GTI
Wireless Solution for 5G ENS White Paper

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Wireless Solution for 5G ENS

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Contents

Introduction

Industrial manufacturing, port water transportation, mining, energy production, social activities, and urban management are closely related to the national economy and people's livelihood. They are in a critical period of networked, automated, and intelligent transformation and upgrade. Efficient, reliable, and advanced communications networks are the basis for successful industry upgrade and transformation.

Different from public network services, industry applications have highly customized requirements in terms of coverage, latency, reliability, and transmission bandwidth. Requirements vary among different industries, and it is difficult to use a unified network architecture and performance requirements. Furthermore, security assurance is one of the most important factors for industry applications. Service data transmission security and reliability must be ensured. Besides, the construction cost is also an important factor that must be considered in the customization of enterprise networks.

Operators' 5G enterprise networks can fully integrate the industry chain, leverage scale advantages, reduce costs, and improve quality, which effectively reduces the TCO and ensures leading network performance as well as continuous evolution. Operators' 5G frequencies are used to serve vertical industries, which can be centrally coordinated and operated to maximize spectrum utilization and provide stable and reliable information transmission channels for industry applications.

This white paper analyzes the status quo, development trend, and key issues of enterprise networks, and proposes the M.V.P. solutions for different application scenarios, in which M stand for Mixed Enterprise Network Solution (M-ENS), V for Virtual Enterprise Network Solution (V-ENS), and P for Physical Enterprise Network Solution (P-ENS). It also elaborates on how China Mobile's diversified capabilities enable these solutions to provide six dedicated networks and value-added service capabilities for vertical industries. In the last part, this white paper explores the development trends of wireless enterprise networks and proposes an initiative to build a mature 5G private network ecosystem.

1 Requirement Analysis

In recent years, the development of the global enterprise network market has accelerated, with the annual growth rate increasing from 5% to 10%. Narrowband is still the mainstream of global enterprise networks, but the trend is shifting from narrowband to broadband. The demand for enterprise networks in China is increasing rapidly with a huge market scale, including public security, government, military, transportation, oil, and business. Enterprise network customers generally have high requirements on performance and security and have high customization requirements, posing both development opportunities and challenges to the communications industry.

1.1 Localization and Customization

With the acceleration of intelligent transformation and upgrade, the current wired or wireless enterprise networks cannot meet the requirements for efficient production and management due to the following disadvantages, such as low network bandwidth, high latency, low security and reliability, inflexible deployment, difficult interconnection, and high construction and operation costs.

Industry customers' requirements for enterprise networks are characterized by localized deployment and customized network performance. For example, vertical industries such as factories, ports, campuses, and mines have different network requirements from those of public networks, and thus have high customization requirements on the deployment environment, network capabilities, and data isolation.

Figure 1-1 Typical application scenarios in the industry

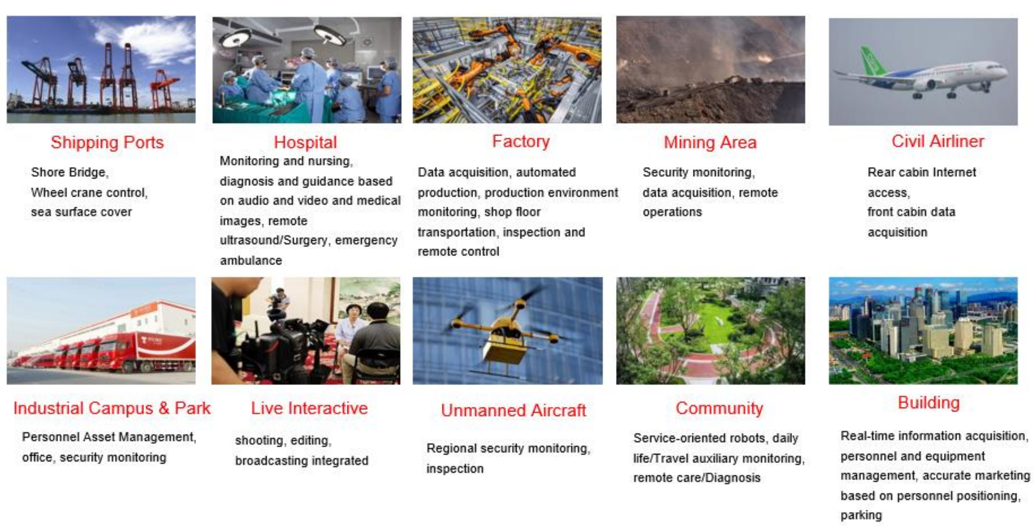


Table 1-1 lists the typical service scenarios and requirements for enterprise networks.

Table 1-1 Network requirements in typical application scenarios

Industry	Service Scenario	Coverage and Mobility Requirement	Network Performance Requirement	Reliability Requirement	Isolation Requirement
Ports	Remote bridge crane/gantry crane	• Outdoor deployment • Fixed- or low-speed moving	• Uplink rate: 30 Mbps per terminal • Downlink latency: 20–30 ms	99.99%	User-plane data is processed on campus.
	AGV/container trailer	• Outdoor deployment • Medium- and low-speed moving	• Uplink and downlink scheduling rates: 200 kbps per terminal (control commands) 2 Mbps per terminal (video stream) • E2E delay: 30–50 ms • Positioning accuracy: cm	99.99%	User-plane data is processed on campus.

Industry	Service Scenario	Coverage and Mobility Requirement	Network Performance Requirement	Reliability Requirement	Isolation Requirement
	Smart tally	• Outdoor deployment • Medium- and low-speed moving	Uplink rate: 30 Mbps to 40 Mbps per terminal E2E latency: 50 ms	99%	User-plane data is processed on campus.
Factories	On-line inspection of material joints (industrial vision)	• Indoor deployment • Fixed-speed moving	Uplink rate: 400 Mbps per terminal	99.999%	• User-plane and control-plane data is processed in factories. • Dedicated radio resources are preferred.
	AR repair	• Indoor deployment • Fixed- or medium-to low-speed moving	Latency: 20 ms	99.9%	• User-plane data is processed in factories. • Radio resources are not shared with public networks.

Industry	Service Scenario	Coverage and Mobility Requirement	Network Performance Requirement	Reliability Requirement	Isolation Requirement
	AGV delivery	• Indoor deployment • Fixed- or medium-to-low-speed moving	Latency: 20 ms	99.9%	• User-plane data is processed in factories. • Radio resources are not shared with public networks.
Campus	Video surveillance	• Indoor and outdoor deployment • Fixed-speed moving	• Uplink rate: 5 Mbps per terminal • Latency: 200 ms	99%	• User-plane data is processed in factories. • Higher-level assurance than public networks is required.

Industry	Service Scenario	Coverage and Mobility Requirement	Network Performance Requirement	Reliability Requirement	Isolation Requirement
Hospital	Medical examination and nursing	• Indoor and outdoor deployment • Fixed- or low-speed moving	• Uplink rate: 100 kbps per terminal • Latency: 200 ms • Positioning precision: 10 m (indoor) or 20 m (outdoor)	99%	• User-plane data is processed on campus, and user terminals can access the public network. • Higher-level assurance than public networks is required
	Remote real-time consultation	• Outdoor deployment • Fixed-speed moving	• Uplink rate: 5 Mbps per terminal • Latency: 100 ms	99%	• User-plane data is processed on campus, and user terminals can access the public network. • Higher-level assurance than public network is required.

