# Challenges and Limitations of Internet of Things Enabled Healthcare in COVID-19

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Mohsin Raza, Nishant Singh, Muhammad Khalid, Suleman Khan, Muhammad Awais, Muhammad Usman Hadi, Muhammad Imran, Saif ul Islam, Joel J.P.C Rodrigues

*Abstract*— **The emerging challenges in healthcare, especially with the surfaced coronavirus (COVID-19) crisis has changed the way how the healthcare operates. Countries where pandemic has hit hard has brought the healthcare institutes to the verge of collapsing where the capabilities of the healthcare departments and hospitals are tested over and over. In these challenging circumstances, the technology alternatives are stressed upon ever before and need for transformation of healthcare from traditional techniques to technology driven healthcare solutions is advocated. While the Internet of Things (IoT) and other healthcare technologies (machine learning, cloud, edge computing, security) were under development for years, yet none of the developments were planned to sustain immense pressure, the pandemics and special circumstances put in. Therefore, a suitable transformation in healthcare technologies is much desirable to cope with the exacerbating world healthcare infrastructure. This paper discusses the role of Internet of Things (IoT) and intelligent healthcare services in emerging health related threats and challenges. It discusses the limitations, challenges and future of IoT in health crisis. The paper also stresses on extensive healthcare infrastructure which benefits from IoT, Artificial Intelligence (AI), distributed control, cognitive decision support services, security and privacy, blockchain, cloud and edge services.**

***Index Terms*—Internet of Things (IoT), e-health, artificial Inteligence, Internet of Medical Things (IoMT), Coronavirus (Covid-19)**

## I. Internet of Things in Healthcare

Pneumonia of unknown aetiology showed an unprecedented outbreak in Wuhan City of Hubei province in China in December 2019. Presenting symptoms of fever, dry cough, and dyspnea, it was just a matter of months when it had spread to almost every possible major country in the world. Coronavirus (Covid-19) has been officially named as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) by the World Health Organization, and the outbreak was declared as a public health emergency of international concern on 30th January 2020. With the advent of a rapidly changing world situation in this pandemic, the need for a more streamlined and dedicated interconnected medical system is desired. This is particularly relevant for access and analysis of the evolving and changing data trends that are unprecedented in the medical community and history of modern medicine. Outbreak of such scale has put all the available resources of the governments worldwide to be utilized at a maximum possible scale. Countries like the United Kingdom (UK) had to make a call to its tens of thousands of retired medics and National Health Service staff to come back to work for help in the battle of an overwhelming Covid-19 situation. Many countries had to set up new hospitals that are solely dedicated to treating Covid-19 patients. Internet of Things (IoT) has played indispensable and vital roles in building some aspects of these emergency healthcare establishments with on the network wearables, patient monitoring devices, and life-saving ventilator systems [1].

### *A. Emerging threats amidst pandemics*

The numbers evolving every day concerning Covid-19 are shocking. One reason is that epidemics and pandemics are rarely discussed in history lessons even though these are facts of life, no matter how upsetting and terrible they may be. Viral pandemic is caused by pathogens that are known mass killers, and this is because they are self-replicating; all they need is a favourable host. The host becomes a cellular factory where the virus thrives and is ready to travel to another host. The victim becomes the delivery system, and with the unprecedented globalization and ease of travel, the virus very comfortably moves across continents along with their host humans (infected or carriers). The likelihood of death from contagion is far more in the modern world than any other established non-contagious disease. Another threat humanity face is the ability and nature of such infectious viruses to rapidly evolve over time. Factually, in the past two decades or so, the world has seen H1N1/09, SARS, Zika, and Ebola, although their outbreak number was not close to the Covid-19 [2].

