Chapter 5
Impact of IoT in Healthcare: Improvements and Challenges

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1 Introduction

In the modern era of communication technology, the internet is one of the most powerful tools throughout the world. As the internet and the World Wide Web have grown to link all signs of intelligence, the idea and practice of connecting everything fructified as the Internet of Things (IoT). In 1999, the term IoT was coined by Kevin Ashton during his work on supply chain management domain (Ashton 2009). At present, there are many definitions of IoT, which may vary based on the context and perspectives of those defined it. IoT may be defined as the "integration of sensors and actuators embedded in physical objects that are capable of establishing communication between devices without human interference" (Ambrosin et al. 2016). The basic foundation of IoT is machine-to-machine communication where two or more devices communicate with each other through radio-frequency identification (RFID) and sensor networks (Da Xu et al. 2014; Bi et al. 2014; Zhong et al. 2011). Even though IoT has survived for more than a decade, the rapid development of electronic devices such as wireless connectivity and mobile devices is the basic reason for the rise of this technology. Further, the growth of the digital economy and knowledge-based capital has also played a key role in the rapid development of this technology. The objective of IoT is to provide a global network-assisting universal computing and context awareness among devices, which are primary requisites of ambient intelligence. The enormous usage of IoT offers benefits such as technical optimization,

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enhanced data collection, increased efficiency, etc. among various businesses. With more than 12 billion devices connected to the internet and researchers of CISCO had estimated that there would be 26 times more connected things than people on the earth by 2020 (Evans 2011). IoT also provides solutions to a variety of applications in different sectors such as industrial automation, traffic congestion, smart cities, waste management, healthcare, agriculture, smart grids, emergency services and so on. Moreover, it is predicted that more than 25 billion things or objects will be attached to the internet to build intelligent decision systems (Ray 2018). Hence, IoT will be emerging as an advanced area of research soon.

Healthcare has always been an important area of research with vast scope. Healthcare is defined as the process of diagnosis, avoidance and medication of disease, illness and other physical and psychological deteriorations for sustainment or enhancement of health. Healthcare is provided by physicians associated with health fields. To meet demands of needy people, healthcare systems are established. As per the World Health Organization (WHO), the efficient performance of healthcare system needs strong finance mechanism, highly trained and sufficiently paid workforce, accurate information and well-maintained health facilities to deliver standard medicines and technologies to the health needs of the targeted population (WHO 2018). Since the last few decades, it has been experienced that there is a stable rise in life prediction in many regions of the world leading to a sharp rise in the number of elderly people. In a recent report of the United Nations (UN 2013: 8–10), it has been forecast that there would be 2 billion (20 per cent of the world population) older people by 2050. It also specifies that more than 89 per cent of aged people live independently. The survey indicates that about 80 per cent of aged people older than 65 suffer from at least one chronic disease (Weinstein 2005). The WHO and UNICEF reports state that each year 585,000 women die from reasons related to pregnancy and childbirth (WHO-UNICEF 1990). It is also found from the WHO survey that out of 57 million global deaths, 63 per cent die from chronic diseases, heart attacks, cancer, blood pressure and glucose. Currently, there has been significant pressure on the healthcare system due to the growing rate of the ageing population and chronic diseases. To overcome the pressure of chronic patients and elderly people, many clinical applications have been proposed (Bau et al. 2014; Lanata et al. 2014; Lobelo et al. 2016; Shemeikka et al. 2015). There are many problems in the current healthcare system such as time-lapse in the diagnosis of diseases, providing same health history when every time patient visits the physician, unavailability of critical information of the patient and so on. Moreover, most of the cancer-related deaths are caused due to the late diagnosis of abnormal cellular growth at the final stage. In the modern era, improving the quality of the healthcare system by providing quality service to the patient with reduced healthcare cost and time-lapse is considered as one of the important goals of the healthcare industry.

Due to the rapid development of inexpensive devices and storage and minimized energy consumption rates, smart devices are bringing a radical change in the development of IoT in healthcare. It provides an extensive study of the current technologies that are used within the proposed framework. The growth of IoT is based on the identification and perception technology. To address short-range communication, radio frequency identification technology is used. For receiving and transmitting signals, RFID uses a tag and a reader. Nowadays, RFID technology with highlighted features such as low cost and reliable tags and continuous monitoring capabilities provide a better solution for IoT (Buettner et al. 2008). Bluetooth, which is used for short-distance communication between two or more devices, is a wireless communication network. It implements security methods based on authentication and encryption (Cvitić and Vujić 2015). On 2.4 GHz band, it utilizes 79 radio frequency channels with a bandwidth of 1 MHz. The connectivity is provided up to 100 m at a speed of 3 Mbps. As IoT applications are used in telemonitoring, all devices used in this scenario are based on low energy consumption solutions such as Bluetooth (Tadoju and Mahesh 2015; Gentili et al. 2016). In the implementation of IoT, ZigBee technology often plays a major role because of its significant features such as security and network resilience, interoperability and low power consumption (Gao and Redfern 2011). As this technology uses a mesh network, even when an object fails, the other objects continue to communicate with one other without disruption (Ndih and Cherkaoui 2016).

Wireless technologies are considered as one of the main components of IoT. Wi-Fi has been extensively used in applications such as home automation, wearable sensor devices, smart devices and smart grids (Lee and Kim 2016). At present, most of the hospitals support Wi-Fi-based LANs. IEEE 802.16a standard is the basic version of WiMAX. It can be operated in licensed and unlicensed frequency bands that have frequency band spectrum ranging from 2 to 11 GHz. WiMAX-standard IEEE 802.16b that operates in a frequency band range of 5–6 GHz provides quality real-time voice service to customers. Besides, WiMAX IEEE 802.16c provides interoperability among various vendor devices and gadgets and operates in a frequency band range of 10–66 GHz (Gupta and Kaur 2018). Rapid development has occurred in mobile communication networks. The first generation uses an analogue system for carrying of voice over the network. The second-generation (2G) network provides text messaging with digital network infrastructure. The third generation (3G) came into existence due to the increasing demand for online information exchange (Gonzalez et al. 2008). The fourth generation (4G) has been developed to overcome the drawbacks of 3G such as quality of services, bandwidth and to provide resources for a reduced cost. Further, the fifth generation (5G) provides high system capacity and improved energy efficiency when compared with 4G. Finally, the sixth-generation (6G) network was initiated to unify satellites and to provide effective coverage in a wider area (Parikh et al. 2010; Li et al. 2009).

Wireless sensor networks (WSN) consist of divergent sensors for observing physical world conditions. Features such as coverage of a larger area, less installation cost and real-time data gathering are benefits provided by WSNs. Because of the benefits, WSNs have been applied in various fields of healthcare such as observing of physiological parameters, drug and device management in hospitals and handling of an emergency (Pandian et al. 2008; Tseng et al. 2006). Sensing technologies play the main role in acquiring physiological parameters from the patient (Woznowski et al. 2015; Ciuti et al. 2015). Different types of sensors such as accelerometers and pressure sensor, electrocardiography (ECG) monitoring and heart rate sensor, fitness band and smartphone (Lo et al. 2005) are used in monitoring healthcare system. These sensors are categorized as inertial, biosensor and wearable sensors, accordingly.