Industry	Service Scenario	Coverage and Mobility Requirement	Network Performance Requirement	Reliability Requirement	Isolation Requirement
Police service	Visualized dispatch and onsite video transmission	• Indoor and outdoor deployment • Mobile	• Uplink rate: 5 Mbps to 15 Mbps per terminal • Latency: 100 ms	99%	High priority must be ensured for policing services.
Temporary burst applications	Mobile live broadcast and emergency communications	• Mainly outdoor deployment • Mobile or fixed	• Uplink rate: 15–60 Mbps • Latency: 50-100 ms	99.9%	• Data is processed locally. • Radio resources are not shared with public networks.

In addition to differentiated requirements for coverage and mobility, network performance, reliability, and isolation, industry users have various personalized enhanced requirements, such as requirements for indoor and outdoor positioning with different precision, hot backup of network devices, network performance data monitoring, and low costs.

1.2 Other Key Issues

Diversified requirements from industry customers provide operators with abundant and real inputs and help operators clearly understand the core of enterprise networks. In this way, operators can develop diversified enterprise network service capabilities.

5G is changing society. Operators have invested a large amount of money in 5G network construction and deployment, including enterprise networks. This white paper focuses on the industry wireless enterprise network solution, that is, how to effectively use air interface resources and capabilities to provide customized capabilities for different industries. Air interface resources are the core resources of mobile communication networks. The air interface technology and processing capability determine whether the enterprise network can meet the key network performance indicators of the customer. Therefore, before putting forward the core capabilities of the wireless enterprise network and customer-oriented network solutions, we need to sort out the following three aspects of the wireless solution:

1. Frequency: Operators have abundant national licensed spectrum. Spectrum with different frequency bands and bandwidths has different coverage and performance advantages. In addition, the dedicated spectrum has unique advantages in ensuring service performance and security. This must be considered during enterprise network design.

2. Networking: Base station type and system configuration need to be considered. Based on the features of large-scale network services, operators customize certain types of base station types and system configurations, such as the frame structure. The advantages of centralized procurement also reduce network construction costs. On this basis, customized network solutions require more flexible site types and incur higher construction cost. This needs to be considered during enterprise network design. And further, collaboration between public and enterprise networks must be considered. Operators must consider interference coordination to allow enterprise network users to enjoy the low cost of public networks without affecting each other. In addition, interference caused by changes in public network services on the air interface must be considered. In addition, in many areas where public networks have been constructed, how to effectively coordinate the coverage of public and enterprise networks is a problem that must be resolved.

3. Service assurance: Theoretically, the wireless side provides multiple service assurance methods in terms of rate, latency, reliability, and access control. As the wireless channel environment is complex, operators need to consider how to effectively implement service assurance capabilities from multiple dimensions and how to identify and specify the assurance scope and effect when designing private network solutions.

In addition to the preceding three aspects, the end-to-end network architecture also needs to be considered in the enterprise network solution, covering the deployment mode of core network NEs, how to operate and maintain the enterprise network, and how to introduce value-added capabilities such as positioning to wireless networks.

2 M.V.P Enterprise Network Solutions

Based on the wireless network devices and spectrum resource application modes, the enterprise network solution takes three forms: M-ENS, V-ENS, and P-ENS.

2.1 M-ENS

The M-ENS refers to a networking mode in which the enterprise networks share some wireless access devices with the public network but occupy independent frequency resources. The M-ENS splits traffic on the RAN and transport network to implement traffic distribution between the public and enterprise networks, and provides SLA assurance for enterprise services.

The M-ENS reuses some 5G resources on the public network. On the network side, the hybrid private network can be further customized based on the isolation and reliability requirements of the industry. In general, the network construction cost of the hybrid private network mode is controllable.

2.1.1 Network Architecture

Figure 2-1 shows the architecture of an M-ENS. The enterprise network reuses public network wireless devices, such as BBUs and RRUs, while exclusively occupies some air interface frequency resources to set up independent cells. On the network side, a separate core network (CN) can be constructed or the public CN can be reused for customization based on service requirements.

Figure 2-1 M-ENS architecture: The enterprise network reuses public network radio resources and occupies some frequencies

2.1.2 Network Performance

2.1.2.1 *Coverage*

The coverage scope of an M-ENS is the same as that of the public network. In weak coverage areas or coverage holes of the public network, enterprise network can be customized. However, radio equipment resources should be shared with public network users.

2.1.2.2 *Reliability*

Based on the service requirements of the enterprise network, some independent frequencies are allocated for the enterprise network over the air interface. Enterprise network services are transmitted on the independent frequency band. Because the frequency band is different from that of the public network, changes of the public network services do not affect the enterprise network services (for example, the interference affects channel quality and data transmission reliability of enterprise networks). QoS is used to differentiate service priorities in the frequency band of the enterprise network to ensure the transmission quality of each service.

2.1.2.3 *Isolation*

On the RAN side, terminals of enterprise and public networks camp on their respective cells through access control to isolate data on the public network from that on the enterprise network. Currently, access control solutions include the multi-PLMN solution, CellBar solution, and CAG solution. In the PLMN solution, different types of terminals (public and enterprise networks) camp on their respective PLMN cells for isolation. In the CellBar solution, the cell whitelist solution is used to allocate specific number segments to enterprise network terminals. The enterprise network cells allow access of terminals in the specified number segments and reject access of other terminals. In the CAG solution, enterprise network terminals are configured and grouped for access to enterprise network cells.

2.1.2.4 *Network Performance*

In M-ENS mode, service performance is limited by frequency resources and system frame structure configuration.

- Rate: The public network uses the system frame structure determined by the eMBB service. For example, the theoretical uplink and downlink peak rates are about 190 Mbps and 1.7 Gbps respectively on the 2.6 GHz 100 MHz band. The M-ENS occupies some public network frequency bands, and the system frame structure is the same as that of the public network. The uplink and downlink transmission rates are calculated by multiplying full bandwidth of the public network with frequency ratio of the enterprise network. In this case, if the enterprise network occupies 20 MHz bandwidth, the theoretical peak rate is about 340 Mbps in the downlink and 38 Mbps in the uplink without considering the control overhead change.
- Latency: The end-to-end latency consists of the transmission latency over the air interface, latency on the network side, and processing latency of each NE. The latency difference of the enterprise network is related to the frame structure configuration of the air interface and the deployment position of the CN. The 2.6 GHz public network is used as an example. The frame structure uses a 5 ms period, and the air interface latency is about 11 ms. When the enterprise network UPF uses the local breakout mode, a 1 ms latency is introduced, and the total

latency is about 12 ms. If the UPF is deployed at the remote end of the enterprise network, the network transmission latency must also be considered.