### *B. Limitations of conventional healthcare systems*

Any pandemic is characterized by a group of epidemiological features such as high attack rates, wide geographical extension, swift movement of the disease, low or minimal immunity in the population, a novelty in its nature, and phylogeny, highly contagious and a high mortality rate. The traditional and conventional healthcare systems are not designed to address such outbreaks and thus struggle to perform under pressure. It

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gets worse in the case when the pathogen is novel as with Covid-19. Molecular biologists have standard methods of pathogen detection and identification like PCR, qPCR, and m-PCR but these take some time, and by then, a larger population is already affected by the virus. A hospital healthcare system can benefit from high-tech, IoT medical equipment. With growing safety concerns of frontline carers and medics, the hospital staff is desired to be able to remotely perform life-saving tasks like changing ventilator settings or monitoring patients remotely. This will limit the physical contact with the patients and thus the harmful pathogen. Enabling real time updates in patients' records is a necessity in the time of international emergencies like Covid-19. The conventional patient data and record system do seem to work efficiently in everyday situations but fail in situations like the Covid-19, mainly because of the overwhelming amount of data being generated and the critical amount of care been required for the patients.

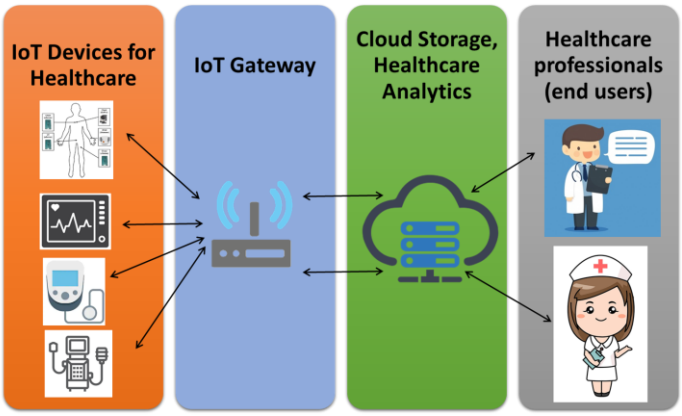


*Figure 1 IoT based smart digital health monitoring system.*

### *C. IoT at the core of digital health*

The quality of livelihood of an individual is greatly affected by his health condition and health-related issues. The development and economic health of a nation are also directly related to its citizen's quality of health and its healthcare system. IoT has by now proven to have extensive applications in digital health care [3]. Based on conventional or custom-assembled sensors that can be worn by the patients, sending information through a wireless system, enables mobility. The data collected is usually physiologically obtained from the patient's body, making use of gateways and stored it in the cloud for analysis and retrieval. This data can be wirelessly transmitted to the healthcare professionals for examination. A block diagram of smart health monitoring system is presented in Figure 1. Advancement with the application of state-of-art machine learning tools and prediction systems, the IoT have advanced their applications in health-issue prediction as well. IoT has enormously enhanced the nature of healthcare by minimizing mistakes and latency in emergency conditions. This also brings down the cost of care by reducing human cost. The ease of access of this system helps patients to rely on it and reducing their hospital visits and thus reducing the workload on hospital staff where they can assess and analyse an emergency, making it economical in terms of time and money. Healthcare monitoring is very important for our society, especially in pandemic situations like Covid-19. With IoT at the core of the modern digital healthcare system, come considerations of data protection and network security.
The main contributions of the work are:

1. To critically review limitations of conventional healthcare system during pandemics.
2. To provide deep insight of IoT driven solutions in mitigating pandemic's effects.
3. To highlight existing challenges and prospects of IoT enabled healthcare.

The rest of the paper is organized as follows.
Section II presents role of IoT in healthcare. Section III covers suitable IoT driven solutions. Section IV presents challenges in adoption of IoT in healthcare. Section V presents research directions whereas concluding remarks are presented in Section VI.

## II. IoT in Health crisis

IoT is an emerging new technology for information processing and communication. The IoT has various applications like smart homes, smart cities, connected vehicles, industrial IoT and e-healthcare. In healthcare, IoT can be used for keeping patients' record, observing critical patients, limiting exposure of medical staff, remote monitoring of patients and fighting excessive human resource limitations. However, the existing infrastructure and IoT solutions in pandemics require substantial changes in present day smart monitoring and diagnosis solutions. Absence of such systems force healthcare professionals to spend most of their time doing patient check-ups, maintaining records and scheduling patients' appointments. In current state, the healthcare system in every part of the world is not capable of operating fully in health crisis, which is also proved by recent Covid-19 spread [4].

