The Application of 5G Communication Technology in the Medical Field

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Abstract. The emergence of 5G technology has brought subversive changes to the medical field. Its characteristics of low latency, high bandwidth and large-scale equipment connection have significantly improved the efficiency, quality and accessibility of medical services. In telemedicine, 5G overcomes the shortcomings of traditional communication technology, enables patients in remote areas to enjoy high-quality medical services, and promotes the sharing of transnational medical resources. In the management of medical equipment, the Internet of Things technology supported by 5G realizes real-time monitoring and efficient management of equipment, optimizes the utilization rate of equipment and reduces the operating cost of hospitals, as seen in the Guangdong Second Provincial General Hospital's connection of over 30,000 devices for real-time equipment management. However, the full application of 5G in the medical field still faces challenges such as high infrastructure construction costs and increased data security risks. Future advancements integrating 5G with artificial intelligence and big data hold promise for driving precision medicine, global health equity, and the digital transformation of healthcare.

Keywords: 5G technology, Telemedicine, Medical Internet of Things.

1. Introduction

The emergence of 5G technology has brought unprecedented opportunities for the digital transformation of all sectors of life. Currently, the application of 5G technology has surpassed the traditional communication field and has gradually penetrated into multiple industries such as industry, transportation, education and health care. In recent years, the construction of 5G networks around the world has been continuously accelerating. According to GSMA Intelligence, 261 operators in 101 countries have launched commercial 5G services, and the number of connected devices has grown rapidly. It is expected that 5G will cover two-thirds of the world's population by 2025.

In the medical field, the application of 5G shows great potential. For example, in 2021, Huawei in China established a 5G remote consultation system specially designed to fight COVID-19, connecting 147 hospitals in 108 counties and 18 cities [1]. Besides, Verizon improves the efficiency of collecting patients' health data through the health monitoring equipment supported by 5G. These cases show that 5G has significant advantages in improving medical efficiency and service quality [2]. However, the current popularity of 5G still faces challenges such as imperfect infrastructure and insufficient uniformity of technical standards, which limits its application in a wider range of fields.

This essay will first introduce the definition and characteristics of 5G technology, and then analyze the specific application scenarios of 5G technology in the medical field. Finally, this essay will summarize previous findings and critically analyze future development trends.

2. 5G Definition and Technical Characteristics

2.1. Definition

5G is the abbreviation of the fifth generation of mobile communication technology. As the core of the new generation of communication networks, 5G marks another revolutionary leap in mobile communication technology. According to the International Telecommunication Union (ITU), 5G is a wireless communication technology that supports extremely high data transmission rates, ultra-low latency, and large-scale device connections. Its core goal is to meet the growing data demands of

modern society, offer users a faster network experience, and provide a solid technical foundation for the digital transformation of various industries [3].

Compared with previous generations of communication technologies, 5G has wider application scenarios and higher performance indicators. The first generation of communication technology (1G) only supported the transmission of analog voice. Then 2G realized digital voice communication. 3G promoted the popularization of mobile Internet, and 4G made it possible to transmit high-definition video and make real-time video calls. Based on these technologies, 5G has achieved a qualitative leap, and its performance far exceeds that of the past. The peak data transmission speed reaches 20Gbps, which is more than 20 times that of 4G [4].

In addition, the 5G network is flexible, and can be segmented according to different APP application requirements, thus providing users with highly customized network services. For example, an integrated 5G network can meet the needs of high-speed video download, low-delay autopilot and large-scale device connection at the same time. Through this flexibility, 5G is not only a communication tool, but can also become an infrastructure solution suitable for various situations, laying the foundation for widespread applications in industry, transportation, healthcare, and more.

2.2. Technical Characteristics

The core advantages of 5G technology are reflected in the substantial improvement of performance indicators and the ability to adapt to various scenarios. Low latency and large equipment connection (mMTC) are the two most important technical features.

2.2.1. Ultra-Low Latency

Low latency is one of the core advantages of 5G technology. Its minimum delay is as short as 1 millisecond, which is 250 times that of human response to visual stimuli. In comparison, the typical delay of 4G network is 200ms [5]. Due to the ultra-low latency of 5G technology, self-driving cars, remote surgery, complex robots and other devices can respond to commands almost immediately. For example, remote surgery needs very accurate control, and network delay may lead to serious consequences. In 2019, in China, the operation delay can be controlled within 2ms through remote surgery supported by 5G technology, and doctors can operate the robotic arm to perform complex operations across regions. [6].