Some brief and detailed studies on applications of IoT in healthcare have been analyzed by several pieces of research. Ahmadi et al. (2018) examined and evaluated 60 different papers on IoT during the period 2000–2016 in the healthcare domain to find out the important application areas, usage of various architectures and technologies and the concerned challenges, compatibility and security issues in the deployment of IoT architecture in healthcare. This paper aims at providing a complete report that reveals the importance of the IoT architecture in the healthcare system. Further, this study also would help officials in the healthcare sector to formulate plans for improving the quality of life and defeating health inequities by implementing IoT in the healthcare sector. The authors have comprehensively reviewed different applications such as home, hospital, etc. drawing upon theoretical considerations. Also, they have presented a tabular comparison of various technologies such as Bluetooth, RFID, ZigBee, Wi-Fi, WiMAX, LR-WPAN, WSN to solve the challenges of the latest trends in IoT. AbdElnapi et al. (2018) have proposed an analysis of medical sensors, technologies and projects used by IoT in the healthcare domain. They have presented a brief description of different technologies used in IoT-based healthcare system such as radio frequency identification, cloud computing and Big data. They have represented different wearable devices and sensors available along with their usage in tabular form. Furthermore, a brief description of IoT projects such as Smart-Mirror, Technology-Enhanced Emergency Management, E-care@Home, CAMI project, etc. has been presented. The study also focuses on the key challenges such as cost of the system, standardization, synchronization, quality of service, balancing and so on.

Yuehong et al. (2016) discussed the implementation in dealing with new situations by examining emerging technologies such as smart devices in the healthcare industry. As rapid development occurred in controlling healthcare, this paper aimed at describing the history, development of futuristic studies and standard assessment of emerging technologies in IoT healthcare systems. Further, the authors discussed some special IoT methods applied for various healthcare systems with their future utilities. They mainly focused on identification, location and communication technologies with its detailed applications. Moreover, some case studies along with various implementation strategies of IoT and Big data have been elaborated. Whitmore et al. (2015) have presented the current state of IoT by reviewing the literature (of 127 papers) in areas such as enabling technologies, applications, challenges, business models and so on. To assist researchers, they have presented future directions and overview/survey of IoT. The results of the literature review based on category, subcategory, section category have been represented in tabular form. Atzori et al. (2010) have done a systematic review of enabling technologies, IoT paradigm, application areas in IoT such as transportation, healthcare domain, smart environment, personal and social domain and issues in the implementation of IoT such as addressing, networking, security, privacy and standardization efforts. They have also represented differences between RFID system, WSN and RFID sensor network in tabular form.

Table 1 depicts the analysis of various reviews on IoT in the healthcare system.

Table 1 Analysis of previous literature reviews on IoT in healthcare

Author/Year	Focused area	Not covered
Ahmadi et al. (2018)	Application areas in healthcare, IoT technologies, IoT Protocols, IoT communication models	Latest technologies such as fog computing, Big data and current challenges in IoT have not been addressed in detail
AbdElnapi et al. (2018)	Medical sensors, IoT project, IoT technologies	Only few IoT technologies in IoT have been addressed
Yuehong et al. (2016)	Enabling technologies, smart healthcare devices and systems, strategies and methodologies	IoT Protocols, challenges and applications of IoT in the healthcare system have not been addressed
Whitmore et al. (2015)	Challenges, business models, technology, applications, overview, future decisions	Not detailed description of technologies and business models has been represented
Atzori et al. (2010)	Different visions of IoT paradigm, technologies such as RFID systems, wireless networks, RFID sensor networks, principal applications and open issues in IoT	Only a few emerging technologies have been addressed

Despite all these studies, some specific areas such as related issues in architecture, challenges, applications, etc. remain to be covered. Drawing upon this fact, a novel attempt has been made in this chapter to discuss various applications and implementation issues in an analytical manner. This chapter makes a systematic review of various papers in different areas of IoT such as applications, architecture, enabling the deployment of IoT in the healthcare sector for technologies and challenges to provide a complete survey that serves as a basis for the deployment of IoT in the healthcare sector for stakeholders such as technocrats, researchers and common people.

2 Application Areas of IoT in the Healthcare Sector

This section describes different areas of the healthcare sector implementing IoT.

2.1 e-Health, m-Health and k-Health

The usage of IoT in healthcare has been highlighted due to rapid development in communication technologies such as smartphones and sensor devices. Various wearable sensor devices have been developed to collect physiological signals from the human body. These signals are then securely forwarded to healthcare organizations that assist in handling a medical emergency.

e-health (Ball and Lillis 2001) is one of the emerging fields in the healthcare sector. In e-health, information related to medical and public health is delivered through the internet and related technologies. It not only connects technical development but also connects communication and information technology to enhance healthcare services locally, regionally and globally.

m-health (Almotiri et al. 2016) is a component of e-health. m-health or mobile health is defined by Global Observatory for e-health (GOe) as medical and public health practice supported through smart devices such as smartphones, sensor devices, personal digital assistants (PDAs) and other wireless devices. To enhance healthcare services globally, m-health also makes use of smartphone facilities such as voice messages, short messaging services, GPRS, GPS, Bluetooth, 3G and 4G telecommunications, etc.

A systematic analysis of the security challenges that have been raised due to the increased implementation of IoT for e-health on the cloud was done by Ida et al. (2016). They have proposed latest solutions to provide security to the medical information against the malicious attacks. They have discussed the possible opportunities, security challenges, network susceptibilities such as data interchange, unauthorized access and multifarious vulnerability and application susceptibility such as native application, cloud and cryptographic vulnerability to secure the e-health information in IoT and cloud without decreasing the quality of service. Furthermore, they proposed an architecture that aims at providing security at different layers of the architecture, namely, hardware, network and software.

Chen et al. (2018) have presented three approaches, namely, power level decision (PLD) algorithm, power level and packet size decision algorithm (PPD) and Global Link Decision (GLD) scheme for deploying fast, accurate and energy-efficient IoT system in e-health care. They have reviewed previous studies and proposed a synthetic optimization approach for improving the performance of the network. The GLD scheme increases reliability and minimizes overall delay by increasing battery energy. The optimal solution is provided by considering two algorithms namely preceptual liver prediction (PLP) algorithm that reduces energy consumption while transmitting data by choosing optimal power level for links and PLD algorithm selects best packet size either by reducing delay or by reducing energy consumption. Further, they have evaluated the performance of GLD scheme by conducting experiments with parameters such as delay, reliability and lifetime of the network and comparing results with lower power level decision system (LPLD).

The concept of fog computing and smart e-health gateways is implemented in IoT-based healthcare system for providing various end-user services such as real-time data processing, embedded data mining, etc. Rahmani et al. (2018) have presented the architecture of fog-assisted IoT-based smart e-health gateways to meet the challenges such as energy efficiency, scalability, reliability, etc. They have also elaborated the features and services of fog computing-based IoT healthcare system. Further, they explained the functionality of architecture by implementing a prototype of smart e-health gateway namely UT-GATE. The functionality of fog-assisted system illustrated with case study called early warning scores that aim in monitoring severe illness of patients.

Focused on providing collaboration between components of hardware and software for incorporating new facilities and challenges in e-health services, Firouzi et al. (2018) have addressed challenges such as scalability, compatibility, safety, device–network–human interfaces that have emerged with the advent of wearable biosensors and Big data analytics through different case studies. They have explained with examples that maximization methods can be used to solve major problems in e-health. Further, they have elaborated the benefits of IoT, the functionality of the three-layer system architecture and have provided a case study of integrative multi-omic investigation of breast cancer for incorporating IoT solutions in the e-health.

