中国移动 China Mobile | 智慧政企

Application Scenarios White Paper

China Mobile, November, 2019

Preface

5G is leading converged innovation, stimulating a new type of information consumption, and fueling a fresh wave of industry upgrades and sustainable economic growth. On October 31, 2019, 5G commercial adoption officially kicked off in China, heralding the arrival of a promising future powered by 5G technology.

As the world's largest telecom operator in terms of network size and customer base, China Mobile will continue to play a leading role in the construction of global 5G networks, the promotion of 5G applications in various industries, and the delivery of user-centered 5G services. A comprehensive "5G Plus" plan will be implemented that touches upon coordinated growth between 4G and 5G, converged innovation between 5G and AICDE (Artificial intelligence, Internet of Things, Cloud computing, Big data, Edge computing), and joint development and expansion of 5G ecosystem and applications. Through this approach, the advantages of 5G will be utilized to improve digital information communications and accelerate industrial transformation and upgrades in a fully connected, intelligent world.

China Mobile has been actively expanding the application of 5G in various industries. With this in mind, the *5G+ Application Scenarios White Paper* has been released to elaborate on the development trends of innovative 5G applications in 100 scenarios across 14 major industries, including industrial Internet, smart energy, smart transportation, and smart healthcare. It also presents a detailed analysis of the deep integration of 5G with these industries and the new landscape of 5G digital economy development.

The road ahead for 5G development will be long and full of challenges; only with concrete planning and action, can we empower 5G to meet its full potential, connecting all people and transforming industries in an era of new possibilities. China Mobile looks forward to collaborating with global partners to drive the integration of 5G with industries and build a new digitally powered future.

Together, let's strive toward an exciting future made possible by 5G.


5G Smart Energy
5G Smart City
5G Industrial Internet
5G Smart Finance
5G Smart Campus
5G Smart Transportation
5G Smart Healthcare
5G Smart Media
5G UHD Industrial Video
5G Smart UAV
5G Smart Park
5G Cloud Gaming
5G Aerial Internet
5G Smart Agriculture


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5G Industrial Internet

Industrial Internet is the product of the new generation of information communication technology deeply integrated with the manufacturing industry. It is a basic network that connects machines, materials, people, and information systems to enable full sensing, dynamic transfer, and real-time analysis for industrial data. These services pave the way for effective decision-making and intelligent control, enabling improvements to the resource allocation efficiency. Industrial Internet has already become a new focus of competition among countries and enterprises as part of their new industry strategies.

China Mobile has been actively leveraging 5G and other new-generation communications technologies to help industrial partners reduce costs and improve efficiency while pursuing flexible manufacturing and fast equipment upgrade. Based on the experience gained through this process, China Mobile summarized 5G industrial solutions featuring remote control, remote onsite, and machine vision.

5G Industrial Internet

1. Service Requirements

5G extends people-to-people connections in the 4G era to full connections among people and things. Such massive 5G connectivity provides an essential means for industrial Internet to support smart sensing, ubiquitous connections, real-time analysis, and accurate control with intelligent approaches across various manufacturing links to improve efficiency. This will enable centralized operation, increased automation in place of manual labor, remote maintenance and assistance, and online service provisioning, addressing numerous industrial pain points. Boasting such extraordinary performance, 5G networks will empower industrial manufacturing with new possibilities and help the industrial Internet deliver three major requirements: replacing wired networks with mobile networks, separating control units from electric units, and replacing humans with machines.

Requirement 1: Wired-by-Mobile Replacement, Enabling Flexible Manufacturing

The failure to exactly match the capacity of different manufacturing processes and the increasing demands for high-quality custom products has led to the rapid growth and complexity of production management. Fulfilling diverse and uncertain requirements means that production lines must support multi-variety, customized production. With wireless communications in place to render wired communications obsolete, greater deployment flexibility can be ensured for production line equipment to support flexible manufacturing and improve production efficiency.

Figure 1-1: Production lines capable of fulfilling custom product demands

Requirement 2: Control-Electric Separation, Enabling Quick Equipment Upgrade

Matching control units with electronic units that store instructions and algorithms requires a great deal of time and labor during equipment upgrade. Decoupling these electric units from equipment by storing algorithms on cloud servers will significantly reduce costs for custom production. This will also enable the computing power of electric units to be improved on cloud servers, facilitating interface standardization of production equipment while enabling custom production of a broader range of equipment. As a result, the equipment will be capable of supporting a higher production capacity.

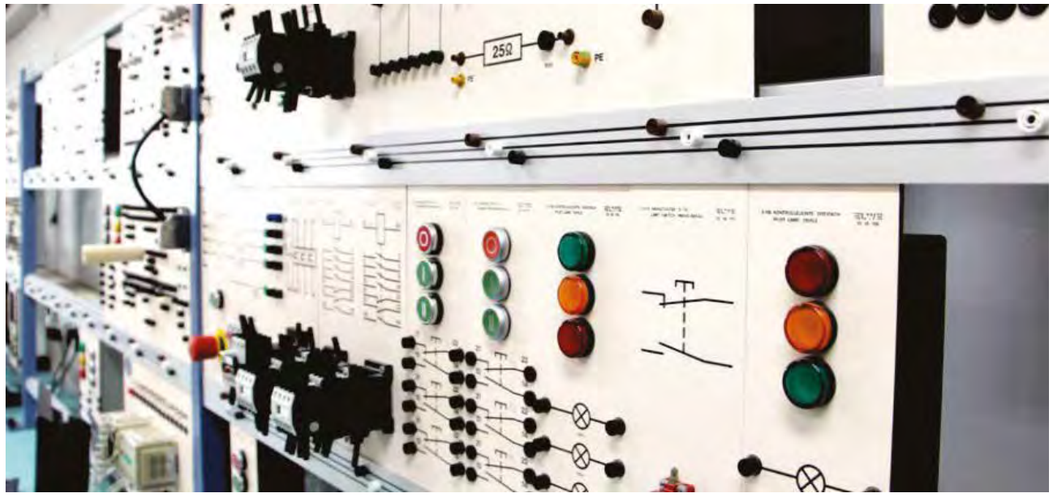


Figure 1-2: Mechanical operation and large-size control system

Requirement 3: Replacing Humans with Machines Reduces Cost and Increases Efficiency

Manual production often exhibits low efficiency, high costs, and can be prone to errors. Machine-based production combined with smart applications offers an alternative to manual operations to significantly improve production efficiency. Automatic command control, remote manual manipulation, and robot inspection can be utilized to standardize product outputs and avoid the uncertainties caused by manual operations while guaranteeing efficient and low-cost manufacturing.

Figure 1-3: Machines replace production workers in a factory

2. Solution Overview

Owing to leading 5G technology combined with excellent terminal and platform capabilities, China Mobile is uniquely positioned to offer Internet of Things (IoT) connections across various scenarios, enabling a diverse category of industrial applications and upstream and downstream industry collaboration.

Collection layer: This mainly includes various industrial and enterprise terminals, including industrial sensors, DTUs, industry-specific terminals, and industry-specific gateways. Using these terminals, industrial and enterprise users can acquire a comprehensive perception of related devices.

Network layer: Various industrial network requirements are satisfied by tapping into the advantages 5G technology offers in high speed, low latency, and massive connectivity.

Platform layer: A general-purpose basic platform of industrial Internet is provided, ensuring quick access and digital O&M for cloud-based devices through connection management, access management, and data analysis. It also provides standard and self-service interfaces to accommodate cloud platforms for vertical industries, such as manufacturing, electrical appliance, and energy.

Application layer: Based on machine vision, remote control, and remote onsite, it hosts innovative applications required for transformation with 5G industrial Internet. These include optical character recognition (OCR) decoding, space guidance, defect detection, production safety behavior analysis, remote machinery engineering, automated guided vehicle (AGV) control, AR assistance to O&M, VR training for complex assembly, production line device control, and 5G programmable logic controller (PLC).

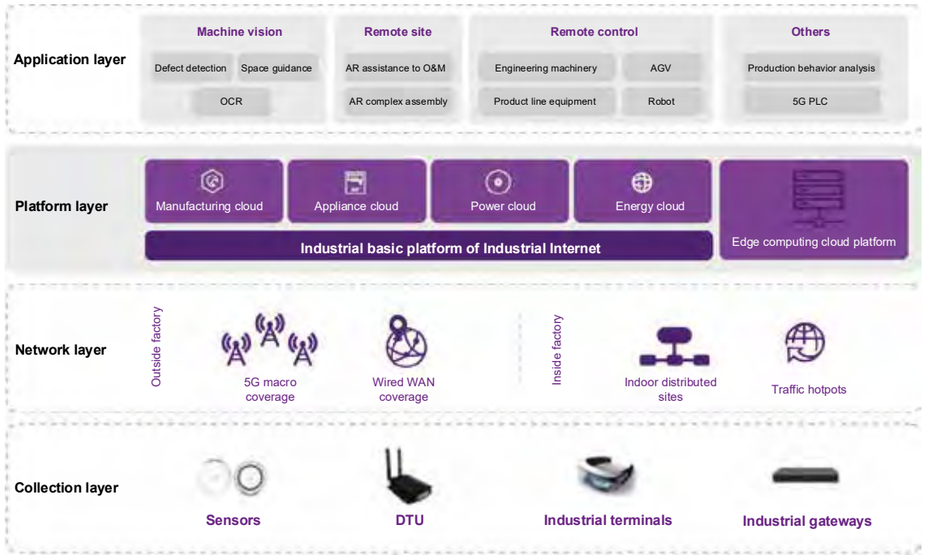


Figure 1-4: Application system architecture of 5G industrial Internet

3. Application Scenarios

Scenario 1: Machine Vision – Defect Detection

Quality inspection still relies on visual processing even in smart workshops, resulting in low efficiency, difficult backtracking, and unstable detection results. Thanks to 5G networks, these issues will soon become a thing of the past. Product images captured by ultra-HD (UHD) industrial cameras are sent to cloud-based servers, based on which real-time quality detection and automatic sorting can be performed. In addition, defect specifics can be recorded to provide a basis for analysis and backtracking.

Figure 1-5: Product defect detection based on 5G technology

Scenario 2: Machine Vision – Space Guidance

In smart factories, space guidance based on machine vision plays an essential role in automatic product assembling, welding, packaging, filling, and spraying. The implementation depends on information about locations and environments, creating an enormous amount of high-frequency data uploads.

5G networks can easily deal with this challenge. Their support for reliable, high-bandwidth uplink data transmission is ideal for space guidance of various automatic execution mechanisms. This provides a solid foundation for the flexible deployment of mechanical arms and flexible manufacturing.

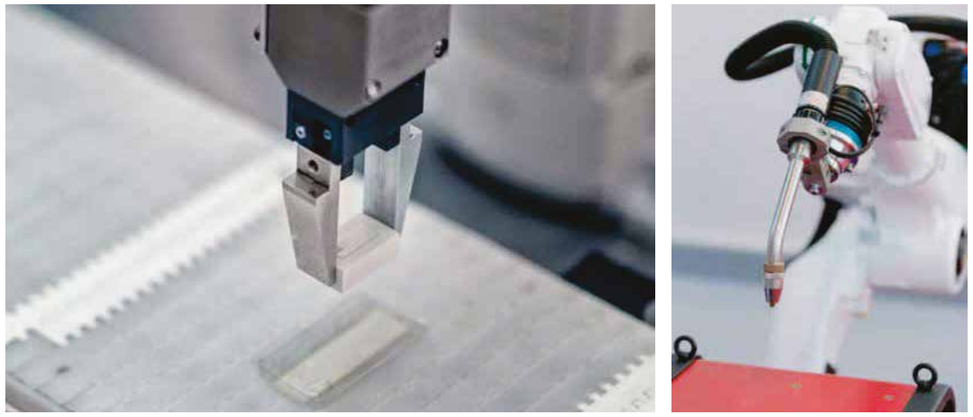


Figure 1-6: Space guidance based on 5G-powered machine vision

Scenario 3 Machine Vision – Optical Character Recognition (OCR)

OCR is a powerful tool used to perform fast digital processing of characters on cards, nameplates, and industrial production bar codes. Based on 5G networks, character images captured by 4K industrial cameras can be uploaded to cloud-based servers in real time where OCR is then accurately completed. In addition, mobile edge computing (MEC) attached to 5G private networks offers additional support to greatly reduce recognition time and improve accuracy.

Figure 1-7: OCR applications based on 5G networks

Scenario 4 Remote Site – AR Assistance to O&M

O&M personnel equipped with AR glasses display their operations to remote experts over 5G networks in real time. Understanding the details from the video broadcast on PC, mobile phones, or other terminals, the experts offer audio or text guidance in real time to the O&M personnel through maintenance missions. In addition, O&M personnel can interact with the experts as if they were onsite. This noticeably reduces maintenance costs and enables experts to share their experience, alleviating any shortage of technical expert resources.

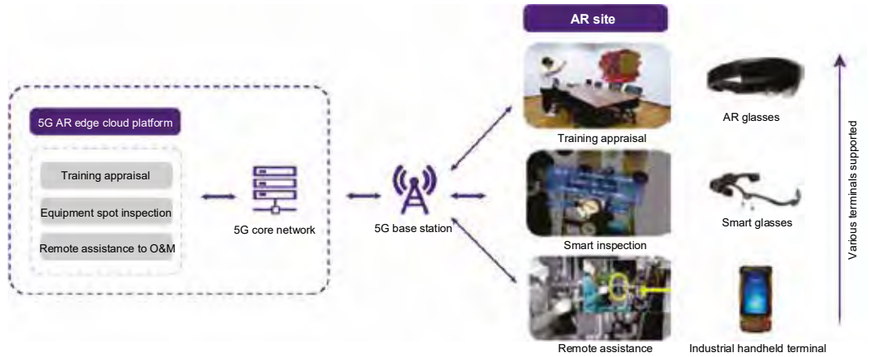


Figure 1-8: 5G connection for AR assisted O&M

Scenario 5 Remote Site – VR Assisted Complex Assembly

A virtual reality (VR) environment is set up to provide realistic training to those requiring new skills. Instructions can be provided to help them understand specific concepts and other related points. Simply by wearing a pair of VR glasses, learners can begin to practice as if they were interacting with real equipment. 5G networks enable relevant instructions, valuable tips, and other training items to be provided and evaluation to be completed.

Figure 1-9: VR applications combined with 5G networks

Scenario 6 Remote Control – Remote Machinery Control

5G offers an effective solution to the issues of high risks and costs arising from operating engineering machinery in remote and hazardous locations, such as in mines and landfills. During construction, 5G communication enables remote manipulation and allows a single worker to control multiple machinery while also improving coordination among these machines. This approach is conducive to safer construction while also offering higher efficiency and less resource consumption. During quality inspection, 5G-powered data recording enables data analysis of real life construction environments, providing input for issue reviews, backtracking, and solution optimization. Smart construction with self-optimization can be implemented in this way.

Figure 1-10: Remote control of excavating machinery

Scenario 7 Remote Control – AGV Control

In the electronics, machinery, cigarette, textile, and papermaking industries, automatic guided vehicles (AGVs) are widely applied, with exacting requirements on their movement, teamwork control and coordination, and smart dispatching. 5G networks offer better ways to fulfill these requirements. With low-latency and high-reliability connections, movement control will be more precise and data uploads will be smoother. They also enable AGVs to connect a massive number of Internet of Things (IoT) devices, facilitating flexible manufacturing, smart production, and smart management while also implementing smart transportation, warehousing, and automatic operations in manufacturing, logistics, and inspection links.

Figure 1-11: 5G-based remote control of AGVs

Scenario 8 Remote Control – Robot Control

Low-latency 5G connections enable reliable, quick data transmission between industrial robots and cloud-based control platforms, facilitating 24/7 remote robot control. At the production base, programmable logic controller (PLC) upgrade, data collection and analysis, and fault diagnosis and troubleshooting can also be completed for robots in remote areas. This is essential for the related industries to improve efficiency and reduce costs.

Figure 1-12: Robot control based on 5G technology

Scenario 9 Remote Control – Production Line Device Control

In smart factories, programmable logic controller (PLC) is software defined at the site and production line levels, and manufacturing execution system (MES), supervisory control and data acquisition (SCADA), and robot collaboration and dispatching programs are centralized onto the cloud-based servers to increase flexibility of control part deployment. Such techniques underline the value of high-performance 5G communication. With 5G modules added to associated control parts, reliable low-latency mobile access and data exchange are implemented for the input/output (I/O) modules, conveyors, valves, and robots. This enables centralized control in production workshops and empowers flexible smart factories production.

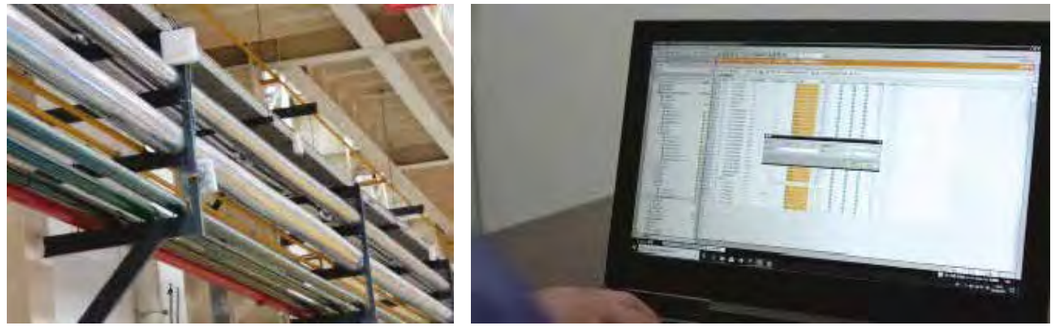


Figure 1-13: Production line device control system based on 5G

Scenario 10 Production Safety Behavior Analysis

With 5G networks, videos of production areas captured by cameras can be sent to servers at high speed to ensure real-time structured analysis of the content based on artificial intelligence (AI) and computer vision technologies, with instructions then delivered based on the analysis results. This approach helps with accurate behavior identification and status detection of dangerous equipment. Alarm area monitoring and video backtracking can be implemented as well to provide the basis for safe production management in factories.

Figure 1-14: 5G-powered industrial vision and smart safety detection

Scenario 11 5G PLC

5G networks enable a programmable logic controller (PLC) unit to send data in real time to other PLC units and in-factory systems with high security performance. This reduces the need for costly physical cabling and facilitates production line capacity matching required for flexible manufacturing. In addition, the data of numerical control machine tools, tiered warehouses, and assembly lines can be reliably transferred to big data platforms at high speed, enabling enterprises to perform real-time analysis and optimize processing, capacity, and energy consumption based on the analysis results.

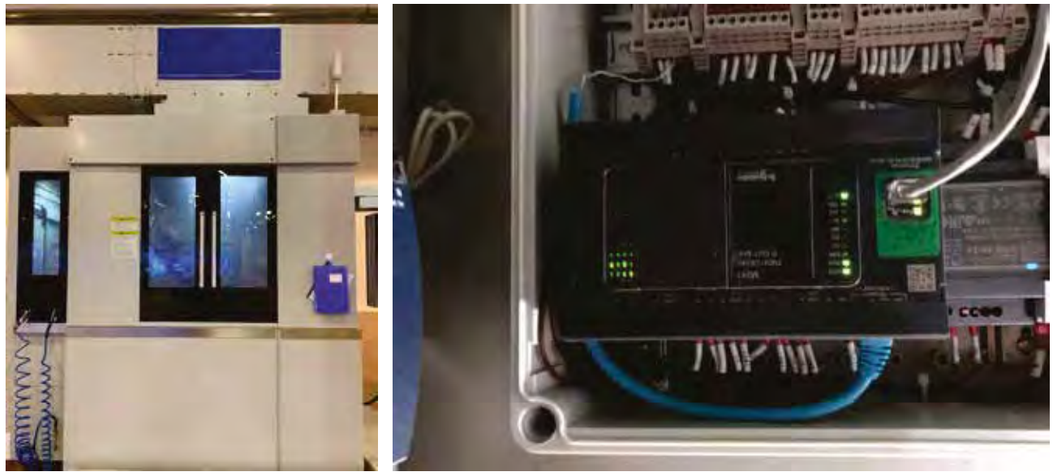


Figure 1-15: 5G-based PLC data collection

4. Use Cases

China Mobile has already developed 5G industrial Internet use cases across 11 categories of application scenarios, covering automobile manufacturing, engine manufacturing, robots, engineering machinery, civil construction, furniture, electrical appliances, and textiles. These use cases have played an active role in encouraging industrial enterprises to pursue smart operation models, achieve new developments, and seek transformation and upgrade.

Case 1: 5G-Powered Steam Turbine Defect Detection

In March 2019, China Mobile and a Zhejiang manufacturing enterprise successfully developed a 3D characteristic defect detection for steam turbines. China Mobile built 5G networks to provide high-bandwidth transmission of 3D cylinder data required for real-time 3D modeling. Seven to eight engineers were once required to perform defect detection for cylinders, metal blades, and other steam turbine components, and the detection result records were not that complete and accurate. This project improved the efficiency significantly. The 2 to 3 days of defect detection time was reduced to three to five minutes, and the detection results could be accurately recorded to help issue backtracking.

Figure 1-16: 5G-powered 3D modeling for steam turbines and the metal blades

Case 2: 5G-Powered Remote Device Maintenance

In July 2019, China Mobile assisted a machinery firm in achieving remote device maintenance over 5G networks. The 5G networks provided a secure transmission channel between the local digital modules and remote devices so that the operating status, parameters, sensor data, and site monitoring videos could be transferred to the local monitoring center in real time. As a result, the firm was empowered to complete remote device monitoring, information collection, fault alerting, and predictive maintenance. Remote maintenance could also be achieved at the monitoring center for the devices based on collected information relating to operating parameters and site videos. As a result, the firm was provided with a new tool for reducing costs and improving efficiency.

Figure 1-17: Remote device maintenance based on 5G networks

Case 3: 5G-Powered Remote Excavator Control

In March 2019, China Mobile helped an engineering machinery company develop a 5G-based remote excavator and demonstrated this machinery system in China's northern Xiong'an District. A remote command cabin starts and completes authentication on the cloud platform over a 5G network and then sends its command seat information to query available excavators from the cloud platform. After the command cabin chooses an excavator, the cloud platform sends it activation instructions and the network address of the command cabin. After starting up, the excavator sets up connections to transmit site videos to the command cabin. Thanks to the high bandwidth of the 5G network, the remote engineer is concurrently provided with a panoramic view of the construction site in addition to video feeds from multiple angles. The low-latency of 5G networks ensures that the end-to-end latency from the excavator to the command cabin (video processing considered) does not exceed 150 ms, enabling the engineer to operate the equipment as if they were on site.

Figure 1-18: Remote excavator powered by 5G

Case 4: 5G-Enabled Remote Robot Control

In April 2019, leveraging its leading 5G networks, China Mobile supported a Zhejiang robot manufacturing enterprise in successfully developing an accurate remote robot control project. The high-speed and low-latency connections of 5G networks enabled the enterprise to break away from previous one-to-one control mode. Remote introductions reached control terminals, such as automated guided vehicles (AGVs), mechanical arms, and equipment on product lines, immediately after they were sent, ensuring rapid, accurate control. In addition, equipment connections, data collection, and remote control were completed over wireless networks. This facilitated cross-region centralized control and remote maintenance with greatly reduced costs.

Figure 1-19: Remote robot control based on 5G

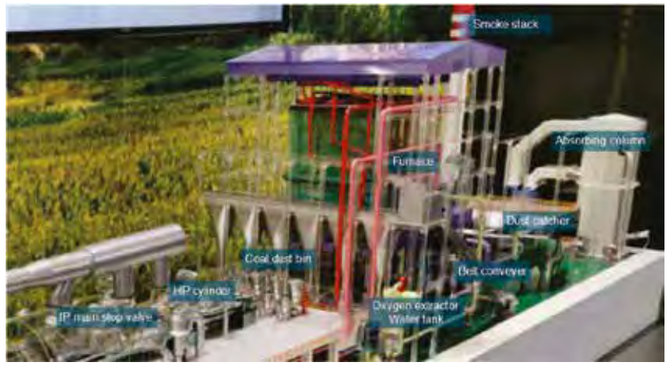
Case 5: 5G-Powered Production Line Control

In May 2019, a furniture manufacturing company in collaboration with China Mobile successfully conducted a 5G-powered smart production workshop project. With the massive connectivity and low latency capabilities enabled by China Mobile's 5G networks, the company achieved mutual connections between the workshop supervisory control and data acquisition (SCADA) system and sewing machines, spring machines, and viscose assembling machines. The end-to-end latency was below 25 ms. 5G networks replaced original wired networks, allowing the company to ease product line adjustment in response to production plan changes and equipment upgrades while also minimizing hidden production hazards caused by aged cables. As such, the project offered strong support for the company to pursue flexible manufacturing with high reliability and safety.

Figure 1-20: On-cloud centralized control for a furniture workshop powered by 5G

Case 6: 5G-Enabled AR Remote Assistance

In 2019, China Mobile worked with an electric group to pilot an AR remote coordination project based on 5G mobile networks. With 5G connections, equipment images captured by AR terminals and other production data were collected and uploaded in real time to enable instant fault alerting on the remote diagnosis platform, ensuring accurate, prompt maintenance. Smart risk analysis and data fetching were also supported, facilitating backtracking, data mining, and other functions associated with smart device control. With original wired lines replaced by 5G networks, cable routing and manual attendance were noticeably reduced, helping reduce costs while ensuring secure, efficient monitoring. In addition, 5G geofencing, remote tool setting, smart data collection, and other useful applications were implemented, enabling the group to make great progress in accomplishing smart production.



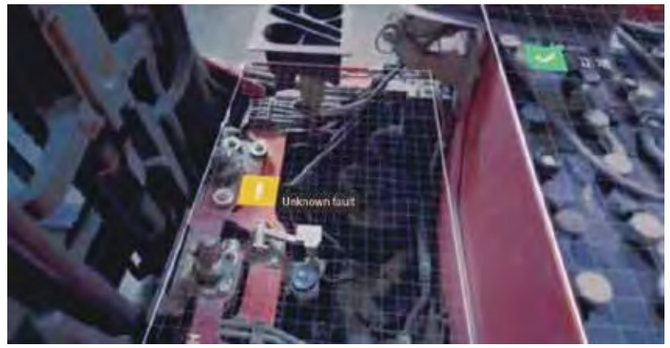


Figure 1-21: AR remote assistance based on 5G networks

5G Smart Energy

Rapid economic development has introduced higher requirements for modern energy systems. China Mobile takes full advantage of 5G networks to provide dedicated solutions for smart grid and smart mining to support high-quality development within the energy industry.

Growing electric power consumption and emerging challenges ahead of grid development resulted in an urgency to build secure, efficient, and green smart grid systems. Electric power communication plays a pivotal role in developing such systems. China Mobile is determined to support the upgrade of electric power communications through leading 5G networks that provide secure, real-time, flexible, and reliable electric power services.

In China, the mining industry plays an important role in economic development thanks to abundant mineral resources. The new trend of pursuing mechanical, automatic, information-based, and smart mining businesses are creating increased basic demands for high-quality network services. 5G supports high speed, low latency, and massive connectivity, offering a powerful tool to fulfill these demands and promote the development of unmanned mining operations.

5G Smart Energy

1. Service Requirements

1.1 Smart Grid

Complete all-optical backbone networks and reliable, efficient connections are already used on prime grids of 35 kV and higher, with optical networks reaching power plants, substations, self-owned properties, and business offices. However, facing the increased adoption of large-scale distribution automation, low-voltage centralized metering, distributed energy access, two-way user interaction, smart inspection, and mobile operations, existing optical networks are falling short of the exploding communication needs. The entire electric power industry is calling for stronger communication capabilities across all links spanning from generation, transmission, transformation, distribution, and usage.

Requirement 1: Flexible Access and Convenient O&M for Power Generation

Self-built fiber rings, wireless private lines, and Wi-Fi networks are mostly used for power plant and substation communications. However, fiber rings require high costs and do not allow for flexible data access. Wireless private lines result in high O&M costs and require expensive terminals, compounded by challenging spectrum acquirement and limited bandwidth. Wi-Fi networks are vulnerable to interference and troubled with poor security and service assurance.

Requirement 2: Efficient Inspection and Real-Time Backhaul for Power Transmission

In transmission line inspection based on unmanned aerial vehicles (UAVs), the console-UAV communication is mainly based on 2.4 GHz Wi-Fi or proprietary protocols. Using such methods, the effective control radius is within 2 km, and the bandwidth is too limited to support real-time video transfer, unable to meet the long-distance and remote diagnosis requirements.

Requirement 3: Diverse Access, Reliability, and Security for Power Transformation

Mobile access in substations is mainly based on Wi-Fi, which uses non-licensed bands and cannot ensure service security. Wi-Fi has limited channels and cannot ensure stable transmission latency or high-speed handover, lacking of the capabilities to support diverse services required for power transformation.

Requirement 4: Massive Monitoring and Real-Time Control for Power Distribution

Power distribution involves an enormous number of devices distributed across a large area, creating frequent two-way exchanges for real-time monitoring and remote control. The high costs and challenging O&M prevent optical networks from providing access to such a large number of terminals. Existing wireless networks cannot ensure the security, low latency, or precise timing required for power distribution monitoring, measurement, and control management.

Requirement 5: Elaborate Management and Personalized Services for Power Usage

In centralized power metering, concentrators collect and send data to metering centers. This lacks two-way real-time interaction and does not support the smart power usage, personalized services, or wide-ranging in-depth usage data collection required for elaborate management.

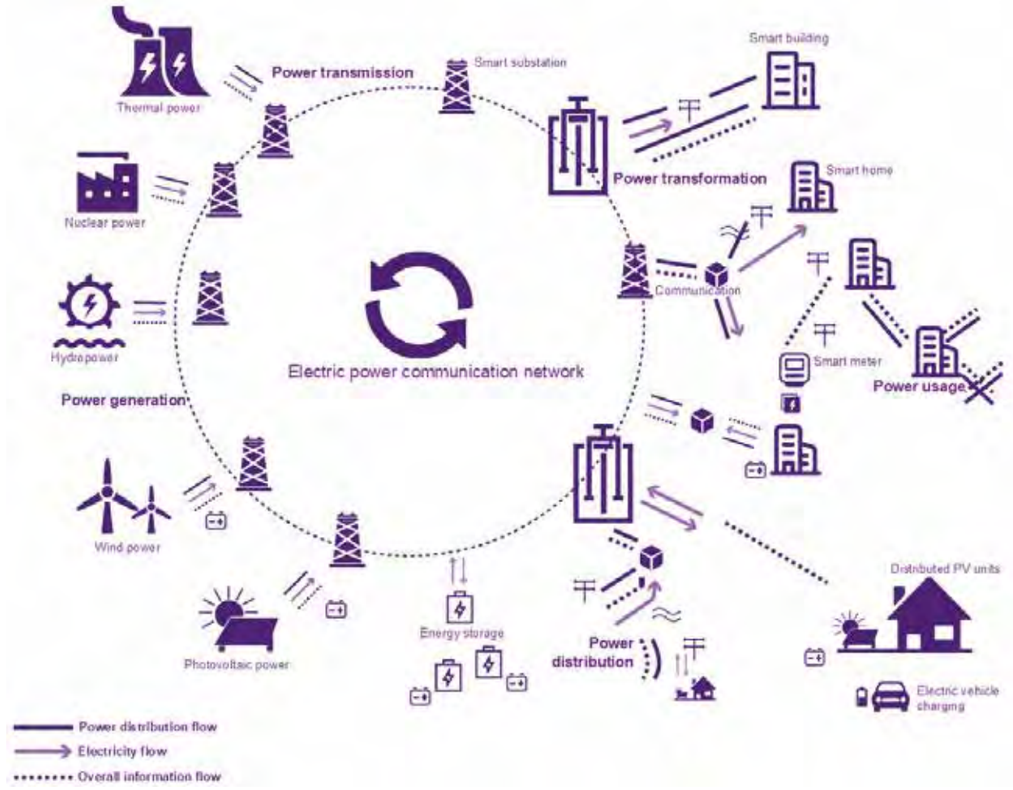


Figure 2-1: Positioning of electric power communications in smart grids

Traditional wireless networks cannot guarantee the mandated requirements of electric power businesses relating to communication security and isolation. 5G boasts high speed, low latency, and massive connectivity. Combined with network slicing and edge computing, 5G mobile networks offer the ideal solution for the electric power industry to achieve high security and support the diverse services for power generation, transmission, transformation, distribution, and usage, driving the industry to pursue rapid business development.

1.2 Smart Mining

Requirement 1: Unmanned Mining Operations

China's Innovation Action Plan for Energy Technology Revolution (2016–2030) has explicitly set a goal for harmless coal mining through innovation. By 2020, smart mining will essentially be completed, with the number of coal-wall workers reduced by more than 50% in key mining areas. By 2030, safe mining will be fully achieved with coal-wall operations unmanned in key mining areas.

Figure 2-2: Unmanned mining through remote control for improved safety

Requirement 2: Transparent Mining

Transparent mining refers to the elaborate monitoring of production status. 5G communication modules are attached to automated mechanical components to guarantee wireless access to 5G networks in mining areas. As such, remote monitoring and cloud-based analysis can be implemented to support transparent mining.

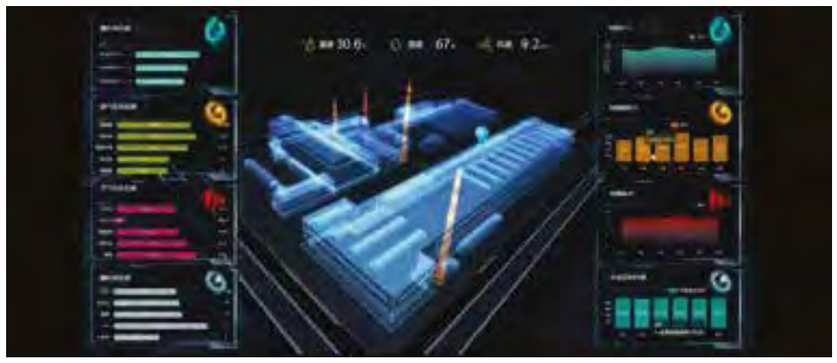


Figure 2-3: Transparent mining: video and equipment data collection and upload

Requirement 3: Mining Private Networks

Underground communication in mining areas is primarily based on Wi-Fi, 3G, and 4G technology. Wi-Fi transmission is too unstable to support Internet of Things (IoT) services, and 3G bandwidth is too limited to work with IoT devices, despite being sufficient for high voice service quality. In addition, 4G has proven unable to adapt to video surveillance and remote control applications. In some scenarios, wideband transfer is still used on mining equipment, such as fully mechanized mining outfit, in order to ensure high stability. 5G networks, combined with edge computing technology, address such pressing needs well for smart mining transformation by ensuring core data security and supporting artificial intelligence (AI) services and remote control applications.

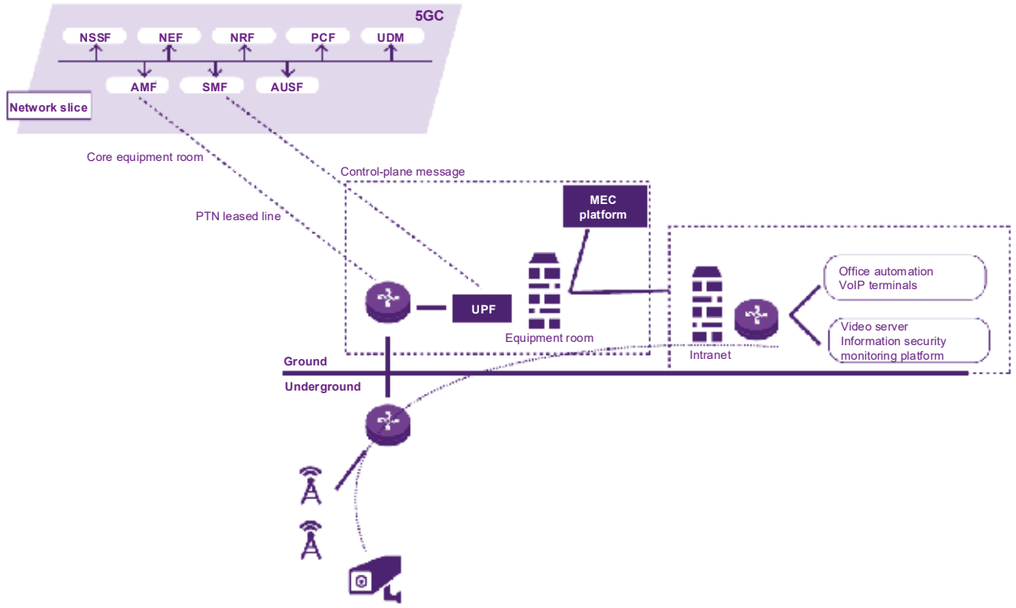


Figure 2-4: Mining private networks: converged networking to ensure highly mobile and secure connections

5G networks enable high-speed and low-latency data transmission, providing strong support for the mining industry to pursue unmanned and transparent mining and construct dedicated private networks in line with diverse ground and underground service requirements.

