The Implications of IoT in the Modern Healthcare Industry post COVID-19

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Abstract - The healthcare industry has recently seen a massive surge inthe use of the Internet of Things (IoT) during and after the COVID-19 pandemic. IoT's main objective is to provide people with the necessities in these uncertain times. During the pandemic, the availability of IoT-based healthcare systems is crucial. Using IoT, healthcare systems are becoming more individualized, allowing for more precise patient diagnosis, treatment, and monitoring. Since the beginning of the epidemic, many researchers have worked tirelessly to find solutions to this global problem, and IoT technology has the potential to revamp the current system completely. Over 6 million people had lost their lives by the time this document was produced due to the ongoing COVID-19 epidemic. Many lives could have been saved. The problem today is that when people are too sick, they cannot call or contact an ambulance or get safely to the hospital. With new technology, perhaps a button or programming into a device, people in need can press a button on their phone or call out into a voice-enabled device to contact the ambulance or other emergency contacts that they might have. The research has found that if significant companies take this seriously, it could be a remarkable idea that could save many lives.

I. INTRODUCTION

Much potential exists for the "Internet of Things" in the healthcare industry (IoT). The potential societal benefits and life-saving effects are enormous [1].This tool may benefit you, your family, and your friends. Senior adults and many others who cannot call for assistance may be saved by an innovation that could be deployed on various gadgets or incorporated within them. With the aid of this device, the number of fatalities brought on by the inability to summon assistance may be reduced. IoT has gained much traction as a new study area in recent years across several academic and corporate fields, particularly in healthcare. The Internet of Things (IoT) is influencing today's healthcare systems. The evolution of these methods from the standard to the individualized level has improved the diagnostic, therapeutic, and monitoring processes for patients [2].If employed correctly, this medical advancement has the potential to save a significant number of lives. Doctors may follow their patients' health by installing a button on their phones, keeping an eye on them, and deciding when they need urgent medical attention. IoT ensures that Medical professionals treat patients with more: alertness and concentration. Doctors can determine the best course of action for specific patients with data gathered from gadgets like this button [1, 3].

The Internet of Things has revolutionized many business ecosystems by facilitating real-time data collection, analysis, and reporting (IoT). By collecting data, monitoring it, and vastly improving day-to-day healthcare operations, IoT-powered gadgets and sensors have revolutionized how healthcare facilities and systems save and enhance patients' lives. The Internet of Things (IoT) allows connecting everyday devices to the web so that data may be sent between them. Sensors, machine learning, real-time testing, and embedded systems are just a few technologies that have grown out of and contributed to the IoT idea.

Due to its ability to automate hundreds of operations, IoT will profoundly influence the healthcare sector compared to other technologies. Forecasts show that the

The Worldwide IoT market for healthcare will grow at a pace of 19.8% from $60.83 billion in 2019 to $260.75 billion by 2027 [4]. The introduction of IoT into the healthcare industry has transformed patient care procedures by making them quicker and better, particularly during Covid-19. During COVID-19, let's examine the importance of IoT in healthcare and how it creates possibilities for healthcare businesses.[5-8]

This includes not just the concept of an intelligent hospital but also any additional related fixed or wireless infrastructure. To accomplish a job, clever gadgets may collect and share relevant information. Health care, urban infrastructure, transportation, electronics, and media are just a few industries benefiting from the Internet of Things. Sensors, medical devices, AI, and state-of-the-art imaging technologies are the backbone of IoT applications in the medical field. In well-established businesses and new communities, these gadgets boost productivity and quality of life [1, 9].
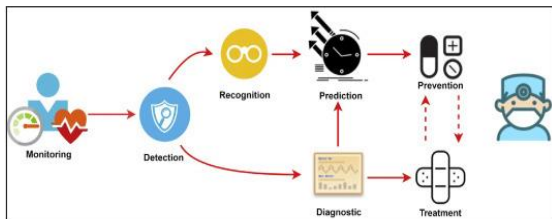

Fig 1. Use of IoT in Healthcare Systems [12]

The Internet of Things (IoT) is a system that transmits data between devices over the Internet without requiring any human intervention, using only digital, mechanical, and computer technology[10]. This technology thrives in the health monitoring sector during the current COVID-19 Pandemic. In the present climate, erroneous and premature health information is contributing to a large number of deaths. By using sensors, this technology may quickly identify health issues [10-11]. The cloud stores all patient data from COVID-19, which may help ensure proper focus [12].

