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Impact of telecommunication network on future of telemedicine in healthcare: A systematic literature review

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ABSTRACT

Telemedicine is a combination of networking technologies and clinical data. The implementation of telemedicine has enhanced the regional distribution of resources, decreased the workforce of personnel, and shortened the space between healthcare staff and patients. Typically, the specialist doctors are settled and offer their services only in large urban areas. It is pertinent to reduce the imbalance of medical resources between urban and rural areas. The advent of telemedicine has the potential to address this issue. However, current telemedicine has its limitations in terms of data transfer and thus struggles to offer low latency in real-time applications. The recent developments in communication systems offer 5G and above connectivity. This study aims to analyze and synthesize the role of telecommunication networks for potential developments in the field of telemedicine. To this end, a systematic literature review has been conducted to address well-defined research questions. These questions aim to understand the working, flow, scope, and framework of the research area. This review provides an overview of telemedicine, the 5G-based telemedicine framework, and its comparison with the current system. It also discusses how the fast communication network (i.e., 5G and beyond 5G) with devices operating at low latency can revolutionize the healthcare system. Furthermore, a framework for future telemedicine has been provided along with potential application domains. Lastly, challenges and future directions beyond 5G have also been presented.

1. Introduction

Offering clinical services to patients without an in-person visit by using electronic communications and software is defined as Telemedicine which came into existence in 1906 by Einthoven, the father of Electrocardiography (ECG). Throughout the 1960s, researchers began developing computerized monitoring systems utilizing process control computers found in industrial automation software (Lilly et al., 2014). Telemedicine is used to provide services to patients such as disseminating information, and telemetry information. Telematics is the joining of several sciences and technologies such as telecommunication, computer systems, and informatics. A telematics system consists of vehicles having tracking devices and other embedded devices that can transmit and store telemetry data. The telematics data can comprise different information such as idle time, harsh acceleration, braking, speed, location, and so on (Tian, 2020). Telecommunication is accomplished through transmission and the evolution of technology impacts the telemedicine service. Telemedicine systems may be used for coaching and training for different purposes. The effects of the processes are cost and time efficacy (Gupta et al., 2019). A basic telemedicine network is given in Fig. 1 to make an understanding of its working. Telecommunication networks have provided a quality experience to communication devices through efficient energy consumption. 5G networks have one of the key factors is device-to-device communication. The application scenarios have been changed in many fields such as real-time

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communication among machines, data, and people as a result of Internet-of-Things (IoT) applying 5G infrastructure (Lin and Hsu, 2021). In many situations, we only have an option to visit a doctor or hospital, when we get sick and medical treatment is required. Typically, the clinicians are concentrated in urban areas, with many of them serving just 20% of the population. 80% of clinicians are serving 20% of the population according to the telemedicine policy study 2011-2017 (Amuomo, 2020). As the availability of doctors is at a long distance, traveling for patients can be a big challenge and time-consuming. Aside from the difficulty in traveling, the patients face other difficulties related to inconvenient clinical and registration processes. Besides, in most developing states, the overburdening of hospitals and overwhelming personnel is a general fact because of improper health sources. The above problems can be minimized by using the telemedicine facility. Telemedicine requires a system that can fast respond with minimum latency in communication and transferring of a large amount of data. However, the existing technologies applied in a large number of hospitals do not fully satisfy the needs. Particularly, the limited bandwidth of the used technologies affects the amount of data that can be gathered and transmitted in real time. Nonetheless, with the advent of telecommunication, we can minimize the above problems as 5G supports long-range, higher transfer speed, and lower latency which will bring significant improvements in telemedicine. Significantly lower latency will improve response time for telemedicine. 5G is a mixture of various technologies and one of its main focuses is to provide a fast communication facility at the user level (Li, 2019). We consider the 5G and concomitant new technologies beyond 5G could resolve these issues and rebuild telemedicine and healthcare systems. 5G can provide a latency time of fewer than 5 milliseconds in some cases with guaranteed quality of service. A summary of 4G, 5G, and other technologies in various scenarios is given in Section 3. We could receive care with comfort from our homes with the help of remote home monitoring systems. Doctors could make recommendations after a short video call and even submit prescription requests. The Telecommunication network enables new possibilities in telemedicine including imaging, diagnostics, data analytics, and treatment. Telemedicine requires wearables and remote sensors devices to monitor and transmit medical data that including medication adherence, physical activity, vital signs, and personal safety. Telemedicine diagnosis and treatment services will be provided by these devices with the help of high-resolution video conferencing.

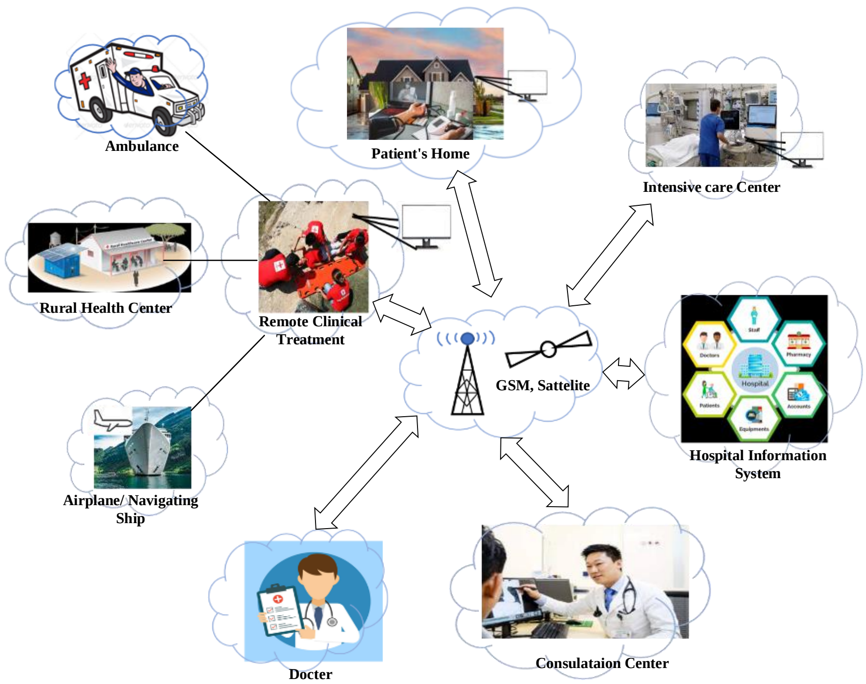

Fig. 1: Telemedicine network

We will consider the typical concept of telemedicine to concentrate on the shortcomings in the current network of telemedicine and provide a concept of a potential 5G solution based on this. Through the comparison of these two approaches, future progress can be measured, and feedback can be given on current innovative works to be followed up for future research projects. Healthcare customers' interest is increasing all over the world in the usage of smartphones, digital health data, social media, wearables sensors, and online communities to track and control their safety, according to Accenture Report. Last year, the global market for Mobile Health apps was estimated to be worth US$ 28.320 billion and is predicted to rise to US$ 102.35 billion by 2023 (Zhang and Pickwell-Macpherson, 2019). 5G-based telemedicine will connect billions of networked medical equipment, clinical wearable technology, and home care remote detectors to create a networked healthcare delivery system of large-scale clinical items. The innovations of wireless 5G, together with the rapid advancements in wearable sensing technology, IoT, and artificial intelligence (AI), will therefore have a transformative effect on potential healthcare delivery systems, facilitating the change from current reactive to potential proactive medicine. Also, telemedicine with 5G, IoT, wearable sensors, and broad health record allows versatile information sharing between patients, physicians, hospitals, and hospital units, allowing the improvement of telemedicine to be encouraged.

In telemedicine, long-distance healthcare, clinical treatment, and education can offer in a modern way, with low cost and comprehensive coverage from the first step to recovery. Public authorities around the world, such as Australia, the United States, and the United Kingdom, are investing in the management of COVID-19 in telemedicine with the specific goal of reducing the number of patients communicating with emergency care units and, in turn, preventing the spread of the virus (Leite et al., 2020). As an example, the Department of Health in Australia in 2020 requires medical personnel to provide telemedicine services, enabling people to remotely access health services to minimize the risk of exposure to COVID-19. Similarly, online consultation in specified areas is offered by the National Health Service (NHS) in the UK to discourage patient visits to healthcare professionals. These programs are consistent with guidelines to introduce telemedicine triage for patients to reduce unnecessary visits to hospitals.

