HIOT: A Case Study of IOT based Health Care Ecosystem Using Machine Learning

Meenakshi Sharma[a*], Bhavneet Singh[b]

sharma.minaxi@gmail.com[*a],bhavneetsingh1111@gmail.com[b]

[*a,b] Global Group of Institutes, Amritsar, Punjab

Abstract: Internet of Things (IoT) is known as a network of various physical devices that are implanted with different sensors, software along with Internet connectivity to allow connected devices to communicate without human interference. Today, IoT has spread in almost all fields, such as agriculture, industries, supply chain management, sports, smart cities, traffic management, driverless vehicle technology, healthcare, etc... Devices can communicate any time at anywhere in all places. , which makes the Internet of Things called the Internet of Everything. Medical care is known as the progression of human health through the prevention of ailments, the diagnosis and treatment of illnesses, accidents and mental disabilities. With technological advancements, machine learning (ML) and deep learning (DL) are gaining popularity in many applications, such as natural language processing (NLP), disease prediction, bioinformatics, speech recognition, etc.. One of the main reasons for deep learning to become popular again is the big data generated by interconnected high-performance devices (GPUs). The main data sources for the deep learning system are medical IoT, electronic health records (EHR), digitized images, and healthcare records. There are certain issues that can be encountered in deep learning, such as privacy, implementation, and optimization. This chapter introduces machine learning/deep learning applications for IoT in health systems and medical sciences by reviewing related work. Finally, this chapter will discuss the challenges, opportunities, advantages, and disadvantages of each study.

Keywords: Machine Learning (ML), Deep Learning, Healthcare Internet of Things (HIoT), Electronic Health Records (EHR), Predictive Analysis

1. INTRODUCTION

Now-a-days, the demand of linked devices is escalating across different industries. With the advancement of technology, IoTis finding applications in the domain of smart cities, healthcare, entertainment systems, smart homes etc. as depicted in Figure 1[5][6][7]. There are numerous applications of IoT in healthcare such as patient's health monitoring, patient tracking in the hospitals, checking the availability of beds, tracking the medicine intake of the patients using smart pill dispensers along with generating alerts to the care givers etc. The primary components for the implementation of IoT are sensors, different medical equipment, artificial intelligence and advance devices used for imaging. These devices help to improve the efficiency as well as quality of life in industries. [8][9].With the use of IoT, certain health conditions can be detectedat an early phase and it becomes possible to generate prompt responses to the health emergencies before even when patient is on the go [1]. Additionally, the IoTcan enable the healthcare agencies to cut down the cost with the usage of equipment track systems [2]. Not only this, it is feasible to improvise the healthcare services quality by providing the personalised care to the patients.

Healthcare is considered to be the most crucial part of life. Health care involves the sustenance and improving the various health conditions by diagnosing various ailments and taking measures to prevent them. While checking the feasibility of healthcare solutions, there are three parameters that need to be considered.
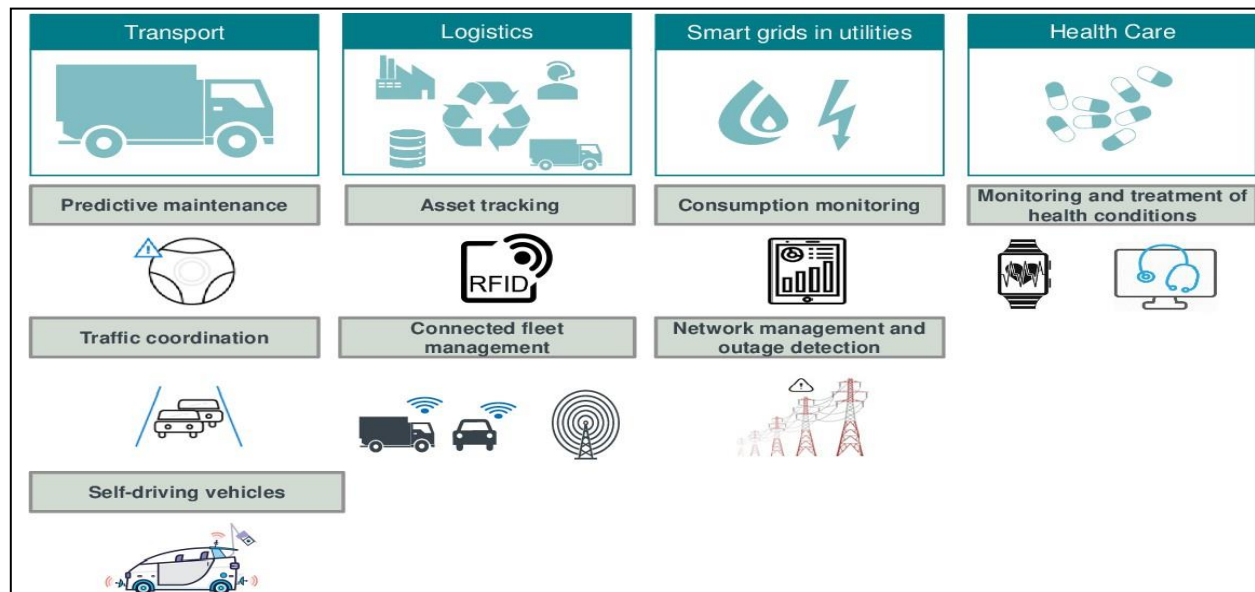
**Figure 1: Applications of Internet of Things (IoT) [11]**

