Chapter 4
Importance of Fog Computing in Healthcare 4.0

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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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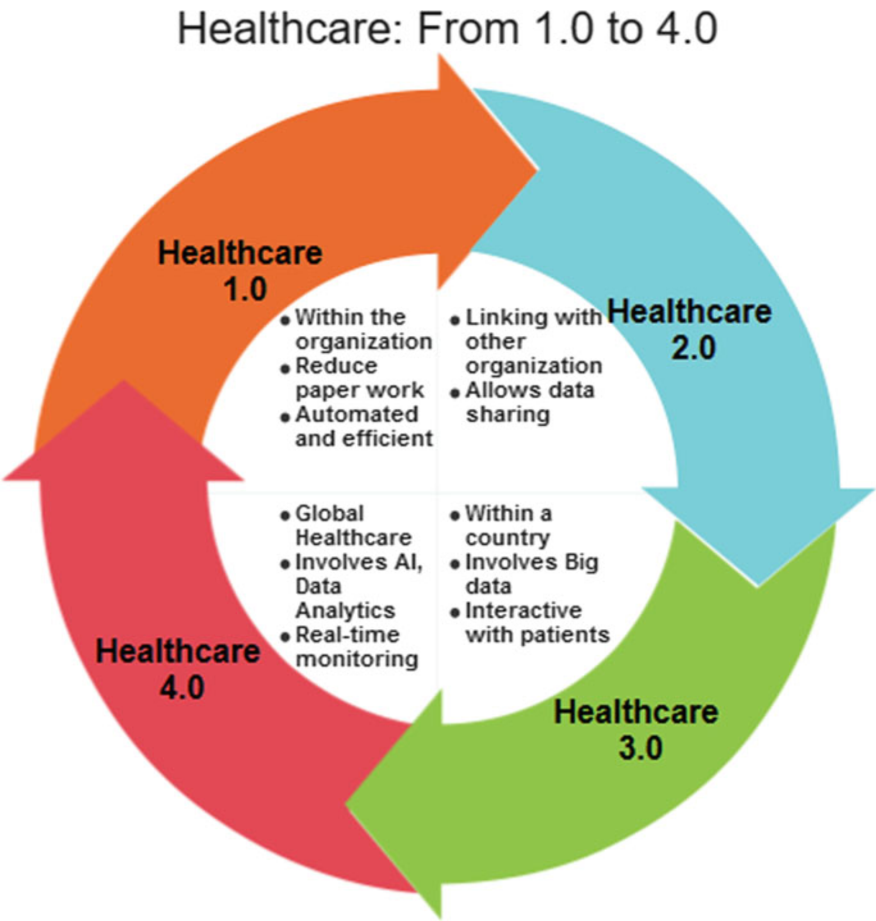

Fig. 4.1 From Healthcare 1.0 to Healthcare 4.0

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

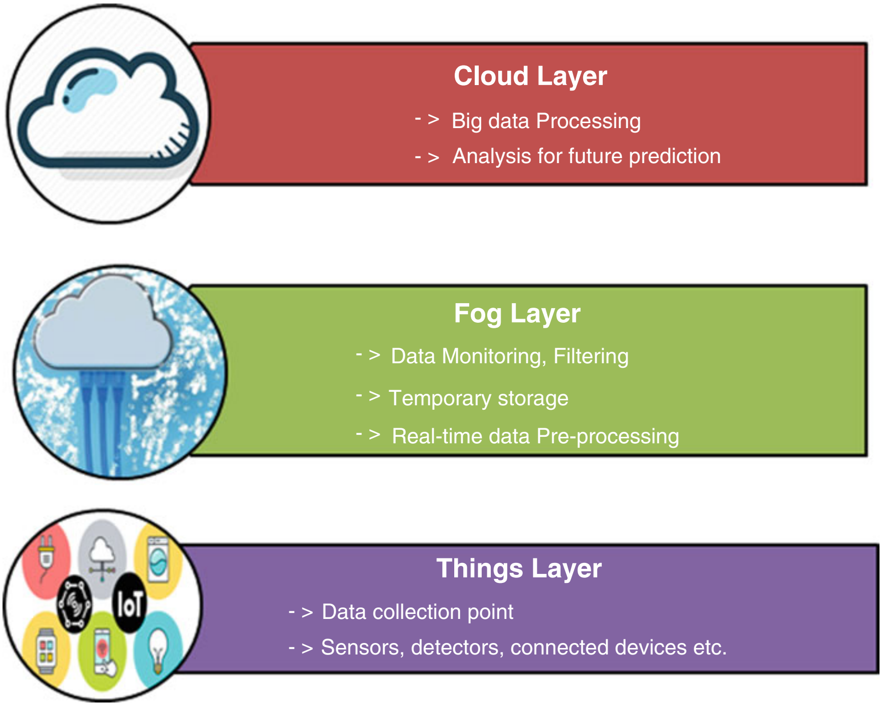

Fig. 4.2 General fog computing architecture

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.

