6G and Healthcare Paradigm: Hope & Hype

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***Abstract*—Recently, new paradigms have been created in multiple fields due to 5G becoming globally commercial. This has compelled the researchers across the globe to start paving the roadmap of 6G by including complex concepts like, telepresence, AI based robots to cobots and medical cyber physical systems (MCPS) etc. This evolution has sparked significant change in the thinking, perception, and behavioral attributes of healthcare professionals and patients in terms of healthcare services across the globe. Online services have changed the perception of people by offering real-time remote access to the healthcare professional, saving time and money and most of all reducing mental fatigue of patients by bypassing the core hurdles in the conventional healthcare system. If just ease in online access, which is a tiny fraction of what 6G can promise, has such a positive impact on the behavior of patients and professionals, then one can imagine what impact it may have on the perception of healthcare sector. This work focuses on providing paradigm changes in healthcare sector due to the evolution of 6G in perspective of telehealth advancement, e-Health, and m-Health (e/m-healthcare). The paper will further provide the opportunities, challenges and the hope & hype in healthcare advancement associated with the progression in 6G technology.**

Keywords—e-health, m-health, 6G, 5G, Telehealth, Telemedicine

I. Introduction

Recent advancements in the cellular technology towards 6G has revolutionized the way world thinks. Researchers around the globe are working in the fields that were once considered impossible, like concepts of industry 5.0 and Smart cities etc. The reasons for this advancement are the three major unique use cases that were promised by 5G, i.e., enhanced mobile broadband (eMBB), massive machine type communication (mMTC) and ultra-reliable low latency communication (URRLC) that build the 5G pyramid [1]. With 5G becoming commercially available in many countries, researchers have started to think about more complex concepts like telepresence, globally synced interconnected AI robots, augmented reality (AR) etc., paving the roadmap of 6G. The extension of 5G use case Pyramid towards 6G use case hexagon is shown in Fig. 1 [2] and the general concept-based 6G use cases, that what emerging fields are expected, is shown in Fig. 2 [3]. As these use cases are still evolving, we may see a lot more till 6G is finalized. With all these new emerging research areas, one of the most intriguing use case, telehealth, has been under the limelight from quite some time.

The word telehealth emerged from the integration of internet services with healthcare. In general, the concept is to use information and communication technology (ICT) to remotely access and manage healthcare services. In the start, when the access of internet through cellular technology was limited, telehealth was limited to telemedicine which is a major field in tele-healthcare. But with the evolution of cellular and other wireless communication technologies telehealth evolved to include e-healthcare and m-healthcare, where e-healthcare are services driven by users (patients) and m-healthcare involves healthcare services completely dependent on the use of mobile/wireless technologies, such as video conferencing between patient and doctor using smart phones, interconnected healthcare devices like medical internet of things (MIoT) etc. As discussed earlier, 6G has opened doors for making impossible possible, so, the later sections in this paper will focus on the progression of telehealth field with the inclusion of 6G services and what to expect in the coming future [4][5].

The remaining paper is themed as follows, the sext section will provide details of e/m-healthcare paradigm shift due to advancement towards 6G, Section III focuses on opportunities and challenges, section IV provides summary of challenges, opportunities, associated to 6G in healthcare sector, and finally section V will provide the conclusive remarks.

II. 6G and Healthcare: The Progression of Telehealth

As aforementioned, the concept of interconnected world through internet has evolved the healthcare / telehealth field to include two major directions e-health and m-health. With the current wireless communication infrastructure, m-health is mostly limited to providing services like preventive healthcare messaging, tracking, monitoring, and limited telemedicine related services due to variation in technical parameters of the networks, whereas e-health is limited to e-medical records, online doctor's appointment, and video conferencing etc. So, e-health is of broader spectrum and includes major telemedicine services due to its independence of network connectivity. But when it comes to remote services that require ultrahigh speeds and ultra-reliability, like high-definition uninterrupted video conferencing or remote robotic surgery (telesurgery) etc., telehealth services are still limited

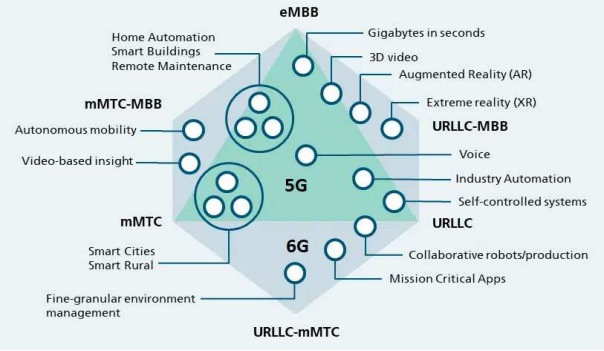

Fig. 1. 5G use cases extended to 6G [2].