With the limited healthcare staff and resources, it is necessary to design such a healthcare system which can operate efficiently without collapsing in crisis. Modern machine learning algorithms based intelligent IoT devices are capable of monitoring critical and routine patients [5]. The IoT as emerging Information and Communication Technology (ICT) in combination with modern decision-making algorithms can help healthcare system from collapsing in pandemics like Covid-19 [1,5]. To provide solution for pandemics like Covid-19, IoT based smart healthcare systems can be used.

IoT based infrastructure can be used in healthcare system to avoid any potential future collapses. Potential IoT based healthcare system should consist of hospitals, health professional, different categories of patients, monitoring devices, emergency services, data repositories and decision-making centre. In pandemics like Covid-19, health professionals with the help of IoT system can authorise care of critical patients on priority basis. To cope with pandemics, it is necessary to prioritize patient based on their health status. Most of the daily patients, who go to hospitals for routine check-ups and repeated prescriptions can be avoided with IoT based smart healthcare system.
IoT based wearable devices can also be brought into use to monitor routine patients. These devices can measure blood pressure, heart rate, diabetes and oxygen ratio. All these

wearable devices, by directly connecting to smart phones can enable data transmission and reception over the internet. In addition, based on the received data, the current health situation of a person can be analysed. The received data of every patient if saved into data centre can enable different machine learning algorithms will be used to draw future projection and potential emergency services needed for that patient. Those requiring health advice will be connected to health professional and they will be able to provide patients with necessary advice and precautions. The remote monitoring of routine patients and collecting their data through smart sensors can enable healthcare system to operate efficiently during the pandemics and to avoid any potential system collapse.

## *III. Sustainable IoT driven Solutions in Pandemics*

IoT can potentially be a cornerstone of healthcare infrastructure to protect it from being overwhelmed and collapsed. Figure 2 describes the key domains where IoT can potentially contribute and these are discussed in detail as follows.

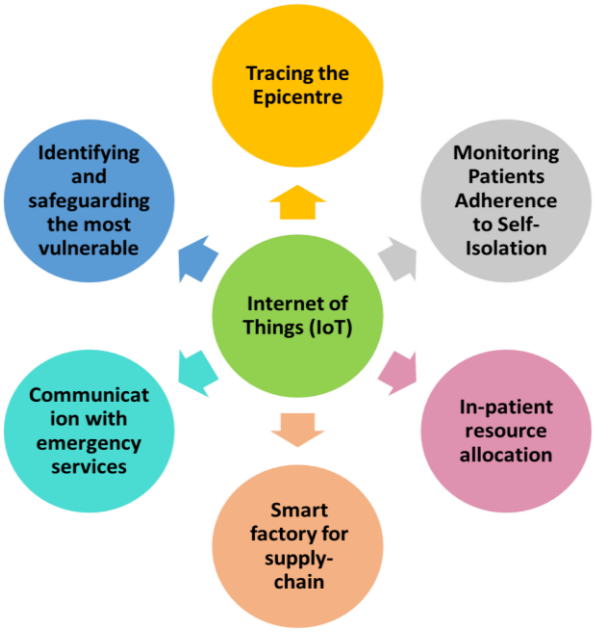


*Figure 2 IoT Solutions to cope with pandemic like COVID-19*

### *A. Tracing the Epicentre*

IoT can significantly help in tracing the epicentre of the infectious diseases in densely populated areas and rural areas by coupling the mobiles devices with geographical information systems and disease surveillance data. The cellular data not only provides a real time mobility patterns of suspected patients but also provides insight on how many people were in close contact with the suspected patients. Moreover, this can also assist the healthcare staff in tracing the patient zero with the help of mobile applications.