Saha et al. (2018) have proposed a new solution, namely, alarm activation that serves the prescribed medicine in time by displaying it on LCD after making a thorough review of the existing health monitoring system. They have also proposed a scheme that sends alert to the patient through email and SMS if any one of the parameters related to healthcare exceeds the threshold value. It aims at providing optimum surroundings that make the environment comfortable for the patient. They have also explained the functionality of basic modules or block diagrams such as health monitoring and data collection, medication and precaution according to needs of the patient, database preparation from acquired data, sending alerts to patients and medical reports to concerned doctors for handling emergencies.

Ullah et al. (2016) presented their work in two components. First, they have thoroughly reviewed the existing literature for the proper set-up of IoT in the areas of e-health and m-health. Second, they have developed a new model called 'k-Health care' consisting of four layers, namely, sensor layer, network layer, internet layer and services layer that serves as a platform for monitoring patients health data using built-in smartphone sensors and body sensors. They have represented the comparative analysis of different IoT healthcare models and applications by considering parameters such as the provision of emergency aid, technology used, standards followed, support for heterogeneous device and implementation of artificial intelligence in tabular form. They have elaborated the working of k-Health care model with a case study. Furthermore, the challenges in the k-Health care model such as security and privacy are considered as limitations of this paper.

2.2 Hospital Management System

Even though hospital attains a certain degree of informatization through Hospital Information System, it has some deficiencies such as manual input of medical information, fixed networking mode, single function, relatively independent between each department, etc. The rapid rise of the IoT has provided a way for a smart hospital where it is possible to connect any items with the internet. Smart hospital support features such as information exchange, intelligent identification, positioning, tracking, monitoring and management of medical data could be accessed by using technologies such as RFID, infrared sensors, GPS, laser scanners and other information sensing equipment.

Thangaraj et al. (2015) have explored the real-time implementation of smart autonomous hospital management system using IoT. The concept of data modelling of medical devices, critical data validation, the workflow of remote device coordination, network architecture middleware, application services have been explained in detail. They have represented smart data objects along with their significant data processing in IoT-enabled healthcare system through algorithmic implementation. Further, they have explained the functionality of framework as architecture.

Muhammed et al. (2018) discussed the implementation of the ubiquitous framework to ensure the quality of service in healthcare through the concepts of edge computing, deep learning, IoT and high performance computing (HPC). They have considered the challenges affecting healthcare domains such as network dormancy, bandwidth, energy consumption, etc. They have explained the working of the ubiquitous framework of three-component and four layers by implementing the algorithm and by applying technologies such as Cloudlets, Deep Neural Network. This paper illustrates advances related to IoT and Big data and advanced applications of mobile healthcare in UbeHealth system. They have assessed the UbeHealth system by considering a nationwide case study and three extensively used dataset to improve the rate of data transmission, routing decisions and to reduce the network traffic.

Rajeswari et al. (2018) have proposed a system that tracks the patient's location and reduces the risk of chronic diseases by continuous examining of patients by physicians with a decision support system. It aims to reduce the risk of ischemic heart disease with IoT devices. They have discussed the trends and opportunities available with IoT in the healthcare domain. They have explained the functionality of IoT in healthcare by considering the use case 'Care at Home'. The proposed work consists of a mobile application that collects all parameters that are relevant to analyzed the risk of the patient using the decision support system. Further, they have addressed key challenges in the implementation of IoT in rural areas such as security, cost of equipment, use of analytical tools, ability to operate IoT devices in rural healthcare, etc.

An approach named HM-oriented Sensing Service scenario (HM-SS) was designed by Neagu et al. (2017) to provide quality service and approachability in health monitoring system by combining cloud computing with IoT technologies. They have explained the opportunities provided by correlating cloud and IoT technologies such as data management, provision for sharing of data, etc. Furthermore, the architecture of the healthcare system based on three layers and the architecture for a smart hospital system that is based on six layers have been elaborated. They have explained the applications of IoT in HM by considering examples of diabetes, heart rate monitoring, body temperature monitoring, etc.

2.3 Home Healthcare

As per the WHO report, the life expectancy has risen beyond 60 years (Navarro 2000). By 2030, it is estimated that healthcare services will be transformed into home care services (Epstein and Street 2011; Koren 2010; Branger and Pang 2015). Rapid development in technology can address various aspects of ageing people such as regular body temperature monitoring, emergency and medication management, rehabilitation methods at the time of strokes and telemedicine (Plaza et al. 2011; Klasnja and Pratt 2012; and Ludwig et al. 2012). Different architectures have been developed for home healthcare monitoring. Care of ageing or disabled people is supported by an IoT-based service called ambient-assisted living (Costa et al. 2015). Ambient assisted living (AAL) can provide better solutions for ageing people suffering from chronic diseases and disabilities (Singh et al. 2017; Kleinberger et al. 2007).

Blackman et al. (2016) have explained three generations of AAL. Wearable devices and alarms have been used in the first generation. Sensors that respond to hazard detection have been presented in the second generation. The third generation combines first- and second-generation devices for monitoring patient health condition and to assist in emergency medical situations.

Woznowski et al. (2015) presented an AAL architecture based on sensor technology, namely, SPHERE. This architecture consists of three components such as body-worn sensors, video sensors and environmental sensors. This architecture provides a better graphical user interface for care donors as well as the patient's family members. Sensing data are collected and then analyzed to send messages to the user periodically. The 3D simulation environment is also provided by this architecture.

Dimitrov (2016) has explained the emergence of new models due to the transformation of healthcare from the traditional system to the digital system. It focuses on the analysis of medical IoT and Big data to avoid chronic diseases and to improve the overall lifestyle of people. It has illustrated that the results of IoT in pharma offer the latest technologies and services in the treatment of disease by reducing the amount of cost incurred on wearable devices and sensors such as Myo, Ziopatch, MyDario, Sleepbot, etc.

Thakar and Pandya (2017) have discussed the impact of the IoT in healthcare for monitoring the health of the aged and children in remote areas regularly. They have explained the functionality of various monitoring systems such as body temperature monitoring, oxygen saturation monitoring, electrocardiogram monitoring, elderly monitoring, etc. Further, they explained applications and services provided by IoT devices in the healthcare system. This paper also addresses various security issues and challenges raised in the implementation of IoT devices in healthcare.

A systematic study of techniques based on the latest publications and productions used for healthcare and assisted living known as the Internet of Health Things (IoHT) has been done by Rodrigues et al. (2018). This work presents analysis and review of advances made in the technologies, challenges to be met and techniques to be used in IoHT; it would serve a platform for beginners as well as experienced researchers. They have reviewed publications on IoHT in the areas such as remote healthcare, monitoring healthcare solutions based on the smartphone, assisted living and wearable devices. They have discussed services provided, companies, product availability and a brief description of characteristics of each of the identified IoHT solutions has been presented. A comparison analysis of technologies used in selected publications by considering criteria such as security, communication technologies and hardware/OS platform.