Hence, in this paper, we have performed a systematic literature review on telemedicine systems that assist in the analysis of individuals living with the assistance and provide an understanding of the above-mentioned shortcomings and a concept for a future 5G-based telemedicine framework. Also, it gives a profound understanding of the execution of 5G. Thus, we supply a notion review about telemedicine, its uses, effectiveness, and ability in distant locations, infrastructure and framework utilizing 5G technologies, the advancement of telesurgery through 5G, its structure, composition, and attributes, and potential dangers in telemedicine and future directions.

The remaining paper is structured as: Section 2 discusses related work. Section 3 depicts the methodology that includes research objectives, research questions, search strategy, and study for inclusion and exclusion. Section 4 presents fundamental concepts and 5G telemedicine. Also presents the online and offline telemedicine system and how can it revolutionize the world with the help of 5G. Sections 5, 6, 7, and 8 present the answers to research questions to understand the 5G-based telemedicine, its complete framework, major technologies in current telemedicine and future 5G, and how future telemedicine framework could be through this. Section 9 is about challenges and future directions for 5G and beyond the 5G telemedicine. And finally, Section 10 presents the conclusion of this survey.

2. Related works

New healthcare technologies encourage patients to be more interested in their treatment, provide easy access to healthcare users, facilitate more personalized, reliable, ubiquitous approaches and reduce healthcare costs. The emerging era of telemedicine offers a modern way of treatment of various diseases and preventive medicine at the cutting edge of health innovation, turning health integration into reality. The literature review is an important factor to coordinate the advancement of any theory. A summary of some articles related to telemedicine has been presented. In these articles, different research has been done on different aspects of telemedicine.

Donati et al. (2019) presented the tracking kits, along with wireless Bluetooth detectors and hubs (phone devices and tablets) linked with a web-based cloud system that gathers and provides medical data to health workers. This system permits doctors and physicians to track their patients at distance, minimize hospitalization and enhance the quality of life for patients. Lindkvist et al. (2021) represented the wireless telemedicine technology distinguishing the outdoor and indoor situations utilizing the different encouraging technologies require for 5G, for example, huge multiple-input and multiple-output (MIMO), high energy networking, body area, and cognitive radio networks. Thuemmler et al. (2018) urged the telemetric cardiac tracking need which is dependent on real-world insights from an initial geriatric collaborative project on health maintenance of disabled people in elderly treatment units after minimally restrictive and aggressive diagnosis in a specialized cardiology department in Leipzig, Germany. Channel state estimation (CSE) is devised by Sodhro and Shah (2017) to present an algorithm for Quality of Experience (QoE) optimization dependent on transmission power control (TPC) in terms of a cycle service and a level of modulation. CSE-TPC allows the transmitter to alter the transfer energy level and focus on the indicator of signal strength of the signal to meet the energy-conserving demand over 5G technology like wireless body area networks (WBAN). A survey about the tracking system of remote patients has been presented by Malasinghe et al. (2019). They represented the cardiac and blood processes, fall tracking systems, systems about the nervous and brain, diabetics, and works on mental health. Recent advancements in contactless camera-based techniques are also mentioned. This survey represents that the new technology sector is having a huge effect both on society and the research world.

Haider et al. (2018) represented tracking of a specific movement of a body of a patient with different sclerosis by using a 5G C-band at 4.8 GHz, particularly the respiratory and tremors design. The respiratory rate could get by utilizing the 5G C-band method in contrast with invasive respiratory detectors to track the chest moves due to breathing. The 5G range for C-band has a spectrum between 1 to 100 GHz, because of this data rates increase from 20 Gb/s to 1 Tb/s which increases the capability and quality of wireless connectivity.

Review studies have been found to be a very useful artifacts for covering and understanding a domain. Several interesting review studies have been found in different fields (Farooq et al., 2021; Ishaq et al., 2021). Review articles are generally categorized into narrative or traditional reviews, systematic literature reviews (Farooq et al., 2021; Naeem et al., 2020) and meta-reviews or mapping studies (Aziz et al., 2020). The literature review is an important stack holder and plays a vital role to coordinate the advancement of any theory. The major aim of this paper is to give a systematic sketch of 5G-based telemedicine and all its related aspects. This paper provides a deep understanding of 5G and beyond 5G-based telemedicine its present importance as well as its trends in the future.

3. Research methodology

The major aim of this systematic literature review is to provide a brief review of the existing telemedicine system, and the role of various technologies, highlight the importance of 5G in telemedicine and try to find out the major technology gaps in the existing telemedicine systems. There are the following steps through which the research methodology has been explained.

3.1. Research objectives

This systematic literature review has the following objectives:

1. How telemedicine is revolutionizing the world with or without the help of 5G?
2. How various technologies are playing roles in 5G-based telemedicine?
3. Present a basic framework of a 5G-based telemedicine system consisting of communication and flow of information.
4. Find out the major study gaps in the present telemedicine systems in terms of future telecommunication (beyond 5G i.e., 6G) directions.

3.2. Research questions

This systematic literature review consists of five questions and their relevant motivation as given in Table 1.

Table 1: Research questions and motivation

Research questions	Motivation
Q#1: How telemedicine with 5G can revolutionize the world and what are the major differences between 4G telemedicine and 5G telemedicine?	To understand the impact of telemedicine with 5G, major services and benefits of telemedicine, and the classification of 5G in smart healthcare. And to find out the differences between 4G and 5G-based telemedicine. To figure out advantages that can be achieved by using 5G telemedicine in the future.
Q#2: How cutting-edge technologies are helpful in the 5G-based telemedicine framework?	To understand cutting-edge technologies such as AI, IoT, Big data, etc., and their helping role in future telemedicine.
Q#3: What are the essential factors for a telemedicine network?	To identify the factors such as scalability, mobility, and compliance, and to understand their effects on telemedicine.
Q#4: How 5G technologies can play role in telemedicine and 5G-based major applications areas?	To identify the role of 5G in backhaul links, energy efficiency, allocation of new spectrum in the field of telemedicine such as online consultation, remote evaluation, robotic surgery, etc.
Q#5: How the 5G and future telecommunication-based telemedicine networks will work in the future to make communication and information flow?	To understand the flow of information and the role of radio access networks with small and macro cells.

3.3. Search strings

The following search strings are used to find out the relevant papers which are related to our research topic. We carried out the research by using the following keywords and gathering relevant information. Detail is given in Table 2. The databases for our research were IEEE, Science Direct, CCM journal, springer, ACM digital library, cross mark, Microsoft, IBM, and Cisco. We use popular electronic sources for our research.

Table 2: Searching strings

Electronic sources	Search terms
Science Direct	"Telemedicine in remote monitoring" "Role of telemedicine in Chronic diseases" "the impact of 5G based telemedicine."
IEEE	"Role of 5G in smart healthcare" "5G based mobile healthcare" "5G based tactile internet" "5G in Emotion aware system" "5G role in chronic disease"
CCM journal	"Security and privacy of 5G and telemedicine"
Springer	"5G based telemedicine framework, 5G technologies used in remote patient monitoring," "Impact of telemedicine after 5G"
ACM Digital library	"Evolution of telemedicine" "5G in smart healthcare"
Cross Mark	"5G in audiovisual based emotion aware system" "Telemedicine in remote monitoring"
Microsoft	"How 4G telemedicine system is different from 5G telemedicine system"
Cisco	"Fundamental components used in 4G and 5G telemedicine system"

3.4. Inclusion and exclusion criteria

All the selected articles did not give us exact information. Therefore, we set a criterion to include and exclude information from all those articles. In the first step, we remove 21 articles out of 220 because of duplication. In the second step, we excluded 121 articles according to titles, abstracts, and keywords out of 199 articles. In the third step, we further elaborate and exclude 20 articles out of 78 because they did not match with inclusion criteria. In the fourth step, phase 58 articles were selected for quantitative evaluation, 7 were excluded due to unusable data and finally, 51 were chosen for systematic literature review.

3.5. Inclusion and exclusion criteria

Our evaluation method was based on research questions related to the telemedicine system and 5G with different aspects. Articles that were not related to our aim were eliminated. Based on the remaining articles we have performed a survey on our topic. The search strategy is also discussed in this section in which popular sites have been used. We tried to choose articles between 2012 to 2021 years and citations were also kept in mind. In short preference for articles, the selection was given to those articles which were recent and good quality, and related to our objective. We have also provided the whole research process in methodology.

