were suggesting fog applicability to solve these issues of healthcare [18]. In healthcare sector, large set of data records of patients and non-patients available such as manual records, electronically handled records. To run the entire system smoothly, it is very important to manage data information and provide conceal environment to those data sets [19]. As market is growing and every day new technologies are introducing, another prime concern is can we incorporate healthcare system with such technologies or not like to handle healthcare data with big data policies and apply amalgamation of IoT with an intelligent system that provides a better solution for handling issues of healthcare data [20]. Upcoming days, usage of IoT devices will surely become a trend and we all know that IoT devices need some sort of energy plug-ins and efficient network connectivity to run properly. So, energy conservation mechanism needs to apply on the IoT system [21]. This will be one of the key concerns if we want to access healthcare data very quickly. Thought of incorporating multiple technologies are good but before that one should know about the profits and consequences, challenges during implementation like now a days 4G is running and upcoming days 5G will be there. So, we should form a systematic review on technologies like its pretty good to blend blockchain with 5G IoT-enabled devices that will surely impose a solid mark on healthcare system [22]. Researcher J. Vora discussed the security issues in healthcare records and proposing a blockchain-based model that will use to provide conceal space to every single records of healthcare [23]. As we all know that, healthcare is one of the fastest-growing sectors that are constantly inclined toward the new technologies and trends like upgrading entire healthcare system into another level called e-Healthcare [24]. To understand the working of such technology researcher Patel D. discussed the contribution of Internet of things in transportation system, as transportation system requires real-time updates [25]. In same fashion healthcare data needs to update in real time that will be beneficial for all stakeholders associated with the industry. Researcher S. Tanver discussed the analysis of human health problem with an artificial intelligence technique and then merging it into fog computation [26]. Researcher V.K. Prasad was introducing the concept of fog computation and edge computing in accessing healthcare data [27]. Now we all know that the access of records is very important and once we get the access we further enlarging our wings and looking for the faster access of those data but to make sure data must maintained its integrity, we need to propose some safety management policies in the mining process of the data [28]. Researcher A. Kumari discussed the methodology of fog computing and how data can be placed into cloud to achieve minimum latency problem [29]. In every day's life human body is dealing with lots of health issues so, the health records of everyone must be stored somewhere and as per the need of the person that can be used to provide better solution to the patients for their health betterment [30]. For maintaining the monopoly of the healthcare system, system must be up to date with recent trends and this will be achievable only if the system is constantly updating and overcome the past issues and challenges [31]. Researcher S. Tanver proposed blockchain-based system that is useful for healthcare application and maintaining electronic healthcare records of patients [32]. As technology is not depending, it keeps updating that is the reason, we found separate model for separate problems in healthcare sector [33]. Utilization of Internet services in prominent manner, we found an architectural study that shows how Internet and fog computing are helpful for the betterment of healthcare system and provides a platform to overcome the challenges [34, 35]. Now to make healthcare system more advanced researchers proposes that the role of IoT is very important like in the development of smart city, it is essential that smart city must provide better environment for healthcare system with real-time processing of health records and in parallel, it also focus on security alarming on individuals personal smart phones with biometric approaches [36–38].

B. Negash discussed the traditional IoT gateway implementation to connect with the Internet for betterment of health services for the patients either at hospital or at home [39]. F. Andriopoulou discussed the architectural model which incorporates Internet of things with fog computing to increase the delivery of services in healthcare [40]. Researcher S. Gill, focused on how cloud provide better services to the patients via health monitoring through IoT and big data technology by minimizing the latency of cloud and proposing a fog-enabled model in cloud environment [41].

22.1.4 *Case Study in Healthcare Environment*

22.1.4.1 General Statement

In recent scenario, we have seen that healthcare market is growing very fast and dealing with lots of data in day to day basis. To provide an effective environment so that data can be sharable in between the customers in an efficient manner, it's very prominent to use such technologies as fog computing, blockchain, and Internet of things.

22.1.4.2 Problem Statement

By seeing the healthcare structure and the amount of data the sector is dealing with, we need to focus on three things like data sharing, data storage, and data security. By seeing these concerns, we must try to overcome the issues related to concealment policy, latency, and storage.

22.1.4.3 Technology Used

As the extension of cloud, fog overcomes the latency issues while dealing with huge data. Usage of IoT devices provides real-time access of the data between the end users and blockchain provides safe and secure environment to the data.

22.1.4.4 Solution

To understand the role of technology in a better way, we are discussing the process of the healthcare sector as in Fig. 22.2. From the patient's point of view, it is dividing into five segments. In the very first segment, it is focused on the fast and effective services to the patients during the problems or treatments. First priority for the healthcare sector is to decrease the death or disability rate. After that, the patient goes into the post examination. In the next step, the patient gets the information on detailed health and diet plans. For further assistance, the patient will get the update related to their health checkups. In the last, once the patient recovered successfully, without any delay hospital gets the full and final settlement of the treatment. Now, we have seen that there is requirement of patient data from some source which we will get from either cloud or fog through IoT devices for document verification, post monitoring, for providing regular updates, insurance claiming, and if data is not available in the case of new patients, immediately creates the record of patient for the future services. All the data whether patient or non-patient data must be stored in decentralized ledger in blockchain. So, that different stockholder can access that data in hassle-free manner through IoT devices at each steps of verification. At each step, it provides faster execution that will make healthcare services more flexible and prominent.

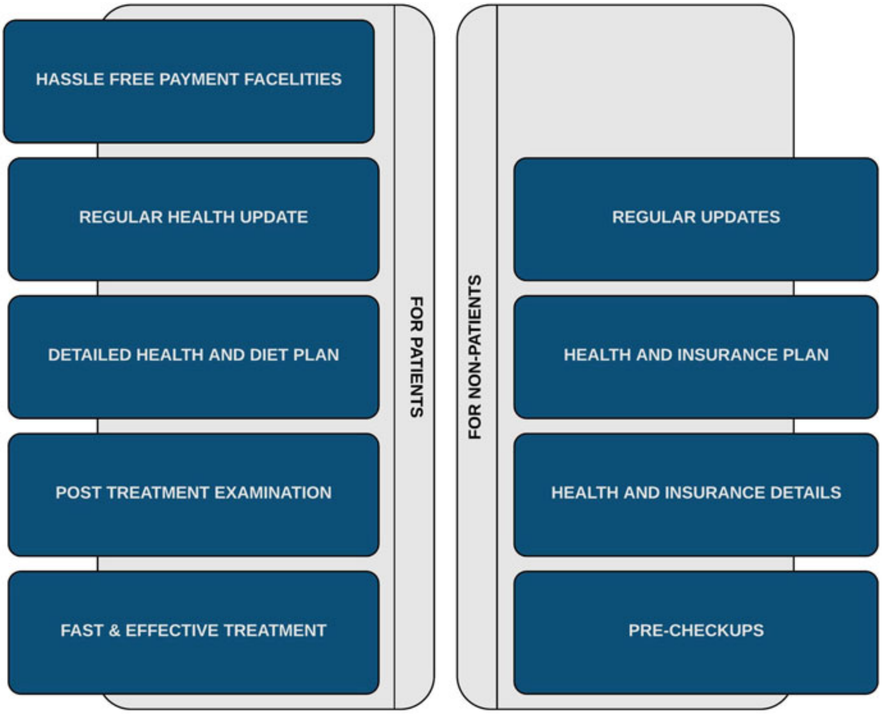

Fig. 22.2 Processing in healthcare for patients and non-patient

For better understanding, we divide the entire study into three segments like fog computing, blockchain, and IoT. First of all entire healthcare data must be transferred into cloud that involves data server which then shifted to fog. So, that it will be easy to access those that with minimum latency. After that data must be stored in decentralized ledger and each ledger should be encrypted with highly secured consensus. Lastly those data must be transmitted and accessed by IoT devices embedded with IoT sensors.

22.2 Fog Computing and Its Application in Healthcare Environment

22.2.1 Fog Computing: An Introduction

In the world of the latest technology, technologies like the Internet of things, cloud computing, fog computing, blockchain, etc. are floating on the top of the cart. These technologies are not restricted between single dimensions; these are flexible, diverse, and multidimensional and keep growing its wing by incorporating other technologies with it. Every technology has its own set of profits and consequences but the primary concern of how much the technology is stable and providing better services to the professional clients as well as normal customers. We have many areas such as healthcare, education, military, business, management, hospitality, manufacturing, etc. By applying the concept of these technologies in such areas, we will surely get a lot of benefits. There will be possibilities that such technology benefits us either by single use or incorporate with other technologies.

Here, we are spotlighting fog computing incorporating with the Internet of things in the healthcare industry. In this, we are covering the general introduction of fog computing, the Internet of things, the healthcare industry, and how these technologies will be beneficial for the healthcare industry. Also, we are covering every single spectrum of these technologies as well as the healthcare industry like the usefulness of fog computing and the Internet of things (IoT) in every wing of healthcare like staff data storage, manufacturing data, patient data, services data, etc. Here, we are also discussing the introduction part of these technologies with architectural working and issues and challenges while dealing with the data. In parallel, we are also discussing the solution to the challenges and betterment of these technologies.

The term "fog" is mainly originated by CISCO earlier but finalized in 2015 and the main reason of giving name "fog" was to provide real-time assistance with faster rate, lower latency rate, and lower workload rate [42]. Fog computing is an extended version of cloud computing that deals with data storage and whenever someone requires the data, the cloud will provide the data accordingly. Fog computing works on the concept of decentralized mechanism where data and application can be stored somewhere between the data source and actual cloud. Researcher discussed about the highly distributed data and how data can be accessed through the devices stored at different locations through virtualized technology such as fog [43]. In the cloud environment data where data is storing and there are many operations performing on cloud data, fog is another way of providing cloud data at a faster rate to the clients or customers. In some contexts, fog computing is also relatable with edge computing that can be interchangeably used. As the technology is growing, a researcher discusses further advancement of fog like researcher S. Naveen and Pagel, discussed the concept of edge computing and how edge computing provides sensitive data processing very efficiently [44, 45].

