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The role of 5G for digital healthcare against COVID-19 pandemic: Opportunities and challenges

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Abstract

COVID-19 pandemic caused a massive impact on healthcare, social life, and economies on a global scale. Apparently, technology has a vital role to enable ubiquitous and accessible digital health services in pandemic conditions as well as against "re-emergence" of COVID-19 disease in a post-pandemic era. Accordingly, 5G systems and 5G-enabled e-health solutions are paramount. This paper highlights methodologies to effectively utilize 5G for e-health use cases and its role to enable relevant digital services. It also provides a comprehensive discussion of the implementation issues, possible remedies and future research directions for 5G to alleviate the health challenges related to COVID-19.

Keywords: COVID-19; Pandemic; 5G; IoT; E-health

Contents

1. Introduction

The recent spread of Coronavirus Disease (COVID-19) due to Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) [1] has caused substantial changes in the lifestyle of communities all over the world. By the end of June 2020 at the time of this writing, over eleven million positive cases of COVID-19 were recorded, causing over 500,000 deaths. Countries have been facing a number of healthcare,

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financial, and societal challenges due to the COVID-19 pandemic. Overwhelmed healthcare facilities due to rapid growth of new COVID-19 patients, are experiencing interruptions in provision of regular health services. Moreover, healthcare personnel are also becoming vulnerable to COVID-19 and this is taxing the healthcare resources even more. To cease the wide spread of the virus, governments impose strict restrictions and control on travel within and between countries, negatively affecting the economies. While the remote work was considered as an alternative with limitations, certain jobs became obsolete. The increased unemployment is a burgeoning problem even for strong economies. Apart from that, government expenditure on unemployed workforce, losing income from sectors associated with tourism such as airlines, hotels, local transport, and entertainment were major challenges for the economies. Governments had to introduce new guidelines on social distancing to prevent the spread of the virus. This resulted in closing schools, isolating cities and even restricting public interactions, affecting the regular lifestyle of people. Such disruptions also lead to unprecedented consequences such as losing physical and mental well-being. Maintaining the societal well-being during the COVID-19 pandemic is therefore a daunting task.

The technological advancement is one of the key strengths in the current era to overcome the challenging circumstances of COVID-19 outbreak. The timely application of relevant technologies will be imperative to not only to safeguard, but also to manage the post-COVID-19 world. The novel ICT technologies such as Internet of Things (IoT) [2], Artificial Intelligence (AI) [3], Big Data, 5G communications, cloud computing and blockchain [4] can play a vital role to facilitate the environment fostering protection and improvement of people and economies. The capabilities they provide for pervasive and accessible health services are crucial to alleviate the pandemic related problems.

5G communications present a paradigm shift from the present mobile networks to provide universal high-rate connectivity and a seamless user experience [5]. 5G networks target delivering 1000x higher mobile data volume per area, 100x higher number of connected devices, 100x higher user data rate, 10x longer battery life for low power massive machine communications, and 5x reduced End-to-End (E2E) latency [6]. These objectives will be realized by key technologies such as mmWaves, small cell networks, massive Multiple Input Multiple Output (MIMO) and beamforming [7]. By utilizing these technologies, 5G will mainly support three service classes i.e. enhanced Mobile BroadBand (eMBB), Ultra Reliable and Low Latency Communication (URLLC) and massive Machine Type Communication (mMTC). The novel 5G networks will be built alongside fundamental technologies such as Software Defined Networking (SDN), Network Function Virtualization (NFV), Multi-access Edge Computing (MEC) and Network Slicing (NS). SDN and NFV enable programmable 5G networks to support the fast deployment and flexible management of 5G services. MEC extends the intelligence to the edge of the radio network along with higher processing and storage capabilities. NS creates logical networks on a common infrastructure to enable different types of services with 5G networks.

These 5G technologies will enable ubiquitous digital health services combating COVID-19, described in the following section as 5G based healthcare use cases. However, there are also implementation challenges which need to mitigated for efficient and high-performance solutions with wide availability and user acceptance as discussed in Section 3. In this work, we elaborate on these aspects and provide an analysis of 5G for healthcare to fight against the COVID-19 pandemic and its consequences.