These are:
1. The quality of Health Care offered
2. Effective cost
3. Desired Outcome

Various diagnostic approaches such as CT Scan, MRI, X-rays are carried out in order to detect the abnormalities lying beneath the skin. The medical specialists and healthcare professionals focus on bringing the innovative methods to detect the diseases and deliver the targets. Numerous health issues such as chronic artery disease and epilepsy can now-a-days be discovered even before their actual occurrence in the patient's body.

As the consequence of population explosion, there is a huge demand for medical professionals and medical resources such as hospital beds, oxygen masks, smart pill dispensers etc. Sometimes, due to misdiagnosis, a huge amount of time as well as resources are mislaid in the healthcare systems. Therefore, there is a dire need to come up with the solutions that could considerably reduce the time, resource wastage and effort that are carried out on current human-assisted healthcare systems. Not only this, solutions need to be generated for maintaining the effectiveness as well as quality of the health care offered. IoT facilitates the healthcare specialists to be more observant so astoconnect proactively with the patients. The data gathered from IoT devices can assist the doctors recognize the best possible treatment for patients and reach the expected consequences.

The Healthcare sector has become one of the fastest growing sector to adopt Internet of Things. The quality and effectiveness of the rendered services can be improved by integrating IoT into medical devices which is really beneficial for the patients with chronic illness. As per the study conducted by McKinsey Global Institute, the total spending on healthcare IoT will reach $1 trillion by 2025 as depicted in Figure 2. Now-a-days hospitals are making use of IoT and it is common to have IoT devices deployed in the rooms of the patients, Electronic Health Records as

well as cloud based resources. However, the major challenge with IoT in healthcare is the security vulnerabilities.
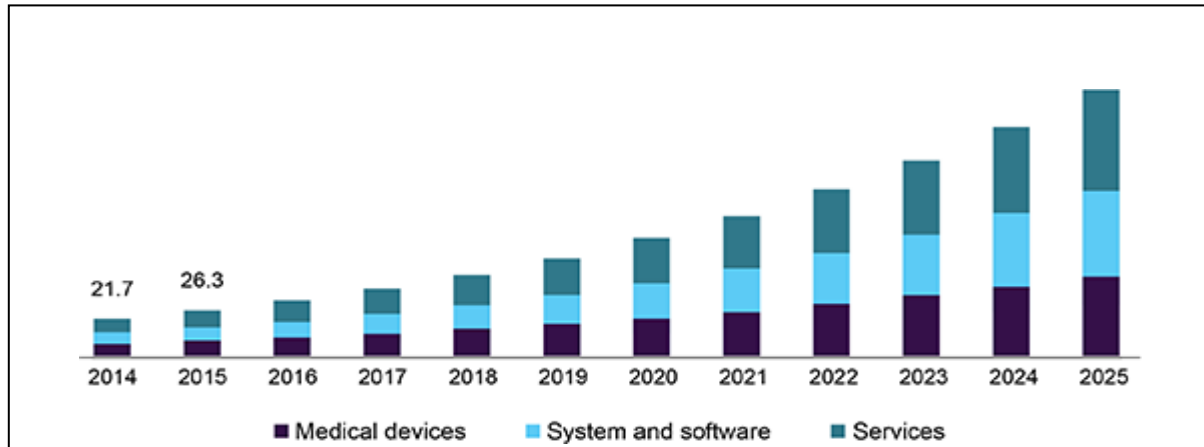
Figure 2: U.S. IoT in healthcare market size, by component, 2014-2015, (USD Billion)
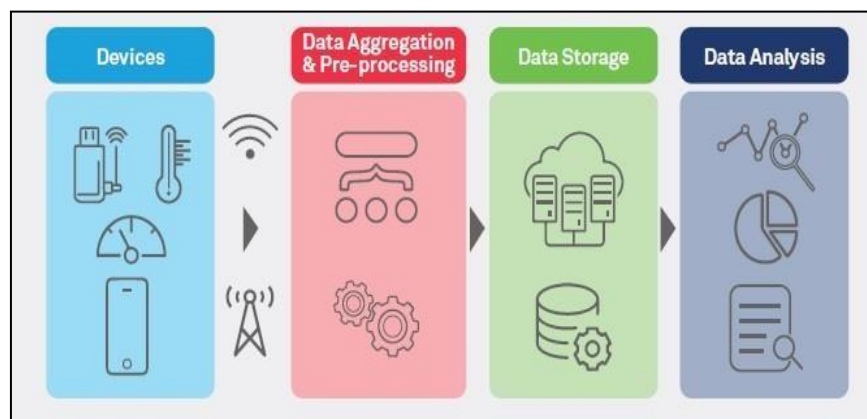
1.1 IoT ARCHITECTURE

