

Part I

BASICS OF SMART HEALTHCARE

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An Overview of IoT in Health Sectors

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Abstract

In the recent past, several technological developments have happened owing to the growing demand for connected devices. Applications of Internet of Things (IoT) are vast, and it is used in several fields including home-automation, automated machines, agriculture, finance sectors, and smart cities. Life style diseases are increasing among urban population and lot of money is spent for the diagnosis and treatment of diseases. Adaption of IoTs in health sectors enables real-time monitoring of the patients and alerts the patients for health checkups whenever required and communicate the information from time to time. During pandemic situations like Covid-19 which we are facing today, the need for IoT-enabled services in health sector is essential as the doctors have to treat the patients from remote locations. The connected devices can help in surveillance and disease control, keep track of nutritional needs, mental health, stress management, emergency services, etc., which will lead to an efficient health management system. This article gives an overview of applications of IoT in health sectors and how it can be used for sustainable development and also addresses various challenges involved in it. Efficient use of IoT in health sectors can benefit healthcare professionals, patients, insurance companies, etc.

Keywords: IoT, healthcare, smart gadgets, health monitoring

1.1 Introduction

Due to the increase in awareness of a healthy life style, the number of people depending on smart devices for monitoring their health is increasing day

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by day. IoT devices have become very essential to be the part of daily life in this technological advanced world. Various advancements are happening in the healthcare sectors from the recent past. With the advancement in technology in the use of IoTs integrated with Artificial Intelligence, a major digital transformation is happening in the healthcare sector. Various research is going on in this area which will add new dimensions to the healthcare system.

Wireless Body Area Networks (WBANs) have also been used extensively in healthcare services due to the advancement in technology. A survey on healthcare application based on WBAN is discussed in [1]. The paper also analyses the privacy and security features that arises by the use of IoTs in healthcare systems.

Use of RFID has become very common owing to the extensive applications of IoTs. A survey on RFID applications for gathering information about the living environment and body centric systems is discussed in [2]. The challenges and open research opportunities are also discussed in the article.

Various research is ongoing on to find the methods to improve the monitoring and tracking of the patients in an efficient manner. In [3], a novel IoT-aware smart architecture is proposed to monitor and track the patients. A smart hospital system is proposed which can collect real-time data and environmental factors by making use of ultra-low power hybrid sensing network.

A secure IoT-based healthcare system which operates with body sensor network architecture is introduced in [4]. Two communication mechanisms for authenticity and secured communication is addressed. The proposed method was implemented and tested using a Raspberry Pi platform.

In [5], authors address a survey paper on the IoT research and the discusses about the challenges, strengths and suitability of IoT healthcare devices and mentions about the future research directions.

One of the challenges faced by the IoT systems is regarding the security and privacy of data. In [6], the authors proposed a hybrid model for securing the medical images data. This model aims to hide the confidential patient data from the image while transmitting it.

Wireless body networks are becoming popular with the increased use of IoT smart devices. In [7], a solar energy powered wearable sensor node is addressed. At various positions of the body multiple sensors are deployed and a web-based application is used for displaying sensor data.

Experiment results achieved good results for autonomous operation for 24 hours.

Body sensor networks is the one of the significant technologies used to monitor the patients by means of tiny wireless sensor nodes in the body. Security of such IoT devices poses a major issue in privacy of the patients. A secure system for healthcare called BSN-care is addressed in [8].

Securing the privacy of patients is of utmost importance for IoT-based healthcare systems. Various research is going on this area. In [9], a big data storage system to secure the privacy of the patients is addressed. The medical data generated is encrypted before it is transferred to the data storage. This system is designed as a self-adaptive one where it can operate on emergency and normal conditions.

Various systems are developed to take care of the personal needs while traveling which can aid in travel and tourism. An intelligent travel recommender system called ProTrip is developed in [10]. This system helps travelers who are on strict diet and having long-term diseases in getting proper nutritional value foods according to the climatic conditions. This system supports the IoT healthcare system for food recommendation.

The issues in the security and privacy of IoT-based healthcare system are a major concern. Most of the system is based on cloud computing for IoT solutions which has certain limitations based on economic aspects, storage of data, geographical architecture, etc. To overcome this limitation, a Fog computing approach is addressed in [11] and authors explores the integration of traditional cloud-based structure and Cloud Fog services in interoperable healthcare solutions.