4. Fundamental concepts and 5G telecommunication-based telemedicine

4.1. Smart healthcare

Smart healthcare offers health care services through smart devices (e.g., tablets, smartwatches, wireless smart glucometer, wireless blood pressure monitors) and networks (e.g., WBAN, wireless local area, and comprehensive space networks). In summary, smart health care allows individuals to get the appropriate information and proper answers (Ahad et al., 2019). The main objective is to reduce medical mistakes, enhance efficiency, and reduce the price in the proper time from your medical field. A summary of 5G and various technologies in the different scenarios is given in Table 3.

Table 3: Summary of 5G and various technologies in different scenarios

Scenario	Driver	Technology	Latency	Data rate
Wearables M2M in a primary care setup	Connectivity for data collection	Zigbee (data collection), Bluetooth (D2D sensors), NB IoT (interconnected devices)	10 to 700 milliseconds rang	Few Kbps to Mbps
Emergency medical services	Emergency communication and speedy response	LTE LTE-A LTE-A Pro	100 to 20 milliseconds	Up to 100 Mbps Up to 1 Gbps Up to 3 Gbps
Digital hospital	Intercampus communication	Wi-Fi	Nonguaranteed 10s to 100s milliseconds	Order of a few Mbps
Remote surgery	URLLC between various locations	5G	20-30 millisecond with guaranteed QoS	Order of few Gbps
Haptic feedback - tactile communication	URLLC, eMBB	5G	< 5 milliseconds with guaranteed QoS	Order of few Gbps
A combination of the above scenarios	Communication, latency, bandwidth, applications	Seamless coexistence of 5G, 4G, Wi-Fi, Bluetooth	milliseconds level latency with guaranteed QoS	From few Mbps to order of Gbps

4.2. What is the internet of things (IoT)?

IoT is a flexible, complicated, and dynamic community infrastructure which links anybody anything, anytime, anyplace, for any solutions. Also, IoT is taking center stage as apparatus are anticipated to create a significant part of the 5G network paradigm. However, the 5G network technology is on the way (Ahad et al., 2019).

4.3. What is 5G telecommunication?

5G is another generation of the 4G communication network which may provide features like capability speed and scalability of their community. The international telecommunication union (ITU) has defined several parameters that can be considered crucial capacities for 5G engineering (Ahad et al., 2019). 5G and telemedicine components are given in Fig. 2. The 5G network supports the following points:

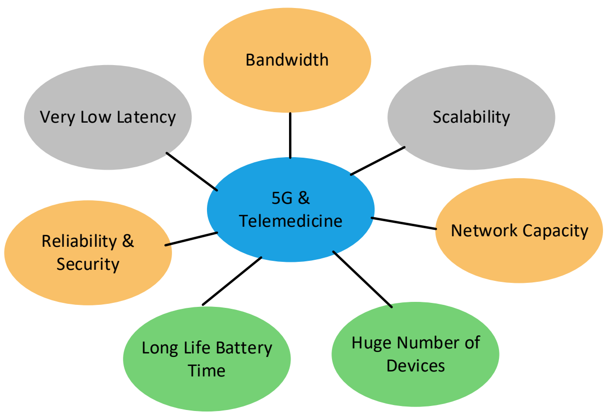

Fig. 2: 5G Components and telemedicine

1. Low latency requirement of (1ms or less than 1ms) should be supported.
2. 10Gbps into data rate must be accomplished in conditions and various situations.
3. A high network must be encouraged and empower enormous communication. High freedom (around 500km/h) must be achieved in the community.

4.4. Telemedicine and 5G

4.4.1. Online and offline telemedicine system

Based on latency in the communication, medium telemedicine is categorized into offline and online programs. An internet system provides health advice using wearable apparatus or detectors to patients. Different online and offline remote monitoring systems use remote treatment (blood pressure monitoring, and heart disease management), store-and-forward telemedicine, and telesurgery.

4.4.2. How can telemedicine revolutionize healthcare?

Telemedicine is the use of information technologies that makes it possible for patients identified and to be treated by a physician without the need for physical visits; it is the first step toward digitizing healthcare (Langford et al., 2020).

4.4.3. Impact of telemedicine after 5G

Epica International group firm develops research and creates robotic imaging devices for human beings and veterinary surgeons. They have created many symptomatic imaging tools that picture external and internal structures in 3D and 2D. Currently, they are focusing on creating robot-based operation technology and 3D CAT scanning, with the intent of earning processes easier to do, safer, and more affordable (Wang et al., 2020).

Epica international firm is also seeking to boost treatment choices with their state of an art laser equipment that can benefit a broad selection of places, from dermatology and dentistry to sports medicine and operation. Their study has manufacturing applications. Some of the examples are given. Sichuan university hospital in West China developed the latest real-time video and web-based telemedicine program for assessments supported by a multidisciplinary group to handle COVID-19. The concentration of this program was on the individual that is more susceptible to serious COVID-19 effects, like older people, infants, pregnant women, and patients with serious health issues. A 5G-based telemedicine system in Sichuan province, China was developed during the COVID-19 pandemic. This network utilizes the latest 5G technology and framework developed by China telecom 5G. The network includes 5 national, 24 municipal, and 179 county base hospitals. The average length is 319 Km (20 to 1191km) between a west China hospital of Sichuan University and spoke hospital (Hong et al., 2020).

4.4.4. Benefits of telemedicine

Notable benefits of telemedicine are given in Fig. 3 and notable advantages of telemedicine are presented by Rosalia et al. (2021) and Aceto et al. (2020).

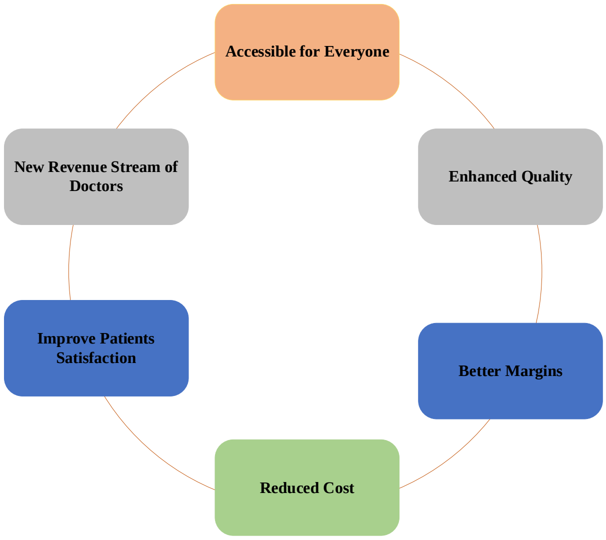

Fig. 3: Benefits of telemedicine

4.4.5. Main services of telemedicine

The center of telemedicine is further classified by wellness policy that is connected to four kinds of remote patient monitoring, live-video conferencing health, providers, and store-and-forward. Telemedicine platforms provide at least one of those services, to the customer section or some market individuals (Spencer et al., 2020). Fig. 4 represents some major services of a telemedicine system.

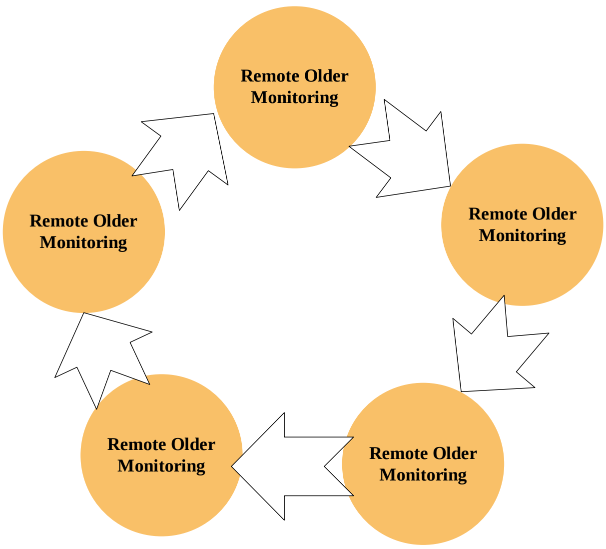

Fig. 4: Major services areas of telemedicine

A relative study of online and offline telemedicine systems is shown in Fig. 5.

4.4.6. Classification of 5G applications in smart healthcare

Fig. 6 represents the classification of 5G applications in smart healthcare (Dananjayan and Raj, 2021).

