5G-based Unmanned Green Mine of Jiaozuo Qianye Cement Company

> Henan Energy and Chemical Industry Group Jiaozuo Coal Group has built the first 5G unmanned green mine in Henan province through partnerships with China Mobile Group Henan Co., Ltd. and Yuexin Shidai. Thanks to the 5G private network, Jiaozuo Qianye Cement Company mine have realised remote-control and unmanned driving, which enhanced the production efficiency and slash the human costs. Additionally, worker casualty, the lifeline of a mine, has been reduced to zero. A safety accident can throw the mine into production suspension or even closure, with the loss usually surpassing CNY tens of millions. Boosted by 5G and other emerging technologies, the traditional mining industry is heading for high-quality and sustainable development.

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Case Overview

In response to the state's call, Jiaozuo Coal Group joined hands with Yuexin Shidai and China Mobile Group Henan Co., Ltd. to take the lead in building a 5G + unmanned green mine in 2019. The mine realises full-process unmanned operation of the open-pit mine areas including shovelling, loading, and transportation, greatly improving the production safety, mining efficiency, and resource utilization of non-coal mines. The 5G unmanned mine project of Jiaozuo Coal Group was divided into two phases, with fourteen 5G base stations constructed and put into operation. The five 5G base stations of the first phase were completed at the end of November 2019, and applications including 5G-based unmanned driving of 60 unmanned vehicles and 5G-based remote control of 13 excavators and 10 drilling rigs were realised in 2020. This project is the first 5G-based unmanned green open-pit mine project in China. Currently, the first phase of its construction has wrapped up, and the second phase will focus on the top-level design for planning and using the OnePOWER Industrial Internet platform.

Industry Challenges

A smart mine usually involves a wide range of factors including equipment, network, detection, data, and management, and requires multidisciplinary solutions that feature innovation and interactions between multiple technologies. This also requires standard data formats across the platforms to facilitate data mining, analysis, and visualised presentation to avoid stove-piped management due to information silos. China is a mineral resource-rich country where mining industry plays a significant role in China's national economy. The mining industry demands mechanisation, automation, informatisation, and intelligence. Specifically, network services of high quality are the foundation for these four demands and can boost their development in mines to meet the requirements of the "Unmanned Mine" policy. The demonstration, implementation, and commercial replication and promotion of smart mines in China will deepen the structural reform of the energy supply.

However, first, production safety risks still exist in the industry. The death rate per million tons (DRPMT) of coal in 2019 was 0.083, five times that in the United States, indicating the great room for safety improvement. Second, the production requires daunting energy consumption. Mining and transportation in mines rely on diesel vehicles, with a large amount of fuel consumed, pushing up the cost. Meanwhile, the resulting pollution and emissions also exceed the standards. Third, the human costs remain high, leading to the difficulty in recruitment and brain drain. If two drivers are assigned for each mining vehicle, the human cost per year will be CNY 160,000, which is quite high. Fourth, the intelligent applications are relatively backward. Currently, manual operation is still the dominant mode and machine-aided operation is in urgent need to improve the production efficiency with new technologies and intelligent applications. According to relevant surveys, the average age of mine drivers in China is above 45, with the aging trend getting prominent. The mining areas have a large temperature difference and boring manners of working, leading to safety hazards after long-time drive. As a result, young drivers are less willing to take the jobs. The annual expenditure in transportation, equipment maintenance, and human resources accounts for 50% to 70% of the total production cost. Safety, efficiency, and cost are the three pain points in traditional mine which stimulates the emergence of unmanned mining trucks.

☑ Solutions and Benefits

Network planning

In the first phase, five 5G base stations were built in the unmanned mine of the Qianye material factory, including five newly built 5G macrocells. The investment covers the main equipment and auxiliary materials, antenna, construction, design, supervision, safety production, EIA, civil construction, iron towers, supporting costs, laying base station transmission lines, and building new communication poles. In the second phase, nine 5G base stations are planned in the unmanned mines of the Qianye material factory according to the mining progress, including four new macrocells. The investment covers the main equipment and auxiliary materials, antenna, construction, design, supervision, safety production, EIA, the civil construction, iron towers, and supporting costs for the nine stations, the base station transmission lines, the supporting maintenance costs, and the maintenance costs of the lines and main equipment.
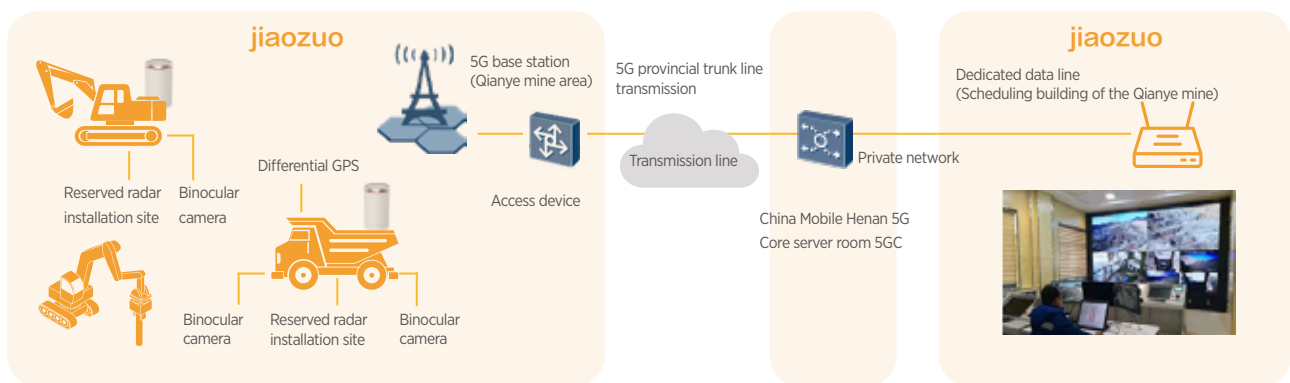
01 5G + remote mining control