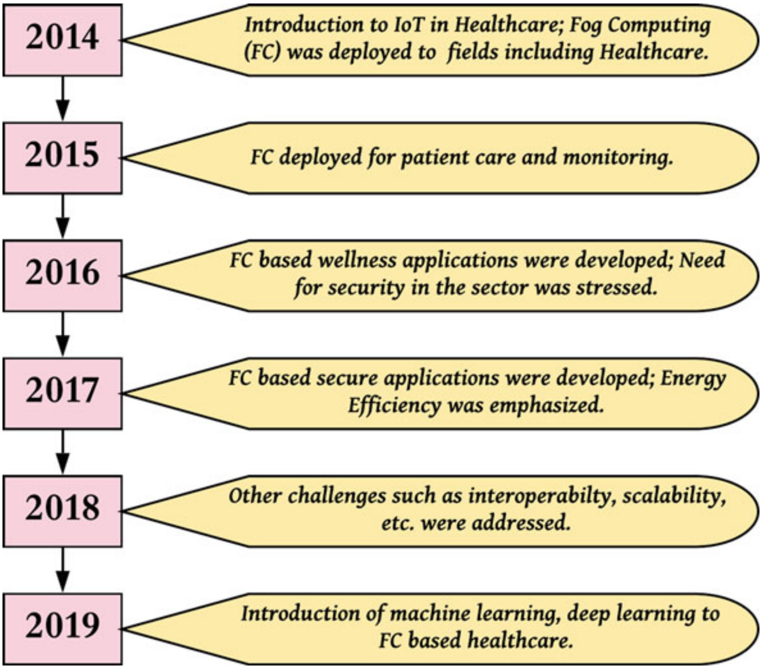

Fig. 4.3 Year-wise categorization of literature on Fog Computing and Healthcare

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

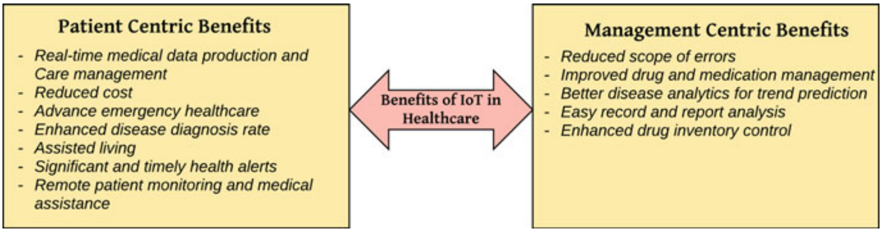

Fig. 4.4 Benefits of IoT in Healthcare

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.

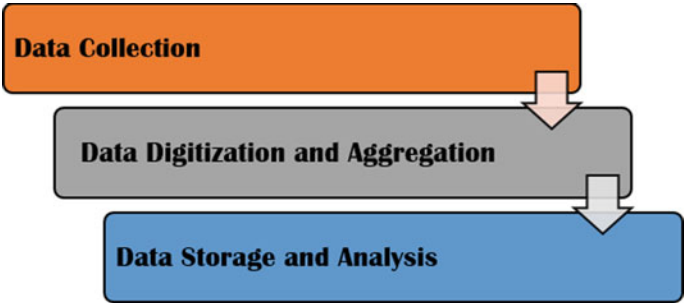

Fig. 4.5 IoT in Healthcare

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

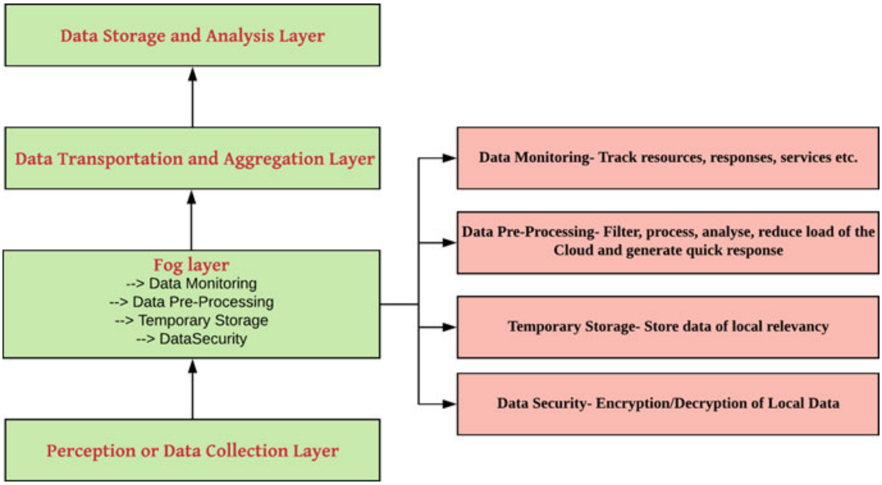

Fig. 4.6 IoT fog-layered architecture

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 healthcare 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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