2. Solution Overview

2.1 Smart Grid

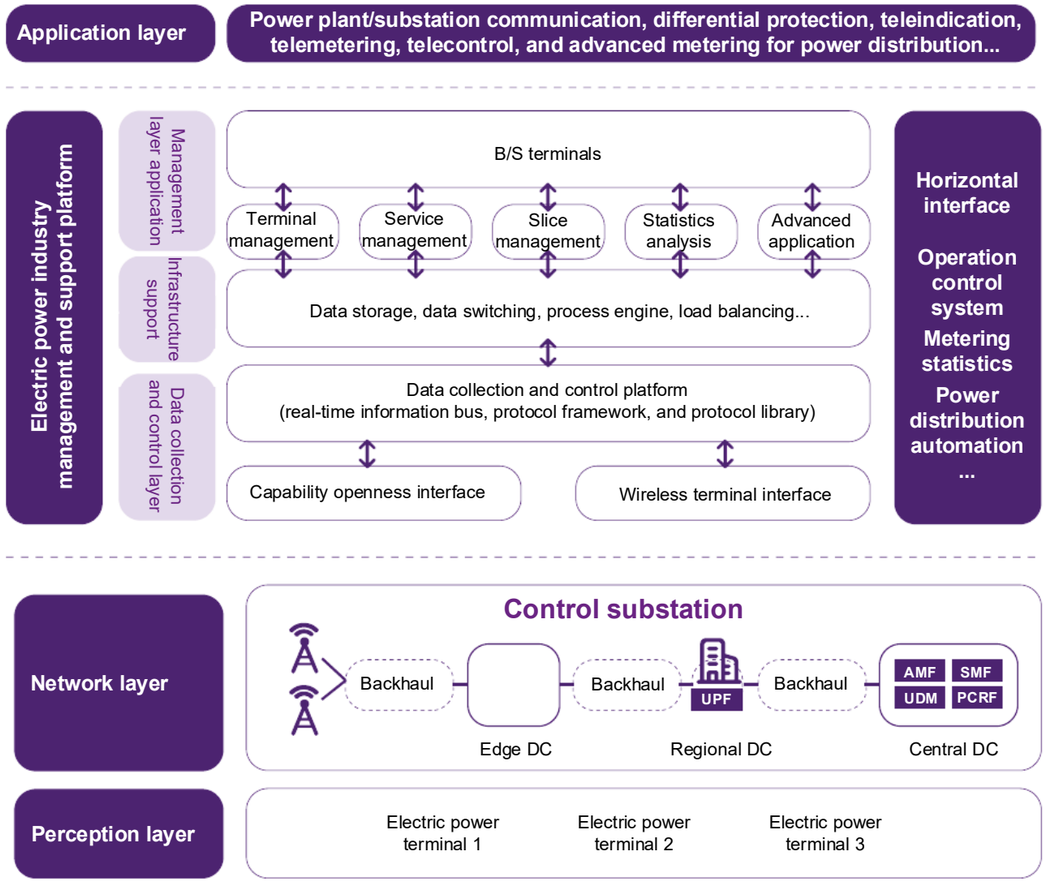


Figure 2-5: 5G application solutions for smart grids

Backed by 5G technology, China Mobile provides an improved wireless access solution for the electric power industry to deliver breakthroughs in power plant and substation communications, smart inspections for power plants, unmanned inspections for transmission lines, comprehensive monitoring for substations, and differential protection, automated teleindication, telemetering, and telecontrol, phasor measurement unit (PMU) support, and advanced metering for power distribution. The following illustrates the architecture of the 5G smart grid solution.

Perception layer: This layer consists of various service terminals. In line with the 5G smart grid requirements on terminal forms, reconstruction costs, mobility, load capacity, and power supply, customer premise equipment (CPE) and embedded modules are a good choice for differential protection, automated teleindication, telemetering, and telecontrol, and PMUs on power distribution networks. Embedded modules are also suitable for power plant and substation communications, smart inspection for power plants, unmanned inspection for transmission lines, comprehensive substation monitoring, and advanced metering.

Network layer: Custom slices are provided, making full use of 5G networks to enable various smart grid services. Each slice can have multiple instances to suit site requirements, enabling customers to differentiate services in line with network resources and service demands.

Platform layer: It provides a service communication management platform based on telecom capability openness. The platform is divided into data collection and control, infrastructure support, management and application, and horizontal interfacing, and is responsible for connection management, terminal management, and slice management of 5G networks.

Application layer: 5G smart grids primarily involve control and collection applications. The former category includes power plant and substation communications and differential protection, automated teleindication, telemetering, and telecontrol, and PMUs for power distribution. The latter includes smart inspection for power plants, unmanned inspection for transmission lines, comprehensive substation monitoring, and advanced metering.

2.2 Smart Mining

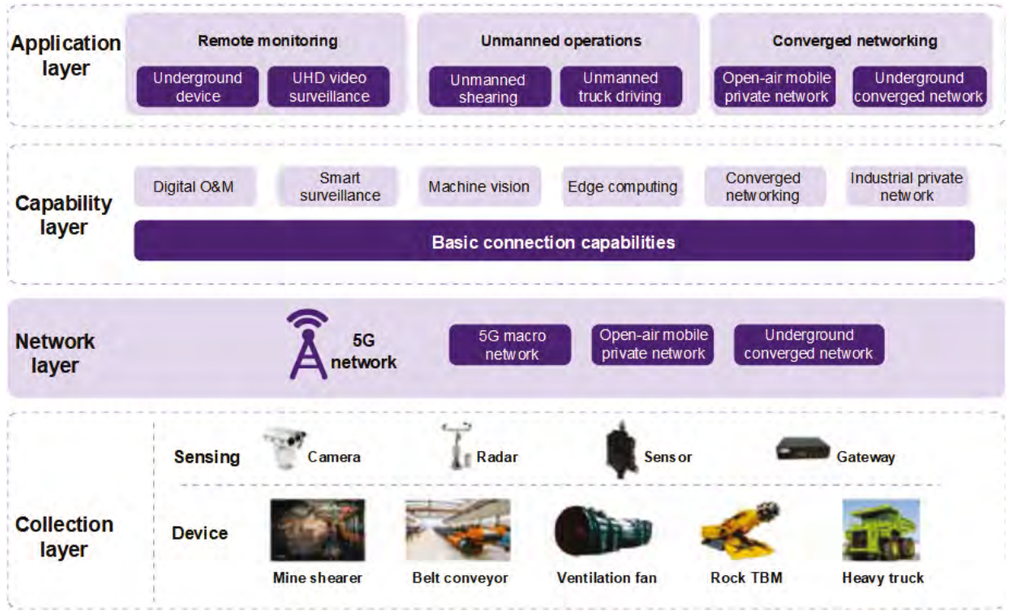


Figure 2-6: Architecture of smart mining solutions

Based on its leading 5G technology combined with excellent terminal and platforms capabilities, China Mobile provides unique Internet of Things (IoT) connection solutions to enable diverse ground and underground applications required for least-manned and even unmanned mining.

Collection layer: Mining device data is collected through various terminals, including ground and underground sensors, cameras, and dedicated gateways. These terminals help customers sense and manipulate mining equipment.

Network layer: This layer delivers services in line with ground and underground environments by leveraging the advantages of 5G networks relating to high speed, low latency, and massive connectivity.

Platform layer: A general-purpose basic platform of industrial Internet is provided, ensuring quick access and digital O&M for cloud-based devices through connection management, access management, and data analysis. It also provides standard and self-service interfaces to accommodate cloud platforms for vertical industries, such as manufacturing, electrical appliance, and energy.

Application layer: 5G-based applications are hosted, covering data collection, UHD video surveillance, unmanned excavation, unmanned truck driving, private mobile networking, and converged networking required for smart mining in underground and open-pit environments.

3. Application Scenarios

3.1 Smart Grid

Smart grid applications are utilized for power generation, transmission, transformation, distribution, and usage. 5G offers powerful features capable of fulfilling differentiated service requirements of electric power communication networks.

Scenario 1: Smart Inspection

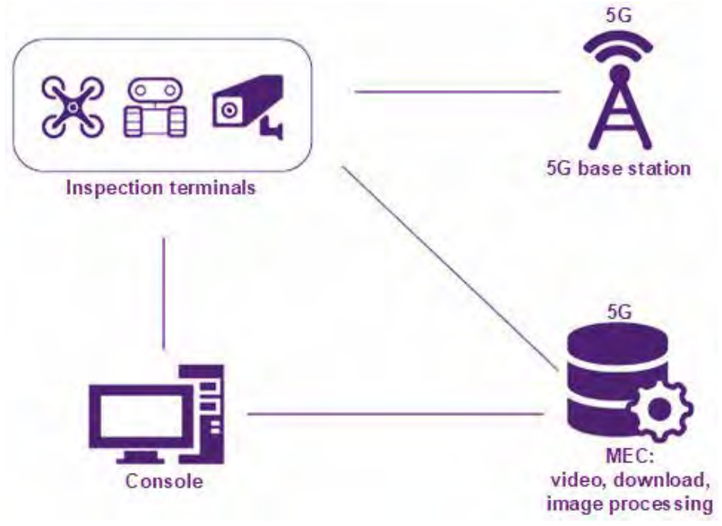


Figure 2-7: Smart inspection

5G supports high speed, low latency, massive connectivity, and high mobility. In power generation, transmission, and distribution, these features offer powerful tools to implement remote control and data collection of inspection terminals while also leveraging unmanned aerial vehicles (UAVs) and robots to increase inspection coverage and improve efficiency. Multiple channels of UHD videos (above 100 Mbps) and diverse sensing information (infrared, humidity, temperature, radiation, millisecond-level remote control sensors) can be transferred at high speed to support smart inspection.

5G Network Performance Requirements

Service Type	Service Name	Communications Requirement			
		Bandwidth	Reliability	Latency	Connection Quantity
Data collection	Smart inspection	100 Mbps	99.9%	≤ 200 ms	100,000

Scenario 2: Differential Protection for Power Distribution

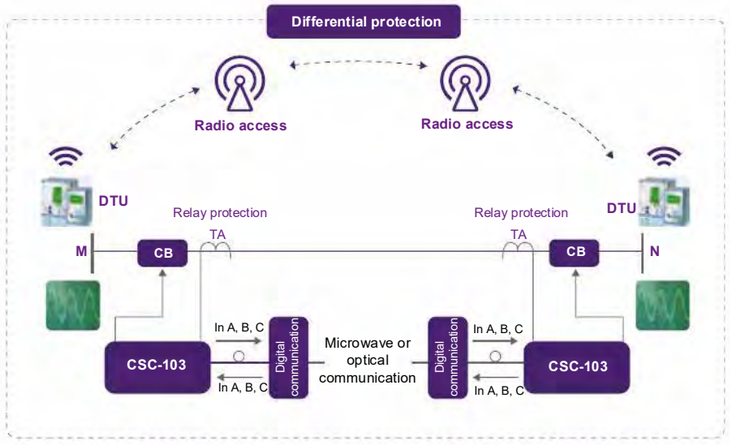


Figure 2-8: Differential protection on power distribution nets

With differential protection in power distribution, current values (vector) of two or multiple ends at the same moment are compared. If the difference exceeds the threshold, a fault occurs and differential protection is triggered to switch power lines to the standby ones. This function enables faults to be precisely located and isolated, and greatly reduces power failure durations.

Differential protection requires end-to-end latency to be less than 15 ms and timing deviations to be within 10 μs. Such exacting requirements are impossible with 2G, 3G, and 4G networks. 5G will offer sufficient communication capabilities for differential protection, helping promote its applications, improve power distribution, and transform smart grids.

5G Network Performance Requirements

Service Type	Service Name	Communications Requirement				
		Bandwidth	Reliability	Latency	Timing	Connection Quantity
Data collection	Differential protection	≥ 2 Mbps	99.999%	≤ 15 ms	10 μs	10X/km^2

Scenario 3: Advanced Metering

In power usage scenarios, advanced metering is based on smart meters to complete in-depth collection of power usage information while also fulfilling smart usage and personalized service requirements. For industrial users, energy service systems are used to collect data and provide smart analysis services to support efficient energy management. For home users, Internet-based energy management services are provided to enable usage and price information sharing, and to facilitate power usage optimization.

Existing metering focuses on low-voltage centralized models. In the future, based on current remote metering, load monitoring, line loss analysis, power quality monitoring, power failure statistics, and demand-side management services, diverse applications will be developed to cater for multi-step electricity pricing, two-way interactive marketing, interactive value-added services, and distributed power monitoring and measurement.

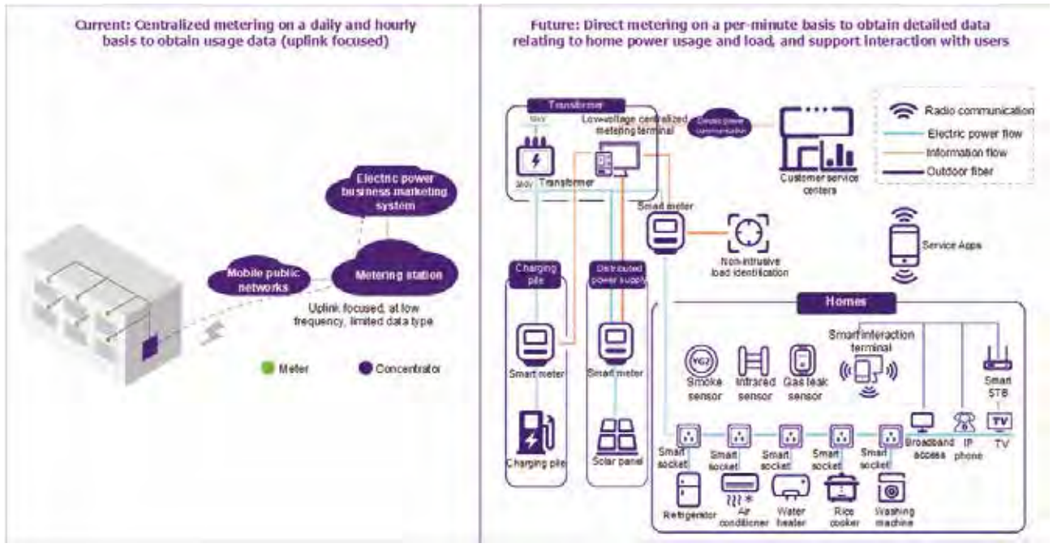


Figure 2-9: Comparison between direct and centralized metering

5G Network Performance Requirements

Service Type	Service Name	Communications Requirement				
		Bandwidth	Reliability	Latency	Timing	Connection Quantity
Remote control	Advanced metering	≥ 2 Mbps	99.999%	≤ 15 ms	10us	10X/km^2

Scenario 4: PMU for Power Distribution

Figure 2-10: PMU for power distribution

In power distribution, phasor measurement units (PMUs) obtain high-precision timing from 5G networks to determine accurate time scales for the voltage and current phases of hub nodes of electric power systems, and then send this data to the monitoring station. Based on the data obtained, the monitoring station determines the exact fault locations and provides grid disconnection, generator tripping, and load switching solutions in the cases of power system disturbance.

5G Network Performance Requirements

Service Type	Service Name	Communications Requirement				
		Bandwidth	Reliability	Latency	Timing	Connection Quantity
Remote control	PMU	≥ 2 Mbps	99.999%	≤ 50 ms	≤ 1 μs	10X/km^2

Scenario 5: Automated Teleindication, Telemetering, Telecontrol for Power Distribution

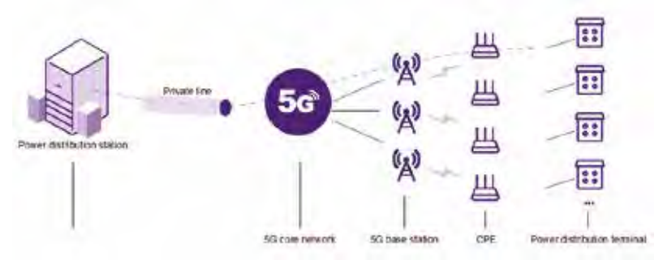


Figure 2-11: Teleindication, telemetering, and telecontrol for power distribution

In power distribution, teleindication is responsible for monitoring device status, including alarm status, switch positions, and valve positions. Telemetering aims to collect measured values on power grids, including measured current and voltage values. Meanwhile, telecontrol helps manipulate devices, such as switch disconnections. These three functions are based on the same network architecture and devices to complete communication between devices and distribution stations through the combined use of technologies involving computer, information, 5G networks, and system integration. Assisted by automatic relay devices, the functions combined enable line and device faults to be accurately located, improving power distribution reliability.

The three automated functions require access from distribution stations to power generation control segments, creating massive challenges associated with security isolation, which cannot be addressed with traditional radio communication systems. 5G slicing enables end-to-end security isolation required for both communication reliability and secure service access.

5G Network Performance Requirements

Service Type	Service Name	Communications Requirement			
		Bandwidth	Reliability	Latency	Connection Quantity
Remote control	Automated tele-services	≥ 2 Mbps	99.999%	≤ 50 ms	10X/km^2

Scenario 6: Accurate Load Control

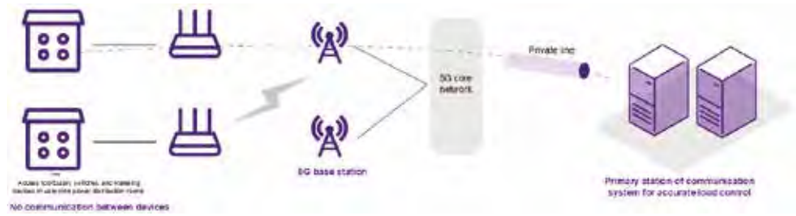


Figure 2-12: Accurate load control

In power distribution, precise load control devices are used to rectify faults on the power grid such as fast drops in frequency and overuse of power on inter-province lines in their early phases. The control systems fall into two categories depending on the requirements: the millisecond-level control system that implements fast load control and the second- or minute-level control system that is more user-friendly and interactive.

In the precise load control system, the control object is precise for interruptible loads within the production enterprise to mitigate the impact on high-level users. Through precise control, unimportant loads that can be interrupted such as electric vehicle charging piles and discontinuous power supply in factories are cut off to reduce social impacts. According to the granularity of small service control and the need for quick response to faults, low-latency load control on electrical devices is required. This imposes stricter requirements on the communications system for ultra-low latency and high reliability.

5G Network Performance Requirements

Service Type	Service Name	Communications Requirement			
		Bandwidth	Reliability	Latency	Connection Quantity
Control	Precise load control	10 kbps to 2 Mbps	99.999%	≤ 50 ms	10X/km^2

Scenario 7: Power Grid Emergency Communications

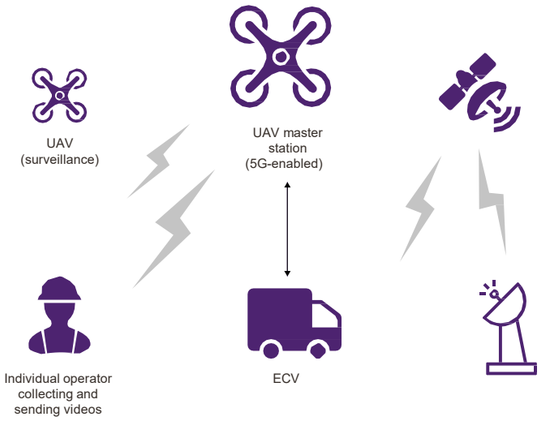


Figure 2-13: Power grid emergency communications

During disasters such as earthquakes, storms or blizzards, and floods or for fault rectification, emergency communications on the power grid is required to provide on-site support for rescue and relief with emergency communications vehicles (ECVs). An ECV is equipped with a 5G-enabled master station in the form of an unmanned aerial vehicle (UAV), which quickly covers a radius of 2–6 km in the disaster-stricken area. Other UAVs or devices for individual operations can access the master station to transmit HD video data or initiate multimedia trunking calls. The ECV pools all information on the site and, with mobile edge computing (MEC), implements a variety of local applications such as on-site video surveillance, dispatch and command, and comprehensive decision-making. The ECV can also feed sufficient power to the UAV master station to operate for over 24 hours uninterrupted.

5G Network Performance Requirements

Service Type	Service Name	Communications Requirement			
		Bandwidth	Reliability	Latency	Connection Quantity
Collection	Power grid emergency communications	20–100 Mbps	99.9%	Video: ≤ 200 ms Control: < 100 ms	5–10 in a local area

3.2 Smart Mining

Scenario 1: Remote Monitoring — Collecting Data from Underground Equipment

Unmanned and intelligent operations reduce the need for operators to personally go underground to implement them. Instead, the personnel can observe the running status of underground equipment in the safety of the ground control center. Therefore, the data on the operation of mining vehicles and machines must be collected first. Devices such as 5G-dedicated communications modules and sensors collect and then transmit this data in real time, as well as monitor parameters to keep track of device dynamics, enabling comprehensive sensing of coal mines.

Figure 2-14: 5G-based underground device data collection

Scenario 2: Remote Monitoring — HD Video Surveillance

In China, exemplary application achievements have been made in wired remote control, using cables or fibers, of intelligent working planes for underground operations. However, there is still a lack of such applications in terms of wireless communications. With 5G HD video surveillance, dust-proof HD cameras are installed on roadheaders, enabling converged access to the automation and information systems above and in the mines.

Figure 2-15: 5G-based HD video surveillance

Scenario 3: Unattended Operation — Unattended Mining

The 5G low-latency capability enhances the control of mining equipment in real-time. Taking a roadheader as an example, an anti-collision and an environment monitoring system are installed on the roadheader to transmit data back to the remote control center. The control center controls the roadheader through a connected 5G-enabled intrinsically safe converter. The solution effectively improves production safety and facilitates the realization of unmanned mining.

Figure 2-16: 5G-based unmanned mining

Scenario 4: Unmanned Operation — Driverless Mining Vehicle

In open-pit mines, unmanned operation of mining vehicles relies on technologies such as inertial navigation using the BeiDou Satellite Navigation System or differential GPS, as well as laser and multi-mmWave radars to control steering, throttle, and braking. With AI-based control, electric wheels travel according to preprogrammed routes, with lateral and course errors controlled to the centimeter, greatly reducing labor costs and vehicle loss caused by manned operation.

Figure 2-17: 5G-based unmanned mining vehicle operations

Scenario 5: Converged Networking — Open Pit Mobile Private Network

Open pits are large in area and excavation equipment needs to change the mining area after a certain distance. With 5G base stations installed on vehicles, the network coverage can be adjusted based on the terrain in the mining area to meet varied 5G application requirements.

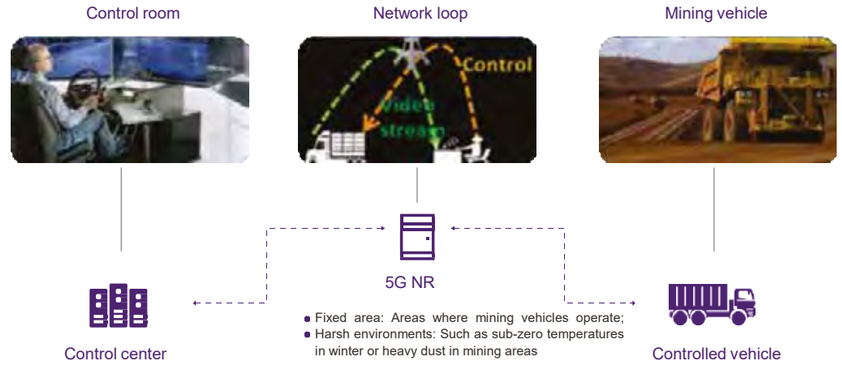


Figure 2-18: Architecture of the 5G-based open-pit mobile private network

Scenario 6: Converged Networking — Underground Converged Network

Underground mining faces challenges in the management of miners, the monitoring of working plane data, the security of control signaling, remote control of working plane devices in real time, and frame freezing in HD video transmission. Operations are at a long distance from the ground, underground hardware needs to be highly reliable, and the working planes are unfixed. 5G enables wireless network coverage for underground operations to facilitate unmanned mining.

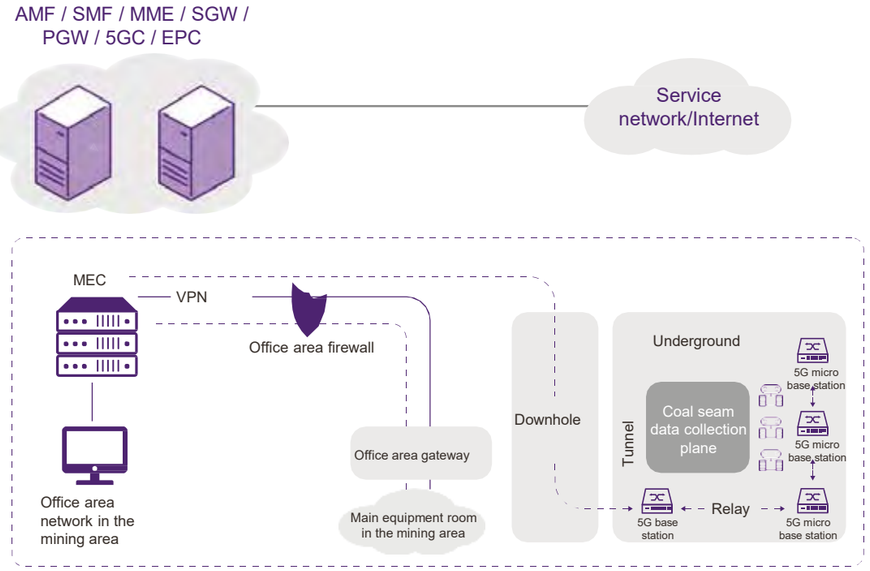


Figure 2-19: Architecture of the 5G-based underground converged network

4. Use Cases

4.1 Smart Grid

Case 1: 5G + Smart PV Plant

In January 2019, China Mobile and State Power Investment Corporation jointly built China's first 5G smart photovoltaics (PV) plant in Jiangxi Province, implementing wireless, unmanned, networked, and interactive smart applications. In the scenario of intelligent inspection, the application platform in the central control center in Nanchang remotely controlled unmanned aerial vehicles (UAVs) and robots in the Gongqing PV plant in Jiujiang to conduct inspections. The UAVs and robots send video and image data of the inspections to the central control center in Nanchang in real time. Wireless data transmission and remote device control were verified. In the intelligent security scenario, panoramic HD cameras were used for monitoring environments in real time to facilitate remote control of the plant and substations. In the individual operation scenario, audio and video data transmission on smart wearable devices and personnel positioning enabled experts in Nanchang to provide remote direction for on-site personnel.

Figure 2-20: 5G + smart PV plant

Case 2: 5G + Smart Substation

At the beginning of April 2019, China Mobile worked closely with State Grid Henan Electric Power Company to complete the construction and usage of China's first 5G test station of a 500 kV high-voltage substation in Zhengzhou City. The 5G network successfully implemented remote HD video interaction between the substation and the provincial electric power company. This test verified the large bandwidth and high reliability of 5G networks in complex, highly electromagnetic environments. The substation's communications previously relied heavily on wired connections. However, 5G will greatly save wired networks and provide new methods for management and control such as remote control and HD video surveillance for the substation services. The solution will significantly reduce the risks of manual operations and upgrade services such as monitoring, operation, and security protection to become intelligent, visualized, and HD video-based.

Figure 2-21: 5G + smart substation

Case 3: 5G + Differential Protection for Power Distribution Networks

In January 2019, China Mobile, China Southern Power Grid, and Huawei conducted China's first field test of differential protection for intelligent distributed power distribution using 5G networks in Bantian, Shenzhen. This is the first phase of the field test for the 5G smart grid application. An actual complex network environment was built for the test. With a single base station, the average latency between Distribution Terminal Units (DTUs) was under 10 ms, and the time serving precision over the 5G air interface was within 300 ns. This solution delivers low-latency communications and high-precision time serving in microseconds for power grid control services such as differential protection for intelligent distributed power distribution. This field test preliminarily verified the feasibility of 5G-based power grid control services and basic functions of 5G network slice management.

Figure 2-22: 5G + differential protection for power distribution networks

Case 4: 5G + Power Distribution Network PMU

In March 2019, China Mobile successfully passed China's first end-to-end test of the micro-synchronous phasor measurement unit (PMU) application on intelligent power distribution networks using a 5G network in the 5G test field in Lingang New City. In this field test, the communications latency between the PMU and the power analog master station was less than 10 ms, and the communications frequency reached 100 times per second. The test data and results show that the highly reliable and low latency capabilities of 5G can meet the special requirements of the PMU for power distribution networks, such as a large number of communications measurement points, high communications frequency, low latency, and complex data types, facilitating the upgrade and development of automation in power distribution.

Figure 2-23: 5G + power distribution network PMU

Case 5: 5G End-to-End Power Grid Slice

In September 2019, China Mobile, China Southern Power Grid, and Huawei demonstrated the industry's first end-to-end management process of the 5G network slicing feature in Shenzhen. This process unprecedentedly implemented full streamlining of network slicing from the network element layer to the management layer and throughout the entire process from service subscription to product delivery. Three network slicing capabilities were built, including the slice for automatic remote communications, remote monitoring, and remote control in the production control area, video service slice in the management information area, and public service slice. Packets were injected on the transmission channel carrying public network services to simulate packet loss and frame freezing caused by congestion and verify slice isolation. The test result proved that an excess of traffic on the public service slice does not compromise the secure running of power services.

Figure 2-24: 5G end-to-end power grid slice

4.2 Smart Mining

Case 1: 5G-based Unmanned Mining Vehicle

In April 2019, China Mobile and a mining enterprise in Inner Mongolia jointly worked on a heavy-duty mining vehicle unmanned driving project. The project utilized the high-speed and low-latency features of 5G to implement autonomous driving of mining vehicles on the 5G network. The application scenarios included reversing the vehicle, loading the excavator, precise parking, automatic dumping, track planning, and autonomous obstacle avoidance.

Figure 2-25: 5G-based unmanned mining vehicle operations

Case 2: 5G-based Underground Converged Network

In July 2019, China Mobile and a mining enterprise in Shanxi province jointly worked on a 5G smart mining project. Based on the 5G network of China Mobile, some core network functions were deployed at the edge nodes to converge the networks above and under the ground. The solution met customers' requirements for security, real-time performance, and confidentiality, delivering unmanned and transparent smart mining.

Figure 2-26: Architecture of the 5G-based underground converged network

5G Smart Transportation

With a wealth of expertise and technologies developed and applied in sectors such as information technology, communications, transportation, and transportation management, smart transportation is intensively integrating with various new technologies, and related products are quickly being deployed on the market due to technological advancements. The smart transportation industry is now developing at a high rate. According to McKinsey and CMRC, the scale of China's smart transportation market is expected to reach CNY 92 billion by 2020, with a gross annual growth rate of over 20%.

Leveraging new technologies such as 5G+AICDE (Artificial intelligence, Internet of Things, Cloud computing, Big data, Edge computing), China Mobile has launched research and development in the cloud, pipe, and device fields in the transportation industry in terms of device, network, platform, and application, providing products and solutions in segmented transportation scenarios. With its "5G Plus Plan", China Mobile has initiated deep cooperation and demonstration of 5G network capabilities in the transportation industry, providing typical and personalized solutions. It aims to promote digitalization of the infrastructure, networked transportation services, intelligent transportation tools, and refined transportation management.

5G Smart Transportation

1. Service Requirements

China has been actively promoting intelligent modernization of the transportation industry. One major effort is the *Implementation Plan for Promoting Internet + Convenient Transportation to Drive Intelligent Transportation Development* released by the government. The thriving development of 5G network technologies provides support for smart transportation including data exchange, collaborative sensing, and collaborative decision-making and control. 5G capabilities such as high rate, low latency, and massive connectivity combined with key technologies such as mobile edge computing (MEC) and network slicing can effectively promote the implementation of smart transportation. This is achieved through multi-source sensing data convergence, high-performance computing, real-time vehicle-to-vehicle data interaction and collaboration, and integrated high-precision positioning.

Requirement 1: 5G+AICDE Enabling Development of the Transportation Industry

5G, combined with technologies such as AICDE, will fully utilize the multiplier effect. This allows for in-depth convergence and system innovation in building a new-generation ubiquitous intelligent transportation infrastructure that integrates transmission, storage, computing, and sensing. 5G can realize vehicle-road collaborative sensing, intelligent facility supervision, edge-cloud synergy control, and big data-based traffic planning. This further enables the all-domain connection, data interaction, and collaborative computing of vehicles, roads, and people. This way, the industry can achieve intelligent infrastructure upgrades making smart driving become a reality.

Requirement 2: Centimeter-Level High-Precision Positioning

The BeiDou Satellite Navigation System has been independently developed by China to defend national security and sustain economic and social development. It's self-reliant and has become an important national space infrastructure providing all-weather, all-time, and high-precision positioning, navigation, and timing services for global users. By establishing a ground-based augmented station, the system obtains differential information of positioning data. This occurs by using a positioning algorithm, and then the system broadcasts the data in a large range. By doing so, the system realizes high-precision positioning of various devices, accurate to centimeters in dynamic settings, and to millimeters in static environments.

Requirement 3: Autonomous Driving with Vehicle-Road Synergy

The vehicle-road synergy system implements intelligent collaboration and cooperation between vehicles and road infrastructures and between vehicles. The system is backed by advanced sensing and wireless communications technologies and is a new-generation intelligent road traffic system. This is designed to ensure safety in complex environments, provide proactive traffic control, and improve road network efficiency. 5G autonomous driving leverages 5G technologies to implement networked all-region sensing, collaborative decision-making, and smart cloud-based control. Demonstrations from low-speed to high-speed, closed to open, and cargo loading to human loading are being launched to accelerate the development of autonomous driving.

2. Solution Overview

1.1 5G Autonomous Driving Through Vehicle-Road Synergy

Based on its core technology, network, and industry resource integration capabilities, China Mobile proposed its 5G autonomous driving solution (namely 5G-V2X). The solution effectively improves the current autonomous driving technology utilizing bicycle intelligence. This further promotes the development of autonomous driving. It enhances vehicle-road-people synergy to link the vehicle system and the entire transportation system together, empowering smart transportation.

Device layer: 5G autonomous vehicles come with or are retrofitted with 5G communications modules, sensors, and computing systems. This allows for the construction of three functional units: vehicle-mounted sensing, vehicle-mounted decision-making, and vehicle-mounted control. The units and the high-precision positioning technology integrating GPS and optical sensing, allow autonomous vehicles to implement perceptive collection. Additionally, both allow for the basic computing of vehicle and road environment data. Moreover, 5G high-speed, low-latency, and massively connected high-performance networks implement the following: real-time transmission of environment data, vehicle data, and vehicle control data.

Regional control layer: The 5G network connects vehicles, roadside sensors, and MEC nodes to construct three functional units: regional sensing, regional decision-making, and regional control. This layer aggregates data regarding roads, infrastructures, and vehicles in a region to construct a 5D spatio-temporal model. The model allows for controlling environment data in each dimension in the region in real time and compensating insufficient vehicle sensing. The 5D spatio-temporal model and the MEC server process data in real time. This is done to formulate and deliver decisions related to regional autonomous driving.

