

# Adopting 5G-Enabled E-Healthcare for Collaborative Pandemic Management

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## ABSTRACT

The spread of the COVID-19 pandemic had a huge impact on personal lives, society, and economies all over the world. Many countries are still struggling with the rising and falling numbers of COVID-19 cases. The drastic effects of the pandemic have brought sharp focus on healthcare and the need for rapid technology adoption and strong collaborative digital healthcare solutions for dealing with the health crisis. 5G networks can play a vital role in transforming the critical components of healthcare ecosystem by providing cost effective, high connectivity to the patients and healthcare workers. This research article investigates and highlights the technical aspects 5G technology, its effective utilization for collaborative e-health services, and the 5G-based solutions. It also presents a detailed discussion on challenges of 5G implementation and possible solutions. In the end, it discusses the future research directions for 5G-enabled e-collaboration in decreasing the health-based challenges and issues in future pandemic outbreaks.

## KEYWORDS

5G Services, E-Health, Healthcare, IoHT, IOMT, Pandemic Management, Telehealth

## 1. INTRODUCTION

The Covid-19 outbreak due to Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) (Lai et al., 2020) proved to be a pandemic that has had a seismic effect on people globally. It brought a dramatic and drastic change to the normal way living of people all over the world. To curb the spread of Covid-19, the governments implemented social distancing, lockdowns and other restrictions. The business organizations and schools had to close down, with the majority having to shift to online medium quickly. This new environment forced people to reevaluate how their everyday tasks were performed and instead pivoted them to the unconventional way which was highly dependent on telecommunication technology and networks for operational continuity and social connect (Hantrais et al., 2021).

Many business organizations and public health authorities had to rapidly launch advanced digital solutions for operational continuity while ensuring safety and health and also to support the societal well-being by keeping social interactions alive through digital mode. There was a considerable dependency upon online collaboration and learning platforms, such as Google Meet, Microsoft Teams,

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Zoom, WebEx, Coursera etc. which were extensively used professional exchange and learning during the lockdown globally. Similarly, for entertainment needs & social interactions, the consumers used varied platforms for example, for media & movies, the use of OTT channels Netflix, Prime, YouTube as such increased, while for social media connect platforms, like WhatsApp, Instagram, Twitter, Facebook, Twitter etc., were used. Usage of multimedia sites for activities such as online gaming and sports, increased manifold during Covid-19 (Elavarasan & Pugazhendhi, 2020).

The Covid-19 pandemic highlighted the strong need for a robust telecommunication and high-speed broadband infrastructure which a huge capacity, to support people in their work, to learn, to shop for essential needs and socially interact while remaining safely distanced from others (Ting et al., 2020). The normal activities in offices, industries, schools, hospitals, and industries shifted to online mediums, this sudden surge in online traffic created huge burden on the existing infrastructure and networks. This was quite a difficult situation for the existing networks. They were never designed and nor capable of dealing with the huge amount of traffic being generated and the change in demand patterns because of the sudden shift to online (Abubakar et al., 2020). The telecommunication providers and network operators with existing wireless networking technologies struggled to meet the new demand. This brought into focus, the need for the deployment of even more advanced telecommunication technologies, such as 5G - the fifth generation mobile networks and beyond 5G (B5G), which can prove to be even more efficient and capable in meeting the user demands and for negating the detrimental effects of the pandemics on all sectors of economy (Boccardi et al., 2014).

5G as a technology is still in developing phase, but it presents a paradigm shift in the field of telecommunication and networks. Many countries across the globe are currently deploying 5G networks. The 5G networks have the capability to provide universal higher data speed, higher reliability, high mobility support, higher capacity, high-rate connectivity, lower latency, give massive device connectivity and overall a seamless user experience while enhancing energy efficiency (Kaur et al., 2020; Soldani et al., 2017).

According to Osseiran et al. (2014), 5G networks would be able to deliver:

1. 100x higher user data rate.
2. 100x higher number of connected devices.
3. 1000x higher mobile data volume per area.
4. 10x longer battery life - for low power massive machine communications.
5. 5x reduced End-to-End (E2E) latency.

The enhanced capabilities of 5G has three main application based use cases as - enhanced Mobile Broadband (eMBB), Ultra-Reliable and Low Latency Communication (URLLC), and massive Machine Type Communication (mMTC) (Navarro-Ortiz et al., 2020). The Table 1 presents the detailed description of each application area.

**Table 1.**  
**The different uses cases of 5G (Abubakar et al., 2020; Boccardi et al., 2014; Navarro-Ortiz et al., 2020; Soldani et al., 2017)**

Enhanced mobile broadband (eMBB)	It provides high bandwidth, high data rates supporting high-resolution streaming services, and high-quality interactive videos for the 5G users. It would prove beneficial for example, in stadiums and concerts
Ultra-reliable low-latency communications (URLLC)	It provides the transfer of high volumes of data exchange with ultra-low latency (delay) Thus, responding with minimal delay and supporting real-time access
Massive machine-type communications (mMTC)	It provides massive connectivity of entities including but not limited to humans, sensors, computers, cloud, vehicles, and UAVs. It would be able to connect billions of different devices to IOT.

These underlying key technologies involved in delivering 5G services include small cell networks, mmWaves, beamforming and massive Multiple Input Multiple Output (MIMO), (Dangi et al., 2021). The 5G networks involve the use of technologies such as Multi-access Edge Computing (MEC), Software Defined Networking (SDN), Network Slicing (NS) and Network Function Virtualization (NFV). MEC provides 5G networks with higher processing and storage capabilities while NFV and SDN enable fast and flexible deployment of 5G services based on programmable 5G networks. NS creates multiple unique virtual networks over a common physical infrastructure allows 5G to provide different types of services very efficiently (Osseiran et al., 2014).