2. 5G based healthcare use cases for COVID-19

Capabilities of 5G technologies can be effectively utilized to address the challenges associated with COVID-19 presently and in the post COVID-19 era. Existing healthcare services should be tailored to fit the needs of COVID-19 era while developing novel solutions to address the specific issues originated with the pandemic. In this section, the paper discusses several use cases where 5G is envisaged to play a significant role. These use cases are depicted in Fig. 1 and the technical requirements of use cases are outlined in Table 1.

Telehealth for patients

Telehealth is the provision of healthcare services in a remote manner with the use of telecommunication technologies [8]. These services include remote clinical healthcare, health related education, public health and health administration, defining broader scope of services. Telemedicine [9] refers to remote clinical services such as healthcare delivery, diagnosis, consultation, treatment where a healthcare professional utilizes communication infrastructure to deliver care to a patient at a remote site. Telenursing refers to the use of telecommunication technologies to deliver nursing care and conduct nursing practice. Telepharmacy is defined as a service which delivers remote pharmaceutical care via telecommunications to patients who do not have direct contact with a pharmacist. (e.g. remote delivery of prescription drugs). Telesurgery [10] allows surgeons to perform surgical procedures over a remote distance. All these healthcare related teleservices are highly encouraged in post-COVID-19 period due to multiple reasons. Lack of resources (i.e., hospital capacity, human resources, protective equipment) in healthcare facilities due to existing COVID-19 patients, social distancing guidelines imposed by authorities, requirements of maintaining the regular healthcare services adhering to the new guidelines imposed by the healthcare administrations and the need to minimize the risk of healthcare professionals getting exposed to COVID-19 are factors motivating teleservices related to healthcare.

These teleservices sometimes have strict requirements and call for sophisticated underlying technologies for proper functionality. As an example, a telemedicine follow-up visit between the patient and the doctor would require 4K/8K video streaming with low-latency and low jitter. Telehealth based remote health education programs should be accessible to the students from anywhere via an Internet connection having

