Internet of Things in Healthcare: Applications, Benefits and Challenges

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Abstract : The Internet and all its associated services and applications have strongly influenced communication, information and marketing across the world. The concept of connected devices or things has given a new rise of the Internet. Anything, anywhere can get connected with the Internet and becomes 'Smart. The interconnection of various things embedded with sensors, electronics, software, and so on, over the internet with the capability of sending and receiving information is named as Internet of Things (IoT). IoT is a rapidly growing network of a variety of different 'connected things'. The impact of Internet of Things has been revolutionized in all fields of life. Healthcare is an important part of life. Sadly, the spread of Covid-19 has strained the majority of health systems and the demand for resources from hospital kits to doctors and nurses have become extremely high. However, the significant advancement in the computing sector have led to the emergence of Internet of Things (IoT) which has now become one of the most powerful information and communication technologies IoT enables real-time alerting, tracking, and monitoring, which permits hands-on treatments, better accuracy, apt intervention by doctors and improve complete patient care delivery results. This paper presents the overview of Internet of Things (IoT), and the role of IoT in health sector.

Keywords – **Internet of Things, Architecture, Remote monitoring, Sensors, Smart health, Telemedicine.**

I. INTRODUCTION

If Internet is connecting the people, the Internet of Things (IoT) is connecting all the objects. Just like Internet has changed the way we work & communicate with each other, by connecting us through the World Wide Web, IoT also aims to take this connectivity to another level by connecting multiple devices to communicate electronically with the world around them thereby facilitating man to machine and machine to machine interactions. The term IoT was first coined by Kevin Ashton in 1999. By the late 1990s, the dot com boom was taking place and researchers such as Neil Gershenfeld at Massachusetts Institute of Technology (MIT) were using terms such as "Things That Think" to describe research into the use of sensors on everyday things. Now Internet of Things (IoT) has impacted a multitude of areas and has given rise to what is popularly called "smart everything" including "smart homes", "smart devices & electronics", "smart automobiles" including driver less cars. IoT allows multiple connected devices to collect and share information with each other.

IoT's impact on the healthcare industry has increased over the years. The digitization of data including health data referred to as Internet of Things and its usage in delivery of healthcare has been growing rapidly across the world. Capitalizing on the efficiency of data retrieval from smart objects in the health sector, it is clear that a solution is necessary and required to improve the health sector in the era of Covid-19 pandemic while continuing to provide a high-quality care to patients. IoT is for better managing chronic disease, medical emergencies, better patient-care, fitness, blood pressure monitoring, health check system, measurement & control system, heart rate checking system, and hearing aids. It can continuously monitor people and provide a better personalisation experience in the medical field due to its capability to connects object such as medical kits, monitoring cameras, home appliances and so on. Reports and alerts give a firm opinion about a patient's condition, irrespective of place and time. It also helps make well-versed decisions and provide on-time treatment.

The COVID-19 pandemic has been a pivot for exponential growth of IoT in healthcare. Several rapidly evolving technologies are converging to influence the trajectory of IoT in healthcare. IoT enables real-time alerting, tracking, and monitoring, which permits hands-on treatments, better accuracy, apt intervention by doctors and improve complete patient care delivery results. There are several challenges in technology development, healthcare delivery as well as issues related to privacy of data, digital divide, role of government and other stakeholders, behavior and adoption by medical doctors and hospitals. The review article provides an overview of the emergence of IoT in healthcare globally, This paper presents an overview of Internet of Things(IoT), the emergence of IoT in healthcare sector, it's benefits and challenges.

II. CHARACTERISTICS OF IOT

Key characteristics of IoT are as follows:

2.1 Intelligence: IoT comes with the combination of algorithms and computation, software & hardware that makes it smart. Ambient intelligence in IoT enhances its capabilities which facilitate the things to respond in an intelligent way to a particular situation and supports them in carrying out specific tasks. In spite of all the popularity of smart technologies, intelligence in IoT is only concerned as means of interaction between devices, while user and device interaction is achieved by standard input methods and graphical user interface.

2.2 Connectivity: With regard to the IoT, anything can be interconnected with the global information and communication infrastructure. Connectivity enables network accessibility and compatibility. Accessibility is getting on a network while compatibility provides the common ability to consume and produce data.

2.3 Dynamic Nature: The primary activity of Internet of Things is to collect data from its environment , this is achieved with the dynamic changes that take place around the devices. The state of these devices the number of devices also changes dynamically with a person, place and time.

2.4 Things-related services: The IoT is capable of providing thing-related services within the constraints of things, such as privacy protection and semantic consistency between physical things and their associated virtual things. In order to provide thing-related services within the constraints of things, both the technologies in physical world and information world will change.

2.5 Heterogeneity: The devices in the IoT are heterogeneous as based on different hardware platforms and networks. They can interact with other devices or service platforms through different networks.

2.6 Security: As we gain benefits from the IoT, we must not forget about safety. As both the creators and recipients of the IoT, we must design for safety. This includes the safety of our personal data and the safety of our physical well-being. Securing the endpoints, the networks, and the data moving across all of it means creating a security paradigm that will scale.