The IoT architecture consists of four stages as depicted in Figure 3. All these stages are connected in such a way that the data which is captured at one phase generates the value for next phase.

Step 1: In the first step, the interrelated devices are deployed which include actuators, sensors, detectors, monitors etc. These devices are deployed for the collection of the data.

Step 2: The data generated by the sensors along with other devices is in analog form, so we need to aggregate and convert it into digital format for further processing.

Step 3: After the digitalisation and aggregation of data, the data pre-processing is done and then the data is moved to cloud.

Step 4: Finally, the analysis is carried out, to bring out the actionable business insights to carry out the decision making effectively.

Figure 3: Stages of IoT Architecture [10]

The network architecture of IoT for healthcare (HIoT) is depicted in Figure 4. It includes the Healtcare sensing devices followed by the networking layer. All the data gathered from the medical devices is warehoused on the cloud. On the basis of gathered information, the monitoring is done and the reports are generated.
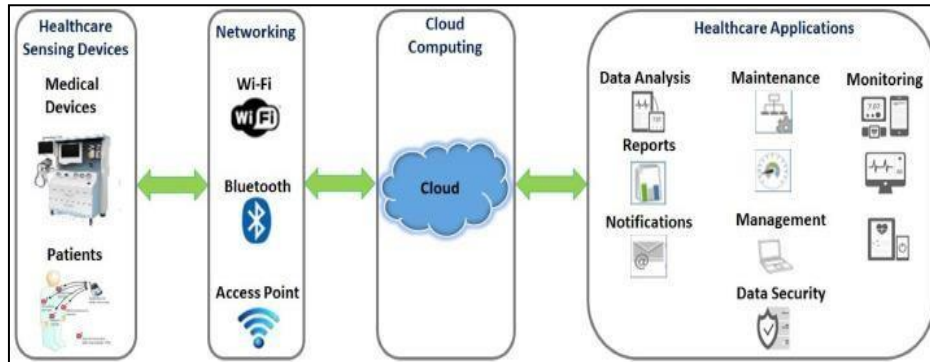
Figure 4:HIoT Network Architecture [11]

1.2 MACHINE LEARNING IN HEALTHCARE

In conducive to dealing with the volumes of data generated by IoT devices in a faster and accurate manner, the medical specialists take aid from the Machine Learning and Artificial Intelligence concepts. By gathering the data from different data points, the machine learning algorithms predict the outcomes by making the analysis. These algorithms also suggest optimal resource allocation along with the timely risk scores. The sole purpose of Machine Learning is to make the decisions on the basis of patterns and the experiences gained. The machine learning algorithms take the data and the logics are built on the basis of the data entered. Now-a-days a large number of data-intensive fields like medicine, astronomy, have adopted the use of machine learning methods to solve the mining problems. The advantages offered by machine learning as depicted in Figure 5 in the health care are:

- Data Collection
- Identification and the diagnosis of diseases
- Drug discovery
- Medical imaging
- Maintenance of health record.