In Table 22.1, we are showing the features of fog computing on the basis of architecture, communication medium, data processing, computer capabilities, number of nodes connected, analysis, latency, connectivity, and security.

22.2.2 How Fog Computing Works

While discussing the working of fog computing, it is important to understand cloud computing concepts. As we know that fog computing is working on shortterm analytics where cloud computing is working on long-term analytics. In this scenario,

Table 22.1 Features of fog computing

Features	Fog computing
Architecture	Distributed
Data communication medium	Directly from edge
Data processing	Close to source information
Computing capabilities	Lower
No of nodes	Very large
Analysis	Very large
Latency	Low
Connectivity	Various protocol and standard
Security	High

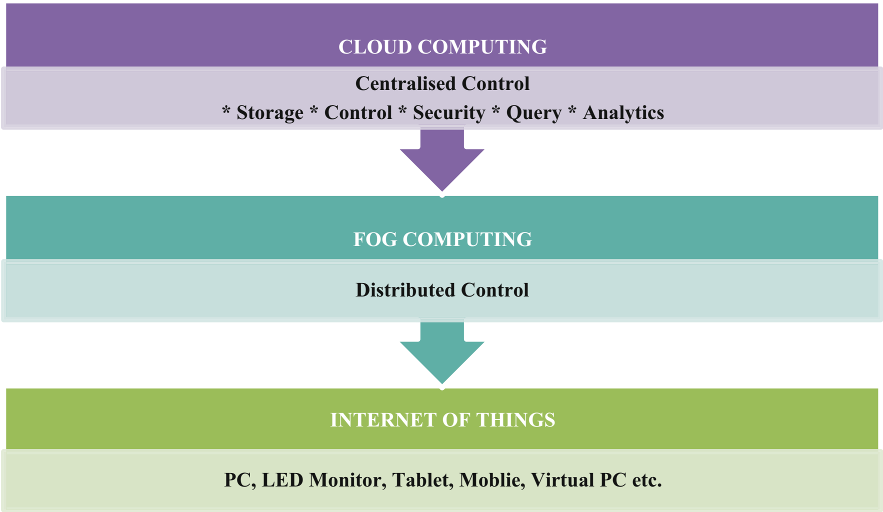

Fig. 22.3 Basic design of fog computing

we have IoT devices and whenever it requires data or want to access some applications it will immediately trigger the message to the cloud and through cloud server over the Internet. Cloud server then connects the endpoints of the entire system like IoT devices and data stored on the cloud to perform the data transfer operations by providing a secure environment, privacy and legal implications in the case of more sensitive data material. In the given Fig. 22.3, we are showing the basic layout of the working of fog technology. Here we are showing three levels of architectural design like cloud, fog, and IoT levels.

As we already have seen that cloud is working on three-layer concepts as per the services provided by the cloud-like software as a service (SAAS), platform as a service (PAAS), and infrastructure as a service (IAAS), researcher M. Asemani discussed the layered architecture of fog computing on Internet of things (IoT) platform [46]. Now, fog is extended from the cloud, it has some additional roles and responsibilities for the data. In Fig. 22.5, we are showing a six-layer architectural concept of fog technology. Each layer has its own working role. These layers are transport layer, security layer, temporary storage layer, preprocessing layer, monitoring layer, physical and virtualization layer. In the transport layer uploading of the data on the cloud can be performed. These data must be preprocessed data and secured data. In the security layer, encryption and decryption operation can be performed and make sure that data must maintain its privacy and security. In the temporal storage layer, the distribution of data and storage of data can be performed. In the preprocessing, operations like data trimming, data filtering, data analysis, and data reconstruction can be performed. In the monitoring layer, monitoring such as activity, power, request, response, and service monitoring can be performed. In the last layer physical and virtualization layer, the operation can be performed over the virtual and physical sensors network. These layers are arranged in such a way that all layers can able to do their jobs in justify manner. These layers are likely equivalent to cloud three-layer models. By seeing the layered architecture of fog computing as well as cloud computing, we can compare the working methodologies of these two technologies. Fog computing works as an intermediate between the cloud computing and IoT devices and one layer of fog is closely attached to cloud environment and the other layer of fog is closely attached to IoT devices. The layer which is connecting to that cloud environment is the transport layer and connecting to the IoT environment is the physical layer. While incorporating IoT with fog technology, many researchers focuses on optimization of IoT services in the fog, IoT devices now worked as storage resource as well as networking resources [47].

Here Fig. 22.4, is the representation of six layers of the fog computing with brief details related to individual layers are also mentioned.

22.2.3 Fog Computing in Healthcare Industry

Healthcare the industry is dealing with a lot of data like patient data, staff data including leading staff and supporting staff, data of services provided by the hospitals. In the patient data, it stores personal information of the patients for proving better services by reading the patient's requirements and patient health data for further study of the problem. In the staff data, it includes leading a staff of the healthcare industry like a doctor, nurses, ward boys, and support staff like accounting and admin staff, management staff, security and maintenance staff data. The healthcare sector also needs to store the data of services provided by the industry like medicine data to know which medicine is currently available or unavailable, effective or not effective, equipment data to check whether the equipment is working properly or not working, monitoring of patients in real time [48]. These data are present in such a larger amount that the cloud is the only solution to store the data and then transfer to fog. By doing this we can solve the storage problem of the data. The main problem arises that is how to transfer such a huge amount of data on cloud and access that data from the cloud. Now the role of the Internet of things (IoT) is showing in Fig. 22.5.

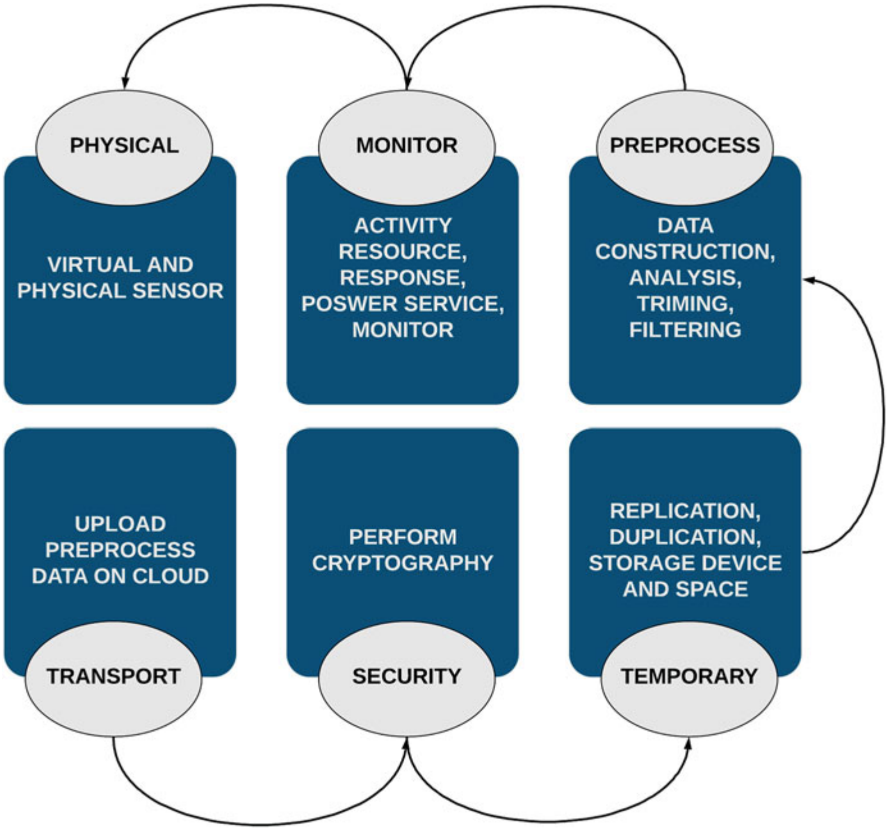

Fig. 22.4 Layer architecture of fog computing

According to recent research, almost 1 Exabyte of the data already stored on the cloud which is further aggregated into fog nodes and almost 400 million IoT devices are currently running in the market. The uploading and downloading of the data on cloud and usage of IoT devices keep increasing rapidly every day. As per the excessive demand and use of IoT and fog researchers focuses on the development of healthcare from 1.0 to 4.0 and discussed the wide range of opportunity and challenges of using fog technology in healthcare [49]. In Fig. 22.6, showing the data need to be stored on either fog or cloud for the betterment of healthcare services.

