Applications of 5G and 6G in Smart Health Services

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Abstract
Healthcare organizations are overwhelmingly embracing smart value-based care strategies, which focuses on providing superior treatment at a significantly lower cost and quality of service (QoS). For these purposes, fifth generation (5G) of mobile service provides an innumerable improvement that clearly outperforms previous generations e.g., 3G and 4G. However, as with most advancements, 5G is projected to introduce new challenges, prompting the community to think about what comes next. This research was conducted to examine the most recent smart 5G technology applications and the solutions they provide to the healthcare industry. Finally, the paper discusses how the upcoming 6G technology has the potential to transform the future of healthcare sector even beyond the current 5G systems.

Keywords: *5G, 6G, healthcare services, robotic surgery, Telesurgery, Tactile Internet, Mobile Health, M-health, eHealth, MEC Networks, 5G-Csys.*

I. INTRODUCTION

Healthcare that is centered on hospitals and specialists is quickly giving way to dispersed, patient-centered care. Numerous technological advances are driving this rapid healthcare revolution. Among other things, communication technology has enabled personalized and remote healthcare. The present 4G network and other communication technologies are heavily used in healthcare for intelligent healthcare applications, and these technologies are continually expanding to meet future demands. As the smart healthcare industry expands, more applications will produce data of varied kinds and types. Existing communication technologies cannot meet the complex and dynamic demands placed on them by varied smart healthcare applications. Thus, the 5G and the future 6G network are projected to enable smart healthcare applications that meet most of the required specifications, including ultra-low latency [1] [2] [3].

Future smart healthcare networks are likely to include a hybrid of 5G, 6G, and Internet of Things (IoT) devices, fog and cloud computing, cloud of things (CoT) [4], improving network coverage, performance and solving security problems. Global 5G innovation deployment has been accelerated. Its components make it ideal for enabling massive advances in the inadequacy and strength of categorizing human services applications, such as In-building information management, more elementary treatment of massive imaging records, remote patient checking, and virtualization consideration. Health care will soon be dominated by a new communication technology known as 6G. 6G will probably change several sectors, including healthcare. Healthcare will be AI-driven and dependent on the 6G connection, changing our way of life. Time and location are now the most significant hurdles to health care, which 6G will solve.

Rest of the paper is organized as follows: section 2 contains the review of literature, section 3 contains the potential 5G applications, problems, and solution in healthcare, 6G application, and challenges are provided in section 4 while section 5 concludes the paper.

II. LITERATURE REVIEW

Ahad et al., [5] stated that the 4G network and communications technology are widely used for intelligent healthcare applications. As the intelligent healthcare industry grows, many connected apps will create data of various sizes and types. This will put significant strain on the network. As the smart healthcare industry evolves, hospitals will need to integrate Massive-Machine Type Communication to meet the connection requirements for many devices and machines with sensor-based applications. Current telecommunications are inadequate to meet the complex and dynamic needs that smart healthcare applications place on communication networks. Consequently, it is anticipated that smart healthcare applications will be enabled by the upcoming 5G network, which will satisfy the bulk of the requirements. 5G and IoT devices will likely be used in future smart healthcare networks to increase cellular coverage, network performance, and solve security problems.

Ruffini [6] stated that using the IoT, which merges technologies functions with daily world objects, the health sector and all other fields will profit in a time and cost manner. Patients with chronic diseases must stay in the hospital for long periods of time to be monitored. These hospitalizations have a detrimental effect on patients' quality of life and impose enormous economic costs.

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Numerous countries have launched various programs to encourage self-management of one's health.

Lloret et al [7] emphasize that in order to have a real-time monitoring of patients, the necessity of 5G technologies is vital. The 5G network technology offers low latency and ensures the bandwidth availability for all users. The proposed architecture consists of several components: sensors embedded in wearable technology that collect body measurements, and a smartphone at the patient's side that processes the data collected by the wearable technology. A database with a smart engine diagnosis and generates alarms by utilizing machine learning on Big Data from various hospitals and patient data.