### *B. Monitoring patient's adherence to self-isolation*

Patients adherence and compliance to self-isolation can be effectively tracked and monitored through the exploitation of global positioning system sensors available in smart phones and wearable devices. Such devices can easily be connected to healthcare infrastructure via IoT and provide real time spatio-temporal activities of patients to healthcare staff. This will eventually assist them in identifying vulnerable individuals who are not adhering to health guidelines of self-isolation. This can also be transformed to a group of individuals sharing common residence.

### *C. In-patient resource allocation*

The in-patient resource allocation has several key domains which can be well managed using IoT to ensure the safety of patients as well as the healthcare staff and other individuals working within a hospital or care unit. The keys domains are: 1) workforce management including the healthcare staff to ensure compliance of staff to patient ratio and ensuring that none of the staff is unrested or working more than normal hours, 2 ) Personal Protective Equipment (PPE) availability to each staff member, prioritizing intensive care unit (ICU) and ventilators' amenities to the most deserving patients, 3) administration to manage the facilities properly by disinfecting and maintaining the resources whenever a patients leave facility, 4) managing drugs availability and storage in hospitals [6].

### *D. Smart factory for supply chain*

The IoT can significantly help in tracking the hospital warehouses through RFIDs and others sensing modalities to provide real insight of the inventory. This will help healthcare management to make informed decisions about the supply-chain trail. This can then be linked with smart factories manufacturing drugs, PPEs and other lifesaving equipment to be in line with the supply chain demand. This smart factory manufacturing supply chain system can be extended nationwide or even worldwide by connecting all hospitals and primary care to meet the substantial needs.

### *E. Effective communication and coordination*

Majority of the healthcare facilities worldwide are overwhelmed during the Covid-19 pandemic which is still ongoing. This is also a result of lack of coordination between hospitals and the emergency services such as ambulances, funeral services and hazardous area response team (HART) common in, UK which could have been easily bridged by incorporating ICT devices coupled through IoT. Since the emergency services were unaware of the hospital's resources, there were long ques of patients in many hospitals waiting for ICU or hospital ward facility while, other nearby hospitals were underutilized [7]. Moreover, the communication gap between emergency services and hospitals also severely affected funeral and embalmers services. A significantly high backlog of dead bodies is observed waiting for burial with a limited burial chambers available in hospital amenities. This could be better managed through IoT by providing a bigger picture of the highly affected regions and hospitals, and the nearby regions which are less affected, and to accommodate the fatalities through such services in less affected regions.

### *F. Identifying the most vulnerable*

The IoT coupled with AI not only helps in identifying the most vulnerable (elderly and other suffering from life threating disease or have underlying health conditions) but also can help in safeguarding these individuals. To identify such vulnerable individuals, electronic health records coupled with ambient

sensors connected through IoT infrastructure and deployed in their residential premises can provide insight in real-time about their mobility and habitual routine [8]. The safeguarding can then be done but incorporating AI to predict the underlying patterns to updates the more concerned peers related to these individuals such as family, friends, healthcare staff, and carers. Moreover, such IoT platform will not only help mitigate the high demand of carers and but also directs them to individuals requiring urgent care.

Another approach that has been very recently applied is the use of voice samples for detection of Covid-19. Automatic recognition of dry and wet coughs, sneezing, throat clearing, swallowing and productive cough have been recognized with better accuracy [11]. Differentiation between maximum phonation time (MPT), jitter and shimmer as acoustic parameters have been found to be very distinctive when compared between Covid-19 patients and normal individuals. In addition, several image-based methods are developed to detect Covid-19 [12, 13]

The development and use of contact tracing apps have been extensively put in use worldwide for effective tracing and locating Covid-19 infected and the people with whom the infected comes in close contact with. Centralized, Decentralized and the Hybrid tracing architecture have all been used to cater the requirement based on the resources available and demographics. The most common is the smartphone based automated contact tracing system. This uses both the GPS and the Bluetooth to serve the purpose. Some apps/protocols that are based on the centralized architecture are Tracetogether, CovidSafe(AU), StopCovid-ROBERT and Aarogyasetu. Some apps/protocols that are based on the decentralized architecture are Apple/Google Exposure notification, PACT (EAST-COAST), CovidSafe – PACT (WEST-COAST), SwissCovid – DP-3T, DP-3T Unlinkable, CovidWatch-TCN, Pronto-C2 and Hamagen. Some apps/protocols that are based on the hybrid architecture are Desire, ConTra CORONA and EpiOne [14].