3 Communication Models in IoT

To establish communication between these heterogeneous objects, the Internet Architecture Board (IAB) has published a list of guidelines in March 2015, based on which, four communication models have been deployed in IoT, as explained in Rose et al. (2015).

i. *Device to Device Communications*: In this model, two or more devices communicate with each other through an intermediate application server mainly using. IP networks or the internet. Protocols such as Bluetooth, Zigbee and Z-wave are used in communication. It is normally used in small applications such as home automation system IoT devices such as bulbs, thermostats, switches, door locks and so on. In this model, messages can be exchanged between devices by using a specific type of protocol.
ii. *Device-to-Cloud Communications*: In this model, the application service provider acts as an interface between the IoT device and internet cloud for exchanging data and controlling message traffic. To establish communication between device and IoT cloud, it makes use of mechanisms such as wired Ethernet or Wi-Fi connections. IoT devices such as the Nest Labs Learning thermostat and the Samsung smart TV make use of Device-to-Cloud communication model.
iii. *Device to Gateway Model*: In this Gateway model, application layer gateway serves as an interface between IoT device and cloud service. This model is also called a device-to-application-layer gateway (AGL) model. AGL provides services such as security, protocol translation and so on. This model is used in consumer devices like a fitness tracker. These devices cannot connect directly to IoT cloud service. These devices make use of smartphone app software that acts as an intermediate gateway to connect fitness tracker to IoT cloud. Rise of 'hub' devices in the home automation application is an example of a device-to-gateway model.
iv. *Back-End Data-Sharing Model*: This model is an extension of the single device-to-cloud communication model where users can collect and export data from a heterogeneous environment and can transmit securely to another user. Only authorized users can access the sensed data from IoT devices. This model suggests an integrated cloud service approach that facilitates the interoperability of smart devices in a cloud environment. Table 2 lists protocols used in different communication models.

Table 2 Communication models and protocols used

Communication model	Protocol stack
Device-to-device communication model	Bluetooth, Z-Wave, ZigBee
Device-to-Cloud communication model	HyperText Transfer Protocol, TTP, TLS, Transmission Control Protocol, Internet Protocol, CoAP, DTLS, User Datagram Protocol
Device-to-gateway model	HyperText Transfer Protocol, TLS, Transmission Control Protocol, IPV6, CoAP, DTLS, User Data gram Protocol
Back-end data-sharing model	HTTP, CoAP, Oauth 2.0, JSON

4 Technologies Used in IoT

The major enabling technologies that have been used in connecting IoT devices for establishing communication are summarized below.

i. *ZigBee*: ZigBee Alliance proposed a new wireless networking technology namely ZigBee (Kinney 2003; Zillner and Strobl 2015). It is an IEEE 802.15.4 standard designed for monitoring and controlling a limited range network because of its short transmission range and low data rate. It belongs to the wireless personal area network (WPAN) because of its low range and high-level communication protocol. Applications such as home automation, smart energy devices, lighting, HVAC are considered as major areas of ZigBee technology. The unique features of this technology are self-organizing, multi-hop, mesh networking and long battery lifetime.

ii. *RFID*: Radio frequency identification (Juels 2006; Jia et al. 2012) aims addresses short-range communication between 100 m and 1 km. It is ISO/IEC 15,693 standard designed for identifying and tracking objects by using small electronic chips called tags. The data rate is up to 1–24 Mbps and to access devices, it needs internet-enabled gateway. The unique features of this technology are low cost, large mobility and efficiency in identifying devices and objects. The implementation of the TCP/IP protocol has not been provided in RFID communication modules. The main areas of applications are agriculture, healthcare and medicine management, defence, environment monitoring, disaster warning management, transportation and so on.

iii. *Bluetooth*: Bluetooth (Bisdikian 2001; Harris et al. 2016) is a wireless communication IEEE 802.15.1 standard. It has been designed for short-range and low-cost devices of wireless radio technology. It is a wireless communication protocol designed for replacing short-range wired communication with lower power consumption. It has a unique feature of providing personal area network during communication and communicates to its neighbour who is not in visual line of sight. It is also known as WPAN. As many devices in the IoT have limited energy resources, it plays a vital role in IoT.

iv. *Bluetooth 4.0 LE*: Bluetooth low energy (BLE) (Gomez et al. 2012; Nair et al. 2015) is a subset to Bluetooth v 4.0 and has been used since June 2010. Previously it was known as WiBree. It consists of a new protocol stack and profile architecture. The unique features of Bluetooth low energy are new adverting mechanism and it uses asynchronous connectionless MAC. Because of this unique feature it offers low latency rate and fast communication.

v. *6LoWPAN*: The 6LoWPAN (Ma and Luo 2008; Kasinathan et al. 2013) is a wireless connection-oriented protocol that consumes less power and utilizes the IPV6 network. In this, the router transmits the data through 6LoWPAN gateway to its next neighbour who in turn is connected to an IPv6 domain. IPv6 then transmits data to the corresponding destination device. In 6LoWPAN, sensor nodes make use of network protocols like HTTP and TCP/IP.

vi. *Z-Wave*: This was developed by Zensys and further aided by Z-wave Alliance (Badenhop et al. 2017; Unwala and Lu 2017). It is designed as open communication and low-energy-consuming protocol. It is mainly used in automation and light commercial environment. It can pass messages from the control unit to one or more nodes in a reliable way. It consists of two types of devices such as a poll controller that sends commands to slaves and the second device sends a reply to the controller for carrying out commands.

vii. *Wi-Fi*: Wi-Fi (Aneja and Sodhi 2016; Dhawan 2007) is an acronym of wireless fidelity. It is an IEEE 802.11 standard protocol that connects devices to the internet without wires. The Wi-Fi standard family uses the wireless network for short-distance communications. Various series of Wi-Fi networks are IEEE 802.11, IEEE 802.11a, IEEE 802.11b, IEEE 802.11 g, IEEE 802.11n, IEEE 802.11e: QoS extension, IEEE 802.11f: extension for managing handover and IEEE 802.11i security extension. It works on an unlicensed spectrum of 2.4 GHz band.

viii. *WiMAX*: WiMAX (Abichar et al. 2006; Wang et al. 2008)) is broadband wireless technology. WiMax is a wireless version of ethernet. It is primarily designed to provide broadband access to customer premises. The unique features of WiMAX are high speed, large range distances and access to a large number of users. WiMAX overcomes the physical limitation of wired infrastructure by providing services to areas that are difficult for wired infrastructure to reach.

The comparison analysis of communication technologies is presented in Table 3 and its advantages and disadvantages are listed in Table 4.

Table 3 Communication technologies: a comparison

Parameters	Wi-Fi	WiMAX	6LoWPAN	Mobile communication	Bluetooth	Bluetooth 4.0 LE	ZigBee	RFID	Z-wave	WSN
Standard	IEEE 802.11 a, 802.11c, 802.11b, 802.11d, 802.11 g,802.11n	IEEE 802.16	IEEE 802.15.4	GSM, CDMA in 2G UMTS, CDMA 200 in 3G, LTE in 4G	IEEE 802.15.1	IEEE 802.15.4	IEEE 802.15.4	ISO/IEC 15,693	Z-wave alliance	IEEE 802.15.4
Topology	Star	Mesh	Mesh, star	Radio access network topology	Star	Star	Mesh	–	Mesh	Star or mesh or tree
Energy Consumption	High	Medium	Low	Medium	Very low	Very low	Very low	Very low	Very low	High
Max Data rate	1 Mbps–6.75 Gbps	Fixed: 1 Mbps–1 Gbps mobile 50–100 Mbps	40–250 Kbps	50–100 Kbps in 2G 200 Kbps in 3G 0.1–1 Gbps in 4G	1–24 Mbps	5–10 Mbps	20 kbps–250 kbps	106 K–424 Kbps	9600 bits or 40 kbits	20–250 Kbps
Range	20–100 m	<50 km	10–20 m	Entire cellular area	<30 m	5–10 m	10–100 m	Up to 100 m	30 m	20–100 m
Spectrum	2.4–5 GHz	2G–11 GHz	2.4 GHz	1.8 GHz in 2G 1.6–2.0 GHz in 3G 2–8 GHz in 4G	2.4 GHz	2.4 GHz	2.4 GHz	2.4 GHz	2.4 GHz	2.4–5 MHz
Channel Bandwidth	22 MHz	1.25 M–20 MHz	868–EU: 868.6 MHz NA: 902–928 MHz WW: 2400–2483.5 MHz	900 MHz in 2G 100 MHz in 3G 100 MHz in 4G	1 MHz	2400–2480 MHz	0.3/0.6 MHz, 2 MHz	860–960 MHz	868 MHz	902–928 MHz
Cost	High	High	Low	Medium	Low	Low	Low	Low	Medium	High