To address the high expense of Diabetes 2.0 for average users, Chen et al. [8] proposed 5G-smart Diabetes application, an intelligent cost-effective diabetes diagnosis solution that is easily accessible to users. This solution leverages 5G technologies such as the smart textiles, artificial intelligence models, and analyzing medical data for offering a dependable detection and analysis to patients with diabetes. Additionally, the authors presented a data exchange mechanism between patients, and a personalized model that uses medical data for the 5G-Smart Diabetes. Eventually, the 5G-Smart Diabetes initiative establishes a prototype system composed of smart textiles, smartphones, and medical data clouds. The results of the research suggest that the system can successfully provide patients with personalized diagnostic and therapy help.

Similarly, in [17], authors proposed an intelligent cloud-based diabetes type II prediction by deep extreme learning machine. The approach was promising in terms of accuracy. Likely a heart disease prediction model using cloud computing and supervised machine learning was proposed in [18]. The technique was smart enough to predict the disease with considerable accuracy.

As a result of the current rise of information and communication technologies in healthcare, which has resulted on the internet of medical things (IoMT), new electronic health services are available, most notably for the elderly who require daily assistance. Cisotto et al. [9] aimed to identify the most typical healthcare situations that may advantage from 5G networks, as well as to summarize the communication needs for these situations. The implications of the primary 5G technology, including medical network, heterogeneous network management and mobile edge computing. Mobile health refers to as the process of delivering healthcare services using mobile.

This paper by Mattos and Gondim [10] summarizes the vision for future 5G networks and how it can solve the present M-health challenges. Additionally, it aimed to integrate recent work on machine-to-machine and device-to-device types of communications to emphasize their potential. Mucchi et al. [11] answer questions regarding the future of 6G network technologies by outlining the new features of 6G, including the use of AI algorithms. Additionally, it demonstrated the services that 6G will provide soon with discussing the potential difficulties associated with integrating 6G technologies.

Ahad et al. [12] presented a protocol clustering in order to enhance the Quality of Service (QoS) along with energy efficiency in 5G oriented healthcare. A body sensor network must be developed to link the human body with medical devices in today's modern healthcare business. In addition, medical data are sent to the medical cloud using the IoMT framework.

Future 5G capabilities may enable substantial advancements in a variety of health-related scenarios, including but not limited to, smart continuous monitoring of patients with chronic diseases, authenticating patients' priorities and emergency levels in 5G networks, 5G-Smart Diabetes, 5G cognitive systems for healthcare, Telesurgery Robot Based on 5G Tactile Internet [19][20].

On the other hand, The Internet of Bio-Nano-Things (IoBT) is intended to enable the human body to be a component of this "Net" via the usage of 6G technology. it is imagined that we'll all be wearing these types of devices in the not-too-distant future. collecting data from every object we encounter. The 6G network will support medical science by treating humans as a holistic system that includes psychological and environmental aspects. Utilization of modern sensors inside and outside the body is required for constant and mobile control. This demands a dependable, secure, and adaptable network, which can be achieved by 6G [13].

III. 5G Applications in Healthcare

A. Smart continuous eHealth monitoring using 5G

Continuous patient monitoring demand is a fact. With the help of artificial intelligence, a system capable of diagnosing patients and alerting them is constructed. The system used architecture simulations of 4G and 5G technologies to show 4G's limitations and the necessity for 5G technology. A case study on cardiac disorders established the intelligent system's credibility as a continuous smart monitoring system for patients. The system architecture is detailed in the following sections.

1) Data Gathering Architecture

This sub-architecture includes wearable sensors that collects vital signs data and send it through Bluetooth to the patient's mobile station, which connects to the database server over a 5G network. The database server will also handle data from multiple medical centers. The system would analyze the sensor and smart engine data next, to decide if it is Typical Data (TD) or Abnormal Data (AD). In an abnormal situation, the database will transmit the last 30 minutes of patient's activity to the doctor. In an emergency, the doctor will either confirm or deny the alarm. The patient can also accomplish this using the smartphone's alarm button. The system effectively gives priority to packets with patient alerts and AD to verify by the doctor.

The architecture of the smart monitoring system in a typical 5G environment is given in Figure 1. All the communication patches are supposedly using the 5G architecture.