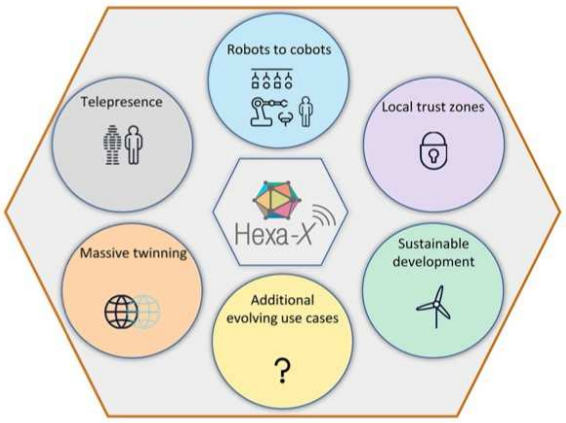

Fig. 2. Hexa-X project: depiction of 6G use-case expectations [3].

due to their dependability on network parameters. In the current wireless networks, even with 5G commercially available, ultra-reliability or extremely low latency is still long way to go. This is where the beyond part of 5G comes into play due to its three unique use cases, i.e., eMBB, mMTC, URRLC. These three major gamechangers allow m-healthcare to inculcate each aspect of telehealth explored to date. Due to which we believe that with complete implementation of 5G and beyond (B5G) globally, e-health and m-health should be presented by a single terminology, i.e., e/m-healthcare with m-health to focus on mobile part with the use of e-health services together [1-3]. As 5G has opened new door in the healthcare sector leading to a concrete telehealth roadmap, similarly, 6G use-cases have added a few more with new concepts like augmented/virtual reality (AR/VR), shown in Fig. 3. 6G is not only considered to bring a paradigm shift but will completely revolutionize telehealth not only from implementation perspective but also research perspective. 6G redefines the e/m-healthcare services by enhancing their scope from only telemedicine to mobile smart hospitals and infrastructure to support applications of augmented reality (AR) in healthcare sector. According to our research and understanding, we have provided an enhanced version of Telehealth model in Figs. 3 and 4 for overall telehealth services and m-health respectively inculcating 6G. These figures show that 6G will take the e/m-health services to a completely new level by sparking new fields from research and implementation perspective. The later parts of this section, starting from telemedicine, are based on the provided depiction model in Figs. 3 and 4.

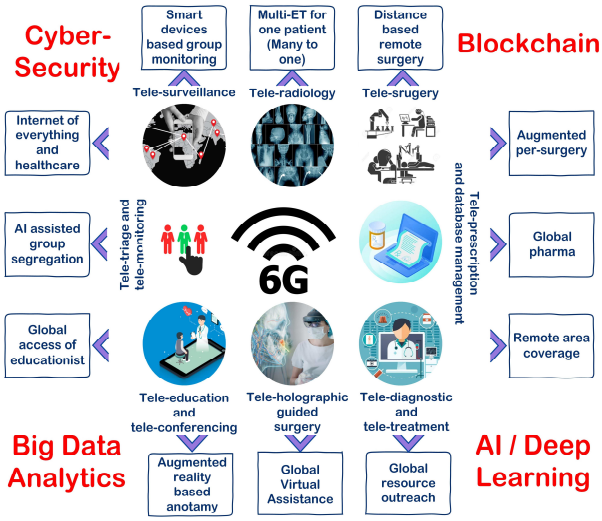

Fig. 3. Telehealth progression depiction inculcating 6G.

A. *Telemedicine and 6G*

The word telemedicine is of wider aspect which includes use of technology by the medical professionals to treat and diagnose patients remotely without visiting the healthcare centres or hospitals. It further includes remote outpatient care, remote hospitalization monitoring, remote urgent care and treatment, remote surgical procedures, remote diagnostics etc. The technology enables real-time remote delivery of healthcare-related services to patients, such as consultations and monitoring using video conferencing and intelligent wearable devices (IWD) or smart devices etc., saving them time and capital expenses.

