



# 5G in Verticals in China

2022





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**Sihan Bo Chen**

Head of Greater China, GSMA

## Foreword

2021 was a key year for 5G's sustainable and mature development after its initial success. Globally, 5G is expanding steadily across all regions, and has become the fastest-growing mobile technology commercially in history. China now leads the world in the number of 5G base stations and connections. There were 480 million 5G connections in China by the end of 2021 and was forecast to grow to 650 million in just one year according to GSMA Intelligence, accounting for over 60% of the global 5G mobile connections.

A pivotal mission for 5G is to empower industries and their digital transformations. The success of 5G in verticals will be an important testament of 5G's full benefits and value. 2021 marked the start of 5G's commercial expansion into verticals, and also its development towards economy of scale for verticals, where the industry is particularly focused on driving greater economy of scale and showcasing 5G's ability to replicate across a wide range of usage scenarios. Scale will be crucial to 5G's ongoing success with verticals, and the journey to reach economy of scale is a critical path to new business opportunities and models in the 5G era.

To achieve economy of scale, the industry needs to explore a wide range of application scenarios to identify practical and genuine demands which will place 5G as the "must-have" or "much-preferred" technology of choice instead of "optional", "substitute" or "back-up" technology. This year, we made efforts to identify 3 areas - 5G City, 5G + smart manufacturing, and 5G + smart mining, as potential breakthrough areas to achieve greater scale. After comprehensive analysis and review of notable application scenarios, we selected a few high quality use cases to promote to the global community for wider adoption that will further encourage development towards digitalized, automated and intelligent transformation.

Jointly with the Chinese operators and industry partners, the "5G in Verticals in China 2022" report presents 16 exceptional cases covering 5G City, smart manufacturing, and smart mining with special focus on industrial scenarios, technical features and future opportunities, including:

- Advanced intelligent city empowered by 5G, and applications in intelligent subway, visualized emergency command system, and emergency medical response command platform;
- 5G in smart manufacturing including, intelligent logistics, machine vision for quality assurance, remote command and control, automated patrol inspection, and flexible production;
- 5G in smart mining, such as production control, environment monitoring, safety protection, and autonomous & unmanned mining truck.

We'd like to extend our sincere gratitude to our industry partners for providing these exceptional use cases, and our appreciation for their efforts and achievements in promoting 5G in verticals. By sharing these valuable experiences to stakeholders in China and the rest of the world, we hope to attract more innovators and pioneers to jointly unleash the massive potential of 5G across industries and achieve more promising economy of scale for vertical applications.



# 5G city

According to the World Bank, the global urbanization rate reached 56.15% by the end of 2020, and China's seventh census also showed an urbanization rate of 63.89% by the end of 2020. This means that more than half of the world's population lives in cities. The continuous influx of people into cities has brought many challenges such as traffic congestion, environmental pollution, complex security situations, and lack of resources per capita. Therefore, city governors need to actively introduce advanced information technologies to improve the digital intelligence of urban governance and build smart cities. 5G has been widely deployed worldwide, and the numbers of 5G base stations and subscribers are growing rapidly. However, 5G is still lack of scale in vertical applications, and diverse and competitive applications of 5G are emerging in urban governance, which may become a breakthrough for scaling up 5G applications.



The mission of 5G is to empower all industries in their digital transformation, and it will certainly play an important role in building 5G City. The application of 5G in urban governance is mainly found in five areas, and there are numerous scenarios for each area.



**Transportation & Logistics**

5G can be applied to public transportation, transportation management, transportation supervision, transportation hubs, road and bridge maintenance, harbor and shipping management, and travel assistance. For example, 5G allows driver fatigue detection, steering wheel snatching alarm, bus priority enforcement, arrival reminder, and crowding monitoring in intelligent buses. When it comes to subways, 5G fuels safety inspection of tunnels and trains, intelligent cloud security inspection, and face recognition at gates. In ports, 5G enables remote control of high altitude cranes, automatic driving of container trucks, and remote driving control. In addition, 5G can help traffic police to analyze traffic accidents, intelligently adjust traffic signals, quickly check driver's licenses, and real-time transmission of videos in traffic police's body camera.



**Emergency services**

5G can be applied to public security, emergency response, epidemic prevention and control, fire fight, disaster prevention and control, safety supervision, etc. For example, 5G allows real-time policy body camera, guard robot control, UAV/unmanned patrol car, assisted reconnaissance of cases; and remote control of fire rescue robots/UAVs, connections of firefighters' smart helmets/AR glasses; and pre-hospital emergency response in smart ambulances, VR/AR training for emergency personnel, infrared thermal sensor data transmission, social distance monitoring during epidemics; and early warning and emergency disposal of flood, earthquake, tsunami, hurricane, landslide and other natural disasters, real-time information collection and delivery; as well as gas use safety supervision and hazardous materials storage safety supervision.



**Environmental protection**

5G can be applied to ecological monitoring, garbage collection, pollution prevention, greening and farmland protection, biodiversity protection, carbon emission management and urban appearance management. For example, 5G enables source tracing of high-rise littering, river garbage cleaning by unmanned boats; and automobile exhaust monitoring, factory discharge monitoring; and forest/green land anti-deforestation and anti-destruction, forest fire-prevention, arable land usage monitoring; as well as endangered animal and plant protection, marine pollution monitoring, and biodiversity monitoring.



**Citizen services**

5G can be introduced in community management, elderly and disabled assistance, radio and television, cultural tourism, sports and entertainment, civil administration, social security and medical insurance management, children's assistance, etc. For example, 5G supports community entrance and exit monitoring, elevator monitoring, parking management; and chronic disease management for the elderly, robot escort for the elderly living alone, intelligent glasses for blind people to see the roads and read books; and interactive museum exhibits and display of changes in tourist attractions; and multi-angle display and immersive experience of sports events and art activities; as well as lost children search and rescue, and prevention from getting lost for the elderly and mental or physical patients.



**Digital government**

5G can be applied to city brain, digital twin city, business administration, customs and justice, fiscal management, public opinion collection, etc. Specific scenarios include rapid data collection and mobile office for one-stop service, production process supervision, taxation audit, end-to-end customs import and export goods monitoring, mobile court, government news pushing, and digital persons for citizen interaction.

To make the amazing 5G City a reality, the following five technologies are crucial:



**Intelligent private use of public network**

Intelligent private use of public network: The public network can be used for private through such technologies as NPN, network slicing, and 5G LAN to reserve resources and isolate critical services on the public network. AI in Networks allows dynamic, flexible, and automated configuration of wireless and core network resources to meet the traffic and performance requirements in emergency situations.

Efficient deep coverage: Pole station, micro/small cell, and digital indoor coverage system support high-performance and blind-free full coverage to satisfy services in indoor, hot spot areas and special scenarios while minimizing costs.



**Efficient deep coverage**



**Low latency and high reliability**

Low latency and high reliability: Ultra-reliable low latency communications (URLLC), edge computing, dual connectivity, and other features can reduce end-to-end network latency, improve network disaster tolerance, and offer appropriate response speed and reliability for critical communications.

Fast high-accuracy positioning: By combining 5G, GPS, and BeiDou, we can deploy positioning enhancement, fast positioning, and other features to enable satisfactory positioning accuracy and speed for critical communications.



**Fast high-accuracy positioning**



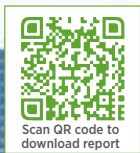
**Secure group communication**

Secure group communication: Features like group management and broadcast/multicast can fuel interoperability and service convergence between 5G and trunk communication, while ensuring the security of the communication process and communication content.

As 5G technologies and urban governance advance, becoming 5G City will be more important than ever and the 5G City vision will become a reality step by step. To fulfill the vision, it is recommended to:

- 1 Make 5G coverage better and wider to include all scenarios with a people-oriented approach, and offer citizens with diverse 5G applications, convenient social services, balanced development opportunities, and consistent experiences anytime and anywhere, therefore improving their feelings of gain and happiness.
- 2 Make 5G an infrastructure to enhance digital government in cities; explore the integrated applications of 5G, AI, and big data in urban governance; build comprehensive governance platforms such as city brain and digital twin city; build digital and intelligent 5G cities in terms of transportation, emergency public security, environmental protection, citizen services, and digital government; and replicate 5G City applications in more cities.
- 3 Leverage 5G and digital transformation to facilitate exchanges and cooperation among cities from different countries, deal with challenges in traffic congestion, environmental pollution, public safety, and public health together, and create green and low-carbon 5G City clusters in the digital era, therefore building a human community with a shared future.





# Smart Nanshan in Shenzhen: 5G-Powered City



As a developed administrative area in the first-tier city, Nanshan follows a comprehensive top-level design plan powered by cutting-edge 5G + technologies to enable city-level governance and services. By taking into account governance, public services and industry development, the plan addresses the most pressing needs of the majority. From terminals to networks, a super-large city-level cognitive network of 5G + IoT capability has been built that presents growth trends of the urban 5G industry in a panoramic, layered, and dynamic manner, and reshapes the coupling effects of 5G+ smart cities.

**Zhang Jun**

Party Secretary and Head of Government Services and Data Management Bureau of Nanshan District, Shenzhen

## Partners



## Case Overview

In 2018, the Nanshan District started to build its 3D modelling database and application system for urban buildings which was completed by telecom included 3D building models covering 170 km<sup>2</sup> in the Nanshan District. Then it started a comprehensive overhaul of the 3D data in the Smart Nanshan database in January 2020 and completed the construction of the Smart Cloud urban application service platform of Nanshan, Shenzhen in April 2021.

A super-large city-level cognitive network of 5G + IoT capability is built based on the existing system of "three networks, three platforms, and three centres" to facilitate the application of 5G technologies in different scenarios. A national level security service system that supports domestic encryption algorithms like SM1, SM2, SM3, SM4, and SM9 is provided to promote innovation in information technology and disaster recovery. The network can connect millions or even billions of IoT devices and enable flexible resource expansion. With independent iterative upgrade capabilities, this digital access network is highly integrated to serve the development of industrialization in the district.

Convergence of 5G with multiple technologies for city-level governance and services - A system that presents vital indicators of city operation is enabled by accurate, comprehensive, real-time, and quantifiable IoT data. In this way, the system provides a consolidate interface to display and monitor key operational indicators of the city for intelligent early warning. To break down barriers in urban services and governance, and to address the pain points in public services and social governance, 5G technology and 5G network are integrated with AI, big data, edge computing, and cloud computing to drive unified access between

urban governance and public services. Smart application across different scenarios then facilitates smooth and efficient governance as well as convenient and considerate public services.

The city's 5G industrial operation is presented in a panoramic, layered, and dynamic manner. The City Information Modelling (CIM) platform makes city's digital-twin possible. Supported by multi-dimensional cognitive capability and real-time interconnection, the entire city is visualized and presented to city managers to assist with their urban decision-making and to optimise the experience and efficiency of urban management. The CIM platform integrates 5G industry information from various dimensions and creates digitalised city twins for comprehensive analysis. This allows the provision of standardised services for businesses and citizens, and fuels the growth of 5G industries to rocket in all aspects.





## Industry Challenges



### Massive connections of 5G intelligent terminals

A city consists of a vast territory, complex requirements, and ever-changing conditions (such as people flow, traffic, transactions, energy consumption, environment, weather, etc.). In the era of intelligent 5G connectivity and IoE (Internet of Everything), a wide portfolio of sensors can be deployed across the city to timely and accurately capture information that reflects the state of a city. As a result, explosive growth has been seen in the number of terminals and types of devices. However, the complexity of the networks that smart sensors connect to can pose challenges to the compatibility and interworking between services in a smart city.



### Convergence of multi-source heterogeneous data

Urban data usually come from multiple origins of different structures. They tend to fall into three categories: unstructured data from images, voice and text; structured data acquired from e-government services; and spatial-temporal data represented by geographic information and IoT data (such as traffic flow, people flow, energy consumption, weather, etc.). Data is large in volume and dynamic, while smart city applications usually require a multitude of data from many different types and origins. It is, therefore, another challenge to manage this complex data and effectively support applications after it has been collected into the system.



### Breaking down information silos

smart public service and management, empowered by 5G, inevitably requires information to be accessible among citizens, governments, and enterprises when needed. This involves a wide range of operations, complex methodologies, and demanding technical requirements. It is difficult to complete this task by any single organization. In the traditional model of "integrator + subcontractors", all organizations involved tend to do their jobs based on their own products and technologies, resulting in information silos, which are difficult to solve.

## Solutions and Benefits

Urban governance solutions are categorized based on the following three types of scenarios:

To enable urban governance and services in the three scenarios, a framework is designed as follows:

### 5G-powered Urban Services and Governance

#### Government governance

- Urban full-lifecycle digital twin applications
- 5G private network construction and integrated management of information infrastructure
- COVID-19 prevention and control powered by "5G + Big Data + AI + IoT"
- Intelligent traffic management powered by "5G + AI + Big Data"
- 5G drone management of illegal buildings

#### Public Services

- 5G-enabled emergency response with multi-functional smart poles
- 5G robots for intelligent urban services
- Cultural tourism and government services based on 5G RCS

#### Industry Development

- 5G-enabled panoramic industrial chain
- Real-time passenger flow and density statistics powered by "5G + AI"



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Smart Nanshan in Shenzhen

#### Government Governance

- CIM
- 5G Private Network Construction
- Epidemic Prevention and Control
- Transportation Management
- Illegal Building Monitoring
- .....

#### Public Services

- Emergency Rescue
- 5G Unmanned Vehicle
- Smart Service Robot
- 5G RCS
- 5G+Vlog
- .....

#### Industry Development

- Pedestrian Flow Analysis
- Industrial Linkage
- .....

Solutions

Solutions

Solutions

### Government Governance

The end-to-end services that cover the entire process and the full life cycle can empower 5G construction. By leveraging 5G as the basic communication technology, we can enable CIM, epidemic prevention and control, intelligent transportation, intelligent building construction, and other applications to assist government decision-making and improve governance efficiency.

### Public Services

The fast, stable 5G network with low latency can allow a series of public services such as emergency rescue, 5G unmanned vehicles, 5G intelligent service robots, 5G RCS, and intelligent cultural tourism.

### Industry Development

The rapid development of upstream, midstream, and downstream industries can be fuelled through network infrastructure construction, the introduction of terminals including sensors, cameras, intelligent robots, drones, and smartphones, and the application of artificial intelligence, big data processing, cloud computing, edge computing, 5G, and 4K/8K HD video.

## 01 Governance Scenarios



▲ 5G in Digital Epidemic Prevention and Control

The Smart Nanshan in Shenzhen project enables COVID-19 epidemic prevention and control in Nanshan entirely digital. 5G network and terminals play a critical role in dynamic data aggregation, data mining and analysis, expert video conferencing, and on-site real-time linkage thanks to fast deployment, high bandwidth, and low latency. The platform can independently and intelligently collect basic information and health status of personnel returning to work online, which helps the government approve enterprises' production resumption application. Citizens' travel trajectories in the past 14 days are automatically tracked to identify any possible source of infection through big data analysis. 5G cameras and NB-IoT locators are deployed in key epidemic prevention and control areas for epidemic monitoring. AI robots can automatically make calls to investigate persons and collect information. Technologies like AI, big data, and 5G are integrated to accelerate virus detection and diagnosis, monitoring and analysis, and full traceability management.

Traffic management involves various complex scenarios. Easy-to-deploy and convenient 5G cameras, together with AI and big data, create a new mode of intelligent traffic management. 5G cameras can be deployed anywhere, both in ordinary locations and restricted areas such as protected historic sites and ancient buildings. They feature easy deployment, convenient usage, and low deployment cost. 5G's high transmission rate, massive bandwidth, and reliability allow the cameras to capture massive high-definition data, which are turned into intelligent traffic information after AI and big data analysis and processing. The information can help in traffic management plan optimization, management policy development, carbon emission reduction, and determination of traffic safety technology and management methods through accident cause analysis.



▲ 5G in Intelligent Traffic Management

As to building construction management, the inspection of illegal buildings is a laborious and time-consuming task, and some unauthorized works may be easily ignored. 5G drones make the process easier. After setting the cruise inspection routes and collecting data during the first flight, officers can establish a digital model. Flight inspections can then be initiated at a certain interval on demand. Automatic algorithm analysis via AI can spot the differences among different periods, therefore finding any new illegal buildings. At the same time, the fast and stable 5G network allows real-time postback and playback of high-definition video to assist manual inspection. 5G drone features high efficiency and low cost and can inspect one square kilometre in 20 minutes.

## 02 Public Services



5G Multi-functional Smart Pole Serving Residents

Unattended early warning for drowning, fire, and trespassing is made possible by integrating 5G border patrol inspection, 5G multi-functional smart poles, 360-degree panoramic live broadcast equipment, and 5G cameras, along with regional monitoring linkage and AI. In case of drowning, fire, and tourists crossing the red line to damage monuments and landscapes, multi-level alarms will be automatically triggered for broadcast repulsion or rescue. When an accident occurs, life-saving equipment can be acquired through face recognition, and the use of equipment and rescue process can be fully recorded in the background. Compared to traditional rescue boats, intelligent rescue robots are smaller and more dexterous, thus greatly accelerating the rescue and reducing the risks faced by rescuers. Fast, safe, and efficient water rescue becomes a reality. 5G broadcast equipment and 5G video linkage enable remote alerting in key areas, as well as advertising and emergency evacuation. In addition, 5G multi-functional poles are equipped with 5G micro-base stations, WIFI6 hotspots, AED defibrillators, and weather monitoring modules.

5G intelligent service robot features voice interaction, conversation for Q&A, face recognition, semantic understanding, environment perception, and autonomous positioning & navigation. The LED screen on the robot can spread the knowledge of history, epidemic prevention, and garbage classification in all areas. When deployed in scenic spots, the robot with a guide function can interact with visitors to introduce the attractions and recommend routes. Pedestrians can throw garbage in the trash can brought by the robot to keep the city clean and tidy.



5G Intelligent Service Robot Serving Residents



5G RCS Serving Residents

"5G+" services drive intelligent empowerment for enterprise employees and community residents. In cultural tourism services, auto photo-taking booths (real-time 5G message pushing), virtual commentary, humanistic propaganda screens, and 3D guide services are provided. In government affair services, active 5G pushing allows the public to access the services anywhere anytime. As long as there is 5G network, residents can open their RCS app to get the inquiry, consultation, reservation, and queuing services offered by the government's public accounts and mini programs, instead of downloading, following, registering, and logging in. Without leaving home, residents can reach out to more than 500 government services.





▲ 5G Intelligent Unmanned Vehicle Serving Residents

Built on L4-class autonomous vehicles and stable, low-latency, and fast 5G network, "5G Smart Unmanned Vehicles" offer a smart service platform on the wheels. It can provide residents and tourists with free meals, first-aid medicine, masks, alcohol, and anti-mosquito medicine. The unmanned vehicle can run 24 hours a day. Residents can beckon the vehicle and scan the code to get the needed services. The vehicle can also be used as a mobile propaganda station for epidemic prevention and extreme weather notification. At the same time, it can act as a video collector to connect tourists, vehicles, roads, traffic data in real time, therefore providing effective data for urban governance.

The "tourist + scenery" star-style 5G + Vlog can be a cultural carrier to better expose the scenic spots by stimulating tourists to share the fun. Customized high frame rate cameras can automatically capture touring clips. With such algorithms as beauty, background defocusing, and automatic exposing and focusing, the camera can generate exclusive travel logs to record the amazing moments for each tourist. Suitable for recording different scenes, the customized camera allows animal recognition, delayed photography, night photography, and wide-angle photography. It can automatically select clips and generate a collection of the best moments for each tourist and the attraction every day. The edge all-in-one machine locally pulls video streams. Supported by customized recognition algorithms and theme templates of the scenic spot, the camera can rapidly edit multi-shot video streams, which can be received and downloaded by tourists through 5G RCS.



▲ 5G + Vlog Serving Residents

## Summary and Next-steps

The smart city built by Nanshan District maximizes the coupling effect of 5G + smart city. It comes with digital services across the process, efficient and orderly urban governance, data opening, integrating and sharing, green and economic development. A construction model for smart city 4.0 or 5G + smart city, is put in place to tailor to city scale, governance needs, construction pain points, budget, industrial distribution, and other factors. All types of administrative areas in not only first-tier cities but also second- and third-tier ones can transform into 5G+ smart cities instantly.

The convergence of 5G with new-generation information technologies such as big data, AI, IoT, and cloud computing will link up the "end-edge-hub" hierarchical smart scenarios to empower smart cities. 5G + AIoT help shape an intelligent Internet of Everything and generate massive data. 5G + MEC contribute to edge intelligence, which boosts the seamless connection between urban cognition and urban intelligence. 5G + IOC make possible central intelligence that promotes data circulation, sharing, interaction, and collaboration to create more value and incubate various innovative applications. This further catalyses urban management and service reform to save countless

labour, resources, and capital, improve management efficiency, and bring down costs. With 5G network, smart cities find more and more application scenarios. Smart community, smart transportation, smart culture and tourism penetrate all aspects of people's life. The adoption of network slicing and edge computing technologies for 5G network can better satisfy user needs, improve service customization, drive deeper integration of network and services, and make services more friendly. Thus, residents can be more aware of the "smart city" and more satisfied with the services. In addition, integrated, intensive construction can avoid unnecessary and repeated construction works for service informatisation, thereby reducing unnecessary and overlapping investment. In the future, smart city applications can also be built on the project's construction achievements and information infrastructure for incremental upgrade or application expansion. This can not only protect existing investment but also save expenditures on managing different networks with common needs.

The demonstration project helps verify the digital twin city system and offers a reproducible solution for 5G-powered urban service and governance.



# Guangzhou Metro 5G + Smart Metro



"5G technology facilitates the digital development of the traditional urban rail transit industry by driving the transformation from the traditional multi-layer, complex and fixed network to the flat, lightweight and updateable architecture. First, the high reliability of 5G network enables trains to better perceive the operating environment and their own operating status, thereby improving the transportation capacity of metro lines. Second, the massive connections of 5G network facilitate the establishment of a visual resource scheduling system for each line of the urban rail transit network. The system is designed to monitor the status of passengers and trains in real time, and improve the efficiency of operation and management. Finally, the large bandwidth of 5G network brings about new customer service platforms, allowing timely and accurate access to services in abundant transportation scenarios in the entire metro travel chain through multiple online and offline channels, and improving the travel experience."

**Cai Changjun**

Deputy General Manager of Guangzhou Metro Group

## Partners



## Case Overview

Metro transportation boasts such remarkable advantages as large capacity, high efficiency, energy saving and environmental protection. It is the backbone of the public transportation system in mega cities and a critical part of the urban comprehensive transportation system, supporting and leading the urban development. Guangzhou Metro is the urban rail transit system of Guangzhou, the third largest city in mainland China, and provides transportation services for 44% of the passengers using public transportation in the city. As of September 2021, the total operating mileage of Guangzhou Metro had reached 590 kilometers, ranking the third in mainland China, and Guangzhou Metro had transported up to 11,569,400 passengers per day.

Guangzhou Metro, China Mobile and ZTE Corporation partnered to optimise the performance of the new 5G private network for Guangzhou Metro, building a safe, accurate, collaborative and green metro service system featuring ubiquitous interconnection and holographic perception. Based on the advanced 5G network technology, a number of 5G + smart applications were deployed to cater to the actual needs of metro stations, which led to significantly improved efficiency of station operation, more convenient metro operation and management, and greater passenger satisfaction.

Guangzhou Metro has been a testament to the capability of 5G private network in integrating and supporting multiple metro services.



## Industry Challenges

There were many pain points in the Smart Subway Construction and Operation:



### Complex systems

There were more than ten systems, including vehicle, power supply, communication, information, water supply and drainage, heating, ventilation and air conditioning, and each system had many subsystems. There were also complicated equipment models and system standards, and a large number of different types of terminals and equipment nodes. In addition, the systems, such as the electromechanical system and communication system, were managed and operated separately, resulting in various operation problems such as low intelligence, intensive labour and slow response. Therefore, it was imperative to improve the operation and management level.



### Inflexible network

The terminals and servers of subsystems in the stations were connected through a wired network, resulting in various problems such as troublesome and costly integrated wiring, inflexible operation and maintenance, and slow emergency response.



### Poor on-board data backhaul

There was a large amount of data from online monitoring of on-board equipment to be sent back. Due to the insufficient transmission bandwidth, transmission reliability and anti-interference ability of the existing vehicle-to-ground wireless technology, the practical application mainly relies on inefficient manual copying, and efficient real-time automatic return transmission is urgently needed.

## Solutions and Benefits

The project combines the actual business needs of the subway, based on the customized and optimized 5G network and multi-cloud platform architecture capabilities, and introduces a series of integrated and innovative applications in typical subway scenarios to effectively improve the efficiency of subway stations and internal management.

### Technology

1

#### Enhanced and optimised 5G private network performance

Carrier aggregation (CA) was adopted to enable a multi-line video backhaul; detection and compensation algorithm for Doppler frequency offset and super-cell technology guaranteed a high-performance network at a high driving speed of 160 km/h; and differentiated tunnel coverage solutions were adopted to boost the uplink rate to 750 Mbps.

2

#### Multi-level industry cloud-based network solution

Hierarchical and fine-grained management was adopted to meet the customers' differentiated business needs with precisely matched cloud-based network solution; safe and effective end-to-end isolation was achieved by "keeping data inside stations"; and the solution was flexibly deployed together with base stations as a plug-and-play solution without prior site survey.

3

#### Innovative 5G indoor positioning

Based on the independently-developed UTDOA (Uplink Time Difference of Arrival) algorithm, 5G indoor positioning could keep the deviation within 2 meters.

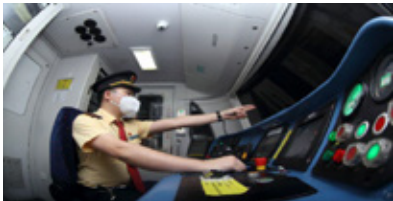
### Application

#### 01 China's first 5G metro train

For the currently fastest D-type metro train, a dedicated 5G receiving antenna and TAU (Train Access Unit) were designed and new trains are equipped with 5G upon leaving the factory to enable full-band 5G reception in shock-proof, fire-proof and wind-resistant environments for rail transit, bring high gains to the customer, and better support the platform for train data monitoring.

## 02 5G vehicle-ground wireless solution

A vehicle-ground wireless solution was created for driving safety control monitoring, operation management and passenger services, leading to enhanced protection, improved operation and maintenance efficiency and better service experience. The advantages of this solution are as follows:



▲ Switch from passive protection to active protection



▲ Switch from offline video surveillance to intelligent online video surveillance



▲ Switch from train operation-centric services to passenger-centric services

## 03 Comprehensive upgrading of physical tunnels to "tunnel digital perception"

The 5G transformation of physical metro tunnels enabled real-time perception of tunnel status from the train cab and monitoring centre, which enhanced driving safety and management and control of the metro line network, accelerated fully automatic unmanned driving, and enabled tunnel digital perception applications such as identification of track water logging, identification of foreign body falling, monitoring of civil air defense door intrusion, identification of roadbed cracks, identification of track deviation, and environmental monitoring.



▲ Identification of track water logging



▲ Identification of foreign body falling



▲ Monitoring of civil air defense door intrusion



▲ anomaly monitoring of tunnel wall box



▲ evacuation platform personnel



▲ Environmental monitoring

## 04 Innovative smart metro applications

Based on the 5G SA environment, various operation management and passenger travel services are provided in metro stations together with partners:



By utilising the benefits of 5G network, such as high bandwidth, low latency and no additional wiring, turnstiles in metro stations are transformed to realise face recognition, which significantly improves the passing efficiency.



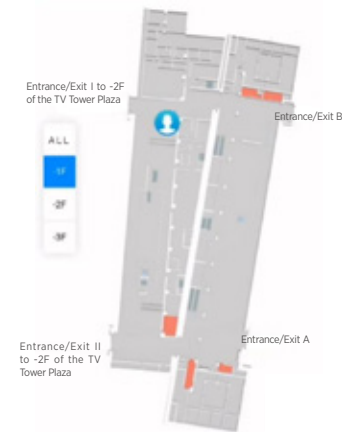


Based on 5G network and 5G CPE, mobile electronic guidance screens, intelligent customer service machines, turnstiles using face recognition, intelligent security control and harmful gas sensors are deployed.

The data generated by the X-ray security check in the security check subsystem are transmitted back to the back office for monitoring through the 5G network in real time, allowing the schedulers in the back office to coordinate the X-ray security check data at all entrances and exits of the entire metro station and quickly locate any dangerous items and persons; In case of any trouble when entering the station, passengers may talk to the administrators in the back-office monitoring centre through the 5G wireless network, instead of waiting for assistance at the side door, which significantly reduces the workload of metro staff.



HD video surveillance cameras in the station are connected through the 5G network, and back-office AI video analysis capability is utilised in various scenarios such as passenger flow analysis, abnormal behavior analysis, and people evacuation.



The high-precision indoor positioning application based on 5G Qcell+MEC integration uses open APIs to connect with third-party applications. Based on the independently-developed UTDOA algorithm, 5G indoor positioning keeps the deviation within 2 meters, providing passengers with accurate indoor navigation, push notifications, in-station navigation and other positioning services.

## 05 Intelligent metro operation and maintenance

A massive amount of data on train operation is collected through 5G, and AI intelligent analysis is integrated to switch from passive to active operation and maintenance, leading to reduced costs and increased efficiency. The real-time backhaul and collection of a massive amount of data on train status enables the switch from passive to active operation and maintenance, timely intervention, and early warning. In addition, previous fixed repair is changed to on-demand repair, which reduces the maintenance cost.

### Economic benefits

At present, the online data on people, trains, operating environment, equipment and scheduling in this Guangzhou Metro project is being shared with unprecedented breadth, depth and speed, which not only improves the driving safety and transportation efficiency, but also reduces the metro operation costs. The Guangzhou Metro 5G + smart metro model may be gradually rolled out to other parts of the country. With 5G's deep integration with and wide implementation in the metro industry, the 5G industry will see substantial growth in economic benefits.

### Social benefits

The research of 5G in the metro industry facilitates the integration with the applications in the metro industry in terms of various wireless network coverage, collaborative management of cloud-edge-terminal resources, etc. By improving the convenience of urban transportation and promote the digital development of traditional industries, a new high-end and intelligent industrial ecosystem will be created to lead the high-quality development of urban rail transit.