Table 4 Advantages and disadvantages of different IoT technologies

Technology	Advantages	Disadvantages
ZigBee	• Cost is low • Consumes less power • Provides longer battery life • Easy to install and implement • More number of devices can be connected • Supports controlling and monitoring of remote devices • Supports scalable and reliable networks • Supports wireless synchronization with other technologies	• Does not support a larger range of communication • Rate of data transmission is low • Vulnerable to security attacks
RFID	• It provides efficiency by scanning multiple items at once • It provides durability as it can handle exposure to sun and rain • It is less vulnerable to security attacks	• Cost is high • It cannot transmit through materials like metal and liquid • Less reliable and accurate when compared with barcode scanners • Difficult to implement and takes more time
Bluetooth	• Cost is low • Easy to install • Easy to connect heterogeneous devices • It is a wireless communication network	• Vulnerable to security attacks • Does not support a large-range communication between devices • Only two devices can be connected at a time
Wi-Fi	• Easy to install • It can be accessed anywhere within the Wi-Fi AP (Access point) coverage area • Wi-Fi-enabled USB dongles are available at low rates • 802.11n, 802.11a, 802.11c supports a data transmission rate of 300 Mbps and higher	• Data transmission rate decreases when more number of computers are connected to the Wi-Fi access point • Vulnerable to security attacks • It can connect up to 30–100 m
Mobile communications	• It offers more efficiency and productivity • It provides flexible and quality service • Provides more access to modern apps and services • It provides efficient communication in and out of the workplace • It consists of enhanced networking capabilities	• Cost is high • More vulnerable to security attacks • It requires additional training

(continued)

Table 4 (continued)

Technology	Advantages	Disadvantages
Z-Wave	• Easy to install network configuration • It consumes less energy • It provides longer battery life • It provides interoperability with different devices available in IoT • The devices that make use of Z-wave technology are available at low cost	• Does not support a larger range of communication • Cost increases if the range of communication increases • More vulnerable to security attacks • It can connect a few number of nodes (232 nodes) when compared with ZigBee (65,000) • It supports the data transmission rate of only 100 kbps
Wireless sensor networks	• Easy to establish network setup • It can transmit data through sea, mountains, rural areas or deep forests • It provides more flexibility in establishing new workstation • Cost of implementation is less • New devices can be easily accommodated	• Less secure • Speed is less when compared to a wired network • Difficult to configure • Due to signal attenuation cannot transmit through walls and large distances • More vulnerable to security attacks • Data transfer rate is low • It may be affected by Bluetooth • Cost is high

5 IoT Protocols

The internet applications make use of HTTP protocol, which is not suitable in a constrained environment. Therefore, protocols such as Constrained Application Protocol (CoAP), Message Queuing Telemetry Transport (MQTT), MQTT-SN, Advanced Message Queuing Protocol (AMQP), Extensible Messaging and Presence Protocol (XMPP) and Data Distribution Service (DDS) have been developed for implementing the IoT architecture (Al-Fuqaha et al. 2015; Luzuriaga et al. 2015).

i. *Constrained Application Protocol (CoAP)*: IETF proposed CoAP protocol for accessing and managing information from sensor devices. The goal of CoAP is to satisfy the requirements of resource-constrained devices. It consists of two layers. It makes use of UDP protocol that made it more suitable for IoT applications (Al-Fuqaha et al. 2015). It supports messages such as confirmable, no confirmable, acknowledge and reset with transaction codes 00, 01, 10, 11.
ii. *Message Queuing Telemetry Transport (MQTT)*: MQTT is a lightweight protocol that is used for device-to-device communication on low-bandwidth environment. It consumes less power. It is a reliable protocol as it uses TCP. MQTT consists

of three components such as connection definitions, routing and endpoints (Al-Fuqaha et al. 2015). The components of this protocol are publisher, broker and subscriber.

Publishers → Broker → Subscribers

While the responsibility of publisher and subscriber is to send messages to the client the broker's responsibility is to dispatch messages between the sender and appropriate receiver. MQTT packet length consists of fields such as control header, protocol, flags, length of message and payload. The difference between MQTT and MQTT-SN is that MQTT makes use of TCP/IP protocol, whereas MQTT-SN makes use of UDP and ZigBee protocol.

iii. *Advanced Message Queuing Protocol (AMQP)*: AMQP is an open-source and asynchronous protocol that aims at providing interoperability among a large range of heterogeneous systems (Al-Fuqaha et al. 2015). Its functionality is similar to that of MQTT. Also, it makes use of a message-exchange mechanism that provides separate queues for the corresponding subscriber.
iv. *Extensible Messaging and Presence Protocol (XMPP)*: IETF proposed a message-oriented protocol, namely, XMPP (Karagiannis et al. 2015). Initially, it was used for chatting and exchange of messages. As it uses XML, it is reused in IoT applications. It makes use of both publish/subscribe and request/response architectures. As it does not provide quality service, it is not used in the machine to machine communication. It consumes more power because of the additional overheads of a large number of headers.
v. *Data Distribution Service (DDS)*: Object Management Group (OMG) designed DDS protocol (Pardo-Castellote 2003). As it depends on the brokerless architecture, it provides a reliable and better quality service in IoT. It makes use of data-centric publish-subscribe and data local reconstruction sub-layers. Data-centric publish-subscribe sub layer is responsible for message delivery and data-local reconstruction sub-layer is responsible for the integration of DDS into the application layer. Among all the protocols, Advanced Message Queuing Protocol and Message Queuing Telemetry Transport are the most widely used protocols. Differences between AMQP and MQTT are presented in Table 5.

6 IoT Challenges

Many challenges have arisen in the deployment of IoT in the healthcare sector. In the following section, we briefly address these challenges.

As IoT devices move around different locations, their IP and network address have to be changed accordingly. This can be done by using the RPL protocol, which in turn creates additional overhead. Another issue that comes up in *mobility* is the address of service provider has to be changed due to interruption in the service.

Table 5 Differences between MQTT and AMQP

	MQTT	AMPQ
Protocol	TCP/IP	TCP/IP
Use of protocol	It is designed for small devices and works on low-bandwidth environment	It works on any device with any bandwidth
Architectures	Publisher/subscriber	Publisher/subscriber
Frame utilization	Uses a stream-oriented approach and does not support fragmentation	Uses the buffered-oriented approach and supports fragmentation
Response	Uses basic acknowledgement	Uses different acknowledgement schemes
Header size	2 bytes	8 bytes

As IoT in healthcare is concerned with emergency management, *reliability* plays an important role. In IoT applications, the system must be reliable and fast, otherwise it may lead to erroneous results. As millions of devices are connected to the same network, another issue that raises is *scalability*. As new services and devices are frequently connected to the same network, IoT applications must be designed in such a way to provide extensible services and functionality. As large number of devices is interconnected, another issue that rises is continuous *monitoring* of devices to enhance the overall performance of the system. Providers should continuously monitor fault, performance, accounting, security and configuration problems raised in the implementation of IoT. It can be considered as software and hardware *availability*. *Software* availability means services should be available to all authorized users at any time. Hardware availability means devices can be accessed and operated easily with protocols of IoT. To embed with IoT devices, protocols should be designed compactly. As different heterogeneous devices are connected, another important issue is *interoperability*. Both application developers and service providers should handle interoperability to provide services regardless of the platform. As large volumes of patient data are shared, privacy and confidentiality play an important role in the implementation of IoT in the healthcare sector. These *security* vulnerabilities are classified as hardware, network and application vulnerabilities (Ida et al. 2016). To provide privacy and confidentiality of patients' data, the system should be protected from these vulnerabilities.