For IoT-based healthcare system efficient authorization and authentication is required for securing the data. Such a system is addressed in [12]. It was found that the proposed model is more secure than the centralized delegation-based architecture as it uses a secure key management between the smart gateway and sensor nodes.

Recent security attacks for the private data and integrity of data is a matter of concern for the IoT healthcare systems. Conventional methods of security solutions are for the protection of data during patient communication but it does not offer the security protection during the data conversion into the cipher. A secure data collection scheme for IoT healthcare system called SecureData scheme is proposed in [13], and the experimental results showed that this scheme is efficient in protecting security risks.

Life style diseases like diabetes are common nowadays. It is very important for such patients to follow a strict diet and most of the time it

is difficult for the healthcare professionals to get the precise physiological parameter of the patients. Without the knowledge of the current condition of the patients, it is difficult for the ontologies to recommend a proper diet for such patients. A fuzzy-based ontology recommendation system is proposed in [14] which can determine patient's conditions and risk factors by means of wearable sensors and accordingly can suggest the diet. The experimental results proved that the system is efficient for diabetes patients.

The data generated through IoT devices are prone to security threats. Maintaining the privacy of the patient data is of utmost importance. Traditional encryption schemes cannot be applied on healthcare data due to the limitations in the properties of digital data. A chaos-based encryption cryptosystem to preserve the privacy of patients is proposed in [15]. Random images are generated by the cryptosystem which ensures highest security level for the patient data. The performance of this model was found to be better than other encryption schemes.

The trends of IoT in healthcare sectors and the future scope for research is discussed in [16]. A sensor-based communication architecture and authentication scheme for IoT-based healthcare systems is addressed in [17]. Various research articles on big data analytics, and IoT in healthcare is addressed in [18].

With the enormous research happening in the field of IoT applications in healthcare sectors, new dimensions to the healthcare treatments and hospital services can be expected in the coming years.

1.2 Influence of IoT in Healthcare Systems

Due to the awareness about the importance of healthy life, people have become more health conscious nowadays. Humans are finding new ways to improve and track their health. Due to the implementation of emerging technologies like IoTs and Artificial Intelligence (AI), the healthcare systems have evolved as an entirely new system replacing the old system. Various stages of IoT system is shown in Figure 1.1.

Various developments have occurred in the healthcare systems in the recent past. Some of the advancements are discussed in this section.

1.2.1 Health Monitoring

Health monitoring on real-time basis became possible due to the invention of wearable smart gadgets. These devices continuously monitor various

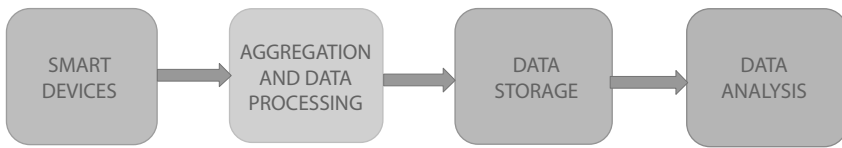


Figure 1.1 Stages of IoT.

parameters like blood pressure, heart rate, oxygen level, and calories burnt. Fitness bands help individuals to maintain their body healthy and fit by regularly alerting them about the steps taken per day and how much calories need to be burnt to stay healthy.

These devices can be interconnected by IoT devices so that the health-care workers and immediate family members can monitor the parameters and they will be alerted for any emergency situation. Such devices are very helpful for elderly persons who are living alone as they get immediate medical attention if there are variations in their body parameters.

1.2.2 Smart Hospitals

Smart hospitals mean all the equipment in the hospitals are connected through IoTs in addition to real-time monitoring system for the patients. Managing the assets in the hospitals can be made in a smarter way by means of IoTs. The equipment like oxygen cylinders, wheelchairs, and nebulizers can be tracked on real-time basis and made available when in need.

Now, in the current Covid-19 scenario, we have observed how the hospitals were managing the resources in a smarter way. The number of occupied beds and available bed status is updated on real-time basis, and the data is made available in various digital platforms.

Cleanliness and hygiene also can be maintained in an efficient manner. Environmental conditions like humidity and temperature can be monitored continuously and the spread of diseases can be prevented efficiently.