III. ARCHITECTURE OF IOT

The architecture of IoT depends upon its functionality and implementation in different sectors. Still, there is a basic process flow based on which IoT is built.
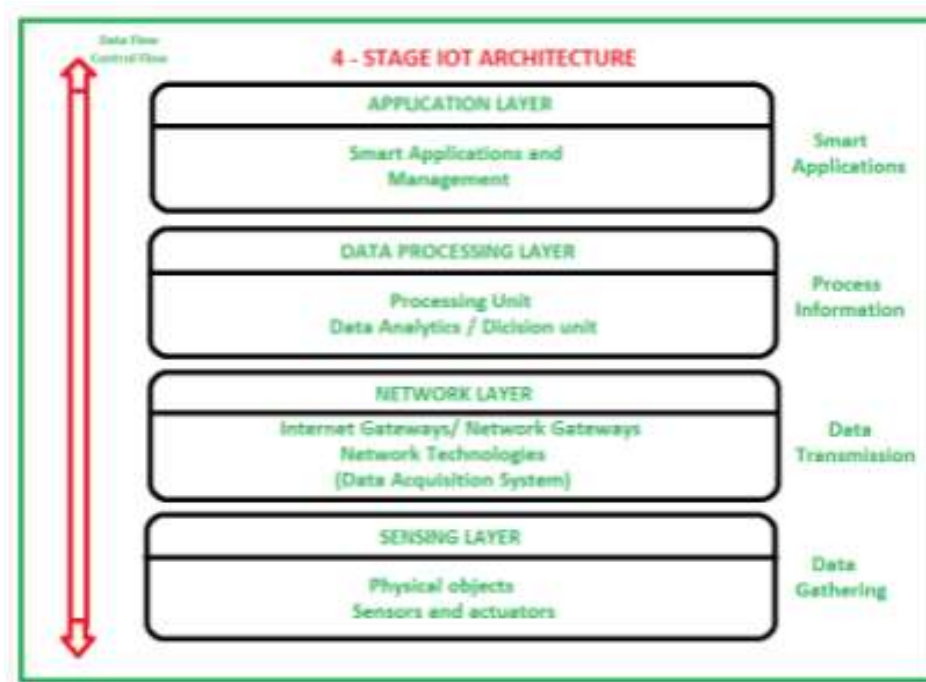

Fig 1: Four stage IoT architecture

So, from the above figure (Figure 1) it is clear that 4 layers are present that can be divided as follows: Sensing Layer, Network Layer, Data processing Layer, and Application Layer.

- **Sensing Layer** – Sensors, actuators, devices are present in this Sensing layer. These Sensors or Actuators accepts data (physical/environmental parameters), processes data and emits data over network.

- **Network Layer** – Internet/Network gateways, Data Acquisition System (DAS) are present in this layer. DAS performs data aggregation and conversion function (Collecting data and aggregating data then converting analog data of sensors to digital data etc). Advanced gateways which mainly opens up connection between Sensor networks and Internet also performs many basic gateway functionalities like malware protection, and filtering also sometimes decision making based on inputted data and data management services, etc.

- **Data processing Layer** – This is processing unit of IoT ecosystem. Here data is analyzed and pre-processed before sending it to data center from where data is accessed by software applications often termed as business applications where data is monitored and managed and further actions are also prepared. So here Edge IT or edge analytics comes into picture.

- **Application Layer** – This is last layer of 4 stages of IoT architecture. Data centers or cloud is management stage of data where data is managed and is used by end-user applications like agriculture, health care, education, aerospace, farming, defense, etc.

IV. IOT IN HEALTHCARE

IoT technologies have a high impact on high-quality medical devices, which help meet the personalised solution during COVID-19 Pandemic. These technologies can capture, store, and analyse the data digitally. All clinical records are maintained

digitally, and with the help of internet facilities, patient data and information is easily shared in emergency cases and make doctors job efficiently By using smart sensors, we achieve an excellent capability to monitor and control all the essential requirements of medical temperature, sugar level, blood pressure, and information regarding patient health. Software plays an essential role in the best way of communication and monitoring. All records are stored confidentially for the best treatment in the future. IoT enhances doctors' and surgeons' performance to achieve accuracy, efficiency, and reliability in treatment. The virtual reality is the best technology of IoT to improve the quality of planning and real-time information.

The growing trend in healthcare worldwide is preventive, predictive, personalized and participatory and underlying these trends is the increasing digitization of healthcare. Over the years, digital health care has extended from primarily maintaining electronic patient data and providing patient Web portals, to allowing further flexibility and convenience in health-care management, and is commonly referred to as connected health. Connected health uses smart phones and mobile applications, together with wireless technologies (such as Bluetooth, Wi-Fi and long-term evolution) to allow patients to connect readily with their providers without visiting them frequently. For example, a typical hypertensive patient would see his/her doctor once in six months to report daily blood pressure readings. With a monitoring application, the patient can transmit daily or weekly blood pressure readings thereby enabling his/her doctor to detect a problem and intervene earlier.