In addition, low-delay technology also has important applications in the field of autonomous driving. The low delay feature of 5G allows seamless cooperation between on-board sensors and central control system, which improves the safety and reliability of autonomous driving. For self-driving vehicles, low delay allows vehicles traveling at 60 miles per hour to react to road obstacles and brake before rollover. Compared with human braking response, this amazing progress enables the car to roll over more than 30 yards before braking. This shows that low latency can not only improve the efficiency of data transmission, but also provide the necessary guarantee for the main business solutions of many industries.

2.2.2. Massive Machine-Type Communication

With the rapid development of the Internet of Things (IoT), billions of devices need to be interconnected via wireless networks, and traditional networks are difficult to meet this demand. 5G technology is particularly outstanding in large-scale device connections. According to ITU standards, the connection density of 5G per square kilometer can reach millions of devices, which far exceeds the capabilities of 4G networks.

This feature is evidently reflected in smart medical care. For example, in a large hospital, thousands of devices are connected to the network at the same time, such as remote monitoring equipment, operating room instruments and wearable health equipment for patients. Traditional networks are prone to delay and instability when faced with such high-density equipment connection, while the high connection density of 5G can ensure the stable operation of all equipment. For example, in 2021, Huawei shared with the Second People's Hospital of Guangdong Province (GD2H) to establish a full-scene smart hospital. This hospital adopted the Internet of Things technology

supported by 5G to connect more than 30,000 devices. Additionally, it established several operation management systems and a series of medical service systems, including hospital information system (HIS), electronic medical record (EMR) and consumables system [7].

3. Specific Applications of 5G Technology in the Medical Field

3.1. Telemedicine

Telemedicine, as an important direction in the digital transformation of the healthcare industry, has the core value of breaking through geographical and resource constraints, allowing patients in remote areas to access medical services at the same level as those in big cities.

With its ultra-low latency of 1 millisecond and transmission rate of up to 20Gbps, 5G technology provides a technical guarantee for the smooth development of remote surgery. In 2019, a Chinese doctor successfully implanted a brain stimulation device into a Parkinson's disease patient located 1,900 miles away with the support of a 5G network. In this process, the 5G network enables the real-time transmission of high-definition images and operation signals, allowing doctors to accurately control the robotic arm to complete difficult operations. This case shows that 5G technology can significantly narrow the geographical gap in medical resources and bring hope of life to patients in remote areas. In addition to hospitals, 5G networks will allow ambulances to send real-time computed tomography (CT) pictures and patient medical information to hospitals. Now, medical personnel can focus on the patient instead of wasting time on transferring paperwork. Further out, physicians in remote locations can instantaneously send patient records, including blood glucose readings and electrocardiogram (ECG) findings, to large hospitals like GD2H. This allows individuals to access more advanced and specialized medical facilities without having to travel long distances.

Moreover, in complex cases, Multidisciplinary diagnosis and treatment (MDT) is the key to improve the accuracy of diagnosis and treatment. Traditional networks are often overwhelmed when faced with large-scale data transmission. However, the high bandwidth characteristics of 5G can easily meet this demand. For example, the China-Japan Friendship Hospital and a Singapore Hospital conducted a remote consultation on a critically ill lung patient and transmitted 12GB of medical image data within 12 hours [8]. The whole process has smooth data transmission and clear images, which enables the expert teams of the two countries to cooperate seamlessly and make accurate treatment plans for patients.

The popularization of telemedicine not only breaks the problem of uneven distribution of medical resources, but also improves the efficiency of treating critically ill patients. Patients in remote areas no longer need to travel long distances to big cities for medical treatment. Instead, they can enjoy top-notch medical services through 5G technology at local hospitals [9]. At the same time, the sharing of cross-border medical resources has also made cooperation in the global medical field possible, especially in responding to global public health events, where 5G telemedicine can play a crucial role.