Road synergy control layer: This layer consists of three functional units: data awareness, comprehensive decision-making, and road control. Based on the data collected and reported by the device layer and regional control layer, this layer implements global data management and model construction. This allows for the provision of decision-making at the overall policy level, such as global overall scheduling, regional traffic management, and vehicle scheduling, and delivers decisions to each system through the 5G network.

Application service layer: This layer carries specific applications and provides platform access capabilities and application services, meeting personalized requirements for customers including: governments, automotive enterprises, vehicles, and the public. For example, it provides regulatory organs with overall traffic data to optimize urban traffic management and vehicle operation units with autonomous driving applications. It further supplies remote vehicle diagnosis, and fleet management services to support vehicle operations. Lastly, it arranges automotive enterprises with vehicle running data collection and in-vehicle entertainment content services.

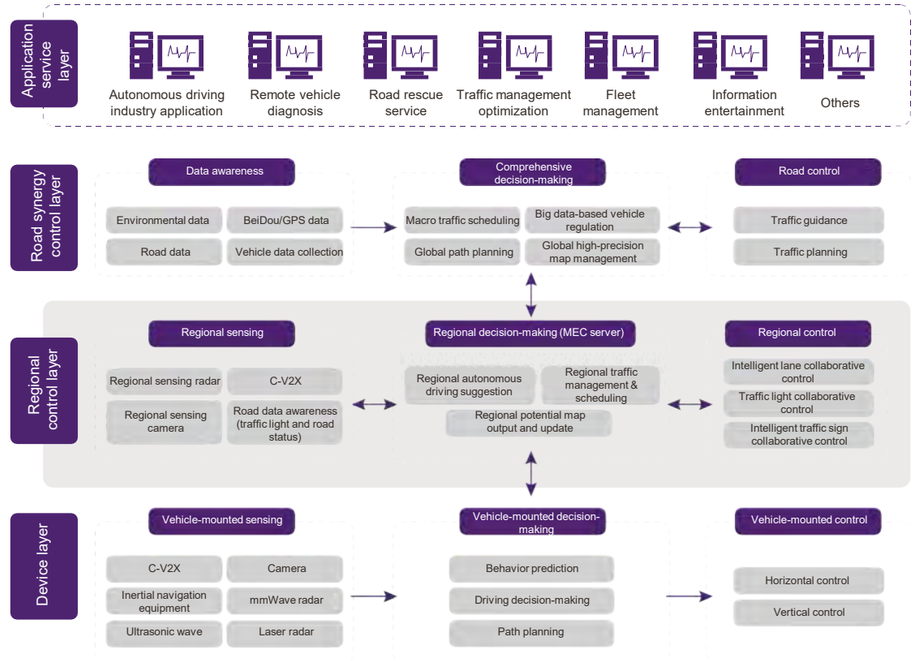


Figure 3-1: Architecture of the 5G autonomous driving application system using vehicle-road synergy hierarchical decision-making

2.2 Smart Transportation Hub

With the application of indoor cellular, big data, AI, and visualization technologies, operation management scenarios such as crowd distribution, displacement track, and people flow monitoring around sites or stations are becoming visualized, manageable, and controllable in time and space, allowing for more intelligent and data-based operation management of sites and stations. Intuitive images and quantitative data are there to support operation decision-making, data-based reconstruction, and passenger flow value conversion.

Perception layer: This layer mainly includes various service devices involved in the smart transportation hub scenario, including smart terminals, sensors, monitoring devices, and network devices.

Basic capability layer: This layer applies basic capabilities such as cloud computing, big data, AI, and Internet of Things (IoT), supporting data processing, transmission, and storage at smart transportation hubs.

Platform layer: This layer builds the data maintenance and analysis system, intelligent service workbench, digital station sub-platform, location service big data platform, and vehicle scheduling platform. This enables upper-layer service applications.

Application layer: This layer accommodates specific applications for different scenarios. This allows for the implementation of: passenger service, business district operation, station operation, and power and environment monitoring.

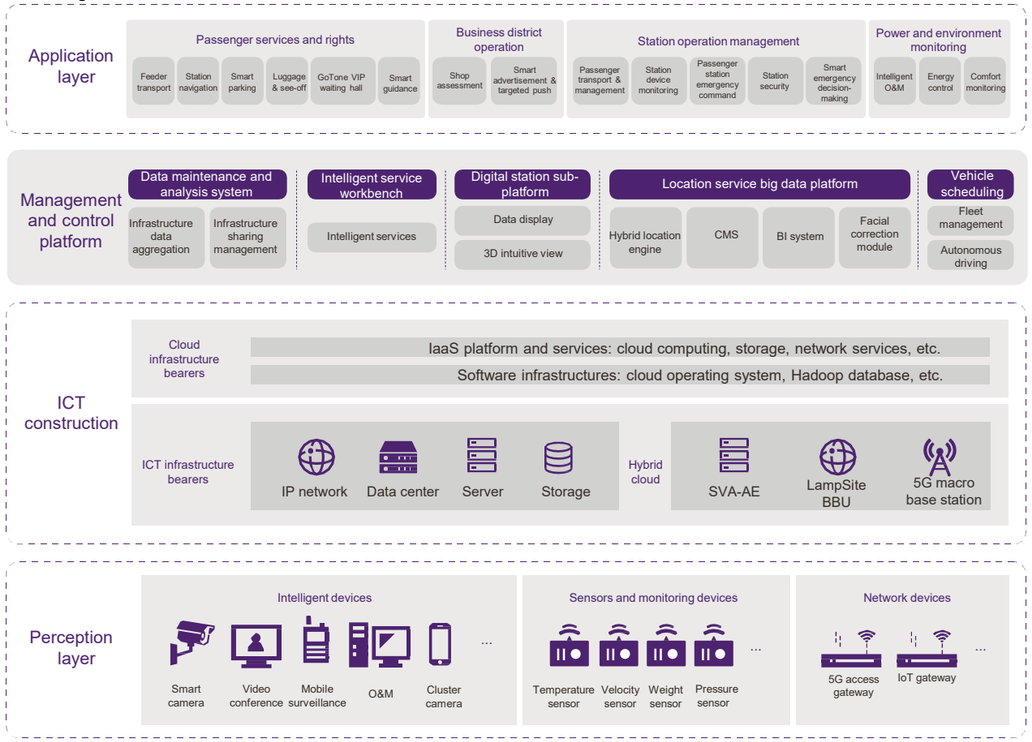


Figure 3-2: Architecture of smart transportation hub products

3. Application Scenarios

Scenario 1: [Autonomous Driving] Public Transportation

Autonomous driving of buses in areas with a large passenger demand and along fixed routes is achieved through sensing and decision-making, after data of fixed driving routes and stations are collected. This is done by the autonomous driving controller and 5G remote driving system, reducing labor costs and improving work efficiency.

Figure 3-3: Autonomous driving for public transportation

Scenario 2: [Autonomous Driving] Freight Logistics

Autonomous driving functions such as fixed route and obstacle identification, as well as the 5G remote driving system are used, during long-distance freight logistics, reducing labor costs.

Figure 3-4: Autonomous driving for freight logistics

Scenario 3: [Autonomous Driving] Campus

In semi-closed areas such as scenic spots and campuses, the 5G networked autonomous driving system performs decision and control functions, further providing 5G remote driving assurance. The system implements autonomous driving for tourists, exhibitions, and campus patrols, reducing labor costs and improving work efficiency.

Figure 3-5: Campus networked autonomous driving

Scenario 4: [Autonomous Driving] Special Vehicles

In remote areas and harsh environments, the autonomous driving system implements autonomous driving, remote monitoring, collaborative operation, and remote operation intervention of special vehicles. Hence, this improves the security of special work types.

Figure 3-6: Autonomous driving of special vehicles

Scenario 5: [Autonomous Driving] 5G Road Test Yard

In open road tests, intelligent sensing devices deployed on the road side obtain road and vehicle data. This is then transmitted and analyzed through the 5G network. As a result, a networked test environment is built for multi-environment simulation and multi-service demonstration, enhancing the test effect.

Figure 3-7: 5G road test yard

Scenario 6: High-Precision Positioning

In industries such as smart transportation, smart logistics, autonomous driving, and unmanned aerial vehicle (UAV), the BeiDou Satellite Navigation System, ground-based augmented network, and real-time kinematic (RTK) technologies are leveraged. This allows for the deployment of high-precision positioning and a calculating platform with the 5G low latency feature. The platform provides positioning services of various precision levels (meters, decimeters, and centimeters) for users. This improves user experience and traffic efficiency, safeguarding lane-level intelligent driving.

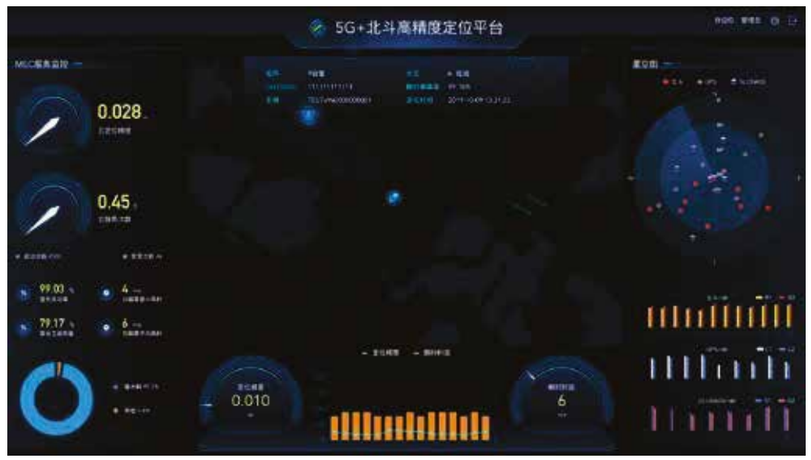


Figure 3-8: High-precision positioning

Scenario 7: High-Precision Indoor Navigation

In scenarios including indoor parking lots, technologies compromising vision, laser radar, mmWave radar, ultra-wideband (UWB), and 5G positioning are used to provide users with submeter-level high-precision positioning and navigation services. These improve the parking experience and give solutions for smart parking lots and smart communities.

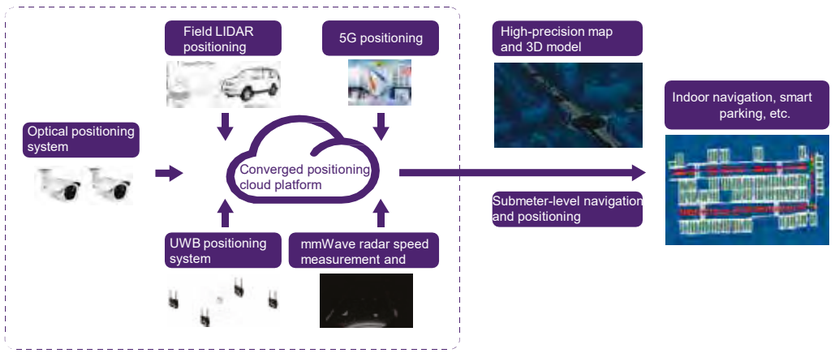


Figure 3-9: High-precision indoor traffic navigation

Scenario 8: [Smart Port] Remote Control of Gantry Cranes

During port production, HD cameras and 5G networks are used to remotely control the container yard and gantry devices in vertical transportation systems. This thus improves work efficiency and the working environment.

Figure 3-10: Gantry crane remote control

4. Use Cases

Case 1: 5G Smart Driving and High-Precision Positioning Demonstration Zone in Wuhan Economic & Technological Development Zone

China Mobile and Wuhan Economic & Technological Development Zone Management Committee jointly built a world-class zone for the 5G all-scenario intelligent networked vehicle technology test and operation demonstration. The zone covers various transportation scenarios and application scenarios, including highways, urban roads, bus lanes, urban expressways, tunnels, shaded roads, overpasses, crossroads and islands with different functions. This further incorporates road traffic scenarios with regional characteristics, and special application scenarios such as airports, ports, transportation hubs, tourist attractions, enclosed scenic spots, and commercial districts. By 2020 it is planned the following will be built: a comprehensive demonstration zone covering an area of 90 km^2 with 68.3 km long test roads and 152 traffic intersections. The zone will be functional in terms of testing, application, demonstration, and experience, providing a test yard for new energy and intelligent networked vehicles, attracting industry partners.

Figure 3-11: 5G smart driving and high-precision positioning demo zone in Wuhan Economic & Technological Development Zone

Case 2: 5G City-Level Application Demonstration Project in Deqing, Zhejiang

China Mobile participated in the construction of a city-level demonstration zone in Deqing City of Hangzhou Province. In the zone, 5G communications and campus networked autonomous driving technologies are provided to implement autonomous driving and 5G remote driving. The demonstration zone, located in a scenic spot, was visited by international customers and partners during the Global Future Mobility Conference 2019. At the first Beautiful China Idyllic Expo, the smart travel demonstration zone showcased future villages to the public.

Figure 3-12: 5G city-level application demonstration project in Deqing, Zhejiang

Case 3: 5G Open Road Autonomous Driving Project in Fangshan, Beijing

China Mobile worked with the government of Fangshan District in Beijing to build the first 5G autonomous driving open road in China, providing a variety of open road scenarios based on visual sensing and mobile edge computing (MEC). The road is 2.2 km long, with 10 5G base stations, 4 intelligent transportation control systems, 32 vehicle-road synergy data collection points, and 115 intelligent sensing devices. The test field provides multi-scenario multi-service test services such as security test, efficiency test, and collaboration tests for different levels of autonomous vehicles. Currently, automobile enterprises including Chang'an, BAIC, Dongfeng, and Great Wall, and logistics enterprises such as Jingdong and Cainiao are conducting 5G autonomous driving tests. Further, they are developing and optimizing their products in this field. The test result shows that the uplink rate is at least 40 Mbps, the end-to-end control signal latency is within 15–20 ms for MEC-based remote driving. The test additionally shows the object detection and recognition accuracy of roadside sensing devices is improved from an initial figure of 70% to 99.9%.

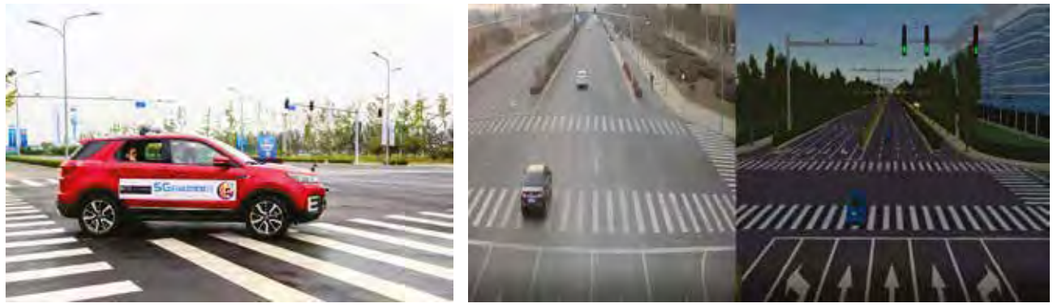


Figure 3-13: Open road test field for 5G autonomous driving in Fangshan, Beijing

Case 4: 5G Smart Mining Vehicle in Inner Mongolia

China Mobile has built a 5G vehicle-road synergy autonomous driving system to endure harsh operating environments and complex terrains in the Inner Mongolia mining scenario. 5G MEC implements multi-source sensing convergence enhancing sensing and decision-making capabilities of autonomous mining vehicles. Mining vehicles can effectively avoid barriers, improving security and greatly reducing mining operation costs.

Figure 3-14: 5G smart mining vehicle in Inner Mongolia

Case 5: 5G Networked Automatic Parking in Shanghai

To address high parking space demands, low efficiency, complex library registration, and insufficient management, China Mobile developed the 5G networked automatic parking solution. The solution uses 5G Internet of Vehicles (IoV) technologies such as parking space guidance and autonomous driving valet parking to facilitate sharing and utilization of parking spaces in a region. In collaboration with Shanghai International Automobile City, China Mobile has built a 5G smart parking lot where the 5G IoV platform uniformly identifies and manages underground and ground parking spaces, and high-precision positioning technology. Overall, this simplifies indoor navigation.

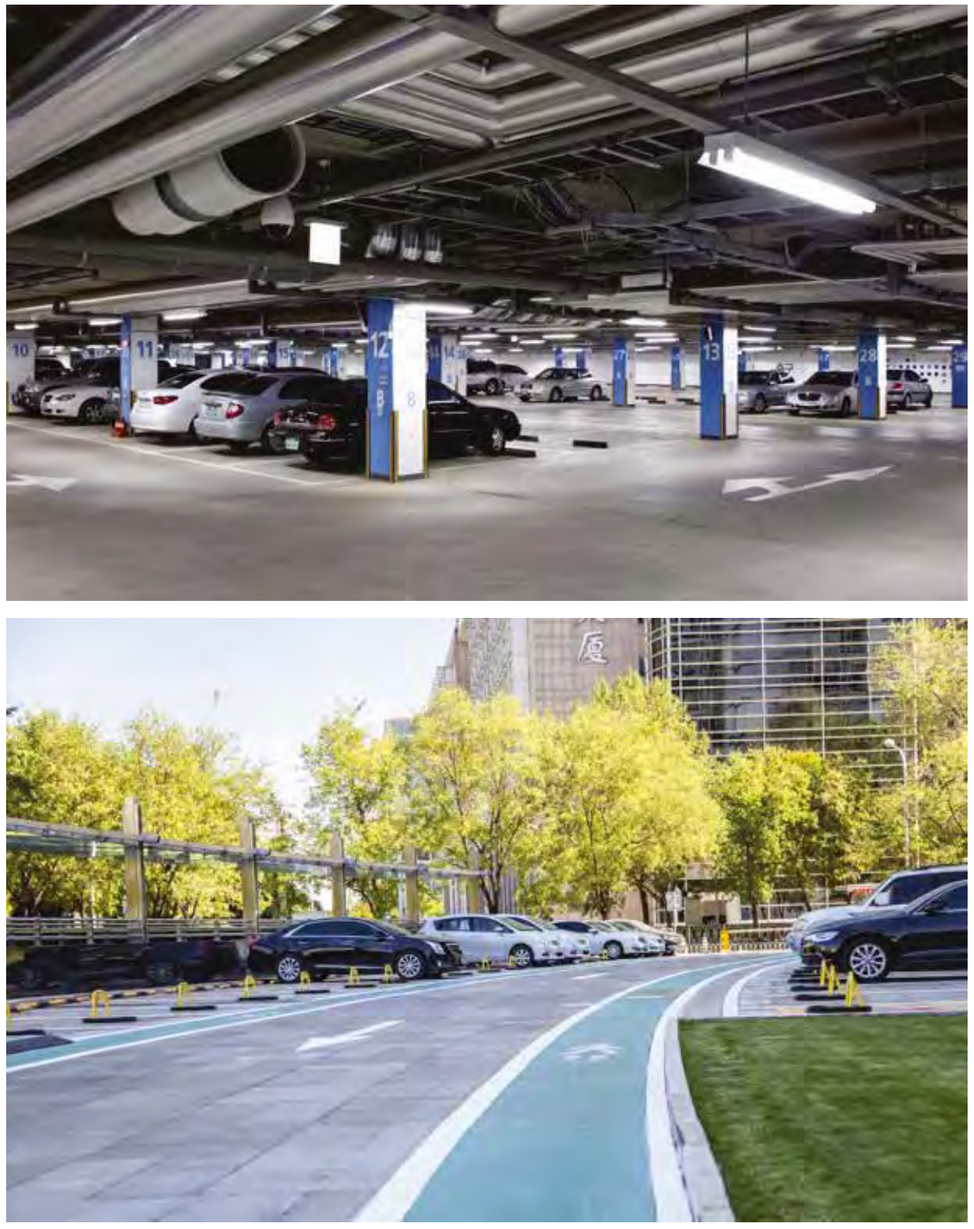


Figure 3-15: 5G networked automatic parking in Shanghai

Case 6: 5G Vehicle-Road Synergy Demonstration Zone in Suzhou High-Speed Rail New Town

Suzhou High-Speed Rail New Town is a core area of Suzhou's central city construction. It focuses on the smart driving industry and is planning to build the Yangtang River Delta Smart Driving Industry Demonstration Zone. China Mobile won the bid for the phase-1 project of the public service platform for the 5G intelligent networked pilot zone in Suzhou High-Speed Rail New Town. It deployed the 5G network, roadside sensing network, and vehicle-road synergy platform to provide capabilities such as roadside sensing convergence, vehicle-road real-time communications, and sensing converged decision-making. The platform has completed multi-service verification of vehicle-road synergy based on 5G New Radio (NR). This implements three typical applications: beyond-line-of-sight (LOS) perspective, traffic light information push, and pedestrian collision prevention reminder at intersections, effectively improving security. In the future, China Mobile will incubate more 5G vehicle-road synergy application scenarios. These can hence be commercially promoted to build a prosperous ecosystem for vehicle-road synergy.

Figure 3-16: 5G vehicle-road synergy demonstration zone in Suzhou High-Speed Rail New Town

Case 7: 5G Smart Port

Yangshan Port is the world's largest port. To improve automation for higher operation efficiency, Yangshan Port proposed the commercial reconstruction of 5G-based remote control of rubber-tyred gantry (RTG) cranes at the Guandong terminal in phase 3. China Mobile has completed full 5G coverage in a 3.8 km^2 area and deployed the mobile edge computing (MEC) platform to provide 18-channel 90 Mbps multi-view HD video surveillance in the uplink and control signaling transmission with a latency of only 18 ms in the downlink for RTG cranes. In addition, China Mobile has developed a 5G smart port comprehensive service platform to help implement centralized network and service operations, collect statistics on operation efficiency of key devices, and provide intelligent tally services. This further improves the port operation efficiency. In the future, China Mobile will continue to optimize the smart port solution, to support unmanned remote scheduling and local breakout of production data.

Figure 3-17: 5G smart port

5G Smart Healthcare

Backed by advanced technologies such as mobile communications, IoT, cloud computing, big data, and AI, smart healthcare implements: interconnection and information sharing between patients and medical personnel, medical institutions, or medical devices. It promotes service collaboration inside and outside hospitals, efficiently distributes medical resources, and provides personalized medical services. Further, smart healthcare is of great significance to improving patients' experience.

5G is vital to the healthcare industry and is leading a digital modernization. It is predicted that by 2020, 5G will help China's smart healthcare industry reach a market scale of CNY 100 billion. Leveraging its technical competence in 5G, IoT, cloud computing, and big data as well as its advantages in industry chain synergy, China Mobile has been actively promoting the in-depth integration of 5G and the healthcare industry. It explores and practices 5G smart healthcare application scenarios in and out of hospitals. Its solutions improve the healthcare service level and hospital management efficiency. It further promotes the sharing and close-to-patient deployment of high-quality healthcare resources.

5G Smart Healthcare

1. Service Requirements

People's health signifies national prosperity. Since 2016, China has released policy documents such as *"Healthy China 2030" Program Outline* and its *Opinions on Promoting the Development of "Internet+Healthcare"*. Policies and market requirements are promoting the development of the healthcare industry. 5G is changing the concept and model of traditional healthcare services and promoting the development of mobile, collaborated, and high-quality healthcare services.

Requirement 1: High-Speed Transmission of HD Images, Videos, and Massive Data in Moving Scenarios

With the development of communications technologies, teleconsultation has evolved from telephone consultation and common standard definition (SD) video consultation to 4K/8K ultra-high definition (UHD) consultation, posing higher requirements on network bandwidths.

5G high rate capability enables high-speed transmission and real-time retrieval of medical images and electronic medical records (EMRs), meeting the requirements on the network transmission rate, mobility, and real-time performance in mobile scenarios such as remote consultation and remote first aid.

Requirement 2: Reliable Remote Control Medical Services

Medical resources are unevenly distributed in China. New remote control services, such as remote examination and remote surgery, help improve the diagnosis and treatment level of grassroots medical institutions. Remote control services have high requirements on latency and security. With 5G features such as low latency and high reliability, remote control services can be responded within milliseconds and accurate to millimeters, effectively ensuring service stability, security, and reliability.

Requirement 3: Massive IoT Device Connection Management

Hospitals have a complex personnel structure and a large number of assets, such as medical devices, consumables, and medicines, complicating hospital security management and asset operation. Based on 5G features such as massive connectivity, wearable devices and various asset devices in hospitals can be connected to the network to monitor and manage assets throughout the lifecycle, improving the security and usage of medical devices and improving hospital management efficiency. In addition, hospitals can locate personnel in real time to improve security.

2. Solution Overview

China Mobile's 5G smart healthcare solution fully utilizes the high-speed and stable communications capabilities of 5G. With cutting-edge technologies such as mobile edge computing (MEC), artificial intelligence (AI), and virtual reality (VR), the solution supports real-time HD remote consultation, low-latency transmission of medical image data, remote control medical services, and connection of massive medical devices. The system architecture is as follows:

Perception layer: This layer includes devices such as intelligent medical devices, remote control robots, and audio/video interaction systems to collect vital sign data and perform remote diagnosis and treatment.

Network layer: The 5G network capabilities of high rate, low latency, and massive connectivity meet the requirements of remote real-time precise control, high-speed transmission of medical image data, HD audio/video interaction, and wireless medical device access.

Platform layer: The medical cloud platform provides basic information services such as health records, EMRs, big data analysis, videoconferencing, and device management. It connects to multiple information systems such as the EMR system, image diagnosis system, and inspection system in hospitals to realize storage and interconnection of various medical data.

Application layer: It provides cross-hospital telemedicine services (such as remote consultation and remote teaching) and in-hospital information services (such as mobile healthcare and smart hospital management) for medical institutions at all levels, comprehensively improving the ICT level and medical service quality of medical institutions and improving the efficiency and competence of medical personnel.

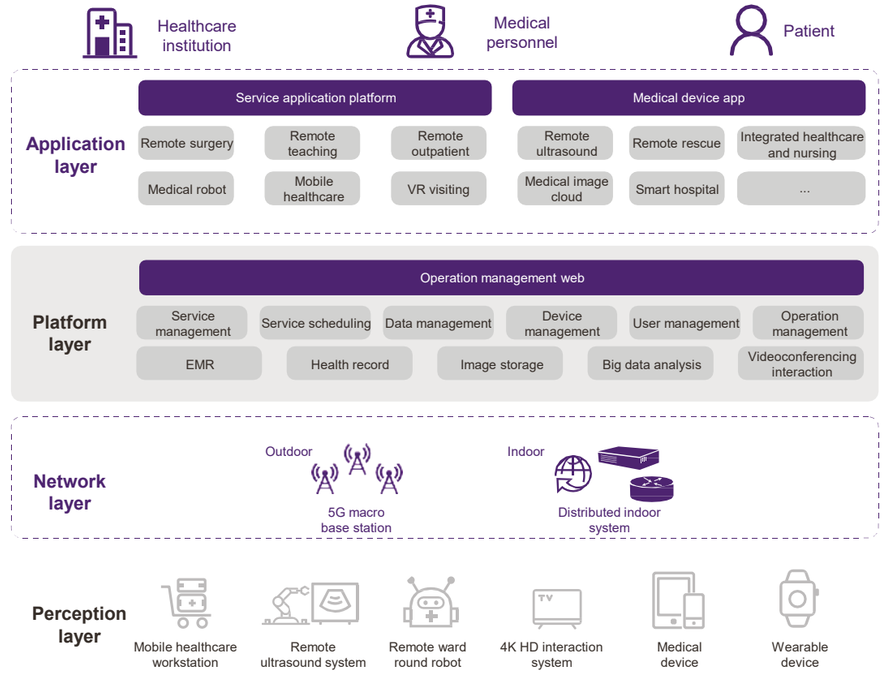


Figure 4-1: 5G smart healthcare solution system architecture

3. Application Scenarios

5G smart healthcare application scenarios fall into telemedicine, emergency rescue, smart hospital, and regional healthcare based on the service scope.

3.1 Telemedicine Application Scenarios

Scenario 1: Remote Consultation

China is geographically vast and medical resources are unevenly distributed. It is difficult for residents in rural or remote areas to access efficient and high-quality healthcare services. Traditional teleconsultation uses wired connections for video communications, resulting in high construction and maintenance costs and poor mobility. The high-speed 5G network supports 4K/8K remote HD consultation and high-speed transmission and sharing of medical image data. Experts can conduct consultation anytime and anywhere, improving diagnosis accuracy and guidance efficiency and promoting close-to-patient deployment of high-quality medical resources.

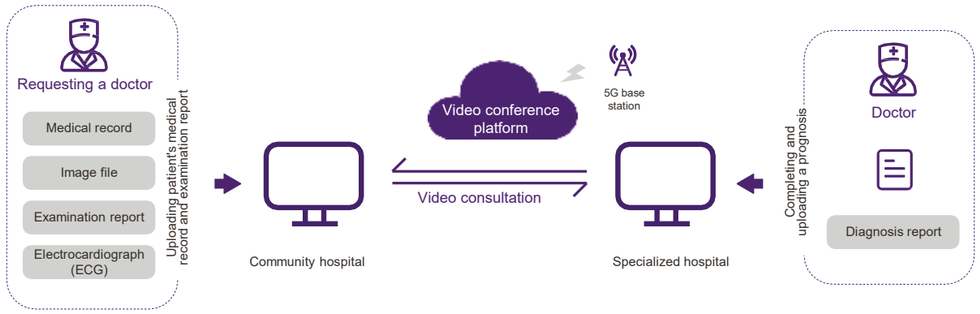


Figure 4-2: Architecture of the remote consultation solution

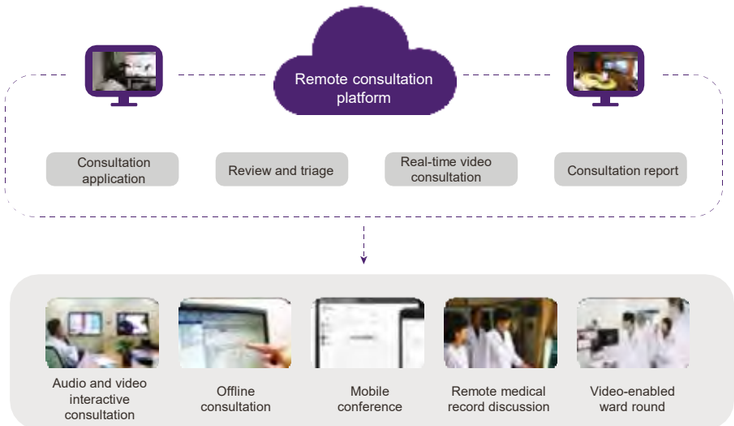


Figure 4-3: Remote consultation scenarios

5G Network Performance Requirements

Service Name	Communications Requirement	
	Bandwidth	Coverage Range
Remote consultation	≥ 40 Mbps	Full coverage in the hospital

Scenario 2: Remote Teaching

Multimedia video content is revolutionizing the way remote teaching is carried out. Experts at a remote location give lectures to doctors based at community hospitals through visual materials. Leveraging technologies such as 5G, virtual reality (VR), augmented reality (AR), and mixed reality (MR), medical images from computed tomography (CT) and magnetic resonance imaging (MRI) can be reconstructed and rendered on the cloud, reducing the end-to-end latency. Doctors at specialized and community hospitals can participate in online classes, facilitating the rapid training of inexperienced doctors. Remote teaching can also be used for medical operation teaching, pre-operation communication, and in-operation guidance.

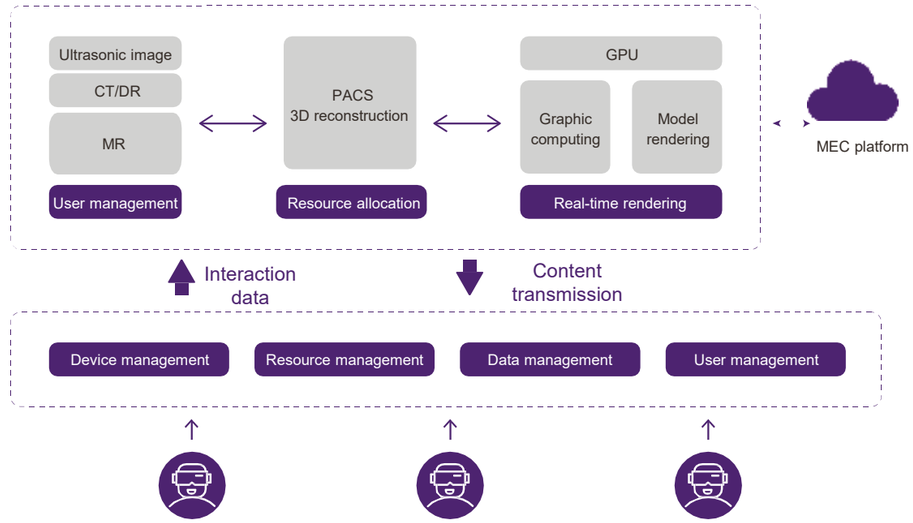


Figure 4-4: Architecture of the remote teaching solution

Figure 4-5: Remote teaching scenarios

5G Network Performance Requirements

Service Name	Communications Requirement	
	Bandwidth	Coverage Range
Remote teaching	≥ 100 Mbps	In-hospital consultation room

Scenario 3: Remote Outpatient Service

Remote outpatient is a new service that allows patients to receive medical services remotely from experts in community hospitals through communications and multimedia technologies. The high-speed 5G network enables HD audio and video interaction and high-speed transmission of medical image data, allowing experts to provide optimal real-time diagnosis, examination, treatment, and consultation services to patients anytime, improving the outpatient service quality of community medical institutions.

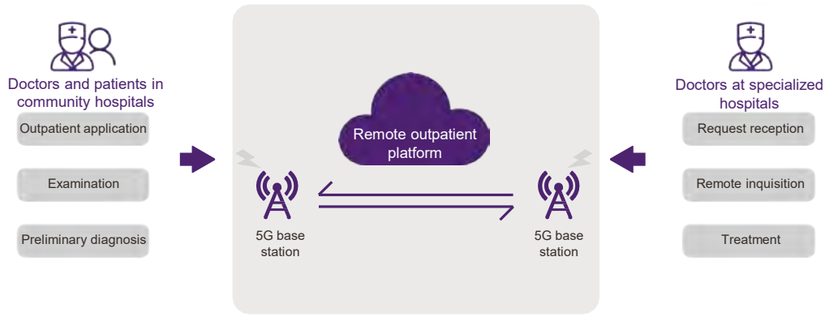


Figure 4-6: Architecture of the remote outpatient solution

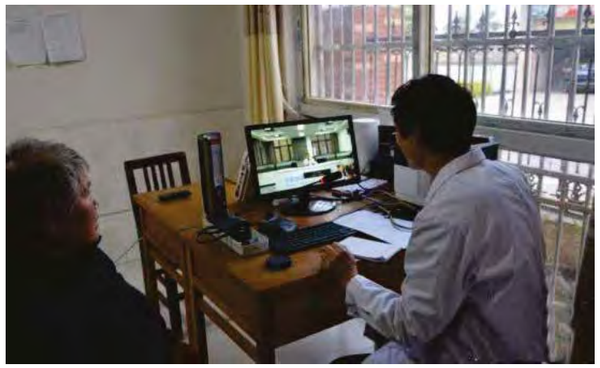


Figure 4-7: Remote outpatient scenario

5G Network Performance Requirements

Service Name	Communications Requirement	
	Bandwidth	Coverage Range
Remote outpatient	≥ 40 Mbps	Full coverage in the hospital

Scenario 4: Remote Ultrasound

Compared with CT and MR, ultrasound examinations require manual operation by qualified doctors. In China, there is still a large shortage of ultrasound doctors, and therefore it is difficult for community hospitals to carry out ultrasound examinations.

Through millisecond-level latency of 5G, experts can remotely control robotic arms to perform real-time ultrasound examinations on patients in hospitals and remote areas. Compared with traditional private networks and Wi-Fi, 5G networks can overcome difficult and costly private network construction in remote areas such as rural areas and islands, insecure Wi-Fi data transmission in hospitals, and high remote control latency.