2.1.3 Application Scenarios

The M-ENS provides end-to-end service isolation capabilities for industry applications, ensuring high service performance and isolation for industry users. In terms of service transmission capabilities, the M-ENS can coordinate frequency resources with the public network based on service requirements. The M-ENS is mainly used in LAN scenarios and can also be used in a few WAN scenarios, such as power grids.

The air interface configuration of an M-ENS is the same as that of the public network. With abundant spectrum resources of China Mobile, the M-ENS can meet the requirements of most industry customers, such as factory AGV distribution, container truck transportation, medical detection and care, and medical consultation.

2.1.4 Industry

The M-ENS shares wireless devices with the public network and maintain the same development pace. The network devices are provided by traditional main equipment suppliers.

2.2 V-ENS

A V-ENS fully reuses radio resources, including base station equipment and frequency resources, provided for the public. It uses end-to-end slicing to ensure that service data on the private network is isolated from that on the public network, thereby providing SLA assurance for services on the private network.

The V-ENS reuses 5G public network devices and frequency resources to a great extent. It is fast to deploy and cost-effective to meet dedicated service requirements.

2.2.1 Network Architecture

Figure 2-2 shows the architecture of a virtual private network. The enterprise network reuses the radio equipment and frequency resources of the public network and shares cells with the public network. The public CN can be partially or fully reused based on service requirements.

Figure 2-2 V-ENS network architecture: The private network reuses public network radio resources and shares cells with the public network.

2.2.2 Network Performance

2.2.2.1 *Coverage*

The coverage scope of the V-ENS is the same as that of the public network. Due to the limited coverage of the macro and micro cells of the public network, the V-ENS cannot provide services in coverage holes of the public network.

2.2.2.2 *Reliability*

The data of the V-ENS and public network is accessed and scheduled in the same cell. The QoS is used to differentiate service priorities and ensure the transmission quality of each service.

2.2.2.3 *Isolation*

In a multi-site cell, the V-ENS and public network are scheduled together over the air interface. The isolation depends on the end-to-end slicing.

2.2.2.4 *Network Performance*

In V-ENS mode, the peak service performance is the same as that on the public network. The peak service performance depends on the frequency resources and system frame structure.

- Rate: The public network uses the system frame structure determined by the eMBB service. For example, the theoretical uplink and downlink peak rates are about 190 Mbps and 1.7 Gbps respectively in the current 2.6 GHz 100 MHz band of China Mobile.
- Latency: The end-to-end latency consists of the transmission delay over the air interface, delay on the network side, and processing delay of each NE. The delay difference of the enterprise network is related to the frame structure configuration of the air interface and the deployment position of the CN. The 2.6 GHz public network is used as an example. The frame structure uses a 5 ms period, and the air interface delay is about 11 ms. When the private network UPF uses the local breakout mode, a 1 ms delay is introduced, and the total delay is about 12 ms. If the UPF is at the remote end of the enterprise network, the transmission delay on the network side also needs to be considered.

V-ENS resources are shared by the public network and enterprise network. Service changes on the public network affect the data transmission reliability and performance of the enterprise network. For example, in areas with heavy public network traffic, co-channel interference exists on enterprise network cells, affecting the transmission rate and reliability.

2.2.3 Application Scenarios

The virtual private network is mainly used to meet the low-cost connection requirements of industry users. It uses existing resources on the public network and network slicing to ensure service continuity.

V-ENS are applicable to WANs that do not require high isolation and sensitivity. Depending on operators' public networks, V-ENS can be used in WAN scenarios, such as wide-area IoT collection, some policing applications, medical detection and care, and medical consultation.

2.2.4 Industry

A V-ENS shares devices on the RAN and network side with the public network and maintains the same development pace. The network devices are provided by traditional main equipment suppliers.

2.3 P-ENS

The P-ENS is oriented to industry applications that have high requirements on reliability and privacy. Dedicated wireless devices and frequency resources are used to completely isolate data from the public network. Changes in public network services will not affect data transmission quality of the enterprise network, forming a highly closed private network for industry applications.

The P-ENS architecture features high reliability, high isolation, and flexible performance customization. However, devices need to be constructed separately, which results in high costs.

2.3.1 Network Architecture

Figure 2-3 shows the architecture of a P-ENS. It uses dedicated gNB and frequency and is completely isolated from the public network. On the network side, some public CNs can be reused or an independent enterprise network can be constructed based on service requirements.

Figure 2-3 Dedicated physical network architecture: dedicated radio resources, inter-frequency with the public network

2.3.2 Network Performance

2.3.2.1 *Coverage*

The coverage of a P-ENS does not depend on the coverage of public networks. Therefore, a P-ENS can be deployed in coverage holes of a public network, such as workshops, underground tunnels of coal mines, and untouched wildness areas. In addition, new devices are required on P-ENS.

2.3.2.2 *Reliability*

The physical private network uses dedicated devices and frequencies, which are isolated from the public network. This prevents changes of public network services from affecting channel quality of enterprise networks over the air interface and avoids resource usage conflicts of wireless devices.

The RRU and BBU hot backup mode can be used to improve network reliability.

2.3.2.3 *Isolation*

Dedicated devices and frequencies are used on P-ENS. The wireless devices and frequencies on P-ENS are physically isolated from those on public networks.

2.3.2.4 *Network Performance*

In the P-ENS architecture, the system frame structure can be flexibly adjusted based on service requirements. You can select a proper frame structure based on the rate and latency requirements.

- Rate: The dedicated enterprise network uses a frame structure that can be flexibly configured based on service requirements. Industrial applications usually have high requirements on the uplink rate. The theoretical uplink peak rate of the 1:3

(DSUUU) frame structure can reach about 570 Mbps, which is three times the uplink transmission capability of public networks.

- Latency: The end-to-end latency consists of the transmission latency over the air interface, latency on the network side, and processing latency of each NE. The latency difference of the enterprise network is related to the frame structure configuration of the air interface and the deployment position of the core network. On the 2.6 GHz public network, the frame period is 5 ms, and the air interface delay is about 11 ms. The frame structure of 1 ms (DS) can be configured for the P-ENS. The air interface latency is about 6 ms, which is half of the air interface latency of the public network.

2.3.3 Application Scenarios

The P-ENS is a high-quality private network solution for scenarios with high service reliability, isolation, or performance requirements. It is usually used in LAN scenarios, such as port cranes/gantry cranes, smart factory industrial vision, AR repair, and some temporary applications such as mobile live broadcast and emergency communications.

2.3.4 Industry

Dedicated wireless devices need to be deployed for P-ENS. In addition to traditional main equipment vendors, small cell vendors can also provide dedicated wireless devices. Currently, the maturity of P-ENS is later than that of public networks.

2.4 Summary

M.V.P. network architectures provide on-demand network customization for vertical industries. The isolation and reliability sequenced in ascending order from V-ENS to M-ENS and to P-ENS. In terms of system performance, P-ENS has the highest flexibility, while M-ENS and V-ENS are restricted by public network configurations and have poor uplink capabilities. In terms of cost, V-ENS reuses all public network resources, achieving the lowest cost. M-ENS has a higher cost, and P-ENS has the highest cost due to dedicated devices and frequency resources. Industry customers can flexibly select and combine services based on their service requirements and budget.