## Summary and Next-Steps

In the future, new types of common network technology including private network for dedicated purposes, edge computing, network slicing and ubiquitous integration will be applied in the Guangzhou Metro project, so as to improve the flexibility, scalability and resilience of the typical industry systems during their construction and application. Focusing on the national key R&D plan "Broadband Communication and New Types of Network" launched by the Ministry of Science and Technology of China, we will continue to make full use of our innovative achievements starting from demonstration projects and establish a complete energy-saving system for 5G equipment in metro scenarios to meet the national requirements for energy saving and emission reduction and achieve technological breakthroughs.



# The Project of 5G Emergency Visualization System in Lishui

“ Lishui is the prefecture level city with the largest land area in Zhejiang Province. With nearly 90% of forest coverage, 5% of water, and 5% of field areas, the city suffers from a wide range of disasters that occur frequently and cause great losses. A visualization system is the basis for quickly handling emergencies, as well as important guarantee for informed decision-making and command and scheduling. Lishui 5G emergency visualization system is a platform integrating cloud, management and terminal based on the requirement of the Bureau of Emergency Management for the benefit of people's livelihood. Powered by the 5G network, 5G mobile cabin, satellite communication system, visualised scheduling system, and other capabilities, the platform provides features such as disaster early warning, remote search and rescue, real-time command, 24/7 and all-weather protection. Early warnings and larger scope of search and rescue provide the possibility to minimize people's losses and the basis for major decision-making. The platform integrates automated monitoring and early warning of disasters and efficient rescue for disaster prevention and relief.

**Yang Jinyue**

Director of Bureau of Emergency Management of Lishui

## Partners

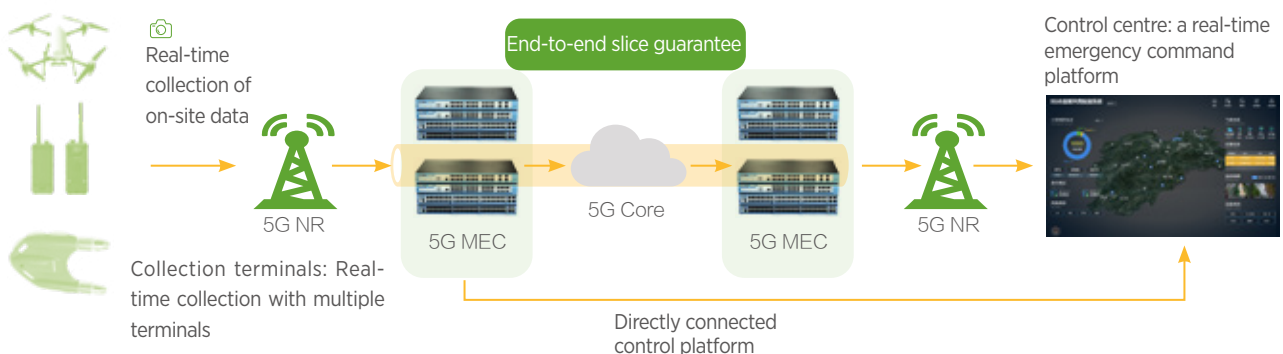


## Case Overview

Lishui is in an area prone to frequent natural disasters. During the flood season, secondary disasters such as mountain torrents and geological disasters frequently occur in small basin areas. According to the "Statement of Work on Local Construction of a Video Scheduling System for Emergency Command" set forth by the Department of Emergency Management and based on the actual situation of emergency management in Zhejiang Province, China Mobile has worked with the Bureau of Big Data of Lishui, Institute of Mountain Hazards and Environment under CAS, the First Geology Group of Zhejiang Province, Ericsson, and Dinnovate Technology to create a dual-way visualized command and scheduling system for on-site disaster relief and emergency rescue at all levels of emergency management departments across the province by leveraging transmission resources such as 4G/5G wireless communication networks and satellite communications, on-site mobile visualization acquisition devices, and TeleEye video platform and Internet of Videos platform of China Mobile Zhejiang.

This project applies 5G capabilities to the monitoring and early warning of and emergency response to natural disasters in small basin areas. By empowering

systems and equipment with 5G network, network slicing and edge computing, a 5G-based converged communication platform is built to connect the mobile visualization front-end devices such as IoT sensors, individual devices, monitoring balls, and drones with communication channels such as satellite communications and 5G cabins to monitor the progress of major disasters in small basin areas in real time. Based on 5G + AI big data analysis, as well as the early warning model of CAS for five types of disasters (mountain torrents, landslides, collapses, dam failures and debris flows) under small basin scenarios, accurate early warning of disasters in small basins throughout the city is realized. 5G RCS is used to broadcast messages and videos of emergency evasion routes to effectively avoid information delay. 5G drones are employed to post back panoramic videos, search and rescue persons with thermal infrared detection equipment, and broadcast in a high altitude. The drones, unmanned ships and unmanned lifebuoys form a life-saving system covering the space, air and ground for automated person search and rescue and a 5G-based closed-loop disaster management and control system to realize real-time disaster early warning and command.



## Industry Challenges

China suffers from many kinds of natural disasters that bring economic losses of more than trillions of CNY per year. The prevention and control of natural disasters have the following pain points:

### inaccurate disaster prediction

Although each business department has an early warning and disposal platform, the disaster early warning systems under the departments of water and land are deployed by district/county, which results in inaccurate early warning, lack of clear goals for disaster prevention and relief, and great challenges at work.

### invisibility of disasters

When a natural disaster occurs, government disaster relief departments and leaders expect to know the current disaster situation as soon as possible. However, there is no flexible and effective rapid response tools that can send all the data on site back to the command centre for informed decision-making.

### data silos

The departments of water, land, and air have their own monitoring and pre-warning systems, but these systems do not share data and are not connected.

### untimely transfer and escape

Natural disasters often occur suddenly and are accompanied by some secondary disasters. It is difficult for ordinary people to tell their occurrence in a timely and accurate manner. As a result, the affected people would not be able to immediately respond to and escape from sudden natural disasters.



Scene of forest fire



Screen of the 5G emergency visualization system cockpit

## Solutions and Benefits

In view of the pain points in the country (excessive small basin areas, frequent occurrence of floods, untimely emergency evacuation, etc.), innovative solutions should be proposed to meet the requirements of the Ministry of Emergency Management of China for the construction of a visualization scheduling system for two-way interactive emergency control. Under the guidance of the Zhejiang Department of Emergency Management, China Mobile Lishui takes the lead in cooperating with Lishui Bureau of Emergency Management to ensure interactive, coordinated and efficient rescue and access at any time via the 5G visualization scheduling system and realize on-site video command, rapid scheduling and broadband and narrow bandwidth wireless communication and other functions. To meet the requirements of "targeted coverage, 24/7 availability and prioritized control", the 5G network featuring large bandwidth, high availability and low latency supports the management and use of the 5G emergency visualization command system.





## Main technical applications in the project

### 01 5G network slicing

Through 5G end-to-end network slicing technology, network resources are flexibly allocated, network capabilities are combined as required, and multiple virtual logical subnetworks with different characteristics are generated based on a 5G network. This technology enables high reliability, high security and service SLA guarantee, ensuring the remote control of drones and unmanned lifeboats. The L4 slice level is used to ensure the over-the-horizon control of drones and unmanned lifebuoys for safe and stable control. This helps to achieve effective coverage of small basin areas.

### 02 Edge computing

In view of the ultra-low latency required for the remote control of drones and real-time processing of HD video backhaul, city-level edge computing provides strong support for the 5G-based closed-loop disaster management and control system deployed in the city. As edge computing supports local data processing, the offloading of large-traffic local services may reduce the burdens on backhaul and effectively reduce costs.

### 03 Various types of 5G terminals

These terminals include individual terminals, monitoring balls, 5G cameras, etc. After the monitoring devices of the project are installed, data is transmitted to the monitoring and control central system for centralised management through the 5G wireless network. The system has a multi-layer structure. It can operate efficiently and is easy to maintain and manage.



Example of 5G terminal in the project

### 04 5G drones and unmanned lifebuoys for real-time rescue

These terminals include individual terminals, monitoring balls, 5G cameras, etc. After the monitoring devices of the project are installed, data is transmitted to the monitoring and control central system for centralised management through the 5G wireless network. The system has a multi-layer structure. It can operate efficiently and is easy to maintain and manage.

### 05 5G real-time 3D modelling emergency command platform

This is the first project in the province to adopt 5G drones and 3D panoramic map. The 5G network is applied to locate the disaster site; drones are adopted to conduct automated oblique photography in the front end; and 3D models are built in the back end. Monitoring information, early warning information, disaster information and resource information are combined for visualized marking and direct display of all the hidden danger points prior to any disaster and the conditions and situation of the affected villages in "one map" for emergency management. The system integrates the information collected in the front end for intelligent decision-making and display on the big screen in the provincial or municipal command centre. The centralized platform facilitates effective real-time guidance from the provincial leaders and experts for on-site prevention and control of disasters.

### 06 5G RCS for emergency communication

5G RCS is used to send messages about escape routes to trapped persons once the escape routes are found through intelligent big data analysis and the trapped persons are located with 5G. The affected people are notified timely for effective evacuation. In addition, "safety code" and intelligent analysis of the monitoring of disaster shelters are also used to get hold of the evacuation.



Example of drone search and rescue in the project

This project is a one-stop solution from automated monitoring and early warning to efficient disaster prevention, management and rescue. If it is widely used in other areas where natural disasters pose a greater threat to the safety of people's lives and properties in the province, even the country, people's lives and properties will be effectively protected through active disaster relief and prevention. After a year of implementation, the project of the "5G emergency visualization system" has achieved its expected goals. According to different types of risks such as mountain torrents, landslides, debris flows and collapses, standardized packages of devices and their alternatives have been specified. Based on the "1 + 30 + 200 + X" distribution plan, a real-time monitoring network covering the whole city will be built in batches. Step by step, the plan will be implemented until all 973 small basin areas in the city are within the scope of monitoring and early warning.

Based on the characteristics of 5G communication network, the system is positioned to be one assisting in early warning of multiple types of natural disasters, collaborative decision-making

and control and scheduling. Through the deployment of monitoring systems, analysis modelling and multi-channel early warnings in various forms, a small closed loop covering "monitoring, analysis, early warning and evaluation" is formed. The early warning information of a small basin area is used as a trigger to start the closed loop of emergency response, and eventually form a large closed loop consisting of "early warning and emergency response for small basins". In addition, the 3D content from oblique photography makes the decision-making more intuitive. The project significantly improves the efficiency of the disaster relief system, expand the scope of its application, and effectively reduce the personal and property losses caused by disasters, making it an inflexible demand for smart cities. By effectively utilizing the 5G communication network and the existing disaster relief resources, the intelligent early warning and disaster relief system allows customized plug-ins at module level depending on application scenarios and geographic conditions to satisfy the needs of typical users in the market in terms of product functions and prices.

## Summary and Next-steps

The 5G emergency visualization system proposed in this project provides a product integrating both software and hardware. For the software, the mainstream modular software development method is adopted to develop server software and client software. The method also supports the customization of plug-ins at module level for different application scenarios, and is compatible with standard general-purpose servers and customized servers. The involved raw material market, logistics, process equipment, human resources, etc. already have mature business models. Therefore, the assessment shows that large-scale production is feasible. For the hardware, on the basis of field investigation of different application scenarios at different locations, devices are customized specifically for small basin areas. All the devices are purchased in bulk from major manufacturers in the industry to reduce costs. The involved raw material market, logistics, process equipment, human resources, etc. already have mature business models. Therefore, the assessment shows that large-scale production is feasible.

Based on the 5G technology, this project supports the customization of plug-ins at module level for different application scenarios, and can be deployed at standard general-purpose servers and customized servers. With the capacities of fast deployment and upgrading, the project adopts 5G network slicing technologies and sensors, and 5G sensor private network slices for disaster relief devices to effectively link all types of early warning with disaster relief devices in the covered areas. More intelligent products for faster response are suitable for wide application in the banks of the Yangtze River and areas where geological disasters occur frequently.

The innovative system integrates 5G into emergency disaster relief, featuring unique combination of devices. Unmanned boats and unmanned lifebuoys account for more than 80% of the domestic market shares, and stand out in battery life, volume, and 5G integration capability.

This project provides solutions to the problems in the emergency

industry such as low degree of digitalization and automation and slow response, boasting promising prospects. It is also a competitive lightweight disaster relief system on the edge side constructed based on the 5G communication network and AI.

This system consists of an emergency control platform, dedicated front-end devices such as 5G drones, 5G unmanned lifebuoys and 5G cameras, which can not only be used for emergency disaster control in small basins, but also for other smart city emergency scenarios such as commanding in emergency response to fires, city monitoring and administration. These make the system expandable into new markets. This project has been widely promoted in other fields. In the field of public security, 5G visualization is adopted for the surveillance system on the cloud. The 5G network featuring large bandwidth, high speed and wide connection enables real-time backhaul of images from the 5G vehicle-mounted monitoring balls and HD videos from 5G high-altitude ball cameras, and deployment of the 5G network within five minutes at temporary sites. Additionally, 5G drones and 5G communication vehicles are also used to assist in security. The security visualization system at high, medium and low levels developed using the surveillance system on the cloud enables whole-process 5G visualization security in major events. So far, it has been used in two national conferences, the National Rural Improvement Conference in Jingning, Lishui, and the worship of Emperor Jinyun in Lishui. This project is the first in Zhejiang Province to be promoted for security in major events. In the field of firefighting, a 5G private network has been established for smart firefighting. With the support of the 5G network for fast backhaul, data are collected in the front end in real time and sent back to the back end for real-time analysis, intelligent early warning, and remote control. In this way, a smart firefighting platform is developed in Liandu District to effectively improve the capabilities for emergency rescue and fire prevention in high-rise residential buildings, reduce fire hazards, and protect the safety of people's lives and properties.



# 5G-Powered Cities: Pre-Hospital Emergency Treatment



China Mobile Guangzhou has built 16,000 5G base stations, making Guangzhou China's first in the number of stations. The endeavour will promote 5G across different industries for business development. We work to build the country's first model pre-hospital emergency treatment project for 5G+ cities to support the Greater Bay Area. In this way, race against time to save lives with prompt medical services.

**Lai Jianjun**

Deputy General Manager, Guangzhou Branch of China Mobile Group Guangdong Co., Ltd.

## Partners



## Case Overview

In 2020, Guangzhou Emergency Medical Centre (hereinafter referred to as "Guangzhou 120") and China Mobile jointly launched the "5G City-level Pre-hospital Emergency Treatment Innovation Demonstration Project" in Guangzhou. Relying on the ability of Guangzhou 120 to coordinate 140 local medical institutions and the 5G technology which boasts large bandwidth, low latency, and wide connectivity, the project combines 5G and remote ultra-high-definition multidisciplinary consultation and real-time return of vital signs with 5G+ interactive video capability as the core, building a 5G urban emergency treatment network and a 5G+ pre-hospital emergency treatment platform, reshaping the pre-hospital emergency treatment process, assigning medical treatment resources in advance, and filling the information blind spots to solve the problems caused by the lack of information, such as patients' inability to save themselves, untimely medical and nursing preparation, and poor pre-hospital and in-hospital handover. The project aims to provide instant first aid, and ensure more efficient pre-hospital emergency treatment, smoother pre-hospital and in-hospital transition, and better integrated service capability of pre-hospital and in-hospital emergency treatment. More time can be saved for patients within the golden emergency time window for higher treatment success rate.

In addition to the emergency command and dispatch system, electronic medical record system, and call positioning system built by Guangzhou 120, the project plans to create a 5G city emergency network and a 5G+ pre-hospital care platform that includes a 5G emergency guidance system, a 5G RCS system, a VOLTE system, a 5G on-board consultation system, a 5G coordinated command and dispatch system, a volunteer paging system, and an AED resource management system. At the same time, 400 emergency vehicles will be updated with 5G technologies.



Guangzhou 120 Dispatchers in Remote Scheduling



Director Li Shuangming (Guangzhou 120) Commanding Treatment in the Centre

## Industry Challenges

### Challenges Facing Pre-hospital Emergency Treatment

#### The 14-minute emergency treatment window and information absence restrict life-saving aid for patients with acute and critical illnesses

It takes an average of 14 minutes for an ambulance to arrive at the patient's location when an emergency call is made. The golden rescue time is only 4 minutes after the onset of common critical illnesses, such as cardiac arrest, foreign-body airway obstruction, and severe burns. The traditional 120 call model fails to effectively collect patients' immediate pathological status, resulting in wasted time window and insufficient information collected, which prevents targeted guidance for self and mutual medical aid and preparation of doctors in the ambulance and hospital. This severely affects the rescue effect and efficiency on patients with acute and critical illnesses.

#### Traditional pre-hospital and in-hospital information is not well connected, leading to untimely assignment of high-quality in-hospital medical resources.

There is a certain degree of interaction bottleneck in the pre-hospital and hospital electronic medical records, pathology information, and registration system, and the relevant diagnosis and treatment information cannot be shared with medical institutions in real time. As a result, the hospital's high-quality medical resources cannot be used in the pre-hospital emergency treatment process in a timely manner.

#### Traditional call technology cannot meet the requirement of instant and efficient video consultation

The traditional mode of communication between the emergency medical command centre and the 120 operators by means of voice call access cannot meet the current demand. Video interaction platforms and technologies are flourishing in China. Although live streaming and on-demand streaming services are common in entertainment and education, they have not yet been employed by government social welfare agencies.

## Solutions and Benefits

Featured with stable, safe, and efficient data transfer, the private 5G medical network has become a trend. It enables video calls among the 120 command centre, first witnesses, volunteers, onboard doctors, in-hospital doctors, medical officers, and patient families by using 5G+ video interaction technology, big data analysis, network slicing, and other technologies. 5G RCS allows rescue mission release, AED resource positioning and release, rescue video guidance, patient identity and family signature, which breaks down the information silos, helps patients in self medical care, gives hospitals necessary preparation time, and guides emergency treatment on the road. In this way, the high-quality medical resources in the hospitals are utilized earlier. Information sharing and collaborative interaction shorten the response time and improve the rescue success rate.

## Solutions

### 01 System architecture

An innovative "1+1+N" 5G+ city-level pre-hospital emergency treatment demonstration project is built by using modern information technologies such as 5G, Internet of Things, cloud computing, big data, and artificial intelligence.

A dedicated 5G emergency treatment network covering Guangzhou is established to connect Guangzhou 120, hospitals, ambulances, medical

personnel, and medical equipment for precise emergency treatment right after emergency calls.

A 5G+ pre-hospital emergency treatment platform is built to allow information sharing and exchange in all scenarios to facilitate collaboration.

A number of pre-hospital emergency treatment scenarios, especially call reception, task scheduling, pre-hospital referral, pre-hospital emergency treatment, hospital admission, and in-hospital emergency treatment, are created to reshape the pre-hospital emergency treatment process and provide medical treatment resources earlier. Such information as 120 first-aid, on-site information of patients, ambulance location, onboard situation, inspection results of medical equipment onboard can be shared to medical treatment officers, social rescue volunteers, in-hospital emergency ICU doctors and other rescuers in real time, which allows instant emergency treatment via professional guidance.





## 5G+ Pre-hospital Emergency Treatment Platform

### First-aid Command Scenarios



Guangzhou  
120 First Aid and Medical Care Command Centre  
Emergency Medical Rescue Command Centre

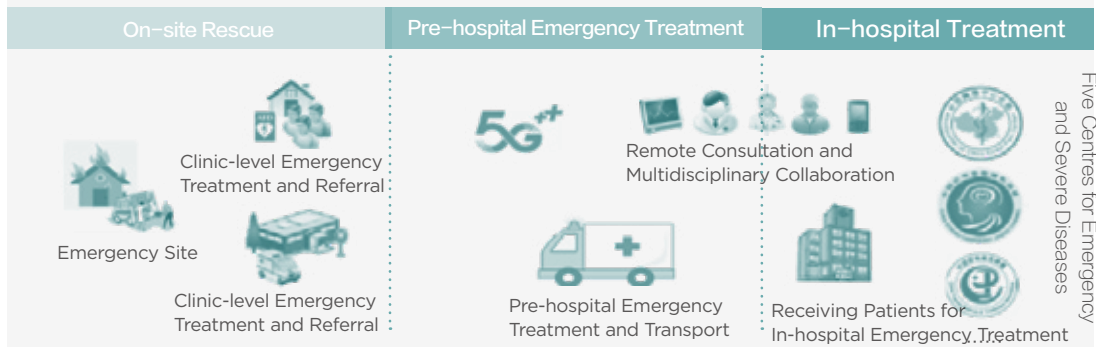


District and County-level  
120 First Aid and Medical Care Command Centres

### Application Software System

Epidemic Prevention and Control Management System	Electronic Medical Record System for Emergency Treatment		Emergency Treatment Management and Training System
120 Commanding and Scheduling System	Incoming Call Positioning System	5G Emergency Treatment Guidance System	AED Resource Management System
Electronic Medical Record System for Emergency Treatment	Volunteer Paging System		Onboard Scheduling System

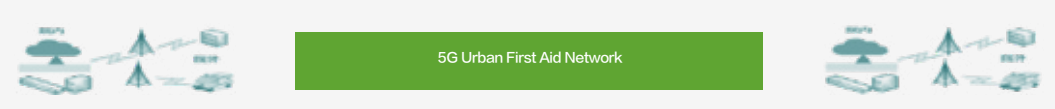
### Emergency Medical Care Scenarios



### Infrastructure and Services

Emergency Treatment Terminal for Epidemic Prevention and Control	5G Ambulance Onboard Consultation System	VOLTE System
Subcentre Standardization Construction	5G Emergency Commanding and Scheduling System	5G RCS

### Network Transmission Services



Systems in operation
Newly-built systems (completed)
Systems in plan (to be built)

## 02 Network

A dedicated, secure, and reliable 5G urban emergency treatment network that offers all-round and continuous coverage, high speed, low latency, and wide connection is built by using key technologies such as network slicing and edge computing to connect the 120 command centre, digital and intelligent middle office, hospitals, ambulances, medical personnel, and medical equipment.

## 03 Technical solutions

### 1 A 5G+ pre-hospital emergency treatment platform

The platform is comprised of a 5G emergency treatment guidance system, a 5G RCS system, a VOLTE system, a 5G on-board consultation system, a 5G coordinated command and dispatch system, a volunteer paging system, and an AED resource management system. Such information as 120 first-aid, on-site information of patients, ambulance location, onboard situation, inspection results of medical equipment onboard can be shared to medical treatment officers, social rescue volunteers, in-hospital emergency ICU doctors and other rescuers in real time. This ensures more efficient pre-hospital emergency treatment, smoother pre-hospital and in-hospital transition, and better integrated service capability of pre-hospital and in-hospital

emergency treatment. More time can be saved for patients within the golden emergency time window for higher treatment success rate.

### 2 Renovation of 5G ambulances

5G is introduced in ambulances with multidisciplinary consultation devices, cameras, and customized management software. When medical equipment and systems such as ECG monitors, ultrasound, and respiratory machines are connected to the 5G network, patients' examination information (such as routine vital signs, and data from ECG, a multi-parameter monitor, and other test and examinations) in the ambulances can be transferred to hospitals in real time to help diagnose patients and develop treatment plans.

## 04 Project Features

### 1 Technological innovation

The project has innovated in and verified the application mode of intelligent medical technologies, especially a dedicated 5G network, big data, Internet of things, positioning, and artificial intelligence. Smart medical technology for pre-hospital emergency treatment quality management combines pre-hospital emergency treatment quality measurement and decision support and single-disease clinical pathway to significantly optimize the pre-hospital emergency treatment process. Built on it, rapid-delivery information solutions and comprehensive product lines have been put in place.

### 2 Management model innovation

Starting from overall informatisation planning and design, quality management, operation management, and patient safety, Guangzhou has presented a new management model for intelligent medical care in pre-hospital emergency treatment scenarios.

First, an intelligent quality management model for pre-hospital emergency treatment is used. A combination of 5G+ video interaction, intelligent mobile emergency care devices, and medical information

integration makes possible the model of "utilizing pre-hospital care quality measurement and decision support to drive pre-hospital care quality improvement" in replacement of the existing model of filling forms for quality management. Guided by the 5R principle, precise medical behaviour intervention and process quality control are implemented in the least invasive way, a solid boost in the compliance of single-disease emergency pathways and clinical guidelines with clear "time windows".

Second, an intelligent pre-hospital and in-hospital emergency operation and management model with multidisciplinary collaboration is adopted. As the emergency green channel management model is integrated with 5G+ video interaction, intelligent mobile emergency treatment devices, and medical information integration, hospitals can allow fine clinical process monitoring that takes into account both facts and subjective judgment based on each patient's conditions. Along with green channel operation assessment indexes and reminder mechanism, it offers an opportunity to solve the lasting challenge of collaboration and coordination across disciplines and departments in pre-hospital and in-hospital emergency care. The original serial processes are parallelized to materialize the patient-first pre-hospital emergency treatment management model.

## Commercial Value

Guangzhou 120 can directly command and schedule the pre-hospital emergency care teams of 140 local hospitals, including over 2,000 first responders and more than 400 ambulances. The mature regional emergency system for mega cities has been operating stably for more than 30 years, receiving over 22 million citizen calls and dispatching ambulances more than 2.8 million times. It is the largest command emergency centre in China, with the appropriate scale and ability for pilot demonstration. In 2021, China has a total of 1.02 million 120 command centres and medical institutions, with about 1.32 million ambulances. Around 400 million pre-hospital emergency cases are handled annually. This means there is a promising scale effect for information system construction. If the 5G pre-hospital emergency treatment platform can be applied to 120 command centres or medical

institutions at all levels nationwide, the estimated market will value more than 20 billion yuan. There are 400 million 120 calls every year, and when the 5G+ video sees scale application, the existing workflows of 120 command centres and medical institutions will be optimized for better work standards, quality, and service methods in pre-hospital emergency treatment. The scale renovation will facilitate the cost sharing of public 5G network and investment in private 5G network by ISPs. The introduction of functions including 5G+ interactive video, VOLTE, and 5G RCS will attract software and hardware players to invest more in R&D and expand the market.

In the future, the 5G pre-hospital emergency treatment platform will cover the entire Guangzhou city and be replicated nationwide.

## Summary and Next-steps

This project is a successful exploration into the application value of 5G+ pre-hospital emergency treatment platform, which is developed for Guangzhou 120's pre-hospital and in-hospital work scenarios. It leverages the excellent network provided by China Mobile to establish a 5G intelligent medical ecosystem led by China Mobile, along with such partners as hospitals, ISPs, equipment vendors, and application service vendors. Focusing on the emergency treatment resource management, process management, and quality management, a city-wide one-stop emergency treatment network targeting multiple diseases is put in place, therefore breaking down the "information silo".

The 5G+ video interaction and 5G ambulance involved in the project have been adopted and tested in the medical security for 2020 Guangzhou Marathon, the command and scheduling for Guangzhou Mountain Marathon in January 2021, and the medical emergency security exercise of Beijiang Dike in April 2021. The excellent results have been praised by leaders at all levels. The incoming call positioning was launched in December 2020, and the system has been running stably for seven months, with 200,000 incoming calls precisely

positioned. 5G ambulances have also been tested in a number of local hospitals.

### Next

1 Along with 5G ambulance transformation for multidisciplinary consultation, integrated vehicle management, electronic medical record expansion, and standardized construction of each 120 sub-centres,

Guangzhou will focus on data integration and service governance, construct emergency care training management module, and standardize pre-hospital care and emergency medical rescue services across the city. The intelligent medical emergency data middle office will be optimized and connected with Guangzhou resident health information platform to obtain patient health data and upgrade the emergency treatment platform.

2 Targeting market demand, the platform will facilitate efficient yet easy ways to save lives. After being recognized by the public, the solution will be replicated to other parts of China.

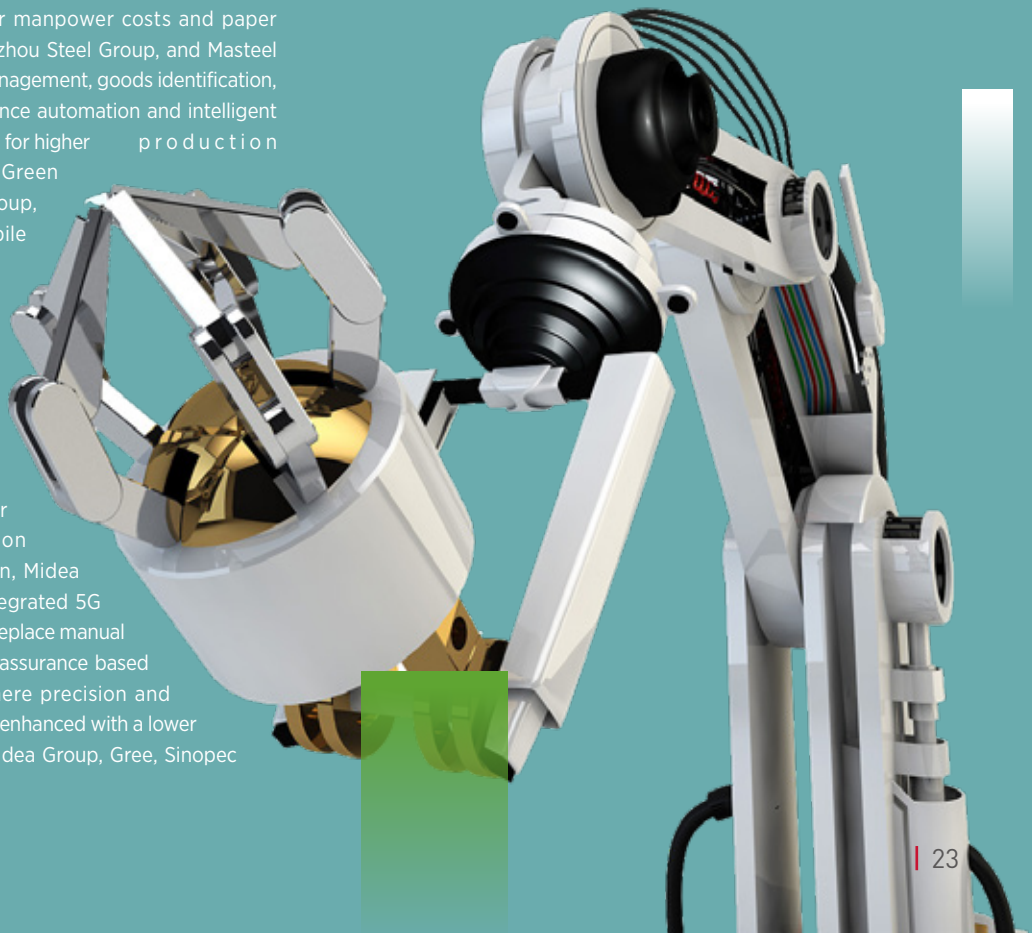
# 5G+ Smart Manufacturing

In the early days of designing 5G, smart manufacturing was one of the targeted industries for 5G applications. As a product of deep integration of new-generation information technologies and advanced manufacturing technologies, smart manufacturing is a key content and essential drive of the Fourth Industrial Revolution, and its core goal and main purpose as well. In terms of speed, latency, reliability, connection, and positioning capabilities, 5G technologies meet the application demands of smart manufacturing and facilitate massive technical innovation and improvements to serve a host of application scenarios in various parts of smart manufacturing, such as equipment connectivity, remote control, flexible production, auxiliary assembly, quality control, warehousing and logistics, safety monitoring, training and guidance. More details can be found in the Ten Typical Application Scenarios and Five Key Industry Practices of "5G + Industrial Internet" released by the Ministry of Industry and Information Technology of the People's Republic of China.