Fig 2. All the Information obtained is stored In the cloud for future use [14]

This device might alert people to potential health issues by monitoring their daily behaviors. The right equipment is necessary to carry out a successful medical treatment. IoT can perform efficient operations and evaluate post-operative results. Therefore, using IoT during the COVID-19 Pandemic improves medical therapy for patients. Diabetes, heart failure, asthma, high blood pressure, and many other potentially fatal conditions may be monitored effectively with the Internet of Things. Connecting innovative medical equipment to a Smartphone makes it simple for doctors to get vital patient information. Measurements of oxygen saturation, blood pressure, body mass index, glucose levels, and so on are also kept. During the recent COVID-19 epidemic [13, 14], the medical community desperately needed a dependable digital information system, and the Internet of Things (IoT) stepped up to the plate. Researching the technology, its advantages, and its critical applications to meet the needs for higher productivity is challenging. However, because of its increased capability, it can address various issues with new knowledge during the COVID-19 pandemic.

II.   IoT During COVID-19

IoT has several advantages for patients with various illnesses, notably COVID-19. People from all over the globe are unable to get medical care when they are really ill during COVID-19 since it is frowned upon to leave your home when you are experiencing COVID-19 symptoms or the disease itself. A chip or ring that may be

worn constantly and can detect whether the immune system is low or when you are feeling unwell is a potential tool [3, 15]. This gadget might save many lives since it can summon an ambulance when you feel ill, allow you to check into a hospital, and provide medical care from nurses and physicians who can make you feel much better (see Fig1). The CDC advises seeking emergency medical assistance for COVID-19 if you have pale, grey, or blue skin or lips, persistent discomfort or pressure in your chest, difficulty staying awake, recent disorientation, or any of these symptoms. Even with other illnesses or disorders, a person's inability to call for help promptly due to their weakness or false sense of security is an issue. Many persons who may have had COVID-19 may have attempted to contact for medical assistance while under quarantine at home, but they may not have been able to get across the room to pick up the phone. This might cause the victim and their family unimaginable harm. With these facts at hand, an IoT-connected device may effectively monitor immune system data and identify any defects or medical issues, which would tremendously benefit society and reduce the number of deaths (see Fig. 1) [1, 4, 16].

Automated Sanitizing and Hygiene Checks

Science's most significant successes are robotics and sensors with AI capabilities, and these technologies are attracting much interest from various businesses. Modern robots may assist humans with a variety of dangerous activities. It would be amazing to introduce robot-driven sanitization in hospitals and afflicted regions [17]. It will not only prevent the spread of the virus to sanitizing personnel, but it will also aid in keeping hygienic conditions. Additionally, non-surgical robots might be used to sterilize and clean hospital patient rooms. Additionally, as exposure to these rays may be dangerous to people, robots can also utilize UV lamps to sterilize spaces [18]. Further, sensor-driven hand hygiene devices may change healthcare personnel and individuals and remind them to wash their hands. Robots may also inform staff that a

room has been sanitized and is safe to use. It implies that disinfection will be very effective in the presence of IoT-enabled gadgets and robots.
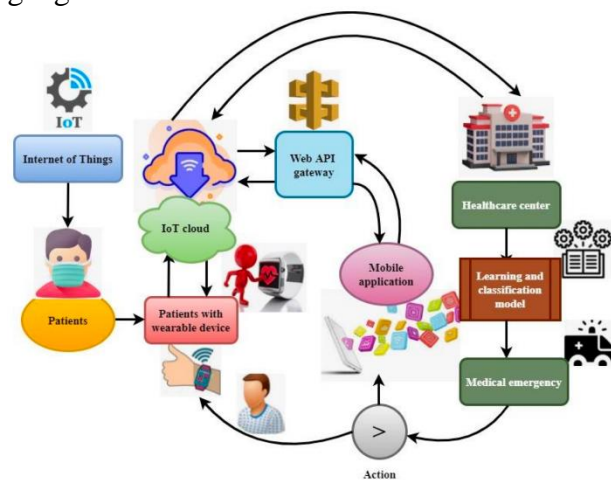

Fig 3. IOT Flowgraph for Healthcare [16]

Person to Person Contact Tracing in Real-time

The Covid-19 virus has a greater rate of transmission than any other virus, and there is a probability that an infected individual may remain asymptomatic. Finding others who have interacted with an infected person is crucial in such situations, particularly during incubation [19].