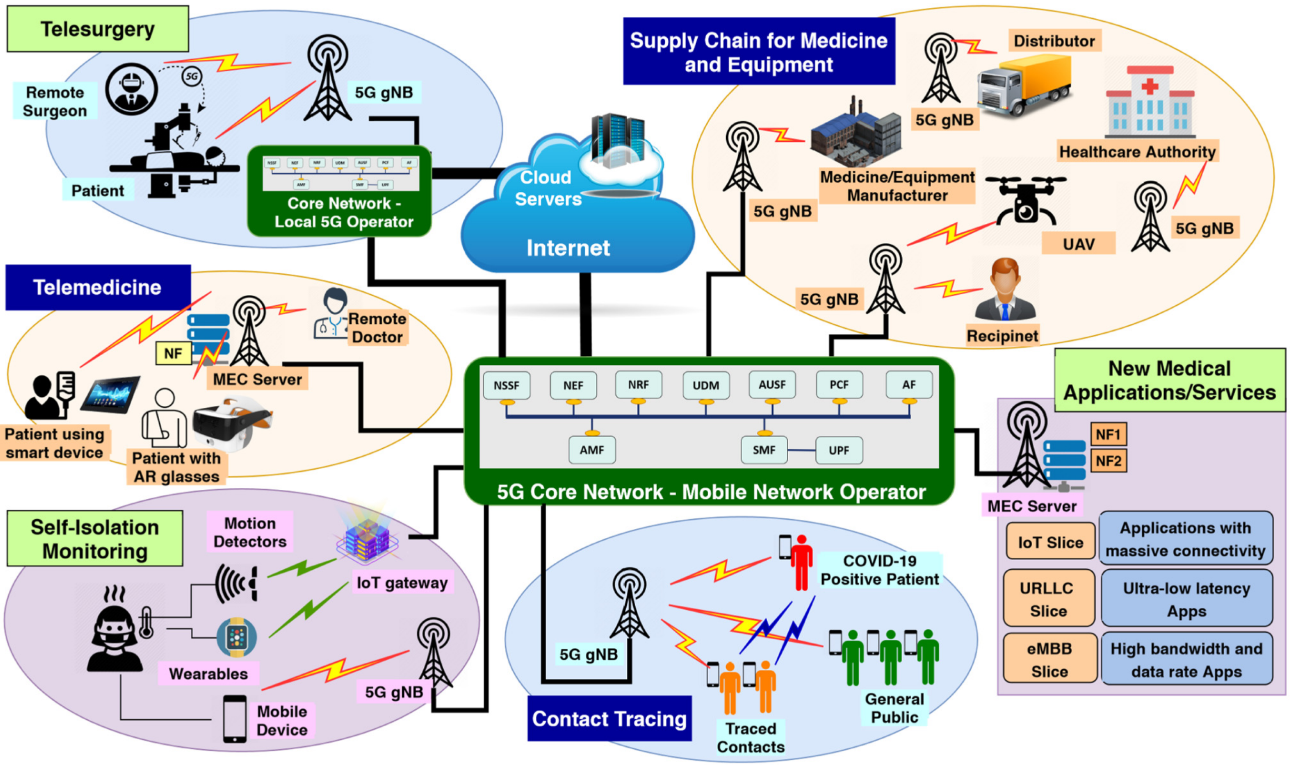

Fig. 1. 5G health use cases for the fight against COVID-19.

Table 1
Technical requirements of digital healthcare related use cases [11–17].

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 supply chain	Intermittent backhaul connectivity Streaming/historical data >95% availability required
	Manufacturing	>1–10 Gbps of data per plant	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 plant	Real-time backhaul connectivity Streaming data 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 isolated person	Real-time/intermittent backhaul connectivity Streaming data type

a proper bandwidth. Monitoring the patients via telenursing also requires uninterrupted HD/4K video streaming between the patient and the nurse. Remote delivery of drugs is possible via Unmanned Aeriel Vehicles (UAV), which requires assured connectivity with base station to send/receive control instructions without delays. Extreme use cases like telesurgery requires ultra-low latency communication (less than 20 ms E2E latency) between the surgeon and the patient, connectivity between a large number of devices such as cameras, sensors, robots, Augmented Reality (AR) devices, wearables, and haptic feedback devices [18].

Role of 5G

The future 5G networks will use the mmWave spectrum, which leads to the deployment of ultra-dense small cell networks, including the network connectivity for indoor environments. Technologies like massive MIMO combined with beamforming will contribute for providing extremely high data rates for large number of sreved users. These technologies together provide a better localization for indoor environments [19]. They realize the eMBB service class which facilitates the transmission of 4K/8K videos between the healthcare professional and the patient, irrespective of the location of access. The new radio access technology developed for 5G networks, also known as 5G New Radio (NR) supports URLLC. The URLLC service class helps to realize the ultra-low latency requirements of telesurgery applications. A Local 5G Operator (L5GO) has its core and access network deployed locally on premises and serves the healthcare facility with multiple base stations deployed both outdoors and indoors to provide connectivity for case specific needs. This deployment is beneficial for telesurgery use case to achieve ultra-low latency, given that there is a requirement of surgeon and patient to be in separate rooms due to the pandemic situation. MEC servers deployed at the 5G base stations can be utilized to deploy the control functions for UAVs for proper medical payload deliveries. The fundamental design changes in 5G networks will enable the communication of large number of IoT devices, which usually transfer less data compared to human activities such as streaming. These mMTC services provide support to 5G enabled Medical IoTs (MIoTs) that can be used to monitor and treat remote patients. mMTC will connect and enable communication between heterogeneous devices into the 5G network so that they can operate in synchronicity. A sensor in a wearable device of the patient can immediately send a signal to the remote nurse via 5G network so that the nurse can activate a special equipment in the patient's room using the mobile device. The use of 5G technologies in a hospital environment for telehealth use cases is illustrated in Fig. 2.