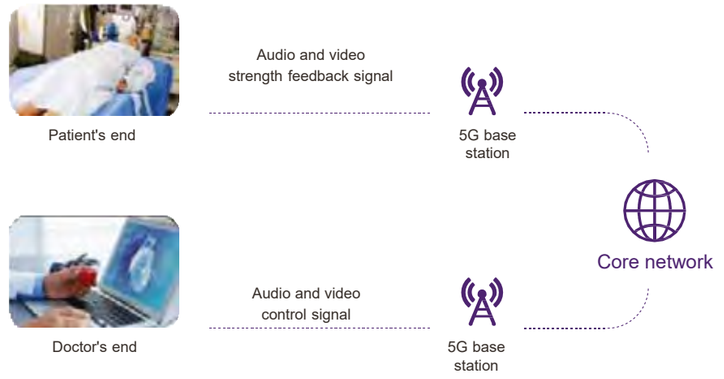


Figure 4-2: Architecture of the remote ultrasound solution

Figure 4-9: Remote ultrasound scenario

5G Network Performance Requirements

Service Name	Communications Requirement	
	Latency	Coverage Range
Remote ultrasound	≤ 20 ms	Full coverage in the hospital

Scenario 5: Remote Surgery

Experts can perform remote surgeries on patients in community hospitals by using medical robots and HD audio and video interaction systems. The 5G network simplifies wired and Wi-Fi network environments in surgery rooms and reduces the access difficulty and construction costs of private lines and private networks. 5G network slicing technology can quickly establish dedicated communications channels between hospitals of different levels, effectively ensuring the stability, real-time performance, and security of remote surgeries. Experts have full control over the surgery and patient's status while also providing careful surgical operations and guidance over a physical distance. This technology can significantly reduce medical treatment costs and facilitate access to high-quality medical resources. Additionally, in challenging environments such as war zones and epidemic areas, 5G can be deployed to quickly establish an optical network environment for remote surgeries, which will greatly help emergency medical personnel.

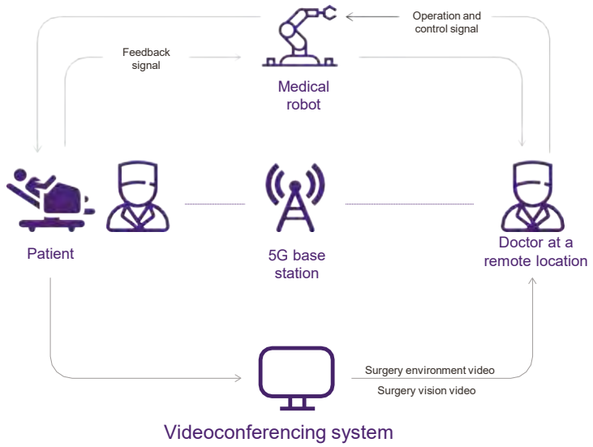


Figure 4-10: Architecture of the remote surgery solution

Figure 4-11: Remote surgery scenario

5G Network Performance Requirements

Service Name	Communications Requirement	
	Latency	Coverage Range
Remote surgery	≤ 10 ms	Surgery site

3.2 Intra-hospital Medical Application Scenario – Mobile Healthcare

Mobile healthcare extends the diagnosis and treatment to patients' beds. Through 5G, doctors and nurses can collect data regarding patient's vitals, and offer bed-side mobile HD consultation, greatly improving the quality and efficiency of ward rounds. In sensitive wards such as radiology and epidemic zones, medical personnel can attend to patients through robots, ensuring the safety of medical personnel.

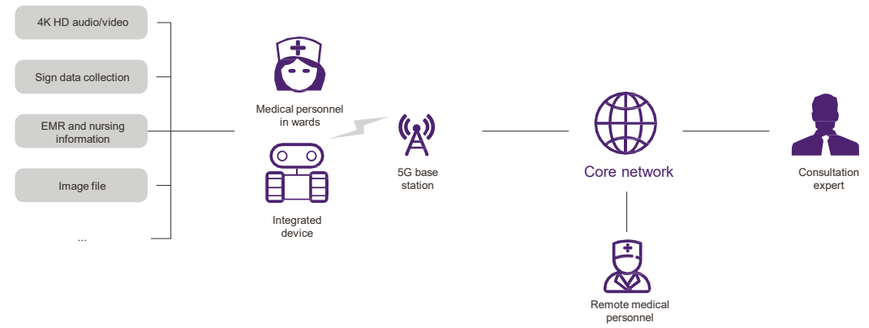


Figure 4-12: Architecture of the mobile healthcare solution

Figure 4-13: Mobile healthcare scenarios

5G Network Performance Requirements

Service Name	Communications Requirement	
	Bandwidth	Coverage Range
Mobile healthcare	≥ 40 Mbps	Full coverage in the hospital

3.3 Application Scenarios of Medical and Patient Services

Scenario 1: VR Visiting

Newborns suffering from jaundice, hemolysis, pneumonia, and other diseases need to stay in the neonatal intensive care unit (NICU) for more than one week. They are isolated from their parents, and visiting hours are restricted. In order to overcome this issue, parents can visit their child through 5G-powered real-time HD panoramic cameras that are installed in the NICU.

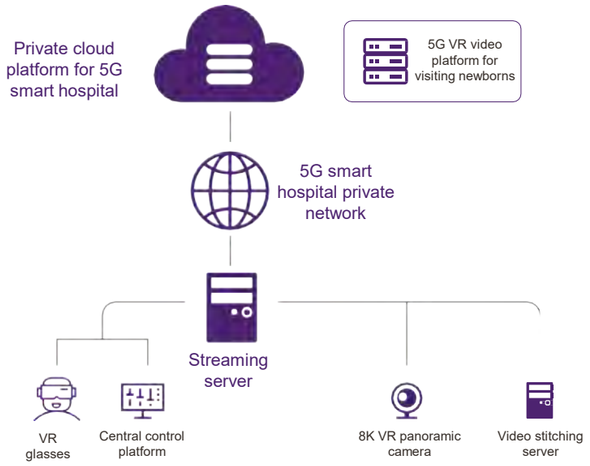


Figure 4-14: Architecture of the VR visiting solution

Figure 4-15: VR visiting scenario

5G Network Performance Requirements

Service Name	Communications Requirement		
	Bandwidth	Latency	Coverage Range
VR visiting	≥ 50 Mbps	≤ 20 ms	Visiting area coverage

Scenario 2: Medical Robots

By integrating 5G, AI, and cloud computing technologies, more and more service robots and medical applications are being introduced into the medical industry, improving medical care, inter-hospital communications, and the overall efficiency of medical personnel. Medical robots replace humans in transporting materials such as medical consumables, medicines, clothes, and medical wastes, improving the material transporting efficiency of hospitals while reducing costs. Medical robots can also guide, navigate, and consult patients.

Figure 4-16: Medical robot application scenario

5G Network Performance Requirements

Service Name	Communications Requirement	
	Bandwidth	Coverage Range
Medical robot	≥ 20 Mbps	Full coverage in the hospital

Scenario 3: Integrated Healthcare and Nursing Solution

In an ageing society, private home care for the elderly is a growing concern for future generations. The integrated healthcare and nursing solution aims to provide medical services to the elderly in their home, in care homes, and in hospitals. By utilizing 5G, remotely monitoring elderly people within their home is achievable, and basic care, data collection, guidance, as well as diagnosis can be offered by medical professionals regardless of location.

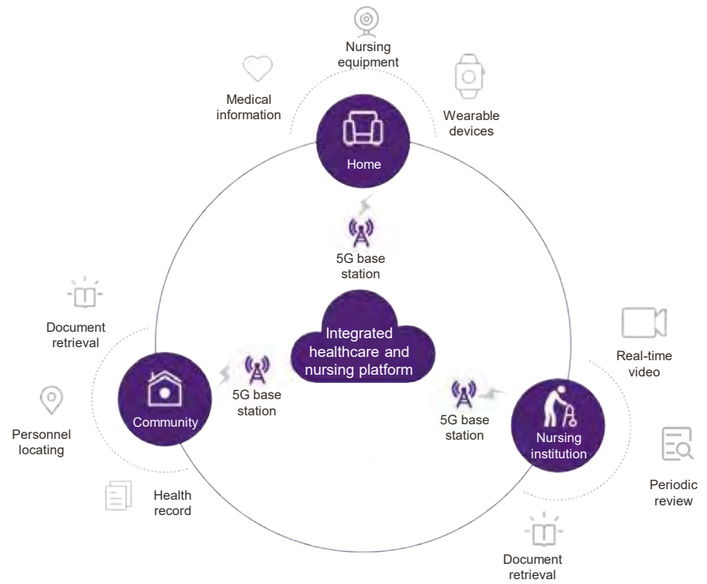


Figure 4-17: Architecture of the integrated healthcare and nursing solution

Figure 4-18: Integrated healthcare and nursing solution scenarios

3.4 Application Scenarios of Hospital Management

Scenario 1: Smart Hospital Management

Real-time patient monitoring, hospital security management, and full-lifecycle management of medical equipment are paramount in smart hospital construction. 5G is critical to ensuring that medical and non-medical equipment and services are interconnected to provide services such as hospital asset management, first aid scheduling, personnel management, equipment status management, access control, real-time patient sign monitoring, and hospital navigation.

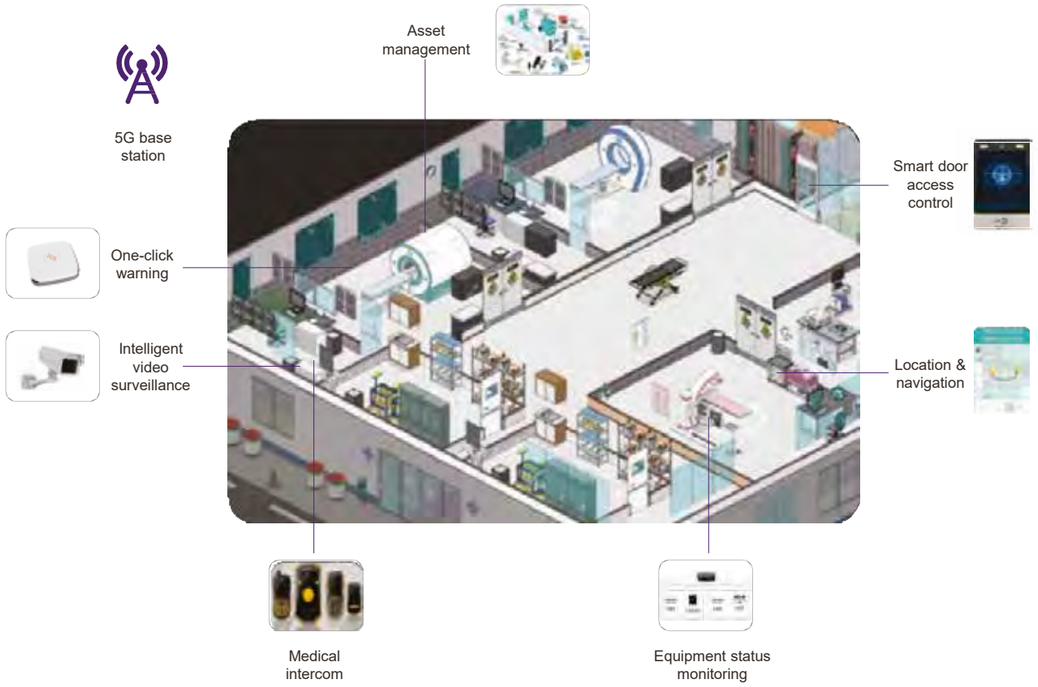


Figure 4-19: Smart hospital management scenarios

5G Network Performance Requirements

Service Name	Communications Requirement	
	Connection Quantity	Coverage Range
Smart hospital	≥ 10^5 km^2	Full coverage in the hospital

Scenario 2: Medical Image Cloud

Medical image data increases by 10% annually, requiring long-term storage. In China, the data storage period is generally 15 years. Furthermore, medical data requires stringent security protection. The medical image cloud provides a space for the long-term online storage of massive medical image data in hospitals. It also provides functions such as high-end 3D image reconstruction and computer-aided diagnosis, as well as supporting data sharing and image interface services. The medical image cloud can serve various hospitals and medical institutions, support applications such as remote consultation, precise medical treatment, and health monitoring, and improve the sharing capability of medical data.

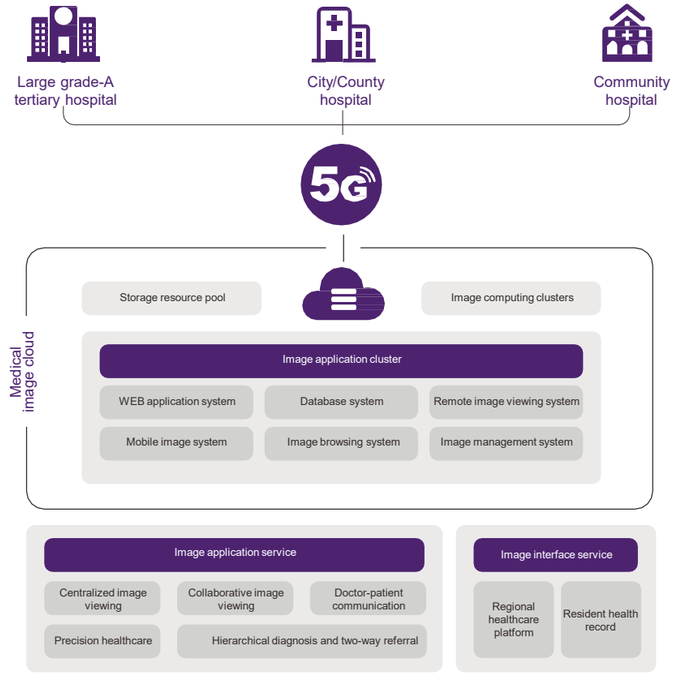


Figure 4-20: Architecture of the medical image cloud

5G Network Performance Requirements

Service Name	Communications Requirement	
	Bandwidth	Coverage Range
Medical image cloud	≥ 40 Mbps	Full coverage in the hospital

3.5 Emergency Rescue Application Scenario – First Aid

First aid refers to emergency care given to patients before they arrive at the hospital. 5G's superior transmission rate in high-speed mobility scenarios allows for real-time information exchange between emergency services and the command center, so that patients can receive optimal emergency treatment. As the patient is being transported to the hospital, medical personnel can use vehicle-mounted medical equipment to constantly monitor vital signs, which are quickly sent back to the emergency command center and hospitals. The HD audio and video interaction system also allows offsite medical experts to expertly assist patients.

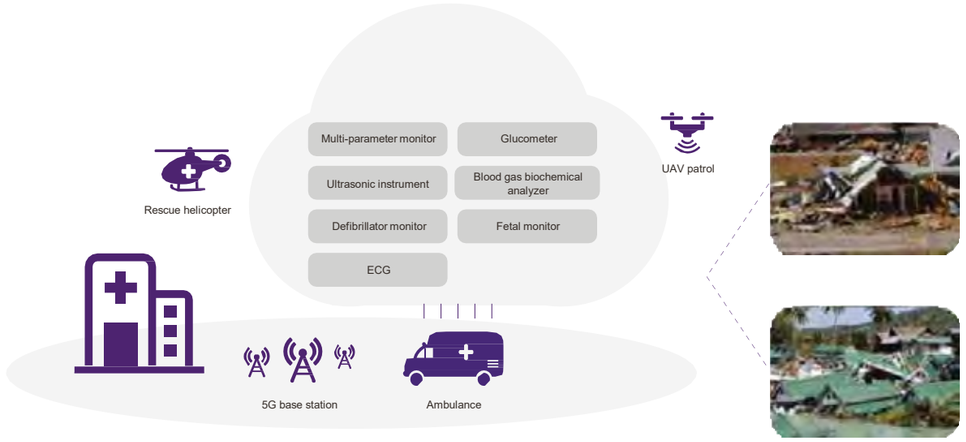


Figure 4-21: Architecture of the emergency rescue solution

Figure 4-22: Emergency rescue scenario

4. Use Cases

5G is revolutionizing healthcare services. China Mobile launched a series of 5G medical service practices inside and outside hospitals through collaboration with industry partners. Such practices helped many grade-A tertiary hospitals set benchmarks for various 5G medical services, including remote consultation, remote ultrasound, emergency rescue, and remote surgery.

4.1 5G Remote Surgery

Case 1: World's First 5G Remote Human Surgery

China Mobile assisted experts from Chinese PLA General Hospital in successfully implementing the world's first 5G remote pacemaker implantation into the brain of a patient with Parkinson's disease, starting a new chapter in 5G healthcare. This event was documented through special interviews and news reports by channels 2, 4, 7, and 13 of China Central Television (CCTV).

Figure 4-23: 5G remote surgery case at Chinese PLA General Hospital

Case 2: China's First 5G Remote LASIK Surgery

China Mobile and Peking Union Medical College Hospital successfully performed the world's first 5G remote targeted laser in situ keratomileusis (LASIK) surgery, starting a new chapter of remote treatment for eye-bottom diseases. 5G remote eye-bottom laser surgery is non-invasive, safe, and widely applicable.

Figure 4-24: 5G remote LASIK surgery case at Peking Union Medical College Hospital

Case 3: 5G Remote Human Orthopaedic Surgery

China Mobile assisted experts in Chinese PLA General Hospital in successfully performing a 5G remote hip replacement surgery. Through the 5G network, experts based in Hangzhou remotely operated the orthopaedic robot located in the Beijing surgery room in real time and provided remote surgery guidance. This case justifies the need for 5G remote surgery.

Figure 4-25: 5G remote orthopedic surgery case at Chinese PLA General Hospital

4.2 5G Remote Consultation

Case 1: 5G Remote Emergency and Critical Consultation

China Mobile and China-Japan Friendship Hospital successfully completed a remote emergency and critical consultation with Jinzhai People's Hospital in Anhui Province using the national telemedicine collaboration platform via the 5G network. Based on 5G technologies, doctors at the higher-level hospital can implement cross-region "face-to-face" HD diagnosis, improving the medical service level of community hospitals, and delivering a new diagnosis and treatment experience to both doctors and patients.

Figure 4-26: 5G remote consultation case at China-Japan Friendship Hospital

Case 2: 5G Remote Ophthalmology Consultation

China Mobile helped Peking Union Medical College Hospital (PUMCH) successfully carry out 5G remote ophthalmology consultation with Pinggu Hospital. The remote consultation was based on the remote medical center platform built by China Mobile and PUMCH. With the low latency and high rate of 5G networks, the platform met the requirements for real-time HD audio and video interaction, and implemented the real-time retrieval of data such as patient fluorescence imaging and optical coherence tomography (OCT) images. This case highlights the availability of high-quality medical resources to community hospitals.

Figure 4-27: 5G remote ophthalmologic consultation case at Peking Union Medical College Hospital

4.3 5G Remote Teaching

Case 1: World's First 5G+MR Remote Pulmonary Surgery

China Mobile worked with Jiangsu Province Hospital to remotely guide doctors at Pukou branch hospital to complete a combined subsegmentectomy on the left upper lung of a patient using 5G and mixed reality (MR) technologies. During the surgery, experts remotely guided the surgeons with the aid of interactive multimedia, and the 5G network was able to display content without delay.

Figure 4-28: 5G+MR remote surgery case of Jiangsu Province Hospital

Case 2: First 5G Real-Time Interactive Consultation of the Da Vinci Robotic Surgery Assistance System in Northeastern China

China Mobile and the First Hospital of China Medical University successfully completed a real-time remote consultation and teaching demonstration while performing a non-invasive Da Vinci robot system-assisted surgery via the 5G network. Relying on 5G and video convergence technologies, experts could share the real-time surgical field while communicating with onsite surgeons, effectively bridging the gap of unbalanced medical resource allocation.

Figure 4-29: Remote surgery practice in the First Hospital of Chinese Medical University

4.4 5G Remote Outpatient Service Use Case – World's First 5G Remote Outpatient Service

China Mobile worked with Hainan Hospital of PLAGH and Sansha People's Hospital to provide 5G remote outpatient services, allowing both military personnel and civilians in Sansha to enjoy high-quality medical resources without leaving the island. 5G enables HD audio and video interaction, image data transmission, and remote real-time ultrasound control to guide patients throughout diagnosis and treatment, making healthcare easier accessible to both military personnel and civilians on the island.

Figure 4-30: 5G remote outpatient practice case at Hainan Hospital of PLAGH

4.5 5G Remote Ultrasound

Case 1: World's First 5G Remote Ultrasonic Outpatient Practice

China Mobile, in collaboration with Hainan Hospital of PLAGH, developed a 5G ultrasound outpatient system. The system successfully implemented "face-to-face" ultrasound examinations for soldiers 330 km away.

Figure 4-31: 5G remote ultrasound practice case at Hainan Hospital of PLAGH

Case 2: 5G Ultrasonic Joint Innovation Lab

China Mobile and Shanghai Tenth People's Hospital set up a 5G ultrasound joint innovation lab. The lab initiated various ultrasonic applications into 5G environments, including China's first 5G real-time ultrasound intervention surgery guidance, remote ultrasound consultation, remote ultrasound virtual consultation via direct connection, and remote robot experiments.

Figure 4-32: 5G remote ultrasound practice case at Shanghai Tenth People's Hospital

4.6 5G Emergency Rescue

Case 1: China's First 5G Urban Medical Emergency Rescue System

China Mobile and Sichuan Provincial People's Hospital built the first 5G urban medical emergency rescue system in China. By implementing 5G into ambulances, the emergency service system integrates medical equipment such as color ultrasound, electrocardiogram (ECG) monitoring, defibrillator, and respirator, which is assisted by applications such as artificial intelligence (AI), augmented reality (AR), virtual reality (VR), and unmanned aerial vehicle (UAV), to create an all-round medical first aid system to effectively shorten the response time during emergency rescue.

Figure 4-33: 5G emergency rescue system case of Sichuan Province People's Hospital

Case 2: China's First 5G Emergency Rescue Solution

China Mobile and the First Affiliated Hospital of Zhengzhou University jointly developed the first 5G emergency rescue solution for mobile application. In a moving ambulance, paramedics can use mobile terminals to view patients' EMRs, use vehicle-mounted medical equipment to continuously monitor patients' vitals, and work with experts over long distances for diagnosis and treatment by using vehicle-mounted cameras. The solution enables image sharing, mobile consultation, and remote medical treatment and diagnosis, effectively improving pre-hospital care

Figure 4-34: 5G emergency rescue case of the First Affiliated Hospital of Zhengzhou University

Case 3: China's First 5G Remote First Aid Green Tunnel

China Mobile worked with the Second Affiliated Hospital of Zhejiang University School of Medicine in building the first 5G remote first aid green tunnel in China. Based on intelligent monitoring and AI technologies, the 5G intelligent 3D first aid network can detect emergencies and allocate first aid resources. Data on the patients' condition is sent back to the hospital in real time from the ambulance. In addition, the vehicle-mounted UAVs can quickly transfer first aid medication, blood, and samples under 5G-enabled precise navigation. Using VR and remote ultrasound technologies, experts can provide real-time remote direction regardless of the physical distance.

Figure 4-35: 5G remote first aid green tunnel at the Second Affiliated Hospital of Zhejiang University School of Medicine

4.7 5G VR Visiting Use Case

5G+VR newborn visiting has been implemented at West China Women's and Children's Hospital in Chengdu, Sichuan Province. Widely covered by local media, this practice has been well received by patients' families.

Figure 4-36: 5G+VR newborn visit practice case at West China Women's and Children's Hospital

4.8 5G Robot-assisted Medical Guidance Use Case

China Mobile worked with West China Women's and Children's Hospital to develop 5G smart healthcare and explore service applications such as consultation robots. Utilizing the 5G network, robots can provide services such as interactive navigation and guidance, consultation, and expert introductions, improving patients' hospital experience and medical personnel's work efficiency.

Figure 4-37: 5G hospital guidance robot at West China Women's and Children's Hospital

4.9 5G Smart Integrated Healthcare and Nursing Use Case

China Mobile collaborated with Yanling County Central Hospital in Henan Province in developing 5G integrated healthcare and nursing solution and implement smart healthcare services.

On September 25, 2019, China Mobile, Yanling County Government, and Yanling County Central Hospital jointly released the first 5G integrated healthcare and nursing platform in China.

Figure 4-38: 5G integrated healthcare and nursing platform

5G Smart Finance

Traditional financial institutions include banks, insurance companies, securities companies, and their supervision departments, with their main businesses including depositing funds, loans, and settlements. In recent years, the emerging FinTech concept that incorporates innovative technologies such as AI, blockchain, cloud computing, and big data is being integrated with digital and intelligent operation modes to improve the quality of financial services, as well as facilitate the integration of technologies, finance, and society. According to China's "13th Five-Year Plan" for the modern financial system, there is a growing demand to further improve the technical application capability of the financial industry. At the same time, the market is expanding year by year, and it is estimated that the industry's overall revenue will reach CNY 361.782 billion by 2022.

China Mobile deeply incorporates the advantages of its 5G network with financial technologies, exploring the construction of a 5G smart financial solution based on requirements from the industry. This solution meets the requirements of industry customers for capabilities in customized network transmission, service expansion, and security isolation, helping financial institutions refine operations, strengthen user loyalty, explore innovative service modes, and implement intelligent transformation.

5G Smart Finance

1. Service Requirements

5G networks lay a solid foundation for the deep convergence of new technologies and financial services. China Mobile's 5G smart finance solution is dedicated to creating a limitless digital smart space which incorporates positioning, intelligence, mobility, interaction, and sharing, while achieving the organic convergence of technologies and people, brand and personality, online and offline modes, and financial and non-financial services, promoting intelligent transformation of the financial industry.

Requirement 1: Extending Financial Services Beyond Boundaries

Owing to the rapid development of Internet finance, the financial industry needs to continuously upgrade and improve service modes to improve customer satisfaction and enhance customer loyalty. New technologies such as 5G, Internet of Things (IoT), big data, and artificial intelligence (AI) greatly enrich financial service modes, expand the coverage and lower the threshold of financial services, and enable financial services to penetrate other fields.

Figure 5-1: Extending financial services beyond boundaries

Requirement 2: Providing Customized Services to Improve Customer Satisfaction

In the 5G era, FinTech not only improves service efficiency and convenience, but also reshapes user services by combining 5G with emerging technologies such as augmented reality (AR), virtual reality (VR), holographic projection, AI, and big data. It diversifies financial services, implements customized and personalized service modes, and improves customer satisfaction.

Figure 5-2: Providing customized services to improve customer satisfaction

Requirement 3: Helping Banks Achieve Digital Transformation and Reduce OPEX

Based on the massive connection capabilities of 5G, IoT will generate a massive amount of multi-dimensional real data. The intelligent system calculates and analyzes the data, providing strong support for customers in the financial industry in terms of market environment, customer conditions, internal resources, and risk prediction and control.

Figure 5-3: Helping banks achieve digital transformation and reduce OPEX

2. Solution Overview

China Mobile's 5G smart finance solution provides a one-stop service system for industry customers, helping them achieve digital, scientific, and intelligent development. The following figure displays the system architecture.

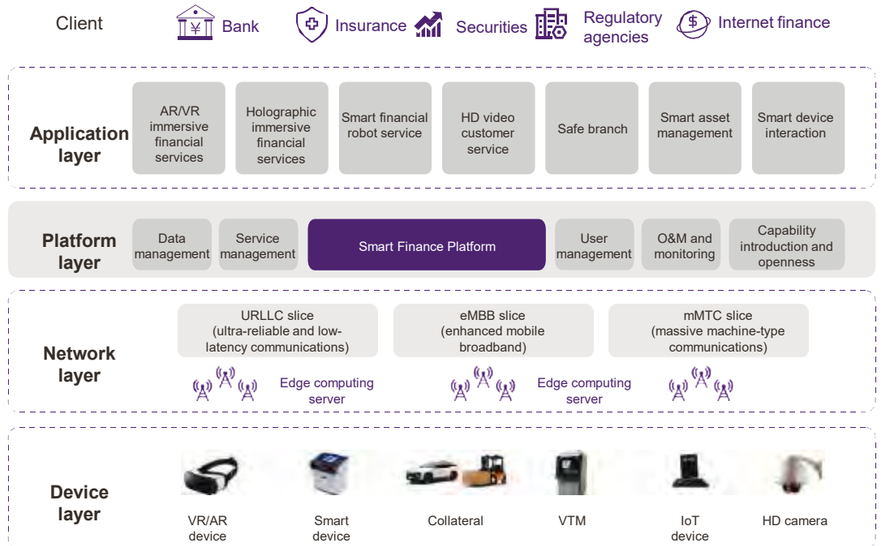


Figure 5-4: Smart finance solution

Device layer: includes various financial service terminals enabled with 5G communications modules, such as AR/VR-dedicated devices, smart devices, collateral, VTMs, IoT devices, and HD cameras. This layer collects service data and video data, and responds to sensor control data.

Network layer: Based on China Mobile's 5G network and high-speed and low-latency features, the network layer meets the network requirements for remote financial services and provides AR/VR and virtual customer services in different scenarios. Massive connection capabilities meet the network requirements of dense connection and monitoring for financial collateral. The network slicing feature enables end-to-end network transmission isolation and encryption for banking services, and provides customized "industrial private network" services for the banking industry, ensuring secure and stable financial services.

Platform layer: encapsulates, orchestrates, and reorganizes capabilities such as data management, service management, user management, and O&M monitoring, and provides support for upper-layer NAs in various forms such as SDKs and open interfaces.

Application layer: Based on different scenarios, develop 5G smart financial products and applications to provide industry customers with AR/VR immersive financial services, holographic immersive financial services, financial intelligent robots, HD video customer services, branch security services, smart resource management, and interaction among smart devices.

3. Application Scenarios

Scenario 1: AR/VR Immersive Financial Services

AR/VR immersive financial services equipped financial service personnel with personal assistants. With intelligent devices such as AR glasses, AR/VR identifies customers in real time and obtains data such as customer profiles, helping service personnel provide more personalized financial services for customers and improving service efficiency and quality.

Figure 5-5: AR/VR immersive financial services

Lobby personnel at banks, insurance companies, and securities companies can wear AR glasses to obtain customer information such as facial images and voices through portable devices.

Such data is transmitted to the edge server via the 5G network. The edge server invokes the background knowledge base, identifies and obtains customer information in real time, and sends the result to the service personnel.

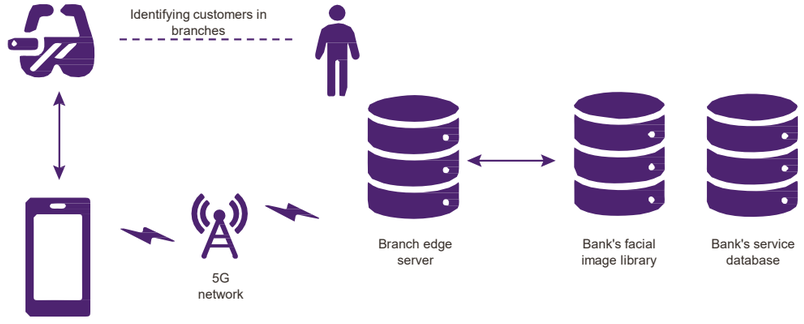


Figure 5-6: 5G-based AR/VR immersive financial services

5G Network Performance Requirements

Service	Communications Requirement			
	Uplink Bandwidth	Downlink Bandwidth	Transmission Latency	Reliability
AR/VR immersive financial services	≥ 50 Mbps	≥ 200 Mbps	≤ 15 ms	99.99%

Scenario 2: Holographic Immersive Financial Services

Holographic immersive financial service refers to using 5G networks and holographic projection technologies to provide scenario-based, immersive, and customized financial services for users, enhancing user experience and improving user satisfaction.

Figure 5-7: Holographic immersive financial services

Customers are served by 5G financial consultants displayed through holographic projection, real-time image capture, and image synthesis. When a customer selects a service, a 5G financial consultant obtains customer information from the background and matches a service specialist for the customer. It projects a holographic image of the service specialist on the screen in real time through the 5G network, enabling the service specialist to provide personalized business services for the customer.

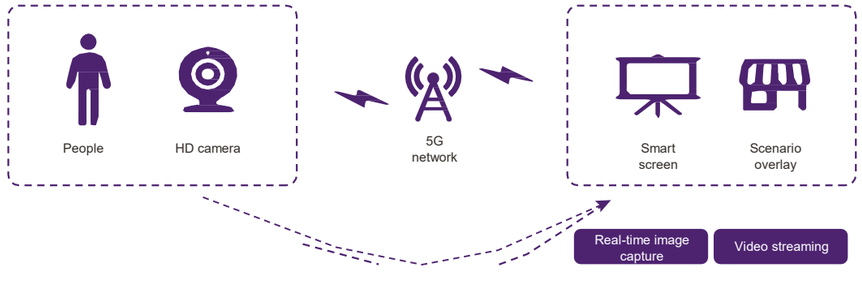


Figure 5-8: 5G-based holographic immersive financial services

5G Network Performance Requirements

Service Name	Communications Requirement			
	Uplink Bandwidth	Downlink Bandwidth	Transmission Latency	Reliability
Holographic immersive financial services	≥ 150 Mbps	≥ 500 Mbps	≤ 30 ms	99.99%

Scenario 3: Smart Financial Robot Service

Smart financial robots can be widely used in customer service centers to provide interactive self-services such as service guidance, area directions, and service handling, improving efficiency and reducing labor costs.

Figure 5-9: Financial robot service

A financial robot collects data relating to users' requirements using cameras and microphones, and transmits the collected data to the backend through the 5G network. The backend analyses the data for information on users' requirements, integrates data from systems such as the service knowledge base and customer relationship management (CRM) to calculate matching answers, and sends the results to the frontend. In the process, the robot can provide smart financial services for users.

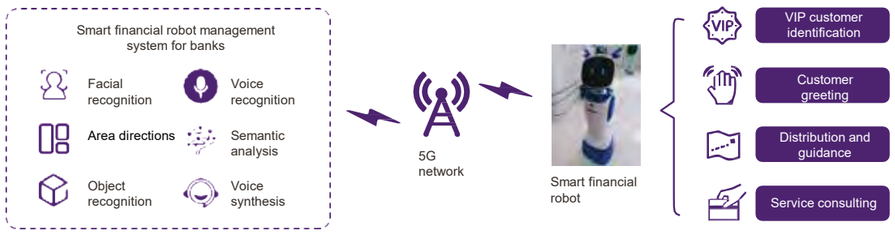


Figure 5-10: 5G-based smart financial robot service

5G Network Performance Requirements

Service Name	Communications Requirement			
	Uplink Bandwidth	Downlink Bandwidth	Transmission Latency	Reliability
Smart financial robot service	≥ 80 Mbps	≥ 100 Mbps	≤ 15 ms	99.99%

Scenario 4: HD Video Customer Service

The capabilities of the 5G network enable end-to-end HD video streaming, providing a platform for multimedia video scheduling to remotely conduct video calls with dedicated customer service personnel through scenario analysis and resource scheduling. This approach achieves convenient and remote interaction between customer service personnel and users which is a huge step up from traditional methods of and improves efficiency in customer service.

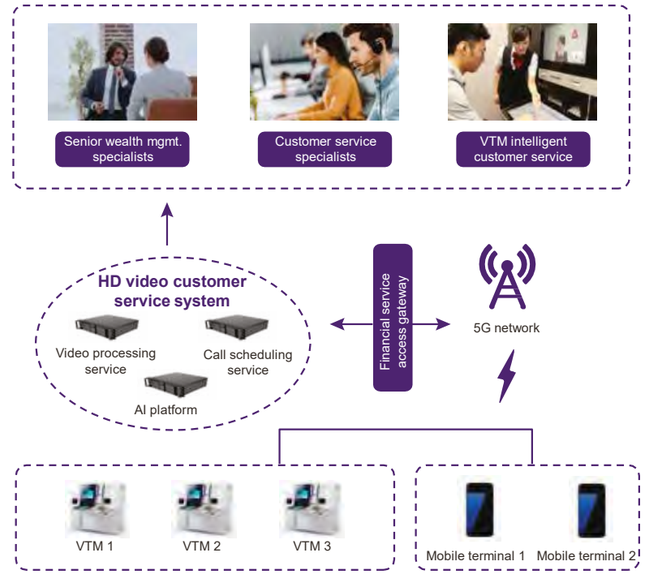


Figure 5-11: 5G-based HD video customer service

5G Network Performance Requirements

Service Name	Communications Requirement			
	Uplink Bandwidth	Downlink Bandwidth	Transmission Latency	Reliability
HD video customer service	≥ 30 Mbps	≥ 100 Mbps	≤ 30 ms	99.9%

Scenario 5: Safe Branch

The financial industry has high requirements for security surveillance in business branches. Safe financial branches use recording devices such as cameras and sensors to record the behavior of users in real time, and transmit the data through the 5G network. The edge computing capability and the monitoring and analysis platform are utilized to analyze, identify, and track the suspicious behavior of customers in branches, improving the automatic and proactive security protection in branches as well as reducing labor costs and increasing efficiency in bank security protection.

