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Research Article

Application of 5G Communication Technology Based on Intelligent Sensor Network in Coal Mining

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Intelligent mining provides an indispensable, strong technical support for the construction of intelligent mines. Intelligent tunneling technology is an inevitable requirement for safe and efficient production of coal and a fundamental way to solve the imbalance of mining in order to improve the deficiency of data transmission in light of intelligent coal tunneling technology. Based on intelligent sensor and 5G technology, this paper puts forward a kind of intelligent tunneling support transportation integrated technology. According to the geological conditions of the surrounding rock in different coal seams, the anchor road header and 5G continuous intelligent tunneling mode are adopted. At the same time, the data communication network coverage suitable for underground unmanned driving is expounded, and the performance indexes that need to be met for accessing WLAN network are given based on the actual engineering experience. The breakthrough of underground unmanned driving application that 5G new communication network will bring is analyzed. And the construction mode of 5G platform of underground coal mine sensor network is given.

1. Introduction

In recent years, coal mining technology has made full progress and made great contributions in meeting the national energy demand [1–4]. In particular, with the progress of science and technology, intelligent coal mining technology has gradually replaced the methods with backward production capacity [5–10]. However, the mine is deep underground, and the efficient communication problem has been one of the research hotspots in the field of intelligent coal mine. Consequently, the traditional coal industry is expected to upgrade to the smart coal industry. It is necessary to make progress in 5G technology of sensor networks. This is also the condition for ensuring the efficient and high-quality development of the leading enterprises in the industry.

Since the 1980s, 1G communication technology has been used in coal mine communication. With the rapid development of communication technology, in the process of coal mine intellectualization, the fifth-generation mobile communication technology can integrate the fourth industrial revolution technologies such as Internet, artificial intelligence, big data, and cloud computing and become an effective thrust of coal mine intellectualization [11–17]. 5G technology is used to enhance mobile broadband, ultrahigh reliability, and ultralow delay communication) and Dalian Internet of Things are used in intelligent sensor networks [18–24] to solve the bottleneck problems such as the intelligent perception of the mining face and the intelligent unmanned transportation of the mining coal mine in the complex relationship between the machine and the environment in the coal mine production [25–28].

Therefore, in order to further promote the applicability of 5G technology in intelligent mining of coal mines. Aiming at the existing problems in intelligent tunneling transportation, this paper puts forward a three-dimensional and all-round intelligent tunneling mode of tunneling support transportation, and adopts 5G technology to realize continuous tunneling. A series of basic support technologies designed in this paper have also been improved, and the top-level design of production and management has been improved. Therefore, the ecological intelligent coal mining based on 5G technology is of great significance in the future coal mine construction.

2. Main Problems and Solutions of Intelligent Tunneling in Coal Mines

2.1. Complex Difficulties in Coal Mining. Coal rock, as a kind of soft rock, often causes geological disasters of large deformation in the process of tunneling. There are joints, fractures, pores, and bedding planes of different sizes in coal, which show heterogeneity and anisotropy. At the same time, large coal seams contain geological complexes such as faults, folds, and collapse columns of different states, which result in the characteristics of nonlinear, large impact, and strong coupling of cutting and drilling load. It brings great technical challenge to the adaptive control of cutting and drilling. In China, soft rock roadway accounts for a large proportion of coal mine roadway. Coal rock is a special rock mass. Its strength is low when it is used as surrounding rock of roadway. Under the action of external weathering and groundwater, the performance deteriorates rapidly. This also increases the instability of roadway construction.

Water damage, gas, dust, rock burst, etc., that may occur in the coal heading face pose a serious threat to the frontline workers. The existence of gob roof and gob wall brings great safety risk to roadway management. The control of surrounding rock in rock burst roadway has always been a worldwide problem. For a long time, the number of water bursting, gas outburst, and roof and rock burst accidents and the number of deaths in the coal mine accidents are more than 30%. The dust of working flour not only causes serious damage to the occupational health of the operators but also brings technical challenges to the application of machine vision technology in the tunneling scene.

Coal cutting, coal loading transportation, temporary support, bolt support, advance detection, ventilation, and dust removal constitute the whole process of coal roadway tunneling. Therefore, in the overall process, due to the limited space of the excavation face, the experience of multiple series operation is adopted. Especially for the anchor bolt to be installed, the process is complicated. The concrete steps include laying network, installing steel belt, drilling, installing anchor agent, installing anchor bolt, mixing anchor agent, and pretightening. The supporting time accounts for about 60% of the tunnel completion time, and the number of workers accounts for 70%. Therefore, the abovementioned procedures are the key and difficult points of high-efficiency and intelligent construction of coal mines.

2.2. Difficulties to Be Solved in Intelligent Tunneling of Coal Mine. Under the target guidance of intelligent rapid tunneling, it needs to be highly reliable for tunneling equipment. It is highly adaptable to complex geological environment, and the operation procedures are highly collaborative. The main purpose is to get rid of the direct control of the machine and realize the high-speed and high-performance self-learning of the machine through 5G technology. Therefore, the whole tunneling system needs to solve the following problems:

(1) At present, the automation degree of bolt drilling equipment based on bolt drilling locomotive and single bolt drilling machine is low. Tunneling equipment based on cantilever road header and excavation anchoring machine is difficult to perform roadway during construction, and tunneling and supporting cannot be operated in parallel. In terms of equipment reliability, the overall reliability of production tunnel equipment is low. It is difficult to adapt to complex and changeable working conditions and harsh environment. High failure rate, low start-up rate, low service life of key components

(2) The stability of surrounding rock in the process of excavation and support is the premise and foundation of intelligent excavation, and the deterioration of surrounding rock such as roof fall, wall slice, and bottom drum may cause the interruption of excavation construction. In traditional tunneling, the state of surrounding rock is determined by manually knocking the wall and asking the top and assisting the roof separation instrument. In intelligent tunneling, the artificial perception is replaced by the intelligent perception of the tunneling equipment so as to realize the dynamic analysis of the real-time perception information of the equipment and the state of surrounding rock during the tunneling process so as to judge the sustainability of the tunneling process, the uncertain factors in the tunneling process, and optimization of the bolt support parameters

(3) A high degree of coordination between the tunneling equipment group and the tunneling process is the goal of future work. At present, each equipment on the working line of the heading face is independent, lacking the functions of information perception, communication and intercommunication, weak real-time cooperation ability, poor human-machine interaction, and no tunneling pipeline has been formed in basic technology and theory

2.3. 5G Network Technology. The fifth-generation mobile communication technology (5G) is a new integration of the new wireless access technology and the existing wireless technology, with high-speed data rate, ultralow delay, and super large-scale access. It is an application scenario of supporting the mobile Internet through communication between people, people and machines, and machines and machines. And with the passage of time, 5G network adapts to the flexibility of different applications and diversified business needs. It provides diversified service requirements and features such as ultrawideband, ultralow latency, large-scale connectivity, and ultrahigh reliability. Providing the best user experience efficiently and flexibly is the guiding goal of 5G network system design. The comparison of key technical indicators of 5G and 4G is shown in Figure 1.