5G Networks have the capability to handle the drastic changes in network service demands and operational procedures due to remote working policies and restrictions on movement implemented by the government and various organizations to curtail the spread of COVID-19

These along with the implementation of AI artificial intelligence (AI) and self-organizing networks (SON) allows 5G networks to function in an intelligent and autonomous manner (Chamola et al., 2020).

Considering the enhanced capabilities of 5G networks which can prove to be immensely beneficial, therefore it was felt important to study the implementation of 5G in healthcare and the role it can play in any future pandemic situation. Based on the initial analysis of the available literature, the present research studies the 5G adoption in healthcare from multidimensional aspect, concentrating on the following research questions:

**RQ1:** What is the need for 5G in Healthcare Sector?

**RQ2:** How can 5G be implemented in Healthcare Sector?

**RQ3:** What are the challenges in implementation of 5G and the possible solutions for them?

## **2. RESEARCH METHODOLOGY**

This paper examines the usage of 5G in healthcare sector with focus on pandemic management through qualitative analysis of research studies catering to application/use cases of 5G technologies in the tertiary healthcare system considering all such dimensions telehealth services, Contact tracing, monitoring self isolation & mental health as well as the supply chain of healthcare products & their manufacturers. Apart from pertinent issues faced in healthcare during pandemic & 5G applications, it has also analyzed through literature survey the implementational challenges of 5G technologies and the possible solutions for each of the challenges which have further been clearly classified. For this multi dimensional study the focus was on peer reviewed studies published in the prominent journals and indexed in valid databases. The 5G related technical papers selected post 2017 while the studies focusing on pandemic aspect are post 2020. Initial search brought forward 96 papers which after the abstract study were shortlisted to 76. These papers were then downloaded for detailed study and only 55 papers were found to be most relevant presenting pertinent novel facts to the current research. Content analysis of the research articles was undertaken to identify and understand the themes, concepts, and framework of 5G applications in Healthcare.

## **3. ANALYSIS AND FINDINGS**

### **3.1 The Need for 5G in Healthcare Sector**

Healthcare was one of the most critical areas, which had to quickly adapt in such dire circumstances. The pandemic exposed the shortcomings of the prevalent of public health systems. The healthcare facilities were overwhelmed by the rapid spread of Covid-19 (Siriwardhana et al., 2021). The regular health services were interrupted; the OPD appointments and the normal surgeries were canceled, or postponed; only the emergency cases were allowed. Like other sectors, the hospitals and patients had to quickly innovate and adapt to digital health services to ensure regular medical service delivery

to patients as well as to protect the health workers from exposure to Covid-19 by reducing direct contact with patients.

During Covid-19, the traditional consultation with doctors shifted to virtual health consultations through mobile telephony and video conferencing. There was need to track the self isolation of Covid positive patients and contact tracing. In some cases the remote monitoring of patients was done through wearable sensors of patients which relayed data to the medical providers (Chamola et al., 2020). Because of the restrictions, all such initiatives were carried out through the telecommunication technologies and networks, especially through smart phones, mobiles and other sensors. Even drones were used for remote deliveries. Though healthcare sector relied heavily on existing wireless technologies for providing the services, but it faced many issues and challenges such as poor data quality, transmission lag, extremely high demand, traffic congestions, breakdowns etc (Dangi et al., 2021).

Thus, 5G with its enhanced capabilities can prove to be the game-changer which can revolutionize the healthcare ecosystem with its high speed and massive connection power. It can meet the needs of patient and healthcare provider conveniently, cost-effectively, efficiently accurately, and at scale. The 5G in healthcare market is valued at an estimated USD 215 million in 2021 and is projected to reach USD 3,667 million by 2026 (Market and Markets, 2020). Further, integration with other ICT technologies such as Big Data, Internet of Things, Artificial Intelligence (AI), Blockchain etc. can make it even more pervasive, accessible and successful in providing digital health services and improve the protection of patients and health workers, especially during pandemic times (Kaur et al., 2020; Soldani et al., 2017). The cloud computing can further support the minimum need of resources to be managed at premises, rather maximum processing and storing can be outsourced to cloud. This would allow the healthcare solutions to be low maintenance and cost effective (Dhaliwal, 2017).

The 5G finds extensive use in providing multiple remote services like telehealth, telemedicine, remote monitoring, tracking and tracing which was extremely useful during pandemic times. The below-given table presents the utilization of 5G networks. The Table 2 given below illustrates the multi-varied challenges that healthcare sector faced during Covid-19. Further, it presents a possible 5G based healthcare solutions and the 5G supported use cases for pandemic situations.

## 3.2 5G Implementation in Healthcare

5G can play a major role in providing remote solutions in healthcare services during pandemic times. It can improve healthcare communication infrastructure in terms of accessibility, reliability, flexibility, stability and scalability of the network, and rapid response of data transmission which can enabling real time monitoring and telesurgery with help of robotics, especially in pandemic situations. The technical requirements for ensuring smooth delivery of services in various aspects of health services are presented below in Table 3 which presents the use cases, relevant 5G applications, expected capacity, and latency along with the number of devices that can be used and any other technical requirements for successful implementation.