Connected health has evolved into smart health wherein conventional mobile devices (such as smart phones) are used together with wearable medical devices (such as blood pressure monitors, glucometers, smart watches, smart contact lenses, and others) and internet of things (IoT) gadgets (such as implantable or ingestible sensors) to enable continuous patient monitoring and treatment even when patients are at their homes. Smart health is expected to keep hospitalization expenses low and provide timely treatment for various medical conditions by placing IoT sensors on health monitoring equipment. The information collected by these microchips can then be sent to any remote destination. For example, wearable sensors (such as a temperature sensor and the heartbeat sensor) can act as data collecting units, collecting the physiological signals from the patient's body. The collected data are then forwarded to a local gateway server via a Wi-Fi network such that end-systems (such as a physician's laptop) can retrieve the collected data from the gateway server. Regular server updates allow physicians access to real-time patient data. These devices work together to create a unified medical report that can be accessed by various providers. This data is not only useful for the patient, but can be pooled together to study and predict health-care trends across cultures and countries. The amount of data that may be generated as a result of combining smart health devices with IoT sensors is massive. Such data are often referred to as "big data." Application of effective analytic technologies to Big Data can help provide meaningful information to physicians which would help them make more timely, informed decisions as well as take proactive measures for better health management.
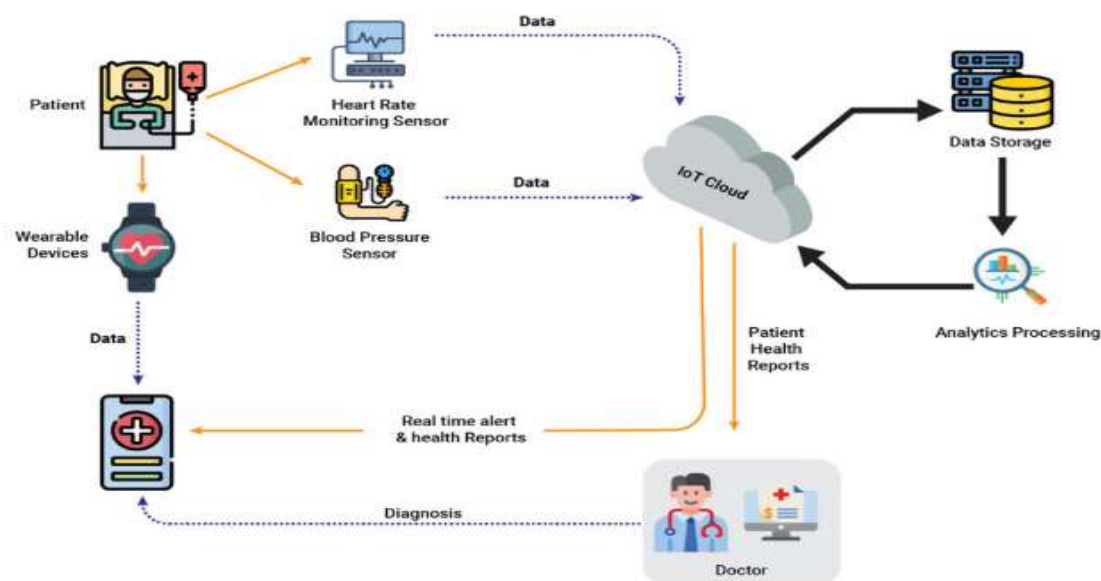

Fig 2. IoT in healthcare

IoT in healthcare refers to a network of connected medical devices that are able to not only generate, collect and store data but also connect with a network, analyse the data as well as are able to transmit data of various kinds such as medical images, physiological and vital body signatures and genomics data. Increasingly a newer term called Internet of Medical Things (IoMT) to describe connected medtech products is being used. The healthcare sector has been modernising at a fast pace over the years by utilising new technology in carrying out medical activities with increased accuracy. Despite the outbreak of Covid-19 which massively disrupted the day-to-day life of people across the globe, technology has been developing at a much faster pace to help the healthcare sector. Some of the important services offered by IoT in healthcare include, telemedicine, contact tracing, robotic sanitization and data privacy and protection in the healthcare sector. The IoT in the healthcare market is expected to grow to 89.6% in 2026.
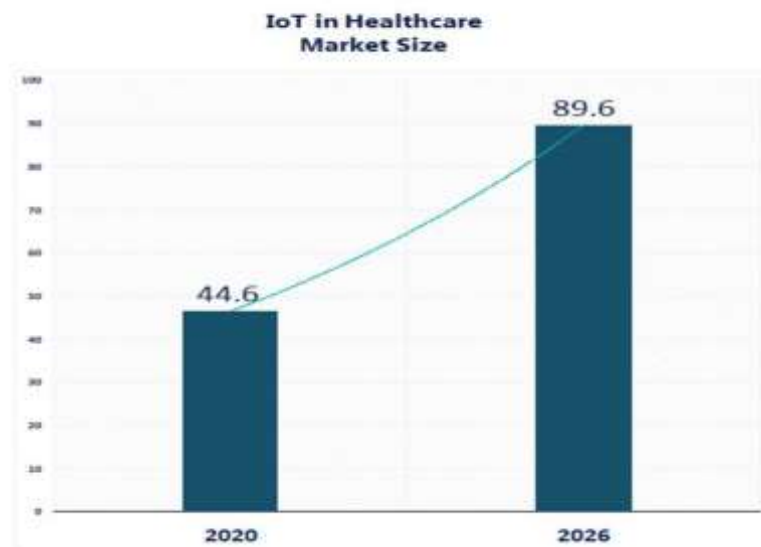
Fig 3. Estimated growth of IoT in the healthcare market

V. APPLICATION OF IOT IN HEALTH SECTOR

The rise of IoT is exciting for everybody due to its different scope of use in various sectors. In Healthcare it has several applications. IoT in healthcare helps in:

- Reducing emergency room wait time
- Tracking patients, staff, and inventory
- Enhancing drug management
- Ensuring availability of critical hardware

Enabling technologies for smart healthcare includes:

5.1. Sensors

The worldwide network of interconnected medical devices and applications is known as the Internet of Medical Things (IoMT). The core components in IoMT are sensors. IoMT has applications in both clinical and non-clinical scenarios. In a clinical context, IoMT is being used to monitor patient vitals such as temperature, ECG, blood pressure, blood oxygen saturation, etc. This allows for continuous monitoring of health vitals related to patients and helps physicians with dashboards to visualize the data. Sensors can be deployed and monitored remotely, thereby allowing for remote healthcare services. In a non-clinical context, IoMT can be used for asset tracking, tracking physician's location, compliance with hygiene standards, locating ambulances during emergencies, and operational efficiency by tracking assets, people inside the hospital, and providing real-time information for logistics.