22.2.4 *Challenges of Fog Computing in Healthcare Sector*

As we all know that fog computing is the extended version of cloud computing. The basic job of both cloud and fog computing is the same as storage of data

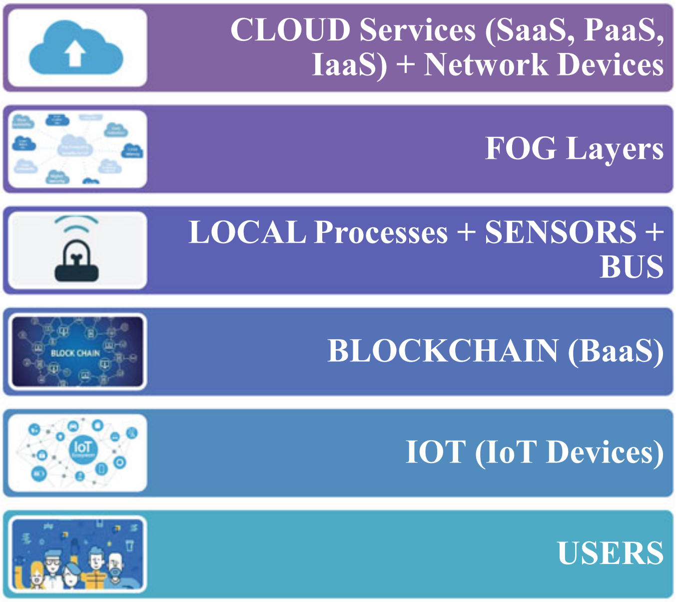

Fig. 22.5 Healthcare data stored on fog nodes

but when we look at the technicality of the process of storing data and providing data as per the requirements, we found that they are a little different from others. Before we discuss the issues and challenges of fog computing, we get to know about the internal working, basic architecture of fog. To understand fog computing, we have to disclose the cloud computing and two terminologies like mobile edge computing (MEC) and mobile cloud computing (MCC). Mobile cloud computing is the technique where the storage of data and processing of the data as per the user's request can be performed outside the IoT devices. In mobile edge computing (MEC), it is similar to the concept of "Cloudlet" where data is more centered toward the cloud and whenever users require the data, they will get the data from the fog server. As we already mentioned that fog computing is the modified chain of cloud computing and acts upon the Internet of things (IoT) [51].

Here in Fig. 22.7, we are discussing a few challenges of fog computing in healthcare sector like privacy or concealment of users data whether they are accessing the data or data are stored inside the fog nodes, the security of network from unauthorized access, management of the network to avoid the extra load on fog nodes by using future networking methodologies like software-defined networking (SDN) and network function visualization (NFV), placement of fog server so that everyone can get the data very easily, power consumption of individual fog nodes, processing or computational delay while accessing the data from the fog nodes, etc. [52].

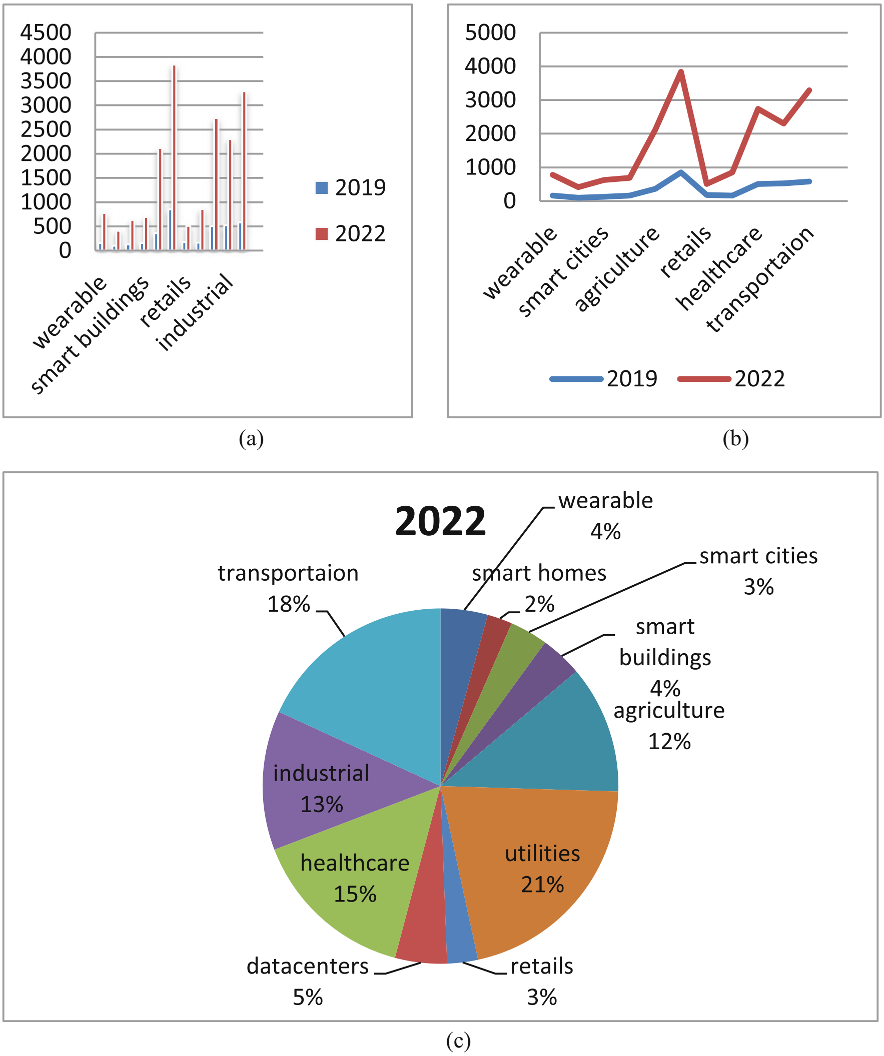

Fig. 22.6 (**a**) growth of different sector due to fog in 2022, (**b**) line graph of growth, (**c**) predicted percentages covered by the sectors in 2022 [50]

22.2.4.1 Concealment of Healthcare Data

Nowadays, the privacy of the data is a more serious issue for any industry and we all know that the healthcare sector is dealing with a lot of data and every moment these data are increasing rapidly. If we look at the hierarchy of data access to IoT devices from fog servers, it is a very simple procedure like layer-wise formation bottom to the top layer. Each layer should have its own set of functionality like getting

Fig. 22.7 Issues related to fog computing in healthcare sector

requests, process the request, security checks, etc. now it is important to make sure the privacy of data still maintains as the original, fog need to apply some security check between the edges of the intermediates. These types of security concerns are important to avoid the leakage of personal and private data of the user that is stored in the fog. To restrict the unauthorized access from any loopholes fog needs to apply some encryption mechanism like home area network (HAN) for security checks [53].

22.2.4.2 Healthcare Network security

There are various types of IoT devices available in the market. Fog nodes are dealing with different IoT devices across the worldwide and each device has its own IP address which provides them their own identity. Now if you see the process, it is very simple when the user sends the request to the fog server for the data, it is the duty of fog server to provide the data as per their requirement but there is a problem like how can a fog server know that the authenticity of the user IP. There can be the probability that the user did not authenticate but due to a lack of promising environment fog server allows to access the actual user information. So to make sure that the authenticity of the genuine user remains healthy and stable, fog computing must know some strong verifying mechanism of user's identity or devices IP addresses.

22.2.4.3 Management of Networks

While providing services to the user network management is another very hectic challenge for fog computing. Users can send the data access request from anywhere, anytime, from any device, and from any network. On the other hand, any number of users can send the request and process the data from the fog. So, to make sure the connection between the heterogeneous devices and fog nodes is stable and burden less, fog must use the proper network management techniques like software-defined networking (SDN) and network function visualization (NFV). These are the future of networking.

To understand the software-defined networking (SDN) and network function visualization (NFV) in a better way, we can say that these are the network abstraction. Software-defined networking (SDN) is used to separate network controlling functions (NCF) from network forwarding functions (NFF) and network function visualization (NFV) is used to separate network forwarding from other network functionalities of the hardware. The main advantage of using network function visualization (NFV) is that it will help to save the cost of capital expenditure and the cost of operating expenses. Network function visualization (NFV) also used to replace network services. In parallel, software-defined networking (SDN) is used to deliver direct programmable network control. Software-defined networking (SDN) is agile and responsive networking that provides programmable control with centralized intelligence [54].

22.2.4.4 Fog Server

As per the usage of fog nodes, it is important to analyze the working and workload on the fog. Another important thing is that fog servers must be placed at the best-suited locations so, it will be easier for fog nodes and servers while providing data to IoT devices. Fog server is the core of the data processing whether its process of the data, storage of the data, and triggering of the data. To make sure the fog server works properly, it is important to perform a regular checkup of the server. This fog server issue is very important and requires serious action.

22.2.4.5 Computational Delay

In the present scenario, we have an ample amount of technology for doing one task in many ways and fog computing is one of the ways of accessing data information. We already know that the data or information is spreading over the cloud through the Internet and as per the user requirement cloud is responsible to provide those data to the authentic user but the challenge is time taken by the cloud. To avoid these types of issues cloud must aggregate the data which is already stored on the cloud and it is the responsibility of the cloud to provide those data to the user in very less time. For that data must be aggregated before actual processing and stored at its proper location so that the user will get the data without any delay [55].

Table 22.2 Profits and Consequences of Fog Computing

Profits	Consequences
Fog computing helps to reduce the amount of data sent to the cloud	Physical location can be taking away
It can help to conserve the network bandwidth	Security issues like IP address spoofing
It can help to improve system repose time toward the client request	Privacy issues
It will help to improve security by keeping stored data at the edge	Availability and costing of fog
It can support mobility	Facing integrity and authentication issues
It will reduce the network and Internet latency	Wireless media security issues

22.2.4.6 Energy Consumption

As we all know that fog computing is working on the distributed methodology. It requires a lot of fog nodes for data storage between the actual cloud and IoT devices. There is no methodology through which we can identify the actual number of fog nodes to be placed. Cloud is already such a huge entity that requires a lot of energy. Now on the other hand fog is associated with the cloud so, it also requires energy to work. These types of arrangements make the entire system less energy efficient. Hence, it will be very challenging for us to make sure they use of energy must be minimal and get the maximum throughput while using fog services [56].

22.2.5 Fog Computing Profits and Consequences

In today's world, there are various technologies. No technology is fully perfect. Here in Table 22.2, we are discussing the key profits and consequences of fog computing.