The advent of high-end tools, like computers, smartphones etc., combining them with communication technologies, sparks the telesurgery era. Telesurgery, referred as remote surgery, requires infrastructural changes, that were promised by B5G, as it is performed by combining the robotic and communication technology together and is of more sensitive nature due to high-data rates and zero latency requirements. Especially in the case of extremely sensitive surgeries like open heart surgery etc. In the current networks, robotic surgery is mostly limited to a controlled local area network environment for experimental purpose or more precisely a robot with direct connection to a computer with wired medium so that there are no delays or any communication error related problems during the procedure. Remote robotic surgery is still under experimentation not because of the robotic technology but because of the communication networks capability in providing ultralow latency and reliability to inculcate such technology. Thanks to 5G technology, telesurgery now has a foreseeable future. In February 2024, a successful live telesurgery was conducted, where officials from different departments of the US government witnessed a surgeon in Orlando, Florida, performed remote surgery over distances exceeding 10,000 km to Dubai, United Arab Emirates, and Shanghai, China, using robotic systems [6]. The benefits of 5G in healthcare are already becoming clear. Hospitals are taking measures to improve patient care experience, such as enhanced pre-operative planning, quicker image retrieval, and scalable hardware solutions connected to cloud systems [7]. Additionally, 5G is enhancing training and education for healthcare professionals and improving the overall patient experience. With these advancements and the progress in cellular networks towards ultra-high data rates and ultra-reliable communication, telemedicine is becoming a viable option, providing access to healthcare in regions where other forms of internet connectivity are unavailable [5][8][9].

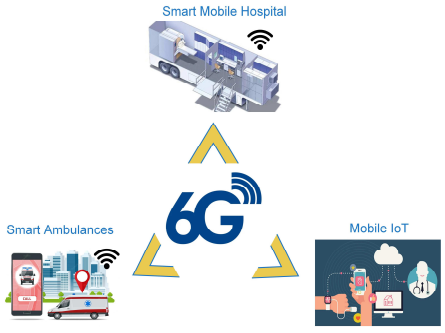

Fig. 4. Telehealth and 6G: m-healthcare perspective.

Moving towards 6G will give rise to key major areas in the telemedicine field like AR/VR Guided Surgery where holographic communication may provide more interactive verbal assistance. The doctor can be present in the surgery for instruction and can also move around to have a better view of the operating area using holographic communication (tele-holographic surgery). Similarly, AR/VR based pre surgery practice where AR based presurvey can be performed by using Realtime AR based 3D imaging-based model of the patient to assess the success rate of the surgical procedure. 6G inclusion will open gates for such complex research fields like AI/Learning based collaborating robots for telesurgery, a concept called Robots to Cobots, where multiple robots will collaborate with each other to perform medical procedures autonomously, then another concept called telepresence may become a reality, where using virtual, augmented, and merged reality guided surgeries can be performed in presence of lifelike fidelity of the surgeon [3][10].

B. Telepharmaceuticals, Telesurvailance & Teleprescription

Tele-pharmaceuticals and tele-prescription normally refer to e-prescription and e-medical record system, where all information regarding the patient medication and history is available. Based on the conducted research, in our perspective both have a substantial future with 6G. Both these fields deal with big data analysis, surveillance, monitoring, and database management. The field of tele-pharmaceuticals may include precision medicine creatin by data collection. Doctors and researchers classify patients according to a common criterion/disease and record their subjective data over the secure cloud, accessible globally with other researcher through. In order to develop new medicines and therapy medicines, health data of clinical trial participants is required, e.g., cell therapy research is being carried out to cure important disorders. Doctors and researchers can use IWDs to collect data. This information will be collected in real time, providing for more precise health statistics. Furthermore, the research may be conducted anywhere on the planet as geographical location has an impact on an individual's immune system. As a result, confining the people under surveillance in one location will change their surroundings. This, in turn, will influence the research. As a consequence, the general practitioner may utilise Intelligent Internet of Medical Things (IIoMT) to monitor people who are being watched all over the world, all such practices lie under the umbrella of tele-surveillance field [11-13].