### 3.2.1 Telehealth

*Telehealth* is a smart healthcare service in which the patients are provided various health services and supervision remotely using telecommunication technologies. It is a broad term for health-related services such as clinical healthcare, health education, health administration, and public health. It mostly is based on collaborative technologies and smart gadgets such as smart trackers, smart phones, smart watches, etc., which gather and share patients' sensor-based information in real-time (Sageena et al., 2021). *Telemedicine* consists of remote clinical services which include diagnosis and consultation by a patient with a healthcare professional remotely, using digital mediums. The patient is guided by a doctor who interacts with the patient using videoconferencing and provides him the required with diagnosis and guidance (Sageena et al., 2021). This was service was extensively used by patients to consult doctors during Covid-19. *Telenursing* refers to the delivery of nursing care and conducting

**Table 2. I**

**Issues faced during Pandemic: Probable solutions through 5G (Abubakar et al., 2020; Boccardi et al., 2014; Elavarasan et al., 2020; Ting et al., 2020; Siriwardhana et al., 2021)**

Issues faced in Pandemic times	Possible Solutions	Domain	5G supported uses
<ul style="list-style-type: none"> <li>Healthcare facilities overwhelmed</li> <li>Large no. of Covid patients</li> <li>Protecting the healthcare providers from exposure to infection</li> <li>Ensuring regularity of healthcare facilities to regular patients</li> <li>Meeting the social distancing guidelines</li> <li>Limited manpower</li> <li>Mobile treatment mechanism</li> <li>Pharmacy support</li> <li>Education of health programmes</li> </ul>	<ul style="list-style-type: none"> <li>Remote examinations &amp; treatments</li> <li>Remote Clinical services</li> <li>Remote Nursing services</li> <li>Remote surgery supported by robotics, AI, Cameras, Sensors</li> <li>Remote monitoring based on Sensors, health trackers, and smart devices</li> <li>Online ordering for medicines</li> <li>Online Education</li> </ul>	TeleHealth Services	Tele Medicine - Remote Patient Consultation & Examination Tele Nursing Tele Surgery Tele Pharmacy TeleHealth
<ul style="list-style-type: none"> <li>Need for Quick tracing of Close contacts of the patient</li> <li>Need for accurate identification of close contacts</li> <li>Isolation of Contacts to control the spread of disease</li> <li>Reduce the human efforts &amp; intervention in manual tracing</li> <li>Enhance the overall effectiveness of contact tracing activity</li> </ul>	<ul style="list-style-type: none"> <li>Bluetooth-based contact tracing</li> <li>Tracking based on mobile phones and smart devices proximity-based data</li> <li>Usage of mobile phone location-based tracking</li> <li>GPS-based location tracking</li> </ul>	Contact Tracing	Sensor & GPS-based Data for Contact Tracing
<ul style="list-style-type: none"> <li>Ensuring compliance with Self-isolation as per the guidelines</li> <li>No Automated mechanism exists for tracking the isolation</li> </ul>	<ul style="list-style-type: none"> <li>Usage of mobile phone location-based tracking</li> <li>GPS-based location tracking</li> <li>Unmanned Ariel Vehicle (UAV) based tracing</li> </ul>	Self Isolation	Smart devices based tracing
<ul style="list-style-type: none"> <li>The excessive surge in online shopping</li> <li>An inefficient supply chain caused severe shortages</li> <li>Artificial shortages created by vendors</li> <li>Medical Items &amp; daily items available at exorbitant prices</li> <li>Panic buying amongst customers leads to scarcity</li> <li>Remote Delivery of medicines</li> <li>Issues in payment collection</li> </ul>	<ul style="list-style-type: none"> <li>Unmanned Ariel Vehicle (UAV) based tracing</li> <li>IOT &amp; AI based Supply chains</li> <li>Contactless payments based solutions</li> <li>Blockchain based solutions</li> </ul>	Healthcare Supply Chain	
<ul style="list-style-type: none"> <li>Excessively high demand for medical supplies such as sanitizers, oxymeters, PPE kits, ventilators, etc. leading to shortages</li> <li>Lower manufacturing and production of medical items due to limited manpower due to social distancing restrictions</li> <li>Outsourcing of production to foreign countries</li> <li>Import of essential medical items from foreign countries</li> </ul>	<ul style="list-style-type: none"> <li>IIOT (Industrial IOT) &amp; AI based Supply chains</li> <li>Blockchain based solutions</li> <li>Automated manufacturing &amp; Production</li> <li>Utilization of robots</li> </ul>	Manufacturing Connected goods	Smart Manufacturing & Factory Automation
<ul style="list-style-type: none"> <li>Isolation &amp; social distancing led to mental health issues</li> <li>Changed personal and professional environment work from home, home-schooling</li> <li>No physical meet-ups</li> <li>Fear of virus</li> <li>Stress and anxiety prevalent</li> </ul>	<ul style="list-style-type: none"> <li>Internet based online entertainment sites, online gaming, Video conferencing, online calls, Online Content availability, OTT &amp; movie subscriptions</li> </ul>	Mental Health	Entertainment

nursing practice utilizing telecommunication infrastructure to deliver remote care to a patient. For example, monitoring remotely through video. *Telepharmacy* refers to providing pharmaceutical care and medicines to patients who are not physically present near a pharmacist but rather are at a remote

**Table 3.**  
**Technical requirements for use of 5G (Mahajan et al., 2020; Navarro-Ortiz et al., 2020; Osseiran et al., 2014; Osseiran et al., 2016; Dangi et al., 2021; Siriwardhana et al., 2021)**