3 Dedicated Services Based on the M.V.P

The network requirements (such as coverage, performance, and isolation) of enterprise customers are greatly different from those of public network users, and package services are required. The M.V.P enterprise private networks provide six "simplified + ultimate" dedicated service capabilities to meet differentiated requirements of enterprise customers, providing customers with simplified delivery interfaces and ultimate private network performance.

Type 1: dedicated network service capability. It includes coordinated spectrum, customized networking, and differentiated services. This type of capability provides customized services based on the capabilities of the wireless enterprise network.

Type 2: dedicated value-added service capability. It includes general-purpose terminals, intelligent O&M, and diversified capabilities. The wireless enterprise network is further coupled with operators' comprehensive capabilities, deriving more value-added services.

3.1 Dedicated Network Service Capability

3.1.1 Coordinated Spectrum

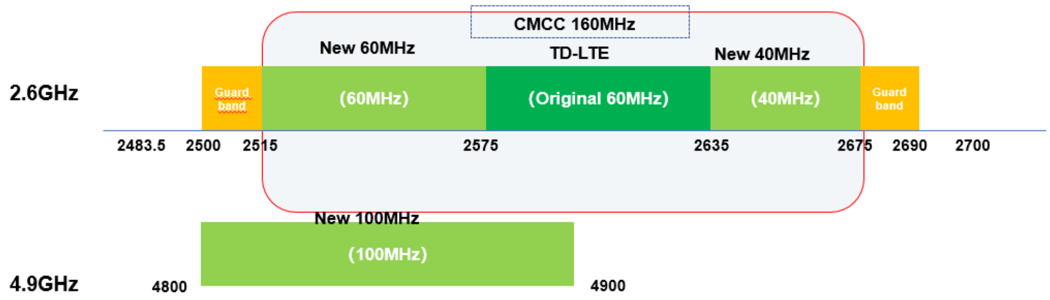
Frequency is the most valuable resource of wireless communications networks. Abundant spectrum resources are the core advantages for expanding 5G private networks.

The 5G spectrum has a large bandwidth. China Mobile has obtained 260 MHz 5G spectrum in the 2.6 GHz and 4.9 GHz frequency bands. A lower frequency band delivers better coverage performance, and that of 2.6 GHz is better than that of 3.5 GHz. In addition, the 2.6 GHz frequency band can reuse 4G devices, reducing the network construction cost, and therefore it can be used to provide general 5G coverage. 4.9 GHz can be used to provide specific 5G coverage duo to flexible frame structure and good performance.

According to the M.V.P wireless enterprise network solution, different spectrum application solutions are customized based on the network performance and isolation requirements of industry customers.

- Connection requirements: The spectrum sharing mode with the public network can be used to implement fast and low-cost solutions.
- Reliability and isolation requirements: The exclusive frequency mode can be used to prevent the impact of public network services.
- Extremely high network performance requirements: The frequency band different from that of the public network can be used to flexibly customize the system configuration (such as the frame structure) to meet the transmission requirements.

Figure 3-1 Spectrum of the 5G trial network of China Mobile



For example, in ports and factories that require high uplink cell capacity, the 2.6 GHz+4.9 GHz dual-band coverage can be provided. Some or all frequency resources can be exclusively used to provide dual-band coordination services. In office campuses that have low requirements on network performance, 2.6 GHz frequency bands can be provided and shared on the public network to ensure service performance based on QoS.

3.1.2 Customized Networking

The 5G public network cannot meet the extreme performance and isolation requirements of various vertical industries. Customized network construction can meet the coverage requirements of special scenarios in vertical industries, such as seaports, underground tunnels, and aviation interconnection. It can also meet customized requirements for network isolation in industries with high security requirements, such as industrial manufacturing, energy, and transportation.

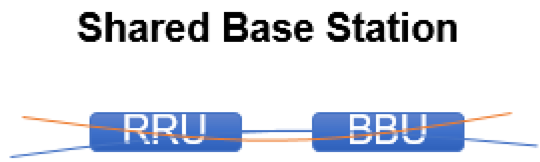
Based on the M.V.P wireless enterprise network solution, operators provide customized networking services for enterprise networks to meet coverage customization and data isolation requirements of industry applications. There are two network construction modes: one is public networks for private use, and the other is customized network construction.

3.1.2.1 *Public Network for Private Use*

Public network for private use refers to providing dedicated resources or QoS guarantee for industry customers on the basis of public network coverage. The site type and frame structure are shared with the public network, reducing costs.

Based on different data isolation requirements of industry applications, two modes are available. One is frequency sharing and logical isolation of data. The other is exclusive use of some frequencies by the enterprise network to achieve higher air interface isolation. The upgrade of public network devices and signaling storms affect enterprise networks. The exclusive frequency usage mode applies to most scenarios and is recommended for large-scale networks.

Figure 3-2 Construction of a dedicated base station on the public network

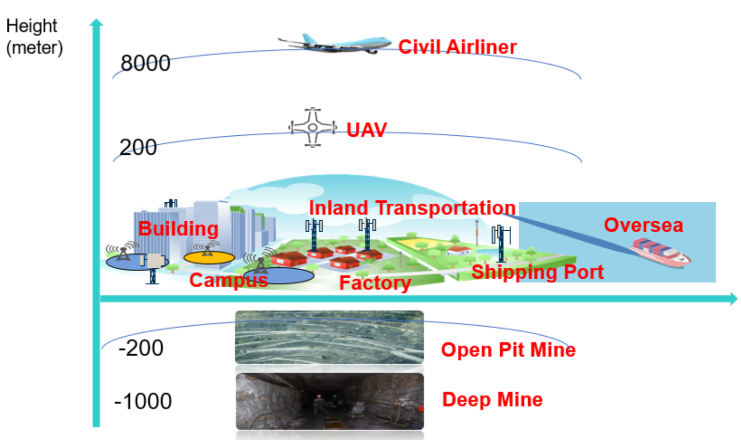


3.1.2.2 *Customized Network Construction*

3.1.2.2.1 Coverage and Site Type Customization

In addition to public network for private use, the customized networking service is provided to meet diversified coverage requirements of various industries. In addition to typical urban, campus, and rural coverage requirements, the solution must meet the personalized coverage requirements of vertical industries, such as high-altitude ATG coverage in civil aviation, low-altitude drone coverage, river navigation coverage, sea surface super-distance coverage, and deep coverage in mines. This solution provides customized site types and scenarios to deliver comprehensive network coverage.

Figure 3-3 Figure 3-3 Private network coverage and site type customization



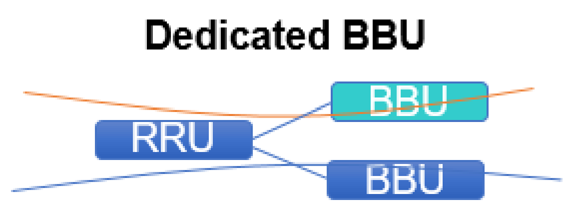
Base Station	
Outdoor Macro BS (2.6GHz,4.9GHz)	64TR
	32TR
	16TR
	8T8R
	ATG
Micro BS (2.6GHz,4.9GHz)	4T4R
Indoor pico BS (2.6GHz,4.9GHz)	4T4R
	2T2R

3.1.2.2.2 Isolation Customization

On the basis of customized networking, customized network construction supports BBU-dedicated or base station–dedicated isolation.