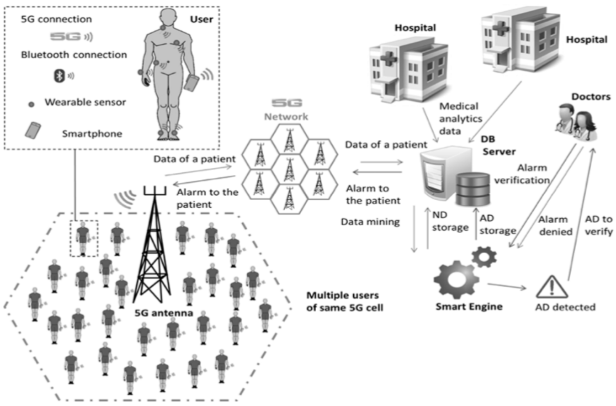

Fig. 1. Smart continuous monitoring architecture

2) Message flow and decision algorithm for the system operation

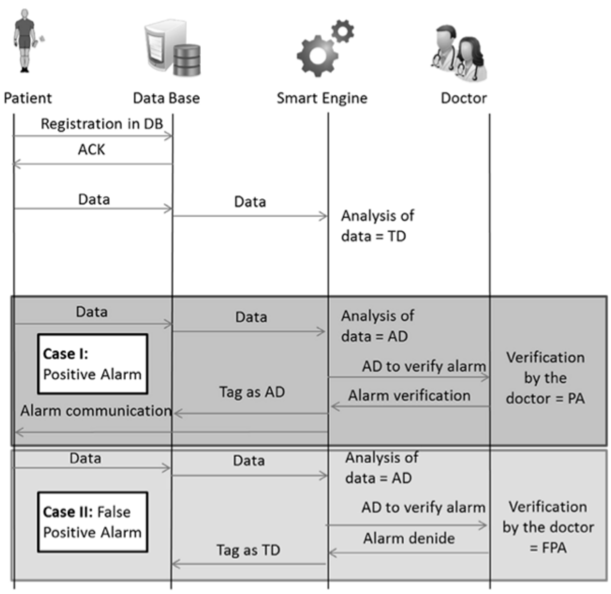

Fig. 2. Message flow diagram

The data flow of the system is provided in Figure 2. The system sends the patient an ACK in case of a registration. The system captures data from sensors and smartphones every second after registration. The smart engine will retrieve this data from the DB and decide if it is TD or AD. If the prediction is AD, the doctor will be notified. A positive alarm (PA) is set when a doctor determines an emergency (the smart engine will tag AD in the DB). The smart engine also alerts the patient to the detected condition. If the doctor classified the AD as a false emergency, the alert is rejected via a denial message so the smart engine can mark it as a false positive alarm (FPA) and tag it as TD in the DB. During an emergency, the decision algorithm determines if the prior data was TD or AD. Also, the alarm verification will only be requested if a new emergency occurs to limit verification request from the doctor. The system can be treated as a decision support system where the decision is taken by an efficient algorithm as depicted in Figure 3.

3) System operation with alarm button

Patients who are ill may use the alarm button to submit their most recent activity data and alert their doctor to an undetected problem by the system. This button will then send the current and prior DB data immediately to the doctor. If the doctor deemed it an emergency, the alarm is PA, and data is tagged as AD, otherwise FPA and data is tagged as TD. Because medial life can be very busy, if the button was clicked by the patient in the last 10s, the above algorithm will discard the click to limit the verification requests from the doctor [7]. The major impacts of this solution are:

- The mechanism may be enabled manually or automatically if the smart engine detects AD.
- The system requires two diagrams and two algorithms for data reception and alarm button activation.
- A doctor can verify collected data by the smart engine using PA and FPA.
- The system learns from FN by pressing an alarm button, and the positive doctor verification will help.
- It uses two algorithms; the first one to distinguish between a new emergency event, and the second one detects alarm button abuse and disables it. [4]