With the exclusive 5G private network, the transmission latency of remote control is reduced to shorter than 30 milliseconds, which has effectively eliminated transmission freezes to ensure real-time control of the excavators.

02 5G + automatic transportation by unmanned green mining trucks.

The combined use of 5G private network + edge computing + BeiDou positioning manages to control the positioning accuracy within 20 cm, which has greatly improved the transportation speed of unmanned intelligent vehicles. The solution also solved issues including the manual operation safety risks, the lower positioning accuracy of vehicles, the vulnerability, and the large amount of pollutant emissions.

03   5G + unmanned convoy

The solution utilises the ultra-high speed and ultra-low latency characteristics of 5G networks and integrates information sources such as vehicle wheel speed sensors, inertial navigation systems, lidar, and machine vision based on the v2x Internet of Vehicles technology. It enables vehicles automatically avoid obstacles, follow the leading vehicle, meet with other vehicles, and automatically plan routes to ensure the convoy safely travels in order.

04   5G + precise mapping using drones

he 5G enables real-time 3D data transmission to facilitate quick analysis and decision-making. The traditional mode relies on manual measurement, which has a high labour cost with delayed data and incomplete information.

Project innovation highlights

Automated formation travel of unmanned vehicles

The solution utilises the ultra-high speed and ultra-low latency characteristics of 5G networks and integrates multi-source information such as wheel speed sensors, inertial navigation systems, lidar, and machine vision based on the v2x Internet of Vehicles technology. Calculating the track based on the differential model of mining truck motion, it enables vehicles automatically avoid obstacles, follow the leading vehicle, meet with other vehicles, and automatically plan routes to ensure the convoy safely travels in order. Meanwhile, a multi-target intelligent scheduling model for open-pit mines has been built taking into account the ore blending plan, allocation balance, production capacity, malfunction status, route, and queuing status. Correspondingly, an evolutionary solution has been proposed based on historical data and experience to realise automatic scheduling control and global optimization of the truck-shovel coordination, with equipment utilization, travel distance, and waiting time considered as well.

Unmanned electric trucks produce zero CO2

The traditional diesel-powered vehicles are replaced by pure electric ones. In view of the surface mine's transportation scenarios where trucks are empty-loaded traveling up, being electricity powered, and loaded traveling down, the vehicles receive charging to recover.

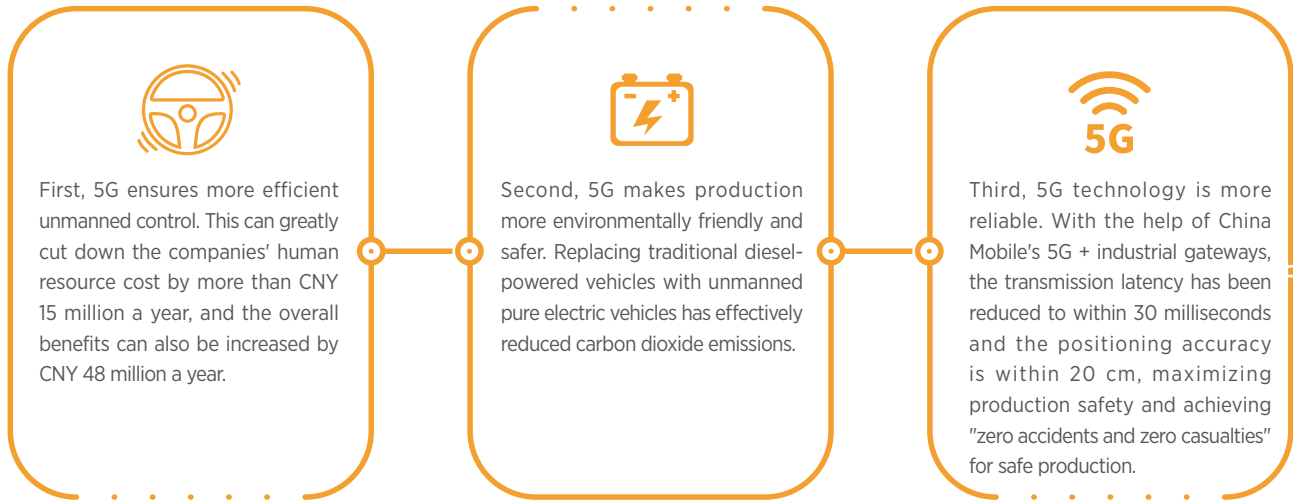**Employed 5G industrial-level gateways of the Internet of Things companies**