Use case	Application	Expected capacity	Expected latency	Number of devices	Other requirements
Telehealth	Telemedicine	>500 million visits per year	<1–100 ms	1–10 per appointment	Real-time backhaul connectivity Streaming data type
	Telenursing	<50 Mbps	<1–100 ms	1–10 per appointment	Real-time backhaul connectivity Streaming data type
	Telesurgery	30–50 Mbps >1 Gbps for holographic rendering	<1 ms	10–100 per surgery	Real-time backhaul connectivity Streaming data type >99.999% availability required >99.999% reliability required
	Telepharmacy	<50 Mbps	<1000 ms	1–10 per appointment	Real-time backhaul connectivity Streaming data type
Supply Chain	Connected goods	Small-data (<1 kbps) per device, >1–10 Gbps of data per supply chain	<10 000 ms	Up to millions per	Intermittent backhaul connectivity Streaming/historical data >95% availability required
	Manufacturing	>1–10 Gbps of data per plan	wide range: <1 ms for time-critical (e.g. robotics), <10 000 ms for non-time-critical optimizations (e.g. asset localization)	1000–one million per city	Real-time backhaul connectivity Streaming data type Indoor connectivity and high availability
Contact Tracing	Using sensor data for contact tracing	>10–100 GB of data per city per day	<1 ms	1000–one million per city	Real-time backhaul connectivity Streaming data type Low power consumption
	Self-isolation	<1 GB of data per isolated person per day	<1000 ms	1–10 per person	Real-time backhaul connectivity Streaming data type

site. It includes ordering the medicines over internet and the delivery of prescription drugs via drones and UAV's (Unni et al., 2021). *Telesurgery* is an advanced state of telehealth where a surgeon is able to perform surgical procedures remotely using robots and other equipment. Since it is a most sensitive scenario therefore, enhanced 5G capabilities are most suitable for telesurgery (Gupta et al., 2019).

During Covid-19, social distancing norms, huge surge in number of Covid patients, limited number of healthcare professional and hospital beds along with non--availability of the protective gears like PPE kits & gloves created an overwhelming situation in hospitals. Therefore, both the patients and health providers quickly adopted the telehealth services as it helped in ensuring regularity in health services while maintaining social distancing as per the guidelines and minimizing the exposure of healthcare providers to the virus. Telehealth services do require the access to telecommunication technologies, high speed internet, and other smart devices for proper functionality.

For instance, a teleconsultation between a doctor and a patient would need 4K/8K video streaming with low jitter and low latency (Osseiran et al., 2016). Similarly, for delivering health education programs would require an Internet connection with high coverage and connectivity to exchange the instructions without any intermittent delay. Whereas in sensitive cases like telesurgery where surgery is being done remotely by a surgeon on the patient using robots would need ultra-low latency

communication (less than 20 ms E2E latency) and seamless connectivity between a large number of devices such as wearable sensors, haptic feedback devices, robots, cameras, and Augmented Reality (AR) devices (Mahajan et al., 2020).

### *3.2.1.1 5G Solution*

5G can be used very extensively in providing Telehealth services. The 5G networks are based on combination of underlying technologies such as spectrum, massive MIMO, beamforming, mMTC, eMBB, 5G New Radio (NR), Local 5G Operator (L5GO), and MEC servers which enhances the overall capability and delivery through 5G (Siriwardhana et al., 2021). Such as, the underlying mMTC will provide an even faster and wider range of services in 5G. The utilization of technologies such as mmWave spectrum, massive MIMO along with beamforming technology would not only help in serving a larger no. of consumers but also provide extremely high data rates. These would provide enhanced localization, network connectivity, and data speeds for even indoor environments. Similarly, eMBB service, irrespective of the location would facilitate the smooth broadcast of 4K/8K videos amid the patient and the doctors (Li et al., 2018). The 5G New Radio (NR) which is the new radio access technology supports ultra-low latency for URLLC technology used in telesurgery applications. In Local 5G Operator (L5GO) the core and access network are set up on-site locally at the healthcare facility which provide enhanced connectivity for medical needs both indoors and outdoors (Siriwardhana et al., 2021). This also helps in achieving ultra-low latency which is advantageous for telesurgery wherein the surgeon and patients are in a separate place because of a pandemic situation. The deployment of MEC servers at the 5G base stations proves to be useful in controlling the functions of unmanned aerial vehicles (UAV's) for proper medical payload deliveries (Li et al., 2018).

The 5G networks would also facilitate the communication and interconnectivity of a larger number of IOT devices at much faster speed and data volumes. For example, the mMTC services would be useful for supporting Medical IoTs (MIoTs) for monitoring and treating the patients remotely. It would enable synchronous connection and communication between various heterogeneous devices such as a sensor and its tracker. For instance, the wearable sensor-based device of the patient can instantly send and share data with a remote medical professional through a 5G network, and accordingly the professional can activate the special medical equipment present locally with the patient through the mobile device (Gaurav et al., 2022).

### *3.2.2 Agile Implementation of Novel Applications and Solutions*

The Covid-19 pandemic led to quick development and adoption of large number of new healthcare based applications and devices. These advanced and intelligent applications and solutions were developed to provide real time access; collect patient related data and for providing remote monitoring. Therefore, these healthcare services/applications required a quick launch and adaptation (Ardebili et al., 2021). Many such AI and Machine Learning (ML) based applications for data collection and its analysis were developed. Such as, the mobile-based apps can gather the data from the patients, also from different hospitals and healthcare providers and upload it to all a cloud server. Thus, providing easy access to holistic information which can help in decision making for public, policy makers and administrators. Similarly, many interactive applications were made for supporting individual interaction between the healthcare providers and the patients remotely (Naik et al., 2020). Similarly, many Sensor-based devices and applications were available in the market through which the medical provider could gain real-time access to patient data for regular health monitoring and guidance. Telehealth based solutions were developed and implemented to educate the people in general about the spread and the safety measures using digital medium. Healthcare solutions which minimized the face to face interaction rather automated the regular work and helped in maintain social distances were quickly adopted by people. Thus, all such applications and solutions need a rapid development and implementation based on a strong flexible network infrastructure that can support the healthcare services rapidly and remotely (Ardebili et al., 2021; Naik et al., 2020).