1.2.3 Tracking Patients

Due to the advancement of technology, hospitals have become more patient friendly. The duration of hospital stay can be reduced due to the online real-time monitoring of the patient data through IoT devices. It is

easier for doctors to track the patient data at the comfort of sitting at a remote location. As the IoT devices are attached to the patients, continuous monitoring of the vital parameters is possible, and the doctors will be alerted for any variations in the parameters.

These smart devices not only track the patient's health parameters but also alert the patients for their consultation schedules. It also keeps the records of previous medications or medical history which aids the doctors in right diagnosis and treatments.

The availability of patient's data on IoT devices helps the hospitals to track the patients and provide quick medical attention in an efficient manner.

1.2.4 Transparent Insurance Claims

Healthcare insurance policy holders are increasing on a yearly basis. Due to the large number of policy holders who aims to get maximum profits by claiming the insurance, false claims are also increasing. Due to the presence of IoT devices which tracks the patient data, insurance companies can easily detect any fraud in the claims.

These devices not only help the patients to manage their insurance policies but also help the insurance companies to track the health of patients, underwriting, risk assessments, etc. Due to the IoT-enabled devices, the insurance claims became transparent and benefitting the genuine policy claims.

1.2.5 Healthier Cities

Population in cities are more compared to the rural areas as people prefer to have better quality and standards of living in cities with better facilities and infrastructures. Most of the cities are crowded and majority of the population use public and private transport for commuting. Vehicle densities in cities are more compared to villages which lead to more air pollution which, in turn, affect the health of the individuals and the environment.

Due to the advancement in technology in terms of usage of IoT devices, continuous real-time monitoring of the air quality is possible. The tracking of the air quality patterns helps the authorities to take appropriate actions to improve the air quality which, in turn, help to maintain a healthier city.

1.2.6 Research in Health Sector

Research in medical field is a continuous process which requires lot of time in gathering the patient data and analyzing it. Connected devices through IoTs generate large amount of real-time data which can be used

for research purposes in an efficient manner as data collection becomes much easier with less amount of time and money. Statistical and comparative study analysis is possible as these devices can be connected anywhere in the world and data can be generated which will aid in medical research.

Innovative methods of treatments can be introduced by doing proper research in an efficient and quick manner due to the presence of IoT devices. This also helps to improve the healthcare services.

Smart monitoring devices will monitor all the parameters inside a medical laboratory and alerts if there is an abnormality so that immediate action can be taken. Based on the data available, various research studies can be done with much ease.

1.3 Popular IoT Healthcare Devices

New devices are invented to match with the technological advancements. These new devices aim to make the life easier for humans. Some of the popular IoT devices for healthcare are as follows:

1.3.1 Hearables

Hearables are one of the popular IoT devices which are used by the people for hearing aid. With these devices, people who have difficulty in hearing or those who are hearing impaired can interact with the outside world. This device can be connected with other smart devices like mobile phones and data can be synchronized. Various types of filters and equalizers are used for better user experience to match with the real sounds.

1.3.2 Moodables

Moodables are devices which enhances the mood of a person by sending triggering signals to the brain. These devices must be worn on head which has inbuilt sensors to elevate the mood.

1.3.3 Ingestible Sensors

These are like small pills which can be ingested to monitor our body from inside and can give warning signals to the doctors in case of any abnormalities. This device is made up with sensors of pill size which can give warning for any underlying diseases. These sensors can detect whether the prescribed medicines are taken properly and also can help in drug management.

1.3.4 Computer Vision

Computer vision technology mimics the human vision by making use of Artificial Intelligence. This technology has been implemented in drones which help them to navigate and detect obstacles. Visually impaired people can make use of this technology to navigate easily.

1.3.5 Charting in Healthcare

IoT devices helps doctors to maintain the patient data in an efficient manner. Doctors can easily get the charting of various parameters like blood pressure and sugar level from the connected devices and it can be immediately reviewed and shared with the patient's devices. This saves huge amount of time that doctors spend in creating manual charts for individual patients.

1.4 Benefits of IoT

Various benefits of IoTs are discussed in this section.

1.4.1 Reduction in Cost

As the doctors can remotely monitor the patients using IoT-enabled devices, the cost in visiting the healthcare facilities and consultation can be drastically reduced. Since the real-time monitoring of the patients is possible with IoT devices, hospital admissions can also be reduced by providing timely treatments.