Furthermore, in most of the countries online prescription system is already under place but lacks global access [12][13]. An intelligent tele-prescription system can be developed, where using 6G capabilities, the prescription data of the patient will be available over a secure cloud only accessible by the patient or the concerned healthcare professional. For example, while scenarios like international travelling, the patient, with the consultation of the medical specialist, will automatically be notified that which medicines are available with the same formulation under different price tags.

C. 6G, e-Health and Big Data Nexus

One needs to understand that all the fields in telehealth are interconnected with each other. Demands for 6G based applications that provide improved medical healthcare systems and services using advanced ICT, are skyrocketing as the population ages. A large range of personal mobile health monitoring gadgets are already available for personal healthcare use. However, use of these devices for self-diagnosis or any other self-treatment is not recommended by the medical specialists. By storing this massive data over a secure cloud and making it securely available over the internet can help medical professionals to provide opinion and guide the individuals in better ways [14][15].

Like the personal devices, novel advanced medical devices are available that are compliant with medical standards and are used in professional medical data monitoring e.g., ultrasound monitoring and recording, MRI and CT-Scan recording, vital signs recording and monitoring of the patients. As an example, here there are two domains, i.e., live monitoring of vital signs and keeping record of the patient's vitals. With 6G in place, patients' vitals can be live monitored and accessed from any part of the world. Furthermore, in all above examples the recorded data can be securely stored and managed using big data over a secure cloud. This can help resolve many issues in fieldwork and in research. A patient can make available their data globally to any medical practitioner of their choice, similarly, researchers will be able to access the recorded data and use it in their research for the betterment of mankind from any part of the world. As aforementioned, that all the fields are interconnected, so where big data comes, security is of the utmost importance, especially in healthcare department, where the integrity of patient doctor confidentiality is a serious matter [16].

D. e-Health and Cyber-Security in 6G Perception

As aforementioned, that where there is data, cyber security is of utmost importance, this not only true for big data but medical field can face cyber-attacks in different shapes, like, e.g., hack during telesurgery can be fatal for the patient. Furthermore, in the concept of interconnected medical devices attacks against health systems, e.g., wearable medical devices and implantable medical devices (IMD) like pacemakers and artificial pancreas that can be connected to the network, may occure putting the life of patient at risk [16][17].

The wireless connection allows components of a heterogeneous system to communicate with one another, creating an environment that could be vulnerable to cyber-attacks. An attacker could submit purposefully false data to the control algorithm being opted to carry out medical operations, if the link between the wearable device for continuous monitoring and the external elaborator is possibly compromised. All traditional health sectors, as well as those emerging from eHealth and mHealth, require attention.

So, information security is not the only concern, whole network needs to be secure. With 6G in place, where everything will be accessible worldwide, the field of cyber security will have a bright and long-term future. Most challenges associated with cyber security in healthcare with 6G are provided in Fig. 5. In short, cyber security risk analysts will have to rethink the whole risk evaluation and mitigation process to redefine the security measures and strategize in accordance with new use cases that will emerge as part of 6G.

E. Virtual/Augmented Reality and AI in 6G Scenario

Most of the aspects shown in Fig. 3 are covered in the aforementioned topics. The remaining are mainly associated with the VR/AR and AI concept in telehealth systems like the tele-education, Tele-holographic guided surgery, AR/VR guided pre-surgery and surgery consultation, Tele-triage and monitoring. AR/VR based surgery related aspects have been discussed in the telemedicine topic briefly, so, we start with

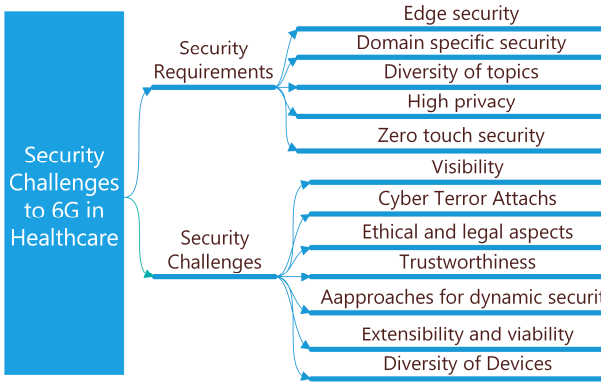

Fig. 5. Security challenges and requirements in Telehealth with 6G.