22.3 Internet of Things (IoT): An Introduction

Internet of things (IoT) is the environment that provides an intelligent connection between the interrelated devices called "IoT devices." Those devices are available on either same or different operating networks but the primary objective of these devices is to allow data transmission between the devices. By seeing recent usage of IoT devices, it is almost more than 10 billion devices present in the market. There are many IoT devices are available in the market and as the usage of IoT devices are constantly increasing, according to CISCO it will cross 500 billion in 2030 approximately.

To understand the Internet of things in a better way, one should understand the key components of the IoT. There are few components are mentioned such as gateways, analytics, connectivity of devices, cloud, user interface, standards and protocols, database, automation, and development. To manage data between the devices through networks gateways are very essential elements. To understand data transmitted efficiently analogy is important. To make sure established connection is working good, sensors are used. Cloud is one of the key components in IoT that stores data in bulk forms. User interface and protocols also play a key role in the development of IoT, while accessing the services either offline or over the Internet connection, it is very important that interface should be user friendly and known to all respective protocols.

22.3.1 Internet of Things (IoT) in Healthcare Sector

In the traditional culture of doctor–patient relation, there was one to one interaction between the doctor and patients either patient met the doctor at the clinic or doctor met the patient at home. There was no such a way that they interacted smartly anywhere, anytime. Internet of things (IoT) is the way through which one can contact or communicate with others without wasting a time like IoT provides a platform to the doctors as well as patients to communicate with each other. IoT has the potential to join multiple communications between doctors and patients. Now the patient can contact the doctor from anywhere, anytime. In the current progressive environment, the Internet of things enabled devices has capabilities of doing various kinds of tasks in parallel. Like in the case of the healthcare industry, it provides parallel monitoring, remote monitoring. It has certain advantages for the doctors as well as patients. If we look at the broader view of the Internet of things then for the doctor's perspective it helps to increase the multidimensionality of workspace, extend the reachability of doctors, providing better platforms, and income sources. For the patient's perspective, it helps to provide quick treatment, reducing the cost of the treatment and other expenditures help to update patients on a regular basis. IoT surely revolutionaries and transform the traditional way of working in the healthcare industry. IoT has various applications in healthcare [57].

In Fig. 22.8, we are showing four step mechanism or process of Internet of things (IoT), all these stages are connected to each other in the order of execution means output of one stage will be the input of another stage. Through this, values pass from one to another and will produce more efficient and dynamic outcomes.

Step 1: Perform collection of data through IoT devices.
Step 2: Perform aggregation operation. So, that data will able to move further to the cloud storage.
Step 3: Perform data transmission to the cloud and store the data.
Step 4: Perform data analysis procedure.

Surely Internet of things (IoT) provides convenient and efficient environment for healthcare sector and when we incorporate IoT with other technology such as fog computing, cloud computing, and blockchain, it will become more productive and

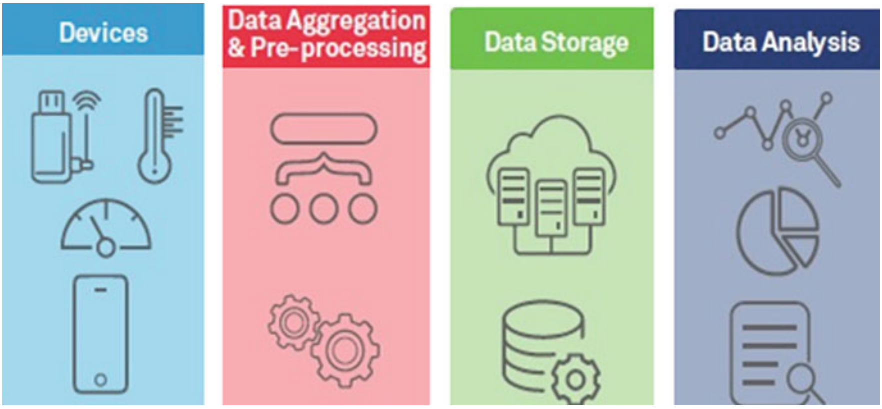

Fig. 22.8 IoT four step mechanism

advanced in providing services to the customers. In the Fig. 22.8, we are showing the four-step mechanism for IoT system to process the data on fog.

The prime advantages of using the Internet of things (IoT) are discussed below:

- It helps to reduce the cost of the treatment, hospitality cost including food, travel, and hotels.
- It helps to improve the treatment for the patients.
- It helps to provide advanced prognosis and diagnosis facilities.
- It helps to reduce the error rate and casualty rate.
- It helps to check the medical compatibility of drugs and equipment.

22.3.2 Integration of Internet of Things and Fog Computing

Nowadays, we are using different kinds of technologies. Each technology has its own taste. All these technologies are surrounded by the data of the user whether they are working the data directly or indirectly but these technologies are connected with the data. Recent days two most promising technologies “fog computing” and “Internet of things (IoT)” are becoming very popular. The beauty of these technologies is that they are complementing each other. In fog computing, as the name suggests “fog” gives its tiny places that are used to store the data of the user. That data can be anything like users’ personal or private data and as per the requirement of the user, the user can process the data very smoothly but the thing is fog is used to store data only. Now we need a technology through which we can access the data or process the data that technology called the Internet of things (IoT). So, through IoT user’s data can transmit over the fog to the user’s device. Now we can say that “technology that is used to store user’s data is called fog computing and technology on which fog computing acted is called the Internet of things (IoT)”.

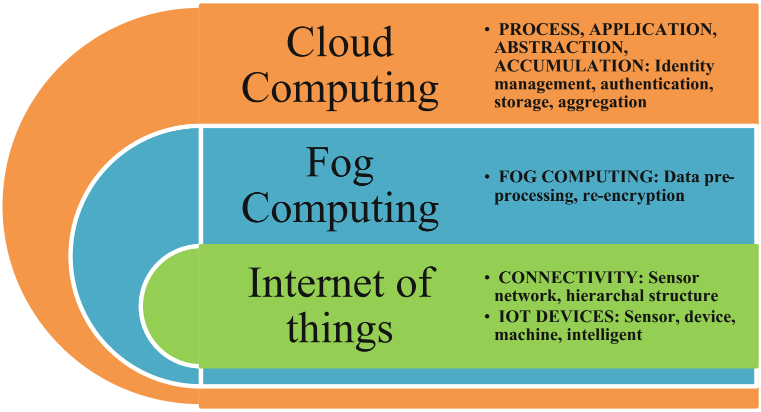

Fig. 22.9 Fog computing with IoT

Table 22.3 Seven-layer architectural model of IoT

Layers	Roles
Physical devices	IoT devices
Connectivity	Communication
Fog	Analysis and transformation
Data accumulation	Storage
Abstraction	Aggregation
Application	Analysis and control
Collaboration	Involving people and processes

We have seen two types of working architecture of any technology either they are centralized or distributed. We know that fog is the modified version of cloud computing and cloud computing is working on a centralized data storage concept but on the other hand, fog is the aggregated form of cloud and working on distributed model of data storage. Internet of Things (IoT) is another technology where devices are interconnected and perform data transmission over the same channel or different channels. These two technologies are ruling the current industry; we have seen vast number of applications of these technologies in various sectors like education, defense, travel, food, healthcare, marketing, information technology, etc. in Fig. 22.10, we are showing the joint venture of IoT with cloud and fog technology.

In the above Fig. 22.9, we have seen that the seven layer architecture of Internet of things model. These layers are defined as Table 22.3 below.

22.4 Blockchain: An Introduction

The blockchain is a technology that provides highly secure distributed ledger of economic transaction which can be coded smartly via smart contracts to record virtually anything of value. In simpler terms, it is a time stamped chain of immutable records of information that is handled by a cluster of nodes (computers) not inherent to any single entity. Each of the blocks in blockchain is well bounded by each other such that any modification in one block affects others in chain therefore making it strictly immutable. Moreover, hashing and other cryptographic keeps it difficult to access without authorization.

Blockchain evolved in stages of 1.0, 2.0, 3.0. Blockchain 1.0 stage was named as "Internet of money" and is for decentralization of monetary values. It was first applied in digital payment systems and was established peer-to-peer for the first time without the reliance in any third party. The consensus algorithm used was "Proof of work." Blockchain 2.0 brought the concept of smart contracts which can automate virtually anything after meeting conditions encoded inside the script. This gave birth to Ethereum. Blockchain 3.0 brought the concept of storing and transferring data in different areas like government data, health data, etc. In all the years of development of blockchain many consensus algorithms developed which forms the crux of blockchain technology: Proof of stake, Proof of burn, Practical Byzantine Fault Tolerance, Proof of Elapsed Time, etc.

22.4.1 Blockchain in Healthcare

Healthcare has become an essential field of Information Technology with the evolution of Electronic Health Record. With the help of EHR it has made it easy to help remote monitoring of patients, health management of population, keeping a record of patients' medical history, etc. But the major problem with such evolution is that the data are too big which makes it difficult and complex to manage it, use it to make complicated analysis, diagnosis, and prediction. Moreover the data confidentiality is at risk keeping in mind the increasing cybercrime cases. Though healthcare data and its sharing may boost accuracy in diagnostic but this information can become a single point failure and if targeted by attackers can result in ransomware attacks and DoS attacks. Therefore, security of healthcare data is an important component of EHR. Healthcare data is sensitive and includes patients personal information which if known to some other person may harm him in many ways, so with medical data third party can't be trusted. And also this data includes a chain of time bound information taken by doctors and this data is widespread and must be shared in some cases. This disclosure of patients data may breach the policies of "Health Insurance portability's and Accountability Act." But this disclosure is important to receive advanced and intelligent medical services. Blockchain technology through its smart contract and distributed ledger technology is expected to offer encouraging solutions to help secure patients' data even though they are being shared and accessed through EHR.