### 3.2.2.1 5G Solution

In case of rapid deployment of applications and services, 5G networks have an intrinsic advantage over 4G networks. 5G by using SDN and NFV technologies supports the formation and functioning of new network services (Barakabitze et al., 2020). According to the need of applications, the NF's can be hosted at operator premises or even cloud servers. The MEC servers would be suitable platform to host these applications as they reduce the dependency of the infrastructure and makes the applications more flexible and reliable in 5G networks (Dangi et al., 2021). Since the network itself is programmable therefore, it is much easier to increase the capacity of the 5G network as per the current demand. 5G networks have the capability of network slicing which leads to the creation of unique logical networks for example, low latency slice and IoT slice which can then cater to a similar type of service requirements, thereby providing guaranteed service levels to the applications (Barakabitze et al., 2020).

### 3.2.3 Managing the Supply Chain of Healthcare

The swift rise of Covid-19 cases, led to a sudden increased demand for Personal Protective Equipment (PPE) kits, thermometers, oxymeters, ventilators, and certain drugs and medicines. This created huge shortages, imbalances and ultimately breakdown of the regular supply chains. (Miller et al., 2021). The manufacturers and producers of healthcare products faced tremendous problems in meeting the demand as they faced a severe shortage of raw materials and labor. Due to social distancing norms, they were unable to maintain regular production levels or enhance their production levels to meet the demand. Inability to outsource the production or to get the imports further contributed to the shortages. Other factors that contributed to shortages included, transport restrictions and breakdown of the established distribution mechanisms making even basic things such as hand sanitizers, N95 masks, and regular medicines inaccessible to people. The situation was further aggravated by the panic buying amongst the consumers, leading to high prices. Some people stockpiled the items in surplus. Thus, creating artificial shortages. This all created a huge imbalance in supply chains (Sriyanto et al., 2021). The delivery of the essential health items and medicines to the end customer, while following imposed restrictions, was an uphill task for everyone involved in the distribution and supply chain of healthcare.

To overcome the challenges in healthcare supply chains, industries can implement AI & IoT-based supply chain solutions which can properly track the movement of the items across the entire supply chain: starting from the production plant to reaching the end user. For dealing with the production shortages, the industries can implement IoT-based smart manufacturing techniques which include sensor networks, use of robots & automated production lines (Dhaliwal 2020; Dhaliwal 2021b). These technologies can monitor closely and dynamically adapt production levels as per changed demand. UAV-based automated deliveries of small items like masks, and medicines sanitizers can be implemented to reduce physical contact with the users (Mariappan et al., 2022).

#### 3.2.3.1 5G Solution

5G can play a vital role in ensuring effective and efficient supply chains. 5G supports the direct connectivity of IoT and mMTC devices. This can encourage an increased adoption of IoT devices in supply chains which could increase their efficiency. 5G based smart manufacturing system can be developed with the deployment of L5GOs which can integrate the IoT sensors, robots, and actuators directly into the 5G network, while the indoor deployment of the mmWave 5G small cells would provide the extensive network connectivity for the robots, sensors, and actuators within the manufacturing and production plants (Taboada & Shee, 2021). Similarly, deployment of Massive MIMO and beamforming in 5G can provide superior quality network connections to a large number of varied devices, while deployment of MEC servers can support processing the data locally thereby ensuring better security and privacy of data and improving the scalability of the systems. 5G integrated MEC can also deploy decentralized solutions via Blockchain (Chang & Park, 2020; Dhaliwal 2021a).



Similarly, 5G based UAV can be used for the delivery of items Beyond Line-Of-Sight (BLOS). 5G capabilities support real-time access for monitoring and tracking of items, leading to more effective, efficient and transparent supply chains at the same times decreasing the chances of exposure and reducing human efforts (Li et al., 2018).

### ***3.2.4 Self-Isolation and Contact Tracing***

To control the spread of Covid-19, self-isolation was suggested to Covid patients who were asymptomatic or had mild conditions. This prevented the overburdening of healthcare facilities. But it was important to monitor and track the self-isolating patient closely, to ensure that he/she was correctly following the self-isolation guidelines. In case of a lapse, the correct guidelines were to be shared with the patient. Such close monitoring was a difficult task. For this monitoring a Mobile device-based app can be used, which tracks and updates the GPS location data of patients' mobile phones to a cloud server (Ahmad et al., 2021). Similarly, sensor based wearable devices and UAV's can be used to track and monitor the current health conditions of the patient (Naik et al., 2020). The real time data of the patient's sensors can be shared to a cloud server through patients' mobile phone where it can be easily monitored remotely. Similarly, UAV-based applications can remotely monitor the conditions. Firstly, it can identify the person using face recognition algorithms and then further examine the patient's conditions such as check body temperature using infrared thermography from a distance (Li et al., 2018).

The contact tracing of positive cases is also enormously imperative to control the spread of disease. But the existing contact tracing mechanism is quite cumbersome as it is very manual and needs significant human intervention. Therefore, it is quite ineffective as identification of all the close contacts of all patients is often not possible. One of the solutions to this problem is, Bluetooth Low Energy (BLE) based application for contact tracing. In this, the BLE devices like a smart watch or smart phone advertise their ID, GPS location and timestamp data periodically which is captured by the other compatible devices which are nearby. So, for any Covid positive patient, the BLE can easily trace and provide the IDs of the contacts who came in close contact (within a few meters) of an infected patient over a period of time (Whitelaw et al., 2020).