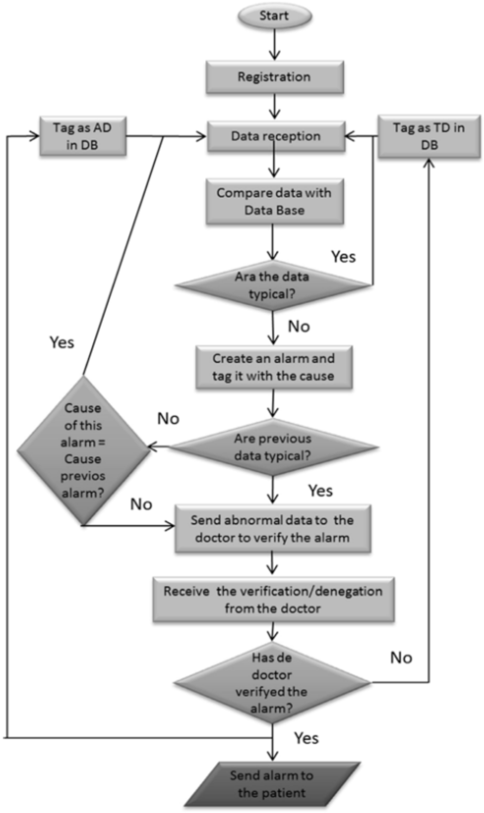

Fig. 3. Decision algorithm

B. *Authentication of users' prioities in 5G MEC Networks*

The data coming from IoT is enormous, consumes time to process, thus, Mobile edge computing (MEC) sends data to the cloud from a cellular base station. The data transmission and computation priorities on a cellular network that is dedicated to healthcare applications must be managed by referring to the validity of users' importance when allocating wireless resources. Suppose the user's priorities are not authenticated. In that case, a user with a low degree of emergency may allocate additional wireless resources to himself, resulting in insufficient wireless resources for high-importance users.

1) *MEC network based on blockchain consensus to authenticate users' priorities*

Traumatic injuries will be considered an example to authenticate users' priorities based on the emergency levels. For traumatic injuries, the Abbreviated Injury Scale (AIS) is the most frequently utilized technique for measuring severity. AIS scores comprise seven numbers to indicate injury severity, which is specified in the table below with its levels of injury, which is, in turn, indicate the patient's emergency level. Network architecture is given Figure 4.

TABLE 1. AIS TABLE

AIS Score	Injury	Example
1	Minor	Superficial laceration
2	Moderate	Fractured sternum
3	Serious	Open fracture of humerus
4	Severe	Perforated trachea
5	Critical	Ruptured liver with tissue loss
6	Unsurvivable	Total severance of aorta

A MEC network built on the blockchain technology features with a small number of mobile users and two blockchains: the integrity chain (I-chain) and the fraud chain (F-chain). Each mobile user's priority must be copied and broadcast to all other cell users through the mobile gateway. Mobile users may utilize consensus methods and steganography techniques to maintain synchronization between the two blockchains. The consent method will be used to authenticate a broadcast message with a user's priority. A notification is signed into the I-chain after it has been certified. If at least half of the blockchain nodes reject a message's authenticity, the message is put on the F-chain.

2) *A telemedicine-oriented network based on MECs*

An MEC cellular network has a mobile station and mobile subscribers. Using a MEC server at a base station, a mobile user may connect to the Internet through the cellular network's core. The Orthogonal Frequency Division Multiplexing (OFDM) is utilized in communication. A guard period and cyclic prefix methods are expected to eliminate inter-symbol and inter-channel interference.

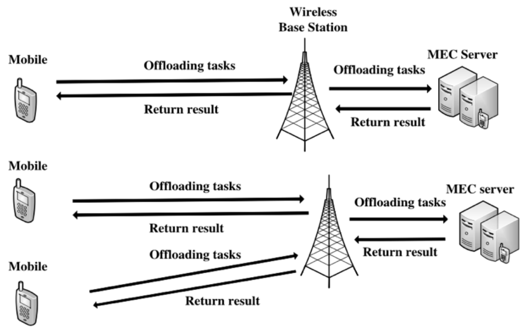

Fig. 4. A cellular network using MEC communication paradigm

The benefit of adopting the blockchain consensus system is that it enables users' priorities to be authenticated. A few users may argue for a higher priority without monitoring user priorities and unfairly gain access to more wireless resources on the network. However, these users use the resources of other essential patients, lowering the data transmission quality for the critical patient. [14]

C. *5G Smart Diabetes*

Since diabetes affects the overall health and economic system, it is critical to improve diabetes treatment and prevention methods. A lack of a mechanism for data exchange and customized analysis of large amounts of data from multiple sources, and a lack of continuous recommendations for diabetes prevention and treatment are the current diabetes detection issues. And that is why this diabetes solution combines cutting-edge technologies like 5G mobile networks and smart textiles. Figure 5 shows the 5G- architecture, which includes three layers: sensing layer, personalized diagnosis layer, and data sharing layer [8].