In Fig. 22.10, we are presenting the incorporation of blockchain with fog and IoT technology. Blockchain is comprised of key features: Decentralized ledger, consensus algorithm, smart contracts, and digital signature. Main key feature here is smart contracts which hold the key to how the blockchain will implement the

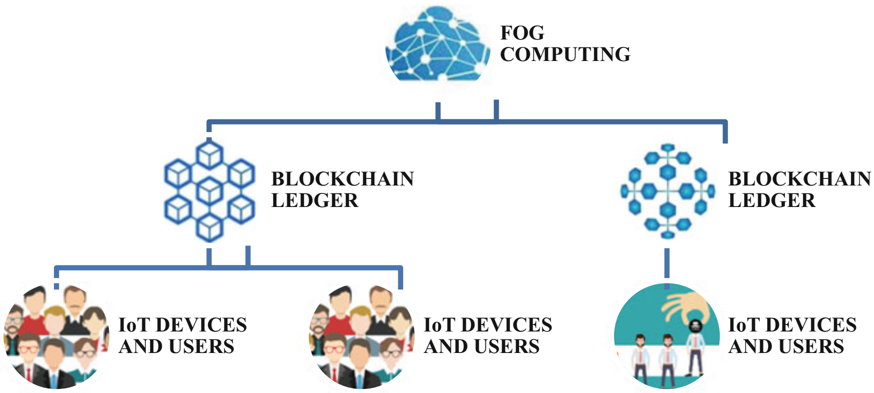

Fig. 22.10 Amalgamation of Blockchain with Fog and IoT

particular solution to a problem. Smart contract in healthcare department can work by approving multiple digital signatures amongst service providers and patients allowing only the authorized stakeholders to access the record or append any to it. Through smart contracts, researchers can be allowed access to patients data and make research to provide better diagnostics and solutions to unsolved problems. Blockchain was developed by Satoshi Nakamoto in 2008 and was implemented in the form of peer-to-peer electronic cash system, bitcoin. Blockchain in itself is a fully developed distributed ledger in a P2P platform using advanced cryptography tools and protocols to secure data transaction of value. Ethereum blockchain is a complete implementation of blockchain in decentralized network in financial areas. Smart contracts are the decentralized applications that support complete programming by running on Ethereum or other platforms. In Fig. 22.11, we are showing the amalgamation of blockchain in healthcare sector to overcome the security-related issues.

Apart from all the good and positive things blockchain has issues related to privacy, security, and scalability as each and every transaction is actually exposed to public since everything and coding is transparent. For example in 2016, a hacker found a hole and exploited it to steal around 50 million dollar eth. Therefore the healthcare data storage in EHR and sharing it using blockchain is risked in privacy, security, and scalability and even heterogeneity. The current study is supposed to provide insights into blockchain environment to help researcher find the gaps in technology and find the solution and application suitable to fill the gap. It discusses this amalgamation via components: system design, model, approach, platform, algorithm, protocols, and scheme. This study also reviews importance, and challenges of blockchain and provides future research scope in integration of blockchain in healthcare department.

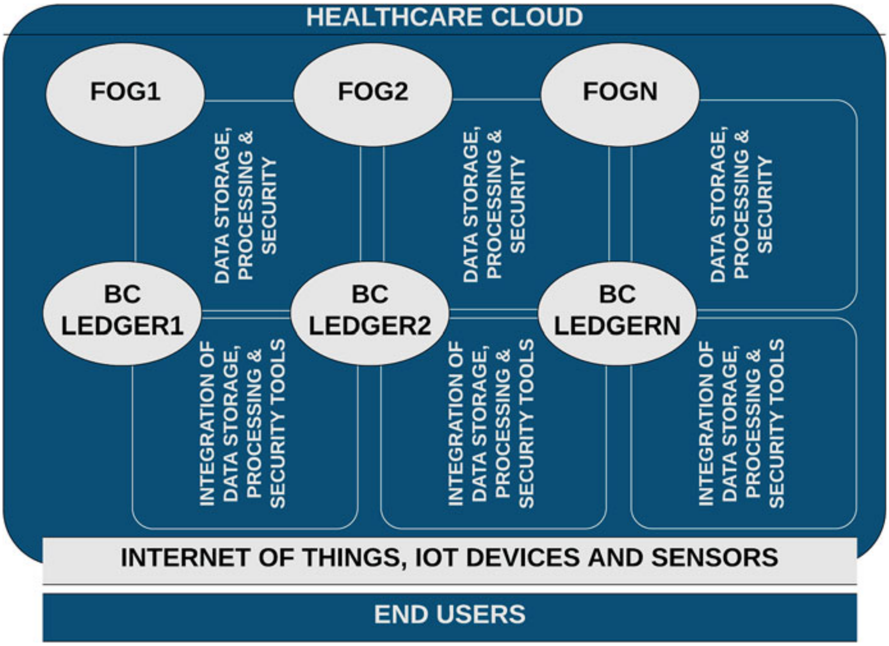

Fig. 22.11 Amalgamation of fog, blockchain, IoT, and end-users

22.5 Review of Technology Usage in Healthcare Sector

As we have discussed technologies such fog computing, Internet of things (IoT) and blockchain and their usage in healthcare industry, all these technologies are supporting each other to accomplish the data transmission task from one device to another device in efficient manner. We already spotlighted the behavior of each technology and what will happen if we incorporate these technologies together in healthcare sector.

In the Table 22.4, we are discussing some research work done by researchers and try to figure the actual problem refereed and technology used for the betterment of healthcare sector.

22.6 Conclusion

As healthcare industry is growing rapidly, amalgamation of technologies such as fog computing, cloud computing, blockchain, Internet of things (IoT) with the industry becomes essential. By introducing these technologies in healthcare, researcher spotlighted the parallel importance of such technology for betterment of healthcare sector. Healthcare is dealing with huge amount of data like patient

Table 22.4 Tabular analysis of research work done by researchers

Author	Year	Problem referred	Technology used
Zohora et al. [5]	2017	Slow response time	Fog Computing and IOT
Dupont et al. [6]	2017	Confidentiality	IOT, Edge Computing
Vora et al. [7]	2017	Data processing time	Fog Computing
Zhang et al. [8]	2018	Secured sharing of data	Blockchain
Moosavi et al. [9]	2016	Security	IOT
Fratu et al. [10]	2015	Privacy	Fog Computing
Yang et al. [11]	2019	Privacy	Blockchain
Akrivopoulos et al. [58]	2017	Heterogeneity	IOT
Liu et al. [12]	2017	Privacy leakage	Fog Computing
Cao et al. [13]	2015	Network latency in health monitoring system	Fog Computing
Srinivas et al. [59]	2017	Healthcare security	Fog Computing
Mahmoud et al. [14]	2018	Energy consumption	Fog Computing and IOT
Islam et al. [15]	2019	Security	Blockchain and Fog Computing
Manogaran et al. [60]	2018	Prediction of heart diseases	IOT and Big Data
Chen et al. [61]	2018	Personalized resource service	Edge Computing
Hossain et al. [62]	2018	Security	IOT
Woo et al. [63]	2018	Fault—tolerance of health data services	IOT
Kumar et al. [16]	2018	Disease prediction	IOT and Cloud
Hussein et al. [64]	2018	Secured data sharing	Blockchain
Tuli et al. [17]	2019	Integrity while sharing data and heterogeneity of data	IOT, Fog Computing, Blockchain
Li et al. [65]	2018	Secured data sharing	Blockchain and Cloud
Fernández-Caramés et al. [66]	2019	Glucose monitoring system	Blockchain, IOT, Fog Computing
Abujamra and Randall [67]	2019	Security, efficient data sharing	Blockchain and IOT
Sharma et al. [68]	2018	Security and privacy	Blockchain, IOT, Cloud
Hassan et al. [69]	2019	Privacy preservation	Blockchain and IOT
Al Omar et al. [70]	2019	Privacy, security	Blockchain and Cloud
Tariq et al. [71]	2019	Security	Blockchain, IOT, Fog Computing

data, hospital data, manufacturer data, employee data, etc. Almost 33 zeta bite data present on a cloud which will be increased up to 175 zeta bites by 2025. The main concern while dealing with such a huge amount of data are data transfer and access. To provide efficient and prominent services to people who are either directly or indirectly associated with the healthcare sector, faster data transfer and access is required. In this chapter, researcher emphasizes on how fog computing works and provides better quality of service toward sensitive data by suggesting real-time storage facilities, decreased latency, increased response time, improved fault tolerance, secured and protected environment. For accessing healthcare data at faster rate, Internet of things or IoT devices hit the solid benchmark like 24/7 connectivity, convenience, wellness, personalization, etc. There are 26 billion IoT devices present in the market, it will increase by 75 billion by 2025 [50]. This will surely helpful in improving security measures, increasing the process efficiency, provide new opportunity, cost saving, increase quality of service, and enhance services utilization. To provide most conceal environment in the health sector data, decentralized security policies needs to be implemented. By using blockchain concept, it will be helpful to overcome the interoperability problems of healthcare sector.

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Chapter 23
Social, Ethical, and Regulatory Issues of Fog Computing in Healthcare 4.0 Applications

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23.1 Fog Computing and Healthcare 4.0 at a Glance

Fog computing is a fresh standard of computing; fog computing as of right now is not a complete model in the open. Fog computing is well thought-out as the addition of cloud computing to the verge of the network, which is an extremely virtualized viewpoint of the resource group that offers computation, data storage, and networking solution to adjacent end users [1].

