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Application and Research of 5G Communication Technology in Intelligent Coal Mine

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Abstract: In recent years, science and technology in China has been developing rapidly, and various industries have begun to undergo changes due to the development. Coal mining is a highly dangerous industry. Therefore, proper technology is needed to improve the quality and safety of coal mining. The application of 5G communication technology allowed for the development of intelligent coal mines, with broad application prospects and research value. This article aims to thoroughly analyze the application of 5G communication technology in intelligent coal mines, considering the practical context. The goal is to offer insights and guidance for future endeavors in this domain.

Keywords: 5G communication technology; Intelligent coal mine; Application

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1. General introduction

After the "Guiding Opinions on Accelerating the Intelligent Development of Coal Mine" was put forward in 2020, the domestic coal mining industry has actively developed new technologies to build intelligent coal mines. As one of the important industries in China, coal mining can provide sufficient power for social production. In order to improve the quality and efficiency of mining, coal mining enterprises must make full use of 5G communication technology. Therefore, it is necessary to analyze the application of 5G communication technology in intelligent coal mines.

2. Introduction to 5G communication technology

5G is the fifth-generation mobile communication technology, featuring high speed, low latency, and wide connection. The International Telecommunication Union has defined three major applications of 5G: enhanced mobile broadband, ultra-high reliability and low-latency communication, and massive machine-type communication[1]. Among these, enhanced mobile broadband addresses the significant surge in mobile internet traffic, ensuring a seamless user experience. Ultra-high reliability and low-latency communication are crucial for applications like industrial control, telemedicine, and autonomous driving, where reliability and minimal delays are critical. Mass machine communication targets smart city development, environmental monitoring, and smart home systems, catering to the needs of data sensing and acquisition. The three aforementioned application scenarios collectively constitute the realm of 5G communication technology. Given the prevailing societal trends, 5G technology has been extensively

adopted across various sectors, showcasing strong application value and promising developmental opportunities.

3. The necessity of applying 5G technology in the intelligentization of coal mines

The application of 5G communication technology marks that our society has entered a new stage. The intelligent construction of coal mines is in line with the development trend of the times and the objective needs of industry development. Its necessity is mainly reflected in several aspects: firstly, the application of 5G communication technology is in line with the construction of intelligent coal mines. This technology facilitates the realization of Internet of Things (IoT) sensing, information integration, smart control, and comprehensive management, significantly enhancing the safety and efficiency of coal mining operations. Moreover, it mitigates the hazards associated with manual labor, thereby reducing the potential risks incurred during mining activities. With 5G technology, the degree of intelligence of coal mines will be greatly improved, and the process of intelligent development will be accelerated[2]. Second, it can effectively control the cost of the enterprise. The application of 5G technology can to replace manual operations by integrating different equipment and machinery, thus improving mining efficiency and quality. Unlike manual operations, mechanical equipment and the application of advanced technology can realize 24 h operation, and only requires monitoring staff, thus reducing manpower and overall cost, and improving production efficiency. Third, the application of 5G technology can greatly improve the safety of coal mining. Since coal mining is usually done underground, mining personnel often need to face a more complex environment, making them prone to safety accidents. In view of this, 5G technology can realize the effective monitoring of the mining environment of underground coal mines. Once a problem occurs, an alarm can be issued in time, thereby avoiding risks, improving mining safety, reducing economic losses of coal mining enterprises, and generating more profit.

4. The application strategy of 5G technology in the intelligentization of coal mines

4. 1. Virtual interaction based on 5G technology

In 3 D modeling, the application of 5G technology can be used for virtual presentation, which improves the intelligence of coal mines. In the past, human-computer interaction was the main mode. This mode has certain limitations. Managers cannot directly obtain relevant data information, which affects the effectiveness of coal mining operations[3]. 5G technology can realize 3 D modeling and virtual presentation. Based on the visual design, managers can understand various information and equipment locations under the mine more intuitively, and various processes such as cloud real-time rendering and hybrid implementation can also be performed, improving the effectiveness of human-computer interaction. This ensures streamlined, accurate, and efficient information transmission, greatly benefiting operators. Precise positioning and data enable systematic management and control of mechanical equipment, thereby promoting standardized operations and optimizing mining efficiency.

