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Applications of IoT in Healthcare

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ABSTRACT

The emergence of the Internet of things has attracted the attention of governments, research scholars, healthcare, and business community all over the world. In the healthcare system, the motivation for using IoT is to offer promising solutions for efficiently delivering all kinds of medical healthcare services to patients at an affordable cost. IoT could be a game-changer for healthcare services. It makes it now possible to process data and remotely monitor a patient in real-time. IoT is important in healthcare because of the services it provides. These services enhance the quality and efficiency of care treatments which benefit patients, doctors, nurses, and hospitals in a great way. This chapter covers various applications of IoT in healthcare and their benefits and challenges.

KEYWORD: *healthcare, Internet, Internet of things, benefits, challenges, global adoption*

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INTRODUCTION

The healthcare industry has been a major contributor to revenue and employment. It is an essential service sector which has ubiquitous demand worldwide. It meets the basic need of every individual in the modern society. The healthcare system consists of patients, medical institutions, and healthcare resources to deliver healthcare services to meet human health needs. Unfortunately, the system is overwhelmed with problems such as expensive services, overworked doctors and nurses, illegitimate patient diagnoses, the growing rate of the aging population, increasing global demand for medical services, rise in the number of chronic diseases, and living environments with poor health [1]. In addition, present approaches used for monitoring a patient in hospitals are time consuming. The Internet of things (IoT) (also known as Future Internet) can resolve these issues quite well.

The Internet has evolved to be an ever more pervasive and critical infrastructure connecting society and enabling global commerce. It allows people and "things" to connect anytime, anywhere using a variety of wired or wireless communication networks. It has become an integral part of modern society. It will have its presence in all sectors of human lives including healthcare. The market for the IoT in healthcare is growing steadily. IoT healthcare helps in effectively managing health and thus improving the quality of life. The central concept of the Internet of things is to connect anything, anytime, and anywhere through Internet [2].

This chapter provides uses of IoT in the healthcare domain. It begins by presenting an overview on IoT. It discusses Internet of medical things. It covers various applications of IoT in healthcare. It addresses some benefits and challenges of IoT in healthcare. The chapter concludes with some comments.

OVERVIEW ON INTERNET OF THINGS

The term "Internet of things" was introduced by Kevin Ashton from the United Kingdom in 1999. Internet of Things (IoT) is a network of connecting devices embedded with sensors. It is a collection of

identifiable things with the ability to communicate over wired or wireless networks. It is the global interconnection of several heterogeneous devices. The devices or things can be connected to the Internet through three main technology components: physical devices and sensors (connected things), connection and infrastructure, and analytics and applications. Figure 1 show the objectives of IoT [3].

The IoT, also known as the Internet of Objects or the Web of Objects, is a worldwide network that connects devices to the Internet and to each other using wireless technology. It has been gaining popularity rapidly since its inception into the IT community and is being used in healthcare, education, gaming, finance, transportation, and several more. The healthcare industry is among the fastest to adopt the Internet of things. IoT is expanding rapidly and it has been estimated that 50 billion devices will be connected to the Internet by 2020. These include smart phones, tablets, desktop computers, autonomous vehicles, refrigerators, toasters, thermostats, cameras, pet monitors, alarm systems, home appliances, insulin pumps, industrial machines, intelligent wheelchairs, wireless sensors, mobile robots, etc.

There are four main technologies that enable IoT [4]:

1. Radio-frequency identification (RFID) and near-field communication.
2. Optical tags and quick response codes.
3. Bluetooth low energy (BLE).
4. Wireless sensor network.

Other related technologies are cloud computing, machine learning, and big data.

Figure 2 depicts the general applications of IoT [5].

The concept of IoT has some the following characteristics [6]:

- **Interconnected:** Internet of things facilitates people to devices and devices to other devices.
- **Smart sensing:** The majority of devices and actuators have embedded or connected sensors to detect current conditions.
- **Intelligence:** IoT devices have some calculating units and software used for smart decisions, predictions and automation control.
- **Energetical efficiency:** All IoT devices must be efficient and able to use recyclable energy, boost own energy harvesting, if the application of device requires and allows it.
- **Data sharing:** IoT connected devices have the capability to express and share their current state to all other connected devices.
- **Safety:** Internet of things devices should ensure the safety of individual life. All medical smart devices are a good example of this characteristic.

IoT supports many input-output devices such as camera, microphone, keyboard, speaker, displays, microcontrollers, and transceivers. It is the most promising trend in the healthcare industry. This rapidly proliferating collection of Internet-connected devices, including wearables, implants, skin sensors, smart scales, smart bandages, and home monitoring tools has the potential to connect patients and their providers in a unique way.

Today, smartphone acts as the main driver of IoT. The smartphone is provided with healthcare applications.

The narrowband version of IoT is known as narrowband IoT (NBIoT). This is an attractive technology for many sectors including healthcare because it has been standardized [7]. The main feature of NBIoT is that it can be easily deployed within the current cellular infrastructure with a software upgrade.