Internet of Things (IoT) offers an opportunity that allows interaction among a large number of objects across the globe through the internet. Like any other domain, the healthcare industry also vitally gets benefitted after utilizing IoT and has developed from the first generation to current, which is 4.0 generation [2, 3]. In healthcare 3.0, the focus was limited to hospitals, in which severely sick patients underwent difficulties due to various hospital visits for their regular medical checkups [4]. On the other hand, with the advent of cloud and fog computing, the patient's difficulties are diminished by cutting down the investment in storage and computing allied to the patient's data. The leading IoT technology makes the healthcare industry work robust, but data processing is not scaling effectively and efficiently to fulfill a centralized cloud computing environment [5]. The healthcare sector is also getting positively influenced by the revolutionary technology called blockchain [6, 7]. Blockchain is a distributed ledger technology that is mainly used to secure transactions in a trustless scenario like HER management, banking transaction, and many more [8–12]. The main problem readily faced by the healthcare industry is the delay in response. The cloud-based application requires the health-related data to be stored on servers after that cloud performs computation

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on the data and store results on the database. Finally, the results are sent to the end device. This whole transaction and computation of data cause unacceptable delays [13].

Fog computing captures its benefits due to the edge position, as an outcome of that this new expertise can support many applications (e.g., gaming online, augmented reality, real-time video streaming, agriculture, healthcare, etc.) with minimal latency necessities [14–22]. Fog computing is also facing several issues related to various services. It is highly essential to assure security and privacy to be considered in every layer of fog computation [23]. Some attention paying issues within fog computing are trust and authentication, network security, sheltered data storage, secure and isolated data communication, privacy, and access control.

The motivation behind writing this chapter is to discuss the problems of cloud computing faced by the healthcare domain and to overcome these problems by emphasizing the use of fog computing for achieving efficiency in this domain.

The rest part of the chapter is organized as follows: Section 23.2 discusses the difference among cloud, fog, and edge computing; Sect. 23.3 explains E-Healthcare architecture using fog computing; Sect. 23.4 throw some light on the healthcare access in rural communities; Sect. 23.5 emphasizes the role of fog in IoT foundations; Sect. 23.6 discusses the current trends and emerging challenges in fog computing market; Sect. 23.7 talks about the future perspectives in health IT; Sect. 23.8 highlights legal, ethical, and social issues concerning fog computing; Sect. 23.9 brings up some of the security concerns. Section 23.10 presents a case study. Finally, Sect. 23.10 gives the conclusion of the chapter.

23.2 Cloud, Fog, and Edge Computing: The Big Difference

Corporations are increasingly utilizing the cloud, edge, and fog computing infrastructures for making their businesses more efficient and real time. These modern architectures permit industries to catch the benefit of a range of computing and data storage assets, as well as the Industrial Internet of Things (IIoT). The three buzz words cloud, fog, and edge computing seem corresponding, but they form different layers of the IIoT [24].

23.2.1 Cloud Computing

Many organizations are acquainted with cloud computing since today it's an average in many businesses. Both fog and edge computing are additions of cloud networks, which are an assembly of servers, including an extensive spread network. Thus this network can permit businesses to impressively surpass the incomes that would then be available to it, releasing establishments from the obligation to keep set up on site.

The chief advantage of cloud-based structures is that they agree data be composed of multiple locations and devices, which is available in any place on the earth.

23.2.2 Fog Computing

Fog computing and edge computing may seem alike since they both take intelligence and processing near the formation of data. But, the main variance between the two lies in where the placement of intelligence and process control is situated. A fog set places intellect at the local area network (LAN). This construction conveys information from terminal points to a gateway, where it is communicated to bases for handling and return transmission of data. Edge computing applies intelligence and processing power in devices such as rooted computerization switches.

23.2.3 Edge Computing

The IoT has acquainted a limitless number of the end with ending profitable communication systems [25]. This drift has successfully made it more stimulating to combine data and processing in one data center, hence growing the practice of edge computing. This model achieves computations adjacent to the edge of the network, which is faster to the data foundation.

23.3 E-Healthcare Architecture Using Fog Computing

A diagram below (Fig. 23.1) displays a complete picture of a Health-IoT system that demonstrates how the elements can be in order over the three layers, which can be helpful in smart hospitals. The deep-rooted sensors note the related material of the patient's health; thus, the personal observance of various variables can be fitted out henceforth helping the patient [26]. This health data can also be assisted in utilizing geographic and social environments. Environment consciousness allows distinguishing a typical system and produces more direct reasoning concerning the state of affairs.

CAT scan, magnetic resonance imaging can be connected with other medical instrumentation for transportation of data from the machine. The machine-building contains the following essential elements:

Medical devices and mechanism of networks: Several ubiquitous identification, detection, and communicating ability, biomedical, and orientation signals are allowed to be accessed from the body and encompassing places. Wireless or wired communications technology, including Bluetooth, Wi-Fi, IR, networks of smart e-Health, helps in transportation of the data to the access providers.

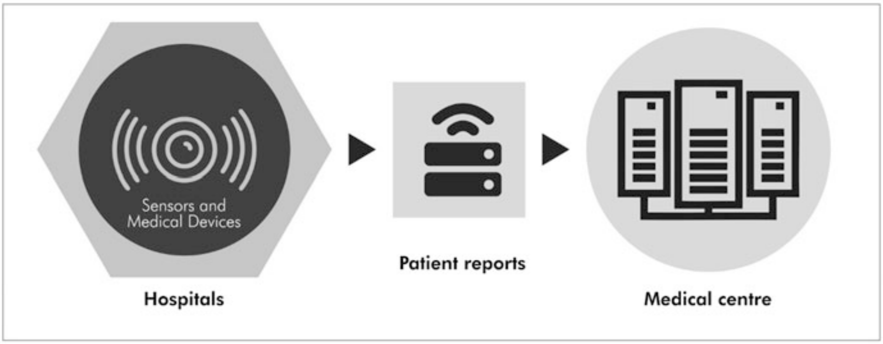

Fig. 23.1 A Smart E-Healthcare Architecture

E-health gateways: Based on various geographically distributed smart e-Health gateways, this layer is prepared, such as processing a virtual fog environment. All entryways act as a link among a sensor network on with the localized switch, which aids in various transmitting communications protocol. These upper-level provisions like data accumulation, data filtration, and spatiality reduction can only be acknowledged if information from different sub-networks, deliver protocol transition provided to them.

Back-end scheme: A cloud computing system that dispatch services like streaming, data storage, and data analytics are achieved in this back-end strategy. In the end, it can accessorize the web client presentation, such as a GUI, for feedback. The beginning of extensive data for statistical and medicine detecting, approaching the outbreak of diseases can be recognized by the controlled health and reference to this information.

23.4 Healthcare Access in Rural Communities

Rural inhabitants often meet obstacles to healthcare that bound their capacity to attain the attention they need. For rural people to have satisfactory contact, essential and suitable healthcare facilities must be accessible and obtainable in a well-timed means. The population of older adults is increasing day by day. They are the most vulnerable group for the society hence need special attention and customized solutions for healthcare and rescues [27–30]. Even when a satisfying source of healthcare amenities occurs in the open, there are other issues to reflect in terms of healthcare admittance [31]. For example, to have decent healthcare access, a rural occupant needs to have:

- Economical means to finance for facilities, such as health or dental cover, which is acknowledged by the supplier.

- Processes to spread and use service area, such as conveyance to facilities that could be placed at remoteness, and the capacity to take a salaried period off for labor to make use of such facilities.
- Self-assurance in their capability to converse with healthcare suppliers, mainly if the patient is not confident in English or is illiterate.
- A belief that they can use facilities without negotiating privacy.
- The certainty that they will achieve quality attention.
- Resolution to the above problems can be suggested in the few below mentioned ways.
- Blocks to care, with staff absences and health cover status, has to be resolved.
- Conveyance for the proper moving.
- Well-being knowledge is given to people.
- Humiliation related to situations in rural societies, such as intellectual health or substance exploitation, should be stopped.

Fog computing is very new terminology, which directly means that we get plenty of improvement opportunities. Figure 23.2 illustrates the Indian industrial IoT market size in this terminology; we have many issues regarding fog computing that concern people and prevent them from accepting this new technology though it has many benefits for the betterment of society on the health-related aspect. The ethical issues related to fog computation are mainly caused by the increase of the IoT-specific technologies at a very high rate nowadays [33].

IoT is based on a global infrastructure network which uniquely connects physical and virtual objects, by collecting the data from the sensors; the equipment used for communication between cloud and IoT device is localization [34–38]. The

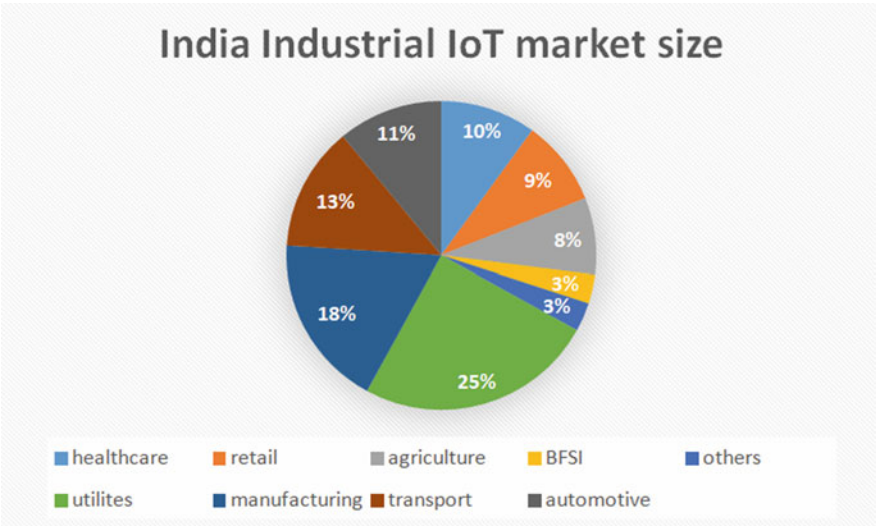

Fig. 23.2 Chart showing India industrial IoT market size [32]

RFID technology lies at the base of this process; however, the basic conception of the IoT has accumulated audience by including new technologies like Near Field Communication, 2D bar codes, wireless devices, localization technologies, 3 or 4G networks.