IoT-enabled tools and programs created by IoT app developers come in handy in these situations. Since fever is one of the earliest signs of illness, smart watches and thermometers with built-in sensors may collect information on affected people by monitoring their body temperature [20]. AI and Big Data techniques may be used to examine the data after it has been obtained from an infected individual. With technology, most Covid-affected locations may be identified and contained. In addition, the government may implement effective quarantine and isolation measures to stop the virus's spread effectively [21]. During quarantine and recovery periods, gadgets like RFID (Real-time location system) wristbands may assist in monitoring a patient's health [22]. The information gathered from these gadgets may also be utilized to understand more about the virus's

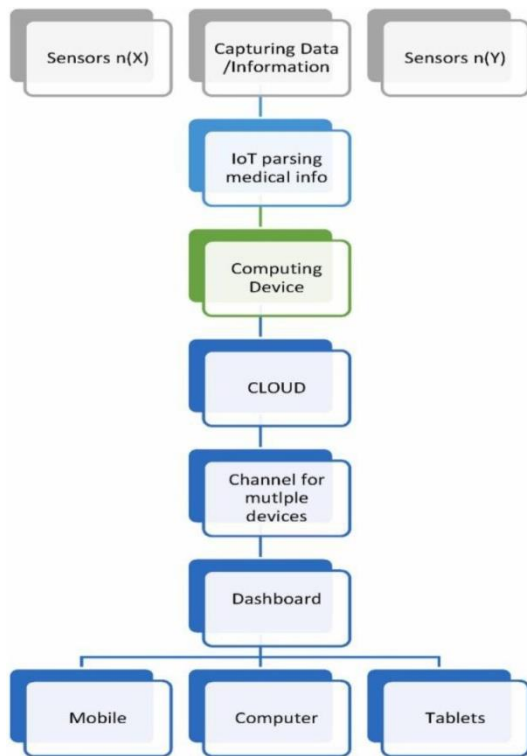characteristics and further research and development.

Fig 4. IOT parsing medical information

III. INTEGRATION OF IOT IN THE MEDICAL FIELD

Cannel to deliver first-rate answers because it uses cutting-edge technologies of medicine; a novel idea is a new fresh life when it results in the highest quality of care for patients with COVID-19 and allows for very accurate surgical procedures. Since the last epidemic [23, 24], complex issues have been readily managed and digitally controlled. By addressing novel problems, IoT aids the development of effective medical support systems for physicians, patients, and surgical teams [24]. Implementing the Internet of Things successfully requires a well-defined set of price—flowchart charts of Internet of Things processes used in a healthcare facility.

People with pacemakers or diabetes who have access s to the Internet of Things (IoT) devices that monitor their heart rate, blood pressure, and blood glucose to live

independently at home if their physician is informed of the situation. A person may be sent to the hospital immediately if data shows they require medical treatment, or they may continue to be monitored at home by IoT devices [10, 25]. Doctors struggle to develop methods to treat the elderly and chronically ill without endangering others since senior health institutions were the COVID-19 vectors. According to Healthcare IT News, funds for disaster assistance may be utilized for virtual visits and remote monitoring to lessen the risk of transmission [26].

IV. ROLE OF IOT IN HEALTHCARE MANAGEMENT

IoT-enabled technology has helped the healthcare industry embrace remote monitoring, which can keep patients safe and healthy while also allowing clinicians to provide extraordinary care. Moreover, it increased patients' involvement and acceptance of their doctors' communication techniques. The use of remote health monitoring also helps reduce readmission rates and shorten hospital stays. The IoT also significantly impacts improving healthcare outcomes, lowering ping expenses [5, 27]. The Internet of Things unquestionably affects the healthcare industry by enlarging the variety of gadgets utilized in which clients interact with services. Medical applications made feasible by the Internet of Things may be helpful for patients, their loved ones, physicians, hospitals, and health insurance.