tele-education. In the current communication networks, tele-education is considered as online education system using tools like Zoom, Google meets or Microsoft teams etc. whereas 6G offers much more over the cellular network like, online lectures based on VR/AR from senior professor worldwide in the field of healthcare, sitting in another corner of the world. Then using AR/VR to perform human anatomy rather than using a live dead body, using AR/VR in prosthesis manufacturing for precision outcome by letting customer try the augmented model of the limb. Similarly, AI can be used in prothesis development and further it can be used in the tele-triage field, where AI based groups using the communication and wearable devices is performed, e.g., like the grouping technique used in Chine to control the COVID-19 pandemic situation.

In recent years, virtual reality (VR) technology has been used in numerous professional verticals of the healthcare sector, including e-health. VR has the ability to transform the daily lives of potential stakeholders and medical professionals in the future since it gives amazing immersive and interactive experiences while breaking through cost and risk limits in clinical sessions. Because virtual reality is a computer-generated world, one of the most important needs for immersive experiences is computing capacity [18, 19].

To explore the potential of combining AR, AI, and B5G in advancing the healthcare sector towards 6G, consider the work at the National University Health System (NUHS) in Singapore. They developed AI software for AR headsets that assists in detecting patient veins. Additionally, NUHS has implemented an indoor 5G network in several wards and operating theatres to test AR for planning pre-operative procedures. This “holo medicine”, enabled by 5G, has equipped surgeons with high-resolution 3D visualization of patient organs without any lag, enhancing surgical planning and execution significantly. For instance, during surgery, surgeons can overlay a 3D hologram of a patient’s brain onto their field of view, enhancing operational precision and efficiency. The future 6G connectivity ensures smoother and lag-free holographic streaming, surpassing 4G or Wi-Fi [7].

Because of its low cost, small size, and portability, mobile VR is seen as the way of the future. Mobile VR devices, on the other hand, lack the processing power to match the high-fidelity VR needs of medical standard operating procedures (SoPs). This invariably leads to poor quality of experience. All three objectives must be met simultaneously by a 6G capable VR system: low cost, high-quality graphics, and portability. Cloud VR allows e-healthcare practitioners to enjoy high-quality VR service experiences whenever and wherever they want, without being bound by time constraints. Despite the fact that small-scale solutions exist now, there are a number of critical difficulties that must be addressed as we move closer to the 6G era [19].

To begin with, cloud VR platforms necessitate the use of mobile edge computing (MEC) with pricey accelerators, resulting in a large initial expenditure. Second, cloud VR services necessitate extremely low latency, which poses a significant barrier in terms of improving client experience. Finally, the research community can optimize the processing pipeline thanks to the cloud VR architecture. To address the issues, a thorough understanding and analysis of existing academic and corporate research and development can aid in the advancement of the cloud VR system to 6G speeds.

With most of the aspect of telehealth covered with advancement towards 6G, we will now discuss the m-healthcare perspective in the next section

F. m-Healthcare and 6G

As mentioned earlier m-health refers to telehealth services that rely on mobile / wireless communication medium. In 6G and beyond m-health is divided into three categories, i.e., mobile-IoT (MIoT), Intelligent wearable devices and 6G enabled smart ambulances / smart mobile hospitals [1], all shown in Fig. 4.

6G claims to offer a large capacity for facilitating massive number of smart devices. It will use Edge technology to deliver highly fast and smooth internet services to smart devices, which is considered critical in healthcare sector. In its Edge nodes, Edge technology gathers, processes, and analyses health data in real-time. The smart medical gadgets are normally placed closer to these nodes so that the user generated data is easily sent to the Edge nodes. The data is then processed and analyzed by the edge nodes, which then decide the best course of action according to the health data. E.g., Edge nodes receives the user data from smart medical equipment and then identifies whether the user is deficient or not. The health-related data is monitored and filtered by the edge node, which then transmits the critical information to the Cloud for storage. In addition, 6G will include a real-time intelligent Edge, which will significantly improve the healthcare system. It will compute and analyze data in real time. To reduce latency in providing services, AI algorithms must be executed in Edge nodes rather than the Cloud [20, 21].