23.5 Fog in IoT Foundations

The present public health structure, which is made to keep up with a patient's illnesses, might not hold up in an age controlled by long-standing conditions and ever-growing advancements in medicine and technology. A counter to this problem can be stated if we take into account long-term and positive perspective. Fog computing will help us tackle the same.

The potential of fog computing includes managing of the swamp of data created by the IoT over the limit of the network. With the advent of mobile communication and numerous mobile apps, the trend is shifting toward finding the issues and identifying more efficient app development techniques [39–47]. Fog computing is now coming into the big picture; it can massively reduce operational costs when compared to cloud computing. As we have seen the benefits of fog computing like more mobility to users, privacy control, low latency, greater business agility, no bandwidth problem, real-time applications, all these things make fog computing a perfect fit for the IoT. Fog computing can also solve the problem of internet generated traffic. Fog computing is an upcoming surface for many IoT foundations. Making these services available through fog computing will pave the way for new business models in the future [48].

Local business models need localized unlocked foundation on which they could enhance their capacity and develop an unorthodox competing argument; these business ventures need rights to interact with and use data in a style which is beyond the old ideas and theories of collecting and analyzing data which are presently in play [49].

23.5.1 Six Mega-Trends Across Healthcare and Fog Computing

Figure 23.3 depicts the most trending healthcare applications of fog computing. Each trend is also explained in brief.

Cloud data: It is a framework of computer information and data keeping in which digital information is stored in multiple servers at different locations. The hosting organization manages these servers. These storage suppliers are accountable for keeping the data obtainable and reachable. Moreover, they are responsible for keeping this data secured and protected. A person could buy or rent storage for these suppliers for various purposes.

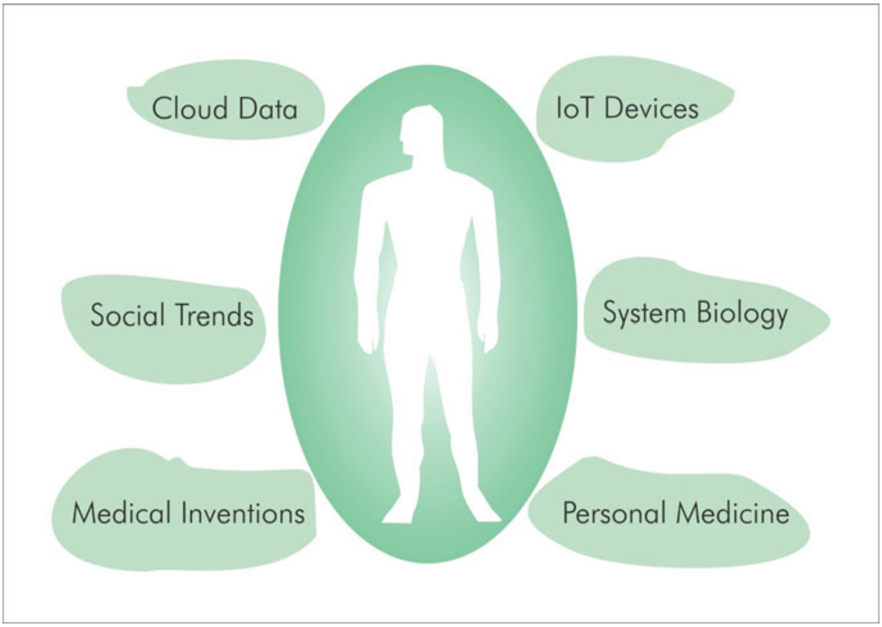

Fig. 23.3 Six mega-trends across a healthcare and fog computing

Social trend: With the growing market of fog computing and its application, data, and interface incompatibility between different products becomes an issue. This could, in the end, obstruct acceptance of the technology,

Medical intervention: It is the act of interceding with the intention of altering the outcome. In medical science, an intervention is usually interpreted in aiding a condition. For example, early intervention in the case of autism in children may help them to speak [7].

Personal medicine: Personalized medicine is a medical model that isolates people into various groups with medical judgment, practices, engagement, and goods being tailored to the singular patient based on their expected outcome of disease [50].

IoT devices: IoT devices consists of wireless sensors, software mechanism, and data processing devices. They are connected to a specific target that could be operated via the internet, sanctioning the transfer of information among devices or groups of people automatically without any human participation [51].

Systems biology: Systems biology is the computational and mathematical investigation and modeling of the compound and complex biologic systems. The study of the interactions and behavior of biological structures.

23.6 Current Trends and Emerging Challenges in Fog Computing Market

Recently, a new study was published by Polaris Market Research, which suggested that the global market for fog computing could reach up to USD 934 million by the year 2026. Fog computing supports cloud computing by boosting up its productivity, also paving the way for data computing capability.

The foremost use of fog computing is to make the cloud more efficient. However, the use of fog computing is also being done for security and privacy. Some significant applications of fog computing are used in several areas, which could include smart cities, smart devices, Healthcare 4.0, smart vehicles, and Industry 4.0 (Fig.23.4) (which will be heavily based on fog computing in the future) [52].

As per today's market, the dominance of fog computing is mostly by developed nations in North America, which include countries, the USA and Canada. These nations are also taking up some initiatives to encourage the promotion of IoT in these regions [53]. After North America, Europe is the second-largest market, which is also experiencing the same growth with the advancement of fog computing and IoT. However, Asia-Pacific is also envisioning to seek out for a high extension of fog computing, which can be credited to growing awareness of fog computing and the availability of IoT devices at standardized rates.

The digital market today is divided into hardware and software based on modules. The software market is indulging in rapid growth and has grabbed the

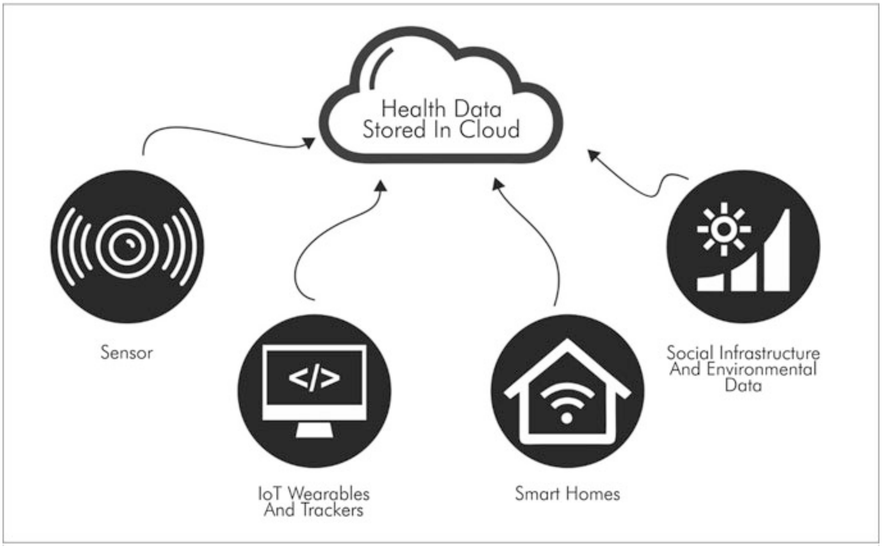

Fig. 23.4 Accumulation of healthcare data on the cloud through various entities across the environment

most substantial portion mostly due to low cost, user-friendly functions, also being future proof in features and designs. Additionally, the constant decrease in costs of devices of storage, sensors, and other semiconductor devices is an essential factor responsible for lighting the fire in the market growth of hardware for fog computing. Moreover, other factors involved in the market growth of fog computing are the advancements in network technology, which accounted for reduced prices of operating expenses across global organizations.

23.7 Future in Health IT

Health IT is moving forward, but the need for a bridge between IT innovations in the near future and the capability to hold such an infrastructure give rise to fog computing. Healthcare using fog computing can extend a helping hand to healthcare organizations, an excellent way to support their IT data, as they get ready for this new digital era. The primary reason for this change in health IT is because medical wearables are progressively being used by healthcare providers to monitor patient problems, providing them with remote medicine and even to support workers and robots in delicate jobs such as surgeries, which can include various transplants. Hence, there is a need for reliable real-time data handling, which is essential for these types of scenarios.

I am taking the example of a patient in the ICU. They have only a short span before their lives take a turn for the worst and turn disastrous, and if data from their wearable sensors got late and didn't reach the nursing staff within that scheduled time, life could be lost for sure. Healthcare providers need to be able to straightaway contact a patient at home with heart failure who shows a significant change in average step count, which might conclude their health has taken a step for the worst [54].

23.7.1 Stepping Toward a Digital Generation

To make the healthcare industry more interactive and efficient, two leading technologies play a key role. AI and wearable gadgets bring up the patient care infrastructure more effective and less complicated. The purpose of AI and wearable devices are discussed briefly.