5.2. Wearable Sensors

Wearable's or wearable devices are smart electronic devices which contains different sensors that can be used to monitor health vitals. The sensors that are used in wearable's to collect data are known as wearable sensors. These wearable's can be worn on the body or incorporated into clothing. Some of the examples for wearable's are Fitbit, Apple Watch, and Samsung Galaxy Gear. The uses of wearable's are manifold. In healthcare, wearable's can be used mainly for activity monitoring and healthmonitoring,where several health vitals of a patient are monitored, and the data is transmitted to remote physicians or doctors for making appropriate decisions. Developing these devices has had a remarkable impact on the early detection of diseases. For example, a wearable IoT device can confirm whether respiratory signs of a patient are normal or not. With this knowledge, the patient can notice any changes in his or her health situation and then decide to make a medical appointment before any other symptoms appear.

Some of the wearable sensors used for tracking health vitals are: Pulse sensors, Respiratory rate sensors, Body temperature sensors, Blood pressure sensors, Pulse oximetry sensors.

5.3. Pulse sensors

Pulse Sensors read the pulse of a human being, which can be used to monitor emergency conditions like vasovagal syncope, cardiac arrest, and pulmonary embolisms. Pulse can be read from the wrist, earlobe, chest, fingertips, and more. Earlobe and fingertip readings are highly accurate but are not comfortable to wear. Wrist sensors are generally considered as a long-term wearable system. Other sensors that can be used to measure the pulse are pressure sensors, photoplethysmographic (PPG) sensor, ultrasonic sensor, and radio frequency (RF) sensor. Based on the research done by several researchers, it is recommended to use PPG sensor for measuring the pulse. Several existing algorithms can reduce the impact of noise on the pulse signal quality.

5.4. Respiratory rate sensors

Respiratory rate sensors read the respiratory rate or the number of breaths a patient takes per minute, which can aid in identifying critical conditions such as apnea episodes, asthma attacks, tuberculosis, hyperventilation, lung cancer, and more. Several sensors were developed for measuring respiratory rate such as a nasal sensor based on a thermistor, ECG Derived Respiration (EDR), microphone, fiber optic sensor, pressure sensor, stretch sensor, sensor made from ferroelectric polymer transducer. All these sensors suffer from noise introduced through motion. For compliance with WBANs, the stretch

sensors are strongly recommended.

5.5. Body temperature sensors

Body temperature sensors are used to read the temperature of a human body, which can be used to detect fevers, heatstroke, hypothermia, and more. Most of the current research works show that thermistor-based sensors are commonly used. These sensors can read a suitable range of temperatures for monitoring the temperature of the human body, with acceptable levels of error. Using thermistor-based sensors for developing future healthcare monitoring systems is strongly recommended. The accuracy of a temperature sensor depends on how close it is placed concerning the human body. Past research works considered sensors that were printed on flexible polymers and looked like a tattoo; in some other works, embedded the sensor into the texture of the cloth fabric. Among these sensor implantable in the clothes is generally preferred over the tattoo-like sensor due to the inconvenience of adhesive coating on the backside of the polymer.

5.6. Blood pressure sensors

Blood pressure sensors are used to read the commonly and frequently monitored health vital, the Blood Pressure (BP). The measurement of BP can lead to detecting hypertension, which leads to cardiovascular diseases like a heart attack. Designing a wearable sensor for reading BP continuously and non-intrusively
is a significant challenge. Based on several research works, an accurate estimate for BP is Pulse Transit Time (PTT), which is the time taken for the pulse at the heart and pulse at another location in the body like the ear lobe or wrist. Some of the previous works tried to measure PTT between ear and wrist, palm, and fingertip. PTT can be determined by placing an ECG sensor on the chest and a PPG sensor on the ear, wrist, or another location. PTT measured between the chest and wrist was found to be accurate so far under ideal conditions. The system for measuring PTT between the chest and other locations is found to be obstructive. So, a system for measuring the readings between ear lobe and wrist was designed, and the results were quite satisfactory. As there are no accurate BP measurement systems for continuous monitoring, it is suggested to develop a system that contains two PPG sensors that can be placed at
different positions on the arm.

5.7. Pulse oximetry sensors

Pulse oximetry sensors read the level of oxygen in the blood, which is another vital parameter that can help in diagnosing conditions such as hypoxia. These sensors measure blood oxygen by retrieving PPG signals. The PPG sensor generally contains two LEDs, one red and another infrared, which are focused on the skin. Most of the light is absorbed by the hemoglobin in the blood. The oxygen in the blood is calculated by the photodiodes by measuring the light, which is not absorbed. Based on how the photodiodes are aligned, PPG sensors are divided into two types: 1) Absorbance-mode and 2) Reflective mode PPG sensors. Generally, pulse oximeters are placed on the finger as a clip. There are two techniques that can be used to reduce power consumption. One is "minimum SNR tracking," which calculates Signal-to-Noise-Ratio (SNR) and adjusts the LEDs on state appropriately. The second technique is "PLL tracking", which estimates the likely occurrence of peaks and troughs in the PPGsignal. These two techniques give a 6x power reduction with a marginal 2% error. A complementary pulse oximeter that can be placed inside the ear to read blood oxygen levels was developed, which acts as an improvement over the fingertip oximeter in certain scenarios. A wearable wrist sensor is also designed for measuring blood oxygen, which is more preferred by the people. Additionally, it can also measure pulse and temperature as well. It is suggested that the focus should be on making pulse oximetry sensors more wearable. Data collected from the sensors is primarily processed by the devices in fog layer, which provides support for emergency care and is then stored in the cloud for long-term data storage or further processing.