Rapid deployment of new healthcare applications and services

The spread of COVID-19 disease demands the rapid launching of new healthcare services/applications, changes the way present healthcare services are provided [20], integrates modern tools such as AI and Machine Learning (ML) in the data analysis process [21]. A new application can collect the data of COVID-19 patients from different healthcare centers, upload the data to a cloud server and make the information available to public so that others can rely on the information for different purposes. Live video conferencing based interactive applications enable healthcare professionals to discuss with patients and help them [22]. Other applications would perform regular health monitoring of patients such as followup visits, provide instructions on medical services, and spread knowledge on present COVID-19 situation and up to date precautions. The difficulty during the pandemic was that there was a need to automate most of the regular work to minimize the interaction between people and new application development needs were also sudden. This calls for a flexible network infrastructure which supports the development of such applications within a short period of time.

Role of 5G

In contrast to the present 4G networks, 5G supports the creation of new network services as softwarized Network Functions (NFs) by utilizing SDN and NFV technologies. These NFs can be hosted at the cloud servers, operator premises, or in the edge of the network based on the application demands. MEC servers equipped with storage and computing power and reside at the edge of the radio network, will be a suitable platform to host these applications. The deployment of such applications will be more flexible in 5G networks because of the SDN and NFV. Bringing the NFs towards the edge eliminates the dependency of the infrastructure beyond the edge, making the applications more reliable. Increasing the capacity of the 5G network is much easier because the network itself is programmable. 5G networks are capable of deploying network slices which create logical networks to cater the services with similar type of requirements such as IoT slice and low latency slice, thereby serving applications with guaranteed service levels.

Supply chain management for healthcare

A surge in demand for Personal Protective Equipment (PPE), ventilators and certain drugs was observed at the beginning of the COVID-19 spread, causing an imbalance of the regular supply chains [23]. Manufacturing plants were unable to maintain the regular production due to shortage of raw materials and labor force, therefore they were not capable of responding to the increased demand for the goods. The supplies of finished products were also delayed due to transport restrictions and there were no proper alternative distribution mechanisms so that the people who are really in need would receive them. N95 masks, hand sanitizers, and regular medicine are some of the goods where this imbalance of supply was often seen. Those who reacted quickly could stock items in surplus while others who are in need did not receive them. Donations to the victims were not always distributed in a fair manner because of the absence of centralized management systems.

Delivery of the items to the final consumer was a concern due to the risk of COVID-19 spread and the restrictions imposed by the authorities to limit the physical contact. It is