2.4. Necessity of Intelligent Application of 5G Technology in Coal Mine. The development of the coal industry must take the intelligent road. This is also an inevitable requirement of the high-quality development core of the industry. Coal mine intelligence cannot be separated from the efficient interconnection of data and information, and the characteristics and

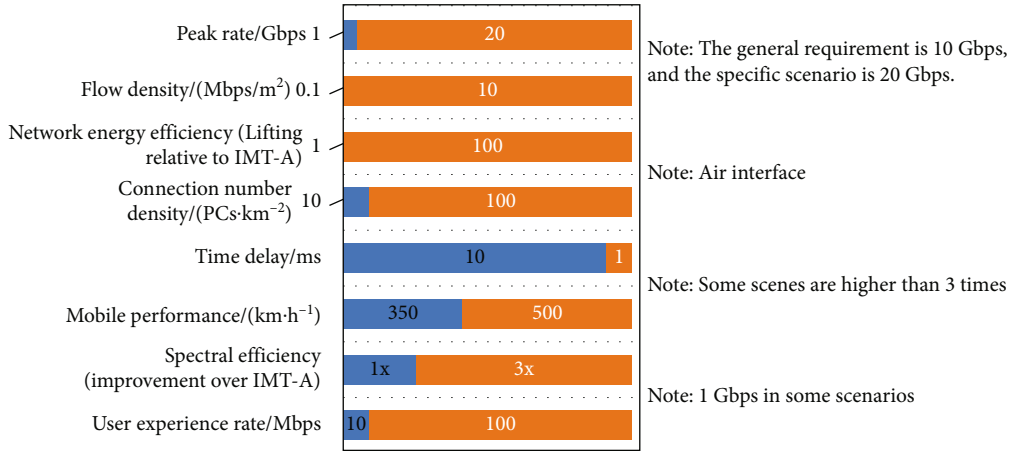

Figure 1: Comparison of key technical indicators between 4G and 5G.

transmission requirements of data in different coal mine application scenarios are very different. The traditional 4G +Wi-Fi data transmission technology is difficult to meet this differentiated demand, which leads to the mutual influence and restriction of various application scenarios in coal mines and cannot support the demand of intelligent development in coal mines. The characteristics of 5G large bandwidth, low delay, and wide connection, as well as the microbase station, slicing technology, and end-to-end connection, provide core technical support for breaking through the bottleneck of intelligent mining data transmission and processing in coal mines. 5G identified three application scenarios at the beginning of its design. Its technical support capability for eMBB scenarios can effectively meet the business needs of large bandwidth such as ultrahigh definition video transmission in coal mines. The technical support capability for urLLc scenarios can effectively meet the communication requirements between unmanned mining vehicles, unmanned excavators, and other unmanned mine intelligent equipment. The technical support capability for mMTC scenarios can better support the sensing data collection needs of various coal mine safety monitoring. Therefore, the application of 5G communication technology in intelligent coal mining (Figure 2(a)) is the only way for future coal mining. It will also effectively promote the process of intelligent coal mining and pave the way for "network communication" to fully open intelligent coal mining.

Fast data generation. Most 5G application scenarios are based on real-time support for large amounts of data. Meanwhile, the instantaneous output of IoT data supported by 5G will be tens or even hundreds of times that of previous data. Data generation will be much faster. The amount of data increases rapidly, and the amount of data per unit time increases exponentially. As time goes by, the amount of data accumulated tends to Pb or even ZB. This also lays the foundation for big data application analysis. Intelligent mining first needs to be supported by a large amount of sensing data, which has the following characteristics (Figure 2(b)).

In the past, in order to solve the problems of timely transmission and isolation of control data, video monitoring data and safety data in coal mines, the independent construction scheme of control communication ring network, video ring network, and safety ring network was mostly adopted. Although the problems of data sharing channel and safety data isolation were solved to a certain extent, the problems of large investment and difficult bottom layer connection and upper layer integration were also prominent. 5G technology adopts slice management technology to customize the network on demand. The private networks are isolated from each other and the underlying end-to-end are interconnected. It provides dedicated channels and security solutions for the transmission needs of different scenarios (Figure 2(c)).

The feasibility of intelligent application of 5G technology in coal mine needs to analyze the feasibility of 5G system deployment under special underground wireless transmission environment. When 5G wireless transmission technology is applied underground, there are mainly phenomena such as rapid attenuation of high-frequency wireless signals, enhanced directional transmission ability, and weakened diffraction ability. This leads to short transmission distance, and coverage is also very limited. These problems faced by 5G technology have been tackled as major problems in the early stage of 5G technology development. Therefore, ultradense networking technology, massive MIMO (large-scale antenna array), and microbase station technology have been developed. The breakthroughs in this series of key technologies have formed the 5G core technology system and supported the commercialization of 5G technology. From the perspective of network deployment, the 4G network currently arranged underground is a 4G+WIFI architecture, and the 4G coverage distance (based on the narrow and long spatial characteristics of the underground without the concept of coverage radius) is about 1500 m. While 5G has two types: macrobase station and microbase station. The macrobase station has large equipment capacity and high transmission power, which is not suitable for large-scale underground applications. Although the equipment capacity of the micro base station is small, its transmission power is low, and its effective coverage distance is about 500 m. Therefore, technically, the use of more than three 5G microbase stations can completely cover the control range of the original 4G network. Bring significant bandwidth and speed improvement and delay reduction. In addition, the power consumption and volume of a single 5G micro base

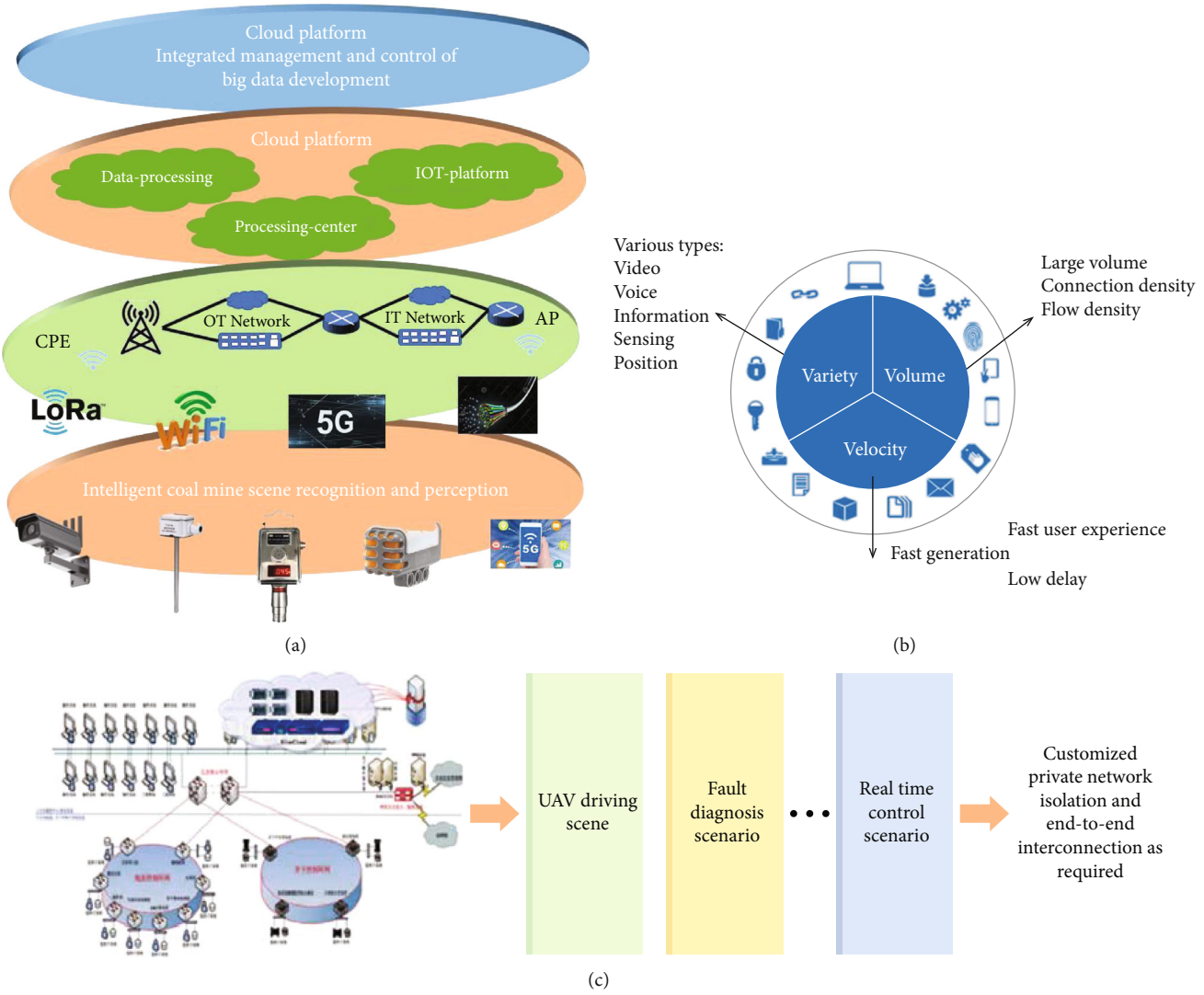

Figure 2: (a) Support for intelligent mining of 5G coal mine. (b) Support for intelligent mining of 5G coal mine. (c) Diversity of coal mine data.

station are smaller than those of the existing 4G base station, which is more conducive to the safety of long-term underground use. The layout of 5G micro base station is shown in Figure 3.

For other adverse environmental factors faced by the coal mine, reasonable application and planning of 5G technology can solve the problems of practical application in the mine. The key to success or failure is to design different 5G deployment schemes for different application scenarios and application environments. For example, for the long and narrow underground space with multiple branches, the mode of wired optical fiber backbone+dense 5G micro base stations should be adopted, and the control of power consumption and optimization of stations are the keys. In view of the problem of synchronous transmission of video monitoring and control signals, the key is to reasonably slice the network and make safety isolation. Therefore, the development of intelligent coal mining must establish a data transmission and distribution platform with 5G network as the infrastructure, build a 5G+coal mine application scenario, and provide a basic platform and application guarantee for the realization of intelligent coal mining.

3. 5G Communication Intelligent Coal Mining System Based on Intelligent Sensor Network

3.1. Coal Mine 5G Application Scenario Analysis. The future development of intelligent coal mines must be multidimensional, which should be reflected in the process of intelligent mining, intelligent transportation, and coal production and intelligent daily inspection. Therefore, 5G communication technology will have great application prospects in coal mines, which can be summarized in the following aspects:

(1) The cooperative remote control of intelligent working face determines the production efficiency and production safety. Therefore, there are extremely strict requirements on the transmission delay and reliability of the uplink production monitoring data and the downlink working face control data of the

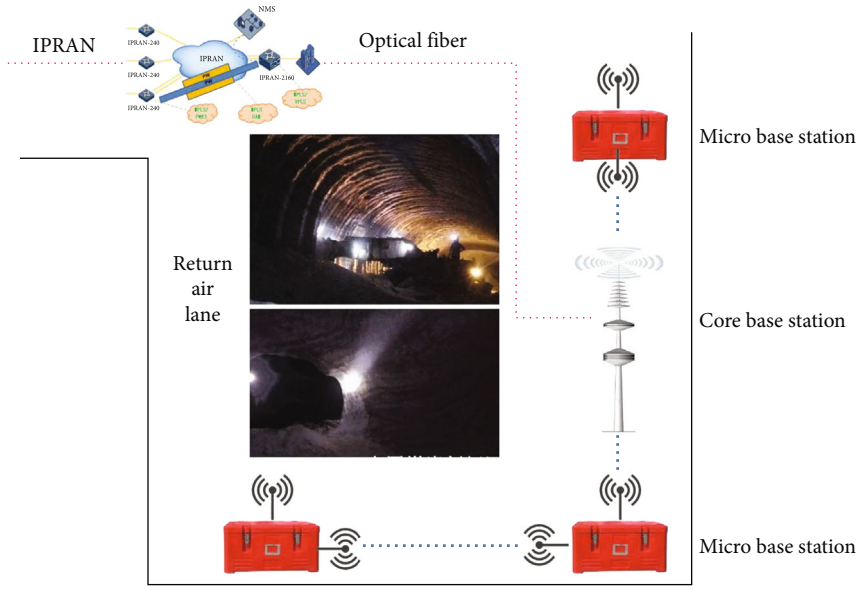

Figure 3: Layout of intelligent component communication working face.

5G wireless network. Uplink production monitoring data is mainly sensor data at present, so there are strict requirements for delay. Industrial image processing requires certain bandwidth and delay

(2) In the future, the maintenance of downhole equipment can be completed by remote guidance of experts. The maintenance workers will transmit the ultrahigh definition video information such as the machine status collected on the site to the remote end through the 5G network. Using virtual reality and other technologies, remote experts will guide the maintenance of onsite equipment

(3) In the scene of underground patrol inspection and security system, a large number of sensors will be connected to the network through 5G. In addition to the monitoring data such as gas and wind speed with low bandwidth requirements, there are also video monitoring data with high bandwidth requirements as well as data with high update frequency such as personnel positioning. It also requires multiple slice fusion processing to complete the support of the scene

3.2. Rapid Tunneling System Based on Support While Tunneling. According to the above analysis of the main difficulties and safeguard measures of intelligent tunneling. In this paper, the basic architecture of an intelligent tunneling system is proposed from four dimensions: edge sensing, platform decision, equipment execution, and remote operation, as shown in Figure 4.Through sensing the geological conditions, dig environment, and equipment working condition of the dig effort, we change the reliance on labor in the traditional dig process for the work surface "environmental perception." Based on the online sensing technique of rock state, we construct a high-precision 3D dynamic geological model oriented to dig work, and then introduce model amendment based on actual geological information uncovered during the dig process to effectively fuse the monitoring parameters of equipment state, advance probing parameters, and the quality of lane formation with the 3D geological model to provide data support for cut-off and support control.

Through data convergence and introducing a control platform for dig decisions supported by the equipment behavior criterion, decision ideas are formed to replace the original link of relying on artificial "judgment" based on technologies such as big data analysis and artificial intelligence. Based on the time control technique of rock, the purpose of this study is to construct an equipment behavior control model by studying the action mechanism and characteristics of cut-off and support based on the criteria of rock destabilization, load bearing characteristics of anchor support, and load bearing characteristics of coal rock.

Breakthroughs were made in key technologies such as intelligent support and automatic cutting, and an intelligent mining system platform was constructed to realize programmed actions such as cutting and supporting by relying on the intelligent mining suite. The intelligent mining suite based on mining support integration technology solves the collaboration between equipment and process and realizes the cooperative operation of multiple devices. The anchorage unit is extracted to realize automatic cutting, anchorage support, temporary support, and loading and unloading functions. The anchor recovery device automatically follows the anchor extraction machine to realize the functions of coal flow buffering, block coal crushing, discharging, lagging anchor support, and so on. For the flexible continuous conveyor system, it realizes the transmission function of winding and long distance reprinting. Smart dig devices need full life cycle maintenance, and their operation and maintenance subjects should be transferred from users to equipment suppliers. The equipment maintenance early warning is enabled by big data analytics and historical data mining. When a device fails, system operating data is uploaded to the cloud, the equipment supplier remotely judges the device operational status via

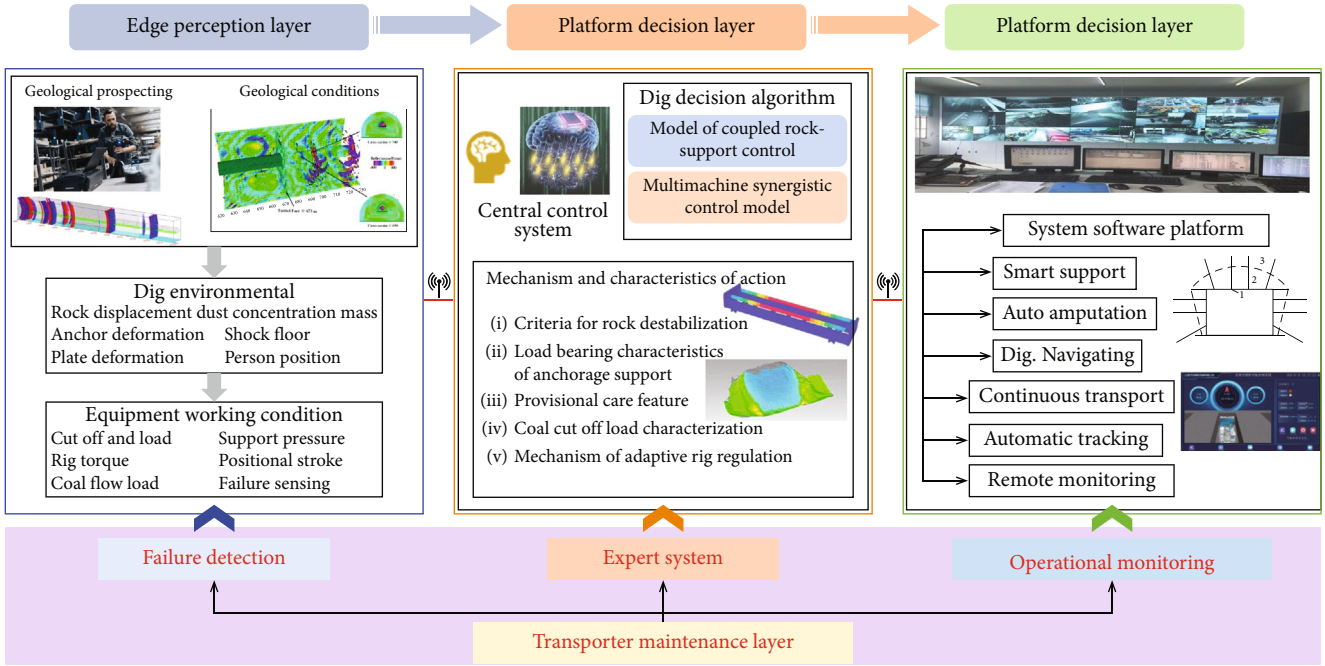

Figure 4: Intelligent rapid-excavation system architecture based on the integration of excavation, support and transportation.

an expert system, and a classical maintenance tutorial based on VR technology is issued to guide the operational maintenance of the system.

The basic architecture comprising the above four links resolves the practical problems of unclear and rapid extractions and failure to repair encountered in the traditional dig model and translates into marginal perception, platform decision-making, equipment execution, and technical assurance of remote operation, which leads to the independent operation of the production process by harmonizing various equipment and environmental organisms at the work surface and harmonizing with each other through the perception of seam occurrence and surrounding characteristics, dig environment, and equipment working conditions. To reduce manual intervention and realize safe, efficient green dig, one key operation of equipment is set into an autonomous perception, autonomous analysis, autonomous decision-making, and autonomous implementation of dig production system. The author summarizes the key techniques of the intelligent rapid extractive system based on extractive support consolidation technology from the equipment execution layer, which mainly includes extractive anchor (mining) integration, autocutting, intelligent support, dig navigation, remote collection control, continuous transport, and spatial multidimensional simultaneous support.

The remote centralized control technology solves the problems of man-machine environment coordination and independent control of the ground and underground remote centralized control center on the heading face and realizes the functions of multimachine cooperative control, visual monitoring, and health diagnosis of equipment status, intelligent environmental detection, active safety protection, wireless data network management, power supply and distribution, etc. The author and his team have developed a remote centralized control system based on the integrated intelligent tunneling technology of excavation, support, and transportation, which has two centralized control modes of mining roadway and ground control room. The architecture is shown in Figure 5. Each operation unit of the tunneling operation system is independent in space and the number of operations is relatively small. It only needs to solve the basic problems of the system, such as automatic follow-up, coal flow starts and stop, and one key start and stop. The system uses a variety of control methods such as over-limit processing, segmented alarm, equipment attitude adjustment, and segmented parking to realize the self-debugging, self-organization, and self-stabilization of the system. For automatic tracking, the bolt transporter is equipped with range sensors and a navigation system. Real-time judgment and adjustment of the relative position and attitude of the two to ensure that the bolt conveyor can effectively receive materials and walk along the roadway center. Distance sensors are installed on both sides of the tail of the walking automaton (to achieve effective stroke adjustment), and collision switches are installed to detect the relative position of the anchor bolt conveyor and the belt conveyor so as to determine its travel distance. Based on the transportation cooperative control technology, the functions of reverse coal flow startup and forward coal flow shutdown of all transportation equipment in the mining roadway are realized. Multicircuit combined switch is used for unified management of equipment. Aiming at the problem of large amount of multisource heterogeneous data in the system and inability to exchange information, based on wireless network communication technology, the 4G wireless LAN of the working face is built, and the signal attenuation caused by blocking is solved by the repeater. The data interaction and uploading of the heading working face are realized by the way of equipment field bus network+working face wireless LAN+Mine Industrial Ethernet. Due to the limitations of 5G and other technologies, the ground control

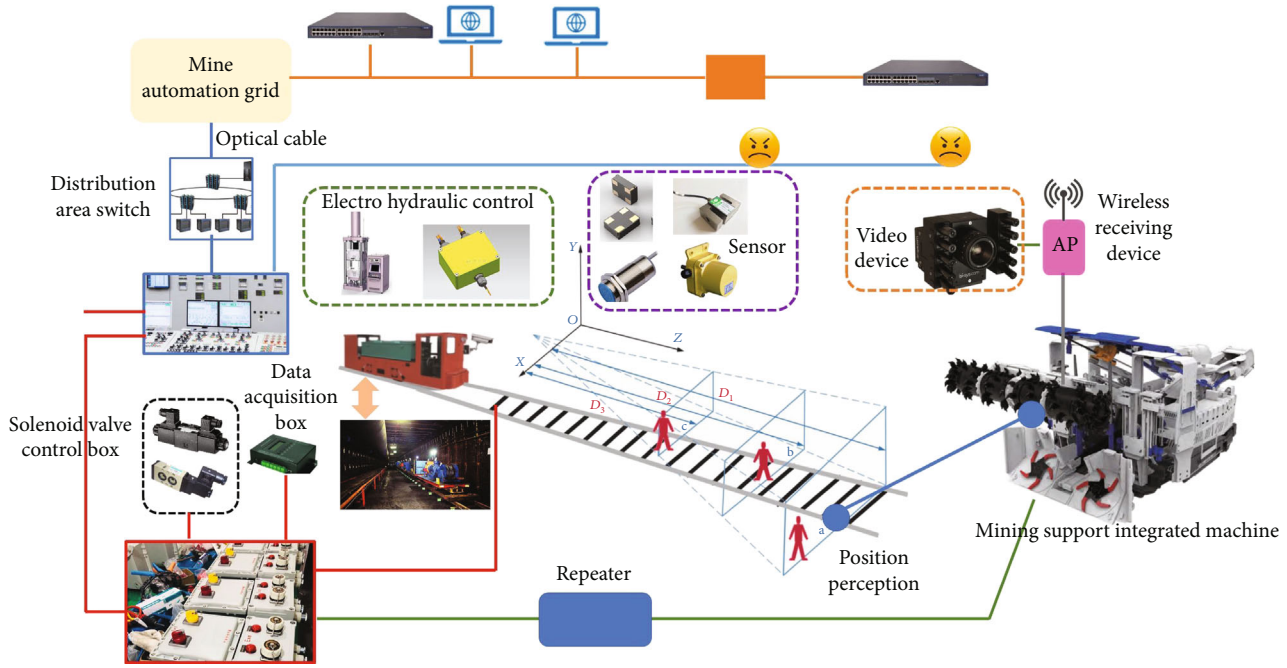

Figure 5: Architecture of intelligent and rapid excavation remote centralized control system for mining, support, and transportation integration.

room mainly realizes the monitoring and one key start and stop functions, and has not yet carried out real-time control of equipment and systems. Establish a remote centralized digital control platform with multimode perception, and realize remote visual monitoring, online visual fault diagnosis, equipment maintenance and early warning, information sharing and multipoint access based on WinCE embedded software, distributed real-time database and macs-scads industrial control configuration software. Based on video splicing, image recognition, panoramic imaging, high-definition dust-proof camera, and other technologies, the video collection and processing of the working face are realized. Based on the digital twin technology, a virtual model of the complete set of equipment is created, and the collected action data of the working face is displayed online synchronously through the virtual model. The working area of the all-in-one anchor digging machine is divided into three areas: danger, shutdown, and safety. The fusion technology of ultra wide band ranging +infrared thermal imaging target recognition is adopted to realize the dual protection of personnel when they are in dangerous areas, such as approach identification, alarm, or shutdown. At the same time, it has the functions of equipment active avoidance, two-way alarm, specially-assigned management, speed compensation, and so on.

The excavation and anchor integration technology is a technology that integrates the excavation and anchor bolt support functions on the same equipment to improve the excavation efficiency and the safety level of the excavation operation, mainly including the cantilever type road header and the onboard anchor bolt drill (standard name "excavation and anchor machine") and the excavation and anchor unit (standard name "excavation and anchor machine"). The anchor digging machine was applied in the 1980s. It arranges 1-2 drilling rigs at the cutting section or both sides of the machine body to realize the anchor after excavation. The minimum empty top distance is 0.3 m, which meets the requirements of full mechanized excavation under complex geological conditions. The main problems are that the excavation support cannot be operated in parallel, the number of drilling arms is small, and the efficiency is low. The all-in-one machine for excavating and anchoring was developed by the Sandvik company in the 1990s. It solves the problem of parallel operation of excavating and anchoring through relative sliding of the main and auxiliary frames. There are up to six drilling rigs on board, and the minimum empty top distance is 2.5 m. The main problem is that the empty top (side) distance and the grounding specific pressure are both large, and the adaptation range is small. On the basis of analyzing and summarizing the advantages and disadvantages of the foreign integrated machine for digging and anchor, the author's team innovated and developed the integrated machine for digging and anchor exploration (Figure 6). The cutting system adopts double drive high-speed combined heavy-duty cutting reducer, with a cutting power of 340kw (imported model 270 kW). The cutting adopts three protection technologies of torque limiter, torque shaft, and electric (imported model only has electric protection), which improves the cutting capacity. The traveling system adopts low specific pressure wide crawler+crawler AC variable frequency drive (imported type hydraulic motor drive) with strong overload capacity and grounding specific pressure of 0.2 MPa (imported type 0.28 MPa), which improves the adaptability to soft floor. There are two configurations of roof bolter according to surrounding rock conditions. The four top anchor drilling rigs are designed with horizontal sliding type to meet the requirements of vertical support. The two auxiliary anchor drilling rigs are designed with large lifting stroke to meet the

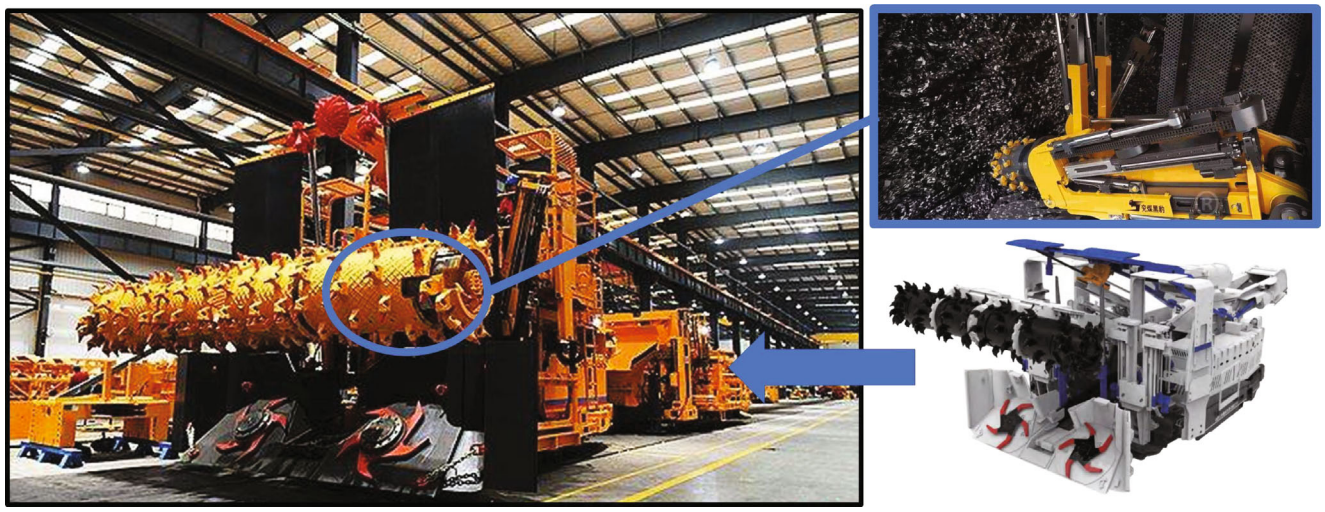

Figure 6: Driving bolt and intelligent detection machine.

requirements of large-scale auxiliary anchor support. The front exploratory temporary support will increase the adaptability of the temporary support to the broken roof by 0.4 m (1.0 m for imported models). For the integrated advanced drilling rig, due to its huge body, the traditional tunnel drilling machine cannot be arranged to the excavation working face for construction. The ear tunnel drilling construction method is usually adopted, and the construction efficiency is low. Therefore, the advanced drilling machine is effectively integrated into the excavation anchor machine to meet the drilling requirements of drilling depth of 80-120 m.

3.3. Application of Intelligent Sensor in Unmanned Driving System of Coal Mining. In the process of coal mine research, not only the tunneling method is very important, intelligent transportation speed is also an important link to a break through. Therefore, the unmanned intelligent transportation system is also researched and developed in this paper. In autonomous operating mode, the road condition analyzer is responsible for the visual perception of road conditions. It uses machine vision to analyze the road condition images of the track ahead captured by the camera in real time. It obtains the information of the existence and distance of the obstacle target and judge its influence on driving. And the transmission to the locomotive controller to complete the honking, deceleration, braking, and other operations. When machine vision is used for road condition recognition, the judgment criterion for safe road conditions is not "stop when the known dangerous conditions are found", but "stop when the known safety conditions are not found", which can ensure driving safety to the greatest extent.

The general process of road condition analysis is as follows: (1) preprocessing the road condition image, including image deblocking, and image enhancement; (2) track line identification; (3) according to the vehicle track line, the road condition scene is divided into warning area and safety area; (4) identify obstacles in the warning area and the warning area itself, where obstacles include pedestrians and all objects and materials affecting driving safety; (5) measure the distance of the identified obstacles; (6) send the results of road condition identification, i.e., obstacle type, location, and distance parameters to the locomotive controller. The division of area types is shown in Figure 7. A is in a safe area, and there is no impact on traffic passing; B in the early warning area, the horn shall be sounded for warning; C in the warning area, which stops the vehicle immediately. Road condition analysis algorithm is a typical application field of artificial intelligence due to its complexity and large amount of calculation. Relevant algorithms are developing rapidly. As a vehicle embedded application, the computing platform has also received attention.

3.4. Construction of 5G Platform of Sensor Network under Coal Mine. The intelligent operation of underground vehicles in coal mines requires continuous interaction with the dispatching room on vehicle operation data, on-board camera video data, and vehicle intelligent sensing data. Mobile equipment in a coal mine can only obtain communication interaction and positioning information through wireless communication. The coal mine 5G technology adopts the topology of high-speed optical fiber core network and 5G base station wireless networking, as shown in Figure 8. The link channel established by the wireless network for large bandwidth backhaul to the 5G core network can provide a variety of functional services such as large bandwidth backhauls, clock synchronization, and slice service management and delivery. Coal Group gathers all coal mine machine rooms to build a pair of STN-B equipment, using 100ge uplink. The underground 5G transmission ring network backbone adopts 100ge networking and the access ring adopts 5G networking to meet the underground tunnel scenario (PR Ru) and the intranet scenario (UPF/MEC). In order to meet the requirements of the internal network of the intelligent mine of the coal mine and the connection of the business platform, the DCWG gateway is deployed in the machine room, the security protection firewall is attached, the stacked tor switch and the network management switch are attached, and the 25G port is connected to the UPF blade server. The layer 3 gateway is deployed on the CE router and is connected with the supporting dedicated STN-A device n × 10GE docking. In

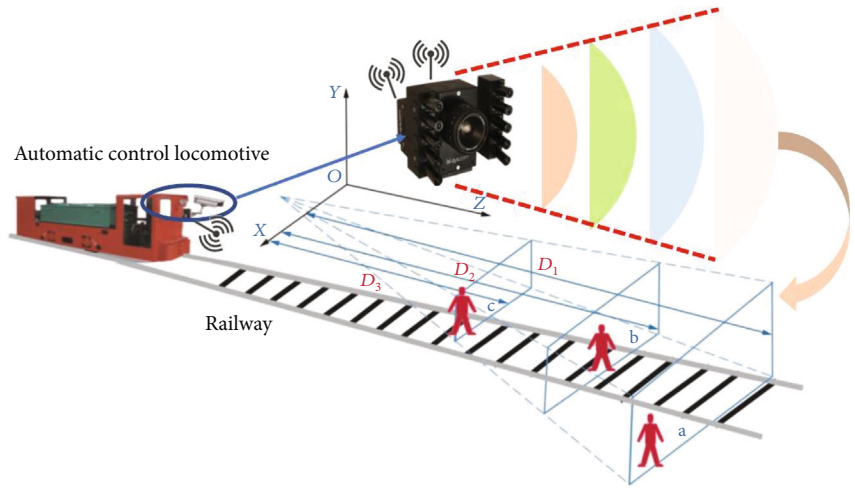

Figure 7: Schematic diagram of underground automatic driving transportation area division.

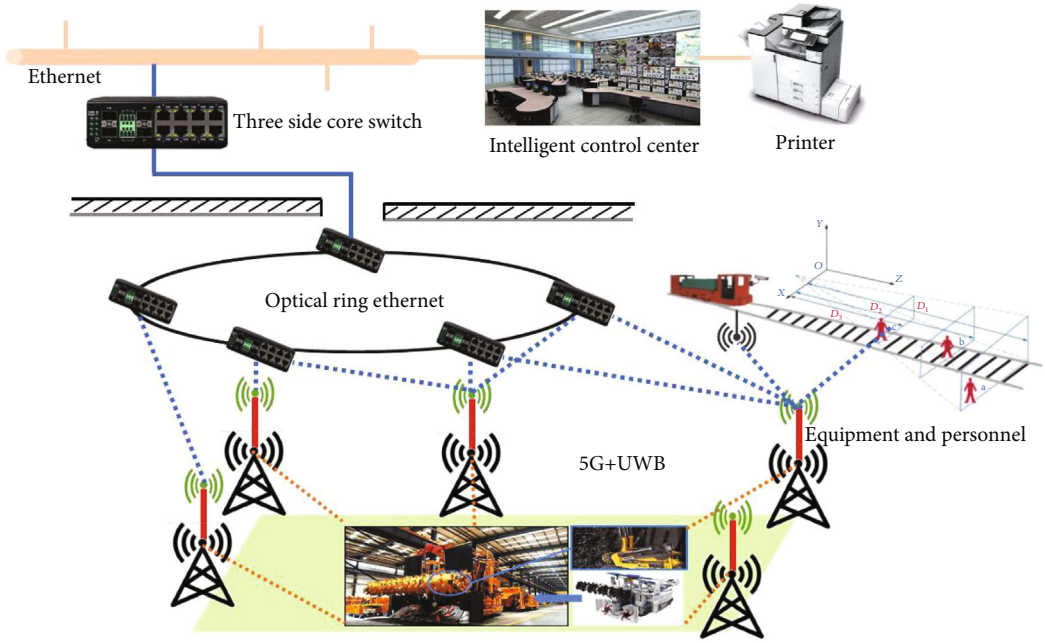

Figure 8: Topology of underground 5G and UWB layout in coal mine.

order to realize 5G bearer network management and automatic release and opening of slice services, a dedicated slice management platform for 5G bearer network is added. Meanwhile, There is no GPS signal underground. 5G wireless networks require the deployment of carrier network 1588 V2 time synchronization scheme. The layout of 5G ring network and local infrastructure network nodes is matched to realize independent networking of integration access point and BBU centralized point. With the goal of intelligentization, an intelligent, efficient, and simplified bearer network is constructed to support the bearer of 5G comprehensive cloud services so as to realize the intelligent opening, optimization, and maintenance of the business. The 5G ring network has high reliability of operation, and the redundancy backup can ensure the high availability of the line. The general performance of the 5G ring network meets the requirements of access and communication of various business systems. It has the function of service isolation network and ensures the isolation and mutual access of underground services through flexible configuration strategies.

4. Discussion

5G technology will become an important driving force for the innovative construction of intelligent coal mines. With the development of intelligent coal mining and the gradual application of 5G technology in the field of coal mining, more and more application cases show that 5G technology can improve the information and intelligent level of coal mining enterprises. However, to make full use of 5G to accelerate the intelligent process of coal mining, further application scenario planning

is needed. Key technologies such as 5G network planning, network slicing, and mobile edge computing are explored for specific scenarios. Therefore, in the research and development process of 5G key technologies for coal mine intelligence, it is necessary to pay attention to the latest technological progress in a timely manner and effectively promote the process of coal mine intelligence in an economic and effective manner.

5. Conclusion

This paper is based on the achievements of the fourth scientific and technological revolution. In 5G communication technology, intelligent coal mining calculation is studied by using existing sensor networks. The main conclusions are as follows:

(1) The tunneling system is developed into a comprehensive underground platform, which integrates various intelligent detection modules as required. During the tunneling process, the geological coordinates of the working face, coal seam status, gas content, geology and hydrology, and other data are collected synchronously

(2) After the mining work of the open-pit coal mine face is completed, the intelligent tunneling transportation integrated system will process the collected geographic information. A fine transparent working face model is obtained. It can ensure the accurate operation of the intelligent mining system and become a pioneer in the industry

(3) The key technologies of unmanned driving system are discussed in the following: UWB ranging can meet the needs of sub meter positioning of locomotive operation, the combination of standard WLAN access network and gigabit optical fiber backbone network can meet the main indicators of the broadband mobile data communication network in the transportation lane in terms of bandwidth, delay, and site switching time

Data Availability

The dataset used in this paper are available from the corresponding author upon request.

Conflicts of Interest

The authors declared that they have no conflicts of interest regarding this work.

References

[1] Z. R. Chong, S. Yang, P. Babu, P. Linga, and X. S. Li, "Review of natural gas hydrates as an energy resource: prospects and challenges," *Applied Energy*, vol. 162, pp. 1633–1652, 2016.

[2] S. Q. Yang, P. G. Ranjith, H. W. Jing, W. L. Tian, and Y. Ju, "An experimental investigation on thermal damage and failure mechanical behavior of granite after exposure to different high temperature treatments," *Geothermics*, vol. 65, pp. 180–197, 2017.

[3] J. M. Estrada and R. Bhamidimarri, "A review of the issues and treatment options for wastewater from shale gas extraction by hydraulic fracturing," *Fuel*, vol. 182, pp. 292–303, 2016.

[4] W. Liu, K. Yang, S. Zhang, Z. Zhang, and R. Xu, "Energy evolution and water immersion-induced weakening in sandstone roof of coal mines," *International Journal of Coal Science & Technology*, vol. 9, no. 1, p. 53, 2022.

[5] W. Cheng, X. Hu, J. Xie, and Y. Zhao, "An intelligent gel designed to control the spontaneous combustion of coal: fire prevention and extinguishing properties," *Fuel*, vol. 210, pp. 826–835, 2017.

[6] A. K. Bhattacharjee, "Design of compact triple frequency microstrip antenna for wlan/wimax applications," *Microwave & Optical Technology Letters*, vol. 57, no. 9, pp. 2125–2129, 2015.

[7] X. Yuan, Y. Wu, L. Sun, and X. Wang, "Research on efficient construction paths for intelligent coal mines in China from the configuration perspective," *Applied Sciences*, vol. 13, no. 1, p. 673, 2023.

[8] Z. Tan and X. Chen, "Discussion on situation and development countermeasures of coal enterprise informatization construction," *Industry and Mine Automation*, vol. 42, no. 7, pp. 63–65, 2016.

[9] Y. Li-min, L. Anqi, S. Zheng, and L. Hui, "Design of monitoring system for coal mine safety based on wireless sensor network," in *2008 IEEE/ASME International Conference on Mechtronic and Embedded Systems and Applications*, pp. 409–414, Beijing, China, 2008.

[10] A. Li, G. Cui, P. Wang et al., "Deformation and failure laws of surrounding rocks of coal roadways under high dynamic load and intelligent prediction," *Sustainability*, vol. 15, no. 2, p. 1313, 2023.

[11] G. Wang, H. Ren, G. Zhao et al., "Research and practice of intelligent coal mine technology systems in China," *International Journal of Coal Science & Technology*, vol. 9, no. 1, pp. 1–17, 2022.

[12] L. Ma, "Study on intelligent mine based on the application of 5G wireless communication system," *IOP Conference Series: Earth and Environmental Science*, vol. 558, no. 3, article 032050, 2020.

[13] A. D. Kwok, *Information System Architecture for Intelligent Manufacturing*, University of Calgary (Canada), 1993.

[14] J. Zhu, N. He, and D. Li, "The relationship between oxygen consumption rate and temperature during coal spontaneous combustion," *Safety Science*, vol. 50, no. 4, pp. 842–845, 2012.

[15] W. Guofa, Z. Guorui, and H. Yahui, "Application prospect of 5G technology in coal mine intelligence," *Journal of China Coal Society*, vol. 45, no. 1, pp. 16–23, 2020.

[16] G. Wang, J. Fan, and X. U. Yajun, "Innovation progress and prospect on key technologies of intelligent coal mining," *Industry and Mine Automation*, vol. 44, no. 2, pp. 5–12, 2018.

[17] L. Peiyan, "Application research of 5G technology in coal mine intelligence," *Shanxi Electronic Technology*, vol. 6, pp. 67-68 +75, 2020.

[18] J. Burschka, N. Pellet, S. J. Moon et al., "Sequential deposition as a route to high-performance perovskite-sensitized solar cells," *Nature*, vol. 499, no. 7458, pp. 316–319, 2013.

[19] T. S. Rappaport, S. Sun, R. Mayzus et al., "Millimeter wave mobile communications for 5G cellular: it will work!," *IEEE Access*, vol. 1, no. 1, pp. 335–349, 2013.

[20] J. H. Grossman, P. P. Reid, and R. P. Morgan, "Contributions of academic research to industrial performance in five industry sectors," *The Journal of Technology Transfer*, vol. 26, no. 1-2, pp. 143–152, 2001.

[21] F. E. Salem, A. Tall, Z. Altman, and A. Gati, "Energy consumption optimization in 5G networks using multilevel beamforming and large scale antenna systems," in *2016 IEEE Wireless Communications and Networking Conference*, pp. 1–6, Doha, Qatar, 2016.

[22] Y. Xu, Z. Zhang, A. Wang, and J. Hou, "Design of three multibranch microstrip antennas compatible with WiMAX/WiFi/4G/5G NR for coal mine applications," *Microwave and Optical Technology Letters*, vol. 65, no. 3, pp. 892–900, 2023.

[23] Y. Xiao, J. Zhang, and Y. Ji, "Integrated resource optimization with WDM-based fronthaul for multicast-service beamforming in massive MIMO-enabled 5G networks," *Photonic Network Communications*, vol. 37, no. 3, pp. 349–360, 2019.

[24] J. H. Kim, H. W. Kim, S. M. Park, and N. E. Lee, "Selective activation and electroless plating of Cu on a polyimide substrate by using a pre-patterned inhibitor layer and plasma treatments," *Journal of the Korean Physical Society*, vol. 52, no. 2, pp. 318–323, 2008.

[25] A. Xq, H. B. Qin, and A. Sw, "Privacy-preserving model training architecture for intelligent edge computing - sciencedirect," *Computer Communications*, vol. 162, pp. 94–101, 2020.

[26] L. Ma, "Discussion on application technology of 5G network in the field of coal mine robots," *IOP Conference Series Earth and Environmental Science*, vol. 692, no. 4, article 042109, 2021.

[27] Y. Bai, "5G industrial IoT and edge computing based coal slime flotation foam image processing system," *IEEE Access*, vol. 8, pp. 137606–137615, 2020.

[28] S. Awwad, C. K. Ng, and N. Rasid, "Cluster based routing protocol for mobile nodes in wireless sensor network," *Wireless Personal Communications*, vol. 61, no. 2, pp. 251–281, 2011.