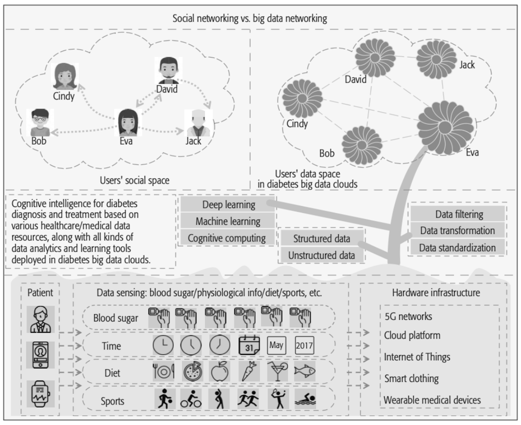

Fig. 5. The system architecture of 5G-Smart Diabetes

1) *Sensing Layer*

Real-time body signals collection from a user's smart mobile and the wearable monitoring device happens in this layer. A smartphone can collect a patient's activity data and track their diet. The data is also collected from users in hospitals and then the 5G network sends all gathered information to the big medical data cloud.

2) *Personalized Diagnosis Layer*

This layer utilizes patients' blood sugar, physiological, nutrition and exercise data into modern deep learning models for accurate disease analysis and prediction.

3) *Data Sharing Layer*

Patients can share diabetes information online to motivate each other and their close relatives in case of an emergency. The healthcare advisor can track multiple patients in real-time for assistance. Patients exist in separate regions and use various clouds to store their data. 5G-Smart Diabetes beats Diabetes 2.0 in these areas:

- 5G-Smart Diabetes uses social networking tools to allow family and friends to monitor patient treatment.
- 5G-Smart Diabetes uses physiological, dietary, and exercise data to improve diabetes diagnosis and treatment.

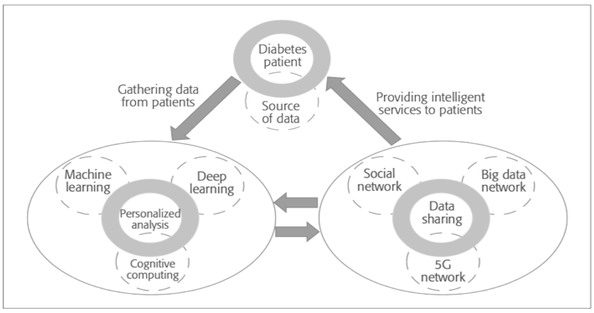

Fig. 6. Data sharing and personalized analysis

To integrate social interactions and physical storage in clouds, hence promoting data sharing via the establishment of a shared social and data environment. The 5G-Smart Diabetes system, which is based on machine learning and cognitive computing, is capable of analyzing large amounts of data linked with diabetes in order to give patients with individualized diabetes diagnoses as depicted in Figure 6.

1) *Data sharing for 5G-Smart Diabetes*

Patients can communicate and share their personal life activities here with other patients, healthcare professionals, and their relatives to check up on them in case of an emergency. In this layer, transmission cost of data exchange is a challenge upon user's movement. This cost might differ dramatically across patients who live in distant places.

2) *Personalized analysis model for 5G-Smart Diabetes*

The public diabetes diagnosis model was trained on hospital diabetes big data. The data in the Electronic Medical Records (EMR) is structured and unstructured. According to the doctor's advice, the system structure diabetes-related features. A convolutional neural network (CNN) selects an unstructured feature. To get a public diabetes risk model, the system uses feature selection and a deep learning algorithm. The cloud labels the diabetes risk which can be modified after receiving the data from the medical devices. After receiving the risk assessment label, the customized data is retrained, thus, improving 5G-Smart Diabetes risk assessment, therapeutic schedule, and daily advice to help patients better manage their diabetes.