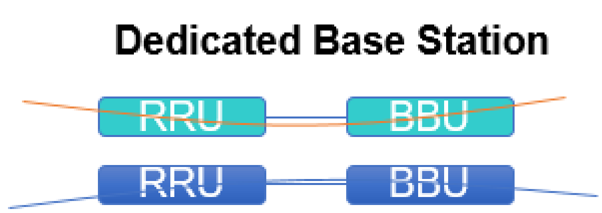
For BBU-dedicated isolation, the enterprise network and public network use shared RRUs and dedicated BBUs (including dedicated boards). The frequency sharing mode is not limited, and the baseband data is physically isolated. In this way, the public network can share most of the costs, RRU version is relatively stable, and BBUs on the public network can be upgraded independently. Meanwhile, the enterprise network maintains high reliability. This solution is applicable to scenarios that require high isolation and reliability, such as factories with high security levels

Figure 3-4 Base station isolation mode 1: BBU-dedicated



For base station–dedicated isolation, enterprise network base stations are deployed independently. BBUs and RRUs are exclusively used (reliability can be further designed). The frequency is exclusively used. All data is physically isolated. Devices are upgraded independently, ensuring high reliability. However, this mode features high construction cost and difficult implementation. It applies to scenarios that require high isolation and reliability or do not have public network service requirements, such as ATG and prisons.

Figure 3-5 Figure 3-5 Base station isolation mode 2: dedicated for base stations



3.1.3 Differentiated Service

The M.V.P wireless enterprise network solution provides differentiated services through customized wireless optimization. It provides differentiated network performance requirements, such as uplink and downlink rates, latency, and reliability, for different users or services on public and enterprise networks. The differentiated service capability is based on the mature QoS and slicing mechanism. In the initial phase, the capability is manually optimized. In the later phase, the capability is automatically optimized based on user requirements.

Differentiated services can provide qualitative and/or quantitative air interface performance assurance for industry customers. For local enterprise network services, the wireless coverage can be optimized to avoid impact of external factors. In addition to the construction of customized enterprise networks, high-quality air interface performance can be ensured.

3.1.3.1 Wireless Optimization

Network performance is mainly determined by the RAN side. Based on radio parameters such as DRX parameters, minBR/AMBR parameters, radio scheduling policies such as scheduling priorities, AMC policies, and power control policies, and function algorithm switches such as uplink preallocation and minislot, differentiated delay, reliability, and customized rate can be achieved.

3.1.3.2 Differentiated Service Mode

The M.V.P wireless enterprise network solution provides differentiated latency and reliability services, such as the lowest air interface delay, different latency levels, and reliability levels, based on customers' service sequence requirements and budget. It also provides customized rates, such as the minimum rate guarantee and different uplink and downlink rate levels.

In addition, this solution provides quantitative or qualitative network performance assurance services based on coverage scenarios. If the wireless environment is uncontrollable in WAN scenarios, the qualitative level assurance service is used. If the coverage of local scenarios can be customized, the quantitative assurance service can be used.

3.2 Dedicated Value-Added Service Capabilities

3.2.1 General-Purpose Terminals

Industry terminals differ greatly from smartphones. Some terminals require only basic communication capabilities, some require communication modules with computing capabilities, and some require all-purpose modules. Industry terminals have different requirements on performance, such as rate, latency, reliability, and security. Some terminals have special requirements on time serving, location, and slicing capabilities. In addition, industry terminals must meet industry-specific requirements, such as waterproof, explosion-proof, shockproof, and low power consumption, to adapt to different working conditions.

Currently, the application scenarios of wireless communication modules are expanding in various industries. Demands for cellular wireless communication modules, especially medium- and high-speed modules, are skyrocketing in fields such as culture and entertainment, smart transportation, smart city, smart manufacturing, and telemedicine. It has become an urgent issue to quickly integrate 5G communication capabilities into industry terminals. After extensive analysis and research, this section proposes two solutions to meet the 5G communication requirements of industry customers.

The introduction of new technologies requires the improvement of terminal access capabilities, which can be translated into higher costs. However, the industry is generally sensitive to costs. The replacement of industry terminals faces the waste of legacy investments and the increase of new investments. Therefore, terminal reuse is an important factor to be considered when new technologies are introduced. The access gateway, CPE, or DTU provides technical means for industry terminals to reuse existing resources. For instance, terminals that can access the Wi-Fi network can directly access the gateway, 5G CPE, or DTU to introduce 5G capabilities. Besides, devices that have high reliability requirements and cannot be connected to the Wi-Fi network can be connected to the CPE or DTU through wired interfaces such as RJ-45, USB, and HDMI. Therefore, 5G data terminals will play an important role in the early stage of 5G commercial use or terminal reuse.

However, CPEs and DTUs also have their own weaknesses. For one thing, these devices require independent power supply. For another, these devices are large in size and heavy in weight. As a result, terminals with high mobility or appearance requirements, such as drones and MR devices, cannot directly use these devices.

In view of the disadvantages of the CPE and DTU, built-in communication modules of industry terminals are an inevitable trend of the industry terminal development after the technology is mature. Against this backdrop, universal 5G modules have become a key link in promoting 5G industry applications, helping resolve industry fragmentation issues, and providing industry terminals with 5G communication capabilities. Unified encapsulation size and interface can further complement industry standards, lower the R&D threshold of 5G terminals, reduce the R&D cost of industry terminals through economies of scale, and promote the adoption of 5G technologies in vertical industries.

Different industries have different requirements for 5G communication modules. Based on the survey and analysis of vertical industries, the requirements and application scenarios of 5G and 5G modules in various industries can be fully explored, and three types of modules can be summarized:

Basic: In the 5G era, 5G modules will be the most widely used modules in most scenarios, such as real-time UHD video surveillance, networked drones, networked vehicles, ACPC, UHD 8K online video, and industrial routers.

Intelligent: Applications such as artificial intelligence and virtual reality technologies require high-performance computing capabilities to process real-time data. Therefore, in addition to the recommendations for the basic types, such modules require a high-performance processor.

All-round: The integrated 5G module provides built-in antenna modules, which can be directly used by industry terminals without any design, reducing device R&D costs.

5G communication modules are integrated on industry terminals to meet diversified and customized requirements. Enterprise network customers can select 5G communication modules that meet their requirements and develop customized requirements such as time serving and precise positioning. For terminals that need to access the public network and enterprise network at the same time, the working mechanism of dual SIM cards and dual registration needs to be studied.

Industry terminals have more diversified application scenarios and more complex application environments. Therefore, the terminal quality requirements are stricter, and the terminal test, authentication, and quality assurance system is especially important. The "chip-module-terminal" solution can reduce the test costs of industry terminals and improve the test efficiency.