Adoption of 5G technologies in manufacturing can significantly reduce labour costs, cut material inventory, improve product quality, enhance production efficiency, and lower safety risks, in addition to enabling quick response to customised demands from customers with less time needed on adjusting production lines. For example, ZTE Corporation, Midea Group, and Gree utilised 5G mobile transmission, edge computing, and positioning capabilities to develop AGVs with autonomous navigation to raise logistics turnover efficiency, reduce site space usage, and lower manpower costs and paper costs significantly. Midea Group, Liuzhou Steel Group, and Masteel applied 5G machine vision to shelf management, goods identification, and stockyard management to enhance automation and intelligent development in logistics management for higher production efficiency and lower labour costs. Green Point Technology, Liuzhou Steel Group, and Masteel utilised enhanced mobile broadband, low latency, and high reliability of 5G to enable remote control of mechanical arms, roller loaders, stacker-reclaimers, and crown blocks to mitigate potential risks in manual operation in hazardous and high-pollution environment. This approach has realised lower labour costs, higher efficiency, and better collaboration among equipment. ZTE Corporation, Midea Group, and Liuzhou Steel Group integrated 5G technologies with AI technologies to replace manual check with machine vision in quality assurance based on 5G's large uplink capability, where precision and speed of quality assurance have been enhanced with a lower error rate and lower labour costs. Midea Group, Gree, Sinopec

Guangzhou, and Masteel capitalised on high definition, stable signal, and flexible deployment of 5G cameras in addition to mobile data transmission of 5G safety helmets, patrol cars, and drones to apply 5G in safety monitoring, unmanned patrol inspections, violation capture, and risk prevention for lower safety risks, earlier prevention of accidents, and higher intrinsic safety. Moreover, ZTE Corporation, Midea Group, Liuzhou Steel Group, and Masteel launched remote collaborative inspection, auxiliary assembly, auxiliary operation and maintenance supported by 5G AR devices, where experts and front-line workers can have effective communication at a lower cost of expert engagement.

Moreover, applying 5G technologies in production processes can realise flexible production that facilitates speedy adjustments to production lines to meet customised requirements from customers. ZTE Corporation and Green Point Technology have launched some trials in this area. For each change, conventional production lines require planning, designing, implementation, and validation, which is time-consuming and costly. Therefore, a minimum order volume threshold is typically needed to cover the costs of production line changes. By using 5G and intelligent equipment, those thresholds are no longer needed when flexible production is realised to enable customers to have their products tailor-made, monitor the productions, or make ad hoc changes to requirements, or even be involved in the production process. For







# 5G+ Smart Manufacturing

manufacturers, flexible production helps them avoid product overstocks, make ad hoc changes to order scheduling, implement seamless changes to production lines, or even change their product categories.

**In promoting 5G application in smart manufacturing, two issues should be particularly noted:**



## Safety

5G as a new type of infrastructure needs high-level safety – a common point amongst all types of infrastructure. For manufacturers, the biggest concern in adopting new technologies is safety risks, as they will endanger their competitiveness subject to massive economic loss upon safety accidents. According to a GSMA survey, 44% of surveyed companies pointed out that they have strong demands for safety in recent periods, ranking the highest in the survey, overtaking other demands such as cloud, high-speed connection, and Internet of Things capabilities. In a 5G era, with significantly higher diversity and significance of supported business, safety requirements also grew massively compared to the previous consumer business. However, as advanced technologies such as network virtualisation have been adopted to meet complex and diversified business requirements at lower operational costs, safety risks associated with 5G have been on the sudden rise. The increases of safety demands and risks happening in the same time mean that safety threats associated with 5G should be fully considered and taken care of.



## Business mode

The issue with the business mode is relating to the pricing model, ownership of network and terminals, quality commitment and division of roles and responsibilities in management and operation. Larger manufacturers have higher requests on controls, which to them mean safety, competitiveness, high efficiency, and flexibility. Therefore, they tend to choose physical private networks instead of virtual ones while smaller manufacturers, on the contrary, look to access simple management interfaces and "pay-as-you-go" services. The operators should consider potential customers' preferences on product and service offerings, division of rights and obligations, management procedures and interfaces in offering physical or virtual private network products. For manufacturers, it's their optimal choice to work with operators even when they choose to deploy physical private networks, as operators have a sound track record in business reputation and accountability, have solid experience in network planning and operational enhancements, can offer unique strengths in public and private network integration and inter-connectivity, have scale advantages in equipment price negotiation and service upgrade, and can substantially support in customer service and onsite work. Currently, majority of global manufacturing giants with their proprietary spectrum have chosen to work with operators in construction of their 5G private networks. In addition to provision of connection services for enterprises' private networks, operators help the enterprises better operate and manage the networks with safety, network management, integration, and consultancy services.

Now, 5G smart manufacturing is facing some challenges in realising scale development, largely due to the lack of clarity on rigid-demand scenarios, disproportionate standardisation, high costs of chipsets and modules, shortage of industrial terminals, as well as poor latency and positioning capabilities of current version of 5G. In view of the status quo, we need to further clarify 5G application scenarios and demonstrative applications after massive screening, set key industrial and cross-industrial technical standards, unify the requirements of 5G industrial modules and 5G industrial gateways, 5G cameras, 5G safety helmets, 5G AGVs, and other terminals, promote further price cuts in chips, modules, and terminals, deploy standards on 5G low latency, high reliability, and enhanced positioning, and accelerate manufacturers' efforts towards digitalisation and intelligentisation.

# ZTE 全球5G智能制造基地 Global 5G Intelligent Manufacturing Base



## ZTE GLOBAL 5G INTELLIGENT MANUFACTURING BASE



The "Intelligent Manufacturing Powered by 5G" project at ZTE Corporation Binjiang site uses 5G + industrial Internet technologies widely to address the pain points during production, which significantly improves the level of intelligent operation at the site, and helps ZTE deliver better 5G system and equipment to global users faster. It is also a great demonstration. All efforts to build a promising Binjiang will ultimately pay off!

**Zhou Jianfeng**

Vice President of ZTE; CEO of ZTE Nanjing

Partners



### Case Overview

ZTE Global 5G Intelligent Manufacturing Base is a factory built by ZTE with an investment of over CNY 20 billion since 2018 to meet ZTE's needs for the manufacturing of ICT electronic equipment. Since its official production commenced in March 2020, it has followed a five-year plan for development spanning from "Digital Binjiang" to "Intelligent Binjiang", and to "Ultimate Binjiang". Firstly, it focussed on reducing costs and increasing efficiency to explore typical 5G applications. Secondly, it started integration of Information Technology (IT) with Operational Technology (OT) between 2021 to 2022 to speed up full automation and intelligent manufacturing. Last but not least, it expects to optimize production and operation to the optimal extent to establish a dark factory. Based on a deterministic 5G precision network, two distributed precision cloud platforms ("industrial intelligent manufacturing" and "smart park"), as well as business best practices adopted in many scenarios, 5G and industrial Internet capabilities have been extensively integrated to realise the application of 5G in all elements and scenarios at Binjiang. 5G is used to promote intelligent and digital transformations of OT to achieve intelligent equipment, digital manufacturing, and intelligent operation.

The base has witnessed rapid development of 5G innovation. With the support of 5G applications for cost reduction and efficiency improvement, the annual output in 2021 exceeded CNY 30 billion at 50% more than the established target, which is a strong proof of the value of the combination of 5G and intelligent manufacturing for the industry. It also joined hands with China Telecom to build a 5G industrial Internet application supermarket to speed up the promotion of successful new infrastructure projects at Binjiang site with the aim to incentivise enterprises to embrace 5G and explore innovations with 5G enterprise private network and business model to be able to drive the development of the industry.



Intelligent operation



Digital manufacturing



Intelligent equipment



# 5G+ Smart Manufacturing

## Industry Challenges

Due to highly integrated nature of SBCs in 5G base stations and their complex production processes, coupled with the impact of external uncertainties, challenges such as the large production volume, disconnected enterprise IT systems and inadequate manpower all have become increasingly prominent. There was an urgent need to accelerate reform and innovation to build a flexible factory featuring automated and intelligent manufacturing to enhance competitive advantage and improve production efficiency.

At the same time, as the integration of 5G and industrial Internet continues, many new technical challenges also emerged. Therefore, it was necessary to leverage experiences in breaking data silos existed across production lines and premises from pilot projects of digital transformation at factory scale. This would help drive improvements in elementary capacity and innovative capability for the integration of 5G and industries.

Faced with the challenges presented in the industry and itself, ZTE Corporation made it clear that the Binjiang 5G factory would be built as a benchmark for digital factory in China's electronics manufacturing sector, and an leading example internationally that aligned with the overall development strategy and technical strength of the Corporation to achieve a lean, automated, and IT-driven operation. Specifically, the focus on informatization was targeted at breaking data silos by the innovative integration of 5G and industrial Internet to quickly respond to internal and external changes, and to ultimately achieve optimized production and management. At the same time, the ZTE Corporation, as a professional in both 5G network and manufacturing, promotes the digital transformation of the industry at ZTE Global 5G Intelligent Manufacturing Base.

## Solutions and Benefits

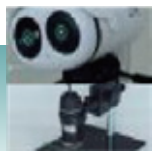
ZTE Global 5G Intelligent Manufacturing Base developed an industry benchmark integrating cloud, network and industry which was built on the elementary architecture of an industry-oriented industrial private network, two self-developed platforms (collaborative manufacturing cloud platform, and premise management and control platform), and many replicable usage scenarios. The project planned for more than 60 innovative 5G + industrial applications in 16 categories that covered all aspects of production and operation, and hoped to continue upgrading the traditional offline management to online intelligent management.

### 01 One 5G virtual enterprise private network based on 5G + MEC

As of December 2021, with support from China Telecom Nanjing, ZTE Global 5G Intelligent Manufacturing Base had built a total of 10 outdoor macro base stations and 751 indoor distribution nodes covering the entire factory premises. Four sets of MEC were deployed across the factory, two of which served the Binjiang 5G manufacturing base/factory for mutual disaster recovery; while the other two sets provided local data traffic offloading for other manufacturing companies in the park.

Based on this, the 5G virtual enterprise private network designed for "Internet +" collaborative manufacturing incorporates 5G slicing and edge computing to cater for the business, connectivity, computing, security and other cloud-network driven needs of ZTE Binjiang factory and other enterprises in the Binjiang Development Zone. ZTE Corporation and China Telecom continue to optimize 5G industrial private network capabilities to meet the deterministic network requirements in intelligent manufacturing scenarios, such as defining different 5QI templates for low-altitude coverage and SLA requirements for 2B services or using PRB resource reservation. The scenarios meet the business requirements of high reliability and low latency, the management needs of visibility, governance and control, and the security requirements of keeping data on premise.

#### Industrial application requirements



Machine vision inspection



Auxiliary video backhaul



Space guiding and positioning



Production equipment control



OEE data collection

High reliability 99.999%

Large bandwidth Uplink rate at 1 Gbps

Low latency < 10 ms

High safety Local guarantee

#### Ultimate Reliability



Equipment-level enhancement: Redundant power supply for single-board computers  
NE-level enhancement: Hot standby for core network, RRU ring network, transmission ring network  
Link-level enhancement: MCS enhancement, keep-alive mode for link disconnection, data replication  
Network-level enhancement: Active and standby CPE, wireless dual connectivity, E2E dual sessions

#### Ultimate Performance



Resource guarantee: Priority scheduling, PRB slicing, EdgeQoS  
Uplink enhancement: SuperMIMO, 3UID, CA  
Ultra-low latency: No scheduling, mini-slot  
Deterministic latency: TSN

#### Ultimate Safety

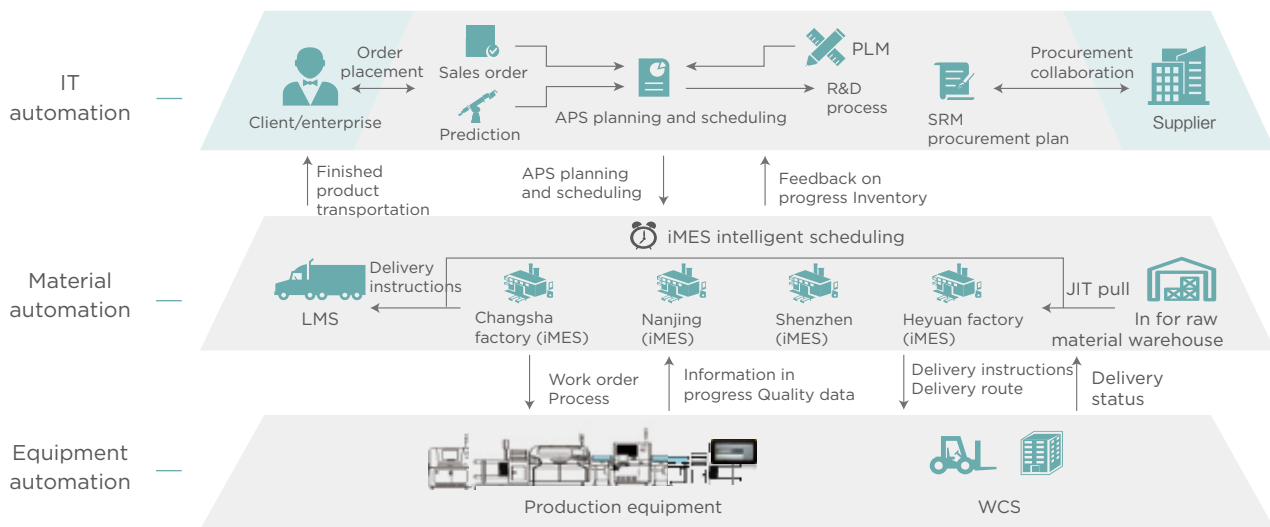


Local guarantee: NodeEngine, i5GC  
Slice isolation: End-to-end soft and hard slicing  
PNI-NPN: NPN CAG  
Security authentication: Access authentication, security encryption, secondary service authentication

## 02 Two core cloud platforms

ZTE built two core cloud platforms at Binjiang 5G factory: the iMES intelligent manufacturing cloud platform and industrial IoT cloud platform.

ZTE's self-developed iMES collaborative manufacturing cloud platform for the electronics industry supports productions of SBCs, standard components, whole units, as well as outsourcing management in the communication and consumer electronics industries. It also supports hierarchical deployment, which can be divided into group operation layer and factory execution layer. The group's operation layer supports multi-factory operation, unified scheduling of production tasks, unified allocation of production resources, operation dashboard, and intelligent manufacturing operation; the factory execution layer connects the factory plans and master production plan, aligns contract details and consolidate information between plans and actual productions, to accomplish service-oriented process management, order planning, material delivery, production and quality management, that are all improvements towards digital manufacturing.



At the same time, ZTE's self-developed industrial IoT cloud platform based on its digital twin technology achieves the intelligent interconnection of equipment, real-time data collection and processing, and automated analysis of working condition protocols, that enables efficient data sharing and eliminates data silos to form a data pool. It also provide data and application support to industrial apps such as digital twin and predictive maintenance of production lines and premises, factory vehicle management, energy consumption monitoring and analysis. Building on the vMAX big data engine and accumulated production data, this platform could also be gradually applied to quality tracking and intelligent decision-making for production lines, which contributes to the creation of a smart brain for the factory and the subsequent transformation into a smart factory with improved efficiency for the factory's production as well as its operation and management.

## 03 Numerous industrial scenarios that can be promoted

Enabled by the full 5G coverage across production lines and factory premises, Binjiang 5G factory has rationalised the end-to-end process of production management, completed the planning for 5G connection across the entire factory, and implemented by step 5G applications in different scenarios based on their readiness level and ROI.

No	Application Category	Typical Applications
1	5G-based intelligent data collection	Collection of SMT data, assembly line data, automation equipment data, etc.
2	5G cloud-based AGV applications	Visual SLAM cloud-based AGV, cloud-based forklift
3	5G- and cloud-based robot control	Cloud-based PLC on-site control, robotic arm control
4	5G-based mobile production management	5G PDA task assignment and production monitoring, contactless infrared temperature measurement and screening, industrial wearable dashboard equipment, etc.
5	360-degree panoramic surveillance	Production site inspection and monitoring with Giraffe robot
6	5G-based industrial AR	Remote SBC maintenance guidance, XR training
7	5G- and cloud-based machine vision	AAU thermal pad, thermal paste, thermal silicone grease, screw quality inspection, SMT machine vision-guided robotic arm stack
8	5G video surveillance	5G video surveillance across production lines and factory premises
9	5G logistics tracking	Whole-process tracking of goods





No	Application Category	Typical Applications
10	5G-based indoor positioning	Precise positioning of production tools and personnel
11	XR multi-player collaboration	Product design consultations, product demonstrations, etc.
12	Energy efficiency management	Energy saving management, demand forecasting, energy efficiency metering, power distribution monitoring, etc.
13	Environmental monitoring	Monitoring of water quality, noise, air quality, workshop dust, etc.; digital twin in the industry park
14	5G robots	5G handling robot, 5G patrol robot, etc.
15	5G-based digital twin for production lines	Digital twin for collaborative manufacturing
16	Unmanned driving	Unmanned commuter minibus, unmanned sweeper, vehicle-road coordination for inter-plant handling

By the end of October 2021, the Binjiang 5G factory had implemented more than 30 5G convergence application scenarios and deployed more than 400 5G industry terminals (and more being planned), with the peak real-time enterprise offloading data reaching 4 Gbps. After more than a year of exploration, three trends stood out from application: (1) flexible combinations of applications increase production efficiency and reduce labour costs from multiple dimensions while improving product quality. (2) applications should be coordinated across different stages of the process. For example, AGV is applied in many scenarios connecting all delivery and turnover gaps throughout the production process to enable factory-level end-to-end unmanned transport; (3) applications should be adapted from core processes into greater reuse in other processes to reduce marginal cost of deployment and provide more flexibility for faster deployment of innovative applications. Below are some representative and innovative application scenarios for further sharing.



Jack-up 5G-powered AGVs operating in the SBC area

### 1 Factory intelligent logistics based on 5G cloud-based AGV

There are more than 40 AGVs in the demonstration plant at the ZTE Global 5G Intelligent Manufacturing Base and a total of more than 70 5G-powered AGVs in the factory. These AGVs automatically deliver materials in batches and in real time, carrying nearly all material handling tasks throughout material turnovers and delivering a designated amount of materials to workers at designated locations at specified time.

ZTE's self-developed industrial 5G-navigated AGV uses combination of laser and vision for navigation positioning, and can be scheduled by the cloud iMES and AGV scheduling system in real time in a unified manner via the 5G network. In addition, it can render cloud-based maps from the MEC, and coordinate with inventories near production lines, JIT improvement system, and smart warehousing to improve logistical efficiencies in the streamlined factory. With 5G's low latency and high reliability features, industrial 5G-navigation AGVs receive more stable network connection than WiFi-powered ones, and can render cloud-based maps from the MEC, which resulted in 20% efficiency increase in cargo turnover, 15% reduction in site construction cost, 100% manpower savings, and a reduction of more than CNY 2 million in labour costs.

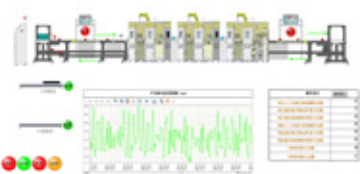


Assistance of 5G + cloud-based machine vision in the precise positioning for robotic arm lamination

### 2 Multiple applications of machine vision based on 5G + MEC

Machine vision has a number of applications such as AOI, quality inspection, and guided processing in the production lines at Binjiang factory. The integrated 5G + POL network is deployed along the production site for industrial camera or laser scanner access. High-definition product images are taken in real time and transmitted to the general-purpose machine vision platform deployed on the MEC, which are then spliced, recognised and processed in the edge computing centre. This way, existing production lines can be quickly transformed to improve the efficiency of machine vision recognition, reduce labour costs, and improve product quality.

The introduction of 5G and MEC makes the end-to-end industrial machine vision system more flexible, convenient and scalable. They allow computing capacity required by multi-point machine vision applications in the factory to be flexibly allocated and coordinated using GPU virtualization. At the same time, deep learning and re-training can be performed on the 5G and MEC machine vision platform to optimise AI algorithms' accuracy to further improve recognition quality and efficiency.



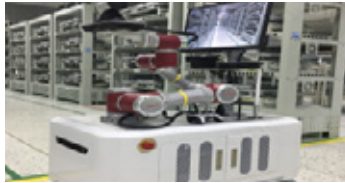
5G + cloud-based machine vision for the quality inspection of AAU filter screw/adapter column

### 3 Flexible manufacturing based on 5G cloud-based PLC control

Working with its partners, ZTE was the first to launch the production line ready 5G cloud-based PLC on the test production lines for small base station at Binjiang Intelligent Manufacturing Base. The control logic of the PLC runs on the MEC side and the IO module is deployed on site that form a cloud-based PLC solution that is able to replace multiple traditional hardware PLCs. With extensive tuning of the 5G network and leveraging technologies such as NodeEngine and MCS enhancement, the solution can maintain the 5G network's latency down to less than 12 ms, and reduce fault rate to no more than two per month. Free from the limits on traditional PLC hardware, programming environment and interface protocols, 5G cloud-based



Remote SBC maintenance guidance



Remote inspection of production lines



VR panoramic view/HD surveillance



Giraffe robot in production lines/  
unmanned patrol on factory premises

PLC supports cloud-based graphical programming, unified control, offline simulation, multiple protocol support, and more flexible expansion to make the production lines more intelligent and flexible. Compared with traditional hardware PLCs, the 5G cloud-based PLC improves efficiency for operation and maintenance and reduces the turnaround time for production line changes by more than 20%.

#### 4 Remote equipment control, on-site auxiliary assembly and unmanned intelligent patrol inspection based on 5G and ultra-high-definition video

A 5G network with large bandwidth enables wireless transmission of ultra-high-definition videos to mobile terminals that enables remote management of production processes and the industry park facilities.

Precise, remote and real-time control of industrial equipment in production facilities is achieved in the control centre using panoramic HD videos from the production environment and data from various types of terminals in real time through the 5G network. In ZTE Global 5G Intelligent Manufacturing Base, ZTE released its first 5G robot specially designed to resolve problems in production lines and conduct patrol inspections. Using the 5G network and ultra-high-definition conferencing system, production experts could view the live production environment and control robot's arms remotely in real-time. This improves sharing capacity of experts and reduces problem resolution time by more than three times.

On-site data such as images, videos and audio are transmitted in real time via the 5G network to help on-site operators to carry out assembly and maintenance of complex or delicate equipment. The remote expert guidance system powered by 5G and 4K ultra-high-definition videos connects front-line operators with cloud-based knowledge library and remote experts in real time to access guidance on the maintenance of SBCs, which effectively improves communication efficiency and maintenance accuracy. The remote expert guidance system significantly reduces amount of business travel by 30% and lowers the maintenance response time from magnitude of "days" to "hours".

Mobile and intelligent security devices such as patrol inspection robots or drones are connected to the 5G network to replace personnel inspectors. Binjiang Park launched 5G inspection robots and 5G drones to replace personnel patrols, and with the optimization of 5G network coverage in high-altitude and open environment, that can send real-time video and other related data back to the industry park management platform through the 5G network. A single device can complete an equivalent of 3-4 people's workload. Through intelligent analysis on the cloud and real-time early warning, these devices could improve operation and management capabilities of the industry park.

## Summary and Next-steps

With 5G + industrial Internet, ZTE was able to upgrade processes and management capabilities of its global 5G intelligent manufacturing base's production processes and industry park management, that led to improved levels of automation, intelligence and flexible manufacturing. It increased quality and efficiency on the factory floor, rationalised costs, and enhanced output. At present, Binjiang's smart manufacturing best practices has brought significant benefits to the company in cost reduction, quality improvement and efficiency increase: 80% decrease in the missed inspection rate of assembly quality, 46% reduction in the defective rate of key processes, 28% cut in the production line personnel, and 20% shorter production line adjustment cycle. At the same time, the willingness to better utilise 5G to create more innovations in the working level has skyrocketed. In the future, we will continue to innovate and optimise our solutions to increase both scale and depth and develop more black factories with 5G as the driving force and technical enabler, with the aim to increase its share of total factory capacity from 26.1% to more than 80%.

One of the purposes and significance of building ZTE's global 5G intelligent manufacturing base is to explore application scenarios that can truly improve quality, reduce costs and increase efficiency through its own exploration in the capabilities of 5G + industrial Internet, so as to promote the implementation of 5G for enterprise business and thus showcase the real value of 5G + Industrial

Internet. As of November 2021, Binjiang factory has welcomed more than 500 enterprises and institutions totalling more than 10,000 visits, showcasing its flagship role to demonstrate 5G+ industrial Internet. Building on the implementation results from Binjiang factory, ZTE has started to deploy 100+ 5G innovative application scenarios for 60+ clients with significant social impact.

Next, we will act swiftly to replicate Binjiang's successful practices in other factories, while to also accelerate the integration vertically into different application scenarios. We hope to improve application scenarios used in ZTE's global 5G intelligent manufacturing base, and at the same time use these experiences to empower a wide ecosystem of industries to digitalise and transform intelligently.

Through the Binjiang Industrial Internet Innovation Centre, we provide an environment for partners to conduct R&D of industrial applications as well as testing at ZTE's Nanjing factory to facilitate greater development of the industrial ecosystem. Over the past two years, our success in the digital transformation of industrial enterprises at Binjiang factory can be shared and used by other stakeholders and our partners. Our knowledge and learnings in connectivity assurance, extracting data value, and ecosystem partnerships. We may establish a prosperous and healthy ecosystem with our industry partners, so that everyone could benefit from 5G-powered digital transformation and safeguard the healthy development of 5G and industrial Internet.



# Full 5G Connection at the Shunde Factory of Midea Kitchen and Water Heater Appliances Division



Technologies such as 5G, big data and AI are adopted by traditional enterprises in digital transformation. The 5G + industrial Internet innovation in Midea factory has proven the capabilities of 5G in terms of large uplink rate, integrated positioning, one network serving multiple purposes and high reliability, and created great values for the customer. China Unicom Guangdong Co., Ltd. will continue to leverage the advantages of 5G to meet the needs of key industries and boost high-quality economic development in Guangdong.

**Feng Huajun**

President of the Government and Enterprise BG of China Unicom Guangdong Co., Ltd.

Partners



## Case Overview

Established in 1968, Midea Group ranks the first in China's home appliance industry in terms of revenue. In line with Midea Group's strategy of "full digitization and full intelligence", the Shunde factory of Midea Kitchen and Water Heater Appliances Division has formulated its own strategy of intelligent manufacturing based on 5G + industrial Internet. In collaboration with China Unicom and Huawei, it has worked out a map of 5G + intelligent manufacturing application scenarios, planning to launch 23 scenarios and over 600 point locations in 2021, 35 scenarios and over 2,000 point locations in 2022, and another 55 scenarios in 2023. In this way, it aims to fully realise interconnection based on 5G network at the factory level, and set a benchmark for 5G intelligent manufacturing at the national level.

Leveraging the customized private network, edge cloud, and four platforms (slice management platform, AI analysis platform, private network self-service platform, and integrated positioning platform) of China Unicom, the factory has achieved full 5G coverage. As of the end of October 2021, the factory had launched a total of 16 scenarios in five major categories, including intelligent logistics, quality management, equipment management, flexible production lines, and industry park safety, 327 5G point locations, and had realised 5G integrated positioning and intelligent warehousing for commercial uses in factory

scenarios for the first time, making full use of the 5G network for multiple purposes.

Full 5G connection reduced the overall cost of the factory by RMB 32 million, leading to significant breakthroughs in reduction in energy consumption by logistics equipment, intensive management of equipment and paperless drive. As a result, the company has won many awards such as China's Benchmark for Smart Factories, the 4th China Quality Award, Foshan Industrial Internet Demonstration and Benchmark Project, Forbes China Top 10 Industrial Internet Enterprises in 2021. Jointly led by Midea, China Unicom and Huawei, the project engaged more than 20 partners in the fields of 5G terminals, industrial equipment, application integration and AI algorithms to promote the development of the industrial chain. The successful project has been replicated and promoted in large scale in the upstream and downstream of the industrial chain (such as Annto Logistics, Midea Wuhu Kitchen and Bath Base and Midea Foshan Shunde Base), within Midea Group, and in the home appliance/electronics manufacturing industry. The three parties will join hands to apply 5G in more scenarios, work out more solutions, and continue to empower external parties with the help of the industrial Internet platform of Midea, contributing to intelligent manufacturing in China.





## Industry Challenges

China's home appliance manufacturing industry has reached a value of about RMB 1.5 trillion, mainly including production units such as electronics, stamping, injection molding, powder impregnation, final assembly, finished products and logistics, hence a typical discrete manufacturing industry. Currently, the industry mainly faces the following challenges:

### Frequent adjustments to production lines

In the home appliance industry, orders are placed in small amount and many batches. The rapid iteration of products leads to frequent adjustments to production lines and high cost. That's why the industry is in need of flexible production.

### Disadvantages of traditional in-plant logistics system

Too many process breakpoints, offline processes and repetitive operations. Manual operation is required for communicating and recording logistics information, recording and reporting information on material shortage, confirmation of material shipping by phone, making inventory of finished products, etc. Using traditional WiFi network for information transmission often causes such problems as insufficient access capability, network disconnection and high latency, which compromises the efficiency and accuracy of in-plant logistics, and further restricts the improvement in production efficiency.