4.4.7. What are the major differences between 4G telemedicine and 5G telemedicine?

Table 4 shows different scenarios through which we can differentiate between 4G telemedicine and 5G telemedicine. Thus, we can also differ in terms of the download speed, latency, bandwidth, and speed of both these networks. We can also say that 5G provides much better and more flexible communication and reduce risks in telemedicine. The performance measure is given in Fig. 7 (Latif et al., 2017).

5. How cutting-edge technologies are helpful in the 5G-based telemedicine framework?

There are many challenges in the supply of health care services to the aging population that is growing. Recent observations have raised concerns regarding the costs of telemedicine, the imbalance of resources in telemedicine program management, and encounters that were inconvenient.

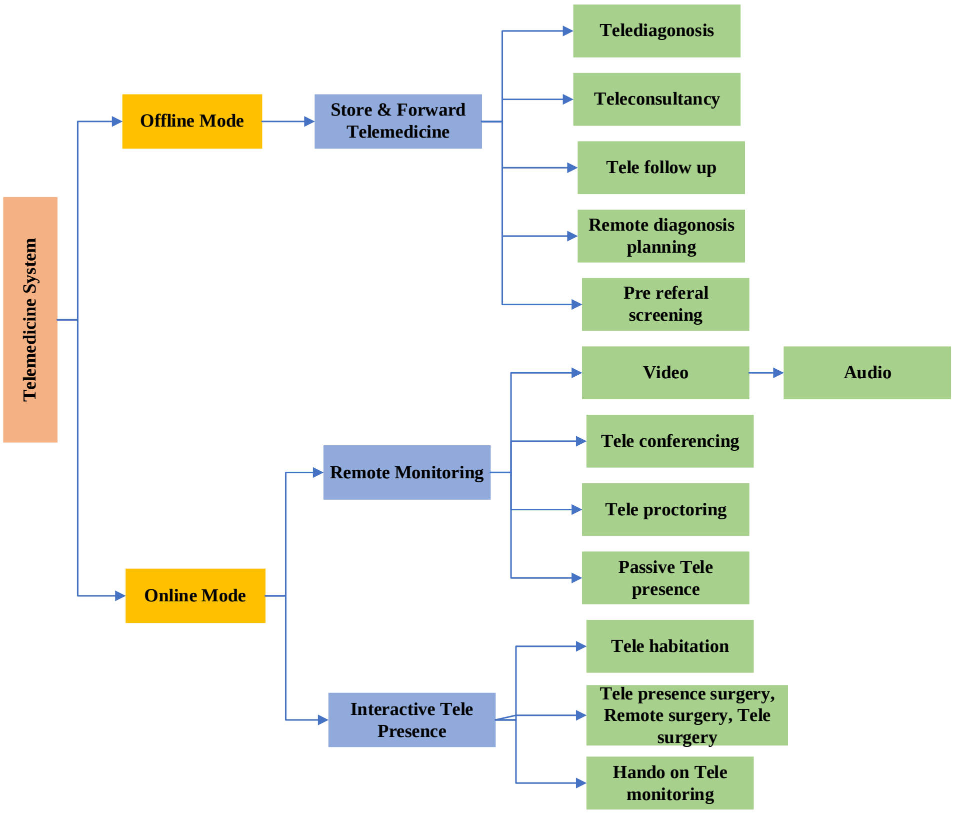

Fig. 5: Online and offline telemedicine system

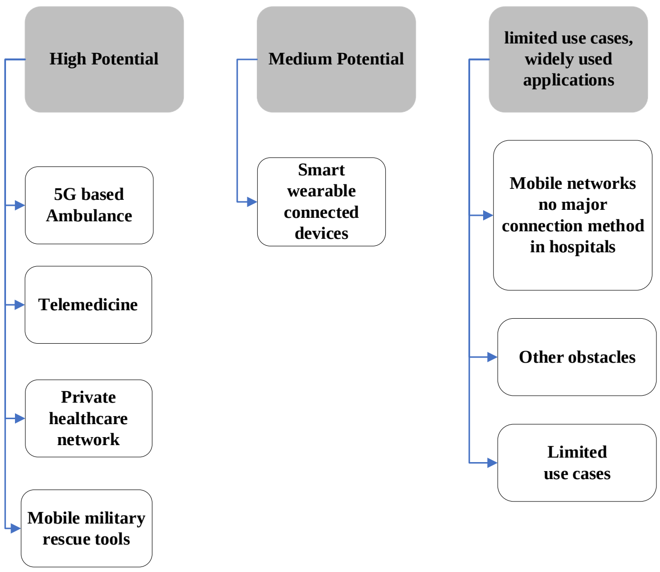

Fig. 6: Classification of 5G applications

Cutting-edge technologies such as big data with large information, AI, and 5G wireless transmission technologies are being designed to meet those challenges and enhance telemedicine service quality. With 5G we can handle 40 times quicker rates as compared to 4G and download 8K or ultra 3D films only in one second (Vij and Jain, 2016).

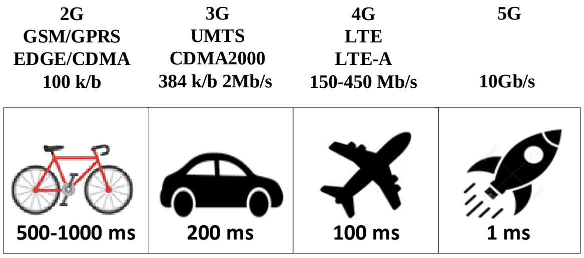

Fig. 7: Performance measures of 2G, 3G, 4G, and 5G

5.1. Framework for future telemedicine?

"Escalation" is the principal approach that defines the making of the backbone of the skeleton in a telemedicine ecosystem, every working facility or sphere is interconnected and overlapped with each other. To start any telemedicine service, it is important to understand every connected unit and its importance in the overlapped skeleton. Due to innovations in technologies, one unit changes position as a requirement then other units will start to change positions to make a plan for stability and sustainability of all the units in an overlapped skeleton (Magsi et al., 2018).

5.1.1. Location-aware devices

There are four important parts of the escalation model that gives a skeleton a proper shape or stability. The first important part is the government, which makes its policies and defines the regulations to follow best practices. The second important part is the information and communication technology (ICT) industries. ICT plays role in fast access to data and also quick response to a query by using up-to-date innovative systems, sensors devices, and other relevant devices. The third important part is a wireless technology that also includes 5G that plays an important role to access data and real-time quick response at low latency. The fourth part is the industry itself, for example, technology industries, aerospace, transportation, pharmaceutical industries, etc.

5.1.2. Determination of production for initiation of a particular telemedicine service

In the field of telemedicine, a particular service is introduced with the help of medical and technical devices that are provided by technical industries and solutions for a particular telemedicine service. According to an escalation approach, the overall load on hospitals and connected units should be decreased. This goal can be achieved by description or knowledge of each performed task by every connected system or subsystem or unit in providing and dealing with telemedicine or medical emergency care.

5.1.3. Analysis of performed tasks

Many factors can be analyzed by measurement of productivity. Some of the factors include handling of a proper task, communication gap, utilization of technology, according to the medical area, usage of resource availability, motivation level, commercialization, and marketing.

5.2. Framework for future telemedicine?

IoT is a concept of unlimited specific identities that are attached physically and virtually to create an ultimate framework that is persistent. These frameworks receive and transfer data to the cloud to smooth a degree of automation that is efficient and acceptable. Solutions related to IoT are powerful regarding power consumption, CPU, and memory utilization (Anwar and Prasad, 2018).

5.2.1. Big data

We are progressively residing in a virtual world where devices like smartphones, digital health records (EHR), and biomedical and wearable sensors make a huge volume of health information. This type of information could be known as "big data" because of its large velocity and wide selection.

5.2.2. Wireless connectivity

The use of wireless technologies for telemedicine was investigated in an assortment of research. The advancement in computing systems and cellular equipment has enabled a large gain from pervasive manipulation and ubiquitous cellular technologies in medical structure. This tendency will last and be bolstered by the rise of 5G cellular technology, which can offer good functioning that is much greater regarding output and response time in comparison with technology that is 5G.

Fig. 8 shows the role of various types of sensors, big data, and AI in telemedicine. Similarly, layered architecture has been presented in Fig. 9 which consists of four layers.