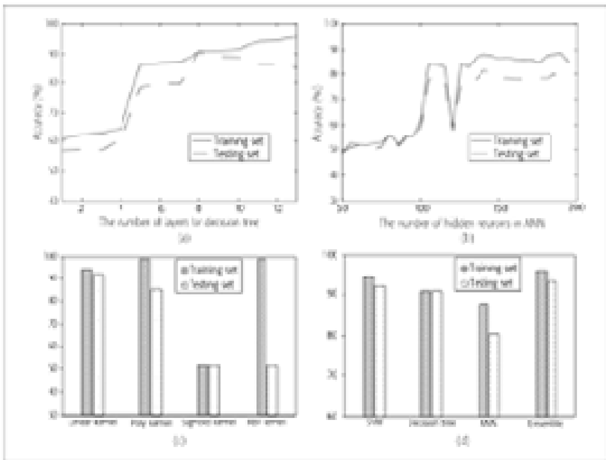

Fig. 7. The testbed of machine learning algorithms

3) The testbed of machine learning algorithms

Three machine learning algorithms were used in this figure come up with a higher detection and treatment accuracy. The ensemble method was also used to combine the three models, resulting in better prediction performance than each model alone. The testbed is shown in Figure 7. By combining multiple machine learning algorithms, and utilizing social sharing among patients and their relatives, this proposed cost-effective system was able to provide a suggested personalized diagnosis and treatment for diabetes patients [8].

D. 5G Congitive System for Healthcare

A healthcare system built on 5G-Csys (5 GCS-Health-Sys) enables physiological and psychological illnesses remote treatment.

1) 5G Conitive System Architecture

5G-Csys framework is introduced from the perspectives of network architecture and communication modes. The network architecture of 5G-Csys is represented in Figure 8, which consists of three layers: infrastructure, resource cognitive engine, and data cognitive engine.

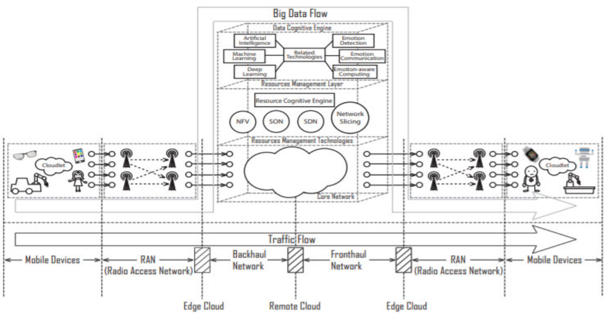

Fig. 8. The 5G cognitive system's architecture

a) Infrastructure layer

User terminals, the radio access network, the core network, the edge cloud, and the distant cloud are all part of this layer. The RAN and core network make up the system's communication architecture. The edge cloud and distant cloud provide storage and processing infrastructure for the system.

b) Resource cognitive engine layer

This layer optimizes resource usage by perceiving and learning about network circumstances and user data. Recent advanced network software technologies include network function virtualization (NFV), software-defined networking (SDN), self-organizing networks (SON), and network slicing. This layer uses cloud platforms and advanced algorithms to build a cognitive engine that enhances the customer experience and handles the connectivity requirements of diverse applications.

c) Data cognitive engine layer

The data cognitive engine may accomplish environmental sensing and people cognition via big data that is why data supply is crucial at this layer. The 5G-Csys system uses big data for perception and cognition, while the data engine analyzes it to detect healthcare requirements. The data cognitive engine can imitate human cognition by gradually accumulating data. Thus, 5G-Csys can better grasp the actual world and humans.

2) 5G-Csys Communication Modes

Considering the disparate communication needs of geographically dispersed individuals in rural areas, 5G-Csys communication modes are divided into four categories, as shown in Table 2.

TABLE 2. CLASSIFICATION OF MODES OF COMMUNICATION

Name	Abbreviation	Communication Mode
5G Communications in Last Mile Network Access	5C-LM	Short or Medium Range Communication
5G Communications over Multiple Macro-cells	5C-MMC	Long Range Communication without Clouds
5G Communications over Clouds	5C-Cloud	Long Range Communication with Clouds
5G Communications over Co-Located Clouds	5C-Cloudlet&Cloud	Communications with Flexible Coverage

When a certain number of users is reached at the edge, cloudlets can be automatically generated to maximize local user communication and service offloading. The following table summarizes the communication ranges for the four types of communication: 5C-LM < 5C-MMC < 5C-Cloud < 5C-Cloudlet&Cloud. In real-world application settings, users' communication modes can be dynamically shifted between the four modes in response to dynamic updates to the user's position.

3) Application of 5G-Csys for Healthcare

5G-Csys can transmit data between faraway clients with extremely low latency and great dependability. Remote surgery is one of the applications for 5G-Csys, as shown in Figure 9.