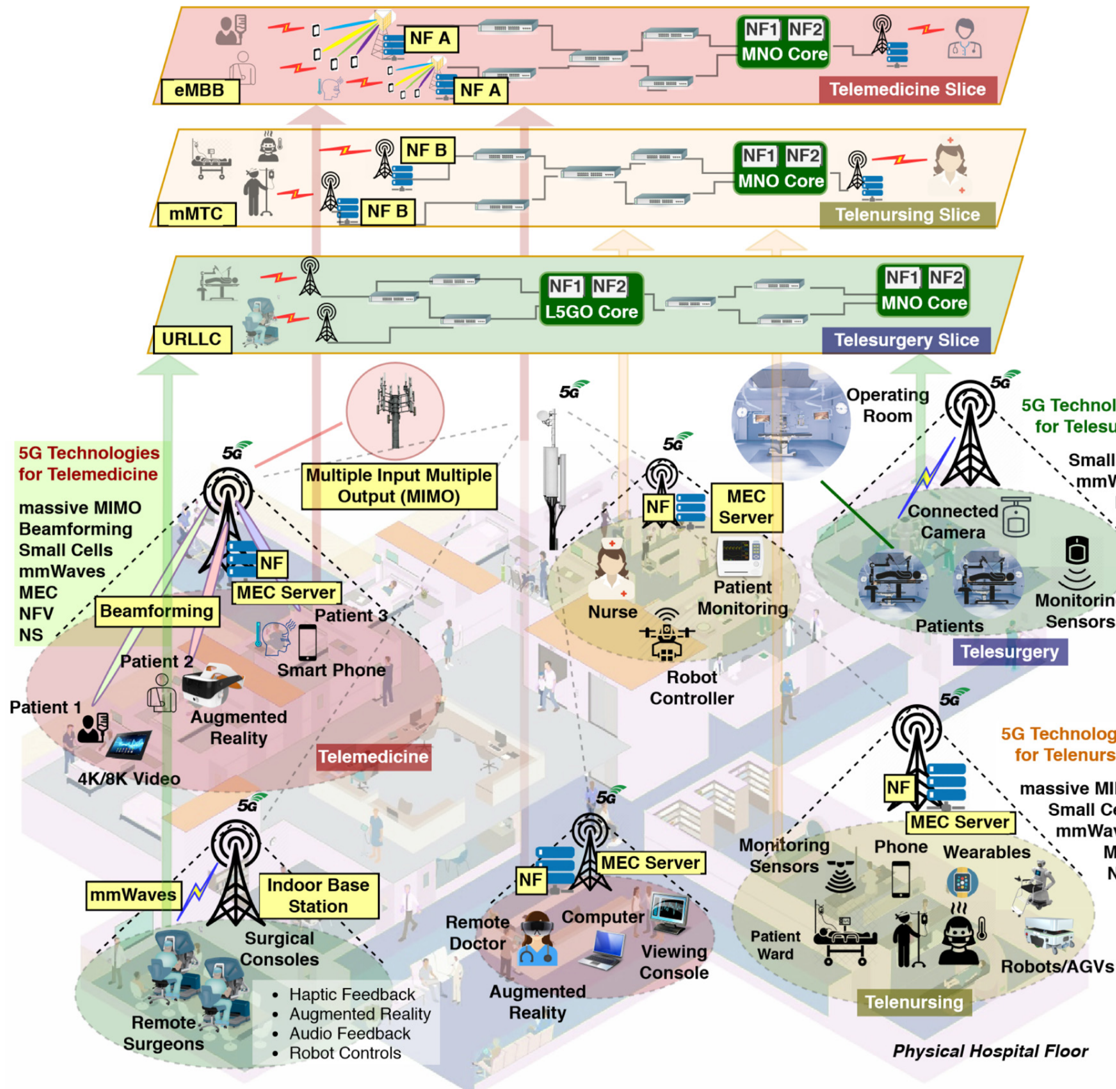

Fig. 2. An overview of 5G deployment for telehealth in a hospital.

a challenge for the governments, healthcare authorities, and distributors to implement proper mechanisms to manage the supply chains of healthcare items in the COVID-19 period. To address the issues in healthcare related supply chains, industries can adopt smart manufacturing techniques equipped with IoT sensor networks, automated production lines which dynamically adapt to the variations in demand, and sophisticated monitoring systems. IoT based supply chains could be used to properly track the products from the manufacturing plant to the end consumer, i.e. connected goods. UAV based automated delivery mechanisms are especially suited in the COVID-19 situation to deliver medicine, vaccines, masks to the end consumer minimizing the physical contact.

Role of 5G

5G supports direct connectivity for IoT and mMTC between IoT devices. This will fuel the possibility to use large amount of IoT devices to increase the efficiency of supply chains. Deployment L5GOs to serve the needs of industries is a better way to integrate IoT sensors, actuators, and robots directly into 5G network enabling a 5G based smart manufacturing system. The proper network connectivity for the sensors, actuators, robots in the manufacturing plants will be enabled by the mmWave 5G small cells deployed indoors. Massive MIMO will provide connectivity for a large number of devices and beamforming technique ensures a better quality of the network connection. The direct connectivity of goods into the 5G systems makes the supply chains more transparent. MEC integrated with 5G, can be used to process the data locally to improve the scalability of the systems as well as security and privacy of collected data. Moreover, MEC integrated with 5G can easily be used to implement decentralized solutions via blockchain [24,25]. The delivery of items to the final destination can be performed via Beyond Line-Of-Sight (BLOS) UAV guided by the 5G network. This could minimize unnecessary interactions in COVID-19 period and reduce human efforts. Real-time data is available for the authorized users for monitoring and tracking, which increases the transparency of the operation.