5.2.3. AI and machine learning (ML)

Learning is usually used to detect skin cancer in pictures with a similar number of mistakes as done by professional artisans. Lately, a research group of geneticists, pathologists, biomedical engineers, and computer scientists at Stanford's faculty of medicine enabled in production of a learning algorithm that can find lung cancer considerably much more precisely than pathologists. Telemedicine systems predicated on artificial intelligence, ML, and possible models have the capability to offer therapeutic suggestions, outlook learning, and modified real-time hazard grading.

Table 4: Difference between 4G and 5G telemedicine (Vij and Jain, 2016; Acharya et al., 2012; Adebusola et al., 2020)

Scenarios	4G telemedicine	5G telemedicine
Remote surgery and patient care	For such types of applications, 4G networks are not appropriate as the delay time between input and output may often be 2 seconds. This large latency is enough for catastrophic in the surgery room.	5G network aims to minimize the 2-second latency of the 4G telemedicine
Medical data (Data transfer speed)	Hundreds of GB of data per day, per patient can be developed because of broader image files from MRI or CAT scans from clinical records. In 4G data transfer speed is not enough (In 4G data speed is 200 Mbps to 1 Gbps)	Eventually, 5G aims to change the medical sector by dramatically raising the quantity and quality of useful patient information which could be obtained and analyzed at high speed. Transferring huge information can be done by implementing a 5G. 5G will improve healthcare by minimizing the download information time to achieve a diagnosis and start treatment (In 5G 1-10 Gbps speed is expected.)
Healthcare AR / VR from the cloud	In the healthcare industry, AR (Augmented Reality) and VR (Virtual Reality) were currently estimated at USD $769 million in 2017 (Latif et al., 2017).	5G latencies are sufficiently small and the bandwidth is sufficiently high to enable the computational workload related to Augmented reality/ Virtual Reality / Mixed Reality to operate in the cloud and be distributed by 5G to patients or healthcare personnel. It is expected to increase by USD 4,998 in 2023.
Autonomous driving for healthcare	3.6 million American patients skip doctor visits every year because of a lack of adequate transport, causing "no-show" rates of up to 30 percent (Latif et al., 2017).	5G would allow autonomous driving by supporting computational workloads, like optimal routing, maintenance, patient interaction, and interactions. 5G would also make it possible for others to migrate into the cloud, further lowering the cost of autonomous vehicles and potentially helping to minimize healthcare expenses.
Pathology and diagnoses (Pathology is an analysis of the causes and symptoms of disease or injury. The term pathology also relates to the study of illness.)	Earlier clinical pathology at a Korean hospital includes the transfer to pathologists in an adjoining room of tissues collected from the patients through surgery, a procedure that took 20 minutes, and makes on-site community evaluation a task (Vij and Jain, 2016).	Korean telecom (KT) has developed at Samsung medical center (SMC), an enterprise dedicated 5G system that contains digital pathological evaluation driven through 5G. the digital pathological evaluation is the globe's first scenario of utilizing 5G technology for medical issues on site, according to the firms. In this, doctors can get pathological information by utilizing a 5G system which provides high speed and low latency during operation accurately and easily (5G will take less than 20 minutes as compared to 4G).
Fast, secure, and real-time monitoring system	According to the study, chronic illnesses could be handled with a real-time remote health monitoring system, and healthcare expenses can be minimized. But a network with slow speed, low bandwidth, and poor link, is not efficient for this (Magsi et al.,2018).	With 5G, patient remote monitoring can be performed in real time by healthcare professionals. Doctors can quickly access the required data in real time and handle their patients with adequate treatment before it is too bad.

6. What are the essential factors for a telemedicine network?

6.1. Scalability

In a telemedicine system, scalability is an important factor, and it varies from a couple of users to thousands of users according to the requirement. The telemedicine system will not simply function in the clinic or physician's office but are also easy and cost-effective. It is also sufficient to scale from small to large systems including a group of little clinics, homes, and perhaps individual patient houses.

6.2. Mobility

As one of the facilities provided by the organizations is the concept of bringing your own device (BYOD) fad. With the addition of BYOD, the telemedicine systems not only need to work with “network-approved apparatus" but also work with BYOD devices that include computers, wearable devices, smartphones, tablets, or other available medical apparatus. To operate moveable devices or BYOD mobility is an important factor in telemedicine systems (Doargajudhur and Dell, 2020).

6.3. Compliance

Telemedicine systems cannot skip and must adhere to a rule, such as a policy, standard, or specification. They absolutely must satisfy the regulatory criteria of local and international medical identifications. Patient health record and their privacy are important; therefore, it is required to be protected. Patient records must be proactively protected irrespective of network type or apparatus.

6.4. Open standards

Open standards mean to be made available to the public, developed, and maintained via a collective and agreement process. Based on open standards, users can communicate at any stage and to any user. This not only advances reach but also grows the ROI (return on investment) of technologies. As ROI is used to measure the effectiveness of the IT systems, which makes it useful no matter procurements, strategy overhauls, or much more.

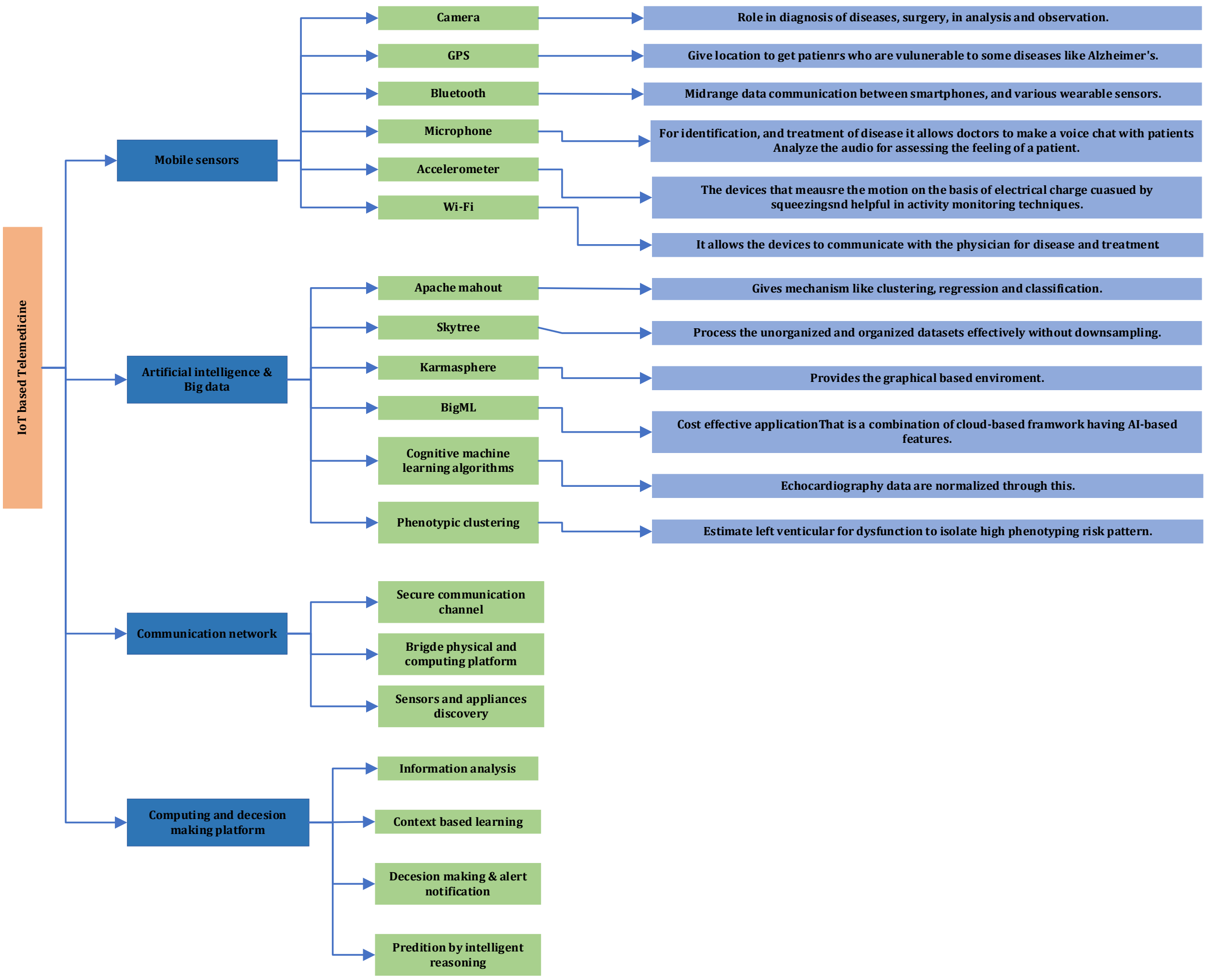

Fig. 8: Role of various technologies in telemedicine (Khan and Alotaibi, 2020)