## IV. Challenges in widespread adoption of IoT solutions

Despite indisputable merits, pandemics like COVID-19 impose inevitable challenges in widespread adoption of IoT. Some of these are as follows.

### *A. Patient Monitoring*

The COVID-19 pandemic has pulled out the world from its fast-moving operation to almost completely lockdown situation where most of the people are restricted to their homes. This makes the situation more challenging for medical IoT to enable all IoT features to monitor patients at home. The patients at homes and care centres require technology experts to support elderly patients in using different wearables. Some patients might not be comfortable using and connecting different devices. This hinders efficient use of IoT technologies and restricts monitoring and treating patients with the latest technologies.

### *B. Energy and Power Usage*

The key asset of IoT infrastructure is to collect the data through sensors. However, in this pandemic, the challenge faced by IoT is also the energy consumption of too many sensors used to monitor the masses for social distancing or observing patients' health conditions at homes and care centres. An efficient process is required to reduce the consumption of energy by reducing required sensors or by sensing the data with minimal energy consumption. In such situation where everyone is putting their best efforts to save the lives, such limitations with energy provisions make this task difficult, especially when it can result in sensor failure due to low battery. However, this could be an important future research area where the scientists would be minimizing the energy consumption of the sensors in pandemic situations.

### *C. Security, Privacy, and Trust*

The large number of sensor devices dispersed to collect data might be of interest to attackers to exploit the data. The limited computation and storage capability of the sensors create hurdles for security experts to integrate security features in it. This could affect the data privacy and data integration process in mass health crisis such as COVID-19. Attackers could get command of the sensors by inducing breaches and making the system malfunction. Security is not a key concern at this moment as all government staffs and managerial position holders are putting efforts to reduce the death rates which happened due to COVID-19. However, it is an important aspect of IoT systems and need full attention.

### *D. Integration with Technologies*

The importance of medical IoT can be stressed by its feature to monitor patients without exposing medical staff. However, to be even more beneficial, IoT need to combine with the different technological infrastructure to produce valuable outputs. For instance, the data collected needs to be stored on cloud servers. Information needs to be distributed to different investigational hubs which might require distributed computing and block chains. Further, the collection of the data needs to be analysed with scientific findings that might demand big data analytics, and so on. The combination of IoT and all these technologies makes the situation more complex. Therefore, an optimized solution is required which could integrate IoT with emerging technologies in easy, fast, and secure manner without affecting its performance in large.

### *E. Data format*

The data collected by the sensors is usually passed to the medical practitioners to evaluate patient's conditions depending on the data. This needs to be accomplished on a real-time basis to avoid any delays which might affect the health condition of the patients. The near real time requirements for data to reach doctors offer a significant challenge. It becomes further complicated when the collected format is different from the desired format of the data. Moreover, different data from many sources could result in data overload problem that could affect the performance of the doctors while dealing with the data formats rather than performing their key role.

### *F. Innovative wearables and Innovative IoT applications*

This pandemic opens new opportunities for the medical IoT industry to launch some new wearables and applications which could cope with this current situation. New innovative wearable needs to be designed and function so to accurately collect

patient symptoms and forward it to the end systems. The existing wearable devices have played a vital role in monitoring the patients. However, they were not built for this current situation which limits their functional capabilities. For instance, it is quite challenging for a wearable device to sense that the patient is suffering from normal flu or COVID-19 virus. This still requires to be worked out by the scientists especially after exploring the real data of the COVID-19 patients.

### *G. Legal and Ethical Issues*

Currently, many companies are requesting patients and people to upload their symptoms and vitals to the online portal for further prediction and analysis of the COVID-19 outbreak. However, this might create legal and ethical issues regarding the personal information of the users which might affect them in some aspect. There are no clear legal standards or operating procedures available which could help users to be confident enough to provide personal health information. The government and legal bodies should take the initiative to provide a clear guideline for the users in using technologies and providing information without any fear which could protect their legal rights.