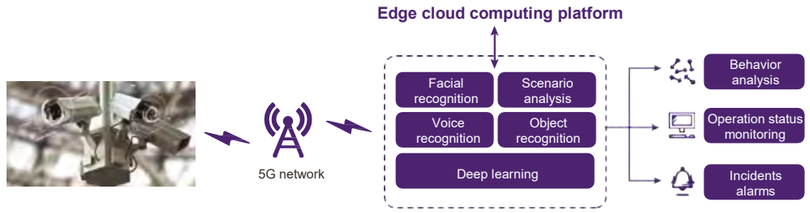


Figure 5-12: 5G-based safe branch

5G Network Performance Requirements

Service Name	Communications Requirement			
	Uplink Bandwidth	Downlink Bandwidth	Transmission Latency	Reliability
Safe branch	≤ 150 Mbps	≤ 400 Mbps	≤ 30 ms	99.9%

Scenario 6: Smart Resource Management System (RMS)

5G networks and IoT, AI vision, blockchain, and AI technologies are used to integrate physical perception and financial data. In addition, IoT financial big data is recorded to build an objective credit system and capability for risk management that incorporates physical and credit information for movable property financing and insurance, asset securitization, movable property insurance, receivables, and lease financing. This helps small- and medium-sized enterprises to raise funds.

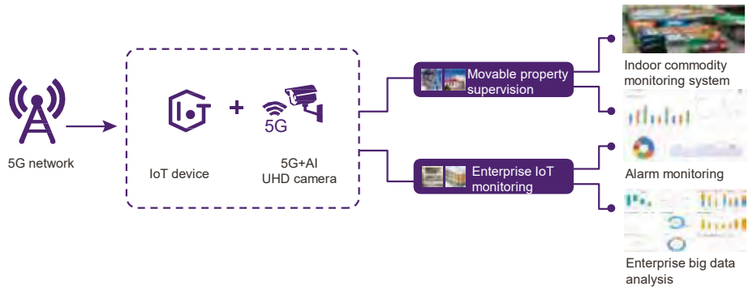


Figure 5-13: 5G-based smart resource management system

Movable property monitoring: 5G, IoT and AI vision technologies are used in scenarios involving indoor commodity pledging to support detection of suspicious handling of movable properties, 3D machine vision monitoring, device awareness, and alarm monitoring, as well as to build a platform system to monitor multiple movable properties. They are also used to intelligently monitor movable collateral.

Enterprise IoT monitoring: 5G network capabilities can record massive volumes of enterprise data. The production data of loan enterprises can be obtained through equipment such as NB-IoT current rings, smart water and electricity meters, and 5G+AI UHD cameras on the OneNet platform to form associated data bodies and establish a big data risk warning system. This facilitates multi-dimensional monitoring of enterprise operations and provides enterprise risk management and warning solutions for financial institutions and government financial supervision departments.

5G Network Performance Requirements

Service Name	Communications Requirement				
	Uplink Bandwidth	Downlink Bandwidth	Transmission Latency of Video Footage from Cameras	IoT Device Connections	Reliability
Smart RMS	≥ 20 Mbps	≥ 80 Mbps	≤ 3s	$10^4/km^2$	99.9%

Scenario 7: Smart Device Interaction

Smart financial devices such as air screen, embedded interactive screen, and desktop interactive projection utilize both the 5G network and the cloud-pipe-device design to streamline online and offline financial services and improve user experience.

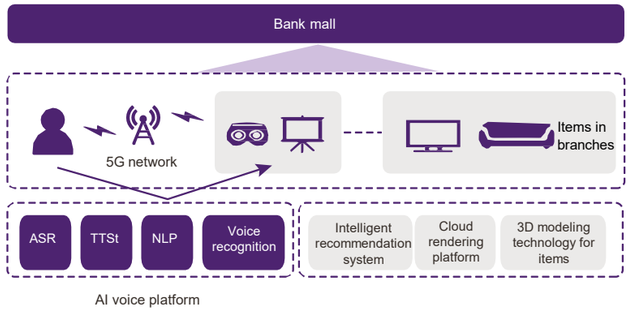


Figure 5-14: 5G-based interaction between smart financial devices

5G Network Performance Requirements

Service Name	Communications Requirement			
	Uplink Bandwidth	Downlink Bandwidth	Transmission Latency	Reliability
Smart device interaction	≤ 50 Mbps	≤ 200 Mbps	≤ 30 ms	99.9%

4. Use Cases

China Mobile works together with multiple large financial institutions to explore new applications of 5G service and promote innovation in service scenarios, service experience, and business models.

Case 1: 5G Smart Banking Branch in SPDB

China Mobile and Shanghai Pudong Development Bank (SPDB) explored the innovative convergence of 5G technologies and financial services. On June 27, 2018, the SPDB-China Mobile Joint 5G Financial Innovation Lab was established, and on May 17, 2019, the "5G + Smart Banking" branch was established in Zhangjiang, Shanghai. The bank launched the 5G smart counter, "i-Counter", a 4K HD video customer service, intelligent authentication, and 5G immersive experience that utilizes virtual imaging technology and augmented-reality glasses, providing customers with more secure and convenient services.

Figure 5-15: SPDB's 5G smart banking branches

Case 2: CCB's 5G Smart Banking

On March 12, 2019, China Mobile and China Construction Bank (CCB) signed a *Memorandum of Understanding on the 5G Joint Innovation Center*. The two will work together on innovations in the 5G field and deepen cooperation to achieve convergence of scenarios. Based on the design concept proposed by CCB, China Mobile quickly responded to requirements and developed a 5G network slicing solution to meet service demands such as intelligent monitoring and fast payment in business branches, and provide users with "5G+Internet" high-speed Internet access.

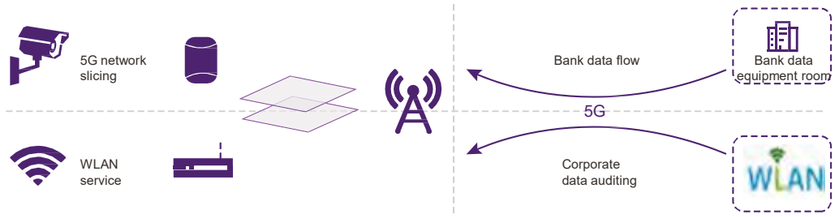


Figure 5-16: Technical solution of CCB's 5G smart banking

On July 11, 2019, the first batch of CCB's "5G + Smart Bank" showcase branches based on China Mobile's 5G network were deployed in Beijing, including the Tsinghuayuan Branch, Jianguo Branch, and Xingrong Branch, and more 5G technology banks were utilized later.

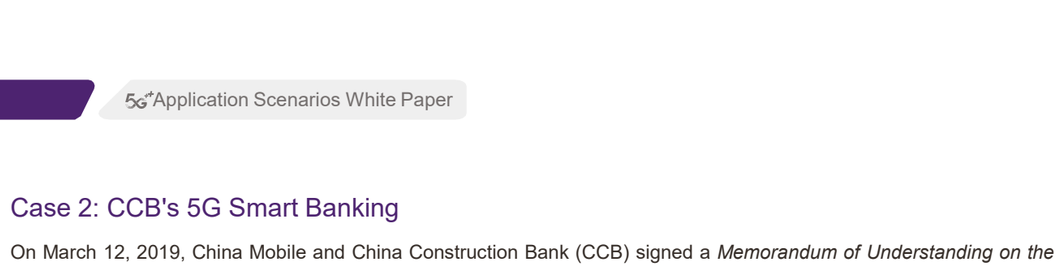


Figure 5-17: CCB's "5G + Smart Banking"

Case 3: ICBC's 5G Smart Branch

On June 11, 2019, the Industrial and Commercial Bank of China (ICBC) released the "5G Smart Branch" in Suzhou. Based on China Mobile's 5G network, ICBC provides users with intelligent financial services using technologies such as big data analysis, low-latency information transmission, and AI. Innovative devices for smart health checks, book borrowing, and self-service shopping are widely used in smart branches, hugely improving the refined operation capability, as well as the risk prevention and control capability, helping ICBC build a one-stop smart branch ecosystem.

Figure 5-18: ICBC's "5G Smart Branch"

Case 4: Smart Banking in Suzhou's Financial Town

On April 16, 2019, China Mobile and Suzhou Merchants New Investment and Development Company signed a cooperation agreement for "5G + financial town" to jointly promote the innovation and development of the financial industry in Suzhou. Currently, China Mobile has already implemented multi-layer coverage of 5G signals in the financial town. Based on 5G network capabilities, the solution provides a better transaction experience for bank branches in small towns, implements 5G immersive financial services, and supports the access and management of a large number of self-service financial terminals and IoT devices, implementing smart management of resources and improving efficiency in financial services.

Figure 5-19: Smart banking in Suzhou Financial Town

5G Smart Media

As the media industry evolves towards HD, multi-view, and strong interactive experiences, the media industry has increasingly high requirements for large bandwidths, as well as cloud and AI technologies. It is estimated that 5G will bring a market space of hundreds of billions of dollars to the media industry by 2022. 5G networks will evolve the media industry by implementing: 1. Mobile collection and transmission of 4K/8K/AR/VR/holographic ultra-HD (UHD) videos; 2. More mobile and intelligent management and processing of media assets; 3. Precise transmission of media content and multi-terminal coverage of media information.

China Mobile has built a 5G smart media product system integrating clouds, pipes, and devices. Based on the media cloud platform along with abundant mobile collection and editing devices, China Mobile provides a package of solutions including mobile collection and editing, intelligent media assets, and an intelligent voice function for the media industry, facilitating the transformation of the traditional media industry and cultivating the new media industry.

5G Smart Media

1. Service Requirements

The booming development of 5G network technologies enables real-time transmission of UHD videos in the media industry, as well as mobile and intelligent management of content production. 5G features high speeds, low latency, and large connections, which allows for real-time transmission, bidirectional interaction, intelligent editing, intelligent review, and converged release of high-bit-rate audio and video content, and promotes the implementation of 5G + 4K + AI.

Media convergence has become a mainstream trend in recent years. At the national conference on publication and ideological work, General Secretary, Xi Jinping, called for the construction of county-level media centers. Subsequently, construction specifications have been released, and national coverage of county-level media centers is to be achieved by the end of 2020. All media units are expected to follow the integration and convergence policy and create a batch of new mainstream media with strong influence and competitiveness.

Requirement 1: Real-Time Collection and Transmission of 4K/8K UHD Videos

With the development of 4K/8K technologies, video content is developing from high-definition (HD) to ultra-HD (UHD), and program production has increased requirements on mobility and real-time performance.

Traditional UHD video collection and transmission rely on wired connections, satellite, and microwave. Private lines need to be deployed onsite, resulting in poor mobility, high costs, and long commissioning time. 5G provides stable uplink and downlink bandwidths of 100 Mbps to 1,000 Mbps, which can be used for 4K/8K live broadcast and clip transmission in scenarios such as breaking news and large concurrent events in multiple places. The 5G network slicing capability ensures clear and stable live broadcast and transmission of videos by establishing dedicated virtual channels.

Figure 6-1: UHD video collection and live broadcast

Requirement 2: Upgrade from One-Way Transmission to Real-Time Direction and Audio and Video Interaction

On traditional interview-based program productions, on-camera journalists receive remote dispatching directions over the phone, and the production team in the studio are unable to obtain program images in real time. Due to limited network bandwidth and latency, most programs are transmitted remotely or prerecorded, resulting in poor communication. The high speed and low latency of 5G networks can effectively implement seamless bidirectional video connection and interaction, improving program forms and enabling real-time scheduling of multiple on-camera journalists.

Figure 6-2: HD/UHD video transmission

Requirement 3: Mobile Management and Intelligent Editing of Media Assets

Media organizations generally utilize a large number of media assets. Traditional management of media assets features poor mobility and low utilization. Mobile upload, archiving, retrieval, editing, sharing, and processing of media assets, as well as intelligent cataloging, editing, and management have become urgent requirements for current media asset management. With network slicing and edge computing technologies, 5G networks can implement IP-based and mobile production of media assets. In areas covered by 5G networks, UHD video transmission, mobile editing, mobile production, and UHD program production with large bandwidth and large capacity are implemented, achieving smooth transmission between outdoor recording and editing and indoor production.

Figure 6-3: Mobile and intelligent media asset management

2. Solution Overview

Based on new network technologies such as 5G, edge cloud, network slicing, and AI, China Mobile has built a 5G smart media product system that integrates clouds, pipes, and devices. It also has built a media cloud platform that converges audio and video processing capabilities such as ingesting, transcoding, cataloging, non-linear editing (NLE), and scheduling, and incorporates innovative products such as portable 5G backpacks, media assets, real-time translation, and cloud image collection. The system and platform implement functions such as mobile editing, intelligent media assets, intelligent voice function, and precise propagation, helping the media industry develop towards mobility, informatization, and intelligence.

Collection layer: This layer mainly includes various 5G service devices involved in media industry application scenarios, including individual reporter terminals (portable 5G backpacks), interactive broadcasting stations, and converged interactive servers, to record and edit 4K/8K UHD videos.

Network layer: 5G network features such as high speeds, low latency, and large connections, and new technologies such as edge computing and network slicing can meet the network requirements of different media customers for multiple scenarios such as recording, editing, and broadcasting.

Platform layer: This layer provides cloud storage, intelligent cataloging, intelligent editing, intelligent reviewing, and sharing and retrieval of media assets such as audio and video for 5G media industry applications.

This layer also provides communication connection management, intelligent network scheduling, cloud-based broadcast control management, cloud-based converged scheduling and command, intelligent voice transcription, and voice synthesis for 5G collection and editing devices. In addition, standard interfaces and self-service interfaces can be provided externally to enable new media service applications in various forms at the upper layer.

Application layer: For segmented fields such as mobile 4K/8K collection, intelligent news, intelligent media assets, holographic images, augmented reality (AR) and virtual reality (VR) production and broadcasting, and communication analysis, China Mobile develops industry applications in different scenarios to facilitate mobile and intelligent media production and innovate the mode of communication.

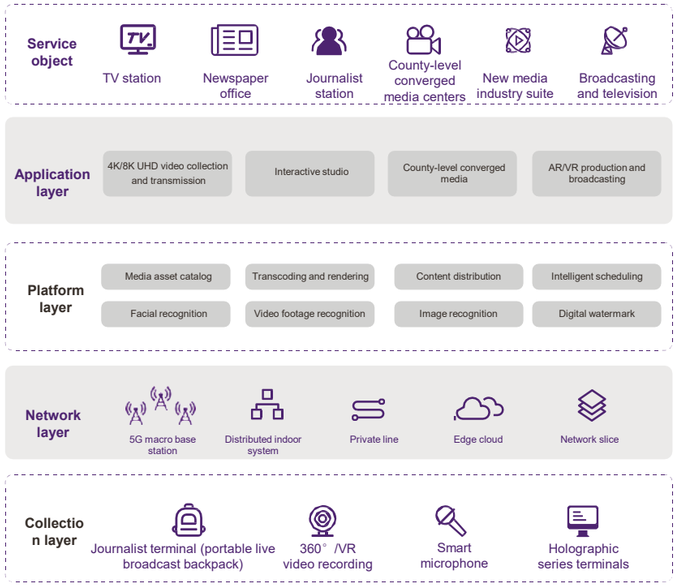


Figure 6-4: System architecture of the 5G smart media solution

3. Application Scenarios

Scenario 1: 5G 4K/8K Live UHD Video Streaming

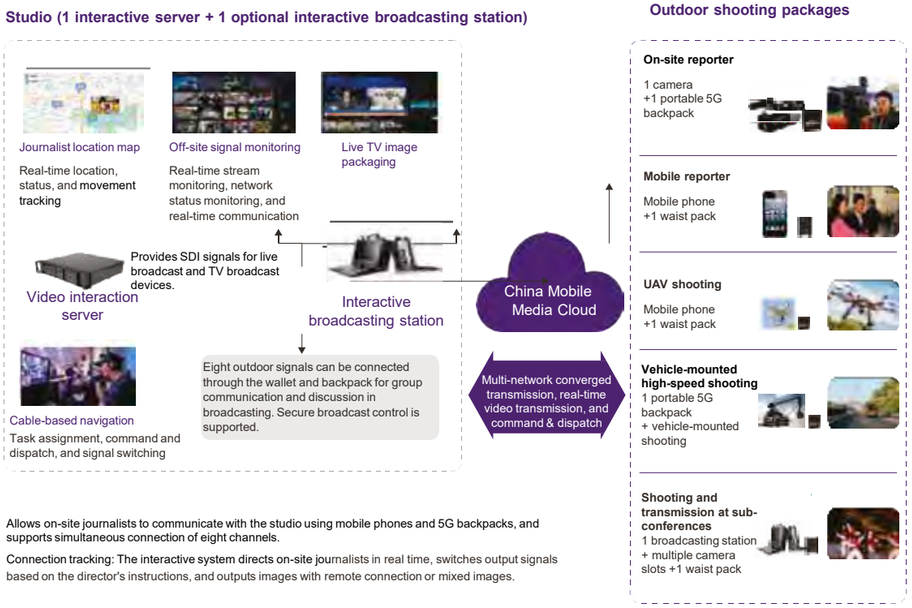


Figure 6-5: Application scenario of 5G UHD video collection and transmission

China Mobile's portable 5G backpack products are connected to 4K cameras or other recording devices. With the high efficiency and low latency of the 5G network, UHD video content can be efficiently recorded and transmitted. After video resources are transmitted to the cloud or directly to the studio, they can be directly broadcasted to users through the content distribution network or TV broadcast network. This ensures that the transmission latency does not exceed 20 ms, fully meeting the requirements of broadcast and television customers for real-time HD video connection and outdoor signal transmission, and resolving the issue of insufficient bandwidth for transmitting 4K/8K videos in the 4G network.

5G Network Performance Requirements

Service Name	Communications Requirement				
	Function	Uplink Rate	Downlink Rate	Transmission Latency	Coverage Scenario
Video communication	4K video	≥ 36 Mbps	≥ 36 Mbps	≤ 20 ms	Outdoor/Indoor
	8K video	≥ 120 Mbps	≥ 120 Mbps		

Scenario 2: 5G Interactive Studio

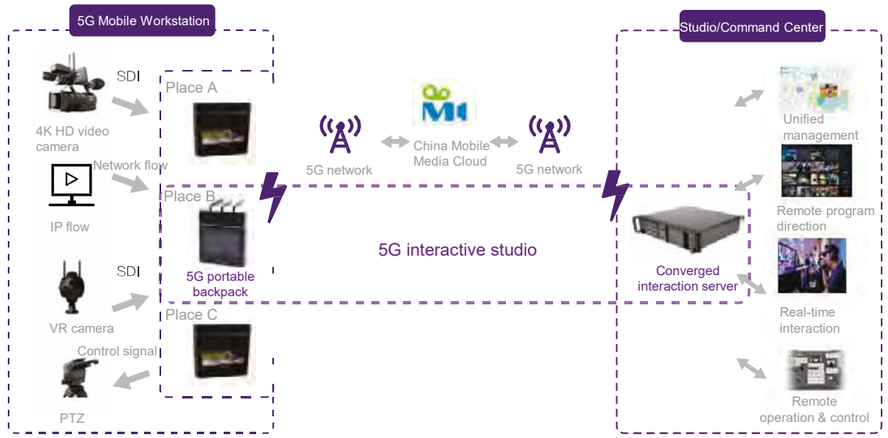


Figure 6-6: 5G interactive studio application scenario

China Mobile's portable 5G backpacks can connect to the cameras and work with broadcasting stations or converged interactive servers through the 5G network to quickly implement the 5G interactive studio solution. By fully utilizing 5G networks, the solution provides around 130 Mbps bandwidth and within 20 ms of end-to-end latency, and transmits HD images of the interview site in real time over the 5G network. The solution provides functions such as multi-camera, cross-location, and interactive connections, signal transmission, remote scheduling, as well as low-latency live broadcast interviews, live sport event broadcasts and other types of broadcasting. This is an innovation to conventional broadcasting modes and facilitates real-time communication.

Scenario 3: 5G County-level Converged Media

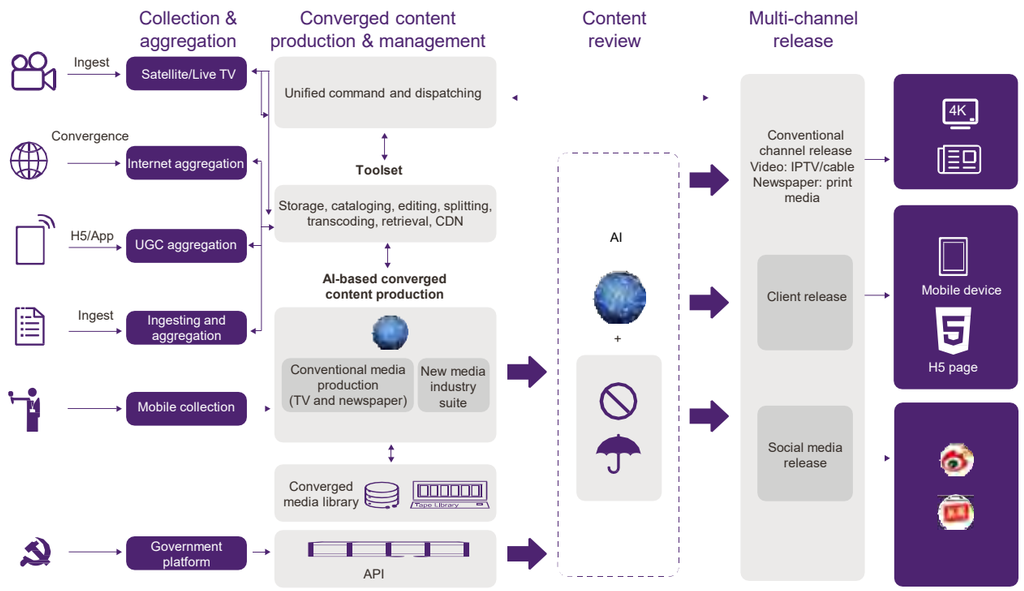


Figure 6-7: 5G county-level converged media

Relying on its 5G network advantages, China Mobile provides a county-level 5G converged media solution backed by the media cloud platform, 5G backpack, and media resources. The solution empowers integrated services, including collection and aggregation, converged production, content review, and multi-channel release. It integrates media collection, editing, broadcasting, storage, and management. China Mobile can build customized converged media platforms capable of content sharing, resource consolidation, centralized construction, and local adaptability. This supports: media, CPC, government, public, and value-added services.

Scenario 4: 5G VR/AR Production and Broadcasting

China Mobile has built a UHD cloud production and broadcasting platform based on the strengths of 5G and VR/AR. The platform can deliver approximately 130 Mbps bandwidth and an end-to-end latency within 20 ms. Additionally it provides cloud content and rendering to extend mobility beyond space, providing users with AR/AR media asset management, media publicity, and entertainment experience. The solution capabilities span across the device engine, pipe, and cloud computing, promoting and benefiting the entire media industry. Processes ranging from concepts, flows, to effects are streamlined to allow for the VR-to-home service.

5G Network Performance Requirements

Service Name	Communications Requirement				
5G VR/AR production and broadcasting	Function	Uplink/Downlink Bandwidth	Transmission Latency	Reliability	Coverage Range
	Mobile and intelligent content production and broadcasting	≥ 40 Mbps	≤ 20 ms	> 99.9%	Outdoor/Indoor

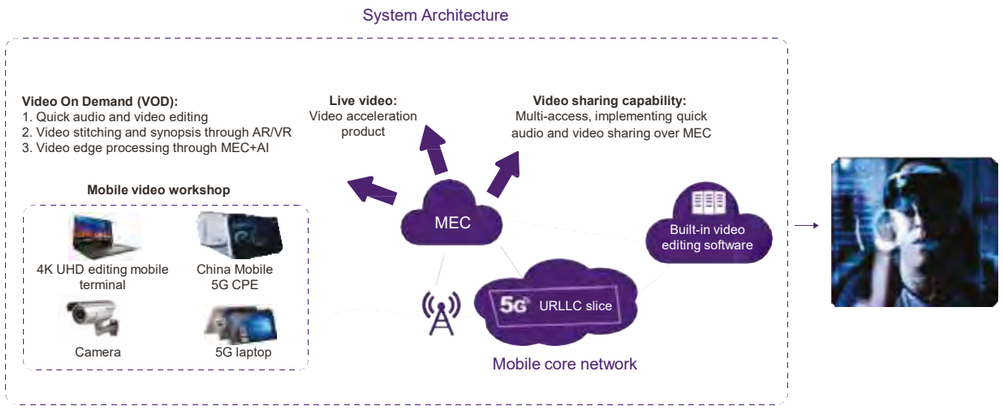


Figure 6-8: 5G VR/AR production and broadcasting application

4. Use Cases

Case 1: Industry's First 4K Live Broadcast of 5G SA Network Slicing

On May 15, 2019, China Mobile and China Media Group (CMG) jointly completed the industry's first 3GPP-based 5G standalone (SA) media 4K live broadcast slice in Beijing, China. Built on China Mobile's 5G SA network, this solution offers an end-to-end network slice specifically dedicated to China Central Television (CCTV) 4K live broadcast services. CCTV can enjoy an exclusive live broadcast channel with ultra-large uplink and downlink bandwidths. Additionally, ultra-low latency is used to ensure a real-life 4K HD video experience. Even with heavy-traffic packet injection on the radio access network, transport network, and core network, live broadcast services with high priorities are still not affected. Further, video playback is clear and smooth.

Figure 6-9: Comparison test of 4K live broadcast and packet injection in 5G SA network slicing

Case 2: 5G 4K UHD Live Broadcast at 2019 China Spring Festival Gala

On February 4, 2019, the Shenzhen fair Spring Festival Gala was aired live in 4K UHD videos over China Mobile's 5G network. Videos were sent back to the outside broadcast (OB) van and the CMG studio in Beijing through 5G base stations. Back in January 13, the first test was also conducted in Shenzhen. Through China Mobile's 5G trial network, 4K UHD videos were successfully transmitted between the CMG studio in Beijing and the Shenzhen Branch. Real-time signals were transmitted over 4K UHD OB vans, with this being the first 4K transmission over 5G networks in China.

Figure 6-10: CMG 2019 Spring Festival Gala 5G 4K live broadcast

Case 3: Digital China Summit in CCTV 5G Lightweight Studio

During the Digital China Summit in May 2019, China Mobile helped CCTV quickly build a 5G onsite lightweight studio. HD cameras were connected to 5G backpack devices, and compressed video streams were pushed and live broadcast through the 5G network, ensuring HD, smooth, and stable live broadcast on CCTV news clients.

Figure 6-11: Digital China in 5G lightweight studio of CMG

Case 4: 5G Mobile Live Broadcast in Zhengzhou, Qingdao, Yinchuan, and Yangzhou Marathons

On March 31, 2019, China Mobile used the 5G backpack solution to support Henan Radio and TV Station for the HD live broadcast of Zhengkai International Marathon. On May 4, the 5G backpack solution supported the Qingdao Youth Marathon by providing 100% 5G signal coverage at over 80 5G sites along the racetrack. This project is the first 5G live broadcast in full mobility scenarios in China. To date, China Mobile's the 5G backpack solution has supported multiple marathons through 5G live broadcast, including those in Yangzhou and Yinchuan.

Figure 6-12: 5G mobile live broadcast at Zhengkai International Marathon and Qingdao Youth Marathon

Case 5: 5G Simultaneous 4K Live Broadcast of a Dance Show at Two Sites in Beijing

On May 11, 2019, the original folk dance show "The Railway to Tibet" was presented through the 4K+5G live broadcast from the National Centre for the Performing Arts of China through multiple channels. These included Capital Cinema and China Mobile Migu clients. The live broadcast is the first to base a cinema live broadcast on 4K+5G technology, globally. 4K UHD technology is executed from shooting, transmission, to presentation. The 5G network assurance brought a clearer and smoother live broadcast quality, thanks to a high frame rate (50 frames/s) and a short frame interval (0.02s).

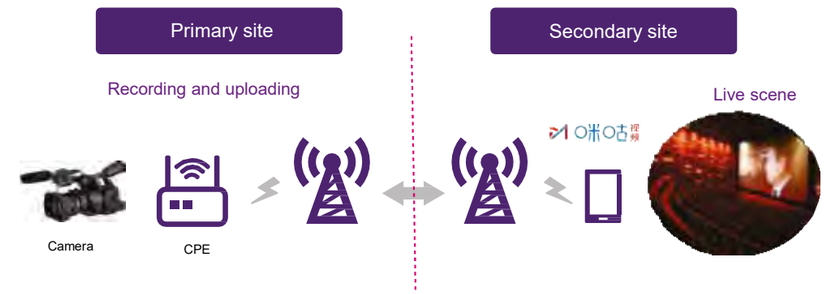


Figure 6-13: 5G 4K live broadcast at the National Centre for the Performing Arts of China and Capital Cinema

Case 6: First Multi-Camera Live TV in Subways in China

During Zhengzhou Metro Line 5's trial run, China Mobile's 5G backpack solution implemented the first 5G multi-camera live broadcast in the subway in China, fully unleashing the potential of multi-channel live broadcast signal transmission. On the strength of 5G, the 5G backpack solution implements multi-camera and cross-location live broadcast, signal transmission, and remote controlling and dispatching. Field journalists communicated with the studio via 5G mobile phones and 5G backpack devices, and accessed UHD videos from eight mobile workstations. The combination of 5G and live TV brings a low-latency HD interactive experience to the audience.

Figure 6-14: First multi-camera live broadcast in metros in China

Case 7: Dolphin Media of Anhui Radio and TV Station

Based on the public cloud platform (mobile cloud) developed by China Mobile, Anhui provincial media cloud platform has been constructed to support production management and release. This includes audio/video production and Internet news production. Its core services include content collection, editing, and releases, including aggregation of diversified media content channels, planning of omnimedia-oriented content production, mobile production tools, and multi-channel content releases. In addition, Dolphin Media provides various audio and video services, such as news, live broadcast, and featured short videos for diversified device users.

Figure 6-15: Dolphin Media of Anhui Radio and TV Station

Case 8: Tianjin Enorth TJyun Central Content Management System

Tianjin Enorth New Media Group achieved "one cloud operation" across the city with the TJyun Central Content Management System. As the provincial platform of converged media in Tianjin, the system has formed a multi-dimensional media matrix covering the Enorth website, Tianjinwe website, Tianjin Today Evening News website, and Tianjin IPTV. Such an innovative system has the potential to become hugely influential among mainstream media in China.

Thanks to the integrated and comprehensive TJyun big data platform, the media group has built an "Internet+" service system related with Internet industries. These include big data, cloud services, smart livelihood, and public opinions on government services. The initiative enhances the group's competitive edge and provides comprehensive government and livelihood services.

Figure 6-16: TJyun Central Content Management System of Tianjin Enorth New Media Group

5G Smart Campus

In light of the significance in education to the national economy and people's welfare, China has proposed the construction of highly advanced cyber and education capabilities. Information and communications technology (ICT) has been crucial to achieving education empowerment. With the advancement of digital ICT and the arrival of 5G, the interactive channels of schools and education institutions are opening up, and learners and educational environments are undergoing tremendous, positive changes. Networked, digital, and intelligent learning becomes a key requirement. Self-learning in an Intelligent environment will become the new norm in the future.

The market size of ICT-based education is about to exceed CNY 250 billion. Depending on its core technology, network, and industry resource integration capabilities, China Mobile provides the education industry with a smart cloud-pipe-device coordinated campus solution. This solution promotes intelligent education services, context-based and popular education applications, aiming to revolutionize conventional education.

5G Smart Campus

1. Service Requirements

To promote the development of "Internet + Education", accelerate education modernization, and strengthen national power, the Ministry of Education released *Education Informatization 2.0 Action Plan* in 2018. This targets "three coverages, two improvements, and one platform" in 2022. The plan promotes extensive application of AI in education, enhancing education effectiveness and optimizing the experiences of learners. The mission is to achieve fairer levels of education with better quality. The high rate and low latency features of 5G enables real-time transmission of high-bit-rate audio and video content, bidirectional interaction, and device-cloud synergy. The Plan promotes 5G, AI learning, campus IoT perception, campus cloud, education big data, and education edge computing. This furthermore allows for interactive teaching, synchronous classes, immersive learning, and campus management and monitoring.

Requirement 1: Balanced Distribution of Educational Resources

Uneven distribution of resources hinders education development in China. The resource imbalance between urban and rural areas and between schools has led to a strong demand for high-quality education. Subsequently the demands for distance education have increased. However, existing distance education solutions are based on wired connections. This presents problems including high construction costs, long construction periods, and fixed installation places, impeding solution promotion. 5G networks, however, allow for flexible deployment, generating a 100 Mbps and millisecond-level transmission experience. 4K HD lectures can quickly and conveniently become available, facilitating the sharing of high-quality education resources and benefiting underdeveloped regions. Additionally, it also allows children in cities to become more familiar with the countryside.

Requirement 2: Innovative Situational Teaching for Improvements on Teaching Quality and Learning Experience

In conventional teaching, students learn passively and inefficiently. This is a pain point for education that conventional teaching methods and models are outdated and impede effective improvements on education quality. Leveraging the virtual simulation technology, a virtual learning environment is created, where students can participate in interactive and game-based learning with their visual, auditory, and kinetic senses mobilized. Abstract theoretical concepts can be presented in a more straightforward and vivid manner. In addition, personalized learning status analysis and talent-specific teaching methods are implemented through big data technology to truly center on learners.

Requirement 3: Efficient and Reliable Intelligent Security Assurance for Campus

Campus security has become a heated, and widely debated social topic. Conventionally, campus security requires a large amount of human resources to perform campus-wide and well-rounded patrol. 5G high concurrency and low latency features make unmanned mobile inspection possible. The inspection robot collects surveillance video data of people, vehicles, and equipment on campus, analyzes and processes the data in real time, identifies people, vehicles, and equipment status, and finally reports alarms in time in case of emergencies, performing smart campus monitoring and management.

2. Solution Overview

China Mobile's 5G smart campus construction solution embodies refined 5G technologies into teaching and management, tackling the access and application difficulties on smart education devices. Also, it eliminates the bottleneck of campus network construction and promotes balanced education development. It paves the way for smart big data applications of lecture education devices. With technologies such as big data and AI, personalized education and teaching become viable, fostering rapid development of education informatization. The system architecture is as follows:

Perception layer: Smart classroom application devices are available, including writing devices, student card devices, teaching video interaction devices, e-whiteboards, VR/AR/MR devices, student mood recognition devices, and various teaching application clients. Safe campus application devices are also provided, including monitoring devices on campus personnel, vehicles, and the environment. Schools provide innovative teaching and a knowledge supply for teachers and students through various intelligent teaching terminals, and implement refined campus management with various monitoring and detection devices.

Network layer: 5G's high rate and low latency features cater for real-time transmission of lecture big data, immersive interaction experience in classrooms, and real-time upload and intelligent analysis of campus surveillance data, ensuring quick emergency response. Additionally, the high capacity of 5G hotspots eliminates the bottleneck of high-speed Internet in densely populated campuses.

Platform layer: The remote interactive lecture platform, virtual innovative teaching platform, and campus smart management platform are available, where video live broadcast, virtual video computing and rendering, and cloud-based intelligent analysis capabilities empower remote interactive teaching and research, AR/VR-based innovative teaching, and safe campus.