Based on the above studies, Table 6 presents the distribution of papers based on the type of disease/condition, IoT application, technology, services, protocols, architecture and publication type.

Table 6 Distribution of papers based on type of disease/condition, IoT application, technology, services, protocols, architecture and publication type

Author(s)	Type of disease/condition	Home health care/ehealth/mhealth/hospital management system	Type of services	Type of technology	Type of protocol	Journal/conference	Type of architecture
Williams et al. (2016)	Patient monitoring	e-Health	Challenges			Journal	
Sreekanth and Nitha (2016)	Patient monitoring	e-Health		Wireless sensor networks		Journal	IoT Gateway
Ida et al. (2016)		e-Health	Challenges			International Design & Test Symposium (IDT)	IoT Cloud
Ullah et al. (2016)		e-Health and m-health		RFID, WSN		Conference	
Sallabi and Shuaib (2016)		e-Health			SNMP	Conference	
Dimitrov (2016)	Chronic diseases	m-Health				Journal	
Sivagami et al. (2016)	Hospital and patient monitoring	Hospital management system		RFID with enhanced WSN (HSN)	6LoWPAN	Journal	IoT Gateway
Natarajan et al. (2016)	AAL	m-health		RFID	MAC Protocol	Journal	
Laplante et al. (2016)		Hospital management system		RFID		Journal	

(continued)

Table 6 (continued)

Author(s)	Type of disease/condition	Home health care/ehealth/mhealth/hospital management system	Type of services	Type of technology	Type of protocol	Journal/conference	Type of architecture
Yeole and Kalbande (2016)	Children monitoring and critical patients					Conference	IoT Cloud
Neagu et al. (2017)	AAL	Hospital management system				Conference	IoT Cloud
Manogaran et al. (2018)	Patient monitoring	Hospital management system		Wireless mobile sensor network		Journal	MF-R (meta fog redirection) and GC (grouping and choosing)
Kumar and Gandhi (2018)	Heart diseases	Hospital management system		5G mobile networks		Journal	IoT Cloud
Prasad et al. (2017)	Patient monitoring	Hospital management system		Wireless body sensor networks, Zigbee	6LoWPAN	Journal	IoT Cloud
Wu et al. (2017)	computer-assisted rehabilitation	e-health		Bluetooth		Journal	IoT Gateway
Laplante et al. (2017)	Acute care, community-based care and long-term care	Home healthcare and Hospital management system	Quality requirements			Journal	

(continued)

Table 6 (continued)

Author(s)	Type of disease/condition	Home health care/ehealth/mhealth/hospital management system	Type of services	Type of technology	Type of protocol	Journal/conference	Type of architecture
Chen et al. (2018)	Patient monitoring	e-Health		Wireless sensor networks		Journal	
Rahmani et al. (2018)	AAL	e-Health, m-health		Wi-fi, Bluetooth	6LoWPAN	Journal	Smart e-health gateways
Farahani et al. (2018)	Chronic diseases	e-Health	Challenges			Journal	IoT Fog
Jabbar et al. (2017)	Heart disease	e-Health				Journal	
Thakar and Pandya (2017)	Chronic diseases	Home healthcare				Conference	
Ali et al. (2018)	Chronic diseases	Hospital management system				Journal	Type-2 Fuzzy logic
Sanjay et al. (2018)	Patient monitoring	e-Health		Bluetooth		Journal	
Rizwan et al. (2018)		e-Health		Nano communication		Journal	
Abatal et al. (2018)		Hospital management system				Conference	IoT Cloud
Rajeswari et al. (2018)	Heart disease	m-Health				Conference	

(continued)

Table 6 (continued)

Author(s)	Type of disease/condition	Home health care/ehealth/mhealth/hospital management system	Type of services	Type of technology	Type of protocol	Journal/conference	Type of architecture
AbdElnapi et al. (2018)	Patient monitoring	e-Health		RFID, Bigdata and Cloud computing		Conference	
Saha et al. (2018)	Patient monitoring	Home healthcare and e-health		Raspberry pi		Conference	
Tse et al. (2018)			Challenges	Bigdata		Journal	
Mahmoud et al. (2018)		e-Health	Challenges	Cloud computing		Journal	CoT
Belesioti et al. (2018)		Home healthcare and m-health				Conference	VICINITY project
Mutlag et al. (2019)				Fog computing		Journal	
Rodrigues et al. (2018)	AAL	m-Health				Journal	

7 Interpretation of Collected Data

As the deployment of IoT in healthcare has been increasing, many research papers on IoT in healthcare have been published in various databases. For this reason, we have selected some standard databases such as IEEE, Springer, InderScience, Science Direct, etc. to create a complete bibliography of review papers on IoT in healthcare. The papers that are published up to 2018 on IoT in healthcare are selected to search for review papers. We used keywords such as IoT in healthcare, e-health, m-health, hospital management system and home healthcare to extract research papers from the concerned standard databases. In our study, related research papers are reviewed through their abstracts, introduction, basic preliminaries, methods and conclusion. To identify appropriate research papers that apply to our research inclusion and exclusion criteria were considered. Therefore, to choose appropriate publications, inclusion measures have been described as follows:

1. Concentrating on technologies that have been used in IoT in healthcare, without considering whether they have been used in a remote or short distance.
2. Concentrating IoT architectures in healthcare and their main components and organization.
3. Concentrating latest trends, their usage and deployment of IoT along with the challenges in the healthcare environment.

However, we have considered the following exclusion measures.

1. Papers or abstracts those were not accessible.
2. Papers that are irrelevant to IoT in healthcare.
3. Papers of IoT in healthcare those were disseminated in the encyclopaedia, data articles, mini-reviews, thesis reports, patent reports and other literature reviews.
4. Papers that were focused on other domains such as agriculture, home automation, industrial automation, transportation, defence, etc.

Later, all the essential data are gathered from the concerned papers. The data that have been considered from each paper are as follows: communication models, enabling technologies, important application areas of IoT in healthcare, the impact of IoT technology in healthcare, latest trends in IoT healthcare and challenges raised in the deployment of IoT in healthcare.

In our analysis, several papers have been found based on the inclusion and exclusion measures that we have considered. From those papers, a total of 5614 papers were extracted that were related to the study. Among those 5614 papers, 4364 papers were found as duplicates and 1000 papers were excluded during the review of abstracts and 150 papers were filtered during the full-paper study. Finally, the full text of the remaining 100 papers was considered for the entire study. A schematic process for searching, by considering inclusion and exclusion criteria, is illustrated in Fig. 1.