In healthcare system, the motivation of using modern technologies such as IoT is to offer promising solutions for efficiently delivering all kinds of medical healthcare services to patients at affordable cost. It makes it now possible to process data and remotely monitor a patient in real time [8]. IoT has been identified as a technological solution to some medical challenges. Through the IoT, anything in the healthcare system can be identified and monitored anytime anywhere. A typical IoT healthcare system is shown in Figure 3 [9]. Such system is also known as health-IoT or H-IoT. IoT in healthcare also helps in [10]:

- Reducing emergency room wait time
- Keeping patients safe and healthy
- Ensuring availability of critical hardware
- Saving doctor's time and work
- Enabling nurses, doctors, and other team members to connect and communicate in real time.
- Receiving critical information at the point of care without unnecessary alerts

The healthcare sector has adopted various IoT solutions by creating the Internet of medical things (IoMT), be discussed next.

INTERNET OF MEDICAL THINGS

The Internet of things in healthcare is variably referred to as IoT-MD, IoMT, Medical IoT, mIoT, and IoHT. Internet of medical things (IoMT), a healthcare application of the IoT technology, has emerged as a combination of advanced medical

sensing system, computer communication technologies. The sensing systems include RFID, GPS, and wireless sensor networks. IoMT enables machine-to-machine interaction and real time intervention solutions which are helping the healthcare industry increase its delivery, affordability, reliability, and productivity [11]. When connected to the Internet, ordinary medical devices become smart and can collect more data, give insight into trends, enable remote care, and give patients more control. For example, IoT devices can be used for reminding patients about appointments, when to take medications, changes in blood pressure, calories burnt, and much more [12]. An illustration of IoMT is shown in Figure 4 [13].

IoMT devices can sense real-time data for patient monitoring. Such devices are used to monitor parameters such as blood pressure, random blood sugar levels, and weight. IoMT will promote personalized care and high standard of living. Technologies used in IoMT can be divided into the three technical classes: local patient systems and controls; device connectivity and data management; and analytics solutions [14]. IoMT technology includes remote patient monitoring and medical system management. Smartphones are increasingly used as integral parts of IoMT. Various medical Internet of things platforms have been built for patient information management, telemedicine monitoring, and mobile medical [15].

IoMT is the technology that embeds wireless sensors in medical equipment, combines with the Internet and integrates with hospitals and patients. It is transforming healthcare industry by increasing efficiency, lowering costs, and improving patient quality of care and safety. The doctors can break the limit of the geographical scope and provide medical education for medical personnel in remote areas.

Medical devices present unique IoT challenges. These include the broad range of medical technologies, the diversity of network protocols, critical security and vulnerability, regulatory compliance imperatives resulting from the handling of patient data and stakeholders with varied interests. Security is crucial in healthcare applications, especially in the case of patient privacy. Wearable sensors, for example, are prone to expose patient information and patient privacy.

EMERGING IOT TECHNOLOGIES

Technology has always been an integral part of healthcare delivery, enabling health practitioners to use various tools to detect, diagnose, treat, cure, and monitor patients. Typical examples of medical technologies include medicines, medical devices, and biotechnology products. The main goal is to enhance quality of life using these technologies. This section deals with emerging technologies in healthcare.

IoT-based healthcare includes cognitive computing, microwave, voice search, voice recognition, chatbots, social media, blockchain, 3D telepresence technology, 3D printing, wireless technology, mobile technology, 3D ultrasound, biometrics, geneticsand genomics, electronic health records, and magnetic resonance imaging (MRI). Among so many technologies, some of the prominent ones are as follows [16,17]:

- **Wireless and Mobile Technology:** This technology would allow medical practice from anywhere, anytime, and from any device. It is touching virtually every aspect of our lives. Mobile devices include tablets and smartphone. The use of mobile devices in the healthcare is a recent update, and it is still in infancy. It has the potential for managing chronic illnesses of the aging population. The rise of the Internet age and the proliferation of smart devices have brought profound changes for the practice of medicine.
- **Wearable Technology:** This technology allows wearing light-weight sensors unobtrusively using regular clothes. Wearable gadgets can screen person's physiological capacities 24 hours every day. 3D printing innovation is arriving at the improvement of wearable gadgets. The significant concern is that wearable gadgets present issues with client protection and security.
- **3D Printing:** 3D printing (3DP) is the method for creating three-dimensional strong items from an advanced model. It has been viewed as one of the mainstays of the third modern upset. From that point forward, it has been utilized in assembling, car, gadgets, avionics, aviation, buyer items, training, amusement, medication, concoction, and gems businesses. Advantages of 3DP in human services incorporate restorative items, medications, and hardware; cost adequacy; expanded profitability; the democratization of plan and producing; and improved coordinated effort. Emergency clinics might make things on request, and this would fundamentally adjust the healthcare inventory network.
- **Augmented/Virtual Reality:** Augmented reality (AR) is an exceptionally intelligent, PC-based media condition in which the client turns into the member in a PC-created world. For instance, careful understudies can utilize virtual overlays of the circulatory framework to help direct them during methods. Charging operators can utilize

"shrewd glasses" to see understanding protection and charging data when they are away from their PCs. It can help lessen the measure of uneasiness a patient is feeling when medical procedure. It tends to be utilized to prepare specialists in a practical and generally safe mimicked condition. It offers remedial potential and restoration for intense agony and nervousness issue.