Self-isolation and contact tracing

COVID-19 positive patients with mild conditions are usually advised for self-isolation to prevent further spread. While self-isolation is a better alternative to manage the capacity of healthcare facilities, the self-isolating individuals should be properly monitored to make sure that they follow the self-isolation guidelines. The challenge is to track every movement of the patient, which is currently impossible. In an event of a violation of self-isolation guidelines, control instructions should be sent. Mobile device based self-isolation monitoring is possible via an application which sends GPS data of patient's mobile phone to a cloud server. Wearable devices attached to the patient's body use their sensors to measure the conditions of the patient and upload the data via the mobile phone. UAV based solutions can monitor the conditions of the patients from a distance. UAVs can monitor body temperature via infrared thermography and identify the person via face recognition algorithms. Moreover, contact tracing of identified positive cases is extremely important [26]. However, present contact tracing mechanisms involve significant human engagement and consist of a lot of manual work. This prevents the identification of all the possible close contacts and hinders the effectiveness of the contact tracing. Manual tracing does not guarantee that all the possible close contacts are identified. Bluetooth Low Energy (BLE) based contact tracing applications use BLE wearable devices, which advertise its ID periodically so that other compatible devices in close proximity can capture the ID and store with the important details such as timestamp, GPS location data (optionally). Once an infected COVID-19 patient is detected, the BLE solution provides the IDs of the close contacts over a defined period. BLE based solutions identify the contacts in the range of few meters, whereas pure GPS based solutions do not have that accuracy.

Role of 5G

mMTC in 5G is responsible for massive connectivity of heterogeneous IoT devices such as sensors, wearables, and robots. The small cell networks equipped with MIMO and beamforming in 5G will ensure better connectivity and positioning including indoor environments. Hence, IoT devices directly connected to 5G network can be effectively used to monitor the compliance of self-isolation. Instead of using general mobile device data, the patients can be attached with low power wearable devices which transfer data via BLE technology. Those sensory data can be updated to the cloud via the 5G network and the authorized parties can monitor the behavior of the patient. A similar concept can be applied to contact tracing where the wearable BLE devices collect data of nearby devices and upload to the cloud via 5G network. Once a patient is tested positive, all the close contact details are already in the cloud and they are notified for proper safety measures such as self-isolation. MEC servers deployed at the 5G base stations are useful to increase the scalability of the operation as the resource demand increases. Allocating a separate network slice for contact tracing data transfer is a better approach to assure the Quality of Service (QoS) and strengthen the privacy and security of the data.

3. Implementation challenges

Despite the use-cases for 5G concerning healthcare and the fight against COVID-19, there are also imminent challenges ranging from technical ones such as scalability to socio-economic ones including technology acceptance. The impact of pertinent deployment challenges on each use case is depicted in Table 2.

3.1. Privacy protection issues

A video recording of a telemedicine session may contain personal information which the patient would like to disclose only to the doctor. In addition, automated contact tracing applications aggregate sensitive location data without the owners' knowledge. Sharing such sensitive user data with unauthorized parties such as third-party advertisers is a serious privacy violation [27]. In addition, privacy protection is a legal requirement, which is posed by various legal frameworks such as GDPR [28] and Health Insurance Portability and Accountability Act (HIPAA) [29].

Possible solutions

To address the privacy challenge, solutions like Privacy by-Design [30], software defined privacy [31] have to be deployed with 5G health applications already at the design phase. Privacy-by-Design relies on the notion that data controllers and processors should be proactive in addressing the privacy implications of any new or upgraded system, procedure, policy or data-sharing initiative, not at the later stages of its life-cycle, but starting from its planning phase [32]. The developed e-health solutions in 5G should consider the entire life-cycle of health data when protecting them. To protect privacy, access control methods managing how different parties access information are necessary. Edge computing is beneficial to minimize data transmissions through different network elements and enable local processing, improving privacy aspects [33]. Furthermore, users of e-health technology should be made fully aware of what they are consenting to regarding data sharing and processing when they are using such digital solutions. Similarly, transparency in the form of informing users about potential privacy risks is effective to improve the adoption of e-health solutions [34].