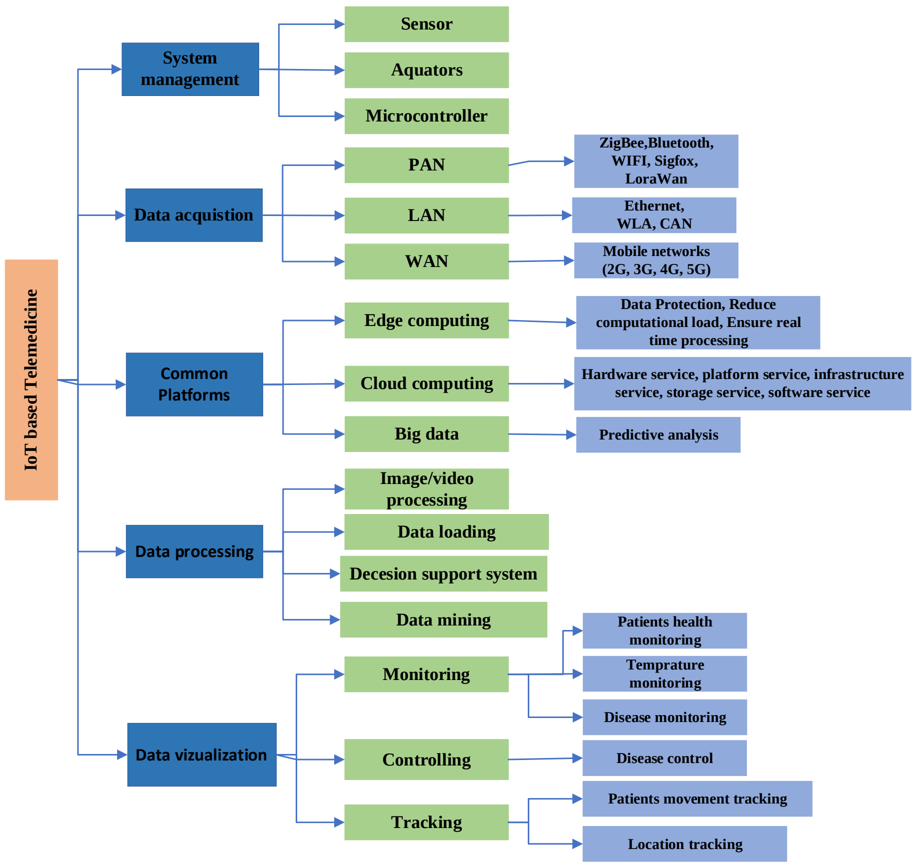

Fig. 9: Layer's architecture of telemedicine (Farooq et al., 2019)

6.5. Resource and community management

Resource and community management means the telemedicine system should work on house calls if technical support is not available. Anyhow the predominant telemedicine system must support already existing clinical applications to manage the resource and community.

6.6. Return on investment (ROI)

The affordability and attainability of telemedicine systems and the perfect business decision depend on potential ROI for large and small organizations. The telemedicine systems that do not achieve acceptance throughout the telemedicine system may be cheaper and promising, but they will not offer any ROI in any respect.

7. 5G technologies and their suitability in telemedicine and application areas

There are many existing techniques and functions that are used as the basic unit to build telemedicine and 5G technology-based systems and their applications (Adebusola et al., 2020). Some of the examples are radio access technology, hyperdense small cell, self-organizing network, machine sort communication, millimeter-wave rate, and backhaul links redesign. 5G use cases have been shown in Fig. 10.

7.1. Evolution of present radio access technologies (RATS)

5G is an assortment of RATs, having a unique evolutionary design from present RATs and contrasting to a different RAT. Some crucial RATs include massive multi-input multi-output, millimeter wave, device-to-device communication, etc., and play an important role in telemedicine infrastructure for communication (Habibi et al., 2019).

7.2. Creating hyperdense small cell

With the deployment of hyper-dense small cells, telemedicine devices can move closer to the wireless network and fulfill requirements for a 5G-based telemedicine system. This innovative alternative is named Hentet since it helps improve the region spectral in addition, it matches the 1000x ability crunch, as well time provides additional energy efficiency (EE) to the machine (Xu et al., 2014).

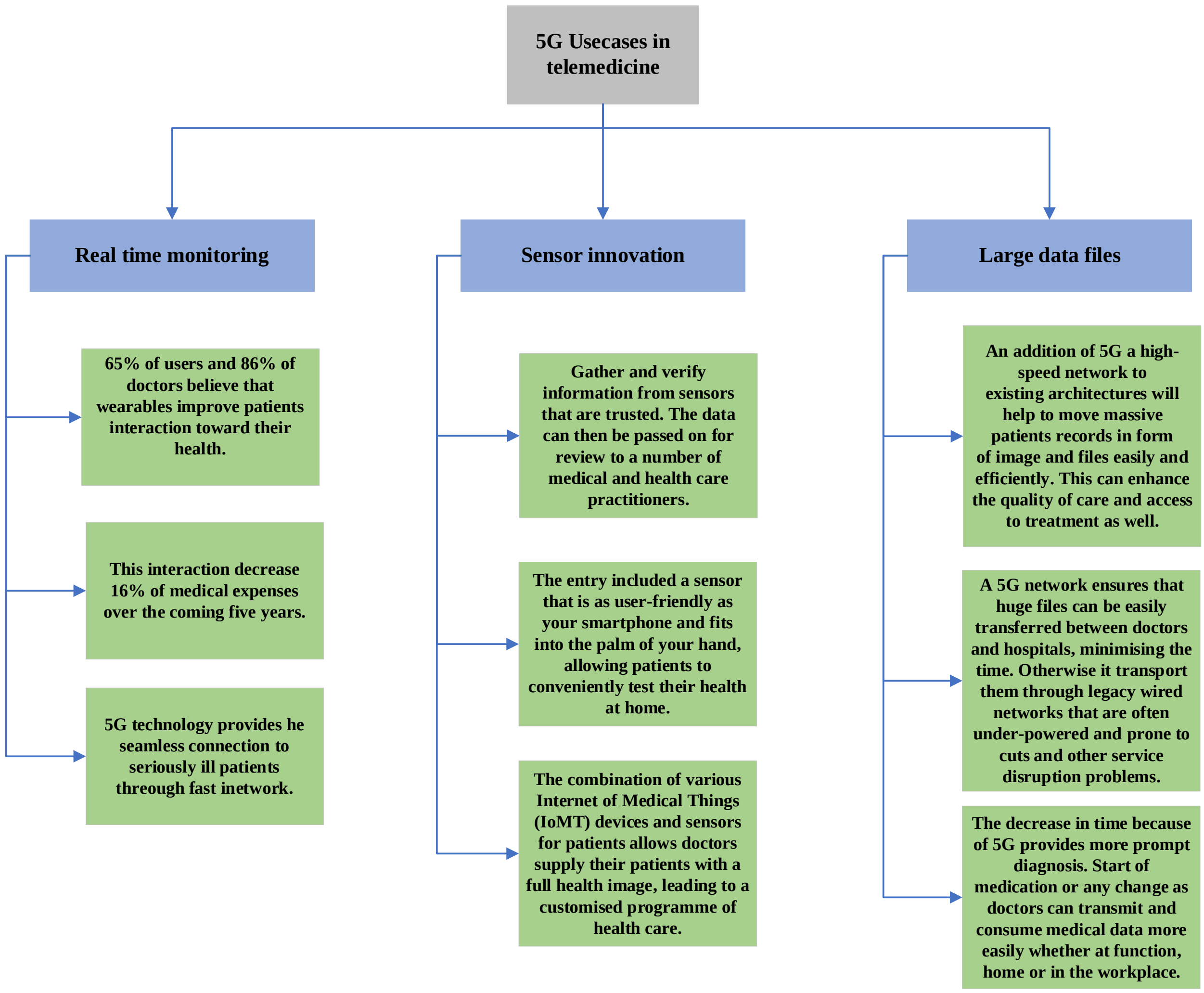

Fig. 10: 5G use cases in telemedicine (Murudkar and Gitlin, 2019)

7.3. Self-organizing network (SON) capacity

In telemedicine, a network required the self-organization of patients' records and as well communication among the users. 5G wireless self-organizing networks (SONs) will provide the opportunity for a more adaptable, autonomous, smarter, network as compared to current networks. This SON will manage and organize the network automatically as the number of cells increases in the 5G network (Murudkar and Gitlin, 2019).