4. 2. Precise positioning

Traditional coal mine underground positioning is performed using ultra-bandwidth transmission and Bluetooth, but it is difficult to achieve accurate positioning through these methods. When the infrastructure is not well positioned, the effectiveness of coal mining will be affected[4]. The application of 5G technology can greatly improve positioning accuracy and avoid the above problems. It involves the comprehensive collection of diverse data produced during coal mining and production via extensive network coverage. Subsequently, this information is relayed to the control center, ensuring both timeliness and

efficacy while delivering more precise and comprehensive data support. Evidently, 5G´s low latency emerges as a primary developmental focal point. This attribute facilitates improved network positioning and the expansion of application services. Accurate and autonomous positioning of mechanical equipment not only enhances its operation but also facilitates dynamic data feedback, which, in turn, supports informed decision-making for effective deployment planning. This contributes to the overall scientific efficiency of deployment strategies.

4. 3. Collaborative operation & maintenance based on 5G technology

Through the analysis of the application of 5G technology, it is not difficult to see that the remote collaborative operation and maintenance of mines belongs to the scenario of mobile network communication technology[5]. Since coal mining is usually carried out in an underground environment, the mining space is small and unique. In view of the continuous shrinking of the mine space, it is necessary to upgrade, install, and transform the intelligent system. Traditional manual maintenance methods alone will not be sufficient. The establishment of a dedicated remote system is crucial to facilitate seamless collaboration between manual and remote commands, thereby enhancing the overall efficiency of operation and maintenance processes. Leveraging 5G technology for comprehensive data collection from the mine, encompassing audio, video, parameters, and more, allows for real-time data transmission. This data can then be utilized by intelligent equipment to ensure the development of robust virtual operation models or systems, providing a solid foundation for effective implementation. With virtual reality, coal miners and managers can cooperate better, and the need for manual maintenance will be reduced, thus reducing personnel cost investment and reducing the safety risks of miners[6].

4. 4. Mobile edge computing based on 5G technology

Mobile edge technology' s advancement predominantly relies on the utilization of IT service environments and computational capabilities to cater to end-user needs. These dual functions will serve as efficient tools to facilitate user engagement with mobile nodes, resulting in reduced latency and an elevated user experience[7]. By applying 5G network mobile edge computing science to the construction of intelligent mines, it can be reflected in various scenarios of the IoT, and then according to the needs of intelligent management and control, it will be analyzed with reference to mine scenarios to optimize the design of the scheme to ensure the application effectiveness of the technology[8]. The construction of mines needs to be analyzed based on the actual needs of intelligent coal mine construction. Cloud-edge collaboration technology should be used to improve mobile edge computing, so that the overall scientific research can be greatly improved. In addition, 5G technology can also be applied in the construction of a multi-layer intelligent framework, which can effectively promote the integrated development of cloud computing and edge computing, and the effectiveness of collaborative processing has been greatly improved. It is necessary to ensure all-round coverage, scientifically use artificial intelligence and deep-learning algorithms, cooperate with 5G technology, strengthen the operating environment perception of multiple types and multiple devices, ensure the accuracy of data collection, and speed up the process of information transmission. With the effective application of 5G technology, delays in the calculation process can be reduced. In case of an emergency or unforeseen situation during the underground coal mining process, the equipment hosting system can be initiated promptly to gather and analyze data. Subsequently, algorithms can be enhanced based on the situation, effectively elevating the level of intelligence.

4. 5. Monitoring technology based on 5G technology

5G technology is essential for safety monitoring in the construction of intelligent coal mines. Using 5G

technology, some dangerous areas can be better detected. In order to improve the effectiveness of environmental monitoring, it is necessary to install a large number of sensors on underground mining vehicles and equipment. While undertaking the installation process, it is crucial to focus on achieving low cost, solid stability, and minimal energy consumption. Besides, maintaining strong connectivity with the communication transmission network is essential to enhance transmission speed and ensure real-time performance. The 5G wireless communication system' s low power consumption and large connection scenario can control the terminal delay within 1 ms, and the connection density can reach $10^6/km^2$, fully meeting the needs of the mine safety monitoring information collection[9].