1.4.2 Quick Diagnosis and Improved Treatment

Doctors can easily diagnose the diseases as real-time monitoring is possible with IoT devices and can give appropriate treatment on time at an early stage. Patients can also be fully aware about their health conditions and the treatments provided. Hence, the transparency in treatment can also be maintained. Doctors can provide proactive treatment to the patients based on the real-time data collected.

The continuous monitoring of patients helps to save many lives during emergency medical situations which arise due to heart attacks, asthma attacks, high blood pressure, etc.

1.4.3 Management of Equipment and Medicines

It is very important for the hospitals to manage the healthcare equipment as the utilization of those equipment should be optimized. Through IoT connected devices, it will be easier to manage the equipment as the utilization of the equipment is properly monitored on real-time basis and the equipment which are available for use at a particular time can be easily identified with the location of the equipment. Similarly, the medicine stocks can also be properly monitored using IoT devices.

1.4.4 Error Reduction

As the real-time data is continuously collected through IoT devices, decision-making becomes much easier which helps in the smooth functioning of the healthcare systems. This not only saves the time but also reduces the cost of operation.

1.4.5 Data Assortment and Analysis

Huge amount of data is collected by IoT devices. These data can be used for analysis purposes. As IoT devices collect and analyse the data, storing of manual records is not required. The data is available on real time and stored in cloud and can be made available to the healthcare professionals or patients. The error in analysis can be eliminated compared to the manual analysis.

1.4.6 Tracking and Alerts

The patients are connected to IoT devices so that the doctors can keep track of their health on real-time basis. Doctors get alerts on life threatening emergency situations which enables them to take proper decisions and provide right treatments with better accuracy.

1.4.7 Remote Medical Assistance

In an emergency, patients can contact doctors through connected devices irrespective of the location which enables them to avoid the hospital visits and un-necessary expenses. Doctors will be able to check the patients online and prescribe the medicines. In future, delivery chains are aiming to provide machines which can distribute medicines to the patients based on their data available through the connected devices.

1.5 Challenges of IoT

Various challenges faced by the IoT devices are discussed in this section.

1.5.1 Privacy and Data Security

Data security and privacy are the most crucial challenges of IoT devices. As huge amount of data is generated through the connected devices, it is highly susceptible to cybercrimes. Without proper data security and protocols, personal data of patients as well as doctors can be hacked and misused. Fake IDs may be created by cyber criminals which can be used for fake insurance claims and businesses.

1.5.2 Multiple Devices and Protocols Integration

Various devices of different manufacturers must be interconnected for the implementation of IoT. As there are no standardized communication protocols to be followed by the manufacturers, integration of multiple protocols becomes difficult and it will hinder the operation of these devices. Also, the system may become more complicated. This may result in an inefficient system if standardized communication protocols are not in place.

1.5.3 Huge Data and Accuracy

A huge amount of data is generated by the IoT devices. As the number of devices increases, the data generated also will increase. If huge amount of data is generated, it will be difficult for the doctors to analyse the data and take proper decisions which, in turn, may affect the accuracy.

1.5.4 Underdeveloped

Even though the use of IoT devices in health sector is increasing day by day, still the development is not up to the mark. It is still in development stage only. It has to progress in a faster pace for better results.

1.5.5 Updating the Software Regularly

With the implementation of hardware for IoT devices, software also becomes part of the system. It has to be regularly updated for better performance and added security features. Regularly monitoring and updating the software is required which may not be possible easy at times.

1.5.6 Global Healthcare Regulations

For every new technology implementation, proper approval from healthcare regulating bodies is required. But formulations of new regulations are not done very frequently and is a time-consuming process which may cause difficulty in implementation of new technologies and innovations.

1.5.7 Cost

The cost of healthcare facilities in developed countries is high compared to the developing countries. With the use of IoT devices, cost is not reduced for using the healthcare facilities. It must be made cost effective then only it can benefit the common man.

1.6 Disadvantages of IoT

Disadvantages of IoT is discussed in this section.

1.6.1 Privacy

As IoT devices operates hugely on personal data, serious security issues can happen due to hacking which may result in data theft. So, there should be proper security and firewalls in place which may require additional expenses.