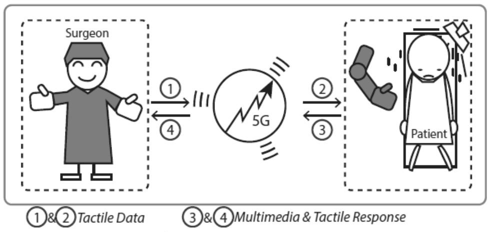

Fig. 9. Remote surgery

Because of a shortage of medicinal resources and time, remote surgery has been proposed, where the patients and doctors are in distant extremities. Using displays and touch sensors, doctors may gather real-time data, diagnose patients, and perform procedures. 5G networks deliver haptic data from the doctor's arm to the patient's side operation terminals. The robot arm accurately replicates the doctor's movements on the patient. On the other hand, a patient's sensor can send audio, visual, and tactile feedback to the doctor. The doctor can use the data to plan future procedures. [15]

E. *Telesurgery Robot Based on Tactile Internet*

Predicated on 5G network and AI, the cognitive system covers tactile and emotional stimuli. The 5G wireless network may serve as a suitable reference system for wireless internet access to the tactile Internet. Telesurgery robot is such a well revolutionary surgical technology that is used in minimally invasive procedures globally, opposed to the traditional surgical concept. Three critical components comprise the hardware of a 5G tactile Internet application in surgical robots:

1) *Master control terminal:*

The master control terminal is made up of a surgeon, a controller, and tactile feedback. The surgeon uses a control device to operate it. The tactile feedback system simulates the actual tactile behavior by providing feedback in real-time. The tactile feedback technology allows the surgeon to touch and perceive remote patients.

2) *Controlled terminal:*

The telesurgery robot, patient, and tactile sensors are all contained within the controlling terminal. The master control terminal controls and operates the telesurgery robot on the patient. Simultaneously, the tactile perception device detects and transmits the patient's tactile feedback to the master control terminal.

3) *Transmission network:*

They connect the controlling terminal to the master control terminal via the transmission network. The RAN and core network form the transmission network's core. As a communication architecture, 5G with RAN and core network can provide the basic communication requirements necessary to realize the tactile Internet vision. [16]. The Figure 10 shows the interaction between the master control terminal, and the controlled terminal through the tactile Internet.

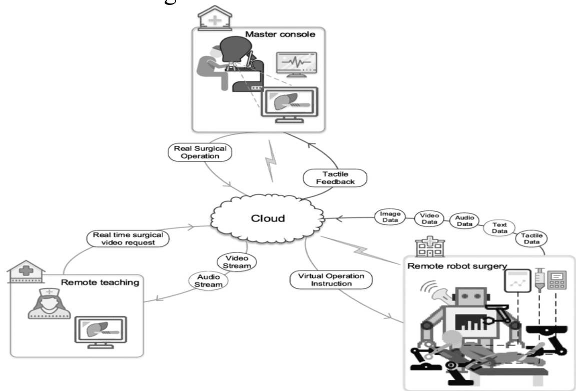

Fig. 10. The interactive mode of a telesurgery robot

Telesurgery demands a high level of reliability, a short response time, and a high data transmission rate; hence, the robot's communication requirements for multi-modal sensing data transmission via 5G tactile Internet are provided in Fig. [16].

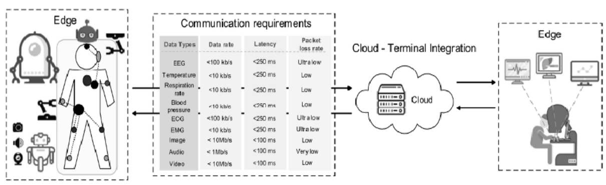

Fig. 11. Communication of a telesurgery robot for the 5G tactile Internet

Telesurgery systems of the future will necessitate upgrading the hardware infrastructure and designing a better communication strategy to meet the requirements of the application.

5G Solutions

The reason why mobile health (M-heath) is significant is that it provides a befitting solution to the difficulties we continually experience in the medical profession, such as avoiding clinical errors and boosting the performance of medical services, thereby decreasing overall operational expenditures. These solutions may be implemented utilizing the following 5G network capabilities:

1) *Low Latency*

When it comes to telesurgery, communication latency has a direct effect on robotic engines. Communication latency can be lowered to less than one millisecond using 5G.