3.2. Security challenges

Attempts by adversaries to attack the databases containing sensitive information pose security risks. The importance of e-health systems exacerbates the impact of attacks on the availability requirement. The integration of MIoT increases security risks of healthcare systems. Such low-end devices are comparably easy to hack and vulnerable to Denial-of-Service (DoS) attacks. Massive amount of connected devices increases the number of entry points for attackers to perform unauthorized operations, i.e. increases the attack surface, on the healthcare system [35].

Table 2
Pertinent deployment challenges on use cases and their impacts [11–17].

		Deployment Challenges							
Use Case	**Application**	**Privacy Issues**	**Security Challenges**	**Scalability Issues**	**QoS Provisioning**	**Limited Connectivity**	**Societal Impact**	**Legal Issues**	**Regulatory Restrictions**
Telehealth	Telemedicine	H	H	H	M	H	H	M	H
	Telenursing	M	M	M	L	L	H	M	M
	Telesurgery	M	H	L	H	L	H	H	H
	Telepharmacy	L	H	H	L	H	L	L	M
Supply Chain	Connected Goods	M	H	H	L	L	M	L	L
	Manufacturing	L	M	H	H	L	L	L	L
Containment	Contact Tracing	H	M	H	L	H	H	H	H
	Self Isolation	H	M	H	L	H	H	H	H

L = Low Impact, M = Medium Impact, H = High Impact

Possible solutions

Lightweight and scalable security mechanisms must be designed to secure MIoTs. Adequate security mechanisms are crucial to address the limited capabilities of constrained sensors, as well as the additional vulnerabilities if part of the security functions are offloaded to the cloud. For the digital health services, widespread automation, data analytics and smart control requires ML and AI techniques in 5G systems. Encrypted data transmission and distributed security solutions such as blockchain can prevent attackers from gaining access to the network and thus protect the collected user data of different premises. The employed security mechanisms and algorithms should support continuous updates with minimal effort to adapt to discovered vulnerabilities and emerging security threats.

3.3. Scalability and QoS provisioning in massive connectivity regime

A rapid deployment of new healthcare applications will add extra traffic as well as increase the number of 5G users who access such services. This will lead to increased network congestion. As an example, AR based applications used in telemedicine require high bandwidth and low latency. However, a congested network fails to satisfy the service levels for such applications. Moreover, it is challenging to manage billions of MIoTs. When a large number of IoT devices generate ad hoc data transfers, the network should be scalable to cope with the increased number of traffic events. The small data characteristics and intermittent connectivity of IoT encumber the medium access and physical layers of access networks serving e-health applications.

Possible solutions

NS in 5G with dynamic scalability is a possible solution to address this problem. The slices serve similar type of services and they can be made adaptive based on the various parameters such as priority of the service, present network traffic, available network resources, QoS requirement, number of IoT devices presently connected [36]. Deployment of virtual NF based on demand at the MEC servers will provide a solution to the congestion caused by sudden increase of localized demands. For improving scalability, edge computing systems and distributed clouds can perform visual processing on large computational capabilities like GPUs and transmit the audiovisual outputs enriched with analytics results to mobile e-health devices. In this way, the impact from device limitations is elastically minimized while congestion towards core network is also mitigated. Regarding the physical layer, PHY techniques such as full beamforming technologies using a large number of antenna elements increase scalability, high-frequency utilization efficiency and high-speed communication.

3.4. 5G deployment and limited connectivity challenges

Network operators need to deploy these 5G based solutions as soon as possible. The limited deployment of 5G networks and limited availability of 5G devices will be an immediate problem for many countries. Undoubtedly, the 5G proliferation is expected to be gradual in terms of network connectivity and capacity. The complexity and implementation issues of 5G devices including power consumption due to high frequency transmissions as well as multi-band support of upper and lower frequency bands complicate the device cost and production challenges.