### Strict process requirements and high local AI quality inspection costs

Faced with fierce competition, manufacturers have to follow strict requirements for production processes and quality control to gain a sound reputation and a significant market share. Using AI for quality inspection requires local deployment of dedicated hardware, resulting in high cost, heavy maintenance workload, and low resource utilization.

### A large number of production equipment and high operation and maintenance costs

There are over 1,000 pieces of production equipment in a single factory, many of which are imported. Due to the COVID-19 pandemic, equipment manufacturers are not be able to quickly send technicians for troubleshooting on site in case of any equipment failure, which delays production. In addition, the monitoring of equipment status requires regular manual inspection, which means high labour input and low inspection efficiency.

With the help of 5G high-quality mobile connections and in combination of the edge cloud, AI, big data and other technologies, the above problems may be addressed by establishing digital construction scenarios that feature large uplink rate, precise positioning, high reliability, low latency and ultra-flexibility.

## Solutions and Benefits

### 01 5G in-plant intelligent logistics

The 5G + in-plant intelligent logistics system adopts 5G integrated positioning for the real-time and accurate positioning of key elements such as trucks, forklifts and tractors to obtain the location and status of vehicles and the cargo. It also matches the physical logistics with the information flow in the Manufacturing Execution System (MES) and Warehousing Management System (WMS) of Midea to realise real-time display of cargo information, automatic inventory, consistent accounting and intelligent management. Compared with the traditional single positioning technology, this system features wide integration and fast switching, which can meet the complex needs for the ways and accuracy of positioning in different production areas, further improve positioning accuracy, reduce environmental dependence and network latency, and connect data silos. At the same time, compared with the cumbersome automation system, this system features lightweight and low-cost deployment, greater flexibility, and maximized utilization of 5G network for multiple purposes, providing a new option for the industry.

5G integrated positioning uses the original 5G network coverage of Midea to obtain wireless signals of terminals through the base stations of digital indoor system, and deploys positioning algorithms

on the edge cloud to calculate the results of 5G positioning and other positioning technologies through dynamic filtering algorithms. Finally, these results are reported to the applications of Midea through the standard interfaces. This network, without additional network building or maintenance, serves multiple purposes and features low building cost, large bandwidth, low latency, and wide connection to support the positioning of a large number of terminals in the factory and quick response.

The 5G + intelligent logistics solution has helped Midea Kitchen and Water Heater Appliances Division achieve labour reduction, paperless office and improved efficiency, saving RMB 8.89 million in labour costs and RMB 100,000 in paper costs, and earning RMB 1.74 million as a result of improvement in efficiency. This solution has been replicated and promoted in the upstream and downstream of the supply chain such as Annto Logistics, Midea Wuhu factory, and Midea production bases to increase both efficiency and value in the manufacturing chain through end-to-end 5G intelligent logistics. The widespread application of this solution will further boost the capabilities of 5G positioning and industry maturity, and contribute to the formulation of industry standards for 5G positioning by the ISO.



# 5G+ Smart Manufacturing



## 02 5G predictive maintenance & AR remote assistance

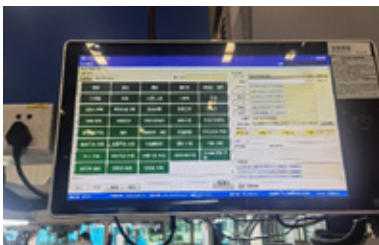
The powder impregnation lines are imported and need on-site guidance and maintenance by foreign experts in case of any equipment failures. However, it is a challenge for foreign experts to arrive on site due to the COVID-19 pandemic, resulting in high maintenance and repair costs, long affected period and lowered production efficiency. Furthermore, manual spot check on the production equipment in all workshops is conducted twice a day. In a single workshop, there may be hundreds of items to be checked. The heavy workload could easily lead to negligence or recklessness.

Additionally, manual check makes it impossible to record the process.

First, the status parameters of the powder impregnation lines are monitored online through the 5G network. The equipment operation model is established for the analysis of real-time data and failures and the prediction of failures. The maintenance schedule is formulated in advance to ensure the early detection, prevention and handling of hidden dangers and defects. Second, AR technology is used to support online simultaneous translation of multiple languages with the support of 5G network featuring large bandwidth, low latency and high quality. This enables real-time remote guidance by foreign experts, visualization of daily spot checks, and exploded view of key parameters and components.

## 03 5G + AR glasses for remote inspection of goods

The goods produced for an order cannot be released for shipping until on-site inspection and acceptance by the customer, which often causes a backlog of goods. Due to the COVID-19 pandemic, on-site inspection is subject to travel restrictions and may be a challenge to pandemic control at the factory. The on-site operators wearing 5G AR glasses communicate with and transmit the videos needed for inspection to customers in real time through the 5G network featuring large bandwidth and low latency, which provides customers with the same experience as on-site inspection and acceptance, thus improving the stock turnover rate.

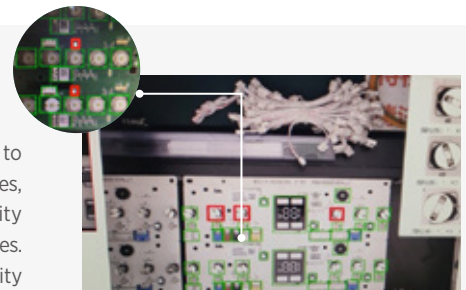


## 04 5G cloud-based IPCs

There are about 500 IPCs in the factory, which are locally deployed in various workstations. Workers provide product feedback and installation issues to the MES through the UIs on the IPCs. Currently, IPCs are highly priced and generally run much slower after two years of operation. Their maintenance is challenging as the Group's IT team is incapable of maintenance and the vendor has to do the job, which is costly. In addition, due to the frequent adjustments to production lines to meet the order requirements, the local deployment of a large number of servers and network cables results in elevated cost of production line transformation and compromised production efficiency. Moreover, as IPCs connect and interact with the interfaces of SCADA, MES, etc., it is difficult to debug and maintain the interfaces. The factory virtualises the IPCs on MEC and only retains the thin clients locally to connect code scanners and screens, and connects terminals and edge cloud through the high-quality 5G network to achieve centralized management of operation and maintenance. This solution reduces the cost of deploying IPCs locally, improves the efficiency of centralized operation and maintenance, and decreases the network cables to be deployed, contributing to enhanced flexibility of production lines.

## 05 5G + AI for quality inspection

In the production lines such as electronics, metal plates and final assembly, it is required to conduct quality checks on many intermediate parts and processes (such as PCBs, metal plates, label positions, bottom plate screws, and manual inspection actions). Traditionally, quality inspections were done manually, which gave rise to such risks as mistakes, omissions and reverses. This resulted in uncontrollable inspection effect and high labour cost. Alternatively, quality inspections were conducted through AI algorithms in locally deployed servers, which led to high costs due to procurement of equipment, deployment of network cables, and operation and maintenance, and high energy consumption.



Through the terminal-edge-cloud architecture with 5G + cloud + AI, photo information is collected using HD industrial cameras on the terminal side, inference operations are conducted with MEC on the edge side, and AI data training is performed on the cloud. Leveraging the large bandwidth and low latency features of 5G network, it is able to quickly complete quality inspections, interact with MES, and realise automatic determination of unqualified goods and automatic alarm during scanning, which helps to improve the finished product quality, reduce the repair cost and workstations for manual inspection, enhance the utilization of server resources, and make maintenance easier.

## 06 5G intelligent management of mold shelves

In the stamping process, molds need to be changed frequently every day according to the requirements of different batches of orders. Workers receive mold location tasks and recommended shelves through the vehicle-mounted tablets, drive forklifts into the shelf area, scan the code to locate the corresponding molds, and take them out and deliver them to the production lines. Traditionally, the vehicle-mounted tablets were connected through WiFi network, which was often unstable and disconnected. As a result, the tablets may not be able to receive instructions or scan codes. Resolving one single problem could take up to 20 minutes, resulting in low mold delivery efficiency, or even worse, production line downtime. By connecting the vehicle-mounted tablets and code scanners through the 5G network, the stability of data transmission is guaranteed. As a result, the time for changing molds is reduced by more than 20% on average, thereby lowering the production line downtime and improving the production efficiency.



## 07 5G-based industry park management

The industry park security relies fully on inefficient manual defense, control and management without visualised management and effective means of early warning and alert. 5G cameras and sensors deployed in the industry park enable real-time data collection across the park, early warning and alert. The industry park security, fire protection, environmental protection, and other systems are connected for intelligent management.

- 5G intelligent cameras are installed in key areas of the industry park to take photos of illegal behaviors related to vehicle parking, zebra crossing, PPE, etc.;
- Sensors and infrared cameras are put in place to monitor high fire hazard zones in the industry park;
- 5G mobile AI monitoring equipment is used to monitor temporary constructions at different sites;
- The on-site monitoring equipment is connected with the EHS system to send the monitoring results to the system and use it for event recording, early warning and control.

This solution reduces the accident rate in the industry park by 12% and the time to review and approve dangerous operations by 90%, and lowers the security cost.

## Summary and Next-steps

In this project, Midea Group, China Unicom and Huawei have figured out what it takes to be successful, which is detailed as follows. When planning 5G business scenarios, we must take into consideration the company's strategy of digital transformation or intelligent manufacturing, have a profound understanding of the production process to identify the actual needs, and make good top-level designs to create true values. During the implementation of the project, all parties involved must cooperate with each other, and make good use of and develop partnerships to take advantage of each other's resources. A good business model should be designed so that all providers of network equipment, terminal equipment, application integration, and cloud services may obtain commercial benefits. For new scenarios and new needs, we should constantly innovate network capabilities (for example, 5G high-precision positioning), and drive technical upgrade and iteration from the business side, which will ultimately benefit the business and form a virtuous circle. However, some challenges are encountered during the project. The cost of transformation to 5G business scenarios and the cost of terminals are very high and need to be reduced through empowering an ecosystem and large-scale promotion of a successful case. Understanding the industrial production process and designing a 5G network for it are not easy. In network design, factors such as latency, bandwidth and reliability must be taken into full consideration to meet business requirements, which is more demanding than traditional network design. After 5G terminals are launched in large scale, they have to be managed in a professional industry park management platform.

### Next Steps

- 1 Expanded connections: Based on the map of 5G digitalization of the factory, network connections and application scenarios will be further expanded to connect over 2,000 terminals by 2022.
- 2 Further application scenarios: 5G positioning will be further explored and used in more application scenarios. Terminals with higher-precision positioning and lower power consumption will be explored to promote the evolution of intelligent logistics and unmanned technologies and the formulation of industry standards for 5G positioning.
- 3 More reliable private network: In response to the company's demand for high reliability and high SLA of the private network, we will continue to launch and innovate highly reliable private network solutions (such as dual transmission and selective-receiving mode, continuous MEC in spite of network disconnection, and slicing), build an industry park self-service platform, manage and monitor the private network in a unified manner, and quickly identify faults.
- 4 Concentration of services on the edge: Based on the operator MEC, AI quality inspection, AR remote maintenance and other services will be centralized on the edge cloud. At the same time, we will also explore the centralization of production control equipment such as PLCs and IPCs on the cloud to give full play to synergistic network and business and intensive operation.
- 5 Continuous empowering external parties: Through M-IoT industrial Internet platform of Midea, we will continue to empower many other industries with innovative solutions.





# Gree 5G + MEC Smart Factory Innovation



Taking advantage of the prevailing 5G and digital upgrading, we have joined hands with Gree Zhengzhou to build a 5G + smart factory that integrates 5G private network, 5G applications on production lines, and full-scenario and full-process safety production system by adhering to lean production, working out a new model of self-controllable 5G + digital transformation for the home appliance manufacturing industry. In the future, we will continue the efforts in independent innovation to make better use of technologies and tap into the potential of data, making greater contribution to the transformation from "Made in Henan" to "Intelligent manufacturing in Henan".

**Wang Zhi**

Deputy General Manager of China Unicom Henan Co., Ltd.

## Partners



## Case Overview

Gree Electric Appliances (Zhengzhou) Co., Ltd. (hereinafter referred to as "Gree Zhengzhou") has an annual production capacity of 6 million household air conditioners, 6 million compressors, and 12 million motors. It is the largest air conditioner production base in Central China, with an output of more than RMB 15 billion. There are over a hundred supporting enterprises in the surrounding areas.

Since its establishment in 2011, Gree Zhengzhou has positioned itself as a pioneer in intelligent manufacturing in Gree Group, and has set a clear goal to build a highly flexible, personalized and intelligent production model of goods and services by adhering to lean management and value creation. Taking advantage of 5G + industrial Internet, Gree Zhengzhou has partnered with China Unicom and ZTE Corporation to explore the digital transformation of discrete manufacturing.

In September 2020, the three parties carried out a pilot project regarding the integration of 5G innovative technology and industrial Internet in Gree Zhengzhou factory to explore the intelligent manufacturing applications based on 5G + MEC. In 2021, the project

made great progress and the "1+2+N+S" system architecture was successfully established, namely one 5G independent private network, 2 enterprise-level capability platforms, numerous 5G applications, and one end-to-end active security protection system for full business scenarios on the 5G industrial Internet.

Building an IoT platform and a machine vision platform at the enterprise level facilitated further tapping into the potential of data and consolidating AI capabilities. Quick deployment of applications, including 5G cloud-based scheduling AGV, 5G + VR remote guidance, 5G helmet-based safe production management system and 5G UAV patrol inspection, improved the overall operational efficiency.

In order to meet the requirements for information security across the factor premises, a defense system covering cloud, management and terminal has been built based on active defense, realising full-element and full-process protection. At the same time, as the 5G technology and manufacturing continue to mature, a virtual private network has been upgraded to an Industry 5G Core (hereinafter referred to as "i5GC") independent private network, further guaranteeing the security of enterprise applications.

1

5G independent private network

+2

enterprise-level capability platforms

+N

5G applications

+S

one end-to-end active security protection system for full business scenarios on the 5G industrial Internet



## Industry Challenges

In recent years, as new urbanization accelerates and people's living standards continue to improve, the home appliance industry has witnessed rapid development. Meanwhile, due to the trend in "intelligent and customized" home appliances, shorter product life cycle and increasingly higher quality requirements, digital transformation is urgently needed for the home appliance industry.

Gree Zhengzhou faced the following challenges on the way to digital transformation:

### Disconnected systems and data led to "silos"

As a typical representative of the discrete manufacturing industry, the home appliance industry generally features a large number and types of production equipment and complex production environments, which makes it difficult to collect data in the traditional network. Moreover, fragmentation and silos in the information system caused many problems, such as duplicated development, and difficulties in reducing operating costs and expanding new applications. Production managers had to switch between different systems to obtain key production data, which was time-consuming and labour-intensive.

### A large number of visual quality inspection scenarios made it difficult to replicate data

In line with the core value of "pursuing highest quality", every air conditioner produced by Gree Zhengzhou must go through numerous strict quality inspection procedures. In the face of a large number of machine vision scenarios, traditional standalone deployment encountered great challenges: 1. There was limited improvement in the accuracy of traditional image processing algorithms, while AI algorithms meant greater resource investment; 2. data was difficult to be aggregated, and being "stuck" in IPCs meant their value could not be exploited; and 3. large-scale replication of data resulted in a significant increase in the cost of computing resources, operation and maintenance.

### Difficulties in guaranteeing application security caused hidden dangers everywhere

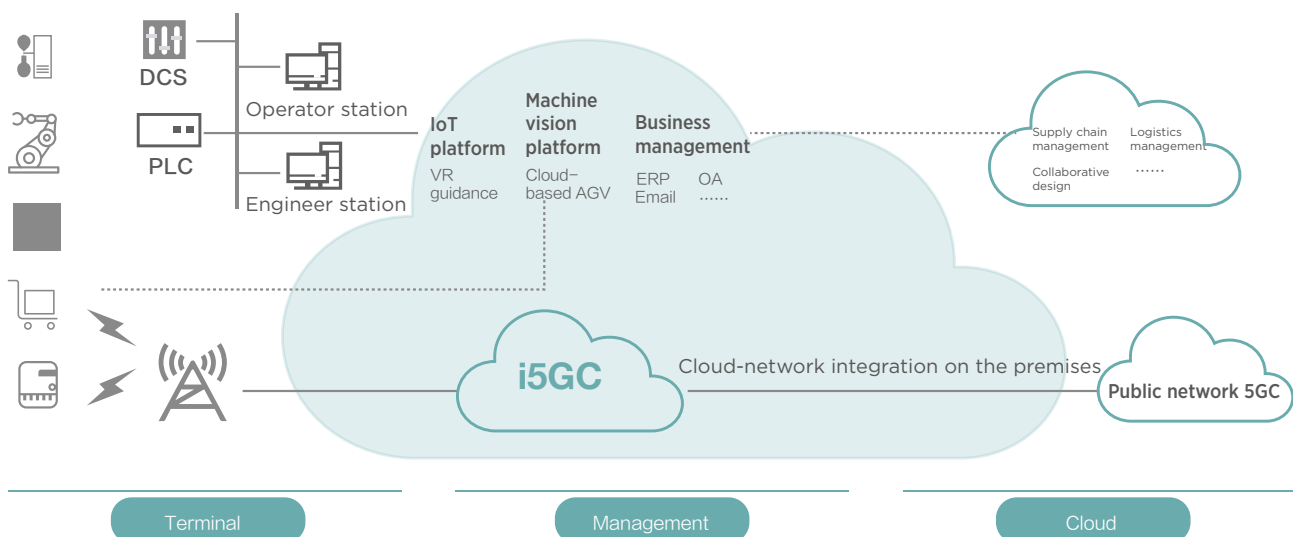
At the levels of network and system platform, the innovative application of 5G + MEC brought about protection problems for edge virtualization platforms, and security threats such as industrial control protocol vulnerabilities, intranet viruses/Trojans, and Internet DDoS attacks were ubiquitous.

At the terminal level, 5G terminals widely used in factories, such as CPE, industrial gateway, AGV, and safety helmet, also had many potential risks such as inadequate terminal security design, untimely update of patches for system vulnerabilities, weak passwords, plaintext data or simply encrypted transmission.

## Solutions and Benefits

### 01 i5GC independent private network

By deploying an i5GC independent private network, the project used the private network for dedicated purposes and realised physical isolation on the site, giving full play to the ultra-high bandwidth/ultra-low latency of the 5G network. Two i5GCs were deployed in a pool on site for disaster recovery and backup, and loads were shared by devices to ensure high security and high reliability. i5GC supports the capacity to evolve to fixed-mobile convergence (FMC) in the future, which allows the ubiquitous access of various terminals in the industry park, and realises centralized management, operation and maintenance. In addition, i5GC may be continuously evolved and enhanced to 3GPP R16, and supports innovative features such as 5G LAN, QoS Monitoring and TSN, constantly empowering smart factories.



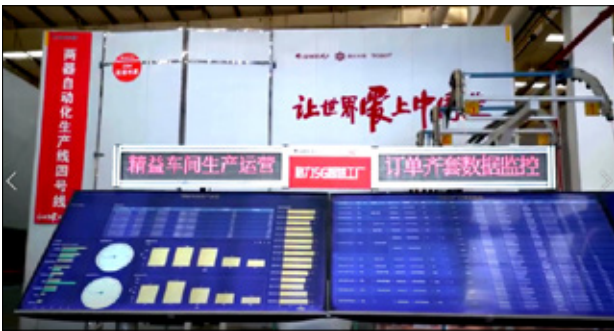


# 5G+ Smart Manufacturing

## 02 enterprise-level capability platforms

### IoT platform

The enterprise-level IoT platform deployed relying on 5G + MEC edge cloud not only allow converged access of heterogeneous networks such as 4G, 5G, eMTC and NB-IoT in the workshops, but also enable connection management, device management, application enablement, operation support and other capabilities for IoT applications. This realised unified collection, management and sharing of data from different terminals, and online management and remote operation and maintenance of various types of intelligent terminals. In addition, the platform connected more than 10 existing subsystems through the northbound interfaces, truly realising data connection and becoming data-driven.



### Machine vision platform

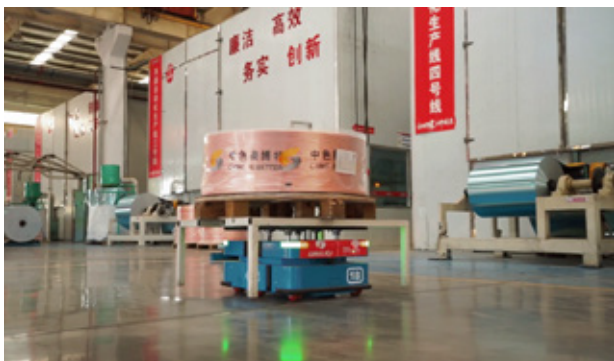
The project built a machine vision platform based on 5G + MEC for AI model training and AI inference. This not only accelerated the training of AI algorithms, but also allowed for analysis and inference of images that were centrally connected to 5G on MEC, improving the compatibility and recognition accuracy of algorithms for multiple workstation replication. As a result, the marginal deployment cost was significantly reduced, and the large-scale replication of machine vision scenarios in the workshops was accelerated. In the future, the machine vision platform will accommodate hundreds of machine vision applications across the factory, and the independent operation and maintenance of vision scenarios will be realised without adding algorithm engineers.



## 03 Numerous 5G innovative applications

### 5G cloud-based scheduling AGV

In the second evaporator and condenser workshop of Gree Zhengzhou, 5G + navigated AGVs were used to realise automatic material ordering and transportation, and independent path planning reduced the on-site deployment costs by 80% and manpower by 15 workers. 5G reduced the rate of dropped WiFi connections by 80% by resolving the problem of AP switching.



### 5G + AI safety helmet

The project introduced integrated smart wearables featuring positioning, perception, early warning and audio and video communication, and an integrated "cloud + terminal" management platform based on a shared IP architecture to solve problems associated with on-site safe production. It integrated perception, analysis, service, command and monitoring, and developed a new model of production safety management focusing on intelligent and fine-grained management and emphasizing both the process and the result in the "Internet+" era. 5G intelligent helmets were used by 89 workers in the second evaporator and condenser workshop.





### 5G patrol inspection

To meet the safety requirements of premises, 5G drones and patrol inspection robots were used to realise the real-time backhaul of 7-channel video through 5G network, providing all-around protection in every corner of the industry park.

## 04 S: End-to-end security protection system



In terms of platform network, 5G network security capabilities including differentiated slicing and security isolation were used to meet the requirement of keeping data inside the industry park. Intranet security measures such as dynamic firewall were used to guard against intranet viruses/Trojan horse, and platform application security measures such as cloud native security and two-factor authentication were used to ensure the security of virtual MEC. In addition, the system also provided data security capabilities for the full life cycle.

Considering the difficulty in upgrading hardware, Gree took four measures to ensure terminal security of 5G applications and data security: conducting security testing before launching terminals; using electronic fences, blacklists and whitelists for network access authentication; applying zero-trust access control for terminal access; and providing monitoring and handling of abnormal traffic.

## Solutions and Benefits

With the core values of "adhering to independent innovation" and "pursuing highest quality", Gree Zhengzhou is committed to building a highly flexible production model of customized and intelligent products and services. At present, the project has achieved the periodic goals of intelligent production set by the company, realising the display of decision-making indicators on the BI platform and human interaction and digital linkage in the whole chain of product R&D, process, manufacturing and quality.

The success of the project also relied on the joint efforts of the 5G Intelligent Manufacturing, Development and Application Laboratory and 5G Empowering Industrial Internet Joint Innovation Laboratory established by the three partners in R&D and rapid output of products and solutions by accelerating technical verification, model verification and commercial application.

In the future, greater efforts will be made based on the existing achievements of the project to connect all of the equipment and apply machine vision inspection in over 100 scenarios in the factory. Moreover, as industrial Internet services such as Gree flexible production continue to develop, protection measures for Internet security and industrial control security may be adopted in the future to further protect 5G application security.

The successful project will also be replicated and promoted in other discrete manufacturing industries in Central China. At the same time, Gree Zhengzhou will continue to play a leading and exemplary role in the local industrial cluster, encouraging dozens of supporting enterprises around it to speed up digital transformation.





# Green Point Technology: Connecting Robot Arms to 5G Networks



From manual collection by administrators to automatic data reporting by devices, ultra-large-scale device networking featuring ultra-low latency has been realized in the 5G era. With the help of 5G private network, all the challenges, such as difficult line transformation under frequent changes of production lines, high latency in equipment networking and sampling, and lack of management of high-value machines have been resolved. Now the time taken to change all the production lines has been reduced by 60% and the production line yield increased by 2%. These remarkable results are credited to 5G digital transformation.

**Zhou Meng**

JGP CTO, Jabil Green Point Group

## Partners

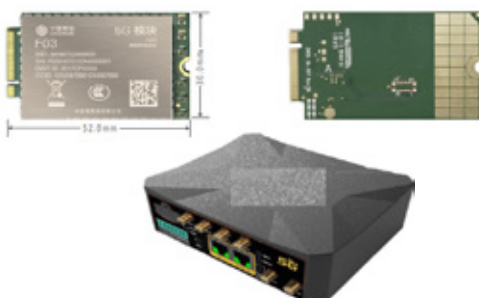


## Case Overview

In the industry of 5G smart factory, China Mobile, Green Point Technology (Wuxi) Co., Ltd., and Ziyun (Shanghai) Internet of Things Technology Co., Ltd. worked together to launch the 5G robot arm networking project in May 2021. By deploying the highly reliable 5G private network and using the 5G edge computing gateway integrated with China Mobile F03X 5G module, thousands of Fanuc robot arms have been connected to the 5G network. Centralised computing has been replaced by distributed computing thanks to the edge computing capability on the gateway side to perform transmission of ultra-large equipment logs, program distribution and remote control, thereby meeting the ever-changing needs of the production-oriented enterprises for innovation.

In the 5G private network, the 5G edge computing gateways integrated by Ziyun are directly connected to the robot arms one on one. A registration request from the 5G module side connects a robot arm to the 5G network and assigns a fixed IP address in the private

network. In case of central server failure or other emergencies, the box may be used as a cache and continue to upload data after recovery, guaranteeing the data integrity and security. Furthermore, the data packets are uploaded to the cloud after edge analysis, and the servers are distributed in a cluster to support high-concurrency and massive data computing. The 5G private network can meet the requirement of data collection latency within 50 ms, and help plants realize flexible production and visualised management of equipment. The calculation shows that the robot arms connecting to the 5G network may save the factory CNY 8 million/year in terms of the wiring cost. The project has been put into commercial use and has become the largest project using networked robot arms to collection data under the 5G SA mode in China. With the help of 5G and edge computing, factory devices become "conscious" and are able to "learn by themselves" and "manage themselves", increasing the production efficiency and yield by 15% and 2%, respectively, and reducing the production cycle by 10%.





## Industry Challenges

Production lines often feature complex processes and many types of devices, mostly foreign brands, and their systems are incompatible with each other. As electronic products are upgraded very quickly, the need for flexible manufacturing will lead to frequent adjustments of production lines and changes in the layout of production lines, devices and logistics in plants. Supporting production devices also need frequent process upgrading.

In addition, electronic information products are knowledge- and technology-intensive products. The products value quality, energy saving and environmental protection, follow industry standards and international standards, face fierce competition, and are upgraded very quickly. Electronic information products are divided into many categories which vary significantly. Although the manufacturing processes of different products are different, they generally follow the idea of modular design and modular production, which covers the whole production process from modules, components to the complete equipment.

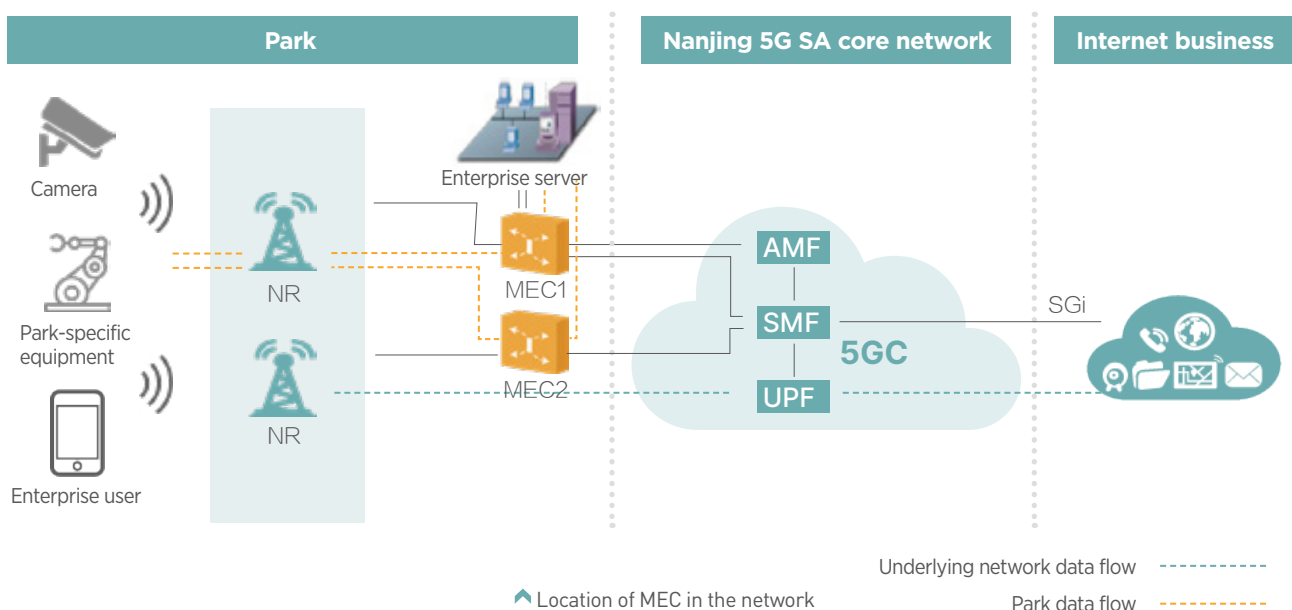
Based on the need for digital transformation and the pain points of production, the project introduces an efficient 5G cognitive network at the edge and an intelligent industrial brain in the cloud. In other words, based on the abundant industrial interfaces and equipment protocols with wide coverage, a centralised industrial data collection gateway at the edge enables the connection of equipment to 5G network and

the collection of full data in industrial scenarios, issuance of process documents and instructions, and one-stop solution for enterprise IoT equipment networking and data migration to the cloud. An industrial knowledge graph is established on the cloud platform based on industrial knowledge, experience and production practices to support high-level intelligent production applications such as product quality tracing, predictive maintenance of equipment, and factory digital twin.