- **Robotics:** Robots have been playing an increasingly important role in our daily life. They are imperative in numerous enterprises. Mechanical autonomy manages the structure, development, activity, and use of robots. Robots are turning into an indispensable piece of the human service toolbox. Robots assume a significant job in health services as they bring down the quantity of medicinal blunders and improve human service conveyance. A wide scope of robots is created to fill various needs inside the healthcare condition.

This outcomes in different sorts of human service robots. A typical robot for complex surgery is shown in Figure 5 [18].

- **Cloud Computing:** Computing is changing the way human service suppliers (specialists, centers, and medical clinics) convey administrations to their patients.

It might give versatile and financially savvy human service administrations.

Healthcare suppliers are progressively confronting sharp challenge and are constrained support less. They are quickly going to the cloud to address the patient requirements.

- **Internet of Things (IoT):** IoT permits all devices to be associated with one another through wired or remote correspondence. It has been for some time anticipated that IoT-based healthcare services will upset the human service segment as far as social advantages, infiltration, available consideration, and cost proficiency.

- **Blockchain:** This innovation comprises common or disseminated database to keep up developing rundown of exchanges called blocks. With blockchain (BC), exchange records are put away and disseminated overall system members. Blockchain in healthcare services will be in clinical preliminary records, administrative consistence, and therapeutic records. The innovation can enable therapeutic specialists to improve and increasingly precise judgments and endorse progressively powerful medications.

- **Social Media:** Advances in technology are impacting the future of healthcare, being more social than ever before. The Internet has engaged people to share health data and associate utilizing web-based social networking. Web-based life is fundamentally online instruments utilized for PC interceded correspondence.

It is an incredible asset that healthcare industry experts can exploit to convey and associate with patients. Although Internet-based life is as yet developing, it has had a significant effect on the healthcare service industry. These technologies are selected because they pose both the risk of disruption and reward of reducing costs.

APPLICATIONS OF IoT IN HEALTHCARE

Besides Internet of medical things, applications of IoT in healthcare are numerous, ranging from remote monitoring to smart sensors and medical device integration. The applications benefit patients, families, nurses, and physicians. IoT healthcare is applicable in many medical instruments such as ECG monitors, glucose level sensing, and oxygen concentration detection. These various applications provide solutions for the patient and health care professionals. Thirteen common applications of IoT and IoMT in healthcare are discussed here [19-28].

1. **Remote Monitoring:** This is the most common application of IoT devices in healthcare. IoT devices allow healthcare professionals to monitor their patients remotely. IoMT is an enabler for remote monitoring for those in hard-to-reach locations. Patient monitoring can be done in hospitals and clinics. The IoMT employs accelerometer sensor, visual sensor, temperature sensor, carbon dioxide sensor, ECG/EEG/EMG sensor, pressure sensor, gyroscope sensor, blood oxygen saturation sensor, humidity sensor, respiration sensor, and blood pressure sensor to observe and monitor the patient's health in a continuous manner. MRIs, X-ray machines, CT scanners, and other equipment can be remotely monitored. Real-time monitoring can save lives in event of a medical emergency like heart failure, diabetes, asthma attacks, etc. Many patients continuously wear medical sensor-based devices to monitor their health statistics. Fitness, health electronics, and even smart watches have roles to play in monitoring, providing feedback, and in some cases a link to medical professionals. Remote monitoring **translates into a greater number of patients worldwide having access to adequate healthcare.** Continuous patient monitoring provides the real-time tracking, collects patient data, and wirelessly transmits for

ongoing display. This increases operational efficiency.