Possible solutions

Governments and networks operators should push forward their deployment plans. Moreover, small scale 5G deployments such as L5GO networks [37] should be encouraged to use in hospitals, manufacturing plants [38]. Purpose-built IoT devices with a smaller but targeted capabilities for e-health use-cases can alleviate the complexity and cost issues regarding the deployment and commissioning of 5G systems. From the business perspective, offering a discount to mobile operators bidding in spectrum auctions in exchange for an improved coverage commitment can expedite the 5G deployment. For improving coverage in poorly served areas, some spectrum bands can be shared by different network providers. From the cost minimization perspective, RAN sharing allows multiple operators to use the same radio access infrastructure and enables an easier coverage expansion for 5G.

3.5. Societal issues and the human factor

Incidents such as destroying the cellular base stations [39,40] due to conspiracy theories linking new 5G mobile networks and the COVID-19 pandemic [41], disrupt connectivity affecting the applications. However, network connectivity and service continuity are critical for connected e-health solutions. 5G solutions may require the user to possess sophisticated level of technical literacy. However, many people lack such level of technical literacy. The provided ease of use is an important factor that supports or inhibits the implementation of e-health systems. Health personnel are deterred from or resistant to using such new systems with additional complexity to their workflows, or requiring additional effort/time [42]. Furthermore, 5G devices are significantly more expensive, leading to a cost burden on users.

Possible solutions

Experts and media have responsibility to clear out these inaccurate social beliefs with the support of civil society and governments. The applications can be made easier to use and to execute on average hardware and devices so that everyone can afford it and use the services. For e-health solutions supporting physician–patient interaction, an effective clinical decision support system must minimize the effort required by clinicians to receive and act on system recommendations. This requirement is extended to include ease of use for patients and their family members and other service users, or even health professionals be-sides clinicians, such as nurses [42].

3.6. Legal and regulatory dimension

Solutions for remote monitoring and contact tracing will result in legal issues unless the sensitive personal data is not properly handled. Examples are contact tracing after the patient has recovered from COVID-19, collecting and storing unnecessary data from the personal devices. Since access to healthcare is a right, if the technical solutions prevent people from obtaining timely healthcare or cause wrong diagnosis/treatment, that is an issue concerning fundamental rights. 5G-enabled smart devices for e-health will have a far reaching impact on manufacturers, service companies, insurers and consumers. Such a situation could also lead to legal issues.

Possible solutions

Adhering to the policies defined by standardization and policy bodies such as EU statement on contact tracing [43] prevents legal issues. Standardization and regulation must cover the whole range of healthcare technology chain from medical device technologies to software technologies, including sensors. Obtaining legal advice before the deployment of different applications would also prevent future legal issues. The traditional product liability limited to the form of tangible personal property should be extended to the correct functioning of network and services in e-health solutions. This is more challenging due to the complex environment of 5G. Therefore, root-cause analysis techniques and pervasive monitoring functions are important [35].

4. Conclusions

Healthcare sectors of the countries were the first to get affected due to the spread of COVID-19 disease, facing numerous challenges. As the countries now have control mechanisms in place to minimize the spread of COVID19, they are reopening the economies so that the public can resume their regular lifestyle. To prevent any “re-emergence” of the disease, healthcare sectors of each country must be equipped with novel solutions to address any emerging challenges effectively. To this end, 5G technologies are crucial. 5G utilizes mmWave frequencies of the radio spectrum with small cell base stations which will provide better connectivity including indoor environments via its NR. Massive MIMO combined with beamforming will serve a large number of 5G devices/users with guaranteed data rates. These technologies deliver eMBB, URLLC and mMTC service classes which enable the development of different types of services using 5G networks such as AR, UAV communication, and collaborative robots. Together with 5G, MEC and NS will improve flexibility, scalability, guaranteed service levels and security for the applications. Hence, solutions developed using 5G technologies serve various health related use cases such as telehealth, supply chain management, self-isolation and contact tracing, and rapid health services deployments. However, a wide range of implementation challenges such as privacy/security, scalability, and societal issues should be addressed before deploying such applications with full functionality.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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