1.6.2 Access by Unauthorized Persons

As the real-time sensitive data is available in connected devices, the access to those data needs to be protected. Proper care should be taken to ensure that the data is accessed by authorized persons only. Unauthorized access may create data leaking and misuse of the data.

1.7 Applications of IoT

Various applications of IoT devices are discussed in this section.

1.7.1 Monitoring of Patients Remotely

Patient monitoring from remote locations is possible with the help of IoT devices. This reduces the number of cases of hospital admissions which,

in turn, reduces the expenses. After a major illness or surgery, when the patients are discharged from the hospitals, doctors can keep track of the health of the patients and reduce re-admissions.

In rural areas where the healthcare facilities are poor, doctors can monitor the patients sitting at a remote location and can reduce the death rates.

The expenses incurred for traveling long distance for consultations, hospitalizations, etc., can be reduced. Even IoT devices can alert the healthcare professionals if the patients are not taking medicines regularly or taking wrong medications. With the continuous monitoring of the patients, health risks can be reduced drastically.

1.7.2 Management of Hospital Operations

Hospital operations involves management of various equipment and drugs. It is difficult to manage this equipment in an optimal way as the doctors are always busy with their patients. By means of IoT devices, management of equipment becomes much easier. As the equipment are regularly monitored, fault in that equipment can be easily detected and rectified. Also, IoT devices can alert the authorities about any outdated equipment which needs replacement.

Most of the time, it is difficult to track how many available equipment are for use and the exact location of the equipment. IoT devices keep track of the available equipment and their locations which helps the healthcare professional to locate the equipment quickly which can save many lives.

IoT devices also alert the hospital authorities about the cleanliness and hygiene of the surrounding environment which can lead to maintenance of a healthy environment which, in turn, prevent the spread of the diseases.

1.7.3 Monitoring of Glucose

Glucose monitoring on a daily basis is very essential nowadays due to the rise in life style diseases like diabetes. Diabetes is a high-risk disease which can lead to high blood pressure, heart attacks, etc. This life style disease is due to the abnormal functioning of the pancreas gland.

There may be variations in sugar level due to the abnormal functioning of the pancreas gland. These variations can lead to organ damages if not properly detected. Hence, continuous monitoring of the sugar level is essential for a healthy life style.

With the advancement in technology several wearable connected devices and sensors are available in the market which can monitor glucose levels on real-time basis and update it on the connected devices.

As the sugar levels are monitored on regular basis, any rise in sugar levels can be detected early and proper action can be taken at the right time before it affects the overall health.

Hence, by the use of IoT devices, many lives can be saved and also can save hospital expenses.

1.7.4 Sensor Connected Inhaler

Air pollution is increasing day by day due to the increase in the number of vehicles on road. Increase in air pollution leads to increase in lung diseases. One of the most common lung diseases which is on rise is asthma. These lung diseases are controlled by inhalers.

Usually, symptoms of an asthma attack appear few hours before the peak. If the sensor connected inhalers are used by the patients, then it can detect triggering factors and alert the patients as well as the doctors about the possibility of an asthma attack through IoT connected devices.

IoT devices not only can alert the patients about the possible asthma attacks but also can help doctors in instructing the patients when to stop inhalers there by optimizing the medication and reducing the expenses for medical bills.

1.7.5 Interoperability

Data collected through IoT devices is huge. These data play a major role in healthcare system as doctors can always look into the historical data of the patients.

Most of the time when a new patient consults a doctor, it is difficult for the doctors to diagnose the diseases without proper testing. But if the historical data is available with the doctors, diagnosis of the chronic diseases becomes much easier. The data can be made available at multiple locations, wherein interoperability becomes much easier and patient care can be optimized. The historical data can also be used for medical research and development.

1.7.6 Connected Contact Lens

Eye is the most important part of human organ. Diagnosis of some of the diseases can be made through by observing the changes that occur in the eyes.

Contact lens is commonly used nowadays for eye sight problems and for enhancing the appearance of the eyes. With IoT-based contact lens, it can do wonders for humans. It not only aids in enhancement of eye sight it also monitors the changes that occurs in the eyes which can lead to early diagnosis of diseases.

By monitoring the variations in the eye ball size, it can diagnose glaucoma at an early stage, any delay in detection of abnormalities may result in loss of eye sight.