2. **Glucose Monitoring:** IoT devices can provide continuous monitoring of glucose levels in patients. They can collect and transfer health data such as: blood pressure, oxygen, and blood sugar levels, weight, and ECGs. They can also report and analyze the data in real-time without the need to store the data. Diabetes has been a fertile ground for developing smart devices. Such devices can help diabetics to continuously monitor their blood glucose levels for several days. Another smart device for diabetes patients is the smart insulin pen, which can automatically record the time, amount, and type of insulin needed to correct a patients blood sugar level [19]. IoT is an enabling tool for the development of smart devices such as smart CGMs (Continuous Glucose Monitors), smart insulin pens, Smart Fridge for vaccines, smart watches for depression.
3. **Digital Hospital:** *Internet of things has broad application prospects in the field of medical information management. Currently, the demand for medical information management in hospitals is in form of identification, sample recognition, and medical record identification. With IoMT, hospital medical work is becoming increasingly intelligent, meticulous, and efficient. Smart devices and wearables are creating "hospitals without walls," where long-term care can be delivered remotely.*
4. **Cancer Treatment:** Smart technology helps simplify care for both cancer patients and their oncologists. By using smart monitoring system, patients were able to effectively communicate with their oncologists the adverse effects of chemotherapy and be quickly treated for them.
5. **Telemedicine:** Telemedicine literally means "healing at a distance." It is now regarded as the use of information and telecommunication technology (ICT) to provide patients with healthcare at a distance. It is a new fascinating development that enhances the level of medical services. Telemedicine holds the promise of significant changes within the healthcare industry since it offers an opportunity to attract and retain consumers.
6. **Drug Anti-Counterfeiting:** The amount of counterfeit medicines in the world has increased greatly and a lot of people die each year as a result of wrong medication. The label attached to a product will have a unique identity that is very difficult to forge and will serve as an effective counter-measure against medical fraud [25].
7. **Elderly Independent Living:** *Elderly people living alone face serious challenges such as having an accident (such as a fall) and forgetting to take their medication. IoT can allow the elderly to maintain their independence while still getting the assistance they might need during an emergency. RFID sensor systems are being developed to support older people so that they can safely stay independent. This application is important in view of an aging population. IoT applications can provide support for the elderly by detecting the activities of daily living using wearable devices.*
8. **Wearables Devices:** Innovative devices, such as wearable devices, implantable chips, and embedded systems in biomedical devices have been developed to continuously track continuous data on patient activity. Smart wearable devices allow the transfer of patient personal information between different devices. They support fitness, health education, symptom tracking, and disease management. They can be used to store health records especially for patients with diabetes, cancer, coronary heart disease, stroke, seizure disorders, and Alzheimer's disease [26]. IoT has introduced several wearables devices which have made lives of patients comfortable. Advances in biosensor technology make possible wearable smart devices that monitor the user's health. On-the-body IoMT sensors give patients freedom, while maintaining close watch on their health conditions. Wearables devices have been developed greatly and are considered reliable tools for long-term health monitoring systems. They have matured into products being worn by patients, transmitting data to physicians and thereby allowing doctors to monitor vital signs in real time.
9. **Body Sensor Network (BSN):** This technology is another IoT development in healthcare system, where a patient can be monitored using a collection of tiny-powered and lightweight wireless sensor nodes. It is essentially a collection of intelligent, miniaturized wireless sensor nodes used in monitoring the human body functions and surrounding environment. It opens the possibility for monitoring systems to operate wirelessly using low-cost wearable sensors [27,28].
10. **Robotic Surgery:** The combination of IoT and robot is giving new solutions in the healthcare industry. Doctors are using IoT enabled robotic devices to perform surgery. This enables doctors

to perform the operation with more precision. The little robotic device can perform operations inside the body of the patient. Robot in each patient's room can make the treatment more effective.

11. **Home Medication:** Monitoring and managing medications, ensuring that patients dose correctly and on schedule is important. Smart home medication dispensers automatically upload data to the cloud when medication is not taken. These devices can also store medication at proper temperatures to ensure viability.
12. **Medical Research:** IoT can be used for medical research purposes because IoT enables us to collect a massive amount of data about the patient. This data can be used for studies that would support the medical research. Much of current medical research relies on resources lacking critical real-world information. Research IoMT can be used for research purposes. IoMT has a great impact in the field of medical research.
13. **Smart Devices:** IoT is transforming the way we interact with technologies and enabling smart devices such as smart thermometer, smart diapers, smart contact lenses smart scales, smart bandages, smart inhaler, and smart watches. The use of smart devices in healthcare has increased steadily. For example, smart thermometer produced by Kinsa can detect patient illness, provide analysis for better care, and to map human illness. Figure 6 shows some wearable smart devices [28].

    Some of these applications are illustrated in Figure 7 [29]. Other applications of IoT include personalized care, cancer treatment, ambient assisted living, medical smart contact lenses, ingestible sensors, insulin delivery, people with disabilities, hearables, tracking of objects and persons, identification and authentication, transport and data collection, disease management, clinical care, personalized healthcare, continuous cardiac or heart-rate monitoring, asthma monitoring, hand hygiene monitoring, depression and mood monitoring, body temperature monitoring, and Parkinson's disease monitoring

BENEFITS

Internet of things is a way of connecting devices to the Internet and to each other using wireless networks. It is injected into everything in healthcare, from X-ray machines to patient monitors. It creates new jobs and employment opportunities and bridges traditional engineering, computer sciences, and health care. It is transforming healthcare industry by increasing efficiency, lowering costs, and improving patient quality of care and safety. Figure 8 shows the most popular benefits of IoT in healthcare [30]. Besides these, other benefits include [31-33]:

- **Quality:** Integrating IoT features into healthcare devices greatly improves the quality and effectiveness of service. It enables a radical improvement of health care and quality of life. IoT healthcare principles are already being applied to improve access to care, increase the quality of care, reduce the cost of care, reduce medical errors, to improve patient safety, and to optimize the healthcare processes.
- **Connectivity and Affordability:** Connectivity lies at the heart of Internet of things. It is the primary purpose of using IoT technology in healthcare, i.e. connect doctors with patients through smart devices, without restrictions. The IoT links the medical devices with the virtual worlds, thereby enabling anytime, anyplace connectivity for anything and not only for anyone. IoT opens doors of opportunity for greater connectivity in healthcare.
- **Monitoring:** Applications deliver care to people in remote locations and real-time monitoring systems that provide a stream of accurate data for better care decision making [32]. IoT enables real-time monitoring of connected smart medical devices. Real-time monitoring can save lives in event of a medical emergency like heart failure, diabetes, asthma attacks, etc. [33].
- **Tracking:** An healthcare facility needs to be able track all the devices and applications on the network continuously. IoT and real-time location systems facilitate asset tracking. This is an inexpensive, effective method of monitoring and tracking day-to-day activities in a hospital setting. The ability to enable location tracking of assets using sensor-based technology has created a service which is known as location-as-a-service.
- **Lower Cost:** The IoT in medical field results in the reduction in healthcare cost since doctors need not meet the patients physically.
- **Local Activity Recording**: Device recording capabilities allow for the collection of data which will vastly improve our understanding of the mechanism of action of these chronic diseases.
- **Automation**: The automation of device and therapy records decreases human error or fraudulent reporting.
- **Precision Medicine**: The IoT technology gives precise data and avoids human error. Targeted stimulation is designed for an individual patient while decreasing negative side effects.

