The Application of WiFi 6 Technology in Underground Mine

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Abstract: Aiming at the problems of large power consumption of 5G communication technology equipment and short wireless transmission distance of wireless signal, the author designs the wireless network coverage scheme of WiFi 6 in coal mine to achieve the full coverage of 5G communication. This paper makes an exposition of WiFi 6 technology from the aspects of technical principle, networking mode, antenna design and power consumption calculation. The WiFi 6 signal coverage scheme solves the problem of wireless network signal coverage in long-distance roadway underground coal mine by realizing the full coverage of wireless network. The data of laboratory experiments and coal mine roadway simulation show that with the characteristics of wide network communication coverage area, fast communication speed and low power consumption, WiFi 6 network scheme can fully meet the requirements of full wireless coverage in coal mine.

1. Introduction
To implement the spirit of the Notice of the General Office of the State Council on Further Strengthening Coal Mine Safety Production [1] (State Office (2013) No. 99), further improve the technical level of coal mine communication and enhance the ability of emergency communication support, the National Coal Mine Safety Administration has organized several times of pilot work of advanced and applicable technology application of coal mine communication. In 2019, Jiang Yaodong, member of the National Committee of the Chinese People's Political Consultative Conference, suggested during the NPC and CPPCC period that the state should speed up the construction of intelligent mines with greater support. At present, several network constructions such as domestic coal mine control network, transportation and marketing network, information network, safety network, Internet of things, Internet of vehicles have led to the increasing amount of coal mine network information transmission data, and the high requirement of time delay in data transmission. There exists problems under coal mine such as poor wireless signal coverage, low channel capacity, narrow bandwidth and high time delay, Therefore, there is an urgent need for a technology that can not only solve the above problems, but also represent the new era of wireless communication to realize the needs of digital mining mines.

2. Characteristics of 5G Communication and its Application and Limitation under Coal Mine
5G [2-3] communication technology is the latest communication technology, representing the forefront of contemporary communication technology. Every country treats 5G communication as a national strategy. It can be said that 5G is the dividing point of the times, with the characteristics of high bandwidth (peak to peak can reach 10Gbps), low delay (maximum time delay is 1ms), large capacity and so on. However, there are some problems in 5G communication technology to achieve full wireless coverage in coal mine. First, the base station adopts various advanced technologies, resulting
in high power consumption of the equipment composed of the base station (the power consumption of AAU and RRU reaches kilowatts \(^\text{[4-6]}\)), and the locomotive roadway and other parts of the coal mine can not be powered. Second, the wireless signal coverage distance of 5G base station is short, so it fails to carry out fully network layout of whole roadway in coal mine. Due to high power consumption, many places have no power supply. Third, 5G signal is transmitted by high frequency signal with high diffraction loss, which can not meet the signal transmission demand of irregular roadway in coal mine.

3. Characteristics of WiFi 6 Communication Technology
Wi Fi 6 \(^\text{[7-9]}\) (formerly known as 802.11. Ax), is the standard name of Wi Fi, which mainly uses OFDMA, MU-MIMO(Multi user, multi input, multi output) and other technologies. Wi Fi 6 uses 8T8R antenna, which can realize the simultaneous communication of eight users instead of signal terminal device communication of the previous generations. In this mode, the highest speed of down Wi Fi 6 can reach 9.6Gbps. Through OFDMA \(^\text{[10]}\) (orthogonal frequency division multiple access), Wi Fi 6 also improves the technical indicators of network delay and communication efficiency (communication delay 10ms). Transmit beamforming technology is used to improve network capacity. Wi Fi 6 wireless router is designed with low power consumption ranging from 9 ~ 12 W, which meets the requirements of intrinsically safe power supply in coal mine. It realizes remote power supply of intrinsically safe power supply and is convenient for network equipment layout.

WiFi 6 adopts dual frequency signal output of both 2.4G and 5G. 5G signal is strong, but due to the use of high-frequency signal transmission, the signal coverage distance is short. 2.4G adopts low-frequency signal transmission with strong signal diffraction and anti-interference, and long transmission distance. WiFi 6 wireless base station automatically adjusts user frequency band through internal control circuit to ensure communication quality and reliability.

4. WiFi 6 Networking

![Figure 1. Wireless Network Coverage Schematic of Coal Mine Reliability](image)

Due to the unfavorable environment of coal mine such as uneven distribution of roadway, irregular roadway, serious electromagnetic interference and so on, the coal mine network should be set as redundant network as far as possible to increase the communication reliability of the network. The wireless network coverage schematic of coal mine reliability is shown in Figure 1. The core computer room in the ground consists of two core switches to form a redundant ring network. The underground wireless base station and the ground core equipment form a ring network through the optical cable, and the base station wireless signal covers the local network. Since the driving roadway and coal mining roadway are in a mobile state, the base station of these types adopts the bridging mode of wireless signal to avoid network wiring and ensure the stability of network communication.