7.4. Machine type communication (MTC)

In a telemedicine system, users communicate with each other, but they required machines for connectivity. Emerging (MTC) technologies and 5G networks are facing a large amount of data, different data traffic (such as machine type of data, human type of data, or hybrid type of data), billions of machines connectivity, and limitations of machines re-sources (Farooq et al., 2016).

7.5. Development of millimeter-wave rates?

In the case of telemedicine, patients' records are kept in images, 3D, videos, and animation according to the need therefore, the system rate must be higher than the current system. 5G networks can increase the 1000 times system rate than the current system. This increase can be achieved with the help of research on millimeter waves for cellular communications. Existing RATs are approaching the limit of Shannon's capacity as congestion of the sub-3GHz increasing (Sakaguchi et al., 2015).

7.6. Backhaul links redesign

As the number of users is growing in telemedicine, the number of devices is increasing hence carrier bandwidth is also increasing. 5G networks require a redesign of the traditional backhaul and interfaces used in 4G. 5G is projected to redesign the backhaul links to broaden capability for traffic during development on the radio access networks (RAN) to combinedly support backhaul and 4G/5G fronthaul interfaces) (Camps-Mur et al., 2019).

7.7. Energy efficiency (EE)

As the number of devices is increasing on telemedicine systems and there is a need for 5G networks to support such devices. With the development of 5G, energy-efficient approaches are required at different stages for RAN, backhaul links as well as user equipment (UE). Some of the approaches or techniques include energy efficiency in a small cell with user association HetNets, energy efficiency in small cells and massive MIMO Massive MIMO, energy efficiency in Cell-free networks, and energy efficiency in multi-cell (Nguyen, 2018; Ancans et al., 2017).

7.8. Allocation of new spectrum

An increase in demand for consumers of telemedicine services in the mobile environment, with a high data rate and mobile broadband communication systems will require more spectrum to be available in the future. One main objective of the 5G network is to increase the current data rate by more than 10 Gbit/s. One possible scenario is to allocate higher frequencies such as above 6 GHz. The allocation of a new spectrum is important as spectrum efficiency improvement can't correctly deal with the 1000x traffic for upcoming wireless communication (Ancans et al., 2017).

7.9. Wireless network virtualization (WNV) of radio access network (RAN)

To achieve cost-effectiveness in the telemedicine system one of the solutions is WNV with RAN. It will provide effective resource utilization with decreased operating and capital expenses. This will achieve by decoupling coexisting virtual network functionalities. This is a sharing of wireless infrastructure from a central instrumentation unit among different operators to manage both wired and wireless networks to improve network efficiency (Kitindi et al., 2017).

7.10. What are 5G-based major applications areas?

It is anticipated the dawn of 5G technology in providing health programs that might be handled by the person, will execute an active part. To maintain reliability in telemedicine, 5G networks will require a higher amount of data (Ullah et al., 2019). Fig. 10 presents some 5G use cases in telemedicine.

7.10.1. Online consultation

5G technology of entities with the Internet of medical things (IoMT), large data evaluation, and machine learning ways allow for improvements in telemedicine programs. In a study on postoperative the findings indicated the sufferers were Gratified with this process for treatment and thought it to be safe and workable with postoperative software.

7.10.2. Online health tracking

With 5G technology, it is possible to grasp the awareness of virtual hospitals that provides many advantages within a communication network. Biswas and Misra confer a low-cost, dependable telemedicine monitoring apparatus with an IoT-based framework that will recognize the vital signs of a person, safely store the information, and analyses the information to create specific proactive alerts whenever required. In the next stage, individual will be connected to the enrolled physicians that have the patient's health information tracked by using medical detectors.

7.10.3. Remote evaluation

Darrell M. west depicts the possibility of utilization of 5G networks to set up distant telemedicine systems. This distant system would allow for real-time observation and management of many sources of health information. One basis of health information is an efficient diagnosis of an illness event will be done prior to its reveal. Brito summarizes IoT and connected telemedicine programs including medical experience utilizing innovative tele-diagnostic tools. Robots are used to remotely control the distant physical evaluation, which may provide output in the form of audio, video, and haptic feedback.

7.10.4. Mobile robotic surgery

With the development of 5G technology, the prevalence of portable robotic operations is set to rise appreciably. To conduct a distant surgical operation, the haptic feeling is an important necessity for an efficient distant surgical process. The operation of autonomous telesurgery is dependent upon several properties of this communication system such as the operation process being executed with haptic feedback.

8. How 5G-based telemedicine network will work to make communication and information flow?

The framework of telemedicine with a 5G network is shown in Fig. 11, in which a 5G network is attached to a telemedicine system and it consists of central servers, local servers, along with 5G macro cells, and small cells. The patient's condition is estimated by a tablet/smartphone or personal desktop. Smart gadgets, tablets, and hospital servers are attached to small cells. The small cells will be in the center and these are the main components of a 5G network. And all this communication takes place with a 5G network in which small cells play an important role. The cellular network consists of micro, pico, femto, and macro base stations and is generally known as a heterogeneous network. Through this, we can get flexible coverage and spectral effectiveness.

8.1. Radio access network

It consists of small cells, towers, and masts and it links wireless networks and smartphones with the major core network (Vij and Jain, 2016).

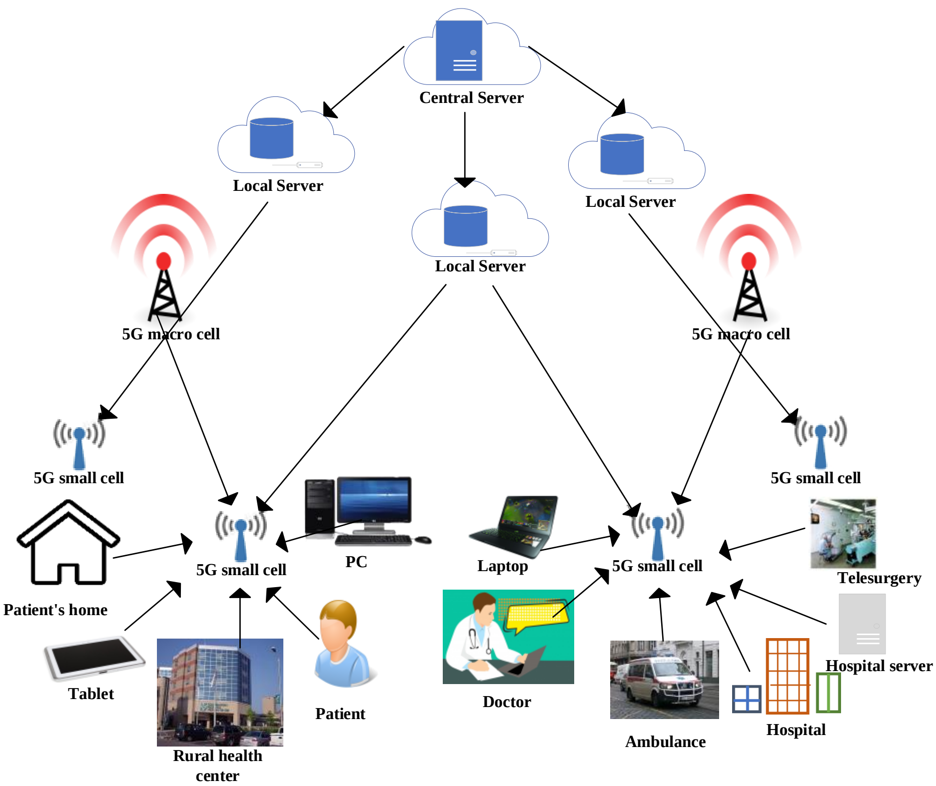

Fig. 11: 5G-based telemedicine network and flow of information

8.1.1. Small cells

Small cells will be spread in clusters to give constant communication based on where the user needs a connection which complements the macro network providing wide-area coverage. By utilizing small cells, the network could rise the spectrum effectiveness with the reuse of high frequency. In small cells, there are control and user plane functions. The control plane provides connectivity, and mobility and the operator plane offers information transportation. Therefore, the user equipment (UEs) should be linked with macro and small cells concurrently. Small cells are the main features of a 5G network specially at new millimeter wave (mmWave) frequencies with limited communication range. Small cell types and their radius users are given in Table 5.