CHALLENGES

Medical devices present some unique IoT challenges. There is also an ambiguity about data ownership and a lack of EHR integration. This allows attackers/hackers to wreak havoc on the network. Besides these, other challenges include [10, 34-37]:

- **Data Security:** Security is one of the forefront challenges because any platform connected to IoT poses the risk of being insecure and open to hackers. Many businesses are wary of the security and privacy issues associated with IoT. IoT service providers need to be sure that their data is going to be safe. Increase in connected devices leads to an increase in endpoint vulnerability. Many IoT platforms consider security a core element and work to ensure it.
- **Privacy:** A significant challenge that IoT poses is of data security and privacy. The data that is being shared across the IoT devices are sensitive. Wearable sensors, for example, are prone to expose patient information and patient privacy. Medical security and privacy issues directly influence patient life and the healthcare system all over the world.
- **Interoperability and Standards:** IoT consists of heterogeneous networks which connect all kinds of devices. Interoperability is the key to open markets to competitive solutions to IoT. The first requirement of Internet connectivity is that connected devices should be able to "talk the same language" of protocols. This makes interoperability the most basic core value.
- **Technology Infrastructure:** Infrastructure is critical for emerging IoT applications. Most businesses lack the infrastructure and network components that huge volumes of IoT data require.
- **Workforce:** Sometimes, there is not enough technical skill to gain valuable insights from the huge amount of data collected from IoT. Healthcare industry should hire experts with the relevant IoT training.
- **Data Overload:** The medical IoT generate massive data which can be utilized to gain insights and make smart decisions. The big data accumulated by IoT devices is a challenge for the IoT data processing.
- **High Investment Cost:** The high initial costs in IoT investments can intimidate small healthcare companies. But IoT costs are rapidly declining. The sensing devices such as RFID tags, sensors, actuator, etc. can be designed to minimize cost.
- **Energy:** IoT consists of various low-power embedded devices. IoT uses low-power lossy networks, which complicates security issues by adding an additional constrain, energy. Since an energy source needs to supply each sensor in IoT, a tremendous amount of energy would be needed to run thousands of these sensors. This is a serious challenge that IoT has to handle.
- **Computation Power:** IoMT devices have limited computation power. If a patient is using implanted medical devices, it is not easy to recharge or replace the devices immediately. Biosensors are small devices with limited energy; if the devices
- **High Infrastructure Cost:** The cost of building the IoMT infrastructure is enormous. Dedicated IT health networks, blockchains, and cloud platforms are all necessary. The initial cost for setting up such systems is significant.
- **Cybersecurity:** This is a concern in the medical field since it is vital to protect all sensitive information. This is perhaps the major reason the industry would be taking a little more time adopting the technology. IoMT interconnectivity leaves medical devices vulnerable to cybersecurity breaches.
- **Lack of Standardization:** The lack of standardization among IoMT manufacturers is a problem. Devices from different manufacturers are often not interoperable. As a heterogeneous network system, the interconnection of different IoMT components is a main problem that needs to be solved.

These are some major challenges that influence the decision-making process of potential customers for a successful IoT implementation. Other challenges include cost, data integrity, data protection, laws and policies, insurance coverage, global misinformation systems, global cooperation, intelligent data analytics, big data problems, and quality of service issues [38,39]. In spite of the challenges, the adoption of IoT continues to expand.

CONCLUSION

The Internet of things (IoT) integrates physical objects, software, and hardware to interact with each other. The era of the Internet of things has already started and it will drastically transform our way of life. The central concept of the Internet of things is to connect anyone, anything, anytime, anyplace, any service, and any network. The Internet of things (IoT) is increasingly being recognized by different industries. Healthcare is one of the major sectors where IoT can have the most relevant economic and social impact. The impact of IoT in healthcare has

been significant since it has opened up a world of possibilities in healthcare. From adherence to diagnosis, the applications are manifold. Due to these applications, the healthcare industry is changing at fast pace and is adopting the IoT rapidly. It is changing the way healthcare is delivered. It has been long predicted that IoT healthcare will revolutionize the healthcare sector in terms of social benefits, penetration, accessible care, and cost-efficiency. The IoT revolution is redesigning modern healthcare with extended benefits.