2) *Bandwidth*

5G networks will be able to accommodate higher frequencies and a larger spectrum, allowing for extremely high transmission rates [21][22].

3) *Scalability and Network Capacity*

5G is projected to reduce congestion and data transfer to a massive number of medical devices while taking patterns into account because of the possible data overload with biomedical sensors.

4) Long Battery Life

5G is designed to operate without requiring a battery c5G is planned to run without requiring a battery maintenance till at least 10 years, making it a promising alternative for linked devices that become self-sustaining all through the medical procedure.

5) Security

Given an increase in number of 5G network tenants, 5G networks should be capable of considering increased privacy protection [23] [24] [25].

IV. 6G Applications in Healthcare

The incorporation of Ai - powered algorithms with 6G provides better tracking of a condition of the patient and the development of automated warnings for healthcare, and real-time and relevant engagement with all health providers. All of this contributes to lowering mortality and morbidity rates, as well as length of stay in the hospital and overall medical costs. This section discusses a few of the 6G technologies to be applied in upcoming healthcare services.

1) In-body, on-body, off-body Communications

This technique intends to remotely monitor people's health by utilizing ICT tools. The Body-Layer encompasses all forms of communication: in-body, on-body, and off-body. Off-body communications enables the transfer of real-time data to edge equipment and the cloud. In the body, sensors are represented by nanostructures or molecules that function as biological communication networks [26].

2) Intelligent Nanoscale Inner Body Communications

Biological cells in the human body bring about a new revolution which is the internet of Bio-Nano Things (IoBNT), where is the intra-body observation and manipulation are possible. Medical information is collected and provided to the doctor or nurse, and appropriate actions are activated remotely. In this regard, 6G technology is significant, it will allow IoBNT and IoNT linking [13][27].

3) Human Bond Communications

In this method, each of the human senses are employed to detect and transmit data. The transmission of a human being's "thoughts" or experiences to another may become a reality soon. 6G may be viewed as a "material" technology that offers a compelling user experience through the perception of the information saved from the emotions' sensors [28]. Enhanced services, such patient monitoring, diagnosis, assistance, and treatment, are possible.

4) Visible light Communication

Visible Light Communication (VLC) refers to type of optical wireless technology. VLC delivers data using light rays as a tool. It may be used to acquire data from the body and for extensive communication between users, as well as to take use of the infrastructure that can provide a downlink channel for enhanced connectivity [29][30].

V. 6G Challenges

Challenges of 6G communication technologies on data privacy and security, technological, moral, and legal concerns are described below:

1) Privacy and Security

The development of encrypted transmission within and on the body continues. Numerous powerful authentication systems and cryptography algorithms featuring shorter key lengths are required. Additionally, additional study is required to address biomolecules' unexpected reactivity and unforeseen catastrophic outcomes [31].

2) Technological Aspects

Communication between body layers enables the retrieval and circulation of critical data to the cloud. Each of these several node kinds has significantly diverse communication requirements. Combining and correlating data from continuous human body monitoring is possible. Collecting data from a diverse range of sensors ranging between micro to macro [32-40].

3) Ethical Aspects

Equity in access to healthcare processes is one of the ethical difficulties that requires citizens to participate in processes that demands higher health literacy; therefore, involving citizens in processes as data owners is necessary for driving processes ethically. To avoid leaving marginalized citizens behind, a unified regulatory framework must be formed.

VI. Conclusion

In this paper, we performed a thorough research of the most recent published papers about the applications of 5G and 6G networks in the health sector. Some papers showed how the need for more advanced technologies is vital due to the great number of limitations that come with 4G networks, including but not limited to, high delays with limited number of users, and high packet loss. Therefore, we presented multiple applications that could solve a great number of limitations in the health sector using 5G and 6G networks. 5G applications have solved a huge number of healthcare industry problems; like eliminating medical errors and enhancing the quality of medical services. While 6G technologies can employ real-time monitoring of patients, such as IoBNT, on-body and in-body communication, which is an essence to the healthcare industry that can be cost and time-effective for both end-users and the government, they come up with challenges. As discussed earlier, those challenges can be ethical, technical or privacy concerned which be solved in the future to allow a new era of advanced technologies that can accommodate developed countries' dreams and achieve the 2030 vision of Saudi Arabia.

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