Figure 5: Applications of Machine Learning (ML) in Healthcare

1.3 IOT IN HEALTHCARE

The Internet of Things (IoT) is well integrated with various organisations including healthcare domains. The IoT enables us to move towards a new era of health monitoring of the patients as well as managing with the digitised health systems. As the healthcare is implementing IoT, the expectations are that the data produced by IoT devices will increase in a drastic manner. The HIoT (Healthcare Internet of Things) refers to the concept where interconnected devices are employed to provide healthcare solutions. These devices also interconnect with each other for efficient implementation of the medical procedures, thereby enabling extraction of information. The automatic resource management is also possible. the solutions provided by HIoT are very flexible. These solutions enable the safety of the patients apart from providing better quality in much less time. The edge devices can be integrated with the cloud through middle network to enable the data generated to be stored on the cloud as shown in Figure 6. The size of the system does not matter at all. The systems can be deployed anywhere if the facility is linked and integrated with the primary sources. the management of medical amenities is even more effective with incessant access to the medical equipment's, necessitated data and patient's medical information. The applications of IoT in healthcare ecosystem are:

- Notifying the patients of the underlying problems
- Health parameters based monitoring
- Automatic reminders regarding medicines etc.
- Detecting the ailments even before their occurrence
- Automatic transfer and exploration of data
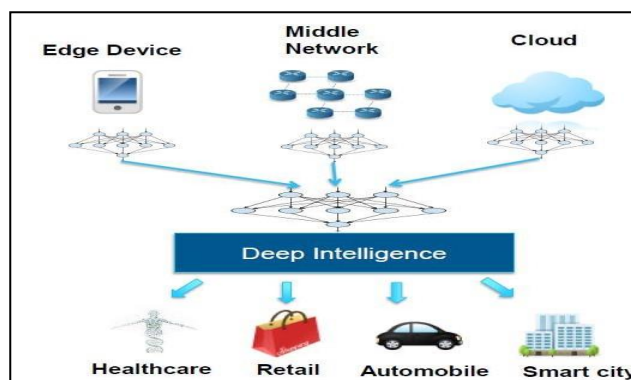
Figure 6: Integration of Edge devices with cloud through Middle network

2. RELATED WORK

SureshkumarSelvarajet. al.[3] investigated the architecture used in the IoT especially the cloud integrated systems. AnuRathee et al. [18] reviewed various concepts with regard to sensor based wireless wearable devices in healthcare domain with the perception of whole IoTecosystem.AshrafDarwishet. al. [19] validated the different instances of the expertise associated with the policy reflections such as scalability, safety, pros and cons, competence of power and unobtrusiveness associated with the systems. In contribution towards the major positives, implanted body sensor domain networks and wearable domain looked into the main challenges and the vulnerabilities in the investigation that are explored beyond the resolution.

Sana Ullahet.al. demonstrated the in-body as well as out-body communication connection on the techniques of wireless communication along with embedded medical equipment with external observation equipment's on the body sensor networks employed in the health-care applications.S. N. Mohamed Hamdiet. al. [20]proposed an encryption protocol which was based on the identity and it was found to be suitable for body smart sensor systems. A well-formulated verification as well as validation architecture was presented by Sanaz Rahim et. al. [21] for the healthcare systems based on IoT.The security of the proposed architecture was ensured by the DTLS handshake protocol that helps to authorise and authenticate the architecture. Further, Nathalie Marcela et. al. [22] demonstrated an implantable sensor which is wearable and flexible. YangzheLiaoet. al. [23] offered amethodical as well as accurate model based on in-to-out (I2O) human body path loss (PL) on the basis of a 3D heterogeneous human body prototypical below security limits.

3. BENEFITS AND CHALLENGES OF IOT IN HEALTHCARE
3.1 BENEFITS
3.1.1 Instantaneous reporting and monitoring

The actual controlling through linked devices can help to save the lives of patients in case of medical emergency such as heart failure, diabetes etc. The smart medical devices connected to a smart mobile application can help to regulate the arising situations. The accompanying resources can collect the medical information along with the additional information to deliver the data to medical professionals.

3.1.2 Affordability and End-to-end connectivity

The treatment of ill patient scan be structured with the help of IoT along with the supporting healthcare manageability result with other modern technologies, and healthcare services for newer generations. IoT enables data interchange, machine-to-machine communication, data sharing, and flow of information which creates the healthcare facilities operative. The protocols ensuring connectivity such as Wi-Fi, Bluetooth LE, Zig-Bee etc., healthcare workers can transform the ways they identify illness in sick persons thereby ensuring to discover innovative methods and procedures for treatment and caring.

3.1.3 Tracking and alerts

In the times of life fatal condition, the on-time warning is an important aspect. With the IoT technology, it becomes convenient for the transmission of data by the resources to the medical professionals for instant follow up, thereby reducing the proclamations to manhood about critical areas through use of mobile applications and additional supported resources. The warnings specify the status of the person's condition and need to be intimated on urgent basis. It furthermore helps in creation of an experienced view and providing proper treatment and caring promptly.

3.2 CHALLENGES
3.2.1 Security and Confidentiality of Data

One of the utmost significant issues associated with IoT is the data confidentiality.