Application layer: To promote balanced education development, high-quality remote interactive live classes and teaching and research guidance are provided for teachers and students in remote areas. Virtual teaching tools and innovative teaching modes are adopted to improve teaching quality. Also, campus personnel, vehicles, and devices are centrally monitored and managed, implementing smart and safe campus.

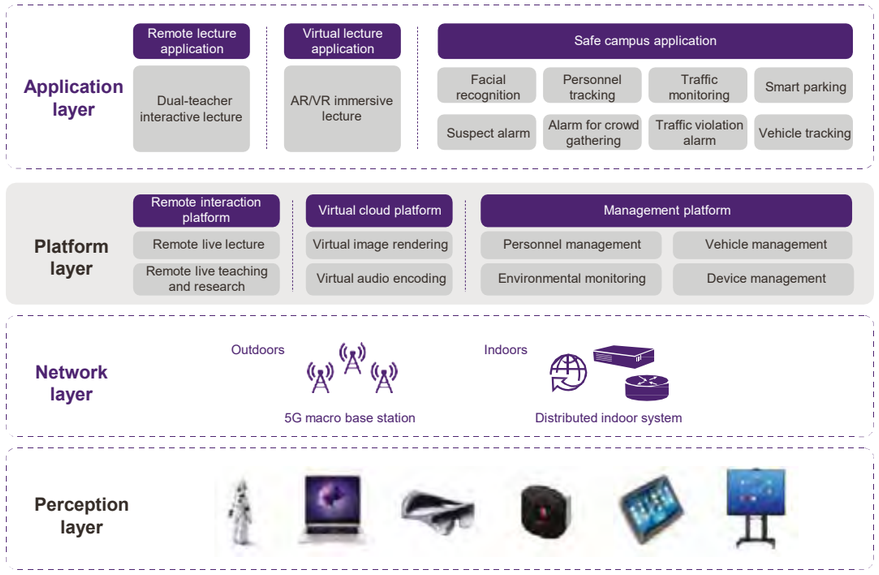


Figure 7-1: System architecture of the smart campus application

3. Application Scenarios

Scenario 1: Remote Synchronous Learning

High rates and low latency of 5G allow for real-time HD audio and video transmission, which makes it possible to learn through remote online lectures of renowned teachers, offline onsite guidance of teaching assistants, and immersive low-latency interaction between distant students and teachers. For education institutions at all levels, 5G network coverage connects a central school and remote schools through remote synchronization, improving education quality in remote areas or underdeveloped areas.

Remote lessons are delivered by two teachers. Existing dual-teacher classes that use wired networks to carry services have the pain points of long construction period, high cost, and poor flexibility. In addition, audio and video delay and frame freezing caused by Wi-Fi networks affect the teaching quality. However, the 5G network features high rate and low latency, enabling flexible and on-demand class scheduling. It solves problems in interaction experience by providing 4K HD video transmission and low-latency interactive and immersive lecture applications, firmly ensuring long-term development of dual-teacher classes.

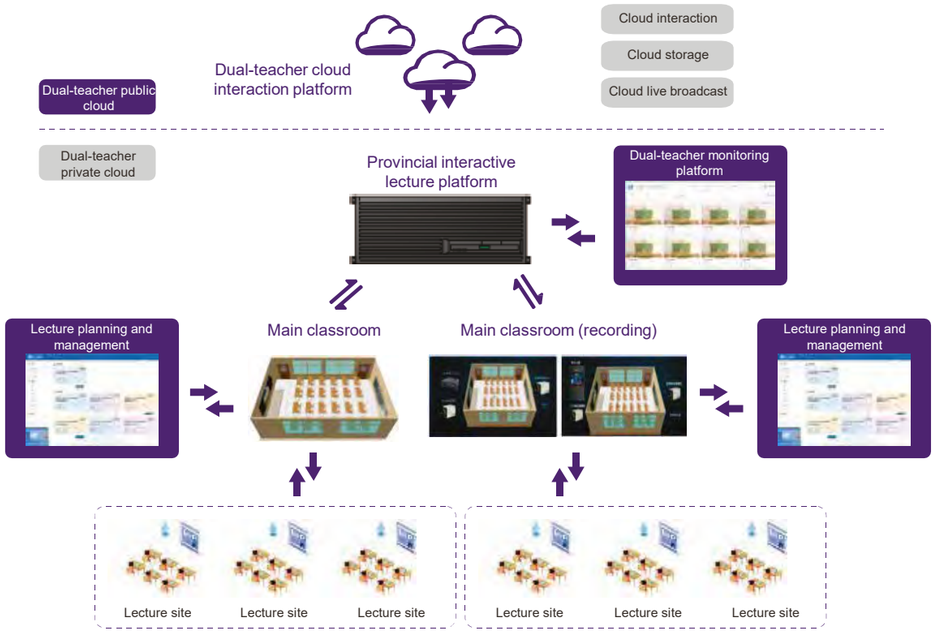


Figure 7-2: Dual-teacher class solution architecture

5G Network Performance Requirements

Service Name	Communications Requirement		
	Uplink Rate	Downlink Rate	Transmission Latency
4K HD dual-teacher class (35 persons per class)	≤ 150 Mbps	≤ 430 Mbps	≤ 20 ms

Scenario 2: Remote Teaching and Research

On the videoconferencing system, experts watch the entire teaching process online and capture videos in real time as materials. On the course evaluation software, experts record, take photos, and record videos of teachers' posture, language, and lecture content. Then, experts grade the performance of lecturers against the international general course evaluation scale provided by the software.

The course evaluation software provides instant messaging services. Experts at different locations can communicate with each other in real time to avoid bias from personal experience. Videos, texts, and audio generated in lectures are taken as materials for background intelligent analysis. Based on the AI model, the system generates comprehensive evaluation reports and improvement suggestions for teachers, helping teachers effectively improve their professional skills.

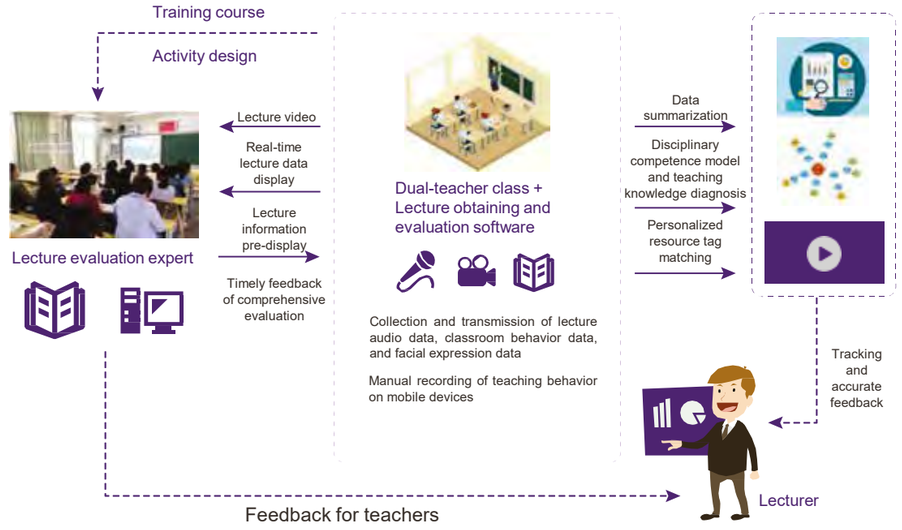


Figure 7-3: Remote teaching and research deployment

Scenario 3: Holographic Projection Open Class

To solve the problem of uneven distribution of education resources in China, VR, AR, and holographic technologies are used to present true-to-life, glasses-free 3D images and courseware contents of teachers to students in remote classrooms, thus achieving natural interactive distance teaching.

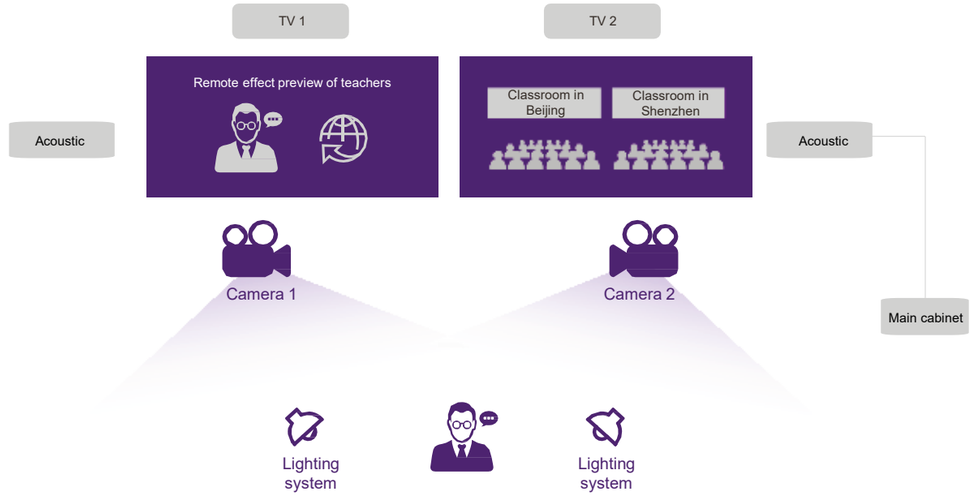


Figure 7-4: Holographic live teaching

5G and holographic projection can solve the problems of uneven distribution of teaching resources and inter-school connectivity. Holography is a scenario of intelligent teaching, achieving one-to-one distance teaching or one-to-many, many-to-one, and many-to-many interactive live teaching. This allows for a sharing of high-quality resources across regions. In addition, holographic classroom realizes distance teaching without changing the interaction habits of teachers and students.

5G Network Performance Requirements

Service Name	Communications Requirement	
	Uplink/Downlink Rate	Transmission Latency
Remote holographic classroom (based on two channels of 4K video per class)	80 Mbps	100 ms

Scenario 4: Cloud AR Interactive Teaching

5G, cloud computing, and XR technologies are used to implement virtualized learning content in classrooms, enhancing the sense of participation, and achieving an immersive interactive learning experience. AR/VR-based teaching content is uploaded to the AR/VR cloud which then runs, renders, presents, and controls AR/VR applications. AR/VR image and voice data is efficiently encoded into audio and video streams and subsequently transmitted to terminals in real time through the 5G network. Cloud AR interactive teaching integrates the VR technology into teaching scenarios to visualize difficult abstract concepts, theories, and knowledge points, providing students with highly simulated, immersive, and interactive virtual learning solutions and increasing learning efficiency.

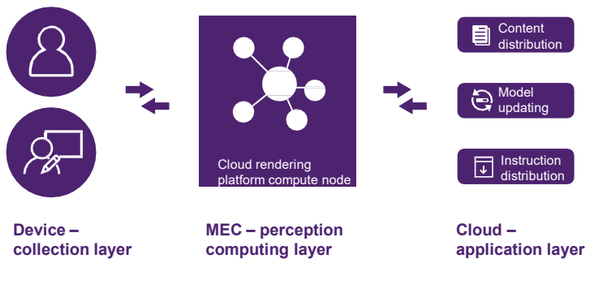


Figure 7-5: Cloud AR/VR architecture

Scenario 5: Safe Campus

In education institutions at all levels, the 5G network is used to ensure safe and efficient campus operation by implementing real-time monitoring, management, and intelligent analysis of people, vehicles, and devices through robots. This solution analyzes the everyday life of students through facial recognition for admission control and attendance. It ensures campus security through video surveillance and alarm generation at campus borders and safety in the kitchens through monitoring. It also provides services such as tracking, video surveillance, AI analysis, and alert generation, allowing parents to keep updated about their children's location and class performance. Moreover, it ensures a secure learning environment by providing powerful security management methods for the campus, enabling prediction of security risks, refined risk checks, and data-based risk handling. Finally, it provides direct and visible supervision tools for education administrative departments.

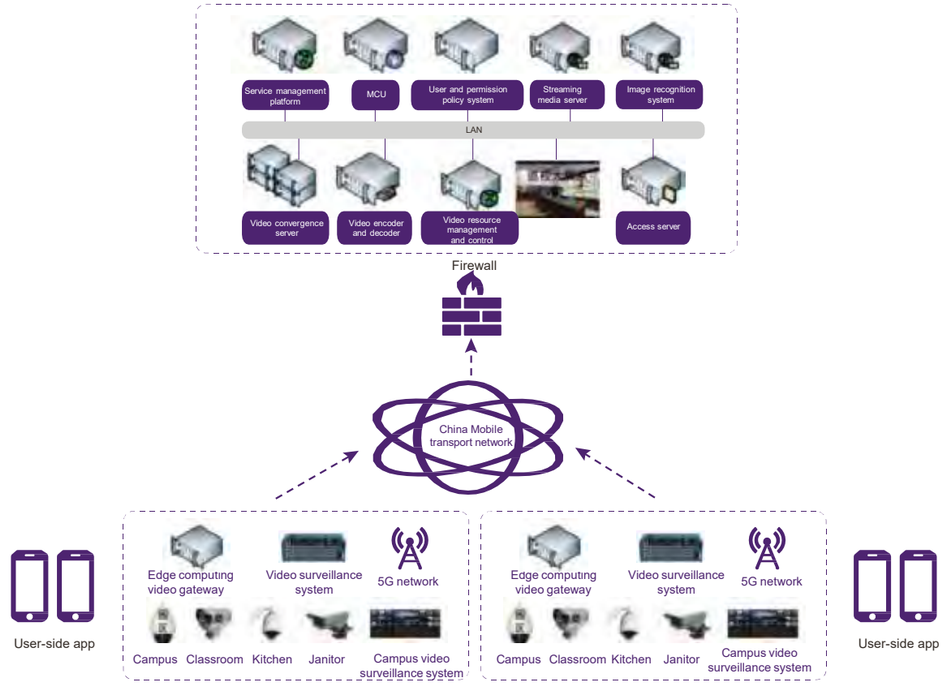


Figure 7-6: Monitoring organization structure

4. Use Cases

Case 1: 5G Remote Synchronous Classroom for Foreign Language School in Science and Technology City, Longgang District, Shenzhen

To develop the deep integration of 5G and education, China Mobile and Shenzhen Science and Technology City Foreign Language School jointly launched a 5G remote synchronous class on July 26, 2019. During the course, with "the secret of rainbow" as the theme, students in Shenzhen and Guizhou attended a scientific inquiry class together. Through the dual-teacher classroom system, the video streams of teachers and students were transmitted between Shenzhen and Guizhou in real time, providing the experience of students in different locations attending a class together. The class fully reflected the innovation brought by 5G to education, and was well received by both the students and the audience alike.

Figure 7-7: 5G remote synchronous classroom

Case 2: Holographic Open Class in Beijing Normal University

To explore approaches to high-quality inclusive education, China Mobile has developed holographic teaching applications for Beijing Normal University. Teachers deliver classes in a green-screen studio and the holographic device transmits the teacher's life-size image to remote areas through the 5G network, delivering high-quality classes to schools in remote areas.

Figure 7-8: Holographic open class

Case 3: Interactive Experience of the Cloud AR/VR Platform at China Science and Technology Museum

On September 17, 2019, China Mobile helped China Science and Technology Museum build a virtual science and technology exhibition hall system using the Cloud XR education platform, breaking the barriers of time and space and providing visitors and schools with rich scientific resources, convenient scientific education services, and a fully immersive experience.

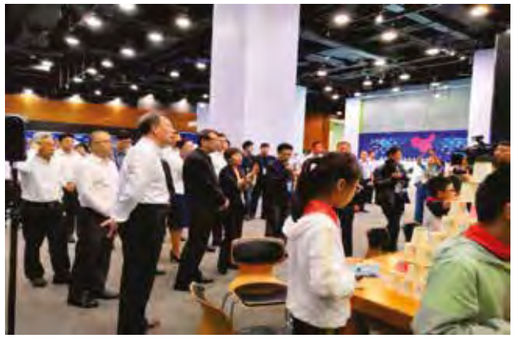


Figure 7-9: Cloud XR interactive experience

5G High-Altitude IoT for Aircraft and Aviation

With the steady growth in air passenger traffic and continuous expansion of air route networks, infrastructure construction such as airports and air traffic control systems has achieved remarkable results. The management system has been continuously reformed and further opened up. China's aviation industry is accelerating the development towards networking, mobility, and intelligence in the wave of informatization reform. Both air-to-ground (ATG) airborne communications and smart airports are closely related to mobile communications, particularly, "ubiquitous connectivity". Based on the next-generation mobile communications network, China Mobile fully leverages the advantages of information technologies and platforms to launch the 5G application solution of IoT for aircraft and aviation, supporting the construction of aviation informatization. In the air-land integration network system, 5G, with its high speed, low latency, and massive connections, uses edge computing and network slicing capabilities to meet the requirements for safe piloting in the front cabin and Internet access in the rear cabin. This system improves the integration of airport informatization upgrades, meets online, cloud-based, and security requirements, enables more innovative applications in the aviation vertical field, and advances towards a new era of "air intelligent network connection".

5G High-Altitude IoT for Aircraft and Aviation

1. Service Requirements

5G mobile communications technologies are vital in promoting the development of the aviation industry, helping improve the quality of the supply system and meeting the increasing requirements for an improved quality of life. IoT for aircraft and aviation will closely meet the huge informatization requirements of the aviation industry, provide passengers with more secure, high-speed, and cost-effective broadband Internet access services in the passenger cabin, safeguard the safety of civil aviation passenger aircraft during flights, and provide convenient and innovative service processes and service modes for the construction of the civil aviation infrastructure.

Requirement 1: Improving Internet Access Experience on Aircraft

With more passengers traveling by air than ever before, traditional in-flight entertainment cannot meet the diversified requirements of passengers for web page browsing, online voice on demand (VOD), instant messaging, and email correspondence. Therefore, Internet access in the air is becoming increasingly popular.

According to Inmarsat's 2017 Inflight Connectivity Survey, more than 60% of passengers believe that in-flight Internet access is necessary, and more than 80% of passengers are willing to pay for these types of services, illustrating high demand for airborne network services. The existing civil aviation industry mainly uses narrow-body aircraft. Therefore, taking the space of the aircraft and the scale of operation into consideration, at least 300 Mbps access bandwidth is required according to Airbus' predication.

Currently, the traditional satellite airborne communications mode features limited bandwidths, low spectral efficiency, and long service latency, which greatly affect the Internet access experience of passengers on board. 5G technology can be customized to facilitate high-speed mobility and wide coverage, enabling high-altitude 3D coverage, improving air-to-ground (ATG) spectral efficiency, implementing high-speed data transmission, and providing a better network experience.

Figure 8-1: High-speed Internet access

Requirement 2: Safety Assurance of Aircraft Piloting

Hundreds of GB data is generated during a flight. However, the high-frequency and very high frequency (VHF) ground-to-air voice communications, and Aero Macs used by civil aviation are all narrowband communications, which are not sufficient for real-time transmission of front-cabin data. Therefore, data can only be transmitted offline after the flight. In addition to the disadvantage of low efficiency, the condition of the aircraft cannot be monitored in real time. The combination of 5G ATG high bandwidth, low latency, and slicing technologies provides a high-bandwidth dedicated network for the front cabin, implementing secure data transmission, the monitoring of the aircraft's location, and video surveillance and transmission all in real time, improving safety in aircraft piloting.

Figure 8-2: Aircraft safe piloting

2. Solution Overview

China Mobile's 5G IoT for aircraft and aviation uses a multi-level distributed system architecture. It uses the 5G network to connect aircraft and airport devices, and deploys edge computing, cloud computing, and AI technologies to monitor the status in real time and collect, process, and push image data, providing one-stop operation services for users in the IoT for aircraft and aviation.

Device layer: Devices in the IoT for aircraft and aviation access the 5G mobile communications network by integrating or installing 5G communications modules, implementing high-speed and low-latency bidirectional data transmission.

Network layer: provides high-speed, low-latency, and massive-connection 5G network services, connects to various core networks based on different service attributes, and connects to the platform layer to implement local processing of key data such as traffic control, identity recognition, and location verification, controlling latency, saving bandwidths, enhancing service reliability, and improving user experience.

Platform layer: encapsulates basic capabilities into common functional modules. It is the core support system of the IoT for aircraft and aviation and the hub of the ground and ATG communications service processes. By connecting to the airline and airport systems, the platform layer provides service product management, user authentication, charging, and billing for Internet access, user management, and service capabilities.

Application layer: provides flexible system architecture support for differentiated vertical fields through capability and data exposure interfaces, and supports diversified 5G network applications. Airlines are provided with front-cabin safe piloting and rear-cabin Internet access services, including real-time monitoring of aircraft location, real-time transmission of front-cabin quick access recorder (QAR) data, Internet browsing, email, instant messaging, social networking, video streaming, VOD, and online shopping.

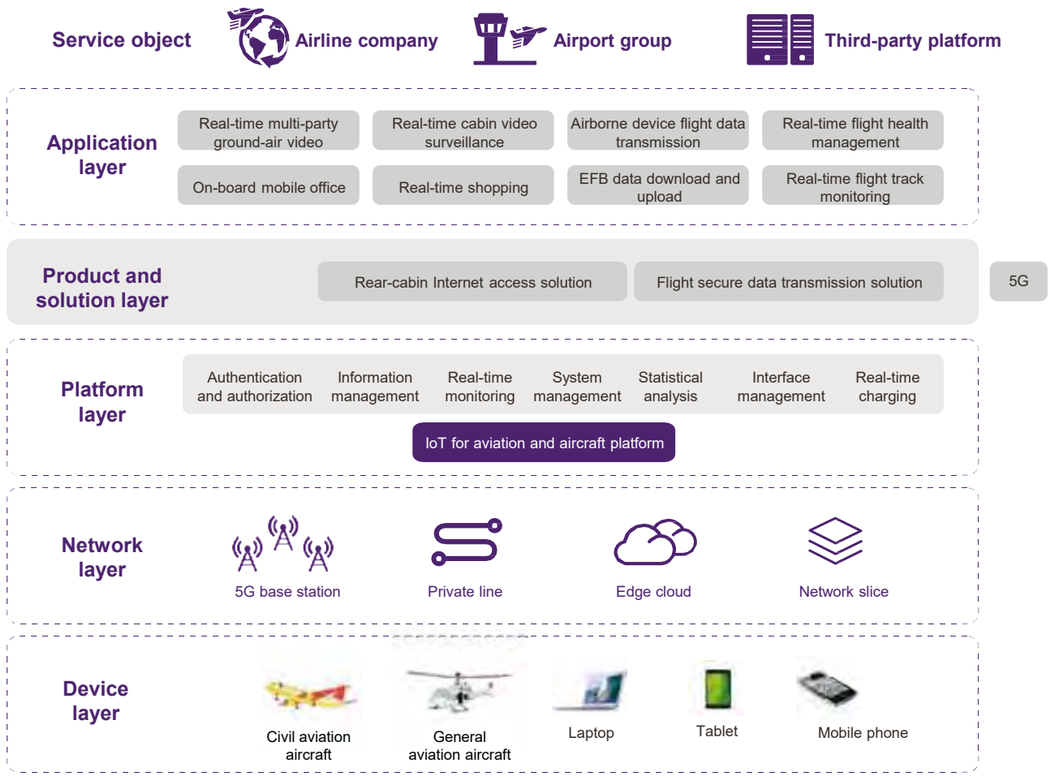


Figure 8-3: Product architecture

3. Application Scenarios

Scenario 1: Rear-cabin Internet Access

After the aircraft enters the cruising phase, the 5G ATG technology is used to provide Internet access with a bandwidth of over 300 Mbps for the passenger cabin of the aircraft and provide Internet services such as online live video broadcast and air-land multi-party video conferencing for passengers, greatly improving the existing Internet access bandwidths of the aircraft, enabling passengers to enjoy more high-speed services.

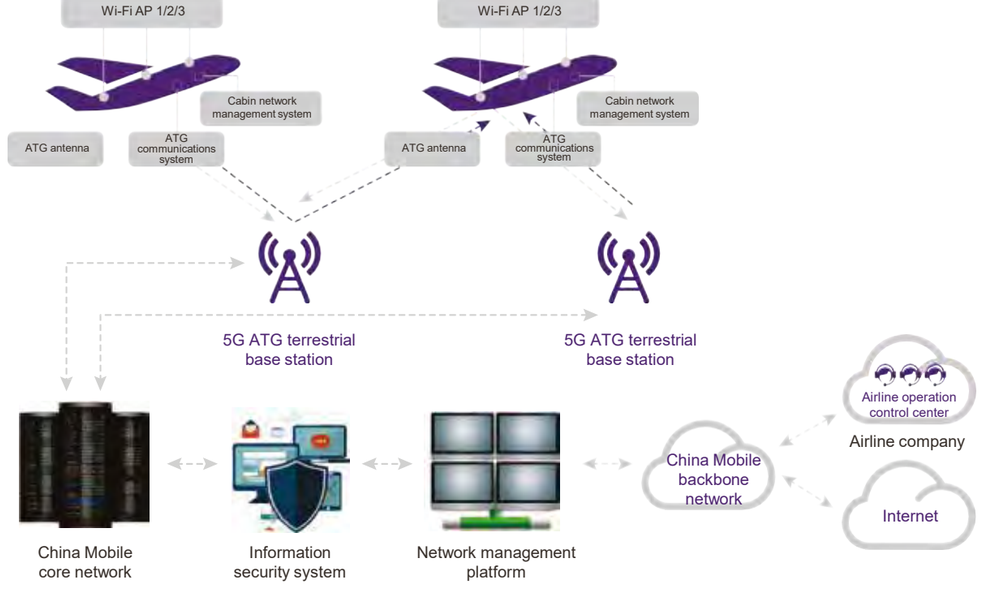


Figure 8-4: Application scenarios of the Internet in the passenger cabin

Scenario 2: Flight Safety Data Transmission

In the front cabin, 5G ATG, featuring high rate and low latency, and network slicing are used to provide a high-bandwidth dedicated network. The network transmits aircraft operation data such as electronic flight bag (EFB) data, QAR data, location data, monitoring data, and video surveillance data in real time, providing real-time data transmission for safe flight and real-time reference data for ground O&M and supervision personnel, and improving the aircraft safety operations and maintenance efficiency after the aircraft has landed.

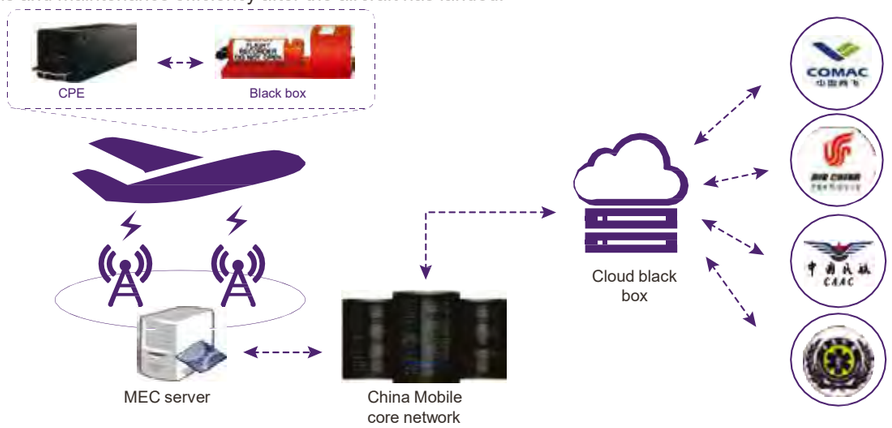


Figure 8-5: Application scenario of flight safety data transmission in the front cabin

4. Use Cases

Case 1: ATG Mainstream Airlines Completed Verification and Pilot Flight

From 2014 to 2017, 52 base stations had been built along three routes, namely, Beijing-Shanghai, Beijing-Guangzhou, and Beijing-Chengdu. Over 400 flights were conducted regularly, and 4G mobile communications technologies were used to build ATG communications networks. The solution enables broadband data communication between the ground network and a civil aviation passenger aircraft at a height of some 10,000 meters. It works with the airline companies to accomplish multiple tasks such as broadband Internet access on board and live broadcast of CCTV Spring Festival Gala, delivering a good experience to on-flight passengers. Currently, it is evolving to the 5G ATG communications solution.

Figure 8-6: CCTV report of ATG verification on mainstream flight routes

Case 2: ATG Access Test for Large Aircraft Manufactured in China

From December 15 to 20, 2018, the "Internet access for China-manufactured large aircraft" project jointly initiated by Commercial Aircraft Corporation of China Ltd (COMAC) and China Mobile at Shandong Dongying Shengli Airport successfully launched their first flight. China Mobile deployed air coverage base stations along the route and used 4G mobile communications technologies to build an ATG communications network. The service tests included real-time transmission of front-cabin QAR data, rear-cabin Internet access, and VoLTE phone service. The actual peak rate was 100 Mbps, and the average rate was 40 Mbps. The ATG communications network can also provide the operation control center with real-time data such as the aircraft location, engine status, and flight status, remotely monitor the safety and condition of the aircraft, and provide warnings against potential threats including severe weather conditions and terrorism. This network is evolving to the 5G ATG communications solution, and 5G high-bandwidth network slices can be used to provide more secure, controllable, and high-speed dedicated network services.

Figure 8-7: ATG access test for China-manufactured large aircraft

5G Smart Agriculture

As the primary industry, agriculture is vital in the development of national economy. Agricultural production is gradually evolving from the small-scale agricultural economy era dominated by manual labor to smart agriculture. As an advanced stage in agricultural production, smart agriculture integrates multiple technologies, such as cloud computing, communications network, remote sensing, and global positioning, to implement precise cultivation, visualized management, and intelligent decision-making for agricultural production. According to the statistics in analysis reports, the potential market scale of China's smart agriculture had exceeded CNY 20 billion by 2018. It is estimated that the potential market scale of China's smart agriculture will reach CNY 26.761 billion by 2020.

China Mobile integrates the technical capabilities of 5G+AICDE (Artificial intelligence, Internet of Things, Cloud computing, Big data, Edge computing) to build a smart product system of "harmonious agriculture". This system focuses on agricultural production, operation, management, and service, and provides services such as precision planting, precision livestock farming, aquaculture, and smart agricultural machinery, to reduce agricultural production costs, improve production efficiency, product quality, and the ecological environment, and facilitate the implementation of the "village revitalization" strategy.

5G Smart Agriculture

1. Service Requirements

Data on soil, climate, crop growth, and pests is the basis of smart agriculture. The utilization of 5G technologies will completely eliminate the bottleneck of data collection in the agricultural industry and promote the in-depth integration of AI deep learning and big data analysis technologies in the agricultural industry.

Requirement 1: Efficient Interconnection of Various Agricultural Data Collection Devices

To improve the intelligence level of agricultural production, the types and number of sensors for collecting various types of basic information will increase rapidly. 5G's large connection capability enables wide-area sensors to interconnect with each other. The interconnection of everything in agriculture will be realized. In addition, 5G's large bandwidth and low latency further promote real-time and precise management of agricultural production.

Requirement 2: Meeting Network Requirements in Various Service Scenarios

Agriculture scenarios are complex and diversified and therefore have different network requirements. For example, smart agricultural machinery requires low-latency and highly-reliable networks. Real-time video surveillance of livestock and crop growth requires large-bandwidth and high-speed networks, and the monitoring of the crop's cultivation environment requires networks with large connection capabilities. These networks need to be divided into independent logical networks based on requirements (such as latency, number of connections, security, and stability) to ensure the stable running of smart agriculture applications. 5G networks can meet various agricultural production informatization requirements to different degrees.

Requirement 3: Analysis of Real-time and Temporary Data and Localized Agricultural Decision-making

In agricultural production, non-real-time and long-term stored data can be processed by the remote cloud platform. Some real-time and temporary data needs to be analyzed immediately for intelligent decision-making and guidance of agricultural activities. For example, 5G+MEC marginalizes real-time agricultural data, reducing the control latency of agricultural equipment and saving network transmission bandwidth.

2. Solution Overview

Based on actual application scenarios and difficulties in agriculture, animal husbandry, and fishery, China Mobile has developed a smart agriculture solution based on 5G networks featuring high rate, low latency, and massive connections and technologies such as big data, cloud computing, edge computing, and artificial intelligence. This solution implements intelligent control and decision-making and supports precision planting and precision livestock farming, promoting digital transformation of traditional agricultural production. The system architecture is as follows:

Perception layer: It consists of devices for video surveillance and the detection and analysis of wind speed, wind direction, atmospheric pressure, temperature, humidity, light, and hydrogen sulfide. These devices collect meteorological information and data on soil and water fertility and crop/livestock status on the agricultural production site, providing necessary data for intelligent analysis and control.

Network layer: Based on the high rate and low latency features of 5G networks, the network layer meets the requirements of real-time transmission, intelligent analysis, and decision-making of big data services such as agricultural monitoring. In addition, the large connection feature of 5G solves the bottleneck problem of the large number of connections of agricultural sensors.

Platform layer: The combination of technologies such as big data, cloud computing, network slicing, edge computing, and artificial intelligence promotes the comprehensive service capability of the smart agriculture big data platform, stores various agricultural production management data, and streamlines agricultural processes. Intelligent agricultural production is deployed through intelligent management of precision planting, precision livestock farming, aquaculture, and smart agricultural machinery.

Application layer: This layer is oriented to farmers, cooperatives at all levels, and supervision organizations. It focuses on agricultural production, operation, management, and services, and provides services such as precision planting, precision livestock farming, smart fishery, and smart agricultural machinery. This layer provides technical support for smart agriculture and effectively improves the production mode of modern agriculture to build smart, efficient, and green agriculture.

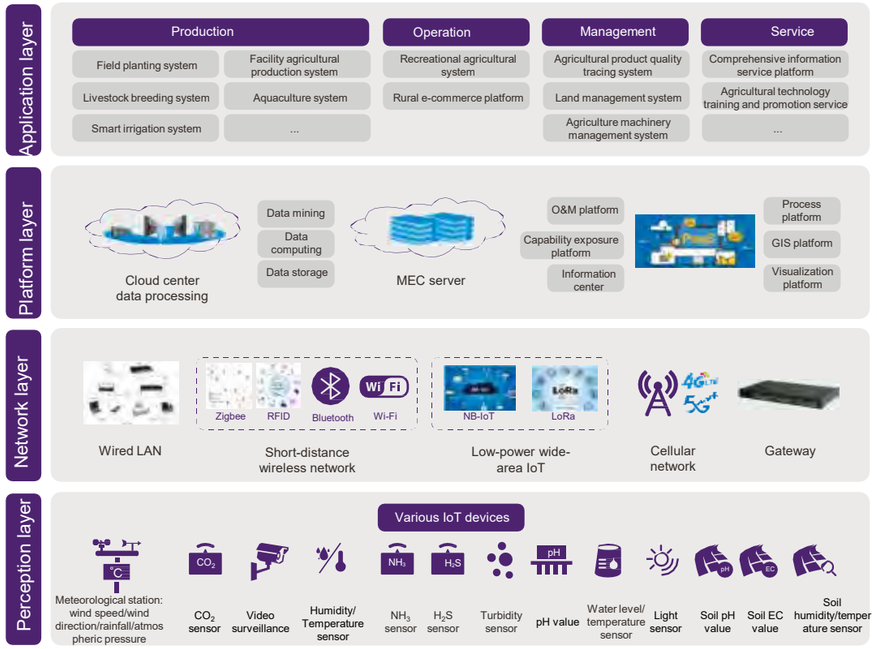


Figure 9-1: 5G smart agriculture solution system architecture

3. Application Scenarios

The smart agriculture solution is used in the "production-operation-management-service" process of agriculture. It is mainly used in scenarios such as precision planting, precision livestock farming, aquaculture, and smart agricultural machinery.

Scenario 1: Precision Planting

The 5G network can accurately collect crop physiological data and crop cultivation environment information in real time to implement land management, crop growth model establishment, crop yield prediction, crop area survey, and pest and disease prediction/prevention. In addition, the low latency of the 5G network enables the models to guide agricultural production activities in the field or greenhouse, such as environment control, irrigation, and spraying, in real time, thereby increasing the agricultural resource usage, saving water and fertilizer, improving crop yields and quality, reducing production costs and environmental pollution, and bringing more economic returns. (The latency of the 4G network is about 6s.)