IoT changes the way the facilities are delivered to the industry. These technologies improve the product, causing a larger effect by bringing together minor changes. Some of the services offered by IoT in healthcare are :

5.8. Telemedicine

Telemedicine refers to the process of collecting information about patients from a remote location without requiring their physical presence in the hospital. Due to the mandatory social distancing and lockdown being implemented all over, telemedicine has become the safer way of seeking medical help. Telemedicine is also found to be cost-effective as it eliminates the cost of travel and it increases patient engagement.

Wearable IoT devices like smart watches have been very efficient in remotely collecting information on a patient's heart rate, blood pressure and other vitals. From the collected data, the physician can monitor the patient. These devices are easy to manufacture, maintain and deploy and they provide security by protecting patient identity information (PII) and patient health information (PHI). These wearable devices are beneficial in the following ways:

1. Patient Monitoring – To monitor patient's blood pressure, sugar level and temperature.
2. Heart rate monitoring – For measuring heart rate accurately without affecting the patient's mobility.
3. Mood monitoring – To understand a patient's mental state.

There are also non-wearable IoT medical devices such as ingestible sensors, connected respirators and connected contact lenses that are available in the market these days for various purposes.
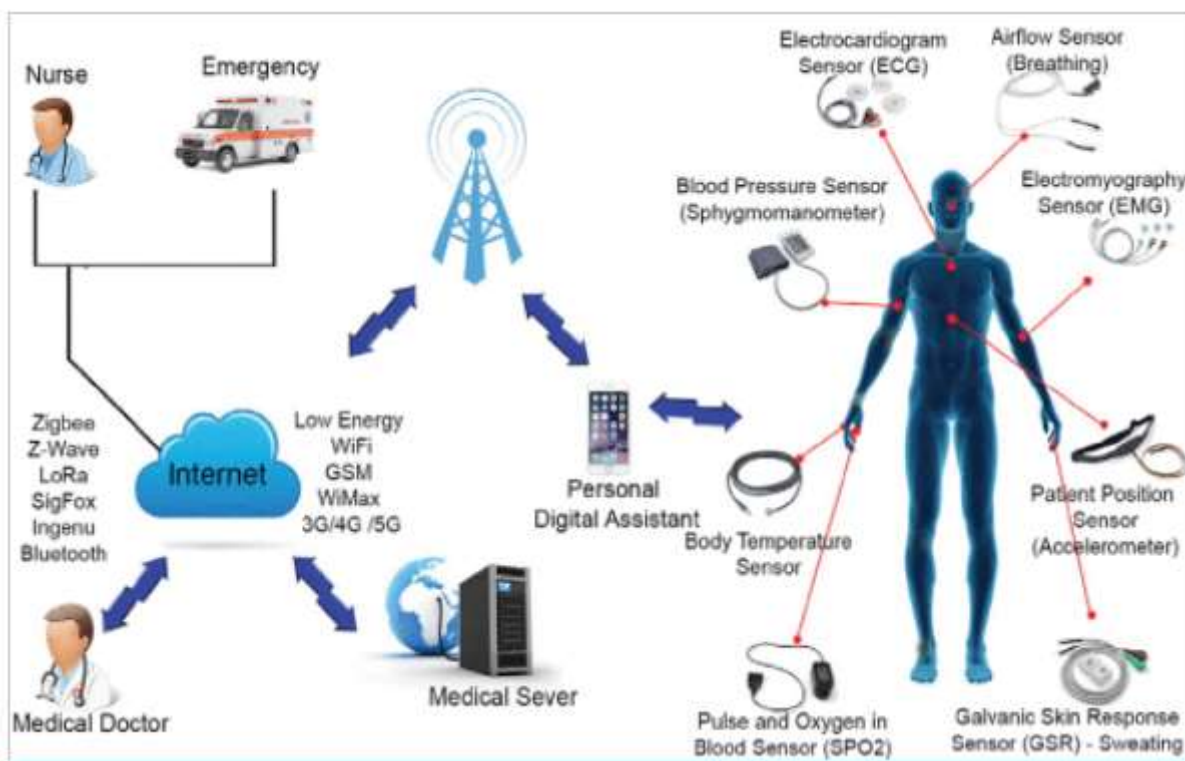
Fig 4. Illustration of an architecture for healthcare monitoring system

5.9. Implantable Glucose Monitoring Systems

Patients who suffer from diabetes can have devices with sensors implanted in them, just below their skin. The sensors in the devices will send information to a patient's mobile phone when his or her glucose levels get too low and will record historical data for them too. This way, patients will also be able to tell when they are most likely to be at risk for low glucose levels in the future, as well as in the present.

5.10. Activity Trackers During Cancer Treatment

Usually the right treatment for a cancer patient relies on more than just his or her weight and age. Their lifestyles and fitness levels also play a huge role in what the proper treatment plan for them will entail. Activity trackers track a patient's movements, fatigue levels, appetite, etc. Plus, the data collected from the tracker prior to treatment and after treatment has started will tell healthcare professionals what adjustments need to be made to the recommended treatment plan. Symptom-tracking apps that send updates on responses to cancer treatment to the physician and which can avoid hospitalization

5.11. Heart Monitors with Reporting

Patients can wear devices that monitor their heart rates, and that can determine whether they have high blood pressure. Healthcare providers will have access to reporting of patient's heart monitor data when they need to pull it during checkups and exams. The wearable devices can even alert healthcare professionals when patients are experiencing arrhythmias, palpitations, strokes, or full-blown heart attacks. Ambulances can then be dispatched in a timely fashion, which can be the difference between life and death.

