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5G-based Remote Mining of Pangang Group Mining Co., Ltd.

Digital transformation is a path that must be taken for Pangang Group and especially mining companies to seek future development. This project is an important part of the company's mine digitalisation and intelligent transformation. This project adopts 5G and edge computing technologies in conjunction with mine engineering technologies, and provides an efficient, stable wide-area mobile network with enhanced mobile broadband uplink access and low-latency via 5G. Remote control of drilling rigs and electric shovels as well as autonomous driving and remote control of mining dump trucks are supported for remote intelligent application of drilling, mining, and transportation equipment. The ultimate goal of this project, however, is not about replacing human workers, but about changing the operational mode to create a more comfortable working environment for workers who can fulfil their responsibilities at a better post with more dignity.

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Case Overview

The Panzhihua-Xichang region in Sichuan province has been one of the most mineral resource-abundant areas in China and the world at large. It is the second largest iron producing area in China with more than 10 billion tons reserve of vanadium titano-magnetite resources, which boast an extremely high value for comprehensive utilisation. For a long time, the mining areas under Pangang Group Mining Co., Ltd. have been troubled by issues such as a poor operating environment with extremely harsh conditions. Mining workers can return to the urban areas only once a week on weekends, so young people are not willing to work in the mining areas.

In view of this, Panzhihua Branch of China Mobile Group Sichuan Co., Ltd. joined hands with its partners including Huawei, Chuangyuan Hi-Tech, and Boonray Technology to create a tailor-made 5G + smart mine solution for the mining area in March 2021. Based on the current drilling, mining, and transportation management status of the Panzhihua open-pit iron mine and existing production processes, the solution is set to serve the core goals including the intrinsic safety, cost reduction, and efficiency enhancement, and revolves around three core scenarios, namely remote control of working face drilling rigs, remote control of electric shovels, and unmanned mining trucks. Supported by the 5G and edge computing technologies, the solution addresses the challenges including the large-bandwidth uplink traffic of HD videos for purposes of remote control of working equipment on the mining face of open-pit mines and unmanned vehicles, and low latency and strong reliability of control commands. It enables remote control of drilling rigs and electric shovels, autonomous driving and remote control of mining dump trucks, and support to the underlying data transmission network of the mine and edge computing resources to lay a foundation for the interconnection and interaction of mining equipment and data. The project involves the renovation of drilling rigs, electric shovels, and mining trucks, as well as the construction of 5G networks, 5G edge data centres and remote-control centres, and remote-control and autonomous driving system.