4. 6. Safe driving of mine vehicles

Under 5G technology and IoT, trackless auxiliary vehicle long-distance data communication and mobile base station layout technology have achieved better application, making full use of the existing dispatch management platform, while integrating high-performance, low-cost sensors and wireless communication equipment. This integrated approach significantly enhances the platform' s performance, enabling more efficient execution of scheduling, identification, and management tasks. [10]. With the support of many technologies, the communication needs of underground vehicles in coal mines can be greatly met. Together with the wide area network terminal, the operating data of all vehicles can be collected and uploaded to the cloud, providing accurate data support for coal mining and vehicle driving[11]. In addition, 5G technology, edge computing, and self-driving technology can improve the automation of personnel and material transportation, reduce the number of human resources required for underground operations, improve the effectiveness of auxiliary transportation, and realize automatic operations. Besides, the dispatching system will also be more efficient. Intelligentization and automation of transportation equipment makes coal mining easier, ensuring that the entire operation is realized under effective supervision to achieve automated operations and production.

4. 7. Remote real-time control

Remote real-time control is also a technique that emerged under 5G technology, which meets the needs of intelligent mine construction. Production control is especially important for the development of coal mining enterprises. Moreover, coal mining itself is a dynamic process, which requires dynamic control of underground conditions and monitoring. Therefore, real-time control is required to ensure mining efficiency and safety, which necessitates the application of this technology. In the traditional mode, remote control is done through routers, network protocols, and sensors. Although this method achieves its purpose, it actually has low transmission efficiency and limited real-time transmission, along with other problems, which greatly limit the effectiveness of coal mining[12]. Using 5G technology, combined with the specific coal mine space structure and operation needs, etc., set up a real-time remote monitoring system and organizational structure, complete the comprehensive and dynamic monitoring of the mine, and develop a professional control module to ensure the effectiveness of remote control. All control tasks will be presented in the form of menus to provide adequate protection for underground operators[13].

5. The development prospect of 5G technology in the intelligentization of coal mines

On the whole, there are still some limitations in the application of 5G communication technology in the construction of intelligent mines. It is believed that with the development of science and technology, its application will be more extensive in the future, making coal mining easier[14]. Specifically, its future development trend includes the following aspects: first, the network is fully covered. Within the scope of intelligent mines, all skeleton networks will be covered in the form of 5G, which improves transmission

efficiency while ensuring normal underground communication and eliminate the limitations of traditional optical fiber network. Secondly, it can be arranged according to the actual working conditions in the mine, and the 5G micro base station can be scientifically adjusted to improve the utilization of resources, help coal mining enterprises save resources, reduce costs, and create higher economic value. Third, on-site analysis should be carried out according to the needs of underground coal mining to realize personalized development and ensure scientific and reasonable technology application. The existing transmission platform can serve as the foundation for establishing an integrated platform mechanism that aligns various scenarios with platforms. This approach not only facilitates real-time transmission but also enhances perception capabilities. This trend represents a significant trajectory for future 5G technology applications. Its application in mining construction contributes to achieving true visualized and intelligent mining operations, thus underpinning the enhancement of coal mining´s quality and efficiency. [15].

6. Conclusion

To sum up, in order to better meet the needs of social production, the quality, efficiency and safety of coal mining must be improved. The construction of intelligent coal mines has been increasingly highlighted after the state promulgated relevant policies, and the application of 5G technology has accelerated its construction. The application of 5G technology will be more extensive in the future. While achieving full coverage, it can also analyze the scene under the mine, and realize the integration of various technologies. The problems of transmission and perception can also be improved, which in turn promotes the development of the mining industry. The degree of intelligence lays the foundation for the continuous operation of coal mining.

Disclosure statement

The authors declare no conflicts of interest.

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