3.2.2 Smart O&M

Some industries with high requirements, such as smart factories and ports, expect to have some independent network O&M capabilities. In addition to operators' management and control over the enterprise network, smart O&M provides simplified management for industry customers, featuring manageable devices, controllable services, performance visualization, and fault recovery.

Manageable devices: 5G white-box micro base stations are compatible with NB-IoT and 4G micro base stations. A unified management interface is provided to simplify route configuration and access permission management. Smart O&M provides network device management services for industry customers.

Controllable services: Service quality requirements can be converted and configured, and interconnection with existing service application systems is planned to be supported. Industry-specific applications and functions are supported. AI capabilities are independently deployed.

Performance visualization: This feature includes user-friendly and interactive GUI design, import of customized industry monitoring indicators, BI display of service quality and network status, software-based data collection of micro sites, MR parsing, and multi-dimensional performance display.

Fault recovery: This feature covers AI-based intelligent alarm root cause analysis (RCA), automatic closed-loop troubleshooting, and network troubleshooting/optimization expert system.

3.2.3 Diversified Capabilities

Most industry customers expect carriers to provide integrated delivery. Therefore, simplified integrated delivery is required in addition to optimal network performance. On enterprise networks, China Mobile provides industry customers with diversified capabilities, such as high-precision positioning, edge computing, artificial intelligence, IoT, and cloud computing, to implement cloud-network synergy.

3.2.3.1 High-Precision Indoor and Outdoor Positioning

Industry applications have clear requirements on network performance. In addition, they also require positioning in application fields such as inspection, logistics, and personnel management. The 5G enterprise network uses technologies such as cellular cell positioning, Bluetooth positioning, and BeiDou satellite positioning to implement integrated capability delivery.

3.2.3.2 Edge Computing

Operators can provide 5G private networks with edge computing capabilities for industry customers. These 5G private networks use multiple end-to-end technologies to shorten the end-to-end distance, reduce network latency, save bandwidth resources through local data computing, and ensure data security through local data distribution.

4 Enterprise Network Cases

4.1 Smart Port

4.1.1 Scenario Introduction and Service Requirements

4.1.1.1 *Overall Port Operation Process*

Figure 4-1 Port scenario

Take container handling as an example. The dock operation process mainly includes:

(1) In the loading and unloading area, the crane moves containers from a ship to a horizontal vehicle (AGV, internal container trailer, straddle carrier).

(2) The horizontal vehicle moves containers from the bridge crane in the loading/unloading operation area to the yard operation area. Gantry cranes unload containers from the vehicle and place them in the yard.

(3) An external container trailer enters the yard via the container gate, load the container, and transport it to the destination.

4.1.1.2 Business Requirements

The following table lists the service scenario values.

Service Scenario	Coverage and Mobility Requirement	Network Performance Requirement	Reliability Requirement	Isolation Requirement
Remote bridge crane/gantry crane	• Outdoor deployment • Fixed- or low-speed moving	• Uplink rate: 30 Mbps per terminal • Downlink delay: 20–30 ms	99.99%	User-plane data is processed on campus.

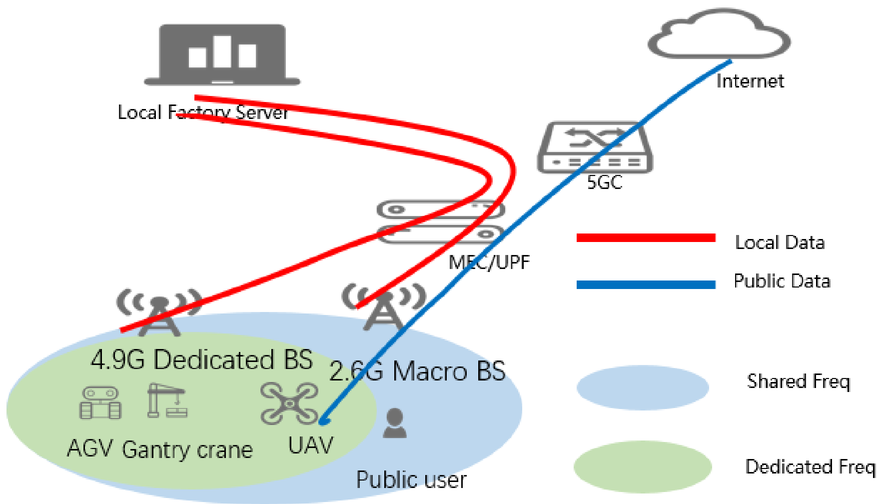
AGV/container trailer	• Outdoor deployment
	• Medium- and low-speed moving
		• Uplink and downlink scheduling rates:
		  • 200 kbps per terminal (control command)
		  • 2 Mbps per terminal (video stream)
		• E2E delay: 30–50 ms
		• Positioning accuracy: cm
			99.99%	User-plane data is processed on campus.

Smart tally	• Outdoor deployment • Medium- and low-speed moving	• Uplink rate: 30 Mbps to 40 Mbps per terminal • E2E delay: 50 ms	99%	User-plane data is processed on campus.

4.1.2 Port M-ENS

Analysis of service indicators for smart ports shows that the port industry has strict requirements on production safety, data control, cost control, and communication network performance, such as localized service scenarios, ultra-low latency, ultra-high reliability, and ultra-high uplink capacity. In addition, there are public network coverage requirements in the port area. Given this, the smart port needs to use the M-ENS architecture.

Figure 4-2 Building a 5G M-ENS for all-scenario port services



On the one hand, the M-ENS allocates dedicated frequency for port production services, greatly enhancing the service performance (such as latency, reliability, and rate). On the other hand, frequency isolation and campus-based UPF ensure data security and isolation for sensitive services in the port.

4.1.3 Exclusive and Value-Added Port Services

1. Coordinated spectrum. 2.6 GHz+4.9 GHz dual-band coverage is provided, allowing for exclusive use of some or all frequency resources. The dual-band coordination service meets the high performance assurance requirements of the port industry.
2. Customized network construction. Base stations are upgraded to support dedicated frequency resources and provide enterprise network cells for port production users, implementing air interface isolation. In addition, special site types, such as super-distance coverage sites and micro sites, are provided to meet the coverage requirements in scenarios such as sea coverage and insufficient macro site locations in the container yard.
3. Differentiated services. QoS and slicing are used to provide differentiated service assurance solutions for different services. For example, low latency QoS is provided for remote control scenarios to ensure quantitative latency measurement.
4. General-purpose terminals. In the early stage, 5G CPEs and DTUs are used to meet the requirements of port devices for 5G access. In addition, special requirements such as moisture-proof, water-proof, and sun-proof requirements need to be met. In the future, communication modules will be integrated in industry terminals.
5. Diversification capability. Port data can be processed locally. The UPF has been deployed on the campus network to meet port requirements. The edge computing platform can be deployed to migrate production services to the edge computing platform for fast service processing. In addition, the 5G+high-precision positioning service is one of the solutions for services such as automatic driving.

4.2 Smart Healthcare

4.2.1 Scenario Introduction and Service Requirements

Hospitals require highly reliable and low-latency network solutions. Medical data involves privacy and has high security requirements. Value-added services such as positioning are also required. In addition, a stable network connection is required for ambulances.