Industry Challenges

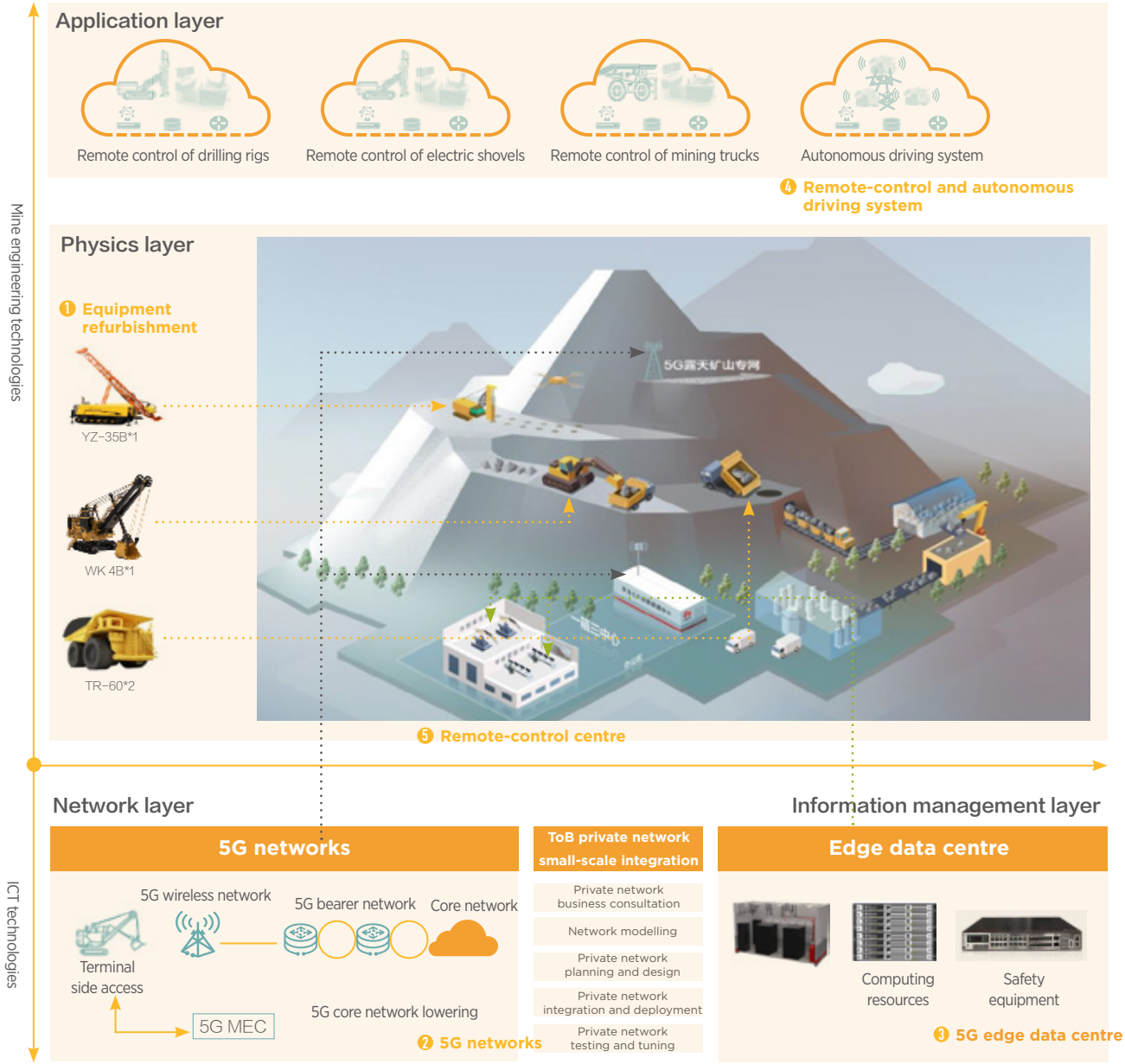
The current surface mining and transportation processes of mines primarily include drilling, blasting, shovel loading, and transportation. Specifically, drilling relies on the drill for drilling different depth of holes, blasting means to bury and detonate dynamite in the holes to crush the ore rocks to a certain degree for the convenience of shovel loading, which means to use an electric shovel to load the mineral aggregate, and transportation relies on mining trucks to transport the loaded mineral aggregate to the crushing station for crushing and then transport them to the storage bunkers via belt conveyors. Mining and transportation operations rely on human workers who use drilling rigs, electric shovels, mining trucks, and other mobile equipment to complete the operation. Due to the harsh operating environment (high temperature, dust, etc.), the mining personnel are exposed to intensive labour and high risks, leading to recruitment difficulty. Meanwhile, the reliance on workers' personal experience for equipment use also results in a low comprehensive utilisation efficiency. Targeting these issues,

solutions utilizing market economy have been employed in recent years to undertake part of the transportation workloads. However, experienced human workers remain essential for on-site operations due to the expensive costs of the drilling rigs and electric shovels among other equipment. On the other hand, the adopted solutions only solve the issues temporarily, instead of resolving them from the root, including the mining and transportation safety of mines, the "aging" of workers, and the recruitment difficulty. For this reason, mines have an urgent need for new solutions.

The network at the mine production site needs to cover a wide area, support mobile equipment and applications, and adapt to harsh, complicated, and unstable scenarios. The existing wired and wireless technologies all find it hard to meet all these business requirements, and the underlying supporting network for wireless transmission becomes a bottleneck. Promoting remote intelligent applications of drilling, mining, and transportation equipment in open-pit mines - which can address challenges including the enhanced-mobile broadband uplink traffic of HD videos for purposes of remote control of working equipment on the mining face of open-pit mines and unmanned vehicles, and low latency and strong reliability of control commands - via 5G technologies is not only a solid demand of 5G application, but also a path that must be taken to achieve less-manned or unmanned surface mining operation.

Solutions and Benefits

Remote intelligent application of surface mining and transportation is a complex and systematic process, which includes the application, physics, network, and information management layers structurally. Specifically, the network and information management layers are the foundation for implementing the complex system which contains the 5G networks and the 5G edge data centres; the application layer mainly refers to the remote-control and autonomous driving system; and the physics layer comprises the equipment renovation and remote-control centres, as shown in the figure below.