Table 5: Small cell types (Ahad et al., 2019)

Types	Cell Radius	Users
Femtocell	0.010 to 0.1 Km	1 to 30
Picocell	0.25 to 1.0 Km	30 to 100
Microcell	0.2 to 2.0 Km	100 to 2000
Macrocell	8 to 30 Km	More than 20000

8.1.2. Macro cells

Macro cells will utilize MIMO (multiple input, multiple outputs) antennas which have different components and link to send and receive information at the same time. The major benefit is that various people can concurrently connect to the network and achieve high throughput. When MIMO antennas utilize a huge amount of antenna elements, they are known as "massive MIMO." However, the size is as same as the previous 3G and 4G base station antennas.

9. Challenges and future directions

Apart from the improvements, there are challenges in embracing 5G for telemedicine, its usability, and research topics (Ahad et al., 2019) which provide us with further directions for research.

9.1. Visual and hearing impairment

One of the challenges is for people with visual and hearing impairment. It is essential to consider the visual and hearing difficulties of elderly people as a problematic factor in managing electronic devices, and we must make reasonable changes to them. Some telemedicine issues have been reported in studies, for example technically confronted workers (11%), reluctance to modification (8 %), cost (8 %), patient age (5%), and patient education (5%) (Soares et al., 2020).

9.2. Mobility of users and devices

In a telemedicine network, in case of the mobility of the doctor, medical staff, or patient's system should have the capability to maintain their communication during their movement. So, doctors, medical staff, and patients can contact each other at any time and at any place.

9.3. Scalability of the telemedicine system

A telemedicine network contains billions of apparatuses and in the future, more devices are going to connect due to an increase in population growth. To support this, many devices, gateways, and protocols are required. With the addition of diverse applications databases and backend systems should be scalable. Therefore, it is required a highly scalable design for the system to handle each addition of the devices intelligently.

9.4. Connectivity in the internet of things (IoT)

A telemedicine network contains billions of apparatuses and telemedicine theory can succeed only when it can offer connectivity to each device within the community, together with the capacities of sensing to create important data. In telemedicine, any accessible communication network may be employed by IoT apparatus, including Bluetooth, Wi-Fi, and mobile systems. However, promising connectivity in telemedicine poses numerous challenges, for example:

1. Guaranteeing connectivity into enormous devices set up in the community in broad selection.
2. Giving connectivity to the devices which contain high-level mobility in any network.

9.5. Resource optimization

As the number of devices is growing gradually, therefore, resource optimization is important. Each hospital needs to calculate or estimate the number of devices, gateways, storage devices, and the size of data that is required to be transmitted. Due to the different sizes of hospital infrastructure, the number of staff, and patients, resource optimization has become a big challenge. To optimize the resources, it is required complex mathematical algorithms and models to estimate the best resource allocation.

9.6. Interoperability

Telemedicine incorporates different IoT apparatuses from several assortments of areas (i.e., remote operation, ECG monitoring, and remote health tracking). Interoperability between devices in various domains is an integral limit because of the absence of criteria for IoT success. To conquer the challenge of interoperability, smart approaches using artificial intelligence strategy are required to permit countless IoT apparatus to communicate with each other.

9.7. Device's lifetime

Usually, IoT apparatus employed for telemedicine correlated with an assortment of sensors are restricted in size. A supply of energy is needed to push these devices, which poses a challenge in terms of price and battery lifetime. Devices should have the characteristics of reduced power consumption with a reduced rate, to tackle these problems in smart health care.

9.8. Big data analytics

Smart and integral research management in health is called Big Data analytics. In telemedicine, many devices are linked, which may create a massive amount of data. The crucial problems that must be addressed are:

1. The protection of user data privacy during data investigation is important.
2. Data secrecy must be offered for delicate information.
3. Infrastructure must be supplied to accumulate, analyze, and save a large amount of information.

9.9. Security, trust, and privacy

70% of IoT apparatus (like telemedicine devices) are in danger of assault in the future. This also contributes to strikes and risks to privacy and security. To make smart, reliable, and secure healthcare systems using the 5G network, these issues must be taken into consideration.

1. For user information, low latency and trust communication must be offered.
2. For secure and easy communication, integrity and credibility must be supplied between a program along with a healthcare device center.
3. User acceptance and trust by providing solitude must be guaranteed.
4. Risk assessment must be made in detail to discover new strikes.

9.10. Beyond the 5G (i.e., 6G) a future network

The early targets of the 5G network involved massive machine-type communications, ultra-reliable low-latency communications, and enhanced mobile broadband (eMBB). Each use case is focusing optimizing one key parameter such as bit rate, or latency. Early 5G networks can be used to enable video-driven machine-human interaction, and augmented reality (AR)/virtual reality (VR) based applications. 5G networks will support sharing and updating high-resolution maps in real-time applications (Park et al., 2019). Distributed mobile edge computing (MEC) helps in the vertical markets for the efficient use of the 5G networks. MEC transforms 5G-based applications into smarter applications proffering advanced services. In the future, intelligent services can be gained with the help of edge devices and AI-enabled platforms over the fixed or mobile access network (Theodoridis, 2015). The mm-wave frequencies will become a common factor for 5G and the next-generation internet of things (NG-IoT) will do some form of convergence (Mazaheri et al., 2019).

A data rate of 100 Tb/s can be achieved by allocating 10 GHz RF channels in THz, optical frequencies, and modulation method having 10 b/symbol in future generation networks. In the future, cognitive processing can be achieved remotely from a platform that is connected with future generation networks e.g., 6G (Rappaport et al., 2019). The plane of the communication network can be controlled and managed with the help of machine learning (ML)/AI algorithms. Really intelligent next-generation communication (i.e., the 6G networks) can be gained with the help of Communications for ML (CML) and ML for Communications (MLC) (Park et al., 2019; Plata-Chaves et al., 2017).

5G is continuously revealing the inherent limitations of Internet of Everything applications and systems. In defining the next generation of 6G, the limitations of 5G are required to focus to integrate far-reaching applications ranging from autonomous systems to extended reality. Although the basic framework and performance components of 6G remain chiefly undefined, it will be a convergence of the upcoming technologies taken from underlaying services (Saad et al., 2019). In this article, the authors have presented a vision and defined usage situations and requirements for multi-terabyte per second (Tb/s) and an intelligent 6G network. They have presented unlimited wireless connectivity for a large and autonomous network architecture with the help of AI and ML that integrates ground, air, space, and underwater networks (Zhang et al., 2019).

In this article, for the provision of connectivity to address the challenges of around half of the world population, a survey of technologies has been done (Yaacoub and Alouini, 2019). Fronthaul and backhaul techniques, energy, and cost-efficiency of the studied technologies are analyzed in situations in remote areas. Therefore, guidelines for the future progress of rural connectivity are outlined.

10. Conclusion

If This paper has introduced an outline of an upcoming healthcare transition that will be driven by 5G, telemedicine, and related technologies, such as IoT, Big data, and AI. To make a better understanding, a framework for telemedicine, 5G, the flow of communication, and major application areas have been discussed. Further, a comparison between 5G with 4G, how patients can get benefit from 5G-based telemedicine, and major technologies in current telemedicine have been discussed. Moreover, the future of 5G, and future telemedicine framework challenges or future directions in 5G telemedicine have been presented. This will help to understand how all these deficiencies can be improved in the future. If 5G telemedicine has been implemented it will provide help to improve the healthcare sector by increasing human resources and by enabling resource pooling, virtualization, good performance, efficient telemedicine, and tactile internet feedback with haptic. It will also minimize healthcare costs while expanding access to more medical staff and patients. However, there are also some issues such as usability, connectivity, big data analytics, security, and privacy. Finally, on the basis of the above issues, future directions and beyond the

5G have been discussed that will help researchers and professionals who are participating and working in 5G telemedicine and related technologies.

Compliance with ethical standards

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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