The following table lists some smart healthcare services.

Service Scenario	Coverage and Mobility Requirement	Network Performance Requirement	Reliability Requirement	Isolation Requirement
Medical examination and nursing	• Indoor and outdoor deployment • Fixed- or low-speed moving	• Uplink rate: 100 kbps per terminal • Latency: 200 ms • Positioning precision: 10 m (indoor) or 20 m (outdoor)	99%	• User-plane data is processed on campus, and user terminals can access the public network. • Higher-level assurance than public network users is required
Remote real-time consultation	• Outdoor deployment • Fixed-speed moving	• Uplink rate: 5 Mbps per terminal • Latency: 100 ms	99%	• User-plane data is processed on campus, and user terminals can access the public network. • Higher-level assurance than public network users is required.

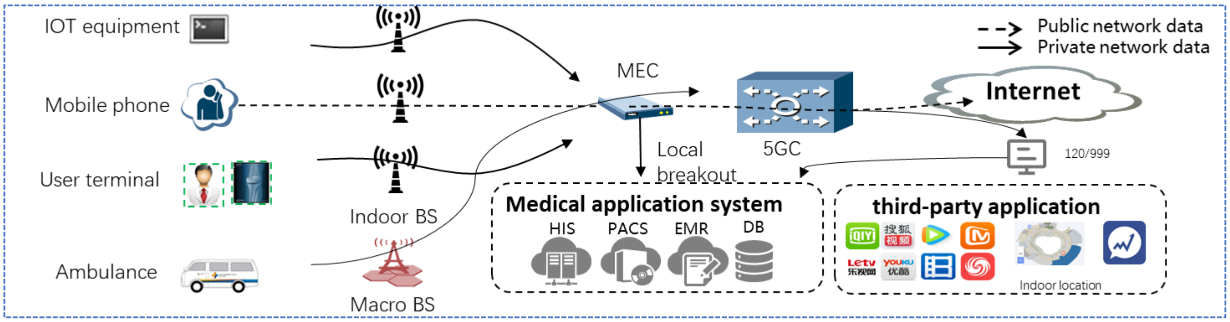
4.2.2 Network Architecture Solutions

1. Medical detection and nursing: This solution meets the requirements for data access in wards, diagnosis departments, anaesthesia departments, pathology departments, and imaging departments. To ensure security, the patient's medical records and imaging materials must be processed in the hospital area. Public network resources can be reused to meet the hospital's service requirements. Independent slices can be configured for hospital services, and resources can be reserved or prioritized to improve the priority of hospital services.

2. Remote real-time consultation: In the case of an emergency, vehicle-mounted medical devices can collect physical status indicators of a patient in an ambulance

and sent the data to the emergency department of the hospital through the public network, improving emergency treatment efficiency. High-level resource assurance is provided for applications on emergency vehicles through ARP and QoS.

Figure 4-3 Network solution for hospital scenarios



4.2.3 Healthcare Network Services and Value-Added Services

The healthcare network services and value-added services provide smart routing capabilities to implement local transmission and forwarding of Internet of Things (IoT) device data and intra-hospital routing and forwarding to form a local hospital data network. In addition, routing IP addresses and routing policies of medical IoT devices can be managed, and information can be exchanged between IoT gateways in hospitals. Moreover, authentication is required for medical IoT devices to access the hospital's internal information system. Only authorized devices can access the hospital's internal information system. Besides, level-3 security protection capabilities are provided, and indoor positioning capabilities are provided for medical IoT devices and mobile phone users.

4.3 Smart Mining

4.3.1 Scenario Introduction and Service Requirements

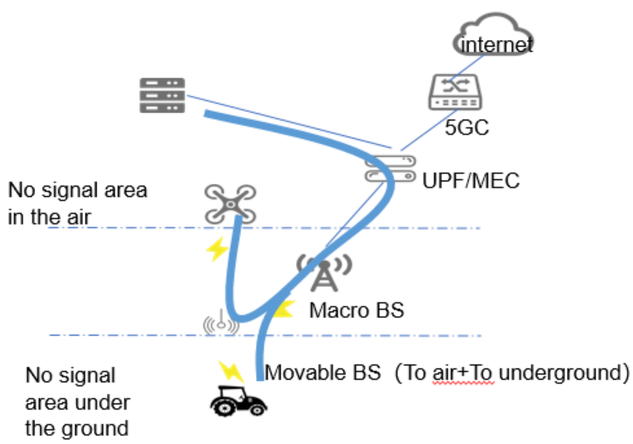
This case uses the overall requirements in the outdoor scenario as a reference model and proposes a specific physical wireless enterprise network solution. For details about the requirements of each application on network capabilities, see the mine application in Table 1-1.

Service Scenario	Coverage and Mobility Requirement	Network Performance Requirement	Reliability Requirement	Isolation Requirement
UAV/Geological radar mapping	• Outdoor deployment • 3D coverage with large height differences	• Uplink rate: 30 Mbps per terminal • Downlink latency: 20–30 ms	99.99%	User-plane data is processed in mining areas.
Remote mining/Automatic mining card	• Outdoor deployment • Medium- and low-speed moving	• Uplink and downlink scheduling rates: 200 kbps per terminal (control command) 2 Mbps x 4/single terminal (video stream) • E2E delay: 30–50 ms • Positioning accuracy: cm	99.99%	User-plane data is processed in mining areas.
Security sensor/Mining terminal	• Outdoor deployment • Stationary	• Uplink rate: 200 kbps for a single terminal • E2E latency: 50 ms	99%	User-plane data is processed in mining areas.
HD video surveillance	• Outdoor deployment • 3D coverage with large height differences	• Uplink rate: 30 Mbps to 40 Mbps per terminal • E2E latency: 50 ms	99%	User-plane data is processed in mining areas.