#### ***3.2.4.1 5G Solution***

Sensors, wearable and robots are all IoT based devices. 5G can be coupled directly with IoT to monitor the patients and ensure the compliance of self-isolation. mMTC of 5G provides the massive connectivity to varied IoT devices such as wearables, sensors, etc. Further, MIMO, small cell networks and beamforming in 5G will provide better connectivity and positioning even in indoor environment (Barakabitze et al., 2020). The patients can even use low-power wearable devices instead of mobile phones. These devices use BLE technology to share data which can be further be uploaded to the cloud using the 5G (Whitelaw et al., 2020). This would give easy access to patient behavior data to the concerned people. Similarly, for contact tracing BLE based wearable devices can easily collect the ID data of other proximal devices and upload the same to the cloud. This way if any person tests positive, then all those who came in close contact can be identified using the using the cloud based data and can be notified to take proper safety measure. The deployment of MEC servers can be used for increasing the scalability of the resources when required while Network Slicing (NS) can allocate a separate network slices for data transfer Thus, providing improved Quality of Service (QoS) and enhanced security and privacy of the data (Jain et al., 2021).

### ***3.2.5 For Mental Health - Entertainment***

Covid had a multi-pronged effect on the health of people. To control the spread of Covid-19, lockdowns, restrictions, and social distancing were implemented by governments all over the world. This created a situation where people were caged in their homes for many months working from home and even schooling from home. There were no social interactions or physical meet-ups. This isolation led to a

humungous rise in mental health issues. The fear of infection added to the stress and anxiety of the people (Torales et al., 2020). With no physical entertainment outside many people turned to the mode of online entertainment to feel a bit normal in such a dire situation. For their entertainment needs the consumption of multimedia platforms such Prime, Netflix, gaming sites increased tremendously. Similarly, for social communications, the use of social media platforms, such as Facebook, Twitter, WhatsApp, also increased manifold since, tourism had come to standstill, one of the solutions was AR/VR-based e-tourism (Whitelaw et al., 2020).

#### **3.2.5.1 5G Solution**

5G is an important technology for fulfilling the entertainment needs of the people by providing high-quality online streaming services for sports, movies, and other entertainment events. The mmWave 5G small cells can provide enhanced network connectivity and higher data transmission rates (Taboada & Shee, 2021). Similarly, Massive MIMO and beamforming provides connectivity to a large number of varied devices. Small cells, mmWave frequencies, and eMBB services together can ensure high-quality streaming, high connectivity, hologram technology support, and higher bandwidth data connection for AR/VR-based solutions (Sher et al., 2021). MEC servers can be deployed to deal with sudden high usage demands by enhancing the scalability of the systems along with supporting low-latency content delivery. 5G supports immersive gaming experience. Many online gaming systems implemented hologram technology so, that players can feel a real presence in the gaming environment (Shah et al., 2022). Similarly, person by using AR/VR technology can enjoy an immersive virtual tour of a place without actually traveling to the location.

### **3.3 Challenges in Implementation and the Possible Solutions**

It is predicted by the experts that 5G will transform the future of healthcare sector. The increased usage of telehealth, wearable sensors and medical devices and ability to remotely monitor in real time are the key reasons for the growth of 5G. It can prove instrumental in future pandemics as it can provide multifaceted support for remote services to be provided faster rate and across a larger no. of devices. But providing these services seamlessly is not easy, rather it presents a complex set of challenges which range from technical issues like scalability to social issues like technology education and acceptance. Some of the important issues that hinder the deployment of 5G are given below:

#### **3.3.1 Privacy Protection Issues**

Privacy is one of the most important concerns for an end user. For example, an online consultation with a doctor was undertaken by a patient through videoconferencing. During this interaction, he might have shared some personal sensitive information that he would like to keep private. Similarly, in the case of contact tracing the automated applications collect a large amount of location data of users without their knowledge. If any such sensitive data gets leaked to any unauthorized party, it can create a serious privacy violation (Hall & McGraw, 2014). Even otherwise there are strict legal guidelines and requirements for privacy protection by government agencies under EU-GDPR and Health Insurance Portability and Accountability Act (HIPAA) (Shuaib et al., 2021).

##### **3.3.1.1 Possible Solutions**

To overcome this privacy issue, the technical solutions such as software-defined privacy and Privacy by-Design, should be implemented in the designing phase of the 5G health applications. In Privacy-by-Design, data handlers and controllers should proactively take care of the privacy issues of any new or upgraded system, the policies and procedures for data sharing etc., right in the initial planning phase rather than later when the systems are already implemented (Kalloniatis et al., 2021). Attention should also be given to the entire life-cycle of health data collected through various e-health applications and solutions in 5G and how to protect it wholly. Different access and controls should be implemented for different users of data. Edge computing can be advantageous in enabling local

processing of data instead of it being transmitted across different networks this ensures the safety and privacy of data (Kalloniatis et al., 2021). Further, the end users or the patients whose data is being collected through e-health applications and services should be educated and informed about what are the probable privacy risks involved, what are the data sharing & processing policies, and also what are they agreeing to when they are using such digital e-health applications. This would enhance transparency and lead to increased adoption of e-health solutions amongst the users.