Even the eye medications can be directly administered to the eyes with the aid of contact lens which, in turn, gets rid of the inconvenience of administering the eye drops.

In future, such technologies will add new dimensions to the eyecare system.

1.7.7 Hearing Aid

Hearing aid has been used by many people around the world who have hearing issues and wants to enhance hearing. But due to the invention of IoT devices, hearing aids became smarter. It not only aids in hearing but also assist in other activities too.

People even can hear their door bells ringing from a far place if it is connected by IoT devices. It can detect smoke if the smoke sensor is attached to it. These devices can filter out the noise effectively so people can enjoy music or personal conversations in a noisy environment without any disturbances. Also, several conversations can be listened simultaneously.

1.7.8 Coagulation of Blood

Clotting of blood plays a very important role in human body. To avoid serious medical conditions which may result in strokes, regular monitoring of blood clot level is essential.

With IoT-enabled devices, it is possible to monitor the blood clot level on a regular basis. With the regular monitoring of clot levels, bleeding in the brain, strokes, heart attacks, etc., can be minimized by seeking medical attention at the right time. This can avoid unnecessary medications, hospital admissions, surgeries, etc., which, in turn, can save the medical expenses.

This IoT devices for monitoring blood clot level helps the anticoagulated blood patients to lead a normal life as the devices alert them to check the blood clot levels.

1.7.9 Depression Detection

Depression is one of the common health conditions faced by the current generation individuals. With the advent of smart devices like wearable smart watches, it is easy to track depression levels. These smart devices monitor the depression levels and provides suggestions about the type of treatments available.

As the data is continuously monitored by the connected devices, it will be available for reference to the mental healthcare professionals. Psychiatrists or psychologists can study about the mental conditions of the patients by observing their historical data of depression levels and can provide right treatments.

With the invention of such smart devices, depression can be easily treated by studying the sleep patterns and depression levels of the patients.

1.7.10 Detection of Cancer

Early detection of cancer is very important to save the life of an individual. Due to the advancement in technology, sensors are attached to the connected wearable devices which can sense any abnormalities in the cell.

The most common and dangerous cancers seen among women is breast cancer, and if it is not detected at an early stage, it leads to fatal condition.

With the advancement in new technologies, sensor-enabled bras are developed which makes use of Artificial Intelligence which, when worn, can detect abnormalities in breast tissues. These bras need not be worn throughout for detection; women can wear this bra for 2 to 12 hours per month. This wearable sensor embedded cloth does not produce any radiations or side effects. This can detect breast cancers at an early stage so that the treatment can start at an early stage for which complete cure is possible.

These wearable devices reduce the cancer risk among women and can reduce the treatment expenses as the doctors and patients will be alerted about the abnormalities in the tissues.

1.7.11 Monitoring Parkinson Patient

Parkinson is a health condition in which brain behaves abnormally which leads to difficulty in movement and coordination. Parkinson affects the central nervous system so the patients may feel stiffness and loss balance in movement.

It is very important to monitor the Parkinson patients on real time. With IoT devices, regular monitoring of Parkinson's patients is possible. Patients may suddenly face lack of movement which is very common in Parkinson disease called Freezing of Gait (FOG). This FOG stage can be detected by means of IoT devices and alerts can be given to doctors and patients. Even early detection of symptoms of this disease is also possible by the use of IoT devices.

In future, such devices will help the Parkinson's patients to lead a better life without risking their lives.

1.7.12 Ingestible Sensors

Sensors are embedded into the pills which can be ingested by the patients. These sensors will monitor whether the patient has taken prescribed medicines at the right time. If the medicines are not taken properly, it will be alerting through the connected devices.

Most of the times patients does not follow doctor's prescription, they either miss to take medicines on time or they may take overdose of the medicines. They may not follow the proper time gap for each medicine. All these issues may lead to serious medical conditions and result in expensive medical treatments.

These situations can be avoided by ingestible sensors which regularly monitors the patients and alerts them to take medicines on time. Taking care of the patients also becomes much easier with the support of such smart devices.

1.7.13 Surgery by Robotic Devices

Robotic surgeries are becoming common nowadays, owing to the precision, it gives compared to the normal surgeries performed by the doctors.