Although 5G has broad application prospects in telemedicine, there are still some challenges that cannot be ignored. Firstly, the deployment cost of 5G networks is high, especially in remote areas. The difficulty and cost of infrastructure construction may exceed the local economic capacity, making the popularization of technology face practical obstacles [10]. Secondly, telemedicine has extremely high requirements for network reliability, but in bad weather or network congestion, 5G signals may be unstable, which in turn affects the real-time and safety of surgery or consultation [11].

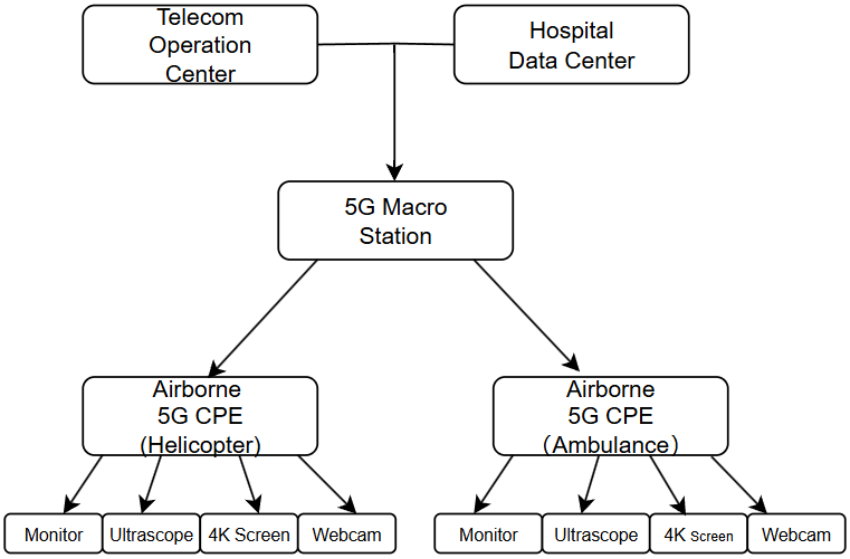

Figure 1. 5G Healthcare Telemedicine Technical Framework

The application structure of 5G technology in telemedicine is shown in Fig. 1. Telecom operation center acts as the central coordination hub for the telemedicine network. Telecom operation center and hospital data center are interconnected through 5G macro station (backbone of the 5G network, providing ultra-fast and low-latency connectivity), which supports real-time high-definition image and data transmission. Air medical units and ground ambulances use 5G networks to connect key equipment, such as monitors, ultrasonic equipment and high-definition display screens, to provide technical support for remote diagnosis and emergency treatment. This 5G-based system revolutionizes healthcare delivery by ensuring that patients receive critical care and diagnosis while being transported, regardless of location, significantly improving medical outcomes.

3.2. Internet of Things in Healthcare

The equipment management of modern medical institutions has become an extremely important and complicated task. With the expansion of hospital scale and the progress of medical technology, the quantity of equipment such as insulin pumps, ventilators, electrocardiographs and other electrocardiographs is increasing. These devices are not only multifunctional, but also expensive, and the demand for real-time monitoring and efficient management is increasingly urgent.

5G offers a higher connection density, enabling the number of devices that can be reached per square kilometer to reach millions, far exceeding the capability of traditional communication networks. This is undoubtedly the technological advantage of 5G, laying a technological foundation for large-scale IoT applications such as medical equipment. Take the hospital as an example, where IoT sensors help track and manage key equipment-mostly small pieces like an insulin pump, a ventilator, or an electrocardiograph-on a real-time basis [12]. This method could not only make the needed equipment easy to find by medical institutions, but also possibly enable real-time status monitoring of the equipment for frailty detection in advance, hence improving maintenance efficiency and avoiding delays in treatment due to equipment failure.

Operating data can be sent to the central management system supported by 5G networks, facilitating comprehensive analysis by medical institutions. For example, if an abnormality in operation is detected by a sensor of an electrocardiograph, the system will automatically trigger an alert to the maintenance team and arrange reviews and repairs in advance. This real-time data processing capability greatly optimizes the efficiency of equipment use. For example, the GD2H Intelligent Operation Center (IOC) is based on 5G network integration, aggregating data from hospital operation management, medical services, and scientific research systems to achieve visualization of the five major modules of overall situation, medical operations, security, fire protection, and energy consumption. This allows GD2H modular prefabrication to shorten the construction time of data

centers by 50%, and intelligent modules to maximize the use of natural cooling sources, saving 17% energy and 40% water.