### **3.3.2 Security Challenges**

Security is the most critical factor of any IT systems. 5G networks too face security issues. The 5G networks are based on the legacy technologies. Any shortcoming of earlier systems will be a security risk for 5G too. Any databases which contain important sensitive information are always at risk of attacks from hackers. E-health systems collect and store a lot of sensitive information, so it is always at the risk of being attacked. Also as applications need to be working in real-time, it further increases the risk of attacks. Integration of large no. of different low-end devices in MIIoTs aggravates the security risks of healthcare systems (Gaurav et al., 2022). The low-end devices are easily hackable and virus infected, even more susceptible to Denial-of-Service (DoS) attacks. Thus, all these various devices act as easy entry points for hackers to enter the healthcare system and perform unauthorized operations or steal data (Ji et al., 2018).

#### **3.3.2.1 Possible Solutions**

One of the possible solutions to enhance the security of MIIot is implementing lightweight and scalable security mechanisms. Since the low-end devices and sensors have limited capabilities and have higher vulnerabilities, therefore, a part of security mechanisms can be made cloud-based (Gaurav et al., 2022). The majority of the digital health services that involve smart controls, data analytics or automation need AI and ML techniques in 5G systems (Ji et al., 2018). In such situations, Blockchain technology and encrypted data transmission can be deployed to protect the network from unauthorized access by hackers as well as protect the saved user data (Chamola et al., 2020). The new type of attacks and viruses are being deployed every day, therefore, the implemented security mechanisms should have the capability to be easily and continuously updated, so that it can tackle the new security threats.

### **3.3.3 Enhancing the Scalability and QoS**

The increased adoption of 5G based healthcare applications and devices would translate into increased number of users and hence additional traffic. This would create network congestion and even breakdown of services. Therefore, scalability of the system is of paramount importance, so that it can meet the requirements of increased network traffic and demands (Siriwardhana et al., 2021). Many applications can work properly, only when the network is not congested. Such as, AR-based healthcare applications need low latency and high bandwidth, so if a network is congested it would fail to meet the basic service levels needed for such applications. Similarly, users now have greater access to IoT based smart technologies and devices than ever before and the number is continuously increasing tremendously therefore, managing such a huge number of MIIoTs is a great challenge (Gaurav et al., 2022). Thus, the 5G networks need to be scalable to be able to cope with the high number of data transfers and additional traffic being generated by these devices.

#### **3.3.3.1 Possible Solutions**

The scalability problem can be tackled with the deployment of Network slicing in 5G which supports dynamic scalability. The slices system can provide adaptive and dynamic scalability based on constraints such as present network traffic, the priority of the service, available network resources, QoS requirements and the number of IoT devices presently connected (Jain et al., 2021; Lee et al., 2018).

Virtual NF and MEC servers can also help in tackling the unexpected surge of localized demands which leads to congestion (Jain et al., 2021). Further, technologies like distributed clouds and edge

computing systems can be deployed to enhance the scalability improvement, as they can carry out visual processing on large computational capabilities and share the outputs directly to mobile e-health devices thereby decreasing the congestion. Similarly, full beamforming can also be used to increase scalability, high-speed communication, and network utilization efficiency (Boccardi et al., 2014; Dangi et al., 2021).

### ***3.3.4 Limited 5G Deployment and Coverage***

5G infrastructure has been implemented in very few countries across the globe. There is as inadequate deployment of 5G networks and limited availability of 5G based devices which poses a big challenge to quick adoption of 5G (Parcu et al., 2022). Thus, there is need of immediate deployment of 5G by the Network operators. The diffusion of 5G technology and its features – higher connectivity and higher capacity has been quite slow. Other issues that hinder 5G devices are heating issues and their high power consumption due to high-frequency transmissions Multi-band support makes production of 5G devices more complex and costly (Cheng et al., 2022).

#### ***3.3.4.1 Possible Solutions***

For faster adoption and implementation of 5G, the different governments worldwide, need to play a pivotal role. Governments along with network operators need to hasten their 5G deployment plans. Especially in the area of healthcare, they can initially deploy small-scale L5GO networks for use in hospitals and also in production facilities as they are easiest to implement (Parcu et al., 2022). Similarly, a single-purpose IoT device with lesser but specific capabilities can be developed for e-health uses as this would circumvent the complex implementational issues of 5G systems. To speed up the deployment of 5G networks, the mobile operators who commit to higher coverage can be offered discounts at the time of bidding in spectrum auctions (Borrallho et al., 2021). Different network providers can also be jointly given spectrum bands to improve the coverage in rural and backward areas which are often poorly served. Similarly, multiple operators can be allowed to use the same radio access infrastructure using RAN. This would help in cost minimization as well as coverage expansion for 5G (Borrallho et al., 2021).

### ***3.3.5 Societal Issues and the Human Factor***

Many conspiracy theories have been shared in public which blame 5G networks for spreading Covid-19 (Alani, et al., 2021). Similarly, 5G have been claimed to be extremely harmful to the environment especially birds and bees. Such theories led to instances of distrust among people. In many places, it even led to cellular base stations being destroyed by the public. These incidents disrupt network connectivity and service continuity which are vital for connected e-health applications and solutions (Kumar et al., 2021). Another social aspect is technical literacy. The users of 5G based applications often need to be a bit tech savvy, so that can properly use and handle the applications. But many people lack such technical know-how and this proves to be a hindrance to the adoption of 5G based e-health services. Technology acceptance by health professionals is another area of concern as they often resist shifting to such new technology which seems to add complexity, and need their effort or time to understand or disrupt their usual way of working (Lamichhane & Neupane, 2022). On the cost front, the 5G devices are quite expensive; this proves to be a deterrent to cost-sensitive users.