01 5G private network construction

A 5G network comprises the 5G terminal-side access devices, the 5G wireless network, the 5G bearer network, and the 5G core network. The solution should be designed and finalised to serve the business goals of low latency, high uplink traffic, strong reliability, and high security among other requirements. 5G terminal-side access includes automated components such as sensing devices, cameras, controllers, and industrial control computers, as well as network access devices such as AR routers and 5G CPEs. 5G wireless network refers to the 5G base stations and their wireless coverage over the mine areas to enable real-time connections between mobile devices in the areas. The 5G bearer network adopts FlexE physical isolation and VPN logical isolation to ensure business security, and a ring networking mode is used to realise strong reliability. The 5G core network includes mining area MEC and the operator's 5GC network. MEC is newly deployed in the integrated cases/cabinets of 5G edge data centres to ensure low-latency access of mining businesses in the mining area. The 5G networks create a private network environment required for the project to provide 5G network planning design and analysis services as well as basic debugging and testing and network maintenance services to ensure proper transmission of related data and control commands, so as to lay a foundation for the connectivity of mining equipment and data.

The solution ensures data security by covering the mining face with 5G networks, building edge UPF on the mine layer, and connecting to the Pangang UPF as backup.

02 5G edge data centre construction

With integrated cases/cabinets that meet the industrial-level standards built, the 5G edge data centres integrate 5G networks and underlying software and hardware resources for edge computing to meet the systematic requirements for production data communication security and network real-timeliness, and support applications related to the intelligent control system in 5G unmanned mines.

03 Intelligent renovation of rotary drills (YZ-35B)

After remotely intelligent renovation, the YZ-35B rotary drills can be configured as needed to achieve precise depth measurement and positioning and automatically balancing, finding holes, changing rod, operating and warping cables, etc., solving the issues happened in manual on-site operation like inaccurate positioning, time-consuming drilling, and vulnerability of components. Specifically, the cables can be automatically wrapped and laid as the equipment moves, the drills are fully electronically controlled and perceived in parallel, the drills' locations and postures are remotely identified with high precision, the drill rods are automatically made up and broken out, and the drills perform automatic drilling operations and clear the dust at the hole orifices.

04 Intelligent renovation of electric shovels (WK-4B)

The control-by-wire unit of electric shovels must be renovated first to realise remote control, so that electric shovels can receive the control signals sent by the computer and send the necessary data generated to the remote- control cabin via the computer. The overall renovation plan of the electric shovels comprises two parts, namely electrification renovation and intelligent renovation.

05 Intelligent renovation of mining trucks (TR-60)

Mining trucks support three driving modes, namely human driving, remote-control driving, and autonomous driving. Human driving has the highest priority, while autonomous driving has the lowest. The operator can remotely take over the driving control system during autonomous driving. The control-by-wire unit of mining trucks must be renovated first to realise remote-control and autonomous driving, so that mining trucks can receive the control signals sent by the computer and send the necessary data generated to the remote-control cabin via the computer.

The mining truck renovation comprises two parts, namely control-by-wire unit renovation and network-based intelligent renovation. The control-by-wire unit renovation of mining trucks includes renovation in power, light, throttle, gear, brake, steering, and lift. The network-based intelligent renovation includes operation monitoring, environment perception of mining trucks, intelligent algorithm support, integrated positioning, obstacle avoidance detection, and safety monitoring.

06 Remote-control and autonomous driving systems

Remote-control and autonomous driving systems include the remote-control system for electric shovels, the remote-control system for rotary drills, and the remote-control and autonomous driving system for mining trucks. These systems collect real-time information including locations, statuses, and videos of mining trucks, electric shovels, and rotary drills, and provide control, monitoring, early warning, and task scheduling among other functions. On the one hand, the systems realise the access and monitoring of rotary drills, mining trucks, and electric shovels dependent on a central control system. On the other hand, they provide a remote-control cabin for related equipment to have real-time remote control of various devices.

The central control system contains four parts, namely high-precision map, equipment positioning, safety monitoring, and scheduling control. These functional parts cooperate to form a stable and reliable intelligent mining system. The system also provides interfaces to connect to external mines' MES and truck scheduling system and software to enable the corresponding management and scheduling functions.

The high-precision map subsystem automatically creates a high-precision 2D orthophoto map or a 3D diorama map of the mining area through automated flight and photography of drones for positioning and navigation use by other intelligent terminals. The large monitoring screen intuitively displays the current real-time locations, operating statuses and other data of the equipment based on the 2D high-precision map or 3D diorama map.

The GNSS positioning system relies on positioning and navigation satellite systems including GPS, BeiDou, GLONASS, and Galileo, as well as RTK positioning base stations to provide high-precision positioning and orientation data for mobile equipment such as electric shovels and mining trucks.