5.12. Medical Alert Systems

Individuals can wear something that looks like jewelry but is designed to alert family members or friends in case of an emergency. For instance, if an individual is wearing a medical alert bracelet and fell out of bed in the middle of the night, the people they designate to help in the case of an emergency would be immediately notified on their smart phones that their help was needed.

5.13. Ingestible Sensors

Patients can now swallow devices with sensors that look like pills. Once the sensors are ingested, they relay information to a patient's mobile app that will help them follow the proper dosages for their medications. Most medications aren't taken as prescribed due to forgetfulness or other human error. This ingestible sensor works to ensure patients are taking the right medications, at the right time, in the right dosages. Some ingestible sensors are also being used to more accurately diagnose patients with things like irritable bowel syndrome and colon cancer.

5.14. Medication Dispensers

Devices can now be implanted in a patient that dispense medication in steady doses throughout the day. Patients will be notified when they need to refill their medications. Doctors can also be informed of missed doses during routine visits.

5.15. Wireless Sensors

Wireless sensors are being used in labs and hospital refrigerators to ensure blood samples, chilled medications, and other biomedical materials are always kept at the proper temperatures.

5.16. Trackable Inhalers

IoT inhalers are telling patients what they're doing or experiencing to cause asthma attacks, by transmitting information to their smart phones or tablets. That information can also be shared with their physicians. The connected inhalers also remind patients when to take their medications.

5.17. Wearables to Fight Depression

Apple has designed an app for its Apple Watch that helps manic depressive patients cope with their depression. The app tracks a patient's episodes outside of their scheduled appointments and helps to monitor cognitive and mood functions.

5.18. Connected Contact Lenses

Currently, connected contact lenses are reading glucose levels of diabetes patients. But soon enough, they'll be able to help restore the eye's focus and improve vision.

5.19. Location Services

Items like wheelchairs, scales, defibrillators, nebulizers, pumps, or monitoring equipment, can be tagged with IoT sensors and located easily by healthcare staff. A lot of times physical equipment can be misplaced or is hard to track down, but with IoT, staff will know where everything is.

5.20. Remote Monitoring

With IoT devices, healthcare professionals can monitor their patients who just underwent surgery or who go home for outpatient care. They'll be alerted if a patient reaches a critical state or needs immediate attention.

5.21. Hearables

Hearables are new-age hearing aids which have completely transformed the way people who suffered hearing loss interact with the world.Nowadays, hearables are compatible with Bluetooth which syncs your smartphone with it. It allows you to filter, equalize and add layered features to real-world sounds. Doppler Labs is the most suitable example of it.

5.22. Moodables

Moodables are mood enhancing devices which help in improving our mood throughout the day. It may sound like science fiction, but it's not far from reality. Moodables are head-mounted wearables that send low-intensity current to the brain which elevates our mood.

5.23. Sanitising hospitals and affected areas using robots

Robotics have been gaining a lot of attention in the medical field lately. It is because of their capabilities to assist in performing highly complex tasks such as neurosurgery and cancer treatments. Apart from this, robotics plays an important role in maintaining hygienic conditions as well. In times like this where human interactions have to be minimised as much as possible. on-surgical robots can be used to sanitise and clean the rooms of the patient using UV-light, which is harmful to humans if exposed. Once this process is complete, the robot notifies the workers that the room is now safe to be used. Robotic disinfection methods are proving to be highly effective, whereas traditional disinfection methods were limited to the surface.

5.24. Computer vision technology

Computer vision technology along with AI has given rise to drone technology which aims to mimic visual perception and hence decision making based on it. Drones like Skidoo use computer vision technology to detect obstacles and to navigate around them. This technology can also be used for visually impaired people to navigate efficiently.

5.25. Healthcare charting

IoT devices such as Audemix reduce much manual work which a doctor has to do during patient charting. It is powered by voice commands and captures the patient's data. It makes the patient's data readily accessible for review. It saves around doctors' work by 15 hours per week.

VI. BENEFITS OF IOT IN HEALTH CARE

The overall importance of healthcare software solutions is difficult to overestimate as technology promises to make healthcare services more effective and alleviate the burden placed on healthcare providers. This is critical in the context of the aging population and the increase in the number of chronic diseases.

The main advantages of IoT implementation in healthcare:

6.1. Simultaneous reporting and Remote monitoring

Real-time monitoring via connected devices can save lives in event of a medical emergency like heart failure, diabetes, asthma attacks, etc.With real-time monitoring of the condition in place by means of a smart medical device connected to a smartphone app, connected devices can collect medical and other required health data and use the data connection of the smartphone to transfer collected information to a physician. Center of Connected Health Policy conducted a study that indicates that there was a 50% reduction in 30-day readmission rate because of remote patient monitoring on heart failure patients. The IoT device collects and transfers health data: blood pressure, oxygen and blood sugar levels, weight, and ECGs.These data are stored in the cloud and can be shared with an authorized person, who could be a physician, your insurance company, a participating health firm or an external consultant, to allow them to look at the collected data regardless of their place, time, or device.