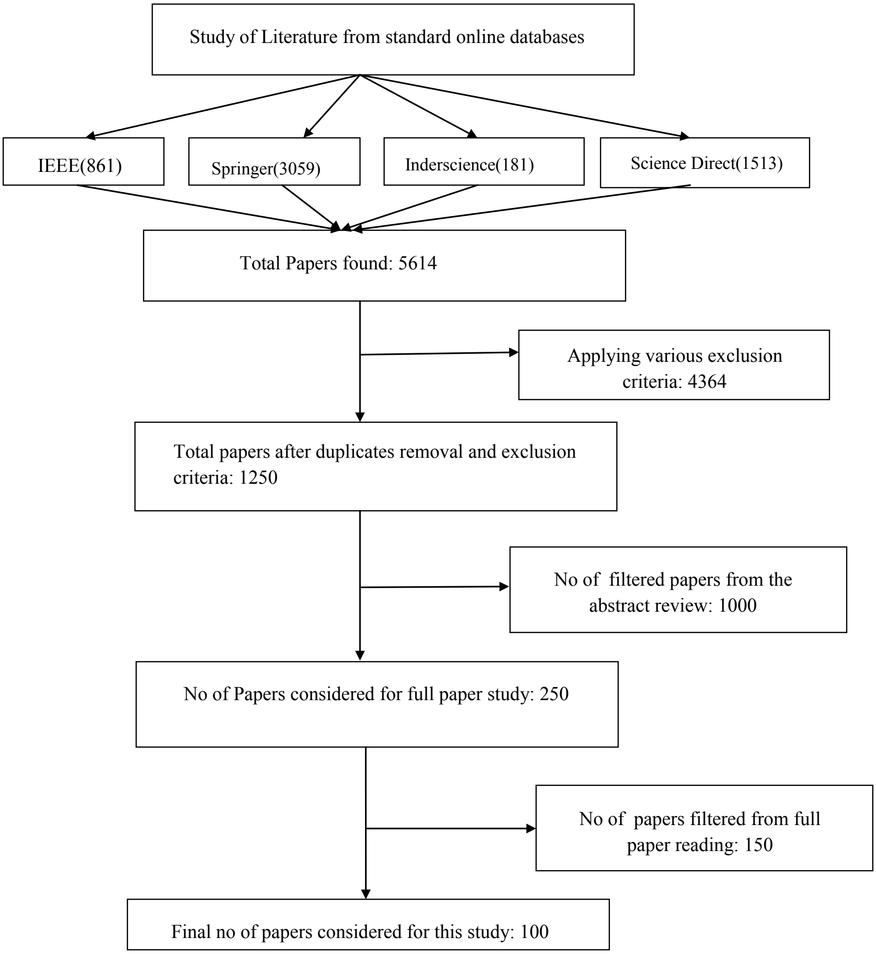


Fig. 1 Flow diagram of the systematic review of research work by considering inclusion and exclusion measures

8 Critical Investigation

The quality of patient life, monitoring of elderly people with chronic disease from remote locations and handling of emergencies can be improved by deploying IoT in the healthcare domain. In our systematic review, a total of 100 papers related to IoT in healthcare have been identified. In our study, a systematic review of application areas in healthcare, enabling technologies used in IoT architecture, advantages and disadvantages of enabling technologies, challenges and issues in the deployment of IoT in healthcare has been carried out. Some of the important inferences drawn are presented in the following.

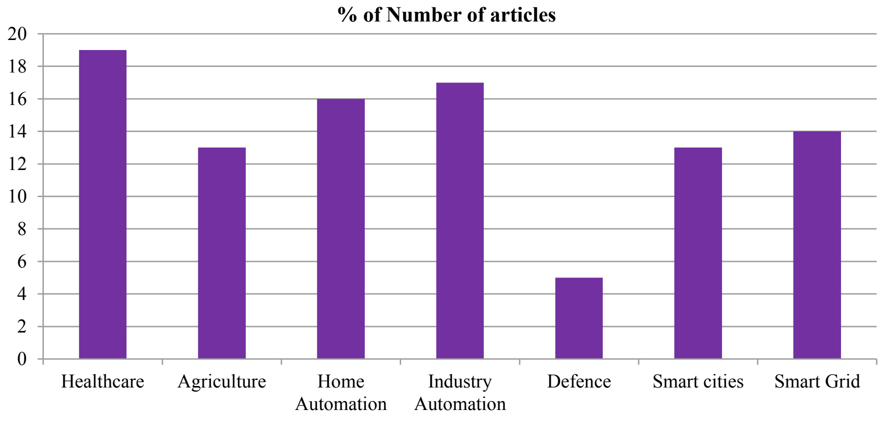


Fig. 2 IoT in healthcare against other domains

8.1 Distribution of Published Articles by IoT in Healthcare Against Other Domains

Figure 2 depicts the distribution of articles by IoT in healthcare sector against other domains. From this chart, it can be observed that healthcare sector is one of the prominent areas among other domain areas of IoT such as agriculture, home automation, industrial automation, defence, smart cities and smart grids. More number of articles have been published in the healthcare sector when compared with other areas of IoT (19%).

8.2 Distribution of Published Articles by Publication Year

From Fig. 2, it is observed that IoT in the healthcare sector has been the most significant among other sectors. More research articles were published in IoT in healthcare. Figure 3 represents the number of papers published in IoT in healthcare from 2014 to 2018. From the chart, it may be concluded that there is a drastic increase in the number of publications from 2016 onwards.

8.3 Distribution of Published Articles by Technologies

The distribution of papers based on enabling technologies in healthcare is depicted in Fig. 4. From the chart, it can be concluded that most of the researchers are making use of RFID technology (29%). As illustrated in the chart, Bluetooth is the next enabling technology that researchers have used (22%). Also, technologies such as Wi-Fi, Wimax, Zigbee have an equal frequency in paper contribution.

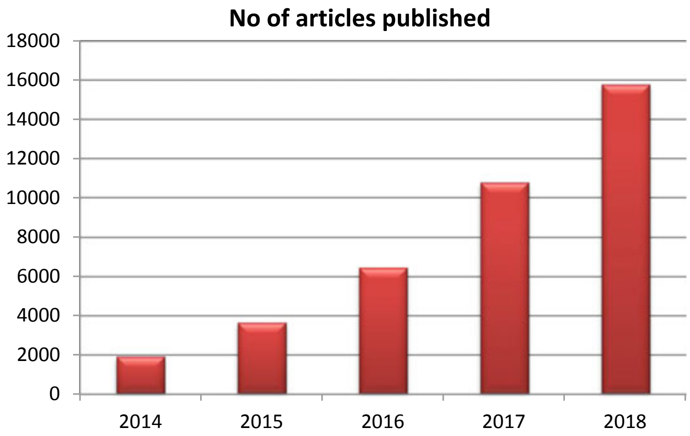
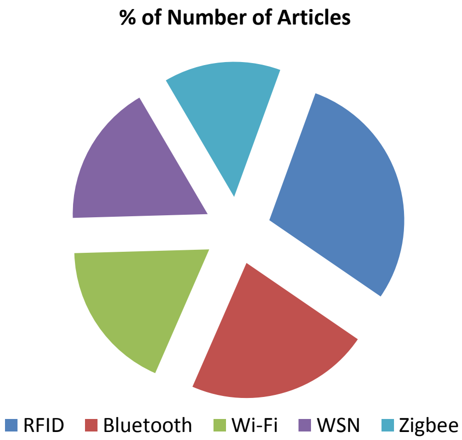


Fig. 3 Statistics of paper publications on IoT in healthcare in the last 5 years

Fig. 4 Distribution of papers based on enabling technologies



8.4 Distribution of Published Articles by Application Areas in Healthcare

In our study, it is established that IoT has been deployed in several application areas in healthcare sector such as e-health, m-health, hospital management system and home care. It has been observed that higher number of research works has been carried out in home care and hospital management system. Distribution of articles by application areas in healthcare is depicted in Fig. 5.