Fig 5. Nurses replaced by robots in healthcare [23]

IoT Applications in Patients

Patients may choose various wirelessly connected devices, including glucometers, blood pressure monitors, heart rate monitors, and other wearable's like a fitness belt. Such devices might be used to keep tabs on a variety of information, including but not limited to location, time spent at a facility, vital signs, calorie intake, and exercise levels [28]. The ability to keep tabs on the health of humans, particularly the elderly, is one of the many ways in which the Internet of Things has enhanced human life. This has significantly influenced people and their loved ones [29]. When there is an unexpected disruption to regular activities, loved ones and medical staff are notified by the alarm system [6, 30].

IoT Applications for Physicians

The doctor can closely monitor the patient's health using wearable's and other Internet of Things (IoT)-based home monitoring gadgets. Anyone may check in on a patient's progress toward their treatment goals and determine whether they need immediate medical assistance. The Internet of Things allows doctors to provide patients with the proactive treatment they deserve. Data from the Internet of Things devices may aid doctors in determining the most effective course of therapy for their patients [31].

IoT in Hospital Establishments

Outside of only monitoring patients' vitals, IoT devices have shown to be fairly helpful in hospitals. Wheelchairs, defibrillators, nebulizers, oxygen pumps, and other monitoring devices equipped with Internet of Things sensors are monitored in real-time. Medical staff deployment may be observed in real-time at many facilities. Patients in hospitals face the grave risk of contracting an infection, but this problem may be mitigated with the aid of hygiene monitoring devices enabled by the Internet of Things. Assets such as pharmaceutical inventory and environmental factors such as the humidity and temperature in a refrigerator may be managed using IoT devices [7, 32].

IoT for Healthcare Insurance Companies

Insurers in the healthcare industry may benefit from using Internet of Things–related intelligent devices. There is potential for insurance firms to leverage data collected from health monitoring devices in underwriting and claims processing. In addition to helping them find new subscribers, this information may also be used to spot any fraudulent claims [33]. Underwriting, pricing, claims administration, and risk assessment is areas where IoT devices increase communication between insurers and their clients [34]. Thanks to the IoT's ability to collect judgments based on data, consumers will have sufficient awareness of the underlying assumptions driving each choice and process result across all operational processes. Insurers might encourage their customers to use and share IoT medical data by offering discounts or other benefits. For example, clients might incentivize Internet of Things (IoT) gadgets to keep tabs on daily routines and adherence to healthcare plans. As a result, insurers may drastically cut down on claims. The information gathered by IoT devices might help insurance firms assess claims [8, 35].
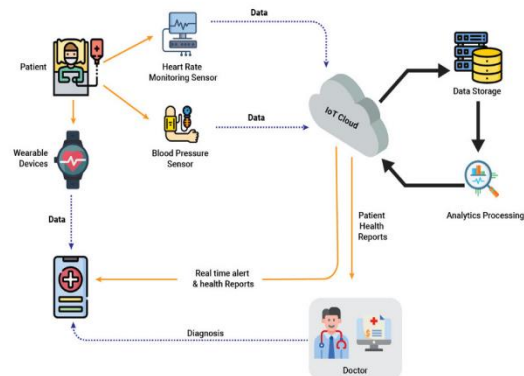

Fig 6. Data processing and analysis of results in IoT system [35]

V. IOT AND WEARABLES

A variety of technological innovations might halt the pandemic. A chip implanted into your arm and used to monitor your immune system's health and temperature might help physicians identify patients experiencing symptoms of illness and

encourage them to visit the hospital. Another possible gadget is a ring you might wear on your fingers with technology comparable to health and fitness watches. It could collect data about your bloodstream, immunological reactions, and whether or not patients need emergency medical attention (see Fig 2).