However, the rapid growth of IoT has presented some significant challenges. IoT's development has been restricted by the challenges. Security happens to be the most prominent challenge for physicians interested in IoT applications in medicine. More information about IoT healthcare applications can be found in the books in [19,41-53]. and other books available on Amazon.

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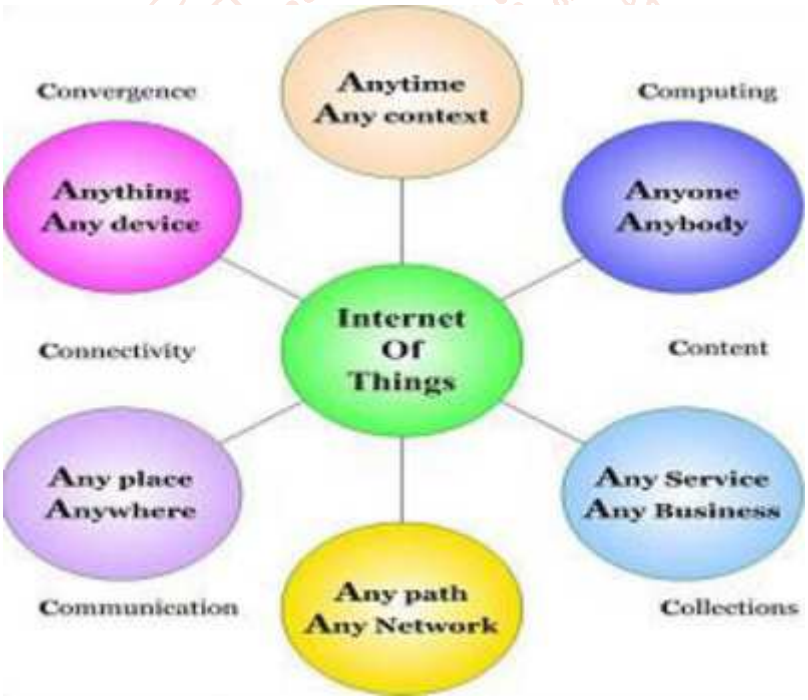

Figure 1 Objectives of IoT [3].

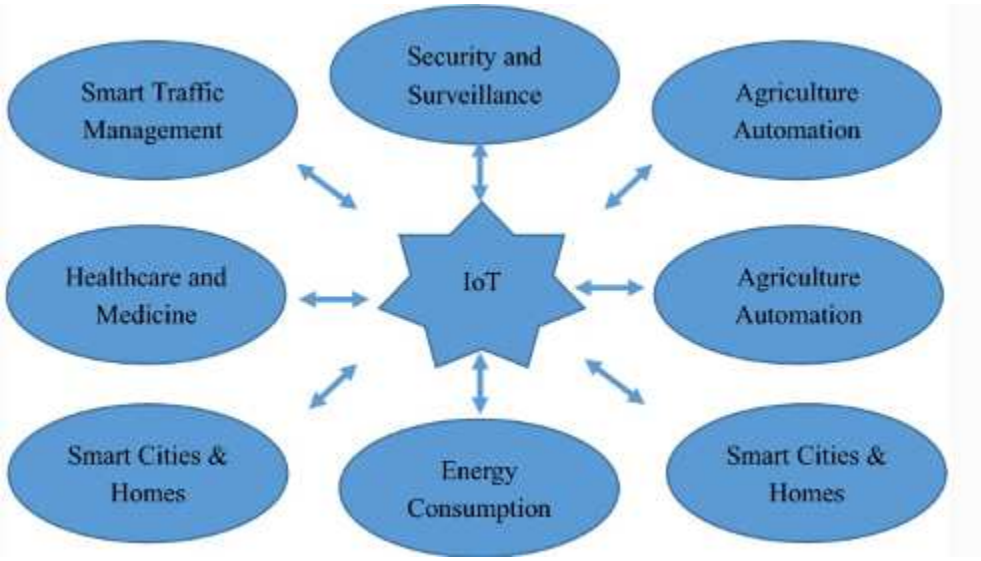

Figure 2 General applications of IoT [5].