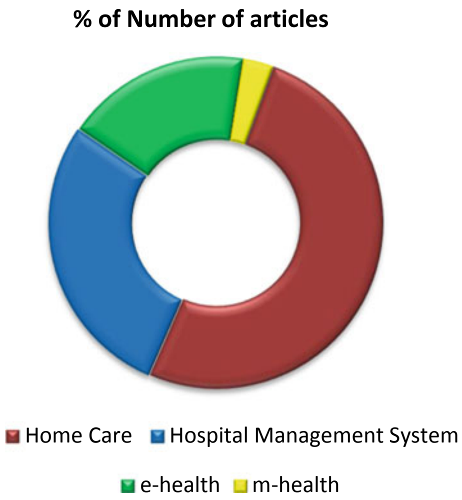


Fig. 5 Distribution of papers in IoT application areas

8.5 Distribution of Articles by Journal and Conference

The papers were selected from various standard journals based on the keyword search. Table 7 depicts the distribution of articles by journal as well as conference. IEEE journals have the top contribution regarding IoT in healthcare (21.7%). *Future Generation Computer Systems* has the second highest contribution (16%). *International Journal of Scientific Research in Computer Science, Engineering and Information Technology* has the third highest contribution of articles (4.3%). The strategies for classifying the articles are described in Table 7.

9 Challenges and Discussions

Due to the increasing use of IoT in a real-time environment, extensive research on IoT has been carried out and many articles have been published by researchers since the last few years. As managing health issues is becoming a serious concern, IoT in the healthcare sector is the eye-catching domain for many researchers. Despite several articles on IoT in healthcare, it is found that there remain several concerns in which extensive research work has to be carried out.

In the deployment of IoT in the healthcare domain, various vendors exist to provide different devices with different protocols. Therefore, standardization becomes a complex issue. From this perspective, detailed studies have to be carried out in providing integrated services using a standard protocol. As medical data are sensitive and it is related to the privacy of the patient, data can be easily misused if it is not properly managed. Big data governance in the health domain is less developed when compared with other domains. In our study, there was no evidence of a framework that provides a complete view of how Big data analysis has been done. Furthermore, due to the dynamic nature of healthcare resources, patients need to share these resources with the lowest cost. From a clinical aspect, implementation of the governance framework and topology- and ontology-based heuristic algorithms are necessary for effective handling of huge volumes of data and for finding optimal solutions for large-scale systems. It has also been observed in the healthcare system

Table 7 Distribution of articles published by journal and conference

Conference/journal	Article type	Frequency	Weightage (%)
International Conference and Exposition on Electrical and Power Engineering	Conference	2	4.3
International Conference on Consumer Electronics	Conference	1	2.1
IEEE Sensors Journal	Journal	1	2.1
IEEE International Conference on Computational Intelligence and Computing Research	Conference	1	2.1
IEEE International Circuits and Systems Symposium	Conference	1	2.1
Procedia Computer Science	Conference	1	2.1
International Journal Of Advance Scientific Research And Engineering Trends	Journal	1	2.1
IEEE	Journal	10	21.7
healthcare Systems Management: Methodologies and Applications	Journal	1	2.1
Research J. Pharm. and Tech	Journal	1	2.1
International Journal of Innovations &Advancement in Computer Science	Journal	1	2.1
International Journal of Scientific Research in Computer Science, Engineering and Information Technology	Journal	2	4.3
Future Generation Computer Systems	Journal	6	13
International Conference On Big Data Science And Engineering	Conference	1	2.1
International Federation for Information Processing	Journal	1	2.17
Int. J. Enterprise Network Management	Journal	1	2.1
International Research Journal of Engineering and Technology	Journal	1	2.17
International Conference on Inventive Communication and Computational Technologies	Conference	1	2.1
International Journal on Future Revolution in Computer Science & Communication Engineering	Journal	1	2.17

(continued)

Table 7 (continued)

Conference/journal	Article type	Frequency	Weightage (%)
Systems, Applications and Technology Conference	Conference	1	2.1
Euromicro Conference on Digital System Design	Conference	1	2.1
Internet of Things Journal	Journal	1	2.1
Journal for Research	Journal	1	2.1
Digital Communications and Networks	Journal	1	2.1
International Conference on E-Health and Bioengineering	Conference	1	2.1
Computers and Electrical Engineering	Journal	2	4.3
International Journal of Mobile Computing and Multimedia Communications	Journal	1	2.1
Wireless Communications and Mobile Computing	Journal	1	2.1
Computer Communications	Journal	1	2.1

that large volumes of patient data from several sources raise security challenges. Therefore, extensive research work has to be carried out in areas of trust and privacy to prevent the unauthorized use of the patient's personal information.

In recent years, the concept of Socail Internet of Thing (SIoT) has been introduced and that provides an environment for intelligently networking the objects. Most of the articles use cloud-based architecture. The issues raised in the implementation of cloud-based architecture such as latency problem and limited storage capacity can be overcome by using fog computing paradigm but none of the articles has demonstrated the functionality of SIoT and challenges raised in deploying the architecture. Very few articles were published on fog computing paradigm. So, intense research needs to be conducted on this aspect. Another advancement in IoT is the IoT of Nano-Things. It describes the interconnection of nanodevices with the internet. Therefore, there is a need to propose an architecture for implementing the internet of nano-things. The problem with sensor devices is power consumption. Most of the articles have presented rechargeable batteries as a solution. Much efforts have to be made to develop sensor devices with low power consumption and renewable energy such as solar power. In our study, it is also observed that most of the systematic reviews have been carried out on enabling technologies, protocols, communication models, applications of healthcare and different devices for implementing the services. None of the studies has provided a review of the cost analysis of different devices. All these limitations are needed to be addressed, so that they serve as the basis of information for most of the technocrats and researchers to carry out further research.

10 Conclusion

Since the past few decades the usage and applications of internet have been growing fast. Rapid development in the technology of information and communications has made the wider usage of the IoT in various applications of real-time environment. Among various domains of IoT, the healthcare sector is gaining more importance. Providing quality service to the patient with low cost and without time-lapse is the main objective of the healthcare domain. Several research studies have been carried out in various fields of IoT in healthcare.

In this study, the relevant research is divided into eight different sections. Some preliminary concepts about IoT, healthcare and technologies relevant to the healthcare sector were explained earlier. It also addressed the areas that have not been covered in previous survey papers. Accordingly, we have addressed different application areas, communication models, enabling technologies with its advantages, disadvantages and challenges raised in the deployment of IoT in the healthcare domain along with a literature survey. In a further section, the strategy for extracting papers based on inclusion and exclusion measures was also specified in detail. Critical investigation and challenges that have been observed were described in the previous section.

Based on our analysis, researchers and practitioners are strongly recommend to focus on Big data governance and security issues for providing an optimal solution in large-scale system and to protect from unauthorized access by deploying fog computing, SIoT architectures.

This survey would help researchers, planners and policymakers to develop strategies for effective implementation of IoT in the healthcare sector. As per our analysis, home care and hospital management system have extended use of IoT when compared with e-health, m-health areas in the healthcare sector. Several research studies have been carried out in latest enabling technologies, communication models and issues raised in the deployment of IoT in the healthcare sector. Further, this survey underscores that the patient should engage on the self-management of their health to live a healthier longer life. Therefore, the deployment of IoT in healthcare sector enhances the patient's life by providing quality service to remote areas at low cost, reduced risk of chronic diseases of elderly people and overcoming inequities existing in the present healthcare system.

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