Such a ring might transform the healthcare sector, provide a significant quantity of data to the Internet of Things, and assist researchers in gathering crucial data on the human body [4, 36]. The following proposed gadget is a button on a laptop keyboard or a phone's back that instantly notifies emergency services to send aid (see Fig. 3). To prevent false alerts, this button would be in a secret place that was only known to the device's owner. The ability to monitor a person's health will be provided through a wearable, such as some jewelry. This piece of jewelry, such as a necklace or bracelet, might monitor a person's well-being and immune system to determine if they have any previously undiagnosed medical conditions. In an emergency, the necklace or bracelet will monitor your whereabouts. In addition to monitoring the temperature and immunological reactions, this wearable can also measure the heart [4, 37]. This gadget will contact emergency services and medical assistance and provide your location if it notices a sudden temperature change or detects anything wrong with your heart. This might significantly enhance IoT and assist the healthcare sector [5, 37, 38].

(A) *Heart Rate Monitoring*-- properly determining a patient's heart rate based on their movement level.

(B) *Mood Monitoring* — to understand the patient's mental state

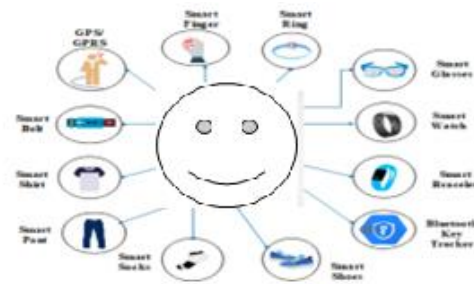(C) *Patient Monitoring*-- Know your temperature, heart rate, blood pressure, and more.

Fig 7. Smart wearables for healthcare by IoT

VI. DATA COLLECTION AND ANALYSIS

The vast amounts of data generated by linked Internet of Things devices give a wealth of value when analyzed via data analytics. IoT analytics has enormous promise in the medical industry for use with patients and as a health-conscious gadget. The designs of these devices have the potential to significantly boost the value of the IoT in the medical industry [5, 6, 39]. The data would be gathered by sensors integrated into IoT wearables or by an outside force, such as webcams or a linked gadget that could be seen. Once data has been transmitted to a storage system, it may be accessed by medical professionals and organizations to assist them in developing treatments or conditions for patients (see Fig 4) [7, 40].

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IoT Analysis may save many individuals from dying from medical issues or COVID-19. By pinpointing the problem with that particular individual, this technique aids medical professionals, patients, and a wide range of other people [9]. Data collection through several devices is an excellent technique to have a variety of data sources so that you don't draw erroneous conclusions from a single set of findings [7, 8]. IoT data analytics is the study of the massive amounts of data created by connected devices, and it has been made possible by advancements in the creation of smart cities [10, 41]. It may help organizations create effective

operations, automatically control trials, attract more consumers, win the confidence of many patients, and empower staff [9, 10].
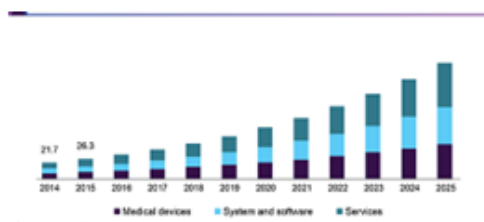

Fig 8. US IoT in healthcare market size (2016-2022)

VII. HEALTHCARE MONITORING SYSTEM

Now there's a way to anticipate health problems before they manifest. Unfortunately, they haven't achieved the required level of accuracy since the wrong machine-learning models were used. There weren't many records in the dataset utilized. The models, even if created, would be challenging to work with due to a lack of a simple user interface. The average individual has a hard time gaining access to it. Some existing systems merely show signs of sickness; they cannot evaluate or offer information about a person's health issues [9]. Due to a lack of knowledge, people struggle to deal with even the most common health issues. Since health-related tests are readily accessible but somewhat expensive and maintaining a health monitoring system requires a series of physically demanding acts, inhabitants of rural areas have limited access to the electronic health system. In healthcare [13–18] and vehicle communication [19–25], researchers are also releasing a variety of approaches to protect the information sent between devices. For IoT-based applications, researchers have developed several techniques [33-35], including picture privacy [26-30].

Telehealth Consultations

Due to the contagious nature of the disease, physicians utilize video chat to determine whether or not a patient has been exposed to the virus without ever having met. The large influx of acute viral variations found in hospitals and elderly homes is an excellent replacement for communication that depends on technology and indoor limits.