23.7.1.1 Artificial Intelligence

Today's richly powered AI has significantly reduced the amount of time scientists and researchers put in to compute and analyze data, testing molecular combustions that help them to modify formulas and create new ones. Figure 23.5 shows the

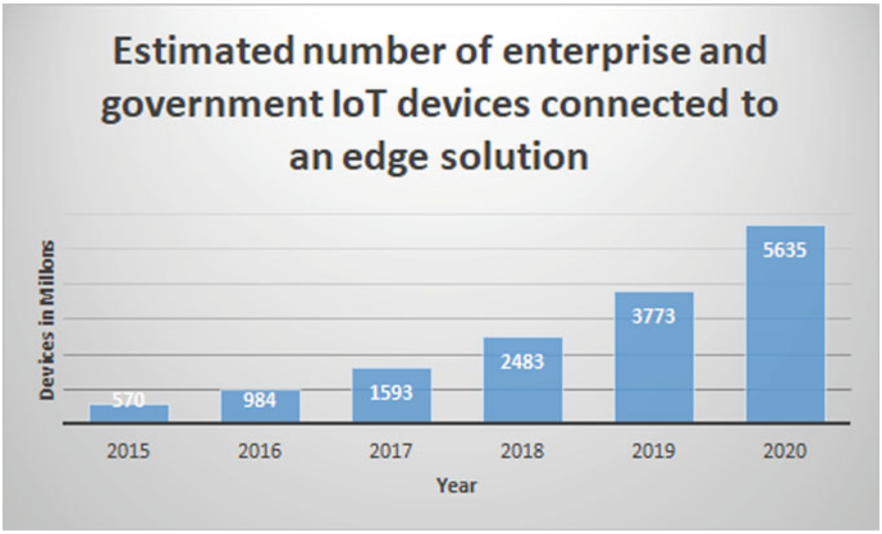

Fig. 23.5 Chart showing the estimated number of enterprise and government IoT devices connected to an edge solution [55]

growth of the estimated number of enterprise and government IoT devices connected to an edge solution. These days many pharmaceutical R&D labs are making use of AI to forecast the link between biological working and infection symptoms. Given the effectiveness of AI, it has the likeness to help boost the detection and treatment of patients. Although AI is an effective way to detect and treat disease symptoms, we must not forget that human expertise can guide AI discoveries. Massachusetts Institute of Technology (MIT), which is a center of AI, encounters, subsequently, its contemporary multi-million-dollar inventiveness with Harvard to progress to virtuous standards in the area of AI shows a good to evolve AI with assurance and also to accept its boundaries.

23.7.1.2 Wearable Gadgets

A considerable role is being played by these gadgets to attain data related to healthcare. Devices like Apple Watch are not only universally available, but they are also meant to be a cherished tool for promoting healthy behavior among human beings. Figure 23.6 illustrate the location of various fitness trackers on the body.

One of the main advantages of these wearable devices is that they can generate real-time data about patients, which furthermore could allow them to describe their problems much more precisely. Some applications also sync with fitness wearable's, which let patients maintain and share a more fulfilled and complex database for broad representation of their health with specialists. Such thorough data

Fig. 23.6 Location of various fitness trackers on body

will correctly permit healthcare workers to supply custom-made care. Moreover, it also enables patients to adopt a livelier part in handling their fitness.

Like every coin has two sides, we must also keep in mind the drawbacks of a data-driven future that we might run into along with effectiveness. Privacy is one of the ultimate factors of importance, data sharing, which has open new doors to possibly provide amenities and welfares for patients when, in the dishonest hands, data can also uncover patients to avoidable danger.

In technological groups, they believe in holding a "fail fast" approach or in adopting the faith that "done is better than perfect. Utmost significant modifications in healthcare will arise from the correct combination of modernization and consideration. By way of new encounters in technology, we fervently drive the borders of its potential higher and visualize the prospective they have to provide patients with personalized and better-quality care. We must, at the same time, shape tools that see the sights of every innovation through an eye of public, financial, and administrative filters to get significantly ahead of the consequences.

Patients being the top priority, we keep advancing to couple the capacity of tech-driven innovations and handling their problems, as we lay down into this intriguing and positive future in healthcare [56].

23.8 Legal, Ethical, and Social Issues

While fog computing offers numerous benefits, there are also impending disadvantages to it as well. There are three issues and concerns regarding every new computing; Legal, Ethical, and Social [57]. Dealing with a nonresponsive cloud provider is mostly difficult for small businesses that use the cloud for general purposes. Their minor proportion and narrow income styles make these companies much more vulnerable to some of the risks associated with cloud use and as a result of that, these small companies are not able to mobilize their lawyers in this way, and that is why these small companies may not be able to eliminate or migrate such performance-related problems that are led by the provider. So organizations and companies must start using cloud computing, they should put some efforts in selecting a cloud provider who is reputable and reliable so that efficient work is achieved [58].

Privacy and confidentiality: Through the use of a cloud system, your business's sensitive information and the material will be kept on various servers globally, and you will perhaps have partial familiarity or control concerning this data. It is highly vital and the problem of grave concern for cloud users who have a tremendous amount of confidential information like healthcare workers, banking data, space program-related data, and credit card corporations. If this has fallen into the wrong hands, countless serious issues/problems get fashioned, and eventually, these companies will be held accountable.

Unable to screen or regulate data motion: Since third-party providers are the ones controlling the data, cloud customers often do not have the skill to supervise where the information is stored onboard and when or how it is progressed. According to [60]: "There must be protocols in place to ensure that one company's data is not blended with data from another company."

23.8.1 Drivers of Ethical Problems

- NFC (Near Field Communication) is a radio communication device tuned at a frequency of 13.56 MHz that is capable of providing communication between two objects that comes under the area of up to 20 cm [59]. The possible uses of

NFC are contactless payments (through mobile phones), sharing of information in the various network, mainly social networks, and many more.

- 4G technology consists of two combinations between 3G and WiMAX. WiMAX is "WORLDWIDE INTEROPERABILITY FOR MICROWAVES ACCESS." 4G provide a broad coverage go 3G network, and the provide speed with the help of WiMAX.
- Sensors like proximity, temperature, ambient light, accelerometers, and others are used to connect devices/objects. Some of these sensors are nanosensors, smaller enough that the size is billionth of a meter. These nanosensors are effectively used to cure, diagnose many illnesses such as AIDS, to check the quantity of pollution in water, to connect robots, which will help us in many disasters and make our life simple. The technique of processing human emotions is based on sensors. The mixture of these new era technologies can help pave the way for discipline literature surroundings in which more and more happenings will be reached unconnected to the things close to us, being surefooted of connecting and this gives the option to do new big business, the facilities accessible by technology might be modified depending on the actions done by the specific being, the device, the setup or given time constrains.

Additional potential usages of the IoT are those connected to the family circle, health nursing devices, and smart cities. Considering into thought these characteristics, a future of endless possibilities could be achieved.

23.9 Security Concerns

When treating massive quantities of private and vital data, safety is a significant concern for both cloud suppliers and cloud users. Cloud users want to be sure that their data is being sheltered and securely moved. Cloud suppliers know that security is a critical factor for success. Since cloud workers are the ones who truly grip and manage the data, it is hard for cloud users to monitor and rheostat how the data is held. The foremost main question with safety is the privacy and secrecy of the information being saved on the cloud. The main worry with this topic is the jeopardy of data dropping into the wrong hands or being distorted for other resolves. The additional issue with security is the drive and behavior of data by cloud workers.

23.10 Legacy Health Breached Due to Phishing Attack: A Case Study

In Portland, Oregon-based Legacy Health notified in the second quarter of 2018 that 38,000 patients' data had been breached due to a phishing attack. On June 21, informed officials determined unauthorized access to some employee email accounts. However, the unauthorized access was started some weeks earlier in May 2018. The health system employed a third-party forensic firm to investigate and determine the cause of breaching. Officials discovered patient data was enclosed in the breached email accounts, which included demographic data, health insurance data, dates of birth, billing details, medical data, and some patients, private details such as Social Security numbers and driver's licenses. Patients who were affected were given 1 year of free health monitoring services. In this case, if the health data is protected and stored through fog computing servers, this mishap could be prevented. Fog computing enables the hospital authority to minimize the uses of emails and other transmissions through a central server. In the past, so many health data related accidents occurred, which caused lots of inconvenience to the various stakeholders of the healthcare system.

23.11 Conclusion

The primary purpose of fog computing is to lessen the processing load of cloud computing. It consists mainly of transferring data, networking, storage, and providing analytic closer to devices and applications that are working at the network's edge. Hence, with the growth of IoT devices trend, fog computing continues to evolve. This chapter presents cog computing as a helping hand for the cloud in handling and managing the two exabytes of data produced on a day to day basis from the IoT. The chapter also describes E-Healthcare Architecture using fog computing and the presence of this new technology in the rural areas of India. Emphasis of this revolutionary technology in different businesses of healthcare is also highlighted. The need for processing data nearer to where it is generated and needed to resolve the challenges of large data volume created daily is emphasized. Fog computing speeds up response to events by getting rid of a round trip to the cloud for investigation and hence reducing latency. The chapter also presents the societal, legal, and ethical concerns about fog computing in a sophisticated field like healthcare. The last part of the chapter describes a case study of a health data breach in the past and highlights the importance of fog computing in such scenarios.

It averts the demand for expensive bandwidth add-on by uploading gigabytes of network traffic from the central network. It also defends sensitive IoT data by analyzing it internally in an organization. Moreover, organizations that choose fog computing increase their business by developing more profound and faster insights, higher service levels, and improved guard for privacy.

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