Experiencing off and peak seasons, Green Point Wuxi site increases or decreases the production capacity at any time depending on customers' orders, and needs to adjust its production lines (at least twice a month) to fit the different products of customers in the upper reach, for example, Apple. Over a thousand CNC machines and robot arms in the factory were originally wired with traditional network cables, which requires long construction period, high costs and is difficult to adjust. Now the 5G-based flexible production lines may ensure efficient change of production lines. At present, the production in the factory is performed in a black box without efficient utilization, maintenance and management of equipment or visualized monitoring. In addition, the frequent equipment data collection in many point locations relies on strong computing power and an end-to-end latency within 50 ms to ensure real-time data collection, which requires highly stable and secure communication. The 5G private network enables local data traffic offloading through UPF to ensure latency of less than 30 ms while avoiding the security risks caused by data leakage.

## Solutions and Benefits

To tackle the above problems, a solution was formulated as soon as the project started to build a 5G private network with high reliability and low latency using MEC. MEC is a "hardware + software" system that reduces latency in network operation and business interaction by providing IT service environments and cloud computing capabilities at the edge of 5G mobile network. Being close to the edge side of the networks of "things" and "data sources", MEC is an open platform that integrates core capabilities such as networks, computing, storage and applications. MEC provides edge intelligent services in nearby environments to meet the key needs of industry digitalisation for agile connection, real-time operation, data optimization, intelligent application, security and privacy protection. The following picture shows the location of MEC in the network:





# 5G+ Smart Manufacturing

After the network was deployed, CNC devices and robot arms in the factory were connected to the 5G network by installing 5G gateways in batches. In this way, the adjustment to production lines was not restricted by wiring, and the constraints of industrial WiFi network on high-concurrency data and latency caused by the excessively long transmission link of 4G networks were also avoided, making the expansion of production capacity faster, more flexible and agile. At the same time, to solve the issue of insufficient cloud computing power of the central cloud due to the access of massive devices, a customized 5G edge intelligent data collection gateway integrating functions such as protocol conversion, data screening and analysis was developed. Data packets can be uploaded to the cloud and interact with the company's MES system at high speed for quick judgment and marking. Based on the underlying device networking and data collection, the project built a data analysis platform and conducted targeted interface development and data conversion to help Green Point with the monitoring of key equipment and data throughout the entire production process and handling of exceptions, and contribute to the innovations in intelligent manufacturing and production model at Green Point.

For large manufacturing enterprises like Green Point, smart factory applications such as intelligent management of devices, product quality tracing and digital twin are developed quickly to help the enterprise achieve digital transformation and full 5G connection in the following main application scenarios:

## 01 Connection of massive devices to the 5G private network

Industrial-grade edge computing gateways were installed on the 3,087 robot arms and CNC devices to be connected to the network to realise the connection of devices to the 5G network and data processing at the edge. The 5G edge computing gateways are directly connected to the devices one on one. In case of power failure or server failure, the box may be used as a cache and continue to upload data after recovery, guaranteeing the data integrity. At the same time, after edge analysis, the analysed data packets are uploaded to the cloud, and the servers are distributed in a cluster to support high-concurrency and massive data computing with balanced load and high processing performance.

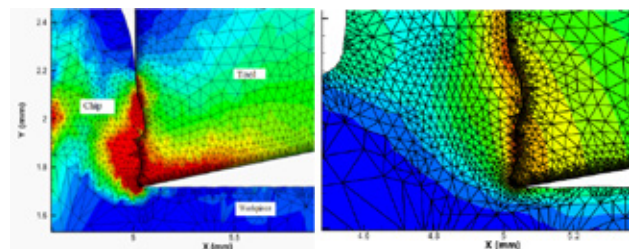


## 02 A visualization platform for IOT data collection

A visualization platform for IOT data collection is used to aggregate and analyse the collected data. The platform accommodates all data-related functions, including storage, processing, collection and labelling. Regarding data processing, data labelling is important for quickly generating sample data, so that the model can be trained to predict new data.

## 03 Modelling and process simulation based on underlying data.

Big data mining and modelling are conducted based on equipment usage and maintenance to build a model of equipment quality assessment index and predictive equipment maintenance. Additionally, process simulation is carried out to build an equipment maintenance knowledge graph and a big data model on product quality. For example, for the predictive maintenance of equipment motors, data on motors such as voltage, current and torque are collected through the gateways of IoT platform to build a data analysis model for lifespan prediction. Predictive maintenance is expected to reduce a single repair time by 50%.



## 04 Remote control

To eliminate the need to debug and configure every workstation on site, the project realizes the remote control verification of the CNC processing centre through the reverse control of the networked devices, and grants access to the equipment remote control system on the platform. The system displays the real-time statuses of the devices and pushes alerts, clears the general alerts from a specific device, and changes the parameters and programs of the devices remotely, so as to ensure transparency for jobs, strong remote monitoring and intelligent fool-proof operation, significantly improving the efficiency of trouble shooting.

This is a great demonstration project for the large-scale commercial use of 5G networks in a production environment, and it is of great significance in setting an example of applying 5G networks and edge computing widely in industrial manufacturing areas. Based on this project, more efforts will be made to explore and develop more innovative solutions in intelligent manufacturing, focus on the real demands of enterprises, further help them reduce costs and increase efficiency by reducing manpower and improving production capacity and quality, and facilitate the large-scale implementation of intelligent manufacturing technologies in the industry field.



## Summary and Next-Steps

After several months of implementation, the 5G-based equipment networked data collection has met the requirements for production. The 5G wireless signal has covered more than 30,000 square meters of the plant area, and the 5G network has met the following indicators for quality:

**<1%**

Packet loss rate

**<15ms**

One-way latency <15 ms  
(5G DTU to server)

**>300Mbps**

5G bandwidth > 300 Mbps

**95%**

5G coverage probability = 95%,  
SS-RSRP > -90 dbm

This is a great demonstration project for the large-scale commercial use of 5G networks in a production environment, and it is of great significance in setting an example of applying 5G networks and edge computing widely in industrial manufacturing areas. Based on this project, more efforts will be made to explore and develop more innovative solutions in intelligent manufacturing, focus on the real demands of enterprises, further help them reduce costs and increase efficiency by reducing manpower and improving production capacity and quality, and facilitate the large-scale implementation of intelligent manufacturing technologies in the industry field. In the next stage, with the purpose of "helping the enterprise reduce costs and increase

efficiency", the project will connect over 1,000 traditional devices to the 5G network and the equipment management platform, and continue to carry out model training to build an application platform at the top level based on the data collected. The empirical relationship of tool durability and finite element method are used to simulate tool wear, and parameters such as sliding speed, contact pressure and contact surface temperature are used to develop subprograms that define more types of tool wear models, and eventually, realize the intelligent management of equipment and visualization of production processes.





# Safe, Green, and Smart Sinopec Guangzhou Empowered by 5G



The success of the 5G + smart petrochemical project has empowered 15 application scenarios in six major business fields, reducing accident rate by 20% and harmful gas emissions by 30%, and creating an annual economic benefit of RMB 30 million. Based on the 5G cloud network, Sinopec Guangzhou has transformed into a safe, green, and smart enterprise, and strives to become a paradigm in terms of both "clean energy" and "transformation", taking the lead in driving the growth of the petrochemical industry.

**Huang Haibin**

Head of the Information Centre at Sinopec Guangzhou Petrochemical Company

## Partners

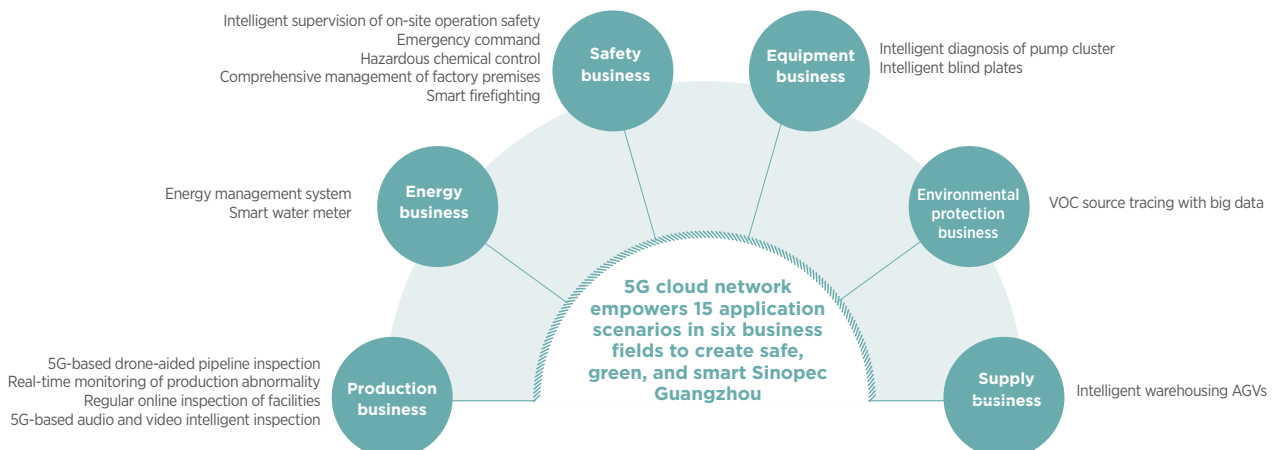


## Case Overview

The petrochemical industry plays a significant role in the national economy and people's livelihood. China's GDP in 2020 stood at RMB 101 trillion, and the petrochemical industry contributed RMB 11 trillion of revenue, accounting for 10.89% of the national GDP. Sinopec Guangzhou Petrochemical Company (hereinafter referred to as Sinopec Guangzhou), is one of the largest modern petrochemical enterprises in South China and the only super-large refinery facility of Sinopec in the Pearl River Delta region, boasting an A-level informatisation level and a crude oil processing capacity of more than 10 million tons.

Sinopec Guangzhou is recognised by Sinopec Group as a key pilot enterprise for the "world-class green and low-carbon urban refinery demonstration enterprise construction". In line with the "safe, green, and smart" development of the petrochemical industry, Sinopec

Guangzhou established partnerships with China Telecom, Petro-Cyberworks Information Technology Co., Ltd., Huawei Technologies Co., Ltd., Guangdong Communications and Networks Institute, and Guangdong Telecom Planning and Design Institute to undertake the special project of the Department of Science and Technology of Guangdong Province and the key research and development tasks of Sinopec Group in September 2020. Relying on the overall architecture of data + platform + applications, Sinopec Guangzhou was able to upload various on-site terminal data to the local data centre in a real-time and secure manner via the 5G private network. Leveraging the intelligent cloud platform's key capabilities in edge-cloud coordination, big data operation, AI applications and business platforms, the company has achieved safe, green, and intelligent applications in 15 major scenarios of six major business fields.





## Industry Challenges

Large state-owned petrochemical enterprises led by Sinopec in China are among the first to explore and systematically propose the concept of smart factories and put them into practice, which has produced an impressive result. By learning from foreign counterparts' best practices in information-based development, Sinopec successfully built its own smart factories, which offered an excellent example for players in the petrochemical industry. However, China's petrochemical industry still has a long way to go with regard to the digitalized and intelligent levels.

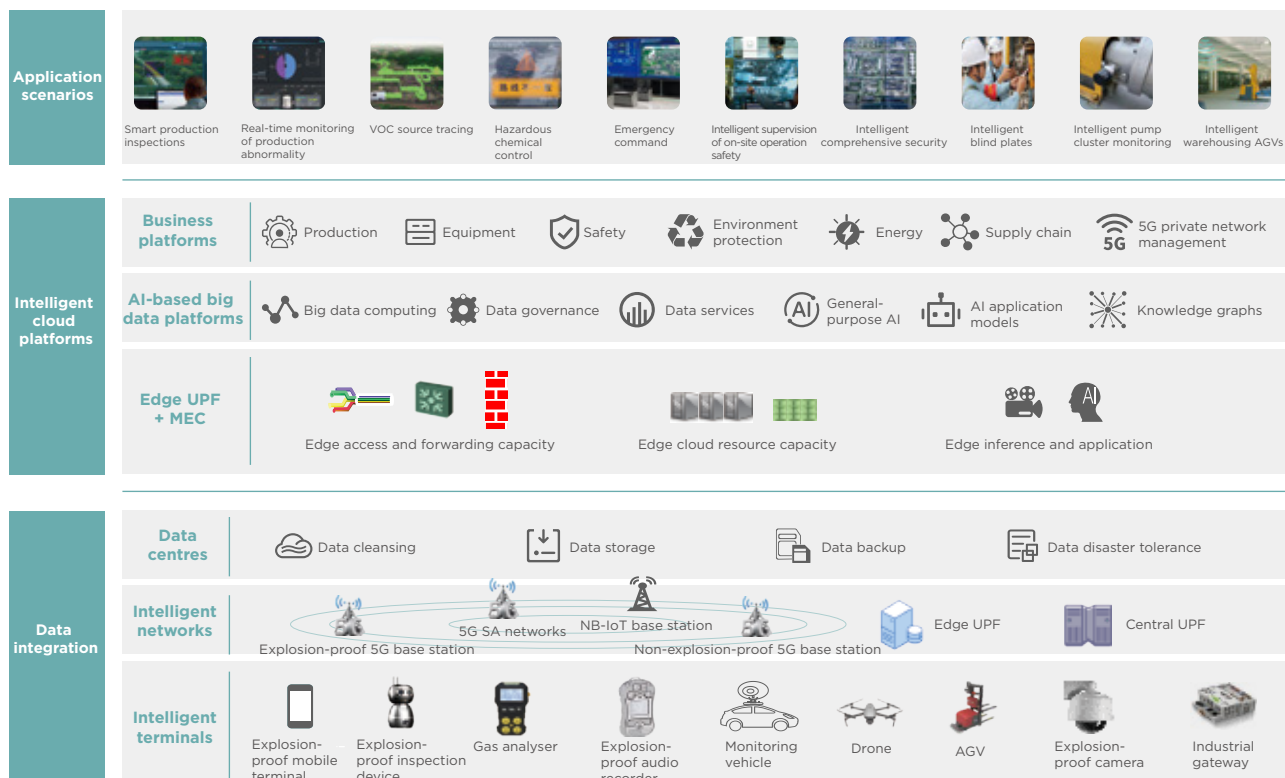
Sinopec Guangzhou identified the following issues during its production. 1. The joint emergency response and command capabilities were insufficient and integrated communications were not available. 2. With respect to collection and transmission of production and equipment operation data, some factories had remotely located control centres from their equipment and used traditional copper wires or optical fibers for wired transmission, which increased the network deployment cost. 3. Grid monitoring of VOCs and odors across the factory premises was in place, but the VOC emissions, fugacity prediction, and emission traceability were not effectively monitored

and managed. 4. The information-based operation management was not well executed due to the large workload on the site. 5. The existing pump equipment status monitoring could not meet the requirement for equipment health management, and the security and availability of the wireless data transmission network needed to be improved. 6. The traditional inspection mode without information-based control was inefficient. 7. The manual collection, delivery, and sorting of bulky cargoes resulted in a heavy workload and a low efficiency.

Therefore, Sinopec Guangzhou had an urgent need to improve automation and intelligent levels in the factory by integrating 5G + advanced technologies, in an effort to achieve lean production, collaboration optimisation, safety enhancement, energy conservation and environmental protection, green and low-carbon development, as well as cost reduction and efficiency enhancement. The "5G + Smart Petrochemical" project has injected new impetus into enterprise management reform, resource optimization, business innovation and efficiency enhancement, providing strong support for building first-class enterprises.

## Solutions and Benefits

The overall architecture of data + platform + applications enabled the company to upload on-site terminal data to the data centre in a real-time and secure manner via the 5G (including NB-IoT) private network. Leveraging the intelligent cloud platform's key capabilities in edge-cloud coordination, big data operation, AI applications, and business platforms, the company was able to achieve dynamic sensing, forecast and pre-warning, informed decision-making, and targeted execution in six business fields, namely production, equipment, safety, environmental protection, supply chain, and energy, bringing down the accident rate by 20% and the VOC emissions by 30%, and creating an annual economic benefit of RMB 30 million.



项目整体架构



# 5G+ Smart Manufacturing

## 01 Integrated solution of 5G private network

### Wireless network coverage

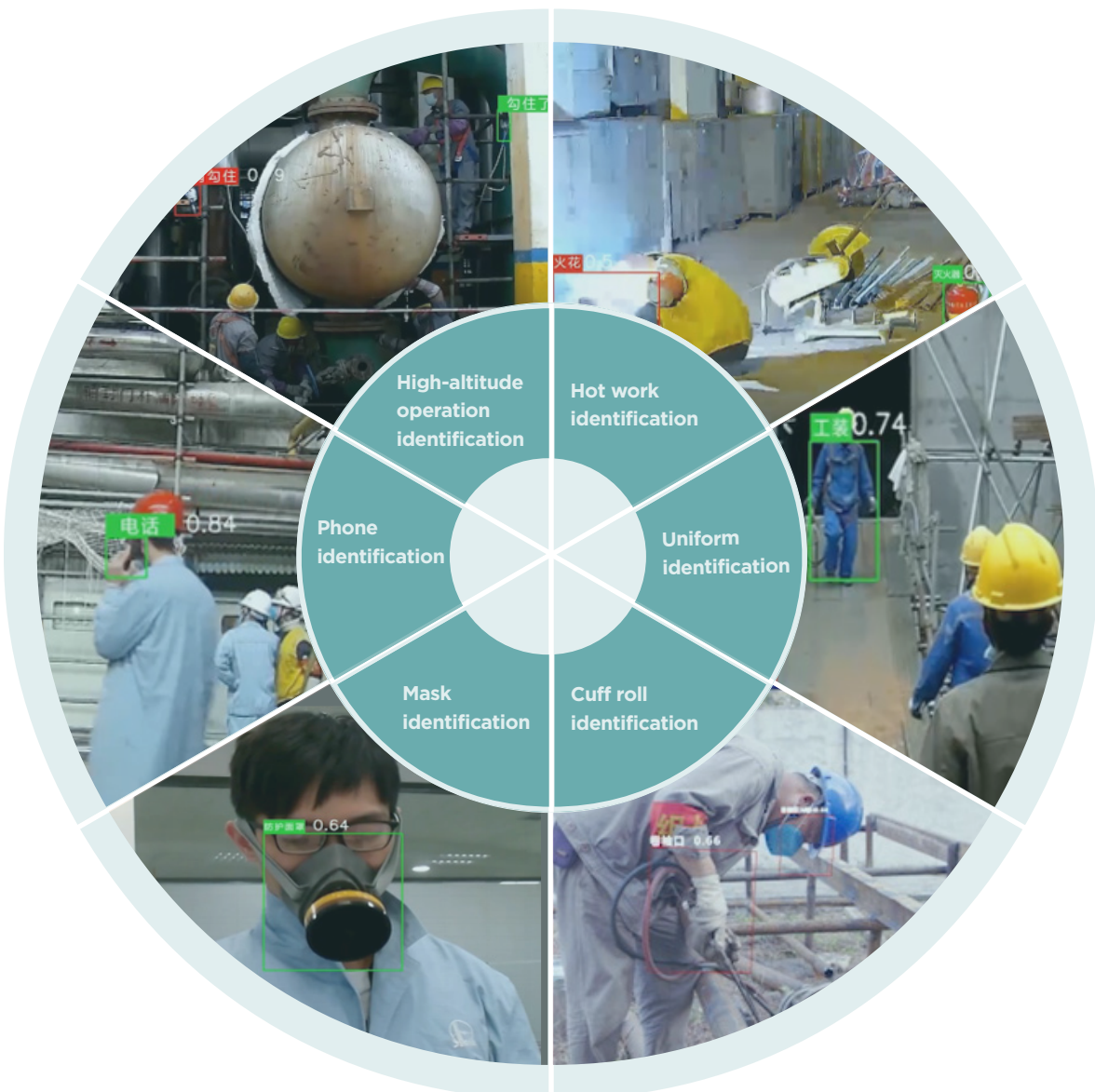
Four 5G explosion-proof micro stations in explosion-proof areas and 13 macro stations in non-explosion-proof areas have been deployed across the factory which covers an area of 4.45 million square meters, with 5G signal coverage rate reaching 95.80%. Blind areas and poor signal coverage areas of 5G networks in explosion-proof areas will be addressed based on project requirements.

### 5G private network solution

The Adjacent and Wide-area dual private network mode has been adopted for the first time in the petrochemical industry. Currently, the Adjacent mode with UPF deployed on lower layers is adopted in the production environment to achieve exclusive sharing of base stations and keep data for exclusive use within the industry park, thereby ensuring data security. The project adopts a Wide-area 5G private network that fully reuses the operator's public network as a backup. When the lowered UPF fails, the data services can be seamlessly switched to the Wide-area private network to ensure high availability of the 5G network.

## 02 Intelligent supervision of on-site operations improves safety

The deployment of mobile 5G cameras allows for real-time site monitoring and online AI analysis, which facilitates the transition from in-event supervision and post-event traceability to pre-event prevention. Online intelligent monitoring is now available for all on-site operations, which increases the standardized operation rate by 30% and secures an annual economic benefit of RMB 5 million.



### 03 VOC traceability improves environmental protection

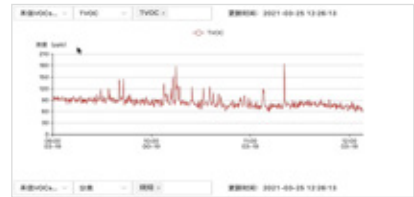
By leveraging 5G and AI technologies, a multi-source integrated 3D monitoring, pre-warning, and traceability system has been established to serve the full life cycle management of environmental protection, covering pollution prevention, source reduction, process control, and final treatment. This has led to a higher accuracy, more monitoring items, reduced early warnings, and a wider scope of traceability. Specifically, the accuracy rate has been increased from 50% to 70%, the number of monitoring items has expanded from 45 to 330, the number of early warnings has dropped by 10% year-on-year, and the scope of traceability has been extended to areas out of the factory.



5G distributed point monitoring



5G-based monitoring vehicle



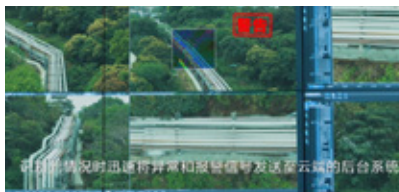
5G multi-source, multi-dimensional big data model

### 04 Intelligent production improves quality and efficiency

Take pipeline inspection as an example. Traditional manual inspection of pipelines have such problems as a low frequency, a high risk, a heavy workload, and difficult implementation. The use of 5G + drones has effectively solved these problems by photographing pipeline conditions from the top and sending the images to the edge nodes in real time for online AI analysis. This has enhanced the pipeline inspection efficiency by 10-fold, with the overall efficiency increased by 30% and the cost saved by RMB 1 million per year.



5G connected drone



Drone-aided inspection



Remotely controlled drone

## Solutions and Benefits

The 5G + smart petrochemical project highlights the following six successful practices

High-bandwidth uplink backhaul in explosion-proof areas. The project team and its partners simultaneously completed the explosion-proof transformation of Huawei pRRU and ZTE pRRU nationwide for the first time to address 5G signal coverage in explosion-proof areas.

5G explosion-proof terminals. The project team developed 5G explosion-proof cameras, 5G AR helmets, 5G explosion-proof mobile phones, 5G audio and video inspection devices, 5G on-site intelligent monitoring stations and other 5G terminals to address 5G terminal challenges in the petrochemical industry.

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Multiple types of 5G private networks. The project production environment used the Adjacent 5G private network with UPF deployed on lower layers, with Wide-area private network serving as a backup to ensure higher availability of 5G network.

Integrated operation of 5G private network and NB-IoT network. The project enabled local data offloading of NB-IoT networks via the lowered UPF for the first time in the industry and provided an operation management platform integrating both the NB-IoT and 5G private networks for visualised management and control of the networks.

Based on the 5G + intelligent cloud platform for the petrochemical industry + application, the project has created 15 application scenarios in six major fields.

The 5G + smart petrochemical solution of Sinopec Guangzhou will be replicated and promoted in 32 refineries under Sinopec Group, and the 5G + petrochemical industry application standards will be outputted. Furthermore, its best practices will be promoted in the petrochemical industry at home and abroad.





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# 5G + MEC Boost Green, Digital, and Intelligent Transformation of Masteel



The 5G private network now witnesses in-depth integration with Masteel's high-quality industrial intranet. With leading end-to-end solutions featuring high reliability and low latency, the 5G private network goes deep into Masteel's key production processes by leveraging collaborative innovation of 5G, AI, edge computing, cloud, and other technologies, achieving intelligent equipment interconnection, intelligent production, intelligent operation, and automatic operation and maintenance. In the future, Masteel will continue to tap into 5G values, pursue integrated innovation, focus on key applications, and converge industrial ecosystems to boost Masteel's green, digital, and intelligent transformation and promote the best practices across the iron and steel industry.

**Yang Xingliang**

Director of the Operation Improvement Department, Assistant General Manager of Masteel

## Partners



## Case Overview

Masteel Harbour Raw Material Factory is located in the northwest of Maanshan City adjacent to the Yangtze River, covering a total area of about 1.15 million square meters. The factory is primarily responsible for receiving, storing, processing, and delivering the raw materials needed for production by the six blast furnaces and five sintering machines of Masteel. The factory records an annual output of 10.1 million tons, being a "granary" of Masteel's iron-making raw materials. The factory covers a large area, and has nearly 100 large mobile machines, cloth vehicles, and tripper cars, with more than 1,000 discrete video surveillance points. Its equipment is connected via 427 belts totalling around 70 kilometres in length. Considering the complicated operating conditions and difficult deployment of communication systems, a 5G private network that is highly reliable, less costly, and easy to maintain is urgently needed to address challenges including mobile network deployment, flexible manufacturing, and green production.

Masteel, PHIMA Intelligence Technology, China Unicom, and Huawei jointly deployed nineteen 5G SA sites in the raw material factory and one set of MEC (UPF + MEP) system in Masteel's data centre for in-depth integration of the 5G private network with Masteel's high-quality industrial intranet. Additionally, Masteel has also piloted 5G + unmanned stacker-reclaimers, a 5G + 3D digital material factory, intelligent inspections of belt conveyors, 5G + AI production behaviour supervision, 5G + intelligent video cruise, and a 5G + AR intelligent operation and maintenance demonstration project, replacing 52 industrial Wi-Fi systems, with the investment cut by 30% and the overall utilisation rate across the factory increased by 20%. These efforts have translated into a manpower cut of 36 persons in the early stage and 200 persons in the later stage, saving CNY 8 million per year. As a result, the factory achieves intelligent equipment interconnection, intelligent production, intelligent operation, and automatic operation and maintenance, setting a benchmark for 5G application in the process industry.





## Industry Challenges

The iron and steel manufacturing process features a long process, many production steps, complex production techniques, a long supply chain, and a wide variety of manufacturing facilities, being a typical hybrid manufacturing process. Modern iron and steel manufacturing has highly automated process and production line equipment. However, this has also introduced challenges including high costs for equipment maintenance, high invisibility of industrial knowledge, increasingly personalised demands from downstream sectors, growing pressure for environmental protection, a low level of intelligence, and serious brain drain. As a result, the industry has a strong demand for digital transformation and upgrading to cut costs and increase efficiency. This is primarily embodied in the following aspects.

**Excessive production capacity, unbalanced supply and demand, and high pressure for energy conservation and emission reduction:** The excessive investment in the iron and steel industry during the 13th Five-Year Plan period has led to a concentrated release of production capacity, driving up the capacity to a level beyond the demand. Companies failed to quickly identify market demands due to the less optimal allocation of supply and demand information in the industry, leading to imbalanced supply and demand. Meanwhile, as the field with the highest carbon emissions in the manufacturing industry, the iron and steel industry is under high pressure for emission reduction, and urgently needs the support of the Industrial Internet for digital transformation.

**Data standard deficiency, data isolation, and stove-piped systems:** Steel factory equipment features many types and scenarios, leading to data silos, data fragmentation, and network diversification, with standalone systems and data, compromising utilisation efficiency of data and restricting the transformation and upgrading to Industry 4.0.

**Poor operating environment, labour-intensive production processes, and serious brain-drain:** The environment of many posts at iron and steel production sites harbour production safety risks such as high labour intensity, much dust, and high temperature hazards. Many production operations such as manual quality inspections still rely on personal experience, which is less efficient. Meanwhile, such posts are less attractive to human resources, resulting in recruitment difficulty.

**High requirements for wireless network connection and network security and stability:** Most of the production intranets in steel companies use optical fibres and Wi-Fi connection. Optical fibres are neither suitable for mobile scenarios nor conducive to flexible manufacturing due to their lossy nature and costly maintenance. Steel mills are dominated by the steel frame structure, which highlights serious electromagnetic and multi-way interference, while high reliability, stability, and low latency are required for some control-type businesses.

Leveraging the enhanced mobile broadband, low latency, and massive connectivity of 5G networks, as well as collaborative innovation of technologies such as AI, AR, and edge computing, 5G solutions help steel mills achieve digital transformation and upgrading with less manpower input and unmanned and intelligent operation.

## Solutions and Benefits

### 01 5G + 3D digital material factory

Previously, the stacking and reclaiming positions, heights, lengths, and widths of the stock piles and strips depended on individual observations and operation plans were revised based on the operator's experience and personal judgments on stockyard conditions. Single raw material management methods and low utilisation rate of the factory exist. To address this issue, the existing operational mode should be changed by deploying 3D scanners on mobile machines to get 3D scanning data of stock piles in real time. However, deploying wired optical fibres on mobile machines is complicated, with a large amount of 3D point cloud data and a significant delay during Wi-Fi communication, making it impossible to timely and accurately obtain the stock pile information.

In the 5G solutions, the massive amount of point cloud data scanned by 3D scanners is sent back to the data centre over the 5G network for 3D modelling and computing of stock piles and strips, enabling real-time stocktaking and operation plan development. After project implementation, the stockyards can be managed in a fine-grained manner to elevate the production efficiency by 20%.



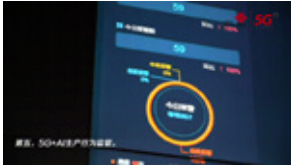
### 02 5G + unmanned stackers-reclaimers

All stockyards are covered with sheds and closed during environmental protection upgrading and transformation. However, the serious vibration and much dust during stacker and reclaimer motions result in the harsh operating environment in the sheds. Remote/unmanned driving of the stackers and reclaimers is required to improve the operating environment. In the traditional mode, optical fibres are used for remote transmission

of video signals and control signals, and optical fibre reels are placed on the rotating discs of the stackers and reclaimers to move, lay, and pick optical fibres. Nevertheless, optical fibres are prone to interruption which can affect normal production, complicate maintenance, and increase the cost.