The project applies the 5G industrial-level gateways of the Internet of Things companies to mining trucks for the first time to support real-time transmission of HD site videos for remote control. Compared with the traditional 4G and microwave networks, the communication quality of the 5G networks has been greatly improved, with a much higher positioning accuracy, a lower latency, and reduced video transmission freezes, operator dizziness, and vehicle damage.

5G+ Smart Mining

The significance of 5G to the project is manifested in the following three aspects

First, 5G ensures more efficient unmanned control. This can greatly cut down the companies' human resource cost by more than CNY 15 million a year, and the overall benefits can also be increased by CNY 48 million a year.

Second, 5G makes production more environmentally friendly and safer. Replacing traditional diesel-powered vehicles with unmanned pure electric vehicles has effectively reduced carbon dioxide emissions.

Third, 5G technology is more reliable. With the help of China Mobile's 5G + industrial gateways, the transmission latency has been reduced to within 30 milliseconds and the positioning accuracy is within 20 cm, maximizing production safety and achieving "zero accidents and zero casualties" for safe production.

This project has fuelled all participants to carry out in-depth technological innovations in their own fields, and effectively promoted the industry value. The green mine solution targets the pain points of the surface mining industry and addresses the high risks of on-site human operation, with a high replication and promotion value. On the one hand, it improves our reputation and economic benefits in the 5G industry, and on the other hand, it builds a closed-loop ecosystem of the industrial chain to promote the industry toward high-quality and sustainable transformation and development. According to Jiaozuo Coal Group, its annual mining output is 42 million tons, so if CNY 0.1 of profit can be contributed for each ton of ore as the service fees of related industries, the total amount will be CNY 4.2 million, which can fully support the development of the entire industrial chain. Meanwhile, it can also increase employment opportunities. It is estimated that in 2030, the total output, the economic added value, and the number of employment opportunities driven by 5G will be CNY 6.3 trillion, CNY 2.9 trillion, and 8 million, respectively.

The 5G unmanned green mine built under this project has driven the traditional mining industry toward high-quality and sustainable development. Fei Dongbin, Deputy Provincial Governor of Henan province, who is in charge of industry development in the province, stated that the energy conservation, emission reduction, and achieving carbon peak and neutrality targets should start actions from surface mines and the cement industry. The government and China Mobile Group Henan Co., Ltd. have set up a focus team to investigate 82 surface mines in the province. So far, 12 of them have showed the preliminary intention of cooperation and 8 projects have been launched.

Summary and Next-steps

The 5G project has achieved its expected performance. Through 5G technologies, remote-control and unmanned driving of excavators have been realised to support unmanned or less-manned operation in the mines. Moreover, two major technical problems have been solved. The first one is delayed response of remote control. The project requires that the delay should not be longer than 50 milliseconds, while the delay using traditional 4G and microwave networks including Wi-Fi connections is more than 80 milliseconds, which compromises the safety. Moreover, the long working hours also caused to vertigo symptoms among workers. The earthquake-resistant 5G industrial gateways now can record a latency of as low as 20 to 30 milliseconds. Workers can work for longer hours, with smoother operation in a more comfortable environment. The second one is the high-precision positioning of unmanned driving. In the early stage, the unmanned driving platform applications were deployed on Alibaba Cloud. However, issues were discovered with both network connection and application operation, and the safety and stability of vehicles could not be guaranteed. Now we have migrated the platform to local, and realised end-to-end edge computing through transferring data to nearer computing gates. A long-distance, dedicated data line from the provincial core network to the control centre has been set up to ensure data transmission stability and improve the system positioning accuracy to within 20 cm. The low-latency remote control of excavators and the high-precision positioning of unmanned vehicles mark the first practice in Henan province.

Looking ahead, the project plans to complete the second phase network construction of the Jiaozuo Qianye Cement Company and explore more applications of utilizing 5G in the cement production.