5G Technology and Its Application in the Seismograph Intelligence

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Abstract. In order to meet the national intelligent development needs of coal mines, construct smart mines, improve their safety production levels and finally realize the vision of flexible manpower line and unmanned development, the application of 5G communication technology in intelligent seismographs for underground coal mines was discussed in this study based on the development history and advantages of 5G technology. Next, the application of 5G technology in the intelligent development of coal mines and the main application scenarios were explored by combining its three major unique advantages: high speed, low time delay and wide connection. The emphasis was laid on studying the seismograph intelligence based on 5G module, and then the uplink and downlink rates of three major operators under the same environmental conditions as well as uplink and downlink rates of the same operator at different positions under the 5G environment were tested. After being connected to 5G module, the seismographs sent data to the server side with fixed IP address, it was verified through the test that the normal communication was enabled under both TCP and UDP forms, and on this basis, the functions of seismograph, namely data passthrough to server and wireless real-time data transmission, were realized.

1. Introduction
In order to improve the intelligence level of coal mines, deeply accelerate the implementation of national new energy security strategy and promote the deeply integrated development of intelligent industry and coal industry, six government sectors like National Development and Reform Commission and National Energy Administration jointly issued and distributed Guiding Opinions on Accelerating the Intelligent Development of Coal Mines in March, 2020, which pointed out the three staged goals of intelligent coal mine development with 2021, 2025 and 2035 taken as the time nodes, and up to 2035, the goal of intelligent coal mine development would have been basically achieved. In March of the same year, the Standing Committee of Political Bureau of CPC Central Committee put forward the guideline of accelerating the new-type infrastructure construction, where the construction contents in four major fields—big data center, 5G base station construction, industrial internet and artificial intelligence—provided an important technical support for accelerating the intelligent transformation and upgrading of coal industry, and thus constructing smart mines, improving their intrinsic safety production level and finally realizing the flexible manpower line and unmanned development became the vision and goal of mining industry. Starting from the development history and advantages of 5G technology, the application of 5G communication technology in the intelligent development of underground coal mine seismographs was discussed in this study.
2. Overview and Application of 5G Technology
Referring to the 5th generation mobile networks or 5th generation wireless systems, the 5G technology is a cellular mobile communication technology that has been commercialize in recent years. The mobile communication technology has totally experienced 5 iterations, as seen in Table 1, and various countries in the world have welcomed the 5G era in succession. The 5G network deployment includes non-standalone (NSA) networking and standalone (SA) networking modes. NSA means deploying the 5G Network by fusing the 4G core network with the existing 4G basic network, and realizing the joint Networking of 5G and long-term evolution (LTE). SA aims to re-establish a 5G network, all base stations and infrastructure need redeployment and reconstruction, and the early-stage construction cost is high. Although SA is able to connect the existing 4G base station to 5G core network by upgrading and reinforcing the 4G base station, the final form of SA architecture is the connection of 5G base station to 5G core network, not relying upon the existing 4G network or base station equipment, and this networking mode supports all new functions and new applications of 5G.

| Mobile communication technology | Core function |
|---------------------------------|---------------|
| 1G | Analog voice service; cellular networking; wireless and mobile; |
| 2G | Analog signal digitalization, mobile digitalization, and mobile voice and short message services; |
| 3G | Digital broadband, start the data era, with a lot of intelligent applications; |
| 4G | Era of wireless broadband, new communication technology specially designed for mobile internet; |
| 5G | Interconnection of all things, not restricted to the communications industry, and stereoscopic ecosystem is constructed. |

3. Why 5G Down the Well?

- Application of adaptive digital twin technology in mines
- Fuse sensing communication to facilitate the development of intelligent mining technology
- Uplink UWB data adapts to mass uplink data of coal mines
- Low time delay
- Wide connection
- High rate

Figure 1. Three Main Features of 5G.
5G technology possesses three major unique advantages: high rate, low time delay and wide connection as shown in Figure 1. The 5G technology has gradually entered the commercialization phase in China, becoming the technological base for applications such as robots in special industries, unmanned driving, virtual reality (VR), super-definition video, and remote control of equipment and acquisition of safety monitoring information. Under the 5G environment, more sensors and super-definition cameras can be deployed to acquire super-definition videos, thus providing mass data base for further analysing unsafe personnel behaviours, environment of working face, geological transparency and operating status of underground equipment, and laying a foundation for the intelligent development of coal mines.