The resources associated with IoT communicate the information in real time. But, most of the resources lack standard protocols thus risking the data security. Apart from this, there is uncertainty in the possession of information. This enables the information to be extremely vulnerable for the hackers.

3.2.2 Data Load and Data Accuracy

Information gathering is a problem for utilisation of different protocols involved in transmission. The IoT devices generate vast chunks of information. This generated information is in such a large volume that it becomes extremely problematic for the medical professionals to draw the accurate conclusions.

3.3.3 Cost

The healthcare facilities provided by IoT so far are not much economical for the ordinary humans. The healthcare expenditures are booming at a rapid rate which is a matter of concern for the progressing nations. The scenario is such that ill people with critical situations are acquiring the healthcare services provided by progressing nations thereby reduction in the prices.

4. APPLICATIONS OF MACHINE LEARNING IN HEALTHCARE ECOSYSTEM

The diagnosis of chronic ailments that require lifelong treatment of the patients contribute to a major portion of the healthcare costs. In order to perform diagnosis of these ailments the different prototypes of predictive framework are applicable in the present days [13-18]. The machine learning prototypes serve in enhancing the quality of medical database thereby reduction in variation of patient rates. So, in comparison to the traditional models, these models are employed for performing the investigation and data analysis. As presented in Figure 7, the body of patient is embedded with various sensors such as Blood Pressure sensors and ECG temperature sensors.
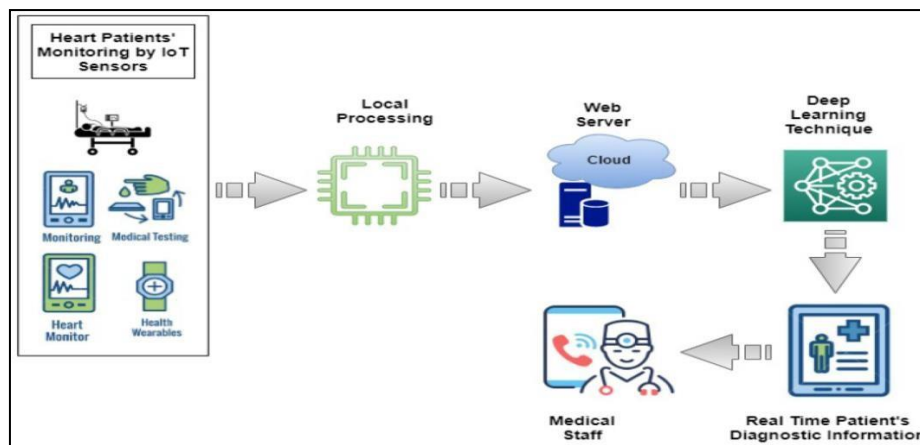
Figure 7: Predictive framework for discovery of chronic ailments [24]

These sensors are accountable for the recording of different health parameters readings. The pre-processing of gathered data is done and the data is sent to the cloud. After this, an appropriate Deep learning or machine learning technique is employed to get the real time patient's diagnostic information.

Some of the major uses of Machine Learning for IoT in health care domain are discussed below:

4.1 Identification of Disease and Diagnosis

Machine Learning models can predict the disease susceptibility thereby aiding in the early diagnosis of the diseases. With the increase in population, the healthcare systems are under pressure due to lack of resources for the disease diagnosis. A UK based expertise start-up (Feebris) make use of AI centered algorithms for the recognition of conditions related to respiratory system which, otherwise are complicated to identify. This procedure involves connecting to the medical sensors and is used by the individuals to detect early issues related to the respiration system. The Artificial Intelligence and Computer Science Laboratory of MIT has created a prediction model based on Deep learning which can detect the occurrence of breast-cancer five years before its occurrence. These models can really prove to be the game changers for the healthcare system.