Digital Diagnostics

After a digital diagnosis has been made, many IoT devices are used to keep tabs on patient records. Smart thermometers like those introduced by Kinsa may collect data to interact with healthcare providers and analyze trends to enhance community safety.

Robot Assistance

Robots connected to the internet are becoming more common. The medical staff has more time to focus on patient care because of its usage in hospital cleaning, sanitizing equipment, and medicine administration. When cleaning hospitals during the crisis, China was the first nation to use UVD robots made by a Danish company. These robots use IoT to ensure that healthcare facilities, such as nursing homes, maintain clean rooms and treatment areas.

Tracking

Temperature spikes detected by IoT–powered monitoring thermometers might help epidemiologists trace the spread of disease. Such information helps pinpoint where conditions could be broken among the local populace. Even better would be the potential to establish a unique user profile for each user in the customized collecting and dissemination of pure, anonymized data—similar thermometers [11, 40].

Vaccine Cold Chain Monitoring

Coordination of vital immunization services during COVID-19 has proven challenging in developing countries. The vaccination supply chain might benefit from mobile and IoT technology. Vaccines are equipped with Internet of Things (IoT) sensors, and cold chain data loggers use mobile data networks to transmit accurate data from condition records to the cloud. The United Nations Development Program (UNDP) and the government of India developed an IoT-

enabled mobile gadget called eVIN to improve real-time cold chain logistics. This application uses Internet of Things (IoT) sensors embedded in vaccines to track their position, temperature, and supply, ensuring reliable and safe delivery. eVin was used to reduce India's vaccine stockpile by 80 percent [12].
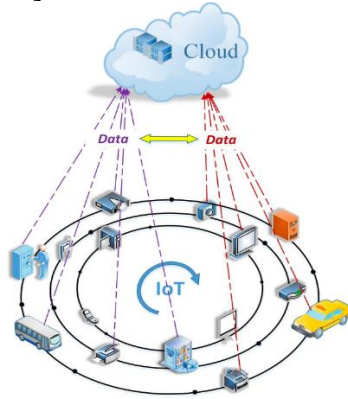

Fig 9. IoT System for Smart Cities [32]

Healthcare Delivery Drones

Diagnostics, EPIs, medications, and other essential medical supplies are a lifeline for people living in remote areas of undeveloped nations because of IoT-enabled drones. Since May 2020, thanks to Zipline, drones can transport much-needed medical supplies to outlying clinics in Ghana and Rwanda. Throughout the epidemic, the drone firm has sent over 160 different medicines to over 2,500 other hospitals and health centers in Rwanda and Ghana. Drones of various varieties were also used to search for signs of COVID and to clean affected areas.

Disinfection Process

Non-surgical robots linked to the Internet of Things have been utilized to clean patient rooms, implement new forms of UV radiation that are more successful at killing COVID-19, and disinfect and sterilizeCOVID-19 in hospitals worldwide. Due to the potentially damaging effects of the light, the door is closed whenever the robot enters the room. The robot reminds workers that securing the room's door when they're done is a top priority.

This speeds up the process of changing patient cabinets and making them ready for the next tenant and reduces the danger to primary caregivers in hospitals and other healthcare organizations. The Internet of Things was already helping patients before the healthcare crisis was widely publicized. In addition to regulating insulin dosages, exercise routines, and pacemaker pulse rates, IoT monitors problems affecting the elderly, who are now in the greatest danger. Connected, wireless devices improve remote monitoring and shorten reaction times in an emergency. The Internet of Things can monitor specific items and send alerts ina crisis. If a wheelchair were to overturn, a nebulizer malfunctioned, or an oxygen tank ran dry; assistance might be shipped immediately. In the face of the COVID-19 pandemic, medical IoT has continued safeguarding patients and medical staff. This trend is expected to continue and even accelerate in the post-pandemic future [7, 33].