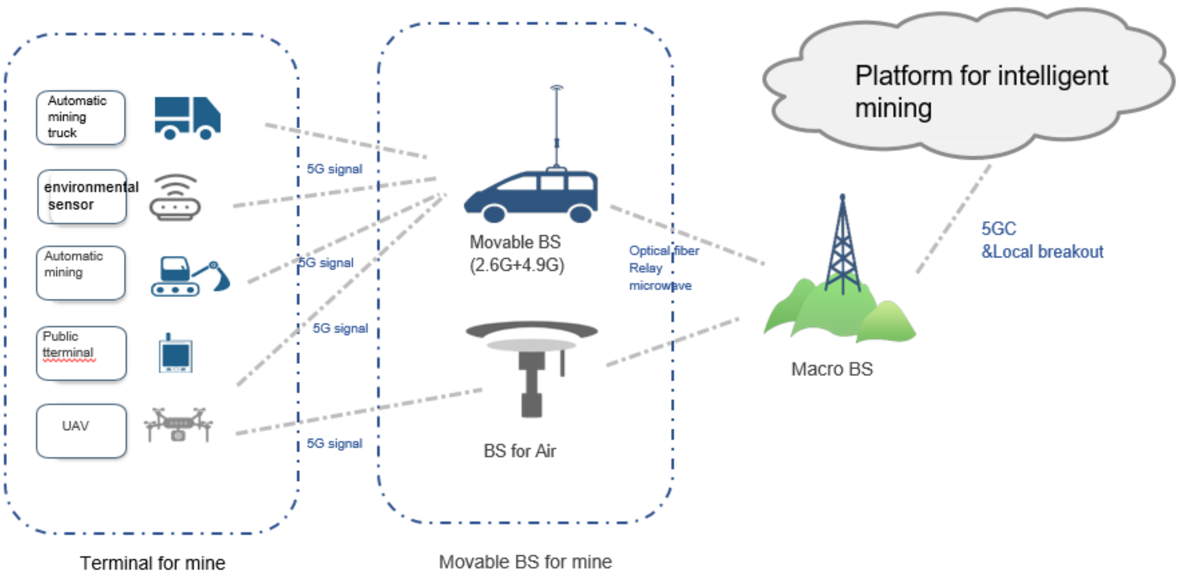
4.3.2 Network Architecture Solution

This solution deploys 5G networks, mine information platforms, and diversified 5G terminals in mines to implement signal coverage, data collection, video backhaul, personnel/vehicle management, aerial modeling, remote mining, and automatic driving.

Figure 4-4 Mine network solution



Dedicated and co-located 5G networks are deployed in mining areas to provide 5G signals with good coverage in and around the mines. A comprehensive information management platform is built for mines with various types of 5G terminals, such as geological information collection terminals, vehicle information terminals, connected drones, and employee terminals. The 5G communications technology is used to connect all units involved in the entire life cycle of mining operations, effectively and comprehensively manage the environment, and safeguard the environmental protection, safety, and efficiency of opencast mining operations.



In this solution, dedicated application terminals are used to meet the requirements of industry applications and public network users. Mobile dedicated base stations and public network base stations are combined to reduce costs and enable fast deployment. Based on service requirements, the user plane functions and dedicated core network (control plane functions) are deployed closer to users. In addition, centralized O&M management and control are used to provide simplified and visualized operation interfaces for users.

4.3.3 Mine Network Services and Value-Added Services

On the live network, multi-frequency and multi-RAT convergence networking is used to optimize radio parameters, coordinate spectrum, and reuse the public core network. To reduce latency and ensure data security, the UPF-based local traffic distribution solution is used together with the outdoor BeiDou, GPS, and RTK technologies to meet differentiated network performance requirements.

Wireless Network Construction Solution	Deployment Zone	Service	Frequency & Site Type	Frame Structure	Others
Solution 1	Full coverage of mining areas	Data backhaul	2.6 GHz 5G macro base station	5 ms period	• The frame structure is the same as that on the public network. • Dedicated Bearer Setup • Each cell supports more than 20 1080p cameras.
Solution 2	Automatic driving area	Automatic driving	4.9 GHz 5G Pico	2.5 ms periodic DSUUU	• Hotspot coverage and customize d frame structure based on services • Provides an uplink peak rate of 560 Mbps and an end-to-en d latency of 20 ms.

The preceding differentiated technologies based on physical enterprise networks are used to optimize control signaling, security alarms, low latency, allowing for high reliability, uplink rates of video surveillance, drones, and remote mining, and high power saving during data collection.

4.3.4 Field Application Effect

5G networks can connect production and auxiliary links ranging from complex scheduling, stripping, mining, transportation, drainage, machine repair, monitoring, and surveillance of the entire mine. In addition, 5G networks can carry access of subsequent systems, for example, the truck dispatch system, slope monitoring system, fire warning system, vehicle anti-collision system, electricity monitoring system, measurement and monitoring system, video surveillance system, coal weighing system, and remote video conference system, to normalize the original complex service scenarios. This way, a complete set of replicable "HD, network-based, intelligent, and highly integrated" smart mine comprehensive system is developed. The annual cost of topsoil stripping alone is reduced by tens of millions.

5 Summary and Initiatives

This white paper summarizes differentiated network requirements of industry customers, proposes three types of wireless enterprise network solutions, and describes and analyzes the network architecture, network performance (coverage, performance, reliability, and isolation), application scenarios, and industry conditions. The main conclusions are as follows:

1. Industry customers have different network requirements from those of the public network. Network customization is required, including customization of network deployment areas and coverage capabilities, network performance, and data isolation performance.
2. Based on the performance requirements of industry customers and the construction and operation costs, operators propose three types of wireless enterprise network solutions based on wireless network devices and spectrum resources. In conclusion, the M-ENS provides high performance, the V-ENS provides performance enhancement at lower prices, and the P-ENS provides high performance, high flexibility, and high isolation.
3. The M.V.P wireless enterprise network solutions can be flexibly combined with China Mobile's extension capabilities to provide customers with six dedicated capabilities, including three dedicated network service capabilities (coordinated spectrum, customized networking, and differentiated services) and three dedicated value-added service capabilities (general-purpose terminals, smart O&M, and diversified capabilities). The six capabilities can better serve various industries, enabling industry customers to reduce costs, improve efficiency, and implement intelligent upgrade and transformation.

Driven by operators' core technologies and capabilities, wireless enterprise networks have a bright future. On the one hand, the 5G private network of operators can fully integrate industry chains, leverage scale advantage, significantly reduce the cost and improve the quality, especially for vertical industries, and ensure the leading and continuous evolution of network performance. On the other hand, operators can coordinate and operate 5G frequencies in a unified manner to maximize frequency utilization and prevent resource waste caused by fragmented frequency usage. In addition, operators' robust capabilities can ensure fast network construction and advanced performance, better serving various industries.

The increasing demand for enterprise network capabilities is the driving force and cornerstone of operators' technological innovation. However, the maturity of enterprise network technology and industry faces many challenges. Some of the challenges come from technical collaboration and engineering cooperation between different fields such as communications, information, and operation, while others come from the differences in the understanding of the industry's digital and intelligent development directions by partners in the upstream and downstream of the industry chain. As an important part of the industry, operators advocate close cooperation in the industry. 5G equipment providers and China Mobile jointly explore and develop more comprehensive customized private network equipment. Application capability providers are fully integrated with China Mobile networks to form more abundant integrated delivery capabilities. Industry users and China Mobile jointly promote the pilot and implementation of the solution, and work together to realize the vision of 5G to change society.

Terminology and Abbreviation

Term	Description
ATG	Air to Ground
BBU	Building Base band Unite
RRU	Remote Radio Unit
SLA	Service-Level Agreement
QOS	Quality of Service
PLMN	Public Land Mobile Network
CELLBAR	cellBarred
CAG	Cell Access Group

Term	Description
UPF	User plane Function
AI	Artificial Intelligence
BI	Business Intelligence
MR	Measurement Report
MEC	Mobile Edge Computing
UHD	Ultra High Definition
ACPC	Always connected personal computer
DTU	Data Transfer Unit
CPE	Customer Premise Equipment
DRX	Discontinuous reception
AMBR	Aggregated Maximum Bit Rate
minBR	Minimum Bit Rate
AMC	Adaptive Modulation and Coding
eMBB	Enhanced Mobile Broadband
AGV	Automated Guided Vehicle

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