4.2 Machine Learning Implication in Radiology

The realisation of machine learning and Artificial Intelligence in radiology is being carried out by the researchers. The software are used by the radiologists to speed up the process of detection. The medical imaging received as a result is used to detect the abnormalities. Most of the time, the supervised machine learning algorithms are used. The machine learning methods to carry out the segmentation i.e. identifying the structures in an image. Thus, machine learning can advance patient healthcare services in the domain of radiology as depicted in Figure 8.
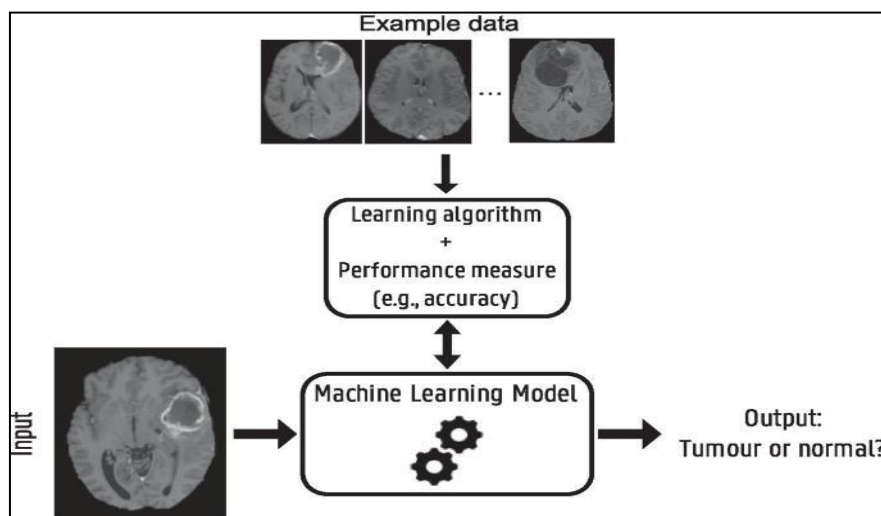

Figure 8: Use of Machine Learning in Radiology

5. APPLICATIONS OF IOT

5.1 Distribution of Medical Information

The distribution of up-to-date and reliable information to the patients regarding their health issues is one of the most rebellious tasks. IoT enables to improve individual's health care in addition to facilitating the professional practice of healthcare professionals. The distribution of Medical information in an efficient manner is one of the commendable innovation in the healthcare IoT (HIoT). The intrusive care is facilitated by the IoT into domains like homes and offices, thereby enabling the systems to use the healthcare services outside the hospitals as well. therefore, individuals can cater to their health conditions on their own. As a result, this has overlaid the path for very smooth flow of the health care, thereby reducing the accidents from miscommunication, and increasing the fulfilment of patients as well (Figure 9).
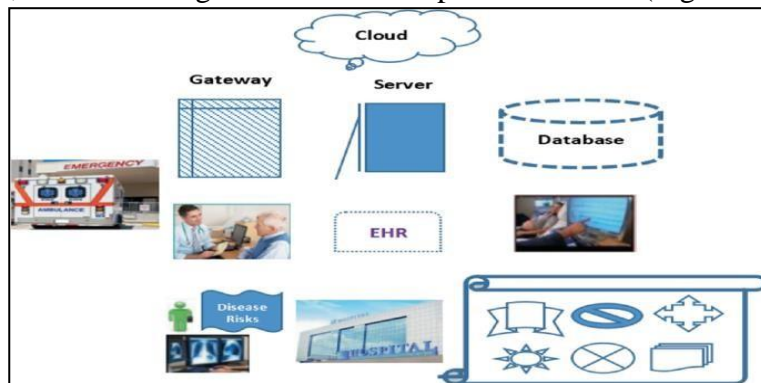
Figure 9: Medical information distribution via IOT applications

5.2 Emergency Care

Limited medical resources along with disconnection with base facilities are the major issues of emergency support services. The effective solution to these problems is the automation and the analytics provided by various IoT applications. The medical professionals can have easy access to profiles of the patients and thereby proper diagnosis can be carried out in due time, even before the patient's arrival in the clinic/hospital. Therefore, in case of any emergency situation, the required steps can be carried out even from distance. This leads to reduction in associated losses thereby enhancing the emergency health care (Figure 10).
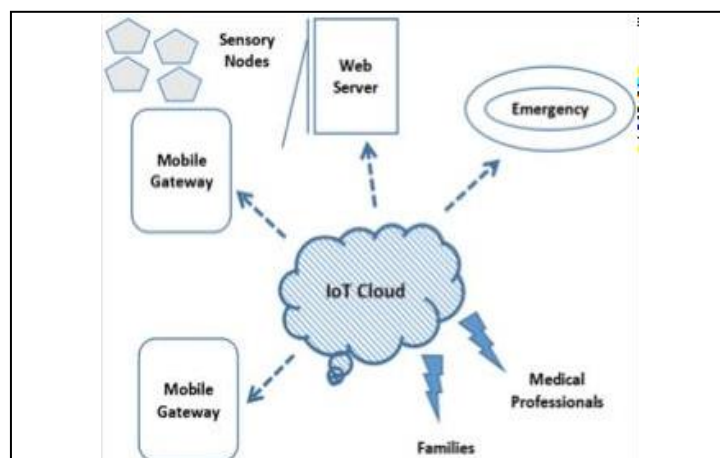
Figure 10:Emergency Care via IOT applications