# 5G+ Smart Manufacturing



Now with the 3D model data, intelligent sensing equipment, and high-definition video technologies of the digital stockyards, real-time communication between the machine-borne control systems and the remote intelligent decision-making systems can be realised leveraging the low latency of 5G networks, enabling inter-system coordination and unmanned operation of stackers and reclaimers.

This scenario requires precise control of production equipment and is demanding on the service latency (usually less than 20 ms). The 5G access and MEC local offloading ensure the smooth operation of remote/unmanned driving. Combined with the network slicing technology, the solution can meet the networking needs for remote/unmanned driving, realise flexible, independent sliced network resources, and guarantee network quality and safety of use.

## 03 5G + intelligent cruise

The material factory has a total of 427 sealing-tape machines, resulting in complexity for managing them. In the event of any equipment faults, it becomes difficult to find the video of the faulty equipment among the massive video signals. When the tapes of different material flows need to be started sequentially, it is necessary to get multiple video signals accordingly to monitor the start-up process.

High-definition videos can be sent back utilizing the high-bandwidth feature of 5G networks. Based on the specific process chain information as well as the electrical fault and alarm messages of the equipment, operators can quickly locate the faulty points and automatically identify the monitoring camera of the equipment to project the image on the large screen or send it to the terminal of the maintenance personnel. The 5G solutions also support video cruise and monitoring of the specific production process following customizable routes.

By deploying application capabilities such as map sharing, route planning, and scheduling management, the 5G solutions can enable remote cruise control and scheduling while sending back data such as real-time high-definition images, equipment information, and environmental information over the 5G network. The edge cloud uses video transcoding and decoding and AI inference among other functions to pre-process video data and then transmits it to the central cloud. The central AI system conducts in-depth analysis of the collected data to identify any abnormality in the equipment or environment in the cruise area.



## 04 5G + AI intelligent supervision of production behaviours

Managers may find it impossible to always supervise and issue reminders on the production behaviours of personnel in scenarios that feature a large area of field operation and scattered operation sites.

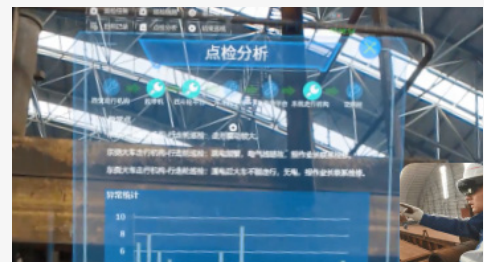
The enhanced mobile broadband of 5G supports transmission of 4K high-definition videos of the operation sites in real time. Coupled with the AI platform, 5G solutions can help analyse production behaviours intelligently and take pictures of and issue real-time alarms on any violations. This can prevent accidents caused by misbehaviours and avoid major personal injury and equipment loss caused by accidents.

With the 5G network traffic to data businesses well managed, one or more recognition algorithms can be configured for video streams or video files as needed by using functional modules such as AI algorithm libraries of atomic capabilities, intelligent analysis of videos, and face management in conjunction. The outputs include the automatically captured event photos, event descriptions, and time of occurrence, achieving 5G + intelligent supervision of production behaviours in the real sense.

## 05 5G + AR intelligent operation and maintenance

Previously, operation and maintenance personnel manually recorded equipment operation and maintenance details in form of text on paper or on an electronic platform as daily routines. For complex equipment, it was necessary to invite experts to the site to offer guidance on a regular or temporary basis. However, this approach highlights low maintenance efficiency and poor information sharing.

In current practices, 5G + AR glasses are used to record the spot check details of each component and perform analysis. In a complex industrial environment, experts provide real-time guidance through text, images, real-time annotations, and other spatial annotation means to enable real-time interactions from the first person point of view and multi-participant, multi-site collaboration. This can quickly locate the issues and share solutions in real time via cloud-based interactions and remote diagnosis.



The automatic offloading of business data on the edge cloud network, as well as the automatic deployment and transcoding, rendering, and splicing capabilities of AR applications lay a network foundation for 5G + AR intelligent operation and maintenance and remote collaboration, supporting AR space annotations, multi-user high-definition audio and video communication, and document sharing among other functions, with the technical support costs dramatically reduced.

## 06 5G + intelligent maintenance and inspection of sealing-tape machines



Sealing-tape machines are prone to motor or reducer failures, belt misalignments, slip, tearing, and other issues during production and operation due to the complex operating environment, the long transportation distance, and the large transportation volume. What's worse, the lack of effective detection and monitoring methods can lead to consequences ranging from lowered production efficiency to severe accidents.

To address the above issues, we have utilised smart sensors and 5G network technologies to improve the detection methods on equipment operational statuses, established a real-time digital model for equipment to manage equipment in a visualised manner, utilised an intelligent analysis model for rapid and intelligent diagnosis of faults, and conducted

a systematic digital health assessment to ensure safe operation of the system. In addition, we have also analysed and evaluated equipment health statuses based on historical data and machine learning algorithms and models to implement predictive maintenance. Meanwhile, we have set up an intelligent maintenance and inspection system including file management, spare part management, and equipment maintenance functions to remotely carry out operation, maintenance, and monitoring in an information-based and intelligent approach.

For the purpose of 5G-based intelligent maintenance and inspection of sealing-tape machines, we collect real-time data on motors, reducers, and tapes via the 5G network, upload the data periodically, and perform state estimation and situational awareness after intelligent, algorithm-based analysis. The results are then sent to the operation and maintenance personnel to predict the equipment status and take measures in advance against any tape faults and safety risks.

### Summary and Next-steps

The 5G pilot application in the raw material factory has proved that the 5G network can well eliminate the pain points of wireless communication such as wired optical cables and Wi-Fi connections. The organic convergence of the 5G private network and Masteel's industrial intranets has connected up the company's CT, OT, and IT systems, enabling deterministic communication with less jitter, a low latency, and high uplink speed. This ensures the high availability of Masteel's industrial production network and helps the company achieve "centralised control and operation, machine-powered operation, remote operation and maintenance, and online services". Thanks to the 5G solutions, the eight types of problems during steel production have been effectively solved, namely poor operating environment, complex network deployment, excessive operators, low work efficiency, high operation and maintenance costs, high labour intensity, difficult operation and maintenance evaluations, and limited supervisory measures. As a result, wireless network services featuring enhanced mobile broadband, low latency, and high reliability become available for industrial sites to empower Masteel's smart manufacturing.

With the joint exploration by the three parties, the capabilities of 5GtoB business modelling, network planning and design, business modelling, and integrated services for business scenarios including video surveillance, remote control, and unmanned driving in the steel industry have been accumulated to tap into the needs in different application scenarios.

5G integration with industrial applications requires the participation of ecological partners to incubate new applications and accelerate 5G integration into R&D and design, production and manufacturing, fault operation and maintenance, logistics and transportation, and safety management among other links. In view of industrial characteristics, we can further build a "5G + Industrial Internet" industrial ecosystem with the upstream and downstream of the industrial chain coordinating with each other to promote infrastructure construction to the lower end and develop industrial application scenarios for the upper end.

### Next steps

- 1 Explore more value-creation scenarios: Make collaborative innovation of 5G, AI, edge computing, cloud computing, and other technologies, go deep into production processes, explore value-creation applications such as 5G + AI intelligent coal blending, 5G data acquisition and predictive maintenance, and electronic fences to improve quality and efficiency, and promote automated, unmanned, green, digital and intelligent transformation and upgrading in multiple links and processes.
- 2 Incubate innovative solutions: Gradually verify and launch advanced solutions that are applicable to the iron and steel industry, such as reliable core network schemes, the dual-transmit and selective-receive mode, and 5G LAN to ensure network connectivity even in case of Internet disconnection, so as to improve the reliability of 5G private networks and facilitate networked operation and maintenance.
- 3 Build an application enabling platform: Build an integrated automatic operation, maintenance, and management platform targeting networks, terminals, and businesses to achieve terminal device management, real-time business process monitoring, fault alarming, and positioning and boundary setting, for the purposes of further solidifying assets, accumulating capabilities, and accelerating business incubation and launch.
- 4 Promote scaled replication in the industry: Develop and improve standard 5G private network solution baselines and end-to-end products targeting iron and steel application scenarios, open up capabilities, and promote scaled replication and industrial upgrading of the capabilities within Magang (Group) Holding Co., Ltd.





# 5G-based Smart Iron & Steel Project of Liuzhou Steel Group



Spirit Like Steel, Ambition Like Sea. From a new starting point and in a new age of preferential policies, Liuzhou Steel Group will adhere to the spirit of the 19th National Congress of the Communist Party of China and Xi Jinping's Thought on Socialism with Chinese Characteristics for a New Era to uphold core philosophies of "inclusive, innovative, transcendent, and sharing" and seize the opportunity as the state is implementing the "Belt and Road Initiative". Boosted by the development of the Beibu Gulf, the Group will focus on the four strategic transformation goals, namely headquarters transformation and upgrading, orderly development of coastal areas, diversified and focused clusters, and strategic management and control by the Group, and fully deepen the supply-side reform to vigorously implement the coastal strategies, speed up the development of an international economy, and head for the goal of making into the world's top 500, as part of its effort to write a glorious chapter in the steel production history in Guangxi and even the whole country.

**Pan Shiqing**

Chairman of Liuzhou Steel Group

## Partners



## Case Overview

Liuzhou Steel Group is the largest iron and steel conglomerate in South China, Southwest China, and even the Pan Beibu Gulf economic zone. It is among the top 50 global steel enterprises and the top 500 Chinese enterprises, with more than CNY 100 billion of annual operating revenue and an annual comprehensive steel production capacity of 23 million tons. Liuzhou Steel Group cooperated with China Mobile Group Guangxi Branch and Huawei on a 5G smart steel project. By integrating 5G, cloud, and AI technologies into the production process, the project aims to build a digital Liuzhou Steel Group. The three parties jointly cooperated with the project team to innovatively launch eleven 5G + Industrial Internet application scenarios in the iron and steel industry, including the 5G Welder Cloud Eye quality inspection, cloud identification of solid waste, cloud identification of steel coil IDs, 5G-based smart cranes, 5G-based remote control of assembly machines, 5G-based remote control of stackers and reclaimers, 5G-based labelling machines, 5G-based predictive maintenance, 5G-based AR remote collaboration, 5G-based manufacturing centres, and security drills of 5G-based cloud networks. Currently, the project is the 5G industrial project with the most scenarios in China.

A series of 5G-based smart steel transformation has increased the benefits and cut the costs of Liuzhou Steel Group by more than 1 hundred million CNY. For example, the remotely controlled loader project has enabled on-site HD video backhaul and remote precise control of loaders, so that operators in the central control room of the Liuzhou Steel Group headquarters can operate the loaders in the Fangchenggang cold-rolled product workshop in real time and from multiple perspectives. This solution not only reduces the human resources required for one lifting operation by 60%, increases the efficiency by 400%, but also greatly improves the operating environment, operation safety, and workers' satisfaction about their jobs, which were known for their harsh conditions.

Relying on the low-latency data transmission of 5G networks and the real-time big data analysis of the industrial brain, Liuzhou Steel Group has employed the machine vision server and AI server in the cloud backend to replace the manual roller transfer. The solution is gradually promoted to other production lines to achieve the aim of a transparent factory of "Technology + Good appearance + Smart".

In the application of 5G-based remote control of cold-rolled cranes, cranes are remotely controlled based on the 5G multi-view capabilities. In the past, three people were required for the lifting task, but now only one person is enough to complete a single listing operation, with the human resources cut by 60%, and the lifting interval also decreases from 20 minutes in the past to the current five minutes, with the loading and unloading efficiency enhanced by 400%. Moreover, the control system uses a gamepad (the first application in the world) as the controller, which significantly improves the operating environment and addresses the recruitment challenge.





## Industry Challenges

The entire production processes of the iron and steel industry are like a "black box" that cannot be seen, touched, or measured, as they feature the coexistence of multiple sites, phases, and variables, strong coupling, significant lagging, and nonlinear characteristics. This gives rise to the big uncertainty in iron and steel production processes and the product quality. Therefore, the steel industry is also the industry with the most urgent demand for intelligent mode. After China clarified the scope of new infrastructure, how to transform traditional manufacturing industry through new technologies including 5G has become the focus of many steel companies.

As an important steel company, Liuzhou Steel Group also faces many pain points that had been nagging the traditional manufacturing industry.

### Harsh operating environment

The high-temperature, dusty, and noisy operating environment damages employees' health, which goes against companies' values.

### Potential safety hazards

Some special positions have a tough environment and require continuous operation, which may easily cause human operation errors and result in safety and production accidents.

### Low operating efficiency

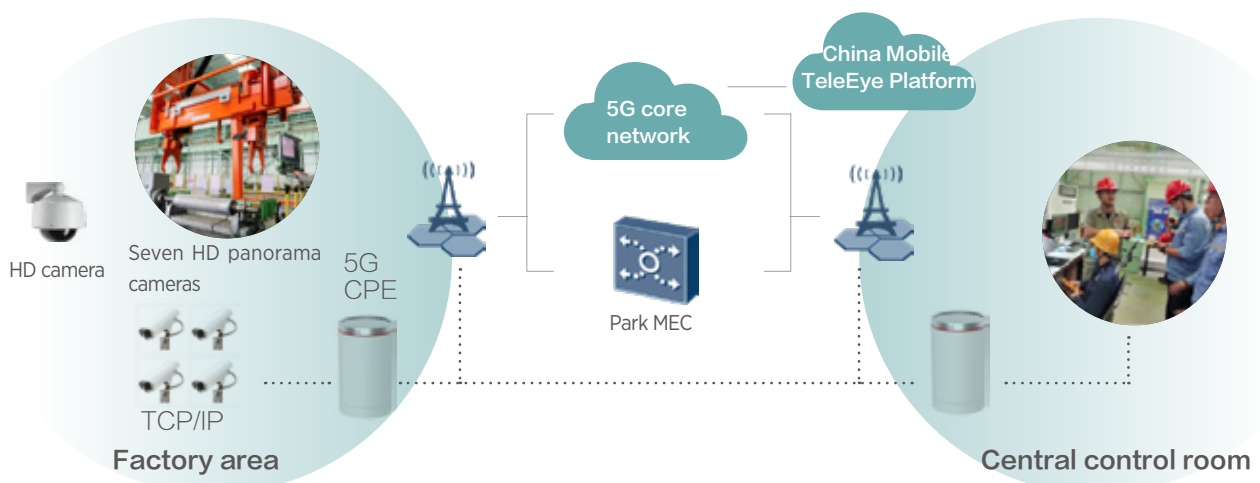
The on-site high-altitude boarding space is narrow and it takes long to get off, which undermines the working efficiency. Moreover, the positions of crane operation workers are scattered, lowering down the organisational and management efficiency. One crane requires multiple dedicated persons, which causes high waste of human resources.

The high-speed, enhanced-mobile broadband, low-latency, and high-reliability characteristics of 5G networks are perfect to meet the needs of Industrial Internet connections, which require diversity, performance differentiation, and communication diversification. It can keep network latency within milliseconds, which supports precise control and improves the production safety in the industrial manufacturing sector.

## Solutions and Benefits

### 01 Smart remote-control scenarios: 5G + AI intelligent roller loaders

Cold rolled product is one of the main products of Liuzhou Steel Group. The grinding roller shift is responsible for providing rollers for various production lines. The grinding roller assembly workshop has very high temperature, and three people are required for each roller lifting operation. Two people stay on the ground to tighten the hoisting ropes, highlighting a low working efficiency and exposure to accidents. What benefits will be created by "transplanting" the gamepad to the factory machinery? The operator is controlling the 5G-based intelligent loader to lift the rollers with a gamepad. The devices that seem so unrelated are now perfectly integrated. Picking up the gamepad, the operator will become a game master to manipulate the loader. These futuristic technologies enable technicians of Liuzhou Steel Group to automate loader operations as if they are playing a large-scale 3D game. In view of 5G networks' technical characteristics including "enhanced mobile broadband" and "low latency", the project has customised a "control terminal + China Mobile 5G network + loader" solution to perfectly support HD video transmission and remote control with high precision. Thanks to this 5G + application, the cold-rolled steel plant has solved the pain points and difficulties that have plagued the company for years. As a result, workers' satisfaction of the positions known for harsh conditions has been greatly increased, the incidence of work-related safety production accidents has been reduced, and the labour productivity has seen a drastic increase. A single lifting operation that used to require three people can now be easily completed by only one person via a computer, the working efficiency being doubled.





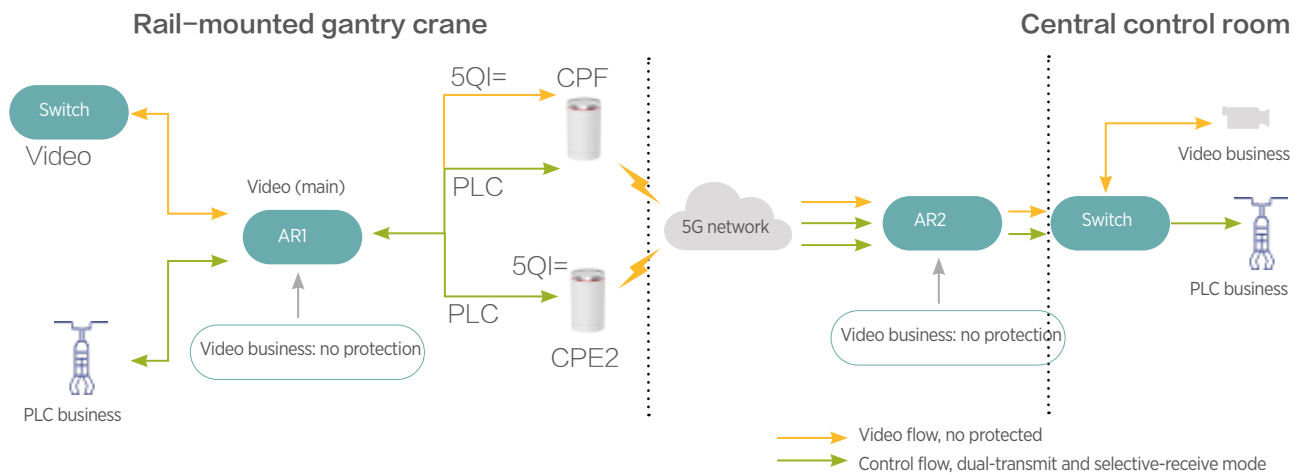
# 5G+ Smart Manufacturing

## 02 Smart remote-control scenario: 5G-based self-stabilizing remotely controlled reclaimers

Stackers-reclaimers are used to transfer coal ore and iron ore in the stockyard and workers usually operate them outdoors in the open, are exposed to strong sunlight, coal powder, and ore dust. The stockyard environment is harsh, and operators need to climb to the cab on top of the vehicle to control the crane. This operating mode features a low operating efficiency and a harsh, dangerous environment. Remote control has become an irresistible trend to improve operating efficiency and eliminate work risks.



Taking advantages of the 5G base stations which have a high power and an optimal coverage distance of within 500 m as recommended, 5G networks featuring high uplink bandwidth, a stable uplink bandwidth of more than 200 Mbps per cell, and the industry's leading dual-transmit and selective-receive technology can ensure stable PLC control latency of below 100 ms and other technical advantages. As a result, network coverage and transmission delay in the outdoor environment can be well addressed to improve the operating environment and efficiency via remote control of stackers.

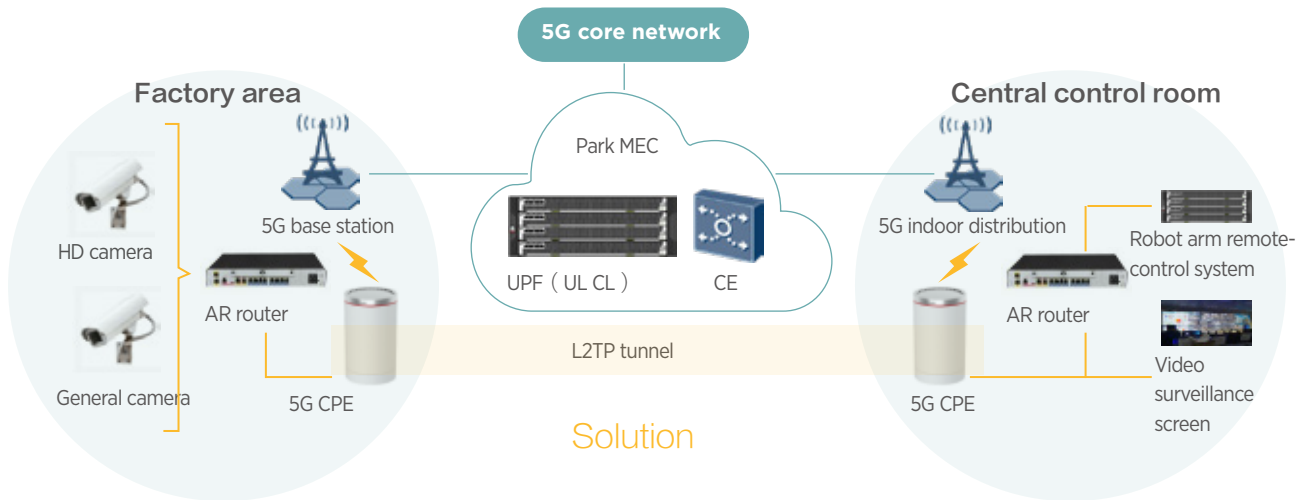


## 03 Smart remote-control scenario: 5G-based self-stabilizing remotely controlled cranes

Cranes are used for loading, unloading, handling, and transportation. They are one of the most important pieces of steel production equipment and a key factor for the operational efficiency of steel plants. Cranes often operate high above the factory floor. In the past, manual operation was required from the crane operating room. This mode was inefficient and exposed employees to high temperature, noise, dust and corrosion, and electromagnetic interference. To increase efficiency and eliminate operational risks, it is necessary to develop a remotely controlled crane system.

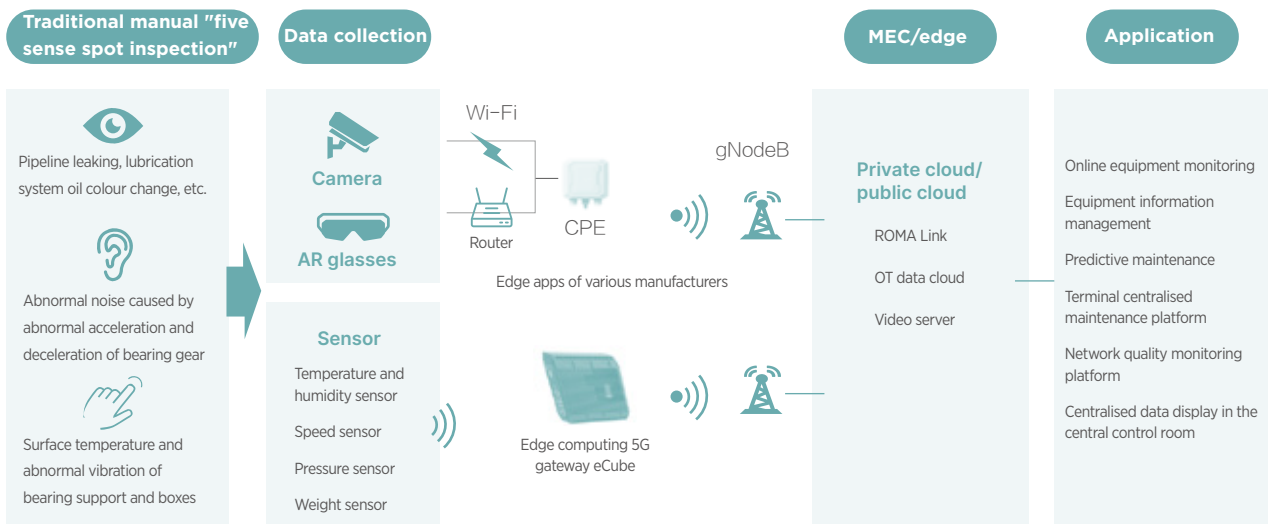
Targeting the existing problems and the wireless environment, in addition to the site situation (such as obstructions and metal structure shielding), wireless network signal coverage requirements, access concurrency and speed, data security, future scale-up, construction costs, and other factors, the project relies on 5G networks' enhanced mobile broadband, low latency, and high reliability to enable HD video remote monitoring and 5G-based remotely controlled cranes from multiple perspectives. A single lifting operation which used to require three people now only requires one, cutting the manpower by 60%, improving the working environment and recruitment efficiency, shortening the lifting interval from 20 minutes to five minutes, and increasing the handling efficiency by 400%.





#### 04 Intelligent operation and maintenance scenario: 5G data acquisition and predictive maintenance

The operation and maintenance of traditional equipment require three shifts a day to perform spot inspections, with workers manually recording operating states of thousands of equipment. This mode relies heavily on the sense of responsibility and experience of point inspectors. If 5G networks are used, data can be collected within a single day by using equipment sensors to complete data deployment and release. Thanks to this solution, important devices such as rolling mills, fans, and winding engines can be monitored online 24 hours a day, increasing the overall operation and maintenance efficiency by 30%, and the AI diagnosis accuracy has exceeded 85%. With the production continuity ensured, unexpected shutdown caused by equipment failures can be avoided to the maximum extent.



#### 05 Intelligent operation and maintenance scenario: AR remotely assisted assembly

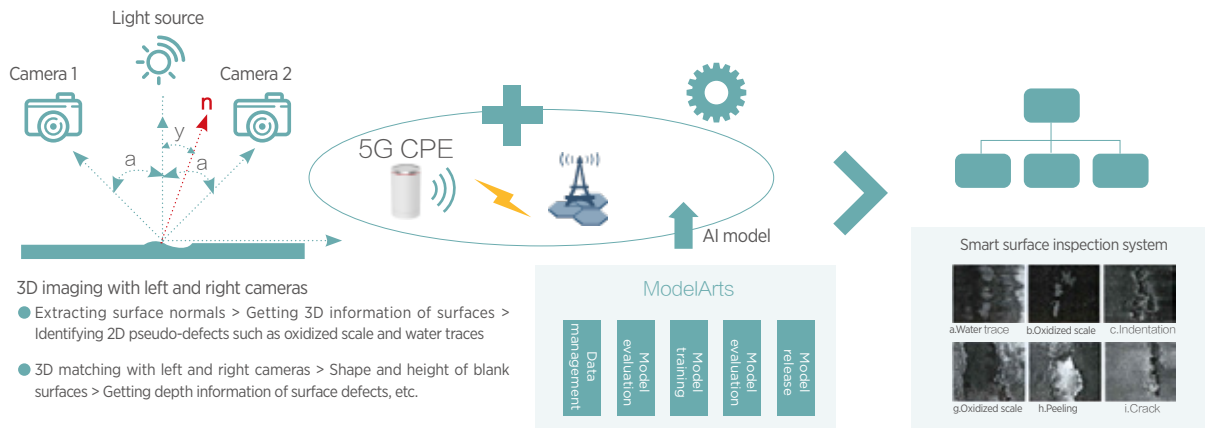
5G + AR cross-border remote collaboration sees its first application in Liuzhou Steel Group. In the past practices of important equipment debugging and repair, the external engineers had to travel to the scene, which was time-consuming and costly, and reduced production efficiency. With the 5G + AR solution, these engineers can add real-time annotations and make audio/video interactions and exchanges from the first-person perspective, with the front and rear teams connected seamlessly. The application of 5G + AR solution also boasts positive reference significance for promoting the efficient multi-base coordination and strengthening the sharing of advantageous resources of Liuzhou Steel Group.





## 06 Intelligent vision scenario: 5G + AI Welder Cloud Eye quality inspection

The cold-rolled steel plant has three welding lines, with welding operation once every three to five minutes. Previously, appearance defects of weld joints were observed visually. However, this approach was prone to large deviation, high work intensity, and high labour costs, and it was impossible to record and trace the welding quality with images. The Welder Cloud Eye quality inspection adopts 5G-based videos to collect images in real time and perform automatic detection online 24 hours a day via AI. This not only reduces the manpower cost by 55%, but also increases the recognition accuracy by 40%, with the welding quality recordable and traceable as well.



## 07 Intelligent vision scenario: automatic identification of steel coil IDs

Steel coil ID is an important identifier of the coil in the production process and is used for quality tracking. In the traditional mode, workers manually recorded the IDs, being low in efficiency and making it hard to trace coils throughout the process. Moreover, it was not easy to lay wiring in the production line. With 5G solution, services can be quickly released online. The 4K AI cameras deployed on the production line can read coil IDs in real time and then send back the data via the 5G network to the production system, delivering a higher operating efficiency at a lower deployment cost.



### Summary and Next-steps

5G connectivity is the foundation and cloud is the key carrier for the steel and iron industry to transform from "manufacturing" to "intelligent manufacturing". The 5G + Smart Factory benchmark application project of Liuzhou Steel Group which values several hundred million CNY leverages the new architecture of "5G + AI + application" to enable steel surface quality inspection, remote control of cranes, intelligent predictive maintenance, and AR remote collaboration among other new scenarios to help the Company address challenges in product quality, production efficiency, and recruitment difficulty among others, so as to ultimately build a 5G smart factory with leading technologies and flexible production capacity.

To gain more insights into the industry trends, be better poised for greater opportunities, tap to more values from transformation, and realise the transformation from "dividing the cake" to "baking a bigger cake", it is necessary to deeply understand the pain points of the industry, build consensus around the ecosystem, and gather diverse capabilities. We should start from the top-level design to pin down scenarios and analyse customers' business scenario demands based on their strategic businesses, that is, "discover values". The key of "innovation enablement" is to adhere to the "5G first" principle, empowers application innovation with network, and continuously optimises the suitable plan.



# 5G+ Smart Mining

Mineral resources are created over a long course of formation, development, and evolution of the earth's crust, where natural minerals were concentrated in geological processes under certain geological conditions. Various types of mineral resources can be formed under different geological processes. Mineral resources have the following characteristics: (1) Non-renewability. Any type of mineral resource is limited in reserve with certain irreplaceability. (2) Exploitation difficulty. Most of the mineral resources require certain geological conditions for formation, and ecological environment can be easily undermined during exploitation of mineral resources. (3) Uneven distribution. Mineral resources are often less in reserve in regions with developed productivity.