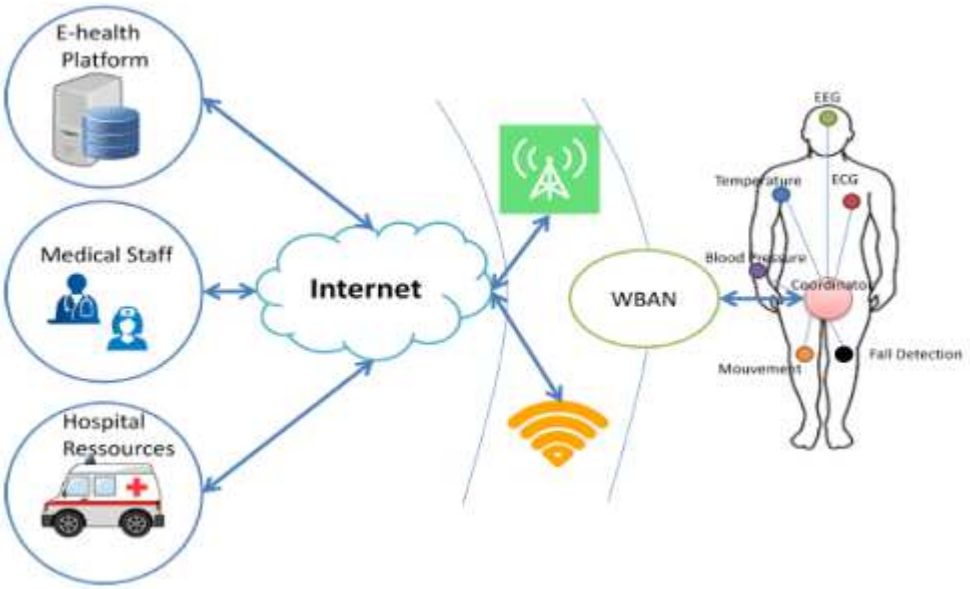

Figure 3 A typical IoT healthcare system [9].

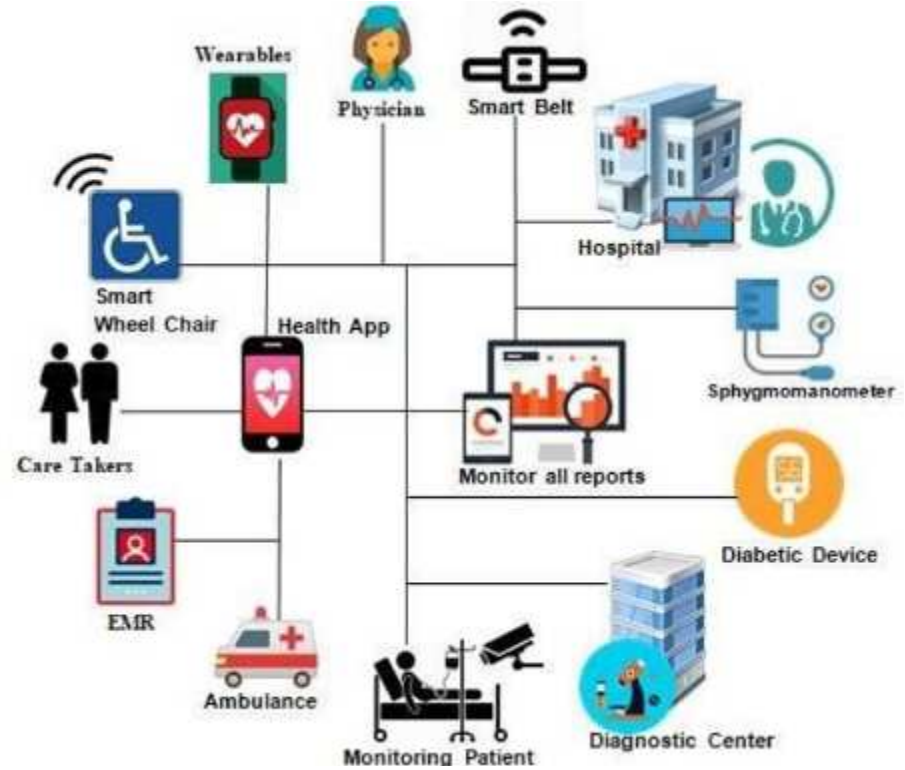

Figure 4 The Internet of medical things [13].

Figure 5 A typical robot for complex surgery [18].