5.3 Dropping Emergency Room Waiting Time

One of the most tiresome task in healthcare system is the emergency room waiting. A huge amount of time is wasted in visiting the emergency rooms apart from various healthcare demands as well as the expenditure. This waiting time in the emergency rooms can be reduced by deploying the IoT in the hospitals and medical organizations as depicted in Figure 11. One instance for the reduced waiting time is that half of the waiting time for the patients needing emergency care was reduced at Mt. Sinai Medical Center in the New York City. All this had been possible with collaboration with GE Healthcare along with IoT based software (AutoBed). This software keeps a track of occupied beds among almost 1200 units by taking into consideration different factors so as to assess the requirements of the patients. This system is really reliable and efficient which highlights more innovative usage of the IoT.

Figure 11: Emergency waiting time reduction using IoT

5.4 Tele-health

With the advancement in tele-health and off-site healthcare monitoring system, there is a possibility that patients do not need to visit hospitals and emergency care rooms. This helps in reduction of overall cost and expenditure on the healthcare services. It also enables to reduce the travel which sometimes gets inconvenient, thereby helping the patients to improve the quality of living. The difference becomes more visible if the patient is not into travelling or he is totally dependent upon public transportation. Some advantages of tele-health or remote monitoring using IoT are depicted in Figure 12.

Figure 12: Advantages of Tele-Health using IoT

5.4 Critical Hardware Risk Management

As the society is advancing day-by-day with the introduction of new technologies, there is a dire need for various hardware as well as software devices that can align with the demands of next generations. There are some IoT based solutions that help to enhance the human life. Similar to the other electronic devices, IoT driven devices are also prone to some risks such as power outrage and system failures, which can become a matter of life or death. Various IoT devices has been developed in order to resolve this issue. For instance, a device named eAlert has been designed by Philips that can resolve this issue. Rather than waiting for an equipment to fail, this device works proactively by virtually monitoring the hardware equipment thereby alerting the staff of any of the issues.

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5.5 Tracking of Information

The most important concerns for any healthcare organization are the safety and security. Therefor it becomes really important to track the assets such as staff members, patients as well as the hardware equipment. It is extremely difficult to ensure the security without the capability of tracking the resources. If the organization is small, then it can be accomplished easily but for an organization with multiple structures having more number of patients and staff it becomes a matter of apprehension. Various organizations are now-a-day moving towards IoT based as well as real-time location based systems. Though it is a cutting edge technology but it is very expensive.

5.6 Improved Usage of Drug

The new ways of medication prescription has evolved as one of the most exciting innovation in the IoT domain. This method makes use of pills that contain minute sensors which can transmit signals to the external devices, especially a patch that is worn on the body in order to ensure the appropriate dosage.

5.7 Better Supervision and Reporting

The real time management by IoT devices can save the emergencies of some patients having chronic disease such as heart attacks, asthma etc. The data pertaining to the disease can be accumulated by IoT device in real-time thereby conveying it to the doctors in real time.

5.8 Data Analysis

The IoT devices can collect the reports and can evaluate the data collected in limited time thereby reducing the shortage. This enables the healthcare professionals to focus on relevant data and to make the decisions effectively.

5.9 Alerts and Tracking

One of the most crucial things in case of emergencies can be the timely alerts. Internet of Things enables the medical equipment to collect all the essential data and transmitting t to the healthcare professionals. The generated reports can depict about the health condition of the patient regardless of the time and location.

6. Challenges of IoT in Healthcare

There are a large number of applications in healthcare where IoT is adopted. IoT provides support in healthcare such as smart homes for patients with diabetes, monitoring of patients. There are certain issues which can occure in HIoT, some of them are listed below:

- As IoT provide high flexibility as the patient is being monitored from home rather than a hospital, sometimes the IoT wearable devices such as sensors are uncomfortable for the patients.
- Sometimes, the quality of data that is being transmitted gets affected due to noise. So, there a good architecture is always required for transmission of data so that it can be transmitted without any distortion. Additionally, noise removal methods can also help to counter this issue.
- The existing ECG monitoring devices analyze the signals in a supervised manner which leads to increase of cost. Apart from this, this can also generate errors while detecting. The Machine learning techniques can be used to analyze the signals which can help in improving the efficiency and reduction in expenses.
- A huge amount of energy is required by the sensors and IoT devices, therefore it leads to increase of power leakage as well as consumption of energy. One can use various optimization techniques to control the energy usage.
- More storage space is required to store the information gathered from the IoT devices. This issue can be overcome by storing the data on the cloud (Figure 13) but this integration of IoT with cloud increases the complexity.
- Another issue associated with IoT is that the devices are more prone to security attacks. It is difficult to apply encryption technique as these devices are low resource constraint.
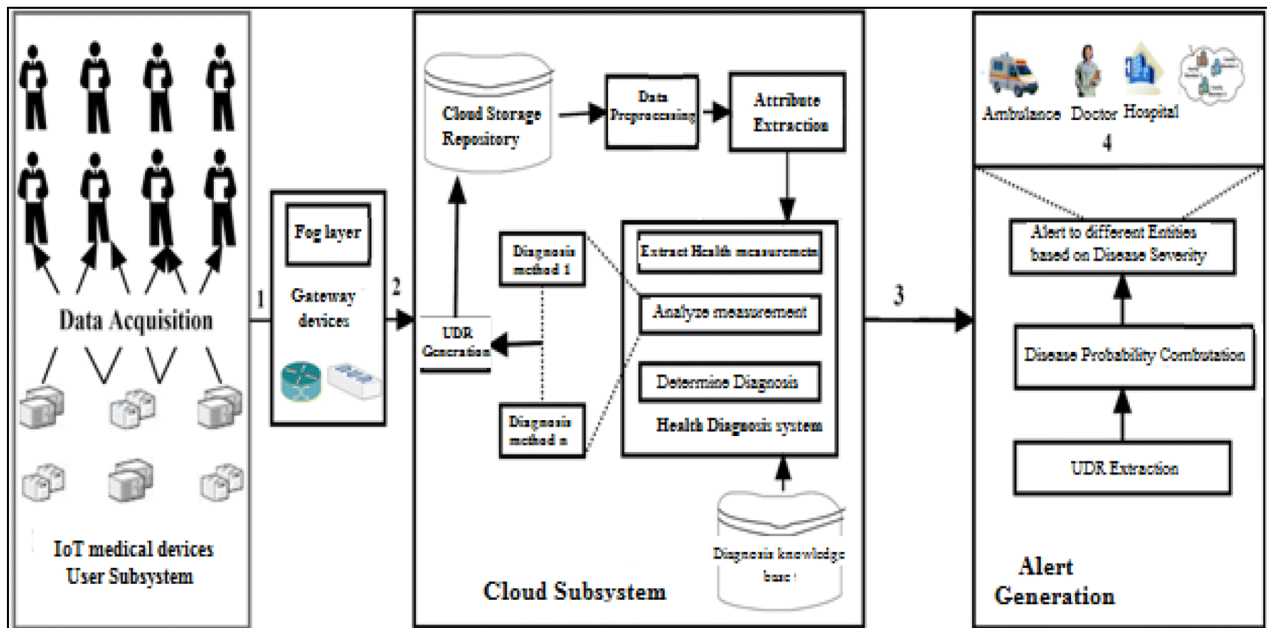
Figure 13: Integration of HIoT with cloud

7. CONCLUSION AND FUTURE DIRECTION

The advent of IoT has brought about a paradigm shift in the design and delivery of healthcare facilities. Harnessing IoT-based technologies has not only improved product performance, but also bridged the gap between healthcare delivery and equipment capabilities. The incorporation of IoT tools has sparked a revolution in the healthcare sector, especially through the use of HIoT, enabling remote monitoring and tracking of patients. Additionally, the integration of cloud computing and virtual architectures gives caregivers real-time information, facilitating evidence-based treatment. This chapter has provided an insightful exploration of the benefits, barriers, technologies, and various applications of HIoT.

One promising direction is the integration of artificial intelligence (AI) and machine learning (ML) algorithms with HIoT systems. By leveraging AI and ML, healthcare professionals can gain deeper insights from the vast amounts of data collected by IoT devices, enabling more accurate diagnoses, personalized treatments and proactive healthcare interventions. Furthermore, the expansion of HIoT in telemedicine and telehealth services is expected to reshape the healthcare landscape. With the ability to remotely monitor patients and provide virtual consultations, HIoT can improve healthcare accessibility, especially in rural or underserved areas.

Another future direction lies in establishing robust security and privacy frameworks for HIoT systems. As the healthcare industry becomes increasingly interconnected and dependent on IoT devices, ensuring the confidentiality, integrity and availability of sensitive patient data is crucial. Efforts to develop standardized protocols, encryption mechanisms, and secure data transmission methods will play a central role in promoting trust and widespread adoption of HIoT technologies.

Overall, the future of HIoT holds great potential to transform healthcare delivery, improve patient outcomes, and advance medical research. Continued research, collaboration between industry and academia, and regulatory frameworks will be essential to realizing the full potential of the IoT in the healthcare ecosystem.

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