Mineral resource development typically involves industrial production processes such as mining, separation, and smelting. However, exploitation approaches vary depending on the type of resource and location of mines. Common exploitation approaches include open-pit mining for a shallow, thick ore body, and underground mining for a deep ore body with less thickness. Open-pit mining requires lower investment in infrastructure, which is a better option for large-size equipment and typically has better productivity, and lower production costs, ore loss and dilution, as well as relatively safer operation conditions. However, open-pit mining is not applicable to all ore bodies. Sometimes, the underground mining is also needed. The same mine may use open-pit mining in the early stage and turn to underground mining later.

**At present, the mineral exploitation industry is facing the following main pain-points:**

## Safety accidents

Mining is a high-risk industry that can lead to major fatalities upon occurrence of accidents. In typically dark, enclosed mining areas, a low level of oxygen and the existence of inflammable and explosive gases make it difficult for miners to escape from accidents and for rescuers to help the trapped miners. For instance, according to the National Mine Safety Administration, China recorded a total of 123 coal mine accidents with 228 deaths in 2020. Due to high risks, it's increasingly difficult to recruit and dispatch mining workers as people are unwilling to take underground mining jobs. As human life is the top priority, industrial leaders in mining are attaching great importance to advanced technologies that can reduce underground workforce and duration, enable intelligent cognition and monitoring of production environment and processes, and increase underground communication facilities, methods, and positioning capability, in order to ensure safe production as well as immediate response to emergencies and effective evacuation or rescue upon accidents.

## Environmental pollution and ecological damages

Main pollution issues from the mining industry include air, water, and soil pollution, such as greenhouse gas discharge and dust pollution from explosion and exploitation, soil pollution released by associated elements, and underground and surface water pollution from wastewater discharge. Additionally, mining tends to cause environmental issues such as ground collapse or subsidence, mountain fracture or landslide, soil erosion and land desertification, destruction of biological habitat, and seawater intrusion to goaf areas. With enhanced oversight of the mining process, better environmental controls, and a higher-level automation and intelligent operation, we can cut the proportion of tailings and promote coordinated development of mining resource exploitation and the environment.

## Complex and dynamically changing production environment

Mining environment is typically complex and constantly changing. In underground mining, the production environment needs to be designed and changed according to the geological structure. Generally, the heading interface is advancing by 5 to 10 metres daily, and the fully mechanised mining frontline is extracted for 8-10 metres every day. Smart mining equipment and relevant infrastructure require flexible deployment, automated configuration, mobility, remote control, adaptiveness to the production environment and other characteristics, such as being dustproof, explosion proof, shockproof, waterproof, and heat resistant.

## Lower efficiency and higher costs

In recent years, the mining industry has experienced a demand slowdown, tightened environmental restrictions, increasing production and management costs, and downward-trending mineral product prices. In 2020, the global coal consumption decreased by 4.2%, the fourth decline in the past six years, and the coal price (the China Qinhuangdao coal spot price) lowered by 3.25% in 2020, a decrease of 34.7% from its peak in 2011. Mining industry urgently needs innovation and integration with new technologies for the purposes of optimizing production processes, reducing wastes, conserving energy, reducing costs, enhancing efficiency, improving competitiveness, and accelerating high-quality development.





# 5G+ Smart Mining

As 5G and other advanced and new technologies are adopted, mining equipment is increasingly growing towards a larger size, automation and intelligence, and the mining methods towards scaled, continued and less manned, with production facilities and techniques being improved, production efficiency being promoted, costs being reduced, safety factor being enhanced, and environmental pollution being decreased. The year of 2021 is marked as a start for 5G-empowered mining digital and intelligent transformation. The application of digital, information-based, and intelligent technologies is helpful for high-quality, safe development of the mining industry, construction of green mines and unmanned mines, and promotion of the exploitation and protection level of mineral resources.

5G network, thanks to its features such as high speed, large capacity, low latency, strong reliability, high security, good positioning accuracy, and flexible deployment, enables real-time HD video transmission, low-latency remote controls, speedy high-precision positioning, real-time information exchanges, automated network deployment, and intelligent operation and maintenance. It provides effective solutions to issues with wired network such as prolonged construction period, higher costs, difficult adjustment, and proneness to fracture, as well as issues with Wi-Fi/4G network such as poor coverage, inadequate capacity, and insufficiently low latency. Therefore, it is a key empowering technology for smart mines and the typical application scenarios include the following.

## The typical application scenarios of 5G + Smart Mining include:

By deep integration of 5G industrial modules and transmission equipment in mining, 5G-based communication for key large equipment can be supported. Deployment of a real-time production control platform and scheduling system based on a 5G mine network realises real-time information exchanges and remote controls in mining and production and reduces the use of on-site personnel.

5G intelligent helmets, sensors, monitoring equipment, inspection robots, and rescue robots enable underground visualised communication, real-time HD video transmission, environment monitoring data collection, and underground miner and equipment positioning to facilitate safe inspection, pollution monitoring, disaster pre-warning and rescue.

5G can empower assisted driving system for establishment and application of unmanned driving system in mining trucks, which can be organised in fleets to effectively address automated obstacle avoidance, traffic following, truck meeting and autonomous path planning at significantly higher efficiency and much lower costs.



### Smart mining and production controls



### Environment monitoring and safety protection



### Autonomous driving of unmanned mining trucks

These application scenarios all require a 5G network that fits the high-dust, flammable, and explosive working conditions in mines and deployment of 5G independent networking features such as 5G network slicing, edge computing and enterprise private network, as well as enhanced technologies such as uplink carrier aggregation, uplink and downlink decoupling, Integrated Access and Backhaul (IAB), low latency, strong reliability, high-precision positioning and intelligent operation and maintenance, to meet the needs for safe, efficient, high-quality, and intelligent production in mines. The following cases provide a detailed explanation on the implementation planning and effect of these 5G applications. In the remote control upgrading for underground equipment such as drilling machine and electric shovel for Sichuan Pangang Group Mining Co., Ltd., unmanned and intelligent operation with one-click operation, wide-angle video, and immersive experience has been realised by feeding back on vehicle incline and vibration via the cockpit to the above-ground driver. In the Shanxi Lvliang Xinyan Coal Mine project, environmental monitoring and safety protection methods were adopted to significantly reduce underground on-duty manpower to keep miners away from risky and hazardous working environment, so their families and friends can be reassured about their safety. Autonomous driving of unmanned mine trucks in enclosed areas in mines have been applied by Sichuan Pangang Group Mining Co., Ltd., Lvliang Xinyan Coal Mine, Inner Mongolia Zhunneng Group, and Henan Jiaozuo Coal Group, where 5G drones have been in use to support high-precision 3D mapping to update the mining environment and route planning in a timely manner. In view of the complex conditions in mines, it's difficult to realise full coverage of 5G with the medium and high frequency bands under complex scenarios such as heading interface, turning, uphill/downhill, ups and downs, and blind angles. The China Coal Group Dahaize Coal Mine project started to adopt integrated network of 700 MHz and medium and high frequency bands to lower networking costs and enable better coverage, which is an emerging trend worth watching.



# 5G Smart Mining Project of Lvliang Xinyan Coal Mine



Since its launch in early November 2020, the 5G ring network in Xinyan Coal Mine has been running stably to support all-weather remote coal mining in the underground intelligent working face. The laborious and dangerous underground work has been replaced with labour-saving panel operations in the office. In 2021, we further expanded the application of 5G in the principle of cost-effectiveness and practicability, and implemented 5G support for 27 subsystems, enabling highly efficient transmission and application of mine big data. In 2022, we expect to make possible 5G-enabled personnel positioning and scaled application of 5G slicing, and enhance the construction of 5G + intelligence to achieve comprehensive cognition and intelligent control across the mine area, building Xinyan into a new benchmark for 5G + smart mining in China.

**Deng ChengJun**

Chairman of Lvliang Xinyan Coal Mine

## Partners



## Case Overview

Xinyan Coal Mine, a coal mining company under Lvliang Dongyi Group Coal Gasification Co., Ltd., has a recoverable reserve of 160.99 million tons and an approved production capacity of 2.4 million tons a year. Since the emergence of 5G technology, Xinyan Coal Mine has actively embraced the construction of 5G + smart mining in response to the national call, in the hope of realising intelligent safety monitoring, production and management featuring increased safety and efficiency as well as less manpower via 5G + intelligence, thereby improving the profitability of the digitalized company. Among the first batch of mines with full underground 5G coverage in China, Xinyan Mine Coal was selected as a national example of intelligent mines in 2020.

In June 2021, Xinyan Coal Mine started the project of converging its nine subsystems with 5G network based on the 5G network and application project at the first phase. In November 2021, the convergence project was completed for acceptance inspection. During the construction and launch of the project, Xinyan Coal Mine joined hands with its partners in the ecosystem including China Mobile Shanxi, Huawei, and Sany Electronic to promote 5G network optimization and incubation of planning-deployment-optimization services suitable for the mining industry. From here, 5G + smart mining has moved on a trajectory from "available" to "productive".



## Industry Challenges

**Operational safety to be improved**

Safe production is the top priority of coal companies. Despite the fact that the death rate per million tons of coal mined fell from 0.093 in 2018 to 0.083 (316 deaths in 170 fatal accidents) in 2019, this figure was still 5 times that of the United States and 11 times that of Australia, at the level of a moderately developed coal-producing country. There was an urgent need to improve working conditions and reduce manpower in underground production by means of mobile communication technologies to minimize production safety accidents.



# 5G+ Smart Mining

## Recruitment difficulty and labour shortage

The average workforce age in the coal industry is above 45 years. Due to factors such as many hazards and risks, poor working environment, intense workload, and long working hours, it has been increasingly difficult to recruit younger workforce, which might lead to a critical labour shortage in the next 5 to 10 years. As the coal industry remains a pillar energy industry in China, it was imperative to address the workforce issues by leveraging intelligent approaches and mobile communication technologies.

## Hurdles in centralised management

The coal mining, tunnelling, electromechanical, conveying, and ventilation systems are distributed in underground tunnels that span over dozens of kilometres. Many areas down the mine are accessible only on foot due to hurdles in underground transport, conveying, and scheduling. Reading meters on site was the only way to monitor production and safety data on people, machines, and the environment, which was inefficient and not on a real-time basis. It was a challenge to solve the centralised management of distributed production systems to reduce workload and improve efficiency.

## Multiple isolated networks

Different networks were deployed in underground systems for different purposes such as production, communication, and management. With the capacity to address business requirements with one common network, 5G provides solutions to centralised operation serving the purpose of multiple networks.



## Solutions and Benefits

In view of the big difference in network requirements amongst systems used in the coal industry, as well as the extremely high demands on safety, availability, and stability of networks and systems, the project team tackled the challenges from the application, network and service dimensions:

### Promoting the convergence of intelligent applications with 5G to realise smart mining:

Targeting industry pain points, the project team worked with China Mobile Shanxi, Huawei, and OT ecosystem partners to introduce eight intelligent subsystems that address practical issues in the actual production of mines.

### Advancing the implementation of key network features to accelerate network adaptation to the industry:

The project team released the first high-availability MEC kite-like solution jointly with China Mobile Shanxi and Huawei, and implemented 5G and ring network active-standby capability of subsystems in specific scenarios with China Mobile Shanxi, Huawei, Sany and OT ecosystem partners.

### Incubating the integrated service of planning, deployment and optimization that serves as a bridge for integration of business and network:

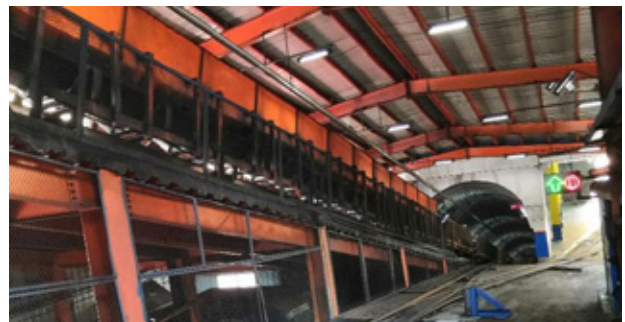
Through joint efforts with China Mobile Shanxi and Huawei, the project team incubated the integrated service of planning, deployment, and optimization based on the launch of eight intelligent subsystems, and aligned business requirements with network features through technical means. With clear business requirements for network planning, the team ensured the availability and stability of the final delivered network, so that the network and applications may better serve the industry, solve business difficulties, and create practical value.

Based on unified 5G network, 5G applications in eight areas as follows were explored under the 5G Smart Mining Project of Lvliang Xinyan Coal Mine:

## 01 Main inclined shaft hoist monitoring system

The main inclined shaft transports materials mainly using a winch with a lifting and lowering capacity of up to 50 tons. This system, which is powered by 5G technology, allows for operational control of the hoist as well as monitoring of component and system condition and running information.

**Benefits** Unattended operation, with 8 onsite winchmen reduced.





## 02 Power monitoring system

The substation, as an underground power supply system, consists of high-voltage switches, low-voltage switches, and mobile substations. This system reads and controls high-voltage and low-voltage switch status in real time and monitors the conditions inside the underground substation via surveillance videos.

**Benefits** Unattended operation, with 8 onsite on-duty workers reduced.



## 03 Auxiliary shaft winch remote monitoring system

The auxiliary vertical shaft lifts objects and people via cages with a maximum lifting capacity of 7.5 tons. This system allows automatic start and stop of the winch to lift and lower the cages to designated positions and monitors winch operation in real time.

**Benefits** Unattended operation, with 5 onsite winchmen reduced.



## 04 Endless rope winch unattended system

The endless rope winch pulls mine cars, flat cars, and other transport facilities using an endless wire rope to transport materials and large equipment over a long distance. This system remotely controls and locates the winch and monitors the operational conditions of the winch via surveillance videos.

**Benefits** Unattended operation, with 12 onsite winchmen reduced.





## 05 Monkey car remote monitoring system

The monkey car operates in a circulating and endless way with the driving wheels and wire rope to transport miners on chairlifts over a long distance. This system remotely starts and stops the monkey car, gives alarms, and monitors the operational status in real time.

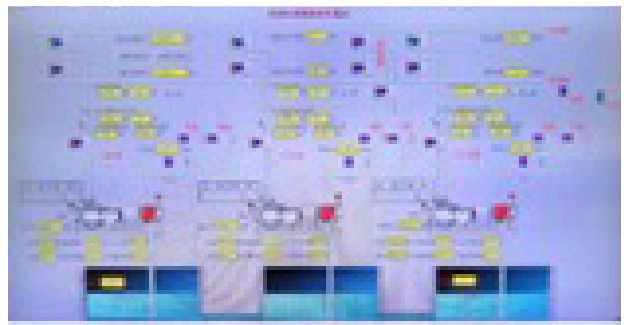
**Benefits** Unattended operation, with 2 onsite on-duty workers reduced.



## 06 Pump house drainage system

Xinyan Coal Mine has a main drainage automation system with three pumps, of which two pumps are active and one is on standby. Based on Siemens S7-300PLC and iFIX configuration software, an underground drainage centralised control system was built which automatically starts the pumps to drain the water when the set high water level is achieved and stops the pumps when the set low water level is reached. This system also allows remote centralised control, such as one-click start and stop, and gives voice alarms with automatic switchover in case of pump failures. Coupled with the above capabilities, the real-time data display on the upper computer enabled by the iFIX configuration software makes unattended drainage possible.

**Benefits** Unattended operation, with 2 onsite on-duty workers reduced.



## 07 Wire rope flaw detection system

With the help of the flaw detector and speed sensor, the system detects the severity and location of damage to the wire rope and belt during their operation, and reports these data acquired with 5G data collection capability to the monitor console of the centralised control centre so that the maintenance staff can take actions accordingly.

**Benefits** This system significantly reduced the wire rope and belt inspection workload and identified problems timely.



## 08 Unmanned electric locomotive

Rail electric locomotives are mainly used to transport materials aboveground and underground. The unmanned locomotive system transmits back data about the locomotive's surroundings and operational conditions via 5G network, allowing the operator to remotely control the locomotive, such as starting/stopping, accelerating/decelerating, tooting, and turning on lights. The system supports autonomous driving, remote driving, and mobile-end controlled driving.

**Benefits** One onsite electric locomotive driver was reduced per set.



### Economic benefits

From the perspective of coal companies, 5G network and intelligent application subsystems helped them reduce human resource. With the 5G network in place, mining efficiency was improved by around 10%, resulting in increased ore production. With less manpower required for fully-mechanized mining, the labour cost was saved by CNY 9.75 million per year (CNY 0.15 million/person/year).

The development of intelligent subsystem market was boosted. Based on the average price of CNY 0.6 million of an intelligent subsystem, replicating the solution on 30 mines can create an additional income of CNY 140 million.

For the 5G industry, the incubation of planning-deployment-optimization services will not only lower the threshold of converging 5G with various industries, but also expand project services to bring up the 5G service market share by 15% approximately.

### Social benefits

For the industry and companies, intelligent subsystem deployment has responded to the needs for less or even no workers or reduced workload in some underground jobs. Now, centralised monitoring and operation are possible aboveground for some jobs, with the underground equipment status being managed and controlled by the centralised control centre to provide greater operational safety. With the shift in the way of working, miners have changed from blue collars to white collars, who can now work in a risk-free environment that reassures their families and society. Consequently, the comfortable working environment aboveground will facilitate talent introduction and improve the competitiveness of mining roles.

Moreover, the planning-deployment-optimization services incubated by Xinyan Coal Mine via releasing eight subsystems have provided substantial support for the convergence of 5G with the coal industry, introducing new growth drivers for 5G and industrial applications.

## Summary and Next-Steps

The solution to the challenges of adopting 5G industrial applications is to "benefit multiple stakeholders." The Xinyan Coal Mine project would not be successful without the support from the operator China Mobile and the equipment vendor Huawei who are key drivers of the project. China Mobile Shanxi sent a team to the coal mine shortly after winning the open bid for the 5G communication system project of Xinyan Coal Mine in July 2020. Three months later, the team delivered an integrated aboveground and underground 5G private network after completing the installation and commissioning of all 55 sets of equipment. In November 2020, Xinyan Coal Mine carried out the first remote mining of underground intelligent working faces via China Mobile's 5G private network, with a safe production of 11 cuts of coal in a single shift totalling around 10,000 tons, which marked the fulfilment of all-weather remote control of production. Huawei also supported Xinyan Coal Mine and China Mobile in the exploration and innovation of project requirements. During MWC Shanghai 2021, Huawei, China Mobile Shanxi, and Xinyan Coal Mine jointly launched a 5GtoB PNI-NPN kite-like solution. Based on the business profiling, fast integration, and collaborative optimisation in service innovation, the 5G requirements of each business system

were accurately measured and translated into network planning to standardise the integrated implementation of mining scenarios, and ensure that key indicators such as network rate, latency, and reliability meet business needs.

In this project, various intelligent subsystem applications were brought online via a single underground 5G network, realising the leap from "feasibility" to "productivity" in 5G network deployment, and promoting the evolution of 5G network and the incubation of industry service capabilities. For the industry and Xinyan Coal Mine, the convergence of 5G with intelligent applications has just begun, and there is still a long way to go before the booming development of industrial intelligent applications. The third phase of the Xinyan Coal Mine project will continue the focus on the convergence of 5G with industrial applications and further deepen the construction of smart mining by launching 19 5G-based applications including the intelligent tunnelling face with integrated driving and anchoring. In addition, Xinyan will advance the network evolution and functional optimization during application release, and improve planning, deployment, and optimization as well as follow-up operation and maintenance services, contributing to the development of 5G + smart mining.





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# 5G + Smart Mining Application of Zhunneng Group Company Limited in Inner Mongolia



The Inner Mongolia Autonomous Region is promoting a three-year action plan for the intelligent coal mine development. The Heidaigou and Haerwusu open-pit coal mines of Zhunneng Group are among China's first batch of demonstration coal mines where we fully utilize benefits of 5G, unmanned driving, remote control and other technologies. In this cooperation with China Telecom, the 5G application helps drive the "1217" development planning of Zhunneng Group and supports the building of a safe, efficient, and green smart mine.

**Du Shanzhou**

Secretary of the Party Committee and Chairman of Zhunneng Group Company Limited under China Energy

## Partners



## Case Overview

Zhunneng Group under China Energy Investment Corporation in Inner Mongolia is a large-scale comprehensive energy enterprise specialising in coal mining, pithead power generation, and coal circular economy businesses. The Group owns Heidaigou (the largest coal mine in Asia) and Haerwusu open-pit coal mines (the total annual production capacity of them is 69 million tons) as well as supporting coal preparation plants, coal gangue power plants, industrial pilot plants, etc. Responding to the state's call for building intelligent coal mines and the industry trends, Zhunneng Group launched the "5G + Smart Mining Application" project in the middle of 2021.

The project is currently in the implementation and delivery stage. Applications enabling unmanned driving and remote control of more than 200 mining trucks, 40 electric shovels, and 1,000 auxiliary vehicles in Heidaigou and Haerwusu mining sites are developed and then implemented through 103 newly built 5G macrocells. With emerging communications and computing technologies such as 5G, AI, HD video, big data, and cloud computing, Zhunneng Group's coal mines have achieved intelligent cognition, ubiquitous connection, and precise control of production lines. The adoption of these technologies has further developed more 5G + application scenarios such as unmanned driving, remote control, intelligent coal mining, and intelligent inspection, which can help ensure the intrinsic production safety of open-pit mines and improve production and operation efficiency.

Meanwhile, many technical segments with achievements obtained in the 5G network construction and deployment, including the application of 5G communication network in ultra-large open-pit mines, the application of 5G Super Uplink in ultra-large open-pit mines, the application of network operation and maintenance technologies such as periodic migration of 5G base stations and network optimization, and the application of 5G base station + site energy in scenarios without optical cables and power supply, will form a "planning, deployment, maintenance, and optimization" baseline scheme for 5G + construction in open-pit mining scenarios. Such scheme can be replicated and promoted in the 5G + construction in coal mining, cement and other industries, increasing 5G + applications on a broad scale.

"It is a great honour to work with Zhunneng Group to build a 5G network in Asia's largest open-pit mine that meets the needs of unmanned driving and remote control," said Gu Hongxun, Secretary of the Party Committee, and General Manager of China Telecom Inner Mongolia Autonomous Region branch. "China Telecom is committed to fuelling the digital transformation of enterprises in the autonomous region and has launched the Bilin and Ruyi modes in the field of 5G customized network to support smart mining. In the future, we will deepen our cooperation in exploring 5G application in mines, helping Zhunneng realise its strategies soon."



## Industry Challenges

The harsh and complex production environment of Zhunneng's open-pit coal mines has resulted in a high rate of occupational diseases among workers and a great number of accidents. The backward and rough management methods have also driven the production and operation costs up to a level much higher than that of other major mining countries. To ensure the intrinsic safety of onsite production, improve operation efficiency, and attract young and highly skilled talents, the coal mining industry is in urgent need of intelligent transformation and upgrading with emerging communications and computing technologies.



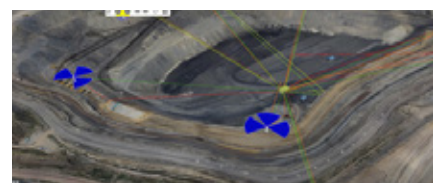
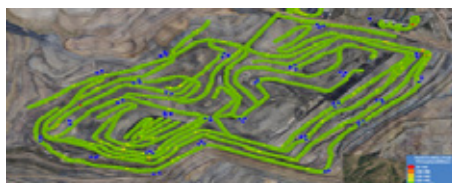
The onsite mining processes of Zhunneng open-pit coal mines include drilling, blasting, stripping, mining, transportation by mining trucks, crushing, and transportation by belt conveyors. These processes require joint operation of core production equipment such as drilling machines, electric shovels, excavators, and mining trucks, and auxiliary production equipment such as loaders, road scrapers, bulldozers, cleaning vehicles, and cranes. Coal mines have complex and diverse geographical environments, require different types and quantity of production facilities in different regional environments, and demand high-availability SLA to support network indicators for business applications. All these result in severer challenges in planning, building, maintaining, and optimizing a 5G network than a traditional wide-area network.

## Solutions and Benefits

This 5G + application project is by now the largest one for open-pit mines in China, and even in the world, with innovations in multiple fields including network solutions and service delivery, sharpening its leading edge in the industry.

### 01 It is the largest project adopting the Ruyi mode of 5G customized network

By deploying a 5G Core network respectively in Zhunneng Group's Heidaigou and Haerwusu coal mines, the project ensured stable, secure, and reliable network signal backhaul of 103 5G macrocells to enable low-latency access to the unmanned driving application platform by more than 200 mining trucks, 40 electric shovels, and 1,000 auxiliary vehicles. The solution can also meet the network capacity demand for intelligent transformation of mining areas in the upcoming five years.



### 02 It marks the first use of drone-based 3D high-precision electronic mapping as the digital base to serve precise network planning

Real-scene 3D models were built by accurately rendering and reconstructing high-definition images of the mining areas collected by drones. Based on the 3D models, the precise capacity calculations of business applications and the uplink deterministic rate simulation technology were employed to plan the 5G network in the mining areas. This method has addressed the low accuracy of traditional difficult manual surveys.

### 03 The project is the first in China to use Super Uplink to address demands of unmanned driving, remote control, and other business applications for large uplink bandwidth

China Telecom and Huawei jointly released the Super Uplink technology to meet the large uplink bandwidth demands in toB scenarios. This technology combines 3.5 GHz TDD uplink and 2.1 GHz FDD uplink to enable full-time-slot scheduling of uplink traffic, increasing base stations' near-point rate by 20% to 60% and far-point rate by 2 to 4 times while reducing air interface delay by 30% to better meet the requirements of business applications for network indicators. The combination of this technology and A + P Ultra-Lean Site can increase the antenna height without installing additional poles, so as to improve the coverage by 20%.

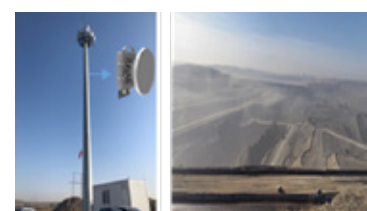
### 04 The project is the first in China to use a towed intelligent hydraulic platform to address the frequent relocation need of open-pit coal mines' communication base stations

As the production progresses in mining areas, wireless sites need to be relocated frequently. The timeliness and accuracy of site migration are particularly important to eliminate relocation impacts on site operation and plan and optimize the network during the relocation. A towed intelligent hydraulic platform was used for the first time, which is compact-sized and conveniently designed for lifting and towing to meet the quick site migration need in mining operation.



### 05 Microwave backhaul and oil-electric hybrid solution

This project innovatively introduced the microwave backhaul and oil-electric hybrid solution for scenarios where electric wires and optical cables could not be deployed in the mines. Microwave links replace the original optical cables to send back the BBU-processed information to the bearer network. In addition, microwave frequency signals, like optical cables, can form a loop network. In the cases of a network failure with any route, data can be transmitted via another route to ensure stable transmission. An oil-electricity hybrid solution was adopted in areas where electric wires could not be deployed. The alternated power supply by the oil engine and storage battery ensured power supply in areas without access to the mains supply. This solution is more power-saving and provides a longer service life than the traditional oil engine room.

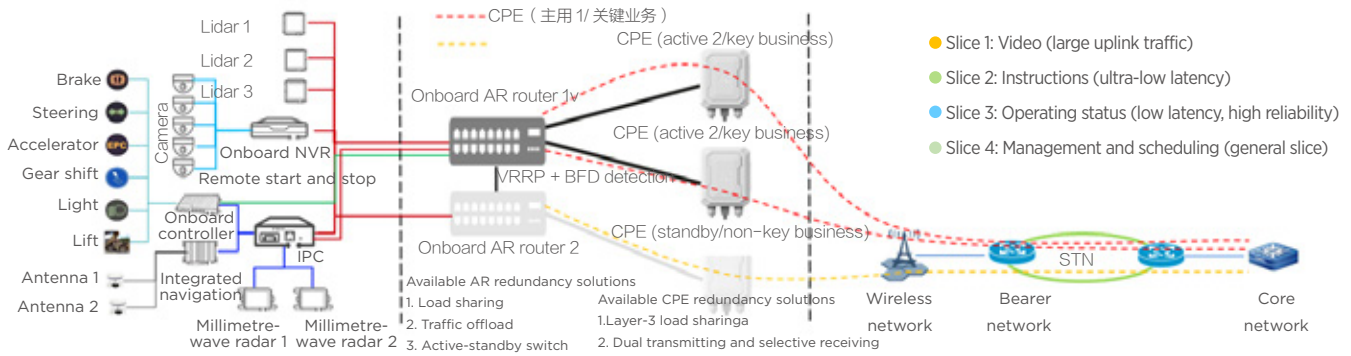




# 5G+ Smart Mining

## 06 The project utilized network slicing to isolate services end-to-end, with the user experience guaranteed.

Different service flows have different network indicator requirements. For example, video service flows have higher requirements on uplink bandwidth stability, and instruction service flows are more sensitive to latency. Different types of data flows can be divided into different network slices to ensure safe and stable transmission of service flows.



## 07 The dual management platforms ensured efficient operation and maintenance of terminals and networks at the mine sites

The mining truck management platform actively perceives malfunctions and safety accidents to ensure safety, stability, and reliability of vehicles and unmanned driving system. The 5G network self-management platform can quickly identify network issues to shorten production interruption time caused by network failures and support customized application development and efficient network operation and maintenance.