Robots connected to IoT devices can perform complex surgeries with more precision and control by the supervision of doctors. Doctors even can instruct robots to perform surgeries sitting at a remote location. This can save many lives as quick action is possible even at a remote location.

Many of the surgeries lasts for hours to complete which is a tiresome job for the doctors. In such situation, robots can perform the surgeries with much better precision. Complicated surgeries can be done successfully with the help of robotic devices connected to IoTs. This gives new dimensions to the classical surgery procedures.

1.7.14 Hand Sanitizing

Due to the current Covid-19 pandemic situation, the awareness about the importance of hand hygiene is increased among the common public. Proper care should be taken to prevent the spread of diseases especially in healthcare facilities. IoT-enabled devices play a major role in maintaining the hygiene of healthcare workers and patients.

With sensor-enabled hand sanitizing machines, monitoring of hand hygiene becomes easier. The sensor sets a threshold value of cleanliness and, if any staff fails to maintain the threshold value, will be alerted about

sanitizing their hands. Even the sensors can track the time of sanitization done and alert them to sanitize their hands.

Since real-time monitoring of the hand hygiene is possible by the IoT connected devices, everyone will be more aware and alerted about the cleanliness and importance of the hygiene hands which leads to a healthy environment and helps to control the spread of viruses.

1.7.15 Efficient Drug Management

Using IoT-enabled devices management of drugs can be done in an efficient manner starting from the production to the supply chain management.

Radio Frequency Identification (RFID) tags are used for distribution purpose which also records a real-time record of the availability of the drugs and whether distribution is correctly done. The temperature during production process is also monitored to detect any variations.

With the proper supply chain management, production cost can be reduced and patients will get good quality drugs at a reduced rate.

1.7.16 Smart Sole

Alzheimer is a dreaded disease for elderly people and their loved ones as handling such patients is a difficult task. The patients tend to forget their daily activities and many of them lose their way back home and it creates difficulty in locating them.

IoT-enabled devices with smart GPS sole embedded system will provide a solution for this problem. It tracks the patient's location and updates it into the connected devices. It is a waterproof system so even if the patient enters water bodies, it will be working and sending signals to the connected devices. It will alert the loved ones about the location of the patients if they are wandering anywhere. This device is easy to wear as it is embedded into the sole and patients will never forget to wear footwear while going out.

Such smart devices will help Alzheimer patients to lead a healthy and normal life.

1.7.17 Body Scanning

To lead a healthy life, regular body checkups are required but most of the time people ignore the checkups on regular basis. To overcome this, a smart body scanner which scans the body and updates about the variations in body parameters can be used.

The scanner is basically a full-length mirror with a 3D camera and a weigh scale which scans the entire body and stores the images and the data will be used for processing the results in a mobile application. This application will create a graphical chart about the variations in body dimensions and parameters which will be helpful in maintaining fitness.

1.7.18 Medical Waste Management

Hospital waste management is a difficult problem faced by the healthcare facilities throughout the world. If these bio medical wastes are not disposed properly, it may lead to spread of infectious diseases. IoT-enabled waste management system will provide a smart solution to this problem.

Sensor-enabled dustbins may be used which is connected through IoT devices. The sensors detect the amount of trash present and automated messages will be generated to dispose the waste when the garbage bin is full. Through the connected devices, autonomous robots can fetch the garbage and dispose it in a smart way.

As robots are involved in disposing medical wastes, this may reduce the risk of spreading of the diseases through housekeeping staff who generally deals with disposal of garbage. This smart way of waste disposal will keep the hospital environment clean and safe.

1.7.19 Monitoring the Heart Rate

There is an increase in the number of heart patients throughout the world due to the unhealthy lifestyle. Most of the time delay in getting medical attention results in the loss of life of the patients.

With the advancement in technology, regular monitoring of the heart-beat and pulse rate is possible by means of sensor-enabled IoT devices. Since it is a real-time monitoring, any variations in the heart rate or pulse rate will be alerted to the patients as well as doctors through connected devices. Immediate medical attention is possible which can save many lives.

1.7.20 Robot Nurse

Workload of the nurses in hospitals are more which makes them exhausted and less efficient. Artificial Intelligence-enabled robots can assist the nurses in their day-to-day activities. The robots may be connected to IoT devices so that the activity of the robots can be scheduled and monitored by the nurses.