The introduction of 5G technology provides a new solution for medical equipment management. Real-time equipment monitoring can ensure that every equipment in the hospital is in optimal condition. This not only reduces the idle rate of equipment, but also effectively prolongs the service life of equipment. At the same time, this efficient equipment management model has also helped the hospital to reduce the overall operating costs, enabling more resources to be used to improve medical services. For patients, the precision of equipment management also means that the safety and timeliness of medical services have been significantly improved. For example, the immediate availability of Electrocardiogram machines, ventilators and other equipment is directly related to the life safety of patients. The application of 5G technology can minimize the risks caused by the unavailability of equipment.

Although in general, 5G has broad prospects in medical device management, it still has some challenges or potential problems. In the first place, every hospital needs to establish comprehensive hardware and software infrastructure for the management of 5G IoT devices, including huge investment costs. Full deployment of 5G technology is unfeasible by less well-endowed medical institutions. In addition, with the development of device connections, the volume of data will increase, raising an ever-higher demand on network security capability. In cases where safety functions in the capacity of a network system are not comprehensive enough, sensitive data produced by devices can leak or be used illegally, thus threatening patient privacy.

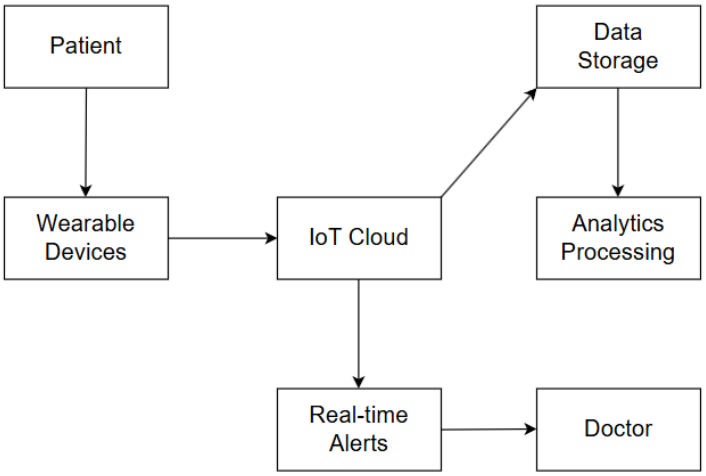

Figure 2. 5G IoT Healthcare Technical Framework

The application structure of the IoT supported by 5G in medical equipment management is shown in Fig. 2. Wearable devices used by patients transmit health data to IoT cloud platform in real time, and the data are then stored and analyzed to generate health reports or early warnings. Doctors can receive reports and make diagnosis in real time, so as to take intervention measures quickly. The advantages of the framework are continuous monitoring, Low-Latency Communication (speed of data transmission is extremely quick), remote access (doctor could monitor patients anywhere) and proactive intervention (doctors can respond quickly to alerts).

4. Conclusion

5G technology has brought revolutionary changes in the medical field. Its characteristics of low delay, high bandwidth, and large-scale device connection have significantly sped up the efficiency, quality, and accessibility of medical services. Telemedicine provides for defects in traditional communication technology, makes every effort to provide high-quality medical services for patients in remote areas, and pushes forward transnational sharing in medical resources. Use 5G in equipment management and IoT to enable real-time monitoring and efficient management of devices. Optimize equipment utilization and reduce operating costs of the devices. These results show that 5G

technology has pushed the medical industry toward intelligence and digitalization by offering new ideas for solving the problem of uneven distribution of medical resources.

Although the medical field has huge application potential for 5G, there are still many challenges that need to be addressed in comprehensive promotion. One of the future development trends is accelerating the deployment of 5G infrastructure in remote areas to narrow the gap between urban and rural medical services. In addition, data security and privacy protection will become the key research direction, and the security and reliability of patient information will be ensured through stronger network encryption technology and data protection mechanism. At the same time, the deep integration of 5G technology with advanced technologies such as artificial intelligence and big data will also play a greater role in medical diagnosis, precision treatment and public health management. Through the continuous improvement of technology, 5G is expected to further promote the fairness and universality of global medical services and achieve greater contributions to human health and well-being.

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