The safety monitoring system provides real-time status parameters of various vehicles, shovels, and drills, and to issue alarms in time in the event of any abnormalities.

07 Remote-control centre

The remote-control centre is equipped with a remote cockpit to receive real-time data of all equipment via remote-control and autonomous driving systems. The centre stores and analyses the data and presents the analysis results in a visualised manner in a human-computer interaction interface to enable remote control of equipment and automatic scheduling of mining tasks. In this project, the remote-control centre is located on the first floor of the iron mine's governmental culture centre building and is about 3 km away from the working face.

Remote-control cabin of rotary drills

The remote operation platform of the rotary drills is consistent with that of the drill cab. It has two screens, one for displaying the operation parameter information, and the other for monitoring. The latter shows the images of the vehicle surroundings, the drill tower platform, and the top of the drill rod warehouse. The operation information is sent by the remote operation platform to the vehicle-mounted 5G terminal via the base station, and then downloaded by the vehicle-mounted industrial control computer and sent to the vehicle-mounted ECU for control. The operation parameter information is sent back to the centralised control centre from the vehicle-mounted 5G terminal via the 5G base station.

Remote-control cabin of electric shovels

The remote-control seat is designed as a replica of the seat in the electric shovel, and its handle, button and other data are connected to the industrial control computer. The seat is installed on a six-degree-of-freedom platform to make the seat tilt and vibrate according to the equipment posture and vibration acceleration detected by the IMU of the electric shovel, so that the remote driver can intuitively know the current posture of the equipment.

Remote-control cabin of mining trucks

The seat is designed as a replica of the seat in the mining truck, and its handle, button, and other data are connected to the industrial control computer. The seat is installed on a six-degree-of-freedom platform to make the seat tilt and vibrate according to the equipment posture and vibration acceleration detected by the IMU of the mining truck, so that the remote driver can intuitively know the current posture of the equipment.

Summary and Next-Steps

This project involves the integrated application of mine engineering technologies and network communication and information technologies, featuring complicated and systematic operations. It covers the network, information management, physics, and application layers among others, with a high degree of complexity and requiring the integration of multi disciplines, fields, and manufacturers. In terms of the mine engineering technologies, an effective organisation that can exert the existing power is required to well lay the foundation in demand, application testing, and continuous maintenance among other links while ensuring the quality. In terms of the specific system construction, 5G technologies are applied at the network layer. This requires the participation of leading companies in network communication technologies and 5G application field. In terms of the equipment renovation and remote-control and autonomous driving application at the physics layer, suitable external units should be selected to participate in the process. Meanwhile, a team with strong capabilities in system integration and management is essential for such a systematic engineering project. The capabilities of core partners are the key to the performance of cross-sector integration and the success of the project.

In light of the current trends for "green, smart, and unmanned" mines, the project team kept optimising and improving the applications in related scenarios while providing solid support with the underlying transmission network and edge computing resources of the mine for connectivity of mining equipment and data. The details are as follows:

The project provides "one-click operation", "video splicing", and "immersive experience" among other capabilities in the remote-control scenarios to continuously optimise the operation experience and efficiency.

1. By offering "cloud host", "network slicing" and other capabilities, the project keeps building and reinforcing the functional and network security of edge terminals to ensure application security in the scenarios.

2. By building "cloud gateway", "data management platform" and other capabilities, the project achieves effective management, digging, and utilisation of application data.

3. To ensure operation safety on the mining face, the project integrates drones, AR/VR and other technologies to support drone-aided inspection and AR/VR remote operation and maintenance scenarios so as to further reduce the staff size on the mining face.

4. The project promotes wind power and PV applications in mines to answer the call for low-carbon and green development of mining face operations, and achieves digital management of energy on that basis.

5. The project integrates the current application scenarios with digital mining software, 3D visualised management platforms, and intelligent truck scheduling systems to improve the intelligent atlas of the mine for system and application integration.

Meanwhile, the practice has also been expanded to three drilling rigs, three electric shovels, and six mining trucks in the Panzhihua iron ore in addition to the current one drilling rig, one electric shovel, and two mining trucks, moreover, there are pilots in Baima iron mine. The project aims to achieve full coverage across the Panzhihua iron ore with 16 drilling rigs, 23 electric shovels, and 27 mining trucks by 2023, with production application and promotion in Baima iron mine, and full coverage of Baima iron mine by 2024. Based on the design progress of Honggenan mine, the project will incorporate the practice standards aligned with relevant scenarios.