On the other hand, IWDs are interconnected devices that send phycological and physical data to the test and monitoring centers. In general, all kinds of vital signs, blood tests, body weight and daily routine data like water drinking habits etc. are the types of data sent over the network. IWD also learns from a person's personal body history and advises them on what to do next, such as going for a walk or running. IWDs keep track of health, nutrition, and habits, as a result, they can advise on what to consume in the event of a shortfall. The frequency of hospital visits can be reduced significantly if small bodily disorders, such as deficiency, are detected. As a result, hospital bills will be lower, and hospitals will be able to focus on more difficult disorders [22, 23].

In addition, with 6G, the data acquisition from IWD can be analyzed by the researchers and medical practitioners to guide pregnant women during their pregnancy to keep the baby and mother healthy, similarly the data can be used to identify potential cancer patients based on their recorded

behavior and can be guided to make changes in their personal life style resulting in low probability of cancer risk. Such examples necessitate the importance of exploring on how to create infrastructures to support such use cases utilizing 5G and 6G technology as IWD has the potential to improve health and extend human life significantly.

The last but not least concept in the m-health is the concept of smart ambulance and smart mobile hospitals. The authors in [1], have discussed the architecture of smart ambulances, as shown in Fig. 6, that is extendable to smart mobile hospitals as both depend on the same wireless technology for data transfer. Just like telesurgery, both require ultrahigh data rates and ultra-reliability in terms of wireless connectivity. The concept is to transmit live video feed and vitals of the patient to the medical specialist available in the hospital. Then under the guidance of that specialist, paramedics can perform multiple procedures, e.g., pre-surgical procedure to ready the patient for surgery before arriving at the hospital etc. In case of smart mobile hospital, access of doctors worldwide will be available. Such hospitals with state-of-the-art equipment are best solution to rural or remote areas in the developing world where basic medical needs are not available. In the end, advent of 6G has opened doors to many applications and can make lives better, as in the field of healthcare. Next section provides summary of challenges, opportunities, hopes, and hypes related to 6G and healthcare sector.

III. 6G and Telehealth: Challenges, Oppertunities, Hope & Hypea

Most of the challenges and opportunities related to 6G and telehealth are discussed in the previous section, in this section a summary of all the challenges, hope and hype are provided. All data provided below revolves around Fig. 3 and 4.

A. Wireless Network Perspective

Major challenge still today is how to achieve ultra-reliability and how to create coeffective market for 6G. To achieve the network requirements for m-healthcare given in [24], one has to explore, identify and create ways to achieve the latency, data rate and minimum PLR requirements. To this extent, multiple coding schemes, and new modulation schemes can be explored for creating new ones or use them in efficient combinations.

B. e-Healthcare: Human Centered Healthcare System

In the e-health services, a need of disease prevention system is required rather than curing the diseases for which AI can be used for manipulating the clinical and medical data to improve daily life. AI based early diagnostics in digital healthcare is one way to achieve prevention where works like [25], but to purely achieve preventive care, AI based medical data curation, analysis and inference is the key player and to achieve this challenge, use of cloud, fog and edge computing concepts is of utmost importance for global data access, especially using generative AI. This necessitates the need of a mMTC and eMBB wireless infrastructure to support such high-end computing with massive data transfer and sharing.

C. Telemedicine

6G inclusion will open gates for complex research areas like AI, machine/deep learning based automated robotic and surgery collaborating robots based telesurgery. There is a lot of room available for research in the development of Cobots and their control mechanism using wireless network, where robots can be trained using learning mechanisms to behave as companions and healthcare workers, then research potential in the field of telepresence can be explored, where using virtual, augmented, and merged reality guided surgeries can be performed in the presence of lifelike fidelity of the surgeon. Moreover, even after 5G becoming commercially available, an ultrareliable infrastructure to support seamless connectivity for such applications is another challenge.

D. Cyber Security and Big Data.

This is a major concern in the telehealth area, and it includes all aspects of cyber security like information security, digital forensics, network security etc. efficient and dynamic encryption decryption algorithms can be developed to enhance the security. Areas like blockchain can be explored to enhance privacy of the patients and resolve big data management problems. Cyber security risk frameworks need to be reshaped as this massive connectivity gives birth to new sets of vulnerabilities and threats. Further challenges, related to the field of cyber security, are provided in Fig. 5.