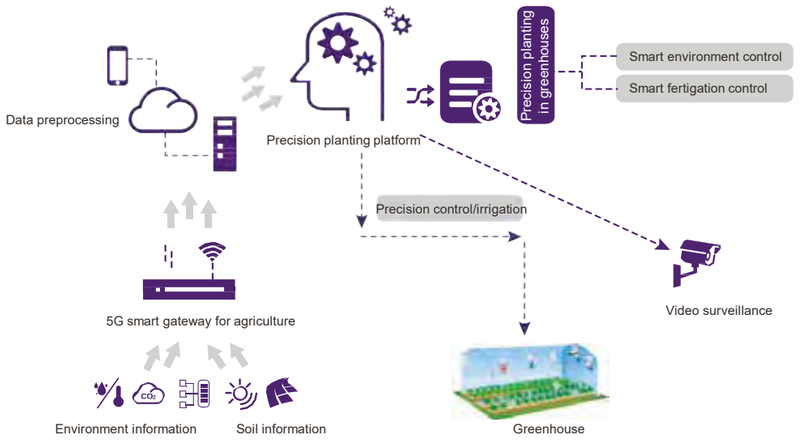


Figure 9-2: Solution architecture of precision planting

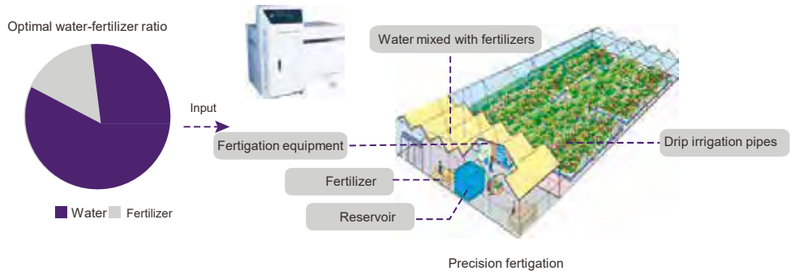


Figure 9-3: Application scenario of precision planting

5G Network Performance Requirements

Service Name	Communications Requirement	
	Bandwidth	Coverage Range
Precision planting	≥ 60 Mbps	Entire plot/paddy field
	≥ 30 Mbps	Inside greenhouses

Scenario 2: Precision Livestock Farming

Precision livestock farming is the use of smart farming devices to manage every aspect of production. Through smart sensors and video/audio recorders, data on pigsty conditions and farming are collected online assisted by 5G networks, which offer high data rates and low latency. The data is then processed using ICT technologies to build a farming data model. Farming is guided by the model, incurring fewer costs, yet yielding greater productions. Moreover, managing and maintaining farm devices become easier.

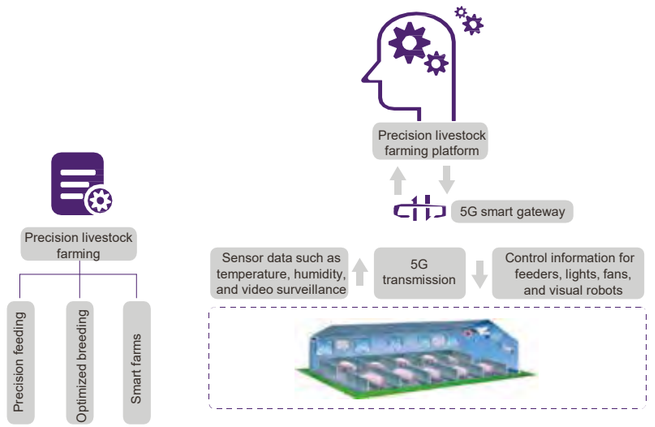


Figure 9-4: Solution architecture of precision livestock farming

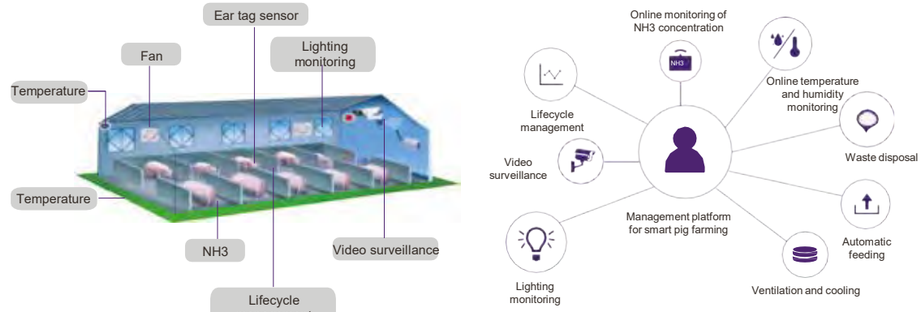


Figure 9-5: Application scenario of precision livestock farming

5G Network Performance Requirements

Service Name	Communications Requirement	
	Bandwidth	Coverage Range
Precision livestock farming	≥ 50 Mbps	Entire farm

Scenario 3: Aquaculture

Various smart IoT devices are used, such as smart water quality sensors, smart fish school monitoring devices, and HD panoramic cameras. These devices are connected to 5G and continuously monitor different kinds of data in real time, including environment indicators (such as the dissolved oxygen, pH, water temperature, ORP, ammonia nitrogen, and nitrite), fish growth data (such as the quantity, size, and density of fish schools), and other dimensions of data on the farm. An aquaculture IoT platform and smart fishery management cloud system are built with big data at the core. They provide functions such as remote farm inspection, smart oxygenation control, automatic feeding, farming data management, precision feeding analysis, and fish product traceability.

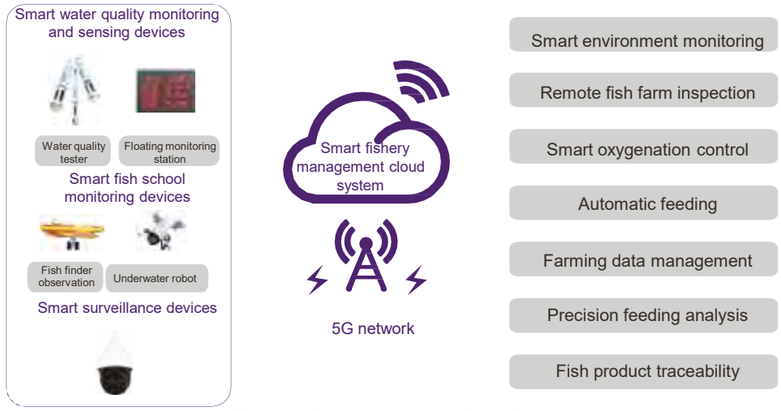


Figure 9-6: Solution architecture of smart fishery

The 5G smart fish finder innovatively uses sonar to estimate the quantity of fish schools and their sizes assisted by 5G, BeiDou/GPS positioning, and data-based modeling. It helps accurately estimate the quantity of fish in breeding ponds in a timely manner. With this device, the value of the subject matter insured is no longer hard to be assessed in the fishery industry. Farm owners can use the estimated results as scientific evidence in applying for aquaculture insurance or loans. In the same vein, the fish finder facilitates quick and accurate loss assessment. Insurance companies and coordinators therefore can work with higher efficiency and lower risks and expand their client base, while farm owners can have their losses covered promptly and correctly.

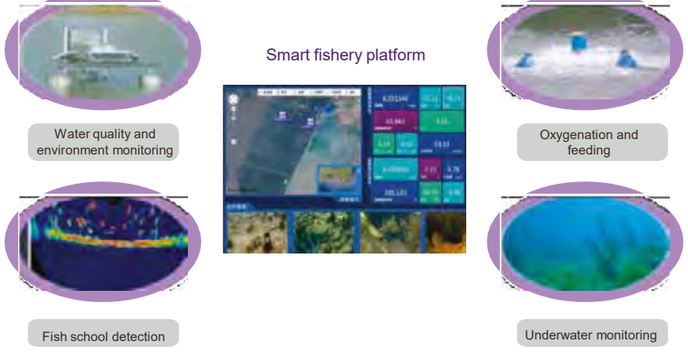


Figure 9-7: Application scenarios of smart fishery

5G Network Performance Requirements

Service Name	Communications Requirement	
	Latency	Coverage Range
Smart fishery	≤ 20 ms	Entire farm

Scenario 4: Smart Agricultural Machinery Interconnection

In the future it will be more widespread for agricultural machinery to become smart by using the latest ICT technologies. Smart machinery is pivotal to smart agriculture, agronomy and machinery combination, and agricultural growth in both quality and profits.

Smart agricultural machinery embodies extraordinary control over mechanics. It uses 5G, which features high data rates and low latency, as well as cutting-edge electronic and hydraulic control techniques, offering an unparalleled experience of automatic driving. The machinery is used in plowing, trench digging, ridging, sowing, spraying, and harvesting. Moreover, the 5G+BeiDou positioning system makes it possible to achieve operations to an accuracy of 2.5 cm, improving efficiency and reducing costs. Drivers suffer less fatigue, while operations can continue for a long time no matter the time of day.

In addition, devices mounted on the machinery can send HD videos stably over 5G for operations quality surveillance. AI technologies are also combined with 5G to further the replacement of humans with machinery. This not only reduces labor costs, but also significantly improves the efficiency of operations.

Figure 9-8: Solution architecture of smart agricultural machinery interconnection

Figure 9-9: Application scenarios of smart agricultural machinery interconnection

5G Network Performance Requirements

Service Name	Communications Requirement	
	Latency	Coverage Range
Smart agricultural machinery interconnection	≤ 10 ms	Agricultural machinery operation site

4. Use Cases

Case 1: 5G Precision Tomato Planting

China Mobile's solution on precision tomato planting in greenhouses features 5G and four key agriculture AI capabilities (environment data collection, video and image recognition, smart environment control, and smart fertigation decision making). With AI-assisted analysis, the environment of tomatoes is adjusted and fertigation is performed in a smart way. Such precision management produces more and better tomatoes.

Figure 9-10: Precision tomato planting in greenhouses

Case 2: 5G Smart Pig Farming

China Mobile and the Information Research Institute of New Hope Liuhe have jointly developed a 5G smart pig farming platform, which they piloted in one of New Hope's pig farms. The platform uses 5G by deploying the Graphics Processing Unit (GPU) on the edge cloud side instead of on farms previously. Traffic is distributed and images are processed on the edge cloud. This resolves the issues of high costs and poor maintainability of GPU servers deployed on farms. China Mobile also contributes its AI capabilities to the pig farming industry. This is achieved through its optimized convolutional neural network that helps identify various biological features of pigs efficiently and accurately. In addition, machine vision is used. Images are uploaded to the MEC platform thanks to high data rates of 5G. Then the AI platform on the MEC platform carries out functions such as weighing, measuring backfat thickness, measuring temperature, and condition monitoring of breastfeeding pigs.

Figure 9-11: New Hope's 5G smart pig farming

Case 3: China's First 5G Smart Fishery Application Demonstration

China Mobile has worked with its partners to develop a 5G-based recirculating aquaculture system. This system can measure and analyze various indicators, including dissolved oxygen, pH, ammonia nitrogen, and nitrite. As well as this, water addition, oxygenation, waste disposal, bacteria pumping, and feeding can all be controlled remotely. The system allows the entire farming process to be logged for each farm, facilitating efficient and safe management. This innovative smart solution makes it easy for each farmer to benefit from scientific farming techniques.

Figure 9-12: 5G smart fishery practice by Celefish

Case 4: Automatic Agricultural Machinery System

China Mobile and Huida Technology have jointly built a 5G-based automatic agricultural machinery control system. The system can accurately plan operation routes and ensure precision operation of machinery at any time. As the machinery now can operate 24/7, it is utilized more efficiently and generates higher revenues.

Figure 9-13: Automatic film laying by machinery at a corps in Xinjiang

5G Smart City

Deeply integrated with new information technologies including AICDE (Artificial intelligence, Internet of Things, Cloud computing, Big data, Edge computing), 5G has become indispensable for the construction of smart cities. In China, building a smart city is now a common goal among all of the sub-provincial cities, 89% of prefecture-level cities, and 47% of county-level cities, and has been proposed in their government work reports or 13th five-year plans. With substantial government investment and favorable policies, the smart city market has enormous potential.

To help realize this goal, China Mobile develops smart city solutions based on its outstanding 5G networks. These solutions address issues such as poor sensing capabilities of cities, weak information protection and cyber security, and low efficiency in environment governance. Connections involving people, things, and everything in between are now more integrated. Cities become safer, more livable, better governed, and operate more efficiently.

5G Smart City

1. Service Requirements

The general offices of the Communist Party of China Central Committee and the State Council released a guideline to encourage the development of safer cities. According to the guideline, China will improve the public safety system by building a social governance model based on collaboration, participation, and common interests. To improve safety in cities, China aims to build a comprehensive urban safety development system based on production safety. This means that urban governance should implement intelligence through multi-dimensional protection and data integration. As government projects such as Skynet, Sharp Eyes, and Blue Sky Protection Campaign progress, higher requirements are proposed for big data integration and sharing as well as smart decision-making in sectors including public safety, comprehensive governance, and environment protection.

Requirement 1: Low-Latency Transmission of Multi-Dimensional Data

Comprehensive urban governance, smart public services, and monitoring and control for environment protection all place higher requirements on network infrastructure. Taking inspection robots and other devices as examples, they are expected to be used for more efficient law enforcement. Utilizing 5G with its low latency is an ideal solution that can help law enforcement authorities to oversee incidents in real time, enabling quick response and efficient management possible. As fast emergency response is critical to ensuring stability in cities, the prompt transmission of various and emergent warnings during inspections must be guaranteed. Based on high-data-rate and low-latency 5G networks, a multi-dimensional security system that covers land, water, and air is developed. Working with an emergency response center based on 5G and big data, the system improves security protection and the capability of incident handling and emergency response.

Requirement 2: Comprehensive Sensing Capability of Urban Public Infrastructure

Traditional mobile sensors for law enforcement have limited capabilities. For example, they have blind spots in high-speed or complex scenarios such as at street corners, intersections, or on rivers; they also easily receive interference in special conditions such as in foggy, rainy, or snowy weather. For this reason, unmanned aerial vehicles (UAVs) and unmanned surface vehicles (USVs) are required to implement full surveillance, and therefore, must improve their sensing capabilities. Furthermore, the autonomous inspections must ensure security and accuracy even under complex conditions.

Requirement 3: Network Reliability

Complex geographical environments and users' special demands require higher computing, sensing, and modeling capabilities in platform equipment. Therefore, edge computing is used to deploy computing and storage capabilities on the users' side. The computing platform is therefore closer to user data. Such flexible deployment meets the data and computing requirements in various scenarios. Moreover, the results of computing and decision-making are more reliable due to enhanced computing capabilities. All these are breakthroughs in the construction of smart cities.

Requirement 4: Connecting and Sharing Urban Big Data

A city encompasses space, roads, vehicles, people, and devices. Traditionally, various systems for cities were developed simultaneously without coordination. 5G, with its high data rates, low latency, and massive connectivity, will connect and smartly coordinate all urban components, innovating the development of these various systems. A city will witness the birth of its digital twin, which continuously generates and consumes data, and evolves with intelligence from both things and humans.

2. Solution Overview

A smart city is composed of a comprehensive sensing system including sensors and terminals, agile neural system incorporating 5G networks and transport networks, smooth vascular system utilizing big data, intelligent brain including analysis and decision-making systems, and powerful immune system including the security system. Big data shared by operators, sensory government administration data, and online data from third parties are collected by sensors and then transmitted over 5G to the IOC platform or smart city central platforms for the analysis of operations in cities to support government decision making.

Perception layer: Urban public infrastructure is equipped with sensors and other sensing devices, including HD cameras, smart garbage containers, smart lamp poles, and smart bus stop signs, along with sensing terminals including mobile phones, computers, UAVs, and smart bands.

Network layer: Data from sensors on the urban public infrastructure is transmitted to the smart city super brain platform over wireless networks, 4G/5G networks, 5G private networks, and IoT.

Platform layer: The smart city super brain platform displays various data, such as data on population and environment, and subsequently monitors, predicts, and analyzes the data to facilitate decision making and implementation.

Application layer: The entire information-based infrastructure, including sensors, 5G networks, and the super brain platform, is utilized in multiple scenarios in smart cities, including 5G mobile law enforcement, emergency response, and big data on urban population.

Display layer: Various data and indicators are displayed in multiple forms, such as on mobile terminals or large screens. Operations in cities are monitored in real time.

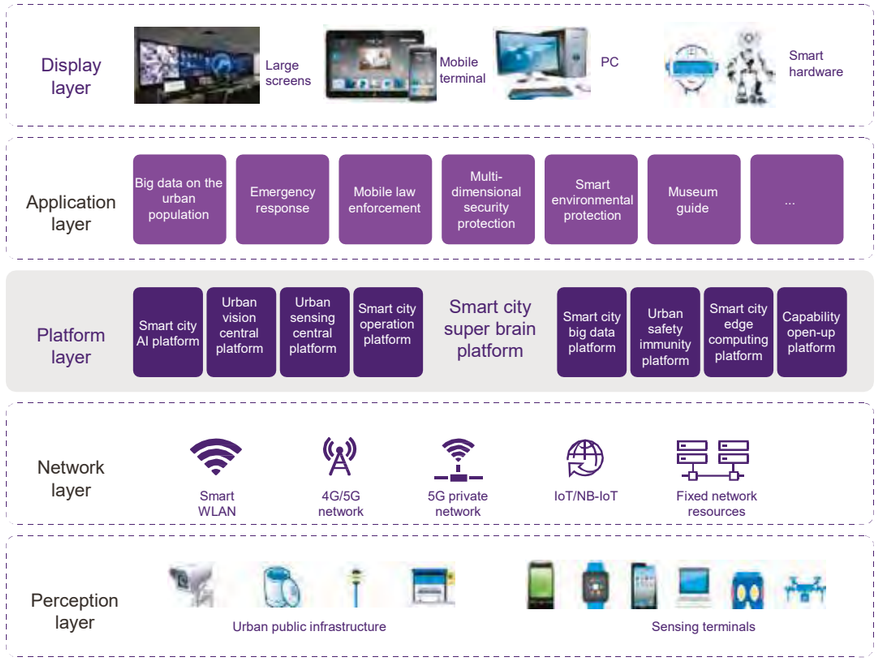


Figure 10-1: Smart city architecture

3. Application Scenarios

Scenario 1: Big Data Analytics on Urban Population

5G boasts Massive Machine-Type Communications (mMTC) and Enhanced Mobile Broadband (eMBB) capabilities, with the former featuring low power consumption and massive connectivity, and the latter delivering wide coverage and massive connectivity. China Mobile leverages the mMTC and eMBB capabilities of 5G to fully collect and analyze its massive amount of signaling data, establishing a complete ecosystem involving data collection, processing, analysis, and display, and improving the big data industry chain. Various types of data, such as population database data, geographic information, grid data, and operator signaling data, are integrated to numerous analytics functions on the urban population big data platform. These functions include demographic statistic measurement, resident and floating population analysis, hometown distribution measurements, population distribution on individual streets, personnel composition analysis, migrant analysis, population profile analysis, as well as real-time monitoring of population flows and sources. These functions can assist governments in fulfilling their administrative duties of urban management, industry upgrade, city planning, and livelihood service optimization.

Figure 10-2: 5G-based big data analytics on urban population

Scenario 2: Emergency Response

China Mobile combines 5G networks with big data analysis, AI algorithms, and geographic information system (GIS) technologies to quickly and accurately collect population information and provide population profiles in specific areas. In the case of emergencies, emergent positioning and monitoring of populations within specific areas can be implemented, allowing SMS notifications to be sent to specific groups of people. Leveraging these functions, emergency command personnel can make better-informed decisions and deal with emergencies, improving the efficiency of emergency handling. During routine management, comprehensive prediction, research, and determination are conducted to provide early warnings against potential risks and emergencies. This serves to prevent potential emergencies, improves monitoring and warning efficiency, and enhances the emergency management capabilities for various public events in cities.

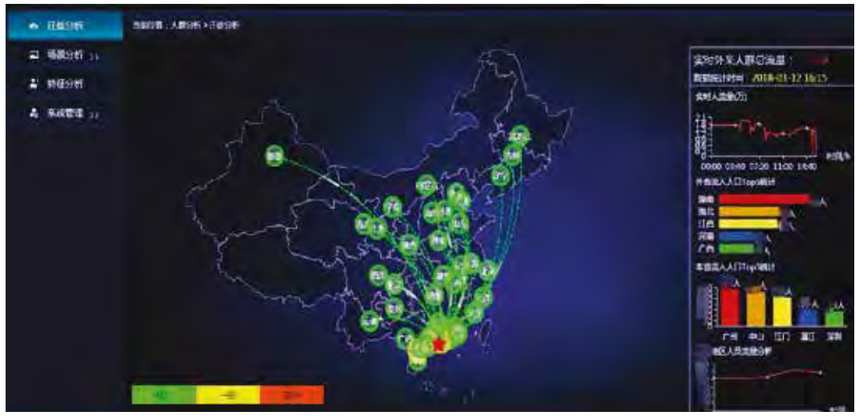


Figure 10-3: 5G-based emergency responses

Scenario 3: Mobile Law Enforcement

China Mobile incorporates mobile terminals, mobile communications, GIS, and GPS technologies into 5G mobile robots, equipping them with facial recognition, video backhaul, and intelligent video analysis capabilities. In the area of law enforcement, the 5G smart city management platform is integrated with the existing urban management system, enabling 5G technologies to be fully utilized to implement facial recognition, data analysis, video backhaul, remote control, traffic violation monitoring, garbage detection, and other functions. This enriches the urban management approaches and reinforces the existing capabilities.

Figure 10-4: 5G-based mobile law enforcement

Scenario 4: Multi-Dimensional Security Protection

Based on its smart city super brain platform, China Mobile applies key technologies such as 5G, AI, network slicing, and mobile edge computing (MEC) to build a multi-dimensional security protection system covering air, land, and sea. This system is used for river patrols, road patrols, campus cruises, emergency command, and environment supervision scenarios. Devices including UAVs, USVs, unmanned vehicles, and fixed cameras collect images for the purposes of fixed area surveillance, automatic patrol, and facial recognition. All areas can be effectively monitored, even in unattended conditions, meeting the surveillance requirements of managers and users, guarding against unexpected security events, and contributing to a harmonious and safe city.

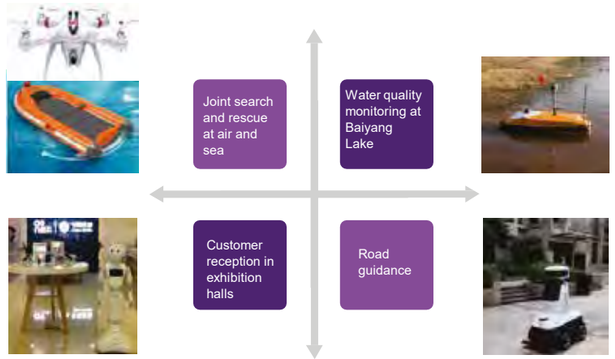


Figure 10-5: 5G-based multi-dimensional security protection at air, land, and sea

Scenario 5: Smart Environmental Protection

China Mobile integrates IoT, AI, and big data into devices such as ultra-HD cameras, air quality sensors, and UAVs, making them more digital and intelligent. With these technologies and devices, a city's air quality can be monitored around the clock in real time, enhancing pollution prevention and control. Pollutant sources and distributions can be efficiently located and tracked, unauthorized and abnormal emissions can be automatically identified with early warnings provided if necessary, and accurate and visualized analysis results can be output at a low cost. This greatly improves the efficiency of managers, helps environmental protection management departments at all levels to implement comprehensive, efficient, and multi-dimensional environmental protection supervision, and allows for unmanned, intelligent environment monitoring and governance. A living environment that is green, environmentally friendly, and low-carbon is now possible.

Figure 10-6: 5G-based water resource management

Scenario 6: Museum Guide

Modern museums are often confronted with challenges relating to insufficient guides, difficult positioning, and limited methods of tourist statistics collection. To address these issues, China Mobile has turned to next-generation information technologies such as 5G+ network slicing, edge computing, and VR/AR to explore museum informatization achievements, enhance tour modes, and deliver an autonomous and smart tour experience. In addition, digital content related to precious cultural relics is generated to be seamlessly integrated into the physical experience, aiming to create a "super-connected" museum that incorporates both offline and online experiences. This breaks the physical boundaries of museums and creates a new business model of virtual museums. Based on edge computing, big data, and AI technologies, this solution provides indoor positioning, IoT data collection, video-based security protection, and big data analysis as open capabilities to various apps. Tourists at home and abroad can now enjoy secure, efficient communication networks and high-quality, advanced information services.

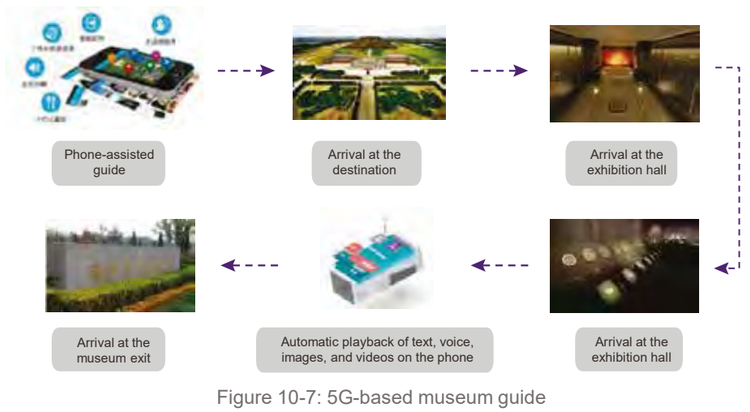


Figure 10-7: 5G-based museum guide

4. Use Cases

Case 1: Wuzhen Internet Conference 5G Operation and Management Center (IOC)

The 6th World Internet Conference (WIC) was held from October 20 to 22, 2019 in Wuzhen, Zhejiang. China Mobile attracted extensive attention with the launch of China's first smart town operation platform tailored for Wuzhen, as well as the release of *5G New Smart Town White Paper*. The platform, known as the Wuzhen 5G Future Operation Center, provides unified IDs for governments, citizens, enterprises, and communities to integrate physical Wuzhen with its digital twin. By building a trustworthy and win-win smart town ecosystem, a converged, integrated smart city operation system is established to boost the development of Wuzhen's digital economy.

Figure 10-8: Smart Wuzhen IOC

Case 2: Air, Land, and Sea Multi-Dimensional Security Protection System in Xiong'an Smart Town

China Mobile has developed smart applications based on the 5G network and adopted new measures to build a digital, smart city. This has led to the establishment of the first air, land, and sea multi-dimensional security protection system, designed to ensure a more secure Xiong'an New Area. 5G USVs cruise around Baiyang Lake to sample and test water quality, as well as backhaul related data at target locations. 5G robots and UAVs perform facial recognition during inspection and monitoring to check for suspicious individuals. The smart security protection platform centrally displays video streams from unmanned devices, allowing for convenient and comprehensive surveillance of all locations.

Figure 10-9: Air, land, and sea multi-dimensional security protection system in Xiong'an smart town

Case 3: Big Data Platform for Beijing-Tianjin-Hebei

China Mobile is collaborating with Beijing Municipal Commission of Development and Reform to develop a population-oriented big data product, which facilitates management and decision-making in the fields of development planning, population monitoring, industry upgrade and transfer, transportation integration, livelihood services, and ecosystem.

Figure 10-10: Big data platform for Beijing-Tianjin-Hebei

Case 4: OCR-based Intelligent Cataloging of Government Files

China Mobile is collaborating with an anti-smuggling bureau in optical character recognition (OCR-based) intelligent cataloging to handle large amounts of anti-smuggling files, which would normally require tedious manually work. The OCR-based intelligent cataloging application satisfies the requirements of the anti-smuggling bureau with functions such as the OCR-based intelligent recording system, intelligent interrogation, stenography, and conference assistant. The application has been highly recognized by the leaders of the municipal bureau, and the smuggling bureau is now designated as a pilot agency to explore and nurture this benchmark application.

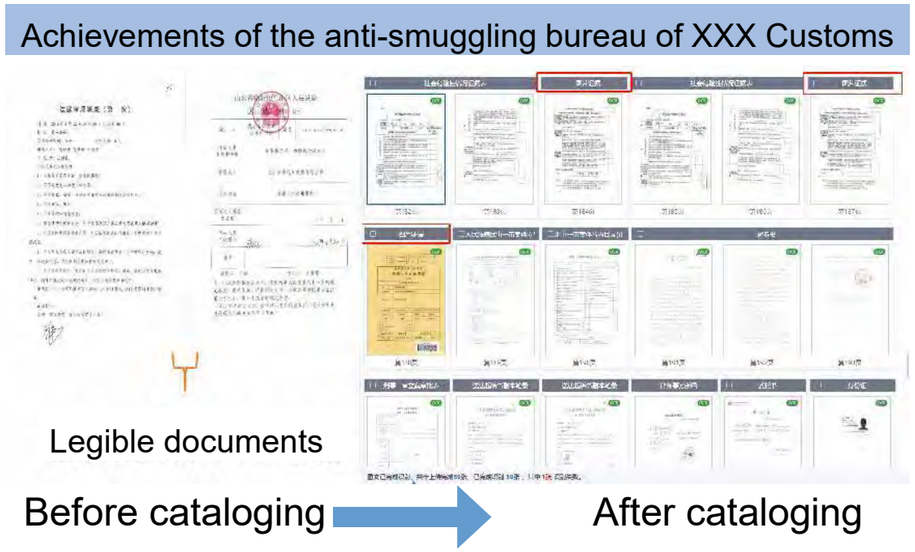


Figure 10-11: OCR-based intelligent cataloging of government files

Case 5: Public Opinion Monitoring Through Online Videos

China Mobile is also cooperating with a municipal publicity department to monitor public opinion through online videos. Vast amounts of online videos are monitored to help governments effectively detect harmful information, receive early warnings regarding sensitive information, stay informed of events, track key accounts in real time, and analyze public opinion relating to specific topics. Specially, technologies regarding search engine, data mining, voice recognition, and video analysis are used to intelligently analyze video content, images, key frames, and audio streams, facilitating public opinion monitoring.

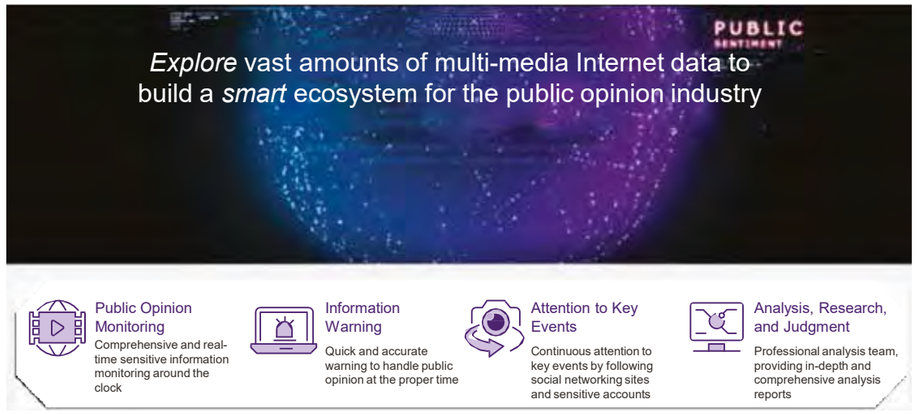


Figure 10-12: Public opinion monitoring platform for online videos

Case 6: Indoor Positioning Products for Smart Shopping Malls, Supermarkets, and Smart Buildings

China Mobile leverages the advantages of 5G edge computing to build smart shopping malls and supermarkets based on indoor positioning technologies. China Mobile works closely with Huiyou Supermarket to build smart shopping malls and supermarkets in Xiong'an, which utilize indoor positioning and commodity location search to help consumers quickly find desired commodities. China Mobile also cooperates with Oceanwide City Square to construct smart buildings in Wuhan CBD, which can provide high-precision positioning and big data analysis services to deliver an intelligent shopping experience.

Smart Shopping Mall and Supermarket

Xiong'an Huiyou Supermarket

Xiong'an Huiyou Supermarket: MEC + Smart Distributed Indoor System

China Mobile cooperates with Huiyou Supermarket to build smart shopping malls and supermarkets in Xiong'an New Area. A distributed antenna system (DAS) with smart indoor antennas is used to replace the original system and ensure coverage. An MEC platform is deployed at the network edge to implement application localization and capability openness for smart shopping malls and supermarkets, while meeting low latency requirements of services.

Smart Building

Oceanwide CBD City Square in Wuhan

Oceanwide City Square in Wuhan CBD: 5G + MEC

China Mobile collaborates with the Oceanwide City Square in Wuhan CBD on the smart indoor distribution project to provide 5G coverage for the entire Oceanwide Mall. An MEC platform is used to provide high-precision indoor positioning and navigation services as well as location-based big data analysis services.

Figure 10-13: 5G-based indoor positioning in commercial buildings

5G UAV

Recent years have witnessed the rapid development of the emerging civil UAV industry. Widely used for personal purposes and in vertical industries, civil unmanned aerial vehicles (UAVs) are playing an increasingly important role in economic growth, social production, and everyday lives. According to a Goldman Sachs' projection, UAVs will unleash a market space of 100 billion USD by 2020 and become a new economic growth point. A smart UAV network will begin to take shape in the future, providing abundant personal and professional application services under any weather. For vertical industries in particular, UAVs and payload devices can work together to implement complicated aerial tasks in unmanned driving conditions. They can replace manual operations and traditional mechanical devices, improving operation efficiency.

Based on the next-generation mobile communications technologies, China Mobile has launched the 5G UAV solution, a breakthrough in UAV industry application. 5G provides higher bandwidth to allow for transmission of clearer images, ultra-low latency to enable more accurate UAV management and control, and wider low-altitude airspace coverage to facilitate smooth task execution.

5G UAV

1. Service Requirements

During the National People's Congress and the Chinese People's Political Consultative Conference held in 2019, some delegates pointed out that the momentum of 5G development provides a golden opportunity to make breakthroughs in China's connected UAVs industry, and to promote the development of the low-altitude airspace economy. The connection of UAVs to mobile communications networks cannot only fulfill national regulatory requirements, but also break down the existing barriers in industry application. UAVs can be widely applied to many fields, including power inspection, safety assurance, firefighting, emergency rescue, logistics, transportation, agricultural and forestry plant protection, traffic management, and remote sensing and mapping. UAV communications service capability requirements vary by application scenario, and include demands on uplink and downlink rates, transmission latency, coverage capabilities, and network positioning.

Requirement 1: High-Speed Transmission of HD Images, Videos, and Massive Data in Moving Scenarios

The uplink and downlink of UAV communications are asymmetrical. The uplink is used for transmission of UAV telemetry data and HD videos, while the downlink is used for transmission of Command and Control (CC) data.

As such, uplink services naturally require higher bandwidth and data rates than downlink services. Insufficient downlink capacity may occur as 5G networks allow the access of a massive number of devices whose service load is ever increasing. The high-speed transmission and real-time retrieval of images and videos in various moving scenarios also pose higher requirements on network transmission rates, mobility, and real-time performance.

Requirement 2: Wide Coverage in Low-Altitude Airspace

Research indicates that signal interference is the primary cause of coverage problems appearing when UAVs are applied in low-altitude airspace. When ground base stations are insufficient, there will be weak signals or even coverage holes in the airspace. As UAVs are always moving, advanced technologies are required to frequently switch beams in order to adapt to new locations, so that seamless coverage is provided and UAV disconnection due to poor network coverage is prevented. Connected UAVs applied to low-altitude airspace pose high coverage requirements. The low-altitude airspace networking solution based on 5G mobile communications can effectively reduce interference and ensure seamless coverage.

Requirement 3: Effective Identity Identification and Verification

According to the *Guidelines on Promoting and Standardizing the Development of Civil UAV Manufacturing* issued by the Ministry of Industry and Information Technology (MIIT), rules and technical solutions need to be formulated for digital identification of civil UAVs in order to achieve "one ID per device". This requires the UAVs to be authenticated on the core network using unique mobile device IDs before take-off. 3GPP defines a mutual authentication mechanism between 5G UEs and the core network to ensure that all admitted devices are trustworthy and their communications are secure. The UE authentication and encryption mechanism as well as the positioning capability provided by 5G networks help identify unauthorized UAVs, contributing to safe flight and UAV management.