Some additional challenges faced by IoT in pandemics and health crisis are depicted in Figure 3.

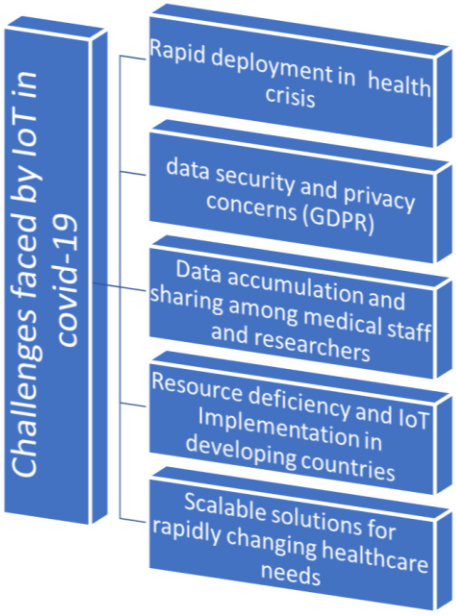


*Figure 3 Challenges in wide-spread adoption of IoT*

## V. Future of IoT enabled healthcare and Research Directions

IoT proffers extensive benefits in the healthcare industry and potential solutions to deal with critical healthcare limitations witnessed throughout the world. The lack of mandatory staff, medical experts, clinical facilities, long-term patients' care centers and recovery and rehabilitation support gave rise to the IoT for healthcare. While the developments in healthcare are sufficiently paced to assist in prevailing healthcare issues in near future, yet, these developments were never influenced by the healthcare crisis such as COVID-19. In such, these developments in the past did not enable IoT to cope with health crisis such as COVID-19 or future pandemics.

### *A. Empowering IoT solutions in Health crisis*

To enable the IoT to cope with the new and emerging challenges during pandemics, the research community must transform the applications and developments in IoT to assist rapid deployment, improved reliability, effective data logging and assistive healthcare. Some of the future areas where IoT can play a significant role in pandemics are presented in Figure 4 and discussed as follows:

### *B. IoT as a service in aftercare and Patient monitoring*

Aftercare and patient monitoring require significant resources of the healthcare department. Patients requiring aftercare for operations/procedures and continuous monitoring in hospitals, old-age houses, recovery centres, and rehabilitation facilities, primarily depend on medical staff. These patients are highly vulnerable in health crisis due to limited access to medical staff. The IoT developments in aftercare and patient monitoring can offer a suitable solution which can substantially impact the balance of the supply and demand. The main developments in the aftercare and monitoring need to focus on how to establish a reliable system, capable of not only recording the vitals of such patients, but also communicate it effectively to the cloud within certain time window. In addition to the IoT solution and cloud-based data accumulation, cognitive decision support is also as significant to allow medical staff to see the vitals in more informative and less time-consuming manner to assist them in making right decisions in limited times. The future IoT systems should also offer AI driven analysis and prediction to decide which patients really need to see their doctors out of all the patients under observation. In addition to legacy IoT systems, changes are required to train distributed algorithms on the network edge to enable the timely responses for the critical patients and to be able to run complex AI algorithms within IoT frameworks. Distributed processing and multi-tasking is an important aspect of patient monitoring in future, whether it is Alzheimer's patients, Parkinson's, elderly in need for support or patients needing attention after medical procedures [9, 10]. The future of IoT enabled healthcare do not advocate standalone solutions rather an IoT framework which includes AI, distributed control, network edge processing and cognitive decision support, especially when the objective is to manage health crisis and pandemics.