E. Teleeducation

This seems to be a fun field, as it provides researchers with the opportunity to create ease in education of medical students using AR/VR techniques. Create techniques, programs and algorithms that can help in human anatomy and perform simple to complex surgical procedures using 3D virtual models. Create educational programs that can help in teleconferencing between teachers and students. Explore the requirements to transmit all such data over the wireless network and find ways to loss less transmission of such data.

F. Mobile IoT and m-healthcare

In mobile healthcare one must understand that it requires high speeds and high reliability requirements, so very first research area is to explore ways to enhance these two. Furthermore, MIoT, smart ambulances and smart hospitals, all require data transmission, which may be vulnerable to external attacks so securing the data is of utmost importance. Then video quality enhancement is another field where techniques can be studied and created to have high quality video transferred over the network using less bandwidth. Mobility can create issue for lossless transmission of the live data in smart ambulances and hospitals, so mobility concerns can be explored for further research areas.

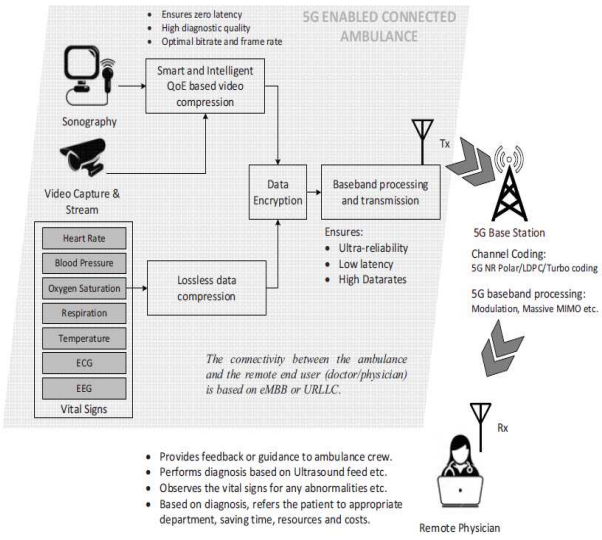

Fig. 6. 5G enabled smart ambulance ceoncept and architechture [1].

G. AI in Teleservailance, Tele-triage and Telemonitoring

The name here is self-explanatory, to provide AI based solutions for surveillance, grouping and monitoring of specific patients or group of patients. These three can be in terms of clinical trials, ethnic group study on different diseases or pandemic control, like in the situation of COVID-19. As an example, search optimization algorithms can be developed based on learning-based strategies or bio-inspired algorithms etc. for grouping, monitoring, and surveillance depending on the reason.

H. Augmented / Vertual Reality in Telehealth

This has been discussed earlier multiple time in different perspectives like tele-education, telesurgery etc. Following areas can be explored for opportunities: infrastructure to support seamless and smooth AR/VR guided surgery where holographic communication may provide more interactive assistance. The doctors can be present in the operation to guide and instruct and can also move around the theatre to have a better view of the operating area using telepresence and AR. Similarly, teams of doctors all around the world without being physically present can perform AR/VR based pre-operative procedure by using Realtime AR based 3D imaging-based model of the patient to assess the success rate of the procedure which will require real-time sharing of the AR field of view of among the doctors, again necessitating the demand for communication infrastructure to support such sharing of data. All these aspects require development of new algorithms, and communication infrastructure to achieve the target.

Exploring opportunities associated with B5G & 6G can help answer most of the above. Even though few of them seem unachievable or unrealistic, like the concept of telepresence, but who knows as these might become a reality in the near future due to the ways ICT is advancing especially with 6G.

IV. Conclusion

With the progression in 6G communication, concepts like telepresence, AR/VR and AI/ML based autonomous robotics are becoming a reality. These concepts have created a massive paradigm shift in the healthcare sector. The paper provides advancement in healthcare sector focusing on e/m-healthcare services due to evolution of communication technologies towards 6G. The paper covers major aspects in healthcare in detail, including telemedicine, telesurgery, tele-education, remote AR/VR in healthcare sector, cyber security aspects and tele-triage, with their respective future scope, challenges and associated hope & hype. This paper will act as a catalyst for any professional, educationist or researcher to equip them, with the latest trends in the Healthcare sector with inclusion of 5G and 6G communication use-cases.

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