6.2. End-to-end connectivity and affordability

IoT can automate patient care workflow with the help healthcare mobility solution and other new technologies, and next-gen healthcare facilities. IoT in healthcare enables interoperability, machine-to-machine communication, information exchange, and data movement that makes healthcare service delivery effective. Connectivity protocols: Bluetooth LE, Wi-Fi, Z-wave, ZigBee, and other modern protocols, healthcare personnel can change the way they spot illness and ailments in patients and can also innovate revolutionary ways of treatment. Consequently, technology-driven setup brings down the cost, by cutting down unnecessary visits, utilizing better quality resources, and improving the allocation and planning.

6.3. Data assortment and analysis

Vast amount of data that a healthcare device sends in a very short time owing to their real-time application is hard to store and manage if the access to cloud is unavailable. Even for healthcare providers to acquire data originating from multiple devices and sources and analyze it manually is a tough bet. IoT devices can collect, report and analyses the data in real-time and cut the need to store the raw data. This all can happen over cloud with the providers only getting access to final reports with graphs. Moreover, healthcare operations allow organizations to get vital healthcare analytics and data-driven insights which speed up decision-making and is less prone to errors.

6.4. Tracking and alerts

On-time alert is critical in event of life-threatening circumstances. Medical IoT devices gather vital data and transfer that data to doctors for real-time tracking, while dropping notifications to people about critical parts via mobile apps and other linked devices. Reports and alerts give a firm opinion about a patient's condition, irrespective of place and time. It also helps make well-versed decisions and provide on-time treatment. Thus, IoT enables real-time alerting, tracking, and monitoring, which permits hands-on treatments, better accuracy, apt intervention by doctors and improve complete patient care delivery results.

6.5. Improved healthcare management

Using IoT devices, healthcare authorities can get valuable information about equipment and staff effectiveness and use it to suggest innovations.

6.6. Treatment of COVID-19 patient

IoT having real-time location service used for the best treatment of the COVID-19 patient. Different medical devices and apparatus like nebulisers, scales, wheelchair, pumps, and other devices are used for monitoring in the context of IoT. Also check, monitor and control the environmental condition like temperature, humidity, etc. IoT devices can transmit, efficiently store and analyse data of COVID-19 patient for better treatment in the future, Increase awareness about the cause of this virus. IoT devices are helpful to check and analyse the recovered of the patient. In life-threatening circumstances, this technology alerts the human for COVID-19 disease with real-time tracking. It quickly notifies people via linked devices. Report and correctly gives an opinion about the condition of human health. Provide real-time alerting, on-time treatment and monitoring with better accuracy.

6.7. Remote medical assistance

In event of an emergency, patients can contact a doctor who is many kilometers away with a smart mobile apps.With mobility solutions in healthcare, the medics can instantly check the patients and identify the ailments on-the-go. Also, numerous healthcare delivery chains that are forecasting to build machines that can distribute drugs on the basis of patient's prescription and ailment-related data available via linked devices. IoT This in turn, will cut on people's expanse on healthcare.

6.8. Research

IoT for healthcare can also be used for research purposes. It's because IoT enables us to collect a massive amount of data about the patient's illness which would have taken many years if we collected it manually. This data thus collected can be used for statistical study that would support the medical research. Thus, IoT don't only saves time but also our money which would go in the research. Thus, IoT has a great impact in the field of medical research. It enables the introduction of bigger and better medical treatments. IoT is used in a variety of devices that enhance the quality of the healthcare services received by the patients. Even the existing devices are now being updated by IoT by simply using embedding chips of a smart devices. This chip enhances the assistance and care that a patient requires.

VII. CHALLENGES AND THREATS OF IOT IN HEALTHCARE

Although the Internet of Things can be of great benefit to healthcare, there are still major challenges to address before full-scale implementation. The threats and disadvantages of using connected devices in healthcare are as follows:

7.1. Data security & privacy

One of the most significant threats that IoT poses is of data security & privacy. IoT devices capture and transmit data in real-time. However, most of the IoT devices lack data protocols and standards. In addition to that, there is significant ambiguity regarding data ownership regulation. All these factors make the data highly susceptible to cybercriminals who can hack into the system and compromise Personal Health Information (PHI) of both patients as well as doctors. Cybercriminals can misuse patient's data to create fake IDs to buy drugs and medical equipment which they can sell later. Hackers can also file a fraudulent Insurance claim in patient's name.

7.2. Integration of multiple devices & protocols

Integration of multiple devices also causes hindrance in the implementation of IoT in the healthcare sector. The reason for this hindrance is that device manufacturers haven't reached a consensus regarding communication protocols and standard. So, even if

the variety of devices are connected; the difference in their communication protocol complicates and hinders the process of data aggregation. This non-uniformity of the connected device's protocols slows down the whole process and reduces the scope of scalability of IoT in healthcare.

7.3. Data overload & accuracy

As discussed earlier, data aggregation is difficult due to the use of different communication protocols & standards. However, IoT devices still record a ton of data. The data collected by IoT devices are utilized to gain vital insights. However, the amount of data is so tremendous that deriving insights from it are becoming extremely difficult for doctors which, ultimately affects the quality of decision-making. Moreover, this concern is rising as more devices are connected which record more and more data.

7.4. Cost

IoT has not made the healthcare facilitates affordable to the common man yet. The boom in the Healthcare costs is a worrying sign for everybody especially the developed countries. The situation is such that it gave rise to "Medical Tourism" in which patients with critical conditions access healthcare facilities of the developing nations which costs them as less as one-tenth. IoT in healthcare as a concept is a fascinating and promising idea. However, it hasn't solved the cost considerations as of now. To successfully implement IoT app development and to gain its total optimization the stakeholders must make it cost effective otherwise it will always remain out of everyone's reach except the people from the high class.