2. Solution Overview

5G-based connected UAVs applied to low-altitude airspace can reduce interference and secure seamless coverage by exploiting cutting-edge technologies, such as multi-antenna vertical beams, Massive MIMO, and BWP-based frequency-division access. Edge computing and cloud computing are used to monitor the UAV status in real time as well as to collect, process, and push images and information. These technologies enable industry users to enjoy one-stop services.

Basic layer: This layer utilizes the 5G cellular network as the core and incorporates devices such as U-BOX, 5G module, and data and image integrated ground base stations. UAV identity authentication is performed at this layer to ensure that flight safety is manageable and controllable.

Network layer: The 5G network meets the requirements of remote real-time precise control, high-speed transmission of image and data from UAVs, HD audio and video interaction, and UAV access and interaction.

Platform layer: This layer processes flight data, application service data, flyer data, and other information. It is connected to multiple information systems, such as other cloud systems and systems for flight monitoring, intelligence, meteorology, and flight tracking, in order to store and exchange various UAV data.

Application layer: This layer integrates the management and operation platforms to provide one-stop UAV management and control, operation, and application services for the military, civil aviation, governments, vertical industry customers, UAV flyers, and the general public.

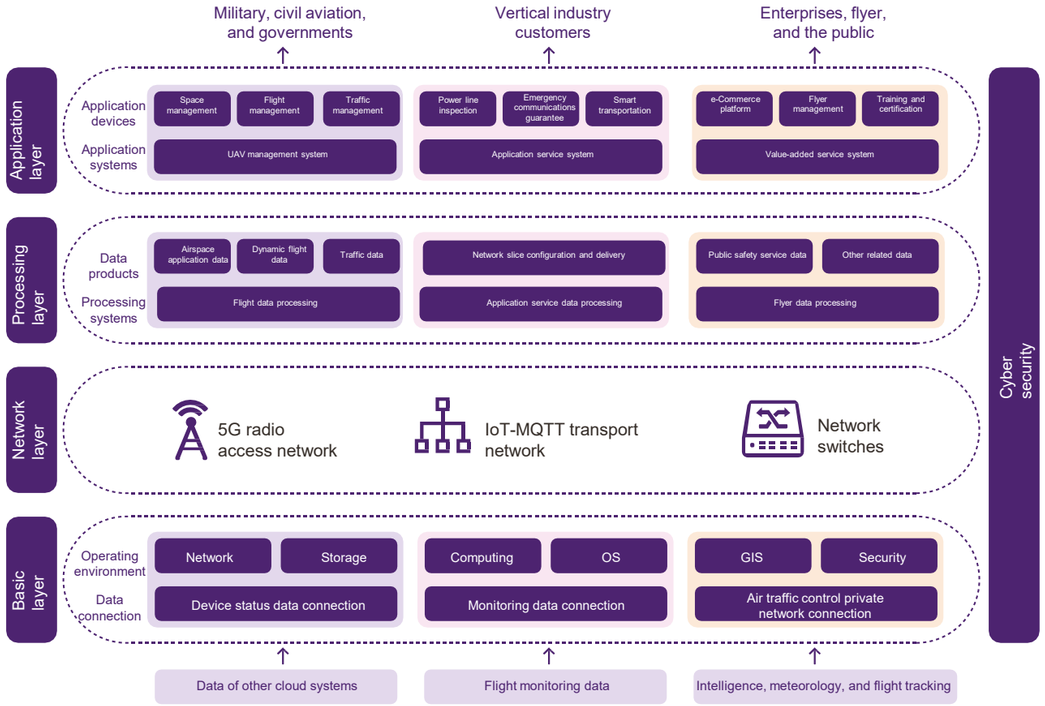


Figure 11-1: 5G UAV solution system architecture

3. Application Scenarios

Scenario 1: Plant Protection

Plant protection UAVs are controlled through 5G networks to implement plant protection operations such as pesticide spraying, fertilization, seeding, disaster warning, and yield evaluation. Unlike traditional plant protection operations which are implemented manually or with the help of heavy equipment, UAVs feature precise operation, high efficiency, environmental protection, intelligence, and intuitive usage, significantly reducing the costs for farmers. 5G UAVs can be mounted with various nozzles to implement spraying and seeding, and can also be mounted with dual-spectrum PTZ cameras to record and transmit visible light images and thermal images, implementing refined operations.

Figure 11-2: Intelligent planning of spraying paths

Figure 11-3: Intelligent and precise seeding

Scenario 2: Security Protection

Event Security

5G patrol UAVs, equipped with professional security devices such as HD and infrared cameras, perform aerial photography in areas where large-scale sporting events and art performances are held. On-site HD videos are transmitted in real time through 5G networks. Those HD videos, together with other technologies including facial recognition, infrared imaging, and automatic tracking, enable quick identification of dangerous persons and areas, ensuring effective warnings and security assurance.

Figure 11-4: High-altitude airspace patrol by 5G connected UAVs

Suspect Tracking

5G connected UAVs can provide all-round 24-hour surveillance under any weather in areas of interest, and perform "intelligent, fast, comprehensive, and precise" suspect tracking with high mobility and low costs. In addition, the payload system enables UAVs to conduct long-distance surveillance and evidence collection in extreme environments featuring smoke, dust, fog, and salt. This guarantees real-time reporting of suspect locations and coordinates.

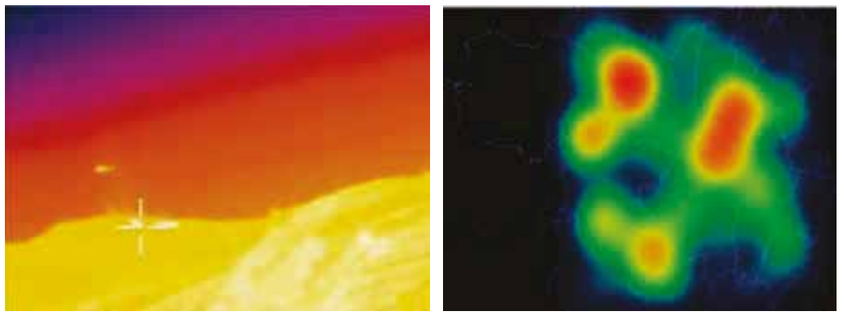


Figure 11-5: Suspect tracking and evidence collection by 5G connected UAVs

Transportation Management

Severe traffic congestion occurs when traffic events are not effectively handled. With this in mind, UAVs continuously patrol urban roads and record video which is transmitted back in real time through 5G networks. AI-powered analysis is then conducted to identify the license plate numbers of vehicles violating traffic regulations in the video. In this way, drivers can be informed of the violation in real time and requested to correct the issue within a set time frame. 5G connected UAVs also play an important role in identifying traffic congestion sources, collecting accident evidence, and rapidly handling accidents, which accelerates the pace of smart city transportation.

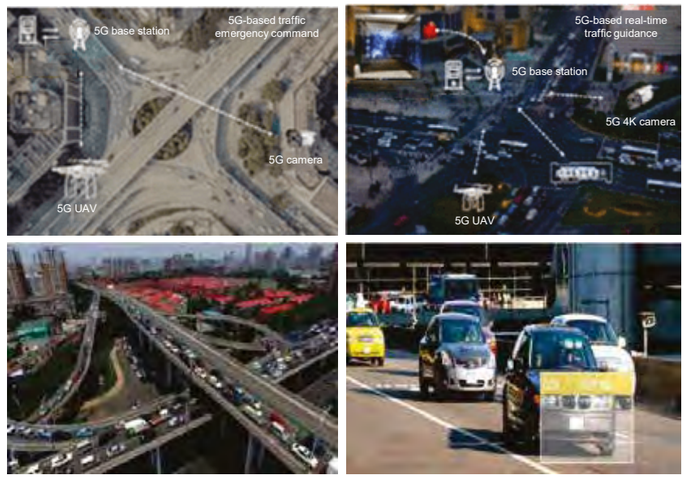


Figure 11-6: 5G connected UAV–based smart transportation management

Geological Mapping

5G connected UAVs transmit modeling images in real time through airborne sensors and 5G communications modules. As a result, high-precision mapping products can be rapidly obtained to facilitate the creation of basic maps of target areas. The geographical information and analysis data provided by 5G connected UAVs contribute to city security and suspect tracking.

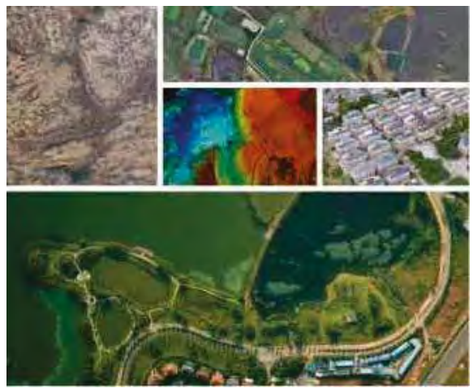


Figure 11-7: Digital orthophoto maps

Scenario 3: Low-Altitude Airspace Emergency Communications

During natural disasters such as earthquakes, floods, mudslides, and severe ice and snow, large-scale communications interruption often occurs, impeding disaster relief in the affected areas. For this reason, fixed-wing UAVs are used to provide emergency communications. With excellent battery life, long-range flight capabilities, and low costs, fixed-wing UAVs deliver remarkable improvements to the response efficiency and coverage range of disaster relief.

Figure 11-8: Post-disaster emergency communications

Scenario 4: Performance and Entertainment

Various tourist spots and city planning departments organize UAV flybys. In addition, UAVs are utilized to record organized performances. Thanks to 5G and VR technologies, audience members, who wear VR glasses, can watch live videos transmitted by UAVs in real time, enabling them to enjoy innovative new experiences.

Figure 11-9: New city image created with 5G UAVs

Scenario 5: Inspection

5G UAVs contribute to fault inspections, disaster damage surveys, project acceptance, information collection, special inspections, and emergency repairs. This is thanks to 5G UAVs' ability to obtain accurate on-site information in real time through 5G networks, irrespective of geographical and environmental conditions. With the audio and video materials provided by UAVs, inspections for power grids, petroleum pipelines, and opium poppy planting areas are more efficient and secure than manual inspections.

Figure 11-10: UAV inspection

4. Use Cases

Case 1: Opium Poppy Identification by 5G UAVs

In May 2019, China Mobile collaborated with Liangshan BeiDou Technology to implement integrated air-and-space monitoring and identification of illegal drug cultivation, during which optical spectrum resources, remote sensing technology, UAVs, AI image analysis systems, and UAV cloud platforms were used. This 5G-based cooperation enabled the Liangshan Public Security Bureau to achieve digital and information-based monitoring of illegal cultivation of opium poppy.

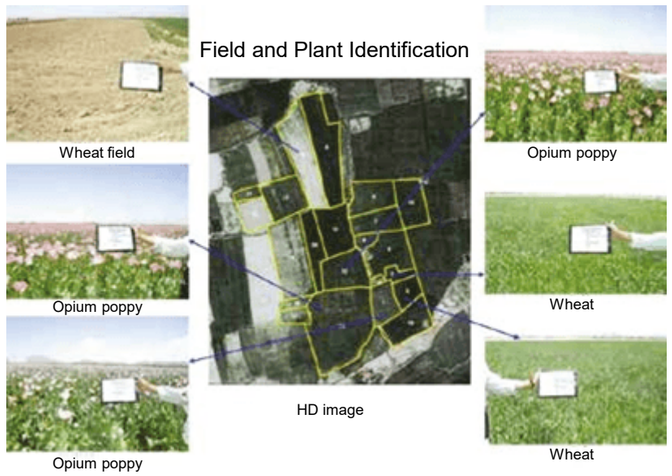


Figure 11-11: Monitoring and identification of illegal drug cultivation

Case 2: Emergency Communications Provided by 5G UAVs

In December 2018, China Mobile, Huawei, Satcom, and Tengden built China's first mobile emergency communications sky base station consisting of large fixed-wing UAVs and satellite communications. The base station excels in efficiency, battery life, moving distance, coverage range, and payload. As such, it can provide emergency communications across large areas under any weather when disasters such as severe infrastructure damage occur.

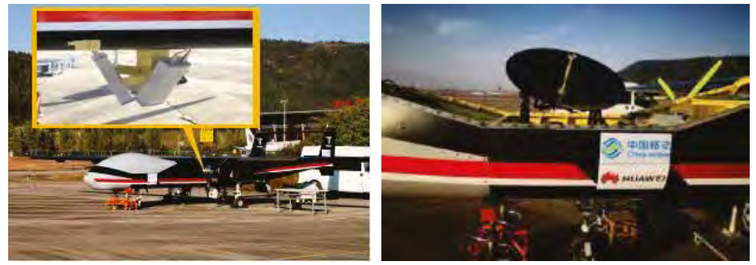


Figure 11-12: World's first flight of an emergency communications sky base station

Case 3: "Dancing in Leshan" UAV Flyby During Mid-Autumn Festival

On September 13, 2019, a dramatic UAV flyby lit up the night sky in Leshan. More than 300 UAVs "danced" in the air, delighting onlookers with an amazing visual display. Such a visual feast was made possible by the combined efforts of China Mobile, Leshan Digital Economic Development Bureau, and EFY Technology.

Figure 11-13: "Dancing in Leshan" 5G connected UAV flyby

Case 4: Forest Fire Inspection by UAVs

On April 7, 2019, a forest fire broke out in Liangshan's Muli County. China Mobile sent a team with six UAVs to conduct fire inspections, providing reliable information to facilitate decision-making by the relief command center.

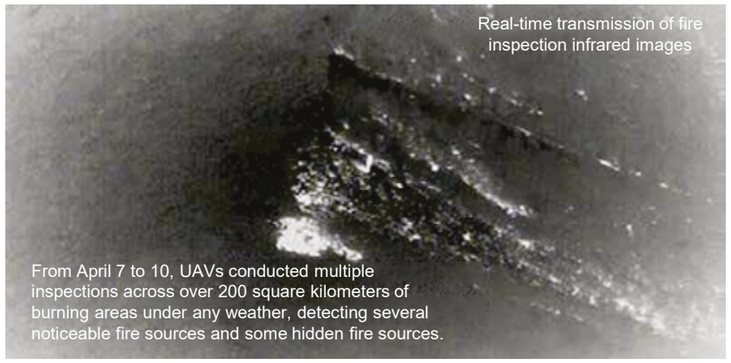


Figure 11-14: Forest fire inspection by 5G connected UAVs

5G HD Industry Video

As video technologies continuously develop, the number of industry video applications skyrockets. HD video serves a variety of fields across various industry scenarios, including production, scheduling, and management. In addition to traditional video applications for HD conferences, surveillance, and live broadcasts, new HD video–based applications are providing advanced services, including emergency command, remote surgery, distance education, industrial control, and video AI.

An integration of 5G and video technologies enables operators to promote video services as their basic services, furthering the deep application of video in industry scenarios. As video technologies lean towards HD, mobility, intelligence, integration, and industry-oriented development, the following improvements are reflected: 5G networks popularize 4K/8K UHD videos; 5G networks with wide coverage enhance the mobility of UHD terminals; 5G edge cloud equips devices with strong computing capabilities, making HD terminals more intelligent; and 5G networks with various advantages unlock more HD video–based applications.

5G HD Industry Video

1. Service Requirements

On February 28, 2019, the Ministry of Industry and Information Technology (MIIT), National Radio and Television Administration (NRTA), and China Media Group (CMG) jointly released a notice regarding issuing the *Ultra HD Video Industry Development Action Plan (2019–2022)*. According to the *Action Plan*, ultra-HD (UHD) video industry development and applications in related fields will be vigorously promoted through the "4K first, 8K in parallel" comprehensive technical roadmap. The plan mentions that by 2022, the overall scale of the UHD video industry in China will exceed CNY 4 trillion, the 4K industry ecosystem will essentially be complete, and breakthroughs will be made in the R&D of key 8K technologies as well as in industrialization, enabling the emergence of internationally competitive enterprises.

Deep integration of 5G and videos will drive extensive transformation of video industry chain links such as collection, production, transmission, presentation, and application. It will also accelerate the wide application of videos in vertical industries, enabling video services such as remote education, telemedicine, live sports, emergency command, and safe campus to be integrated into daily life. Driven by 5G technologies, the video industry will usher in a completely new "blue oceans" market. At the same time, with huge challenges and new development requirements, the video industry's 5G requirements are mainly in the following three aspects:

Requirement 1: Wider Coverage for Video Services

With the development of computer vision and network technologies, traditional video services are gradually orienting towards mobile, HD, converged, intelligent, and industry-based.

The user experienced rate of 5G can attain 100 Mbps to 1 Gbps. Mobile video devices such as mobile phones, tablets, and UHD video devices have broken through time and space limitations, enabling users to enjoy UHD video services anytime and anywhere. 5G networks not only meet the requirements of mobile video scenarios anytime and anywhere, but also solve the problem of providing UHD video services to areas that cannot be covered by wired networks, such as reservoirs, forests, and remote mountainous regions. 5G network slicing can flexibly design network functions on general 5G network infrastructure based on different service scenarios, and provide isolated, dedicated mobile networks, which include the radio access network, transport network, and core network. As a result, video devices can gain access through wireless networks, without geographical restrictions.

Requirement 2: Significantly Reducing Video Service Latency

4K multi-channel UHD videos require a real-time transmission bandwidth that exceeds 100 Mbps. 5G can effectively solve UHD video problems that arise from networks, such as frame freezing and unclear images. Furthermore, 5G can ensure the audio and image transmission quality of voice and video conferences, and ensure conference calls without communication barriers as well as surveillance videos that are smoother. This enables more enterprises to enjoy the convenience brought by HD videos. Network latency must be maintained within a 10 to 20 ms range to prevent VR/AR users from experiencing motion sickness caused by network latency, and improve VR/AR user interaction experience. The air interface latency of 5G networks is as low as 1 ms, which meets the optimal experience requirements for VR/AR application users.

Figure 12-1: Significantly reducing video service latency

Requirement 3: Deploying Video Services More Efficiently

4K/8K UHD video devices require large amounts of data transmission, storage, and computing capabilities. Currently, most of this information is processed on devices themselves, resulting in high device costs. Furthermore, video processing capabilities are restricted by device configurations. 5G introduces edge computing technology and comes with high bandwidth to support display methods such as 4K/8K UHD and VR/AR. It can transfer large-scale and complex computing that is performed on devices to the cloud and network edge, improving the rendering quality of video content as well as reducing the complexity and hardware costs of devices, which in turn enables faster and more efficient service deployment.

2. Solution Overview

China Mobile has integrated cutting-edge technologies such as 5G network slicing, edge computing, and AI to build a 5G-based industry video cloud for industry users and based on existing China Mobile video products (including cloud videoconferencing, clairvoyance, intercom, and commercial live broadcasting). The cloud includes a real-time video switching network and industry video application platform that cover both China and abroad. The system architecture is as follows:

Device layer: provides access for various devices, such as HD video conference, video surveillance, intercom, live broadcast, AR/VR, as well as mobile phones, computers, and smart landlines.

Network layer: provides mobile 5G networks or networks that converge such as 5G, private lines, and Public Switched Voice Network (PSVN) for different application scenarios and requirements. It also provides new network technologies such as edge elements and 5G network slicing to meet users' high bandwidth, low latency, and rapid deployment requirements for video services. Local processing of mission-critical data such as video enhancement, traffic control, and UE identification is implemented to shorten latency, save bandwidth, and improve user experience.

Platform layer: based on China Mobile's video conference, video surveillance, video intercom scheduling, and live broadcasting platforms, it integrates capabilities such as voice/video AI and AR/VR video processing to build a platform with UHD video capabilities, providing comprehensive video services.

Product and solution layer: provides four 5G video products and solutions (5G cloud video conferencing, 5G clairvoyance, 5G intercom, as well as 5G commercial live broadcasting).

Application layer: provides basic services such as HD video conference, video surveillance, intercom, and live broadcasts for various industries. In addition, the application layer deeply integrates with vertical industries to provide a wide range of industry solutions. For example, 4K UHD remote outpatient and consultation, 4K UHD dual-teacher classrooms, 4K UHD live sports, 4K UHD smart surveillance, 4K UHD damage ascertainment, 4K UHD professional inspections, and converged video emergency command.

Target users: users across major industries; medical, financial, educational, and governmental institutions; and offices.

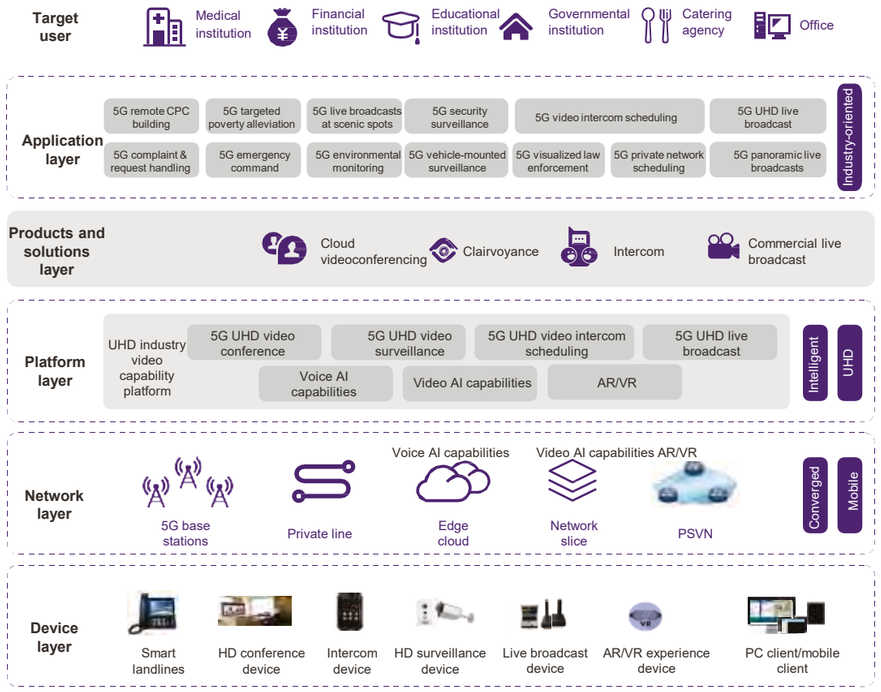


Figure 12-2: 5G HD industry video solution system architecture

3. Application Scenarios

Scenario 1: Cloud Videoconferencing – 5G UHD Video Conference

The wide application of 5G can facilitate the realization of mobile and UHD video conferences. 5G cloud videoconferencing not only offers mobile UHD video conferences, but also provides a combined video conference solution for fixed and mobile UHD venues, enabling all participants to enjoy 4K UHD video conferences anytime and anywhere. 5G cloud videoconferencing UHD video conference provides a high-quality audio and video experience. In addition, it has functions that enable various documents to be efficiently shared, files to be transferred, conferences managed and recorded, and smart monitoring. Furthermore, it can be used on various devices to rapidly and easily convene video conferences, such as mobile phones, tablets, PCs, and UHD conference devices.

In addition, the 5G cloud videoconferencing UHD video conference solution is widely used in various fields, such as government, electric power, education, and healthcare. It can be used to enable remote collaboration between offices, remote education, telemedicine, and emergency command, fully unleashing the potential of video conferences and meeting the requirements of various industries.

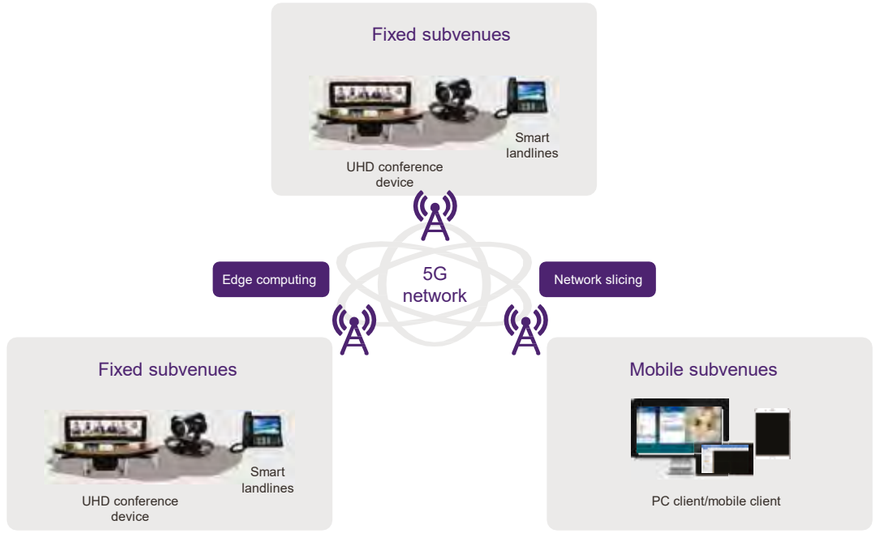


Figure 12-3: 5G cloud videoconferencing UHD video conference

Scenario 2: Clairvoyance – 5G UHD Video Surveillance

Based on 5G technologies, 4K UHD video surveillance has been created to provide wide-coverage, rapid-response, and smart-interconnection urban surveillance services oriented towards supervision departments, which include governments, public security, comprehensive governance, and transportation departments.

Unlike traditional, isolated video surveillance, and based on a unified cloud platform, 5G clairvoyance provides customers with comprehensive video surveillance services, such as video collection, storage, management, and analysis. 4K UHD panoramic video surveillance devices can be installed at public areas, scenic spots, road gates, residential areas, and rivers to ensure a stable transmission of 4K/8K surveillance videos. Surveillance videos are live-broadcast through content delivery network (CDN), providing convenient services, such as daily and real-time traffic flow queries and the ability to view scenic spots online.

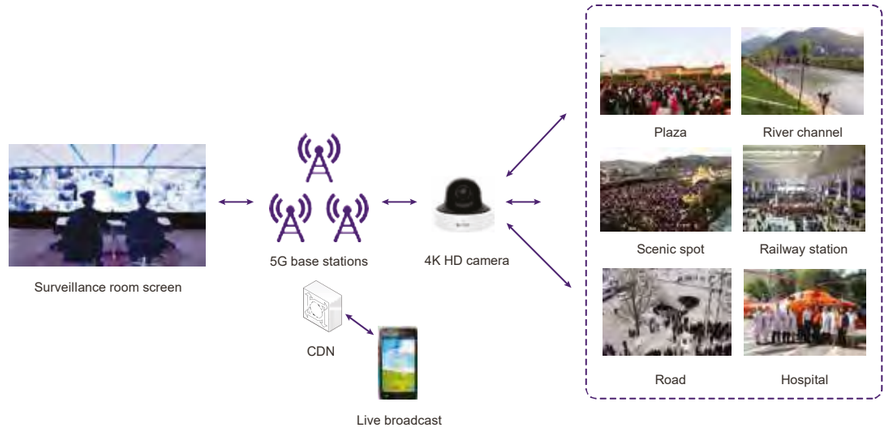


Figure 12-4: 5G clairvoyance UHD panoramic video surveillance

Scenario 3: JeChat — 5G UHD Video Intercom

5G UHD video intercom leverages the advantages of 5G network technologies, integrates AI-based video identification capabilities, and provides efficient voice dispatching functions using Vo5G technology. As an integrated industry solution based on 5G networks, devices, platforms, and AICDE for industries such as public security, emergency firefighting, converged command, and quality supervision, the solution enables highly-reliable, extremely-secure, low-latency, and energy-efficient UHD video intercom services.

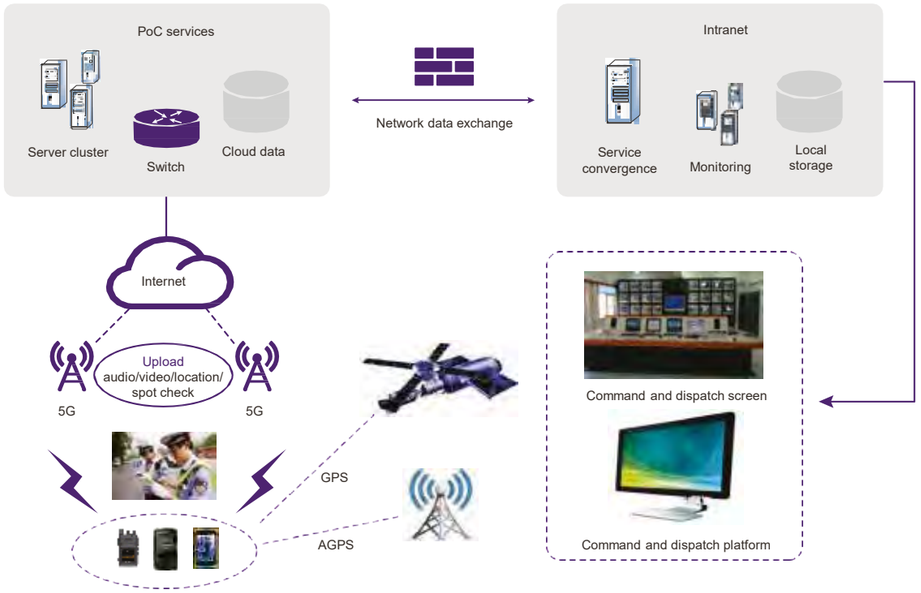


Figure 12-5: 5G HD video intercom in smart law enforcement scenarios

Scenario 4: AndLive – 5G UHD Live Broadcast

Utilizing the technical advantages of 5G networks and terminals, China Mobile provides a multi-site and multi-device interactive live broadcast solution for various live broadcast scenarios, such as large-scale enterprise activities, sports events, art shows, and wedding celebrations. Through this solution, live broadcast becomes clearer and smoother and features lower latency; users can enjoy multi-view, multi-image, comprehensive, and immersive 4K UHD live broadcasts. In addition, with the AI-based video processing capabilities of the live broadcast platform and 5G edge computing, this solution enables real-time cloud stitching, cloud editing, and cloud broadcasting of VR images to create UHD and immersive VR-based live broadcast experience.

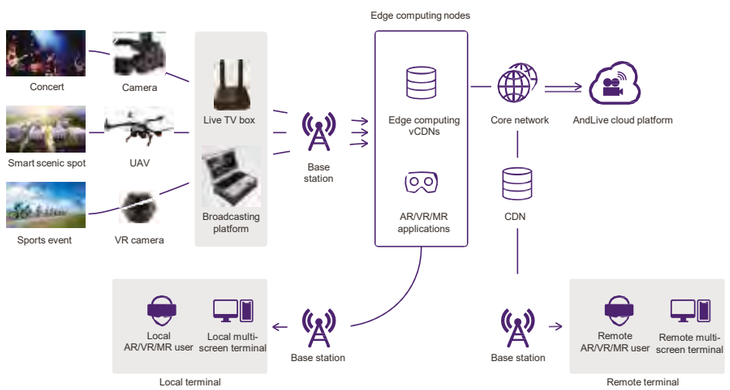


Figure 12-6: Architecture of 5G AndLive UHD panoramic live broadcast application

Scenario 5: Clairvoyance — 5G Intelligent Video Analysis

In addition to channel-level upgrades, 5G networks offer infinite possibilities for intelligent video services. 5G intelligent video analysis uses smart technologies such as behavior analysis, license plate recognition, facial snapshots, and passenger traffic statistics to provide AI support for industries such as city management, public security, banking, and transportation.

In 5G eMBB scenarios, surveillance devices can achieve 4K/8K UHD resolution, enriching video details and improving the value and accuracy of surveillance video analysis. Network-wide surveillance, dynamic detection, and tracking control can be implemented by extracting and recognizing features of objects such as people and vehicles in real-time videos, comparing these with the blacklist and whitelist, and generating relevant alarms. AI is applied in HD panoramic surveillance scenarios and city modeling to implement multi-dimensional data collection. Edge AI technology combining MEC with AI capabilities is also used to quickly process low-latency edge intelligent analysis services.

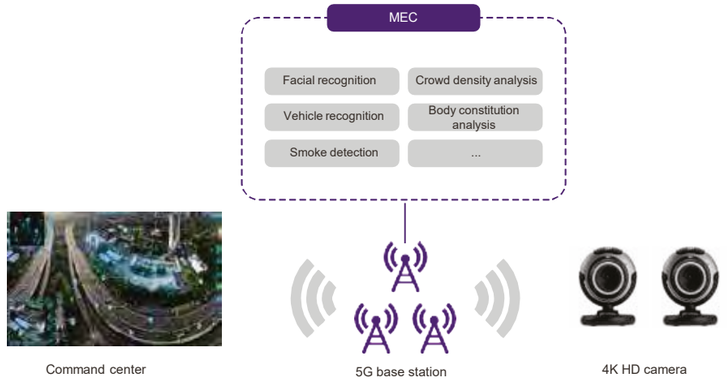


Figure 12-7: 5G clairvoyance-based intelligent video analysis

Scenario 6: 5G UHD Video Convergence

5G UHD video convergence combines the capabilities of four basic products, including ViLin, Clairvoyance, JeChat, and AndLive, and integrates network, video, and AI capabilities. It aims to quickly deploy "5G+HD video+AI" video convergence products and provide flexible video services for multiple industries and scenarios, such as healthcare, education, government, security protection, insurance, and media.

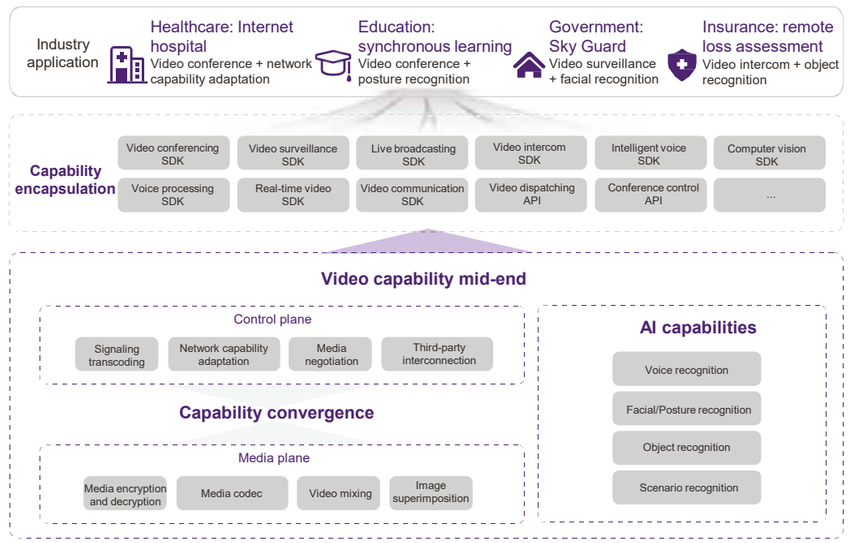


Figure 12-8: 5G UHD video convergence application scenarios

4. Use Cases

China Mobile utilizes the capabilities of its basic products ViLin, Clairvoyance, JeChat, and AndLive to drive in-depth convergence of 5G and the UHD video industry. They work with local governments, hospitals, and industry chain partners to actively carry out 5G demonstrations and implementation.

Case 1: CPC Lectures in Primary Organizations

China Mobile, in collaboration with Dayou Digital Resources Ltd., introduced outstanding lecturers and high-quality courseware resources from the Party School of the CPC Central Committee (CCPS). They organized a series of CPC lectures themed around "staying true to our founding mission" in primary organizations through the ViLin-based CPC building product. The six lectures of phase-one were attended by 518 primary CPC organizations in 141 municipalities across 23 provinces in China. Professor Zhang Zhiming, the Director of the Party Building Department of the CCPS, a doctoral tutor, and the Executive Director and Deputy Secretary General of the National Society for the CPC Building Studies, was invited to give lectures. Phase-two CPC lectures have been prepared and will continue to help the CCPS to deliver high-quality authoritative resources to primary organizations.

Figure 12-9: CPC lectures in primary organizations

Case 2: 5G+ViLin-based Learning

CCTV-10, a Chinese science and education channel, broadcast the CCTV feature story "Ongoing Innovations: Reaching Miles Away". The story examines how China Mobile 5G+ViLin-based learning, an innovative educational service, enables children living in the Dulongjiang mountainous areas of Yunnan Province, China to learn about ancient Chinese civilization and receive oral English lessons from renowned teachers in Beijing. Such innovative services ensure that quality education is shared across China.

Figure 12-10: 5G+ViLin-based learning

Case