#### ***3.3.5.1 Possible Solutions***

It is the duty of Governments, media, and technical experts of 5G to presenting the real facts and debunks the inaccurate stories and narrative built around 5G. Over time, they can change the false notions held by some and thereby create acceptance in society (Kumar et al., 2021). To overcome the hindrance of technical literacy and the cost burden of the end user, it is important to develop applications that are easy to understand and use on cost-effective basic hardware or devices. This ease of use and affordability will ensure easier and wider adoption of 5g applications by everyone

(Lamichhane & Neupane, 2022). To create acceptance of e-health solutions amongst health providers, an effective clinical decision support system should be developed which requires minimum efforts by health providers to reach viable solutions to their problems (Al-Marroof et al., 2021).

### **3.3.6 Legal and Regulatory Dimension**

Legal and regulatory aspects of 5G are of quite important. 5G is a developing technology with many variables and societal aspects still unknown. Therefore, 5G based health applications need to proactively take into consideration various legal and regulatory issues which can crop up in the future. For example, if sensitive personal data is not properly handled by the applications used in remote monitoring and contact tracing, it could develop into legal issues (Bauer & Bohlin, 2022). Similarly, collecting and storing data by the contact tracing application after the recovery of the patient, could also lead to legal issue. Access to healthcare is a fundamental right of everyone. If any technical solution causes some harm to the patient, for instance, wrong diagnosis or suggests some wrong treatment or delays a timely treatment being inaccessible when needed, it would definitely create a legal furore. Similar legal concerns can arise and impact all the stakeholders of 5G-enabled smart devices for e-health, be it a consumer, manufacturer, insurer, or service provider.

#### **3.3.6.1 Possible Solutions**

Any legal issue can be prevented by strictly following the notified standardization policies as well as the policies defined by various bodies such as the EU statement on contact tracing (Sarabdeen, 2012). The policies for regulation and standardization must be implemented holistically for the entire healthcare technology chain (Shuaib et al., 2021). It should cover everything right from basic things like sensors to the advanced medical devices and the software technologies being used at the backend. To avoid legal issues in the future, it is better to get legal advice on all aspects while in the designing phase as well as before the final deployment of the application. Also like tangible products, the limited product liability should be extended to cover the correct functioning of the networks and the e-health solutions. This would create confidence amongst the end users and the health providers. For handling the complexity of a 5G environment, pervasive monitoring and root-cause analysis techniques should be implemented to avoid any unforeseeable legal situations (Reshmi & Azath, 2021).

## **4. CONCLUSION**

In pandemic situations, the Healthcare sector of any country is the first one to get most affected. Covid-19 proved to be a litmus test of the healthcare systems prevalent in the world. Very few could effectively face the onslaught while majority of these failed under the immense pressure of rapidly increasing Covid cases. This has brought a tremendous focus on how to build strong, robust and efficient healthcare systems that can withstand any future pandemic situations. As of July 2022, Monkeypox cases have been increasing all over the world. There is a fear of “re-emergence” of a different pandemic looming.

Considering such unforeseeable situations of future, the healthcare sector of every country needs to be prepared to face and tackle any such emerging difficult situations with help of innovative and novel solutions. To achieve this goal, the role of 5G is very crucial. The different technologies involved in 5G can contribute to the enhanced performance of the entire network. The mmWave frequencies of the radio spectrum through its NR can provide better connectivity in all environments – both indoor and outdoor. Integration of Massive MIMO and beamforming technique will help in serving higher data transmission to a larger number of 5G connected devices. These technologies play a critical role in supporting the use cases of 5G namely; eMBB, URLLC, and mMTC service. These further support the different practical applications and services such as collaborative robots, UAV communication, and VR/AR capabilities which use 5G networks.

MEC, NS & 5G technologies enhance the service levels, the flexibility, the privacy of data, allows scalability of systems, and the security of the applications. Thus, overall, 5G technologies would provide much better connectivity, higher data transmission rate, higher capability to integrate a larger number of smart devices, higher speeds and low latency. Hence, the applications and solutions developed based on 5G technologies can cater to the multi-faceted needs of the overall Healthcare chain.

Some of the prominent areas where these can be implemented include telehealth services, supply chain management, Manufacturing and production of medical items, self-isolation and contact tracing, agile health services deployment, and entertainment. Being a new technology, it does face a wide set of challenges in its implementation. At present, there is a lack of widely available basic 5G infrastructure and 5G based devices. Some of other challenges that 5G faces includes maintaining the privacy of data, ensuring security & dynamic scalability, legal issues, and social acceptance that need to be handled in advance before the 5G and its applications are deployed with full functionality.

## **5. FUTURE IMPLICATIONS**

There are many future research frontiers to explore in the area of 5G in general and for healthcare particularly. One such research domain could be focused on developing competent solutions to the implementation challenges such as in the area of security and privacy problems. Another could be exploring and understanding the potential of 5G with integration with other technologies such as AI/ML, Cloud & IoT in the healthcare sector. Another interesting area of research would be understanding the human behavioral adaptation to 5G devices and newer applications which entails new ways of thinking and functioning, change in regular habits and work patterns, etc., for example, in the case of remote consultations or online entertainment or E-tourism.

At present 5G networks are being rapidly deployed in different countries around the globe. 5G based solutions and applications would certainly prove to be crucial not only in dealing with any future pandemics and other healthcare sector needs but also play an instrumental role in general, changing the communication and the lifestyle of people forever.

## **COMPETING INTERESTS**

The authors of this publication declare there are no competing interests.

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