The most difficult part in the wireless signal coverage of coal mine are long-distance transportation roadway, return air roadway and mining roadway. Due to the long distance of this type of roadway, there is no location for the electricity in the middle, as well as the arrangement of wireless base station nearby. Usually, the way to achieve wireless signal coverage in this type of tunnel is to supply power to the wireless base station through the intrinsically safe power supply, and to cover the signal through the wireless signal stretching. The network topology of long-distance roadway is shown in Figure 2.
Figure 2. Schematic of Network Topology of Long-distance Roadway

An Flame-proof and intrinsically safe power box is installed in substation 1, which provides power for wireless base station A and wireless base station B through cables. The wireless signal of base station A covers 200 meters around both sides of base station A. The base station B covers 200 meters around through the antenna. Base station A and base station B are connected by wireless 2.5G band signal bridge. As the same as substation 2, which supplies power to base station C and base station D, the base station C and base station B are bridged by their respective antennas. Through this kind of antenna bridging mode, signal intercommunication is achieved among base stations A, B, C and D. The signal coverage between the two base stations is 1400m.

To realize the network mode designed in Figure 2, the base station has to meet two conditions. First, the base station has low power consumption and can be powered by intrinsically safe power supply; second, the base station antenna properly designed to ensure a long distance of the signal.

4.1. Power Calculation of Wireless Base Station

The main board power consumption of the wireless base station is 9W-12W (in full load operation, the power consumption reaches the maximum). The peak use time of the mine is commuting time, 2 hours in each period, 4 hours of the total. The converted peak use rate is 0.5 (8-hour working system), so the base station power consumption value of 10.5 W is designed as the power supply.

The working voltage of wireless base station power supply is 9-18 VDC, the impedance of underground cable transmission line is 12.8 Ω / km, the cable transmission distance is 400 m, and the rated output voltage of intrinsically safe power supply is 18 V DC.

\[ U \times U / R = 10.5 \] ①
\[ R = 12.8 \times 2 \times (400 ÷ 1000) \] ②

In Formula ①: U refers to the base station working voltage;
R refers to the loss of transmission cable.

It’s calculated that U is 10.37 V, which is greater than the minimum voltage 9 V required by the sensor. So the intrinsically safe power supply can meet the power supply demand of the two base stations.

4.2. Antenna Design of Wireless Base Station

The antenna mode of WiFi 6 wireless base station is transformed from 2T2R to 8T8R, which can realize the simultaneous communication of eight users. Under coal mine, there are seldom situation when 8 users communicate at the same time. Considering the time delay value (10 ms), the antenna in coal mine is designed in 2T2R mode. According to the characteristics of coal mine roadway, the 2T2R antenna is designed as back directional transmission mode with the antenna pattern in both left and right. The fixed output power of each antenna is 15 dB, the receiving sensitivity of wireless base station is -80 dB, and the long-distance transmission signal frequency is 2.5 GHz. The transmission distance of wireless signal meets Formula ③.

\[ \text{Los} = 32.44 + 20 \log d + 20 \log f \] ③

In the formula: Los refers to the optical loss (95);
d refer to wireless transmission distance, in KM;
F refer to signal transmission frequency, in MHz.
It can be calculated from ③ that the theoretical transmission distance of the base station is 0.52 km. Considering the inconsistency of the field antenna and the absorption and reflection of the field environment to the signal, the actual effective value of the signal is between 200m and 300m. The schematic diagram of the radio signal directional antenna of the base station is shown in Figure 3. The back antenna radiates to both sides through the left and right semi arc antennas with the signal covers the left and right dashed area. The scattered signal of the antenna covers the upper and lower dashed area.

Figure 3. Schematic Diagram of Directional Antenna of Wireless Signal in Mine

5. Experimental Test
WiFi 6 wireless communication equipment is installed in Qingshuixi Coal Mine of Zhongliang Mount according to the mode shown in Figure 1. Data verification tests are conducted on wireless signal coverage distance, wireless signal transmission power and network bandwidth. The parameter test chart of wireless network is shown in Figure 4.

It can be seen from the data curve that, with the extension of distance, the wireless signal and network bandwidth gradually decreases. After the roaming switch in area A, the signal strength and network bandwidth increase significantly. In area B there is a bending angle in the roadway 90-100m, and the network signal and network bandwidth decrease obviously.

6. Conclusion
The experimental data of design principle proves that WiFi 6 equipment is in low power consumption and the intrinsically safe power supply of coal mine can supply power remotely, solving the problem that the power supply can not be supplied in the coal mining roadway and other places. Besides, the experimental data shows that WiFi 6 has the characteristics of high communication rate bandwidth, wide coverage of wireless signal network, etc., which fully meets the fully area coverage of wireless signal in coal mine. Although WiFi 6 can satisfy the need of the underground wireless transmission, the achievement of digitization and intelligent coal mines is inseparable from the high speed of 5G technology, low delay and the inclusiveness of things. The reasonable layout of the two should be the best policy for the network construction of intelligent coal mine.

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