Robots can assist the nurses in picking and placing the medicines and alerting the patients to take medicines on time. They can give personal care for the patients and also can clean the rooms and beds. Nurses can assign the tasks to robots and monitor it. These robots may be controlled by the patients and nurses by means of mobile devices.

With these assistant robots, nurses can manage their workload in an efficient manner and provide better service to the patients.

These are some of the IoT applications in healthcare system which can give a new dimension to the patient treatment and healthcare services.

1.8 Global Smart Healthcare Market

It has been found that the four factors which demand the growth of smart healthcare operations are the following:

- Remote health monitoring for aged people
- Awareness about the importance of health and staying fit
- Increased use of wearable smart gadgets for monitoring health
- New business models based on smart healthcare systems

The global market growth is as shown in Figure 1.2. It has been estimated that the remote health monitoring will increase the global healthcare market by 24.55% by 2020. Increase in the use of ingestible smart pills will drive the market to 6.93 billion dollars by 2020 with a market growth of 23.62%. It has been estimated that the total market value of smart healthcare will be 169.32 billion dollars by 2020.

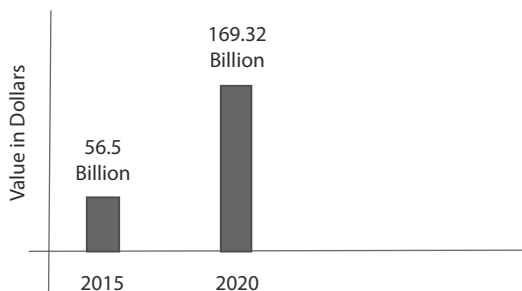


Figure 1.2 Global market growth.

It has also been estimated that the use of robots along with IoTs will increase by 50% in the near future to assist in the healthcare daily activities. Globally, about 60% of the healthcare organizations have implemented IoT devices for their services and facility. This is a digital transformation era for the healthcare services.

1.9 Recent Trends and Discussions

We have discussed about the various applications, advantages, and challenges of IoT in health sectors in the previous sections. The combination of AI and ML along with IoT devices can open up new opportunities in the field of health sectors especially in prediction, detection, risk assessment, treatments, etc. Cloud services can easily be utilized to overcome the limited resources and computational capacity required for the implementation of AI and ML.

The quality of the internet connectivity also needs to be improved, owing to the huge amount of data generated as for real-time data generation, response time, and performance plays a major role. Healthcare professionals should be able to take proactive decisions based on the real-time data to prevent the degradation of health conditions.

Remote diagnostics can be made possible by means of combining big data analytics along with ML techniques and AI by analyzing the vast number of images stored in the database.

Human errors can be reduced due to the advancements in telerobotic surgeries, and hence, the Internet of Robotics will play a major role in future healthcare sectors.

Due to the evolutions of these technologies, more research will happen in biomedical sector and modern healthcare systems which may provide personalized drugs and targeted drug delivery systems.

With the promising research going on in the healthcare sectors, more innovative smart wearables and gadgets can be expected in future. Also, due to the increased use of IoT in healthcare sectors, countries around the globe are formulating new policies and rules for the usage of IoT in medical practices.

More research is happening to overcome the security challenges faced by the usage of IoT devices in healthcare sectors, the future of applications of IoT in healthcare services is very bright, and it will give an unprecedented transformation to the healthcare industry services.

In the coming decade, Internet of Healthcare things (IoHT) will lead to improved efficiency and effectiveness in terms of systems, process and service delivery in treatment, diagnosis and patient care standards.

1.10 Conclusion

IoT in health sectors is a major revolution that has happened in the recent past. With the advancement in technology, the awareness of the smart gadgets is also increasing among individuals. The increase in awareness of leading a healthy life style made the common people to depend on smart wearables to monitor their health and daily activities.

The ease at which the connected devices reduces the workload of health-care facilities motivated majority of the healthcare services to implement IoT devices for healthcare system. With the increase in use of IoT devices, the security and privacy concerns of the patient private data also increased. Continuous research is happening in this field to protect the privacy data from security threats. With the proper care in implementation, securing the privacy data, and maintaining the IoT devices by timely updating it, these devices can bring a new dimension to the healthcare field.

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