## Industry Challenges

### Lessons learned

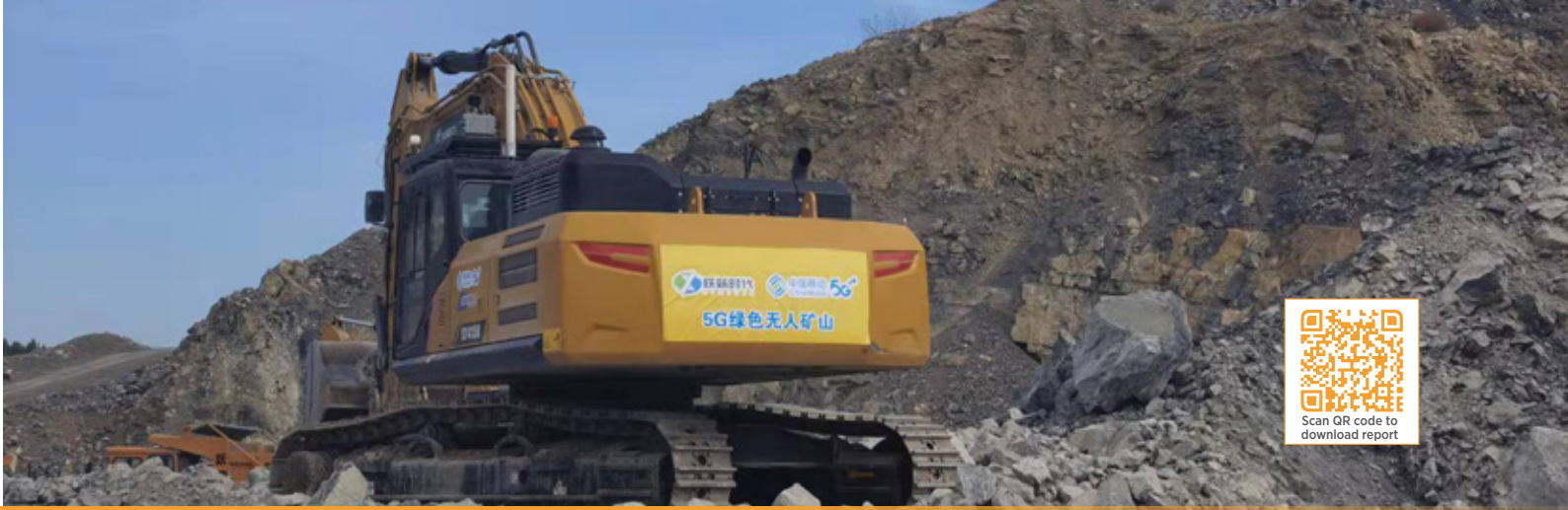
- 1 Accurate business profiling of terminal-side applications is a key input to support precise planning of 5G networks.
- 2 Feasibility should be considered during network planning and design, and toB network planning requires customized network schemes for specific industries and scenarios.
- 3 Risks should be identified in time during the delivery stage, with a risk response plan formulated by stakeholders to ensure delivery quality.

### Next steps

- 1 3D indoor modelling: The project plans to build 3D real-scene models for Zhunneng Group's office buildings and gangue power plants among other indoor spaces utilizing the data matching technology of multi-view point clouds. The 3D indoor models and 3D outdoor models jointly constitute a high-precision mapping digital base for Zhunneng Group's mine sites. The digital base can serve as a foundation for precise planning and optimization of 5G networks. Meanwhile,

the SDK plug-ins provided by the digital base can be connected to different subsystems of the mine, such as personnel and vehicle positioning subsystem and geological survey software to demonstrate the subsystems.

- 2 Video positioning: The project plans to enable decimetre-level positioning based on the visual positioning technology to implement electronic fence monitoring over blasting areas, conveyor belts, and other dangerous operating areas.
- 3 Intelligent management platform: The project plans to standardise the data formats of different production subsystems in the mining areas by establishing an Industrial Internet platform to break production data silos, better tapping into the value of different production data to improve management and operation efficiency.
- 4 Edge cloud: The project plans to implement edge clouds in the mining data centres to save investment in hardware equipment, facilitate local operation and maintenance, and ensure rapid deployment and release of new services and new applications.



# 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.

**Xiao Zhanding**

General Manager of Jiaozuo Qianye Cement Company Limited

## Partners



## 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.

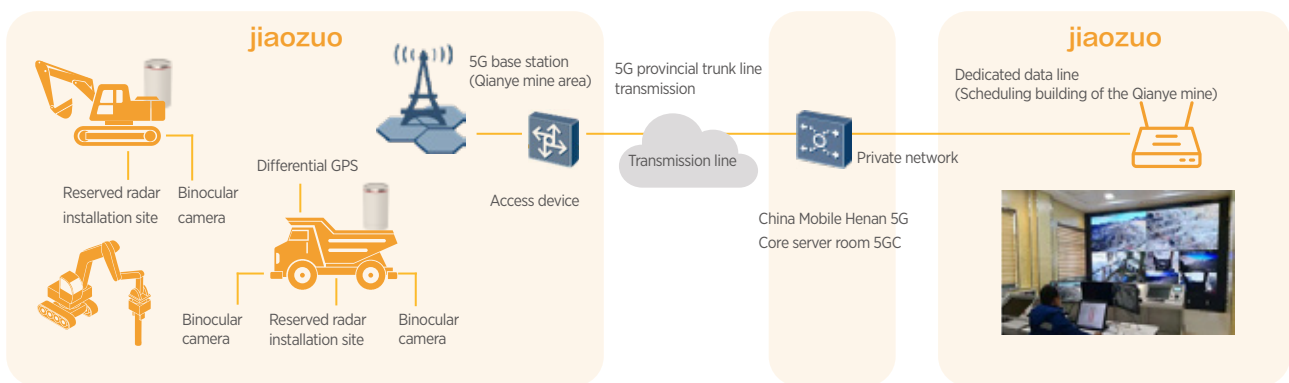




## Solutions and Benefits

### 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

The 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.

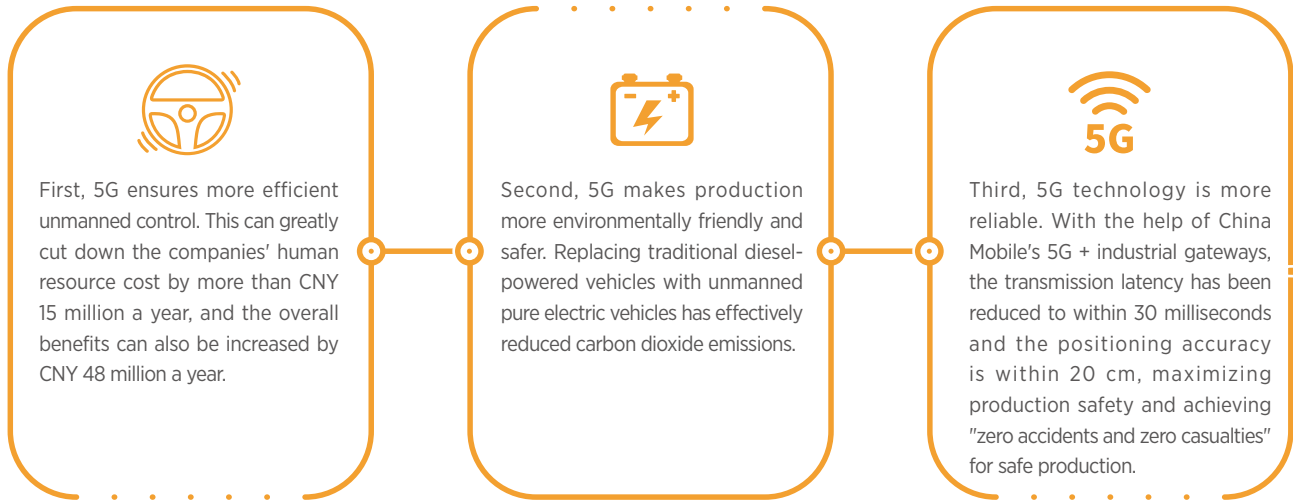
#### Employed 5G industrial-level gateways of the Internet of Things companies

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



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.



# 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.

**Li Yibing**

General Manager of the Enterprise Management Department of Pangang Group Mining Co., Ltd.



## 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 titanomagnetite 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,





# 5G+ Smart Mining

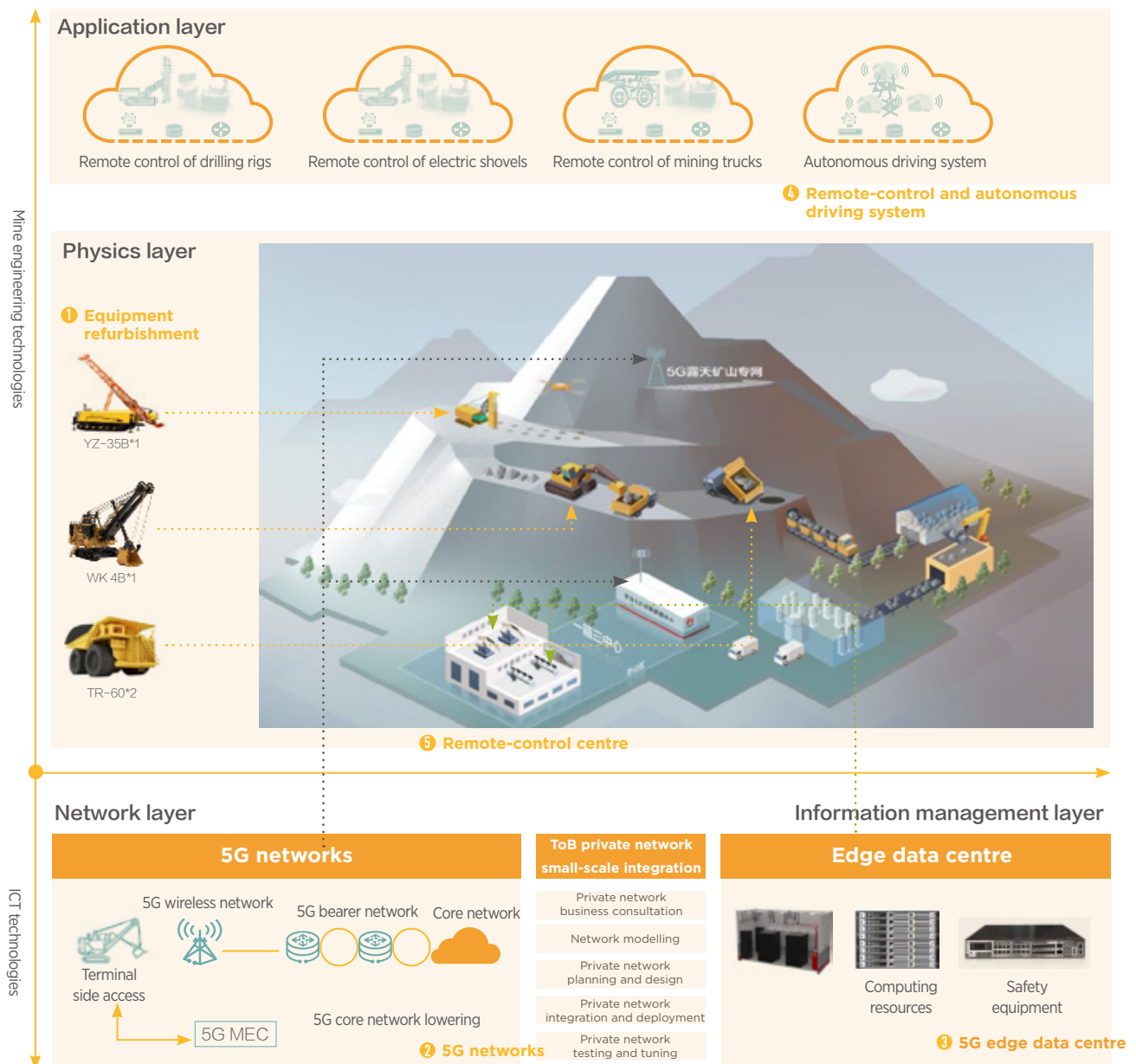
solutions utilizing market economy have been employed in recent years to undertake part of the transportation workloads. However, experienced human workers remain essential for on-site operations due to the expensive costs of the drilling rigs and electric shovels among other equipment. On the other 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.



# China Coal Group Dahaize Coal Mine 5G 700 MHz + 2.6 GHz Integrated Network Project

“ With the accelerated construction of smart coal mines in China, Dahaize Coal Mine adheres to the principles of safe production and high standards and strives to fulfill our responsibilities as a state-owned enterprise. We aim to become a benchmark for smart mines and a leader in the coal industry, and establish a reputable brand image of "smart company" for China Coal Group.

**Zhu Wenliang**

Party Secretary and Executive Director of China Coal Group Shaanxi Company



## Case Overview

Dahaize Coal Mine Project operated by China Coal Group Shaanxi Company is an auxiliary mine for coal chemical projects under China Coal Shaanxi Yulin Energy and Chemical Co., Ltd., a key pillar of the Inner Mongolia-Shaanxi 100-million-ton coal base built by China Coal Group, and one of the first batch of 71 demonstrative smart coal mines approved by the state. Located in western Yuyang District of Yulin City of Shaanxi Province, this project has a construction capacity of 15 million tons/year with a service life of 157.7 years. The total investment is estimated at RMB 12,979 million.

In July 2021, Dahaize Coal Mine completed the 5G 700 MHz + 2.6 GHz integrated network, becoming the first in the industry to realise VoNR high-definition videophone business. Currently, this project offers intelligent mining system, intelligent coal selection plant, intelligent auxiliary production system, and intelligent platform construction system to realise full-coverage 5G VoNR communications and cloud-network integration. It pioneers the construction of "control over one network" based on a new type of cloud-network architecture for coal mine.

Liu Daoyuan, Deputy General Manager of China Coal Technology Engineering Group Mine Intellectualisation Co., Ltd. said that in China's coal sector, the application of 5G technology has been plagued by

such issues as low coverage of conventional frequency bands and high costs. As one of the first batch of 71 smart demonstrative mines in China, Dahaize Coal Mine has innovatively adopted the 5G 700 MHz + 2.6 GHz integrated network to realise full coverage of 5G signals in the coal mine, both above-ground and underground. The overall network architecture and the transmission jitter and stability all outperform the traditional 5G single-frequency network. The better Quality of Service(QoS) for intelligent applications, such as 5G VoNR, mining, transportation, and "ventilation and safety". and lay a solid foundation for establishing intelligent application system clusters and promoting high-quality development of coal mines.



## Industry Challenges

In March 2020, eight ministries including the National Development and Reform Commission of China jointly released the Guiding Opinions on Accelerating the Smart Development of Coal Mines, pointing out that "the smart development of coal mines provides a core technical support for high-quality development of the coal industry". The intelligent operation of fully-mechanized mining, exploration, transportation, ventilation, dressing by washing, safety protection, and management is of great importance to enhance coal mining safety and stabilise the supply of coal.

However, intelligent production in coal mines faces many challenges, including:



# 5G+ Smart Mining

## High risks to personal safety and high accident rates

Safe production is a top priority in smart coal mining. Taking into consideration the key issues such as high concentration of gases, ashes and dusts, flooding and seepage hazards in underground mines as well as long working hours and heavy workloads for miners working underground, it is necessary to effectively reduce the number of miners working underground and cable deployment to achieve intelligent and safe production.

## Incapacity of transmitting sufficient data

Working face visualization is a key condition to realise intelligent mine operation as Wi-Fi and 4G networks are incapable of supporting video-driven smart mining. Moreover, the traditional bearer network fails to realise business segregation, making it impossible to meet differentiated business requirements on video, controls, and communication.

## Difficulty in business integration due to excessive production and management systems

Smart mining require a shift from a single-system approach towards coordination of multiple systems. As coal mine business runs a large selection of subsystems (more than 20 in the case of fully-mechanized working face) that operate separately from each other, It is difficult to realise business integration and operation and maintenance management.

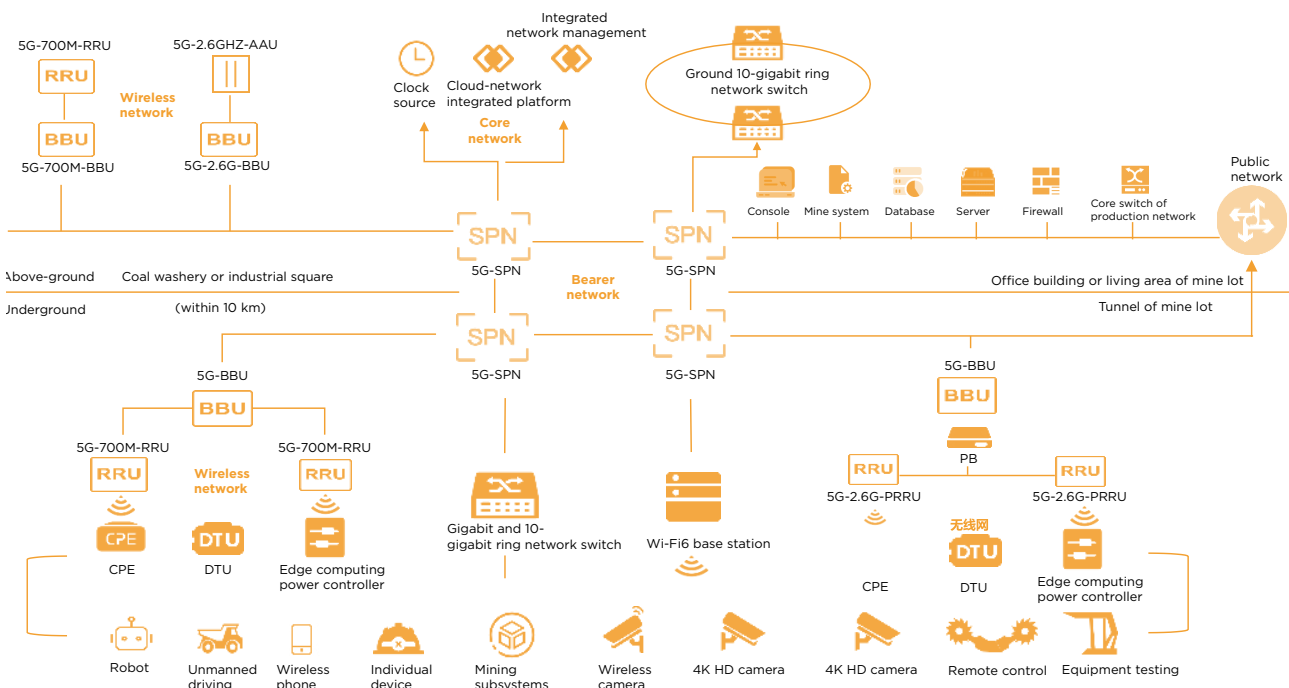
## Low universality of "5G private network 1.0 version" and difficulty in large-scale application

As the current 5G private networks are typically of a single frequency, we face many challenges in large-scale application, including: higher construction cost of 5G network and difficulty in realising 5G full coverage in complex scenarios such as mining face, turning, uphill/downhill, undulation and blind side; data from underground industrial control ring network, video surveillance ring network, and safety monitoring ring network are independent from each other, which requires centralized bearing to enhance stability and operation and maintenance efficiency; and lowering MEC capacities alone cannot address the conflicts between overall digital transformation and fragmented requirements, which requires deep integration of 5G and key coal businesses driven by the new type of cloud-network architecture.

## Solutions and Benefits

The application of a 5G cloud-network integration platform and the combined use of 700 MHz & 2.6 GHz frequency bands in Dahaize Coal Mine facilitate the development of the intelligent application system cluster for coal mines. In this plan, the 700 MHz base station (underground RRU) only accesses the core local private network (cloud-network integration platform) to offer 5G private network coverage. The 2.6 GHz frequency band base station (pRRU) uses MOCN to access the core local private network, and at the same time the operator's core public network to offer two types of 5G coverage, public and private.

5G 700 MHz and 2.6 GHz integrated network is the 2.0 version plan for the coal mine private network, where a new integration mode, an innovative base station with built-in safe features, and a new cloud-network architecture are used to promote the smart development of Dahaize Coal Mine, changing the "tough, tiring, and dirty" working condition of coal mines.





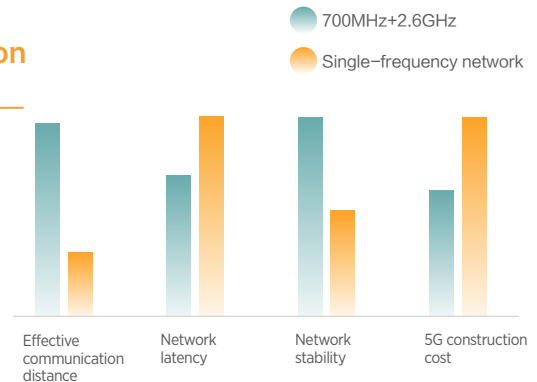
## 01 New networking mode that effectively reduces network construction cost and enables agile connection with the dispatching system

### 1 The first in China to adopt 700 MHz & 2.6 GHz integrated network for network coverage

When the edge uplink throughput of a single 5G 700 MHz base station exceeds 10M per user, the coverage reaches 1,600-1,800 meters; the latency is lowered by 35% and the stability performance is improved by 45% over the conventional 5G single-frequency network; and the 5G construction cost is reduced by more than 40%. Thus, small- and medium-sized coal mines can develop 5G + smart mines with acceptable investment, addressing the high cost and construction difficulty associated with 5G 1.0.

### 2 The first underground 5G VoNR, breaking the bottleneck of 5G network dispatching

Based on new networking, a seamless connection between the private network and the public one is realised. Miners in the underground are able to use mobile service of China Broadcasting Network Group to communicate via the private network with internal lines above-ground, and communication with subscribers of public network above-ground is also supported. Selective call, emergency call, full call, forced insertion and forced disassembly, among other functions, are supported via connection with the dispatching system. By using a single phone card, miners can work more efficiently and keep connection with loved ones outside of the coal mine, effectively addressing the issue in underground dispatching in the age of 5G 1.0.



## 02 The first 700 MHz Intrinsic safety base station in China, enhancing network safety

In complex underground conditions in coal mines, there is limited space for equipment installation. Based on the accumulated project experience, a 700 MHz base station with built-in safe features was jointly developed. This product uses native Electric Explosion Protection measures to enable safer features, so the safety of 5G network is intrinsically enhanced. Compared with common explosion protection equipment, it is smaller in size (80% smaller) and lighter in weight (3 kg/4 L, 90% lighter). No explosion proof box is deployed for underground projects, with no spark risks, lowering project cost by 60%. Super diffraction and anti-interference performance enables 5G full coverage at a single station on the mining face, totally eliminating the need of setting cable network on the mining face. Full coverage of 5G network underground at a low cost is realised and network construction cost is greatly reduced.

## 03 New-type cloud-network architecture that addresses conflicts between centralized management and agile innovation of business lines

### The first to use "three-in-one" hard segregation sliced network based on cloud-network architecture in China

Centralized bearing of industrial control network, video surveillance network, and 5G bearing network enables flexible bandwidth adjustment based on needs. The minimum bandwidth can be sliced to 10M. One-stop bearing of underground networks reduces the investment by 60% and moves underground cable maintenance to the backend, which significantly saved manpower cost and enhance operational efficiency and safety.

### The first to use "three-tiered resilient computing power architecture" in China

By empowering smart and unmanned coal mining, we promote deep integration of intelligent applications in coal mines. Cloud-network integrated architecture not only sustains 5G performance, but also provides backward compatibility with existing industrial ring networks of the mine. It also supports integration with wired and wireless networks such as WiFi6, IoT, and 4G. Furthermore, edge computing controller, CPE, DTU and other fog computing powers are used to empower 5G applications on the -edge and terminal. Issues such as difficulty in integrating with overall mine businesses, information silos, and inconsistent standards are solved.



## 04 Multiple applications on fragmented supply issue to promote deep integration of 5G and industry

### 1 Robot system cluster

Electromechanical chamber (central power distribution room and central pump house) and main haulageway are equipped with 15 sets of 5G mobile inspection robots to enable real-time backhaul of super HD video, audio, and infrared imaging data from on-site devices as well as early detection and pre-warning of device failures. Robots are equipped with multiple parameter sensors (CH<sub>4</sub>, O<sub>2</sub>, CO, temperature, and humidity), dual-spectrum PTZ camera (visible light 2 MP, infrared thermal imaging 640 x 512), pickup intercom, and two obstacle-avoidance lidars, and support 5G dual-frequency transmission. Inspection devices are built with 5G modules, which can communicate with the base station set in the chamber via the 5G wireless network. On the surface, a remote control station is in place to enable remote controls based on data transmitted to the surface via the 5G industrial network.

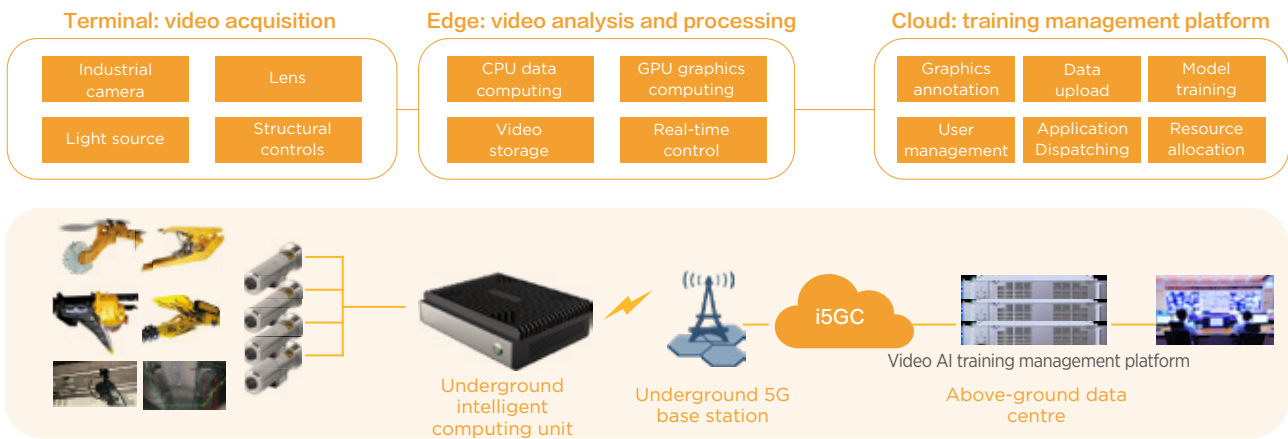
### 2 5G + underground video AI analysis

The overall design of the underground video AI plan is based on cloud-edge-terminal coordination. The terminal side collects videos and upload to the edge side, and receive control commands from the edge side. The edge side conducts video analysis and reasoning. Then, it reports the analytical results to the cloud management platform, and sends control commands to the terminal side (such as control access and control belt). The cloud side performs algorithm training with training and management functions, delivers trained models to the edge side, and manages and dispatches intelligent computing units on the edge side. This deployment mainly realises intelligent supervision



over the fully-mechanized mining face, abnormality detection on the main transport belt, personnel behavior monitoring, regional access management, intelligent control of air doors, electronic seal, hoist head and tail rope detection, AI identification of coal selection plant, and underground intelligent traffic control, among other AI-assisted functions.

Based on the 700 MHz & 2.6 GHz integrated network, multiple applications including the 5G + drone for coal mines, unmanned driving, automated transport, remote industrial control, unmanned mining, precise personnel positioning, and robot system cluster have been realised. Currently, the project has reduced manpower from 4 shearer drivers, 6 hydraulic support workers, and 5 clearance staff to one remote control personnel and one safety inspector. The establishment of 5G robot cluster with 15 robots has contributed to 12 intelligent inspection and collection subsystems and 20 unmanned positions, reducing 90 personnel while cutting coal cost by RMB 12 per ton and labour cost by RMB 20 million per year.



## Solutions and Benefits

With the joint efforts from China Coal Group Shaanxi Company, China Coal Technology Engineering Group Mine Intellectualisation Co., Ltd. ZTE Corporation, China Broadcasting Network Group, China Mobile, and China Coal Information Technology (Beijing) Co., Ltd., the 700 MHz & 2.6 GHz integrated network has been successfully developed. Under the condition of an uplink edge speed of 10 Mbps, the integrated network is capable of realising enhanced coverage and effect of 5G network when tunnels use 700 MHz, with effective actually-measured coverage of 1,600-1,800 meters, which is 4-6 times that of conventional base stations. Overall, the solution has reduced the production cost,

creating economic benefits and practical value for the mining sector. This project marks the first successful application of 700 MHz & 2.6 GHz integrated network technologies in China's coal industry.

We will continue to develop 5G virtual interaction application, robot cluster, unmanned driving, intelligent wearables, intelligent inspection, shearer, and intelligent tunneling machine for China Coal Dahanze Coal Mine, further promote the integration of new 5G infrastructure and Industry 4.0, and provide key support for comprehensive reform and digital transformation in coal mines.

# Conclusion

In our third year focusing on 5G applications in domestic verticals, we have released this version of 5G in Verticals in China report. It is a great pleasure to work with all parties in China to explore the prospects of 5G applications starting from scratch, analyze 5G application scenarios, unlock the potential of 5G applications, promote the implementation of 5G applications, share the achievements of 5G applications, and summarize success stories. Over the past three years, we have seen that 5G applications are becoming more and more diverse, mature, and successful. The past year of 2021 has been critical for 5G applications in vertical industries. In this year, we witnessed the start of commercial 5GtoB, with more and more commercial contracts signed and performed. In this year, we gained a clearer view of 5G application scenarios, with work priorities identified in industries and scenario-based needs collected across industries. In this year, the 5GtoB business has started to thrive at scale, marking its initial success and a further step toward maturity.

Rather than a panoramic view of 5G applications in all vertical industries, we have, for the first time, focused on 5G application cases in three scenarios with good prospects: 5G cities, intelligent manufacturing, and smart mines. We have also included an overview chapter for the first time to outline the pain points, 5G application prospects, and future development in these areas. Hopefully, this will inspire thought and action among our readers.

The ability to scale 5GtoB to some extent determines the success of 5G in its aims to empower diverse industries and promote the digital transformation of the economy and society. The trend for the future is large-scale 5GtoB development, which means a transformation from "1" to "N", from the showroom to the warehouse, and from a potted plant to a forest. In this case, immediate demand is fundamental, standards are our foundation, and modules and terminals are the keys. First, we need to identify scenarios in dire need of 5G applications. We must screen existing application cases and find out where the immediate need for 5G lies, in other words, the areas where 5G is no longer optional, an alternative, or a backup, but preferred and even a necessity. Second, standardization is the prerequisite of large-scale development. To achieve standard 5G applications in key industries, it is also necessary to identify common demands across industries that can be standardized. Finally, the start of large-scale development is always accompanied by the emergence of modules and terminals and a dip in their price.

It is likely that 5GtoB will first scale up in 5G cities. 5G can help improve urban governance in areas such as transportation, emergency response and public security, the ecological environment, basic resident services, and digital government with its applications in multiple scenarios: smart public transportation, smart ports, smart police, smart emergency response, smart environmental protection, smart urban management, smart communities, smart cultural tourism, smart security, and smart customs. Globally, China has achieved the widest 5G network coverage in urban areas, with the largest independent 5G network in the world. Moreover, city operators here are also active practitioners of modern urban governance. We have every reason to believe that China, with 5G City applications that once again attract the attention of the world, will lead the development of new smart cities worldwide as the benchmark for innovation in global cities.



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