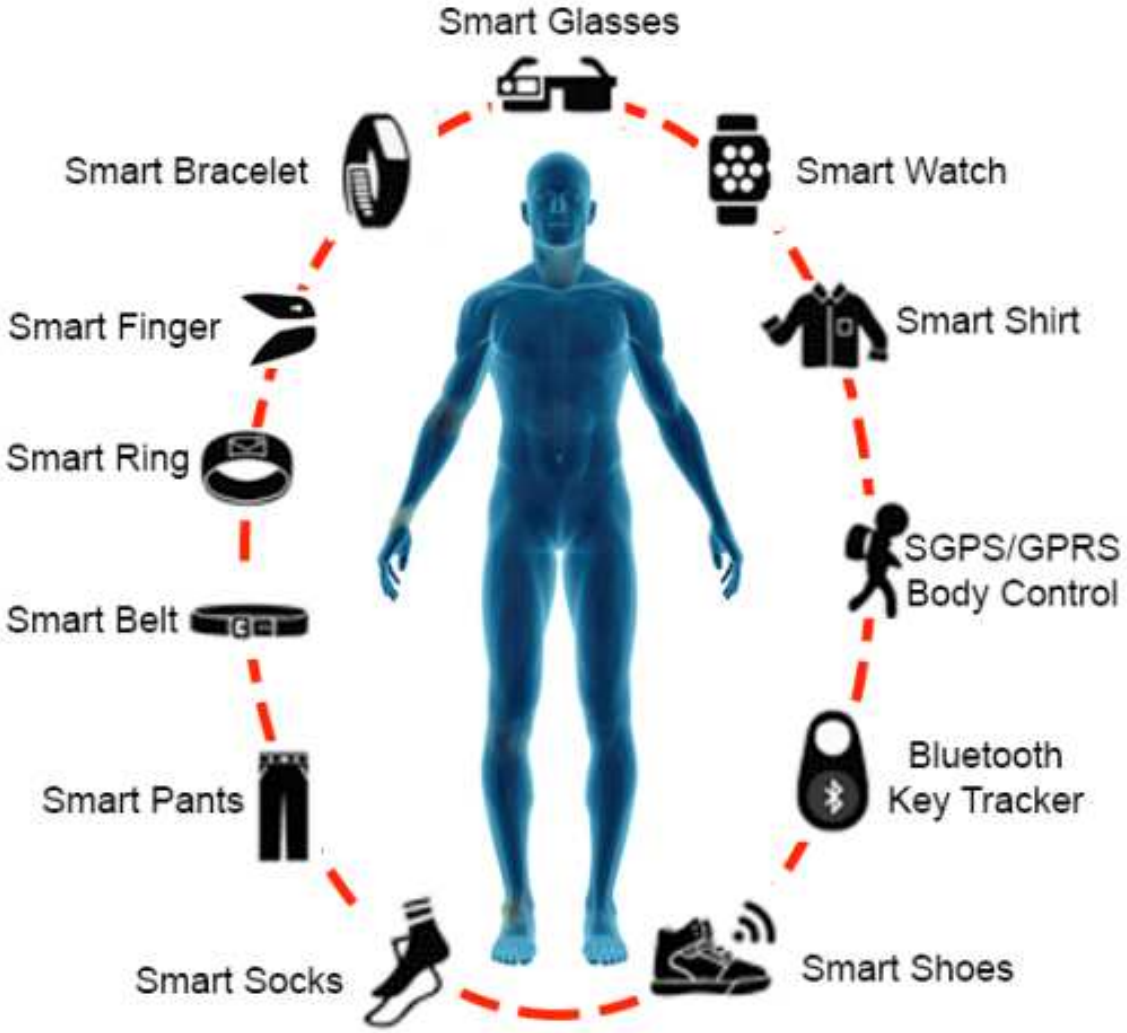

Figure 6 Some wearable smart devices [28].

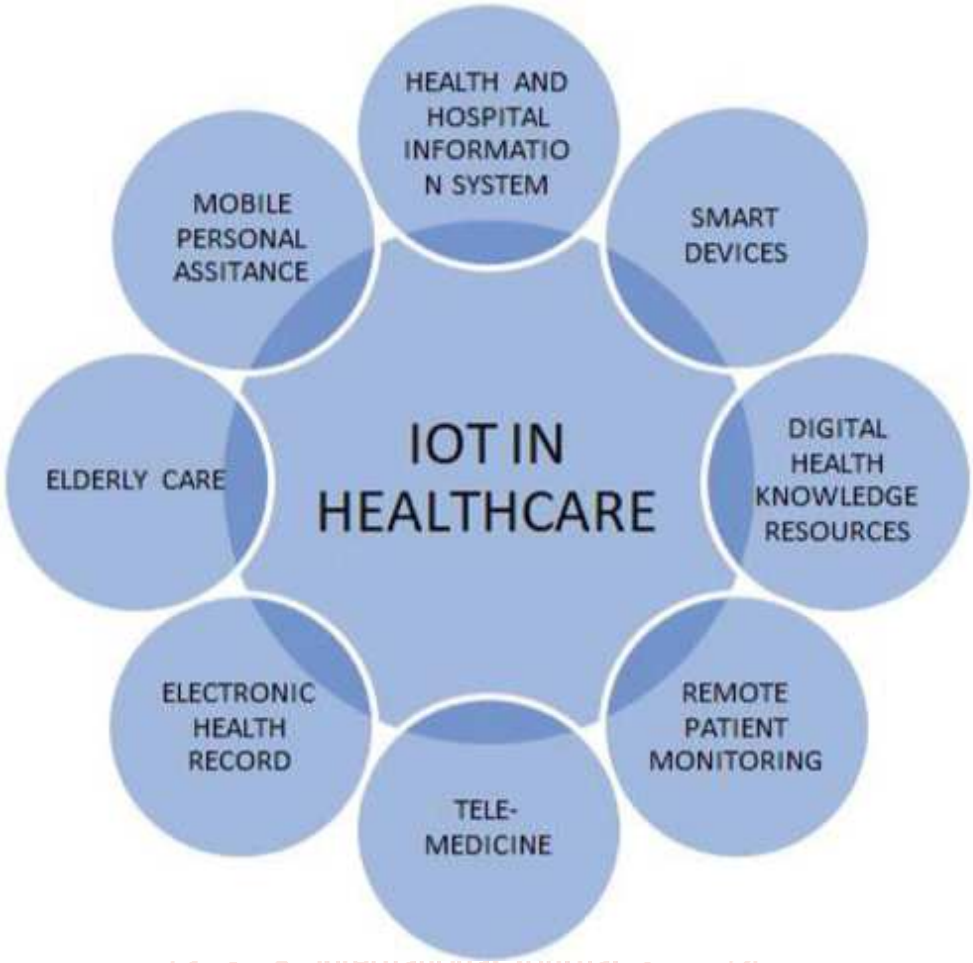

Figure 7 Some applications of IoT in healthcare [29].

Figure 8 The most popular benefits of IoT in healthcare [30].