### *C. AI enabled smart IoT*

Extended AI driven and IoT enabled healthcare services within the hospitals, care homes, rehabilitation centres, while take some burden away from the healthcare staff, yet the limited resources also become challenging in the pandemics. Thus, homecare services are also as important. The implementation of IoT enabled data accumulation, machine learning techniques running on edge devices, data filtration and cloud-based storage offer a suitable infrastructure to enable provision of healthcare services in home environments [15]. While the near real-time data accessibility of home patients' is really important so to reach the medical staff in time, there is also need to have AI driven solutions which can evaluate critical data and take

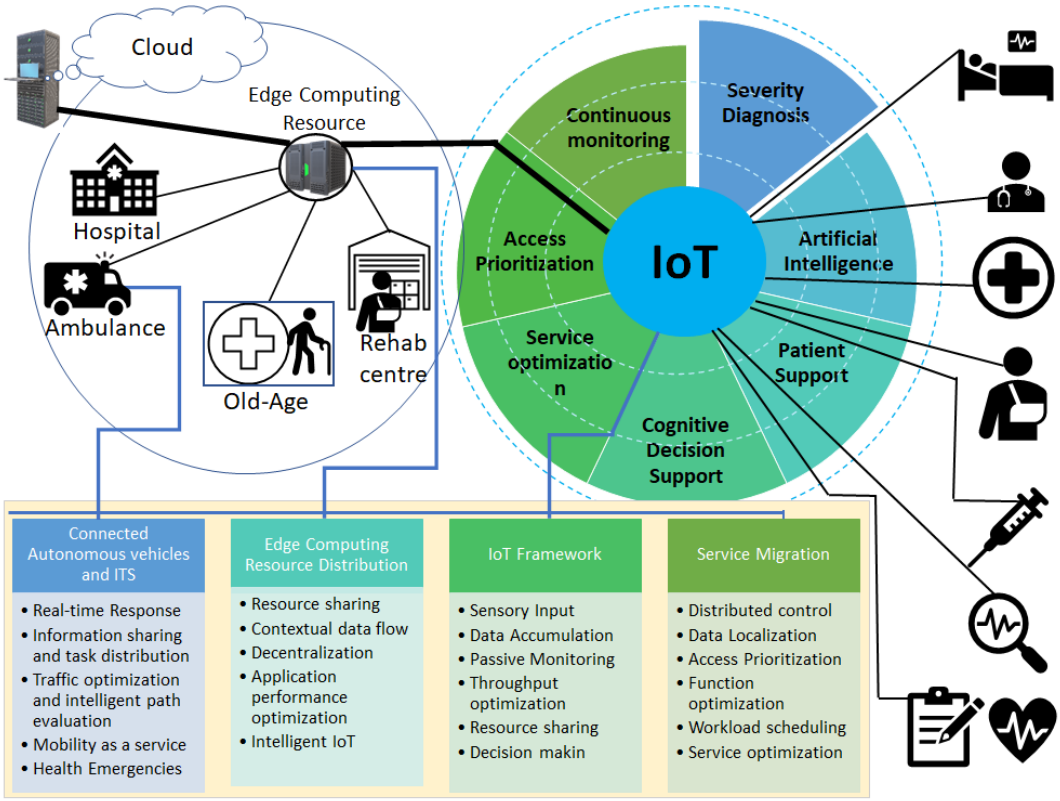


*Figure 4 Future prospects and developments in IoT enabled healthcare*

critical decisions such as calling the ambulance or connecting to medical staff in time of need.

## VI. Conclusion

The Covid-19 pandemic has exposed the global healthcare infrastructure to unprecedented circumstances. Consequently, the hospitals and primary care resources are severely overwhelmed worldwide. Without any discrimination, the developed world countries are equally affected by covid-19 when compared to underdeveloped countries, having limited resources and poor healthcare infrastructure. In such circumstances, it is necessary to introduce technology driven solutions to the problem. IoT offers a potential solution to limit the overwhelming burden faced by the healthcare worldwide. However, the current development in IoT and other supporting technologies are insufficient to offer desired support to healthcare infrastructure. Therefore, suitable developments in IoT and extended IoT framework, benefiting from AI, cloud services, network edge processing distributed control, cognitive decision support, block chain and critical decisioning are essential for improved overall resilience and reduced health system vulnerability.

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