VIII. DATA PRIVACY AND PROTECTION

The healthcare industry stores large amounts of sensitive patient information. Since it's been a frequent focus of cybercriminals, as we go toward a fully digital healthcare system, patient records and other related data will be stored digitally on the cloud. In conclusion, cloud-based data sharing between doctors and patients is inevitable, and security measures are necessary to protect patients and doctors' confidentiality. IoT might be used in these scenarios to safeguard patients and authorized personnel. Medical insurance companies, for example, might utilize the information for underwriting and claims management purposes. They may use this information to find potential underwriting clients and get insight into fraudulent claims. In brief, Internet of Things devices will improve pricing, claim, and risk assessment transparency between policyholders and insurers. With IoT-recorded data and decision-making processes, customers will always have essential insight into the underlying notion behind every action.
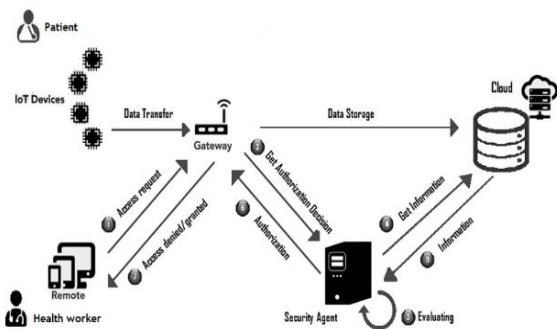
Fig 10. Privacy and Security management in IoT-based healthcare Systems [40]

IX. CHALLENGES AND OPPORTUNITIES

Connections, power, spectrum, bandwidth, and cost are typical stumbling blocks of Internet of Things implementation. Increased mobile broadband penetration (including sensors) and falling costs for IoT in healthcare are expected to propel these developments. The decreasing price of standardized low-energy wireless technologies contributes to this trend. Concerns concerning patient data security and privacy have been raised due to the increased use of technology in healthcare. In response to these worries, national IoT rules have been established in industrialized economies [6, 32, 36]. Yet, poorer nations still need appropriate regulations to advance IoT adoption. Lastly, healthcare that relies on the Internet of Things is frequently unreliable. A physical examination is necessary to diagnose a large percentage of health problems. The resolution of telemedicine photos and videos delivered over the Internet of Things may be low, necessitating further treatment. The participation of mobile carriers may hasten the spread of IoT in healthcare. One such company is Controller, which provides cold chain monitoring systems.

Vodafone Mobile Operator is a partner in this enterprise. Together, they utilize the Vodafone Managed IoT Connectivity Platform to keep a close eye on data from the Controlling Vaccines project. The company is expanding into Africa with pilot projects set to take place in Kenya and Nigeria, joining the company's more established markets in Europe and the Americas. The potential for IoT-enabled healthcare in underserved areas will expand thanks to these mobile collaborations.

IoT technology allows developing countries to solve COVID-19 effectively and, more specifically, to progress the digitalization of health systems by bridging significant gaps in cost, quality, and access. Beyond COVID-19, more IoT research may aid in predicting future pandemics using statistical methodologies, artificial intelligence, and big data. Accordingly, IoT may soon play a crucial role in transitioning from a reactive to a proactive healthcare system [3, 28].

X. FUTURE IMPLICATIONS

With AI's empowerment, IoT is a game-changing approach that enables consistent, accurate, controlled, and scalable solutions in traditional and online healthcare services. This not only addresses the issue of inconsistent, erroneous, and expensive solutions but also provides a mechanism to preserve and get deep visibility into an organization's customer-focused strategy for future growth. This study will help future scholars and researchers study how IoT,with the help of AI, can change future healthcare in developed countries and developing countries around the world.

XI. CONCLUSION

IoT has the potential to improve patient health and perhaps save lives. Medical emergencies may be managed, patient care enhanced, physical fitness encouraged, and disease prevalence recorded. The Internet of Things (IoT) has the potential to improve healthcare dramatically and ultimately save many lives. These innovations can enhance the patient's quality of life by enabling faster access to information and better two-way communication. In the future, this technology will be employed in response to any pandemic caused by COVID-19 to enhance patient care and ensure people can stay healthy. The number of people who lose their lives due to infectious diseases and other medical problems will decrease this. The Internet of Things might revolutionize the healthcare industry as a whole. The Internet of Things has the potential to save

countless lives. It might be helpful during pandemics of infectious diseases like COVID-19 when doctors analyze enormous datasets andpatients are represented and assisted by the Internet of Things (IoT) devices.

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