VIII. FUTURE SCOPE OF IOT IN HEALTHCARE

With every industry affected by COVID-19, the amount of potential effective applications designed to specific areas is rising, with IoT leading the tech race. The main segments that can reap most benefits from IoT systems in this time is Healthcare. In the future, IoT will monitor vital signs of the patient in a real-time environment. This technology will digitally collect all detailed information to prevent ongoing issues regarding treatment of the patient. There will be a major enhancement in healthcare practice, using the latest technologies, and doctors would have to use them.

IoT is a sophisticated developing technology with extensive applications in providing precise medical care that opens up an effective way to analyse valuable data, information, and testing. The future has applications in managing inventories used in the medical field and the medical supply chain for getting the right item at the right time and location. IoT intelligent device would be performing autonomously. There will be data storage with private and public cloud, and even software would also be on the cloud, thus disease identification and follow up could be made efficient. Thus IoT, the disruptive innovation of the information system will facilitate intelligent healthcare service in the Medical environment. Such growth will be due to the increasing demand, the improvement of 5G connectivity and IoT technology and the growing acceptance of healthcare IT software. The plans of tech giants like Apple, Google and Samsung to invest in bridging the gap between fitness tracking apps and actual medical care are sure to contribute to the process too.

Despite the downsides, further digital transformation in healthcare is inevitable and the concept of IoT will continue to capture and change the landscape of healthcare services. Thus, it seems to be high time to look beyond the challenges and embark on the journey to connected healthcare devices.

IX. CONCLUSION

IoT is for better managing chronic disease, medical emergencies, better patient-care, fitness, blood pressure monitoring, health check system, measurement & control system, heart rate checking system, and hearing aids. It can continuously & reliably monitor patients and provide a better personalisation experience in the medical field. IoT-enabled devices can facilitate digital storing of patients' personal health information and connect to different databases. This technology can help to minimise the manual record keeping. With the help of a well-informed decision, it reduces errors and provides results on time. By using this technology, healthcare devices and networks become smarter and efficient during COVID-19 Pandemic. Thus, these technologies give immediate information and extend communication to improve the patient's quality of life. In the future, this technology will create advancement for the better treatment of the patient to stay healthy and will be used to compact any COVID-19 type pandemic.

X. REFERENCES

[1] Liu Y., Dong B., Guo B., Peng W. Combination of cloud computing and Internet of things (IoT) in medical monitoring systems. Int J Hospit Inf Technol. 2015; [Google Scholar]

[2] Nasajpour M., Pouriyeh S., Parizi R.M., Dorothy M., Valero M., Arabnia H.R. Internet of Things for current COVID-19 and future pandemics: an exploratory study. J Healthc Inf Res. 2020 Nov [PMC free article] [PubMed] [Google Scholar]

[3] Shin D., Hwang Y. Integrated acceptance and sustainability evaluation of Internet of Medical Things: a dual-level analysis. Internet Res. 2017. [Google Scholar]

[4] Rahman M.S., Peeri N.C., Shrestha N., Zaki R., Haque U., Ab Hamid S.H. Defending against the novel coronavirus (COVID-19) outbreak: how can the internet of things (IoT) help to save the world? Health Pol Technol. 2020 Apr 22 [PMC free article] [PubMed] [Google Scholar]

[5] Javaid M., Haleem A., Vaishya R., Bahl S., Suman R., Vaish A. Industry 4.0 technologies and their applications in fighting COVID-19 pandemic. Diabetes Metabol Syndr: Clin Res Rev. 2020 [Google Scholar]

[6] Singh S., Bansal A., Sandhu R., Sidhu J. Fog computing and IoT based healthcare support service for dengue fever. Int J Pervasive Comput Commun. 2018[Google Scholar]

[7] Bai L., Yang D., Wang X. Chinese experts' consensus on the Internet of Things-aided diagnosis and treatment of coronavirus disease 2019 (COVID-19) Clin eHealth. 2020 [Google Scholar]

[8] Michalakis K., Caridakis G. IoT contextual factors on healthcare. Adv Exp Med Biol. 2017. [PubMed] [Google Scholar]

[9] Alqahtani F.H. The application of the internet of things in healthcare. Int J Comput Appl. 2018. [Google Scholar]

[10] Kumar K., Kumar N., Shah R. Role of IoT to avoid spreading of COVID-19. Int J Intell Netw. 2020. [Google Scholar]

[11] Singh V., Chandna H., Kumar A., Kumar S., Upadhyay N., Utkarsh K. IoT-Q-Band: a low-cost internet of things based wearable band to detect and track absconding COVID-19 quarantine subjects. EAI Endorsed Trans Internet of Things. 2020 [Google Scholar]

[12] Gupta P.K., Maharaj B.T., Malekian R. A novel and secure IoT based cloud-centric architecture to perform predictive analysis of users activities in sustainable health centres. Multimed Tool Appl. 2017 [Google Scholar]

[13] Rath M., Pattanayak B. Technological improvement in modern health care applications using the Internet of Things (IoT) and proposal of a novel health care approach. Int J Human Rights Healthc. 2019 [Google Scholar]

[14] Ruiz-Fernández D., Marcos-Jorquera D., Gilart-Iglesias V., Vives-Boix V., Ramírez-Navarro J. Empowerment of patients with hypertension through BPM, IoT and remote sensing. Sensors. 2017 [Google Scholar]

[15] Catherwood P.A., Steele D., Little M., Mccomb S., Mclaughlin J. A community-based IoT personalized wireless healthcare solution trial. *IEEE J Transl Eng Health Med.* 2018.