![Diagram](image)

Figure 2. 5G Technology Promotes Intelligent Development of Coal Mines.

As shown in Figure 2, the 5G technology is capable of more real-time, accurate and reliable remote control of equipment and realizing their intelligent linkage by virtue of its low time delay and high reliability. A series of information data (e.g., state, rotation speed and orientation) of equipment like coal cutter and drilling machine need to be timely, accurately and reliably transmitted during the operation process, so as to realize the timely response control at far end. With 5G network, the edge computing technology can be used to realize the early warning and analysis of sensor data in underground coal mines at edge nodes so that the analysis becomes more efficient and intelligent.

Main 5G applications:

1. **5G + VR live streaming**
   5G + VR live streaming helps personnel on the ground to watch the situation at any position of coal mine from an angle and position they prefer, so they can feel being personally on the scene without coming down the well.

2. **5G + safety production management platform**
   By virtue of the large broadband characteristic of 5G technology, the underground production scenarios can be transmitted timely, accompanied by the function of high-precision video acquisition of scenarios like excavation, routing inspection and drilling.

3. **5G + remote equipment control**
   The remote control ability based on wireless technology can be realized by integrating the unique advantage of 5G technology, namely, low time delay, with the remote control technology.

4. **5G + violation analysis**
   Intelligent early warning and interlocking control of circumstances like injury of underground personnel, personnel entering hazardous area and personnel operation by breaking rules can be realized based on the 5G wireless technology, so as to facilitate the safety production of coal mines.

5. **5G + intelligent scheduling**
   The underground real-time high-definition video scheduling ability can be realized based on intelligent terminals like 5G cellphone, safety helmet and vehicle-mounted terminal.

6. **3D geographic information of mines**
The 5G wireless technology enables 3D mine geosystem to implement safety training, model optimization, rescue commanding, emergency drill, etc.

(7). Prediction system of key equipment failures

The 5G network monitoring equipment can not only satisfy the control requirements but also transform passive early warning into passive analysis, thus discovering the equipment abnormalities in advance, hinting the overhaul and lengthening the service life of equipment.

4. Seismograph Intelligence Based on 5G Module

The 5G module designed and developed in this study is as shown in Figure 3. After the seismograph realized the data passthrough to this 5G module via network interface, the 5G module transformed the data into 5G signal and sent the data to server side with fixed IP address.

![Figure 3. Block diagram of 5G Module.](image)

|   |   |
|---|---|
| 1 | 4G/5G/GPS antenna (reserved) |
| 2 | Grounding stud |
| 3 | RST key |
| 4 | 4G/5G antenna |
| 5 | OTG interface |
| 6 | 4G/5G antenna (reserved) |
| 7 | SIM card slot |
| 8 | 5 Pin terminal |
| 9 | LAN port |

4G/5G/GPS antenna (reserved) | Grounding stud | RST key | 4G/5G antenna | OTG interface | 4G/5G antenna (reserved) | SIM card slot | 5 Pin terminal | LAN port |

Figure 3. Block diagram of 5G Module.

![Figure 4. Schematic Diagram of Seismograph Communication Based on 5G Module.](image)

The host functions of existing seismographs include data acquisition, data storage, data transceiving, clock synchronization, key management and interaction management, as seen in the dashed boxes in Figure 4. Moreover, intrinsic safety power circuit management is equipped to provide
the system with digital and analogy power supplies, along with ARM core controller circuit, and bare computer acquisition procedures and management operation procedures with LINUX loading are used. In this study, the 5G module developed based on Qualcomm X55 Open platform supported 5G SA/NSA all-pass networking, showing downward compatibility with all-pass network types like 4G/3G together with convenient and fast networking. The product met various interface requirements such as gigabit network interface and one-way terminal block RS232 serial port, the gigabit LAN port supported 10/100/1000Mbps self-adaptation with a small and exquisite size and low power consumption under online state, and moreover, the product could satisfy the explosionproof certification requirements of coal mines and was applicable to intelligent and wireless embedded 5G applications of mining equipment. As shown in Figure 4, the 5G module was added on the existing seismograph and realized the real-time data transceiving via adaptive connection to LAN port, thus solving the problem in the data acquisition of existing seismographs, namely, the readings were collected and processed only after they were saved and the operation was ended, and furthermore, it could implement the real-time transmission of acquired data to the server.

5. Performance Test

5.1. 5G single-module signal intensity and network speed test
It was found through the test that for the 5G module developed in this study, the uplink and downlink rates of three major operators varied under the same environmental conditions, where the downlink rate of China Mobile was the highest in the laboratory test, China Telecom achieved the highest uplink rate, and China Unicom reached relatively average rates. This was correlated with the 5G network coverage of the three major operators, at present, China Mobile 5G coverage was the widest, followed by China Unicom, but the present coverage of China Telecom 5G was limited, as shown in Figure 5.

![Figure 5. 5G Coverage of Three Major Operators. (China Mobile, China Unicom and China Telecom)](image)

As the coverage of China Mobile 5G base station was the widest in this region, China Mobile was finally selected in the test, from which it was found that the uplink and downlink rate of the same operator (China Mobile) varied with the concrete position in the 5G environment, to be more specific, the downlink rate was high in the laboratory while the uplink rate was not ideal. The uplink rate nearby the position with high signal intensity at the base station doubled that in the laboratory.

Following the test, it was noticed that the 5G network had a very high position requirement, and the present network quality was manifested by two points: (1) Nearby the central position within the coverage of the same base station, the difference value between two points with distance of 10 m or so in the aspect of downlink rate was 100 Mbps or even larger; (2) Within the coverage of different base stations, the two points largely having the same distance to the base station differed a lot in the downlink rate, and the difference value might be one order of magnitude at maximum.
5.2. Performance test of 5G module-based seismograph

The designed 5G module, which was an assembly of five seismographs randomly selected at outdoor spacious places, is shown in Figure 6. After the uniform time serve, the five seismographs were parallely connected onto the same geophone, thus ensuring the signal consistency, and the geophone was embedded into the earth’s surface. During the test, a vibration signal was proactively given to the geophone, and it appeared that all the five seismographs could send data to the server with fixed public network IP address in the laboratory via the public network of operator, the laboratory server side could receive the data signal, and moreover, normal communication was enabled under both TCP and UDP forms, along with the passthrough of seismograph data to the server, which could send command and data to the seismograph end. Both data uploading and stability with seismographs serving as the equipment terminals could basically meet the connection requirements of mining equipment and realize the wireless real-time transmission function of seismographs. The application of 5G module designed in this study to seismographs is only restricted to the ground and laboratory test phase. With the gradual construction and perfection of coal mine 5G network in China, a large quantity of reliability tests remains to be carried out in the later phase to actually test and verify the signal rate, stability and accuracy in underground 5G network environment after the safety and explosionproof certification of coal mines.

6. Conclusion
Based on the general situation of 5G technology, the application of 5G communication technology in coal mine intelligence and the major application scenarios were discussed in this study, with the emphasis laid on developing the intelligent seismographs based on 5G module. Next, the uplink and downlink rates of three major operators under the same environmental conditions as well as those of the same operator (China Mobile) at different positions in the 5G environment were tested. After being connected via the 5G module, the seismographs send data to the server side with fixed IP address, and it was manifested that both TCP and UDP forms could form the normal communication, realize the passthrough of seismograph data to the server, and basically realize their wireless real-time transmission function. However, there lacks actual industrial verification test of underground coal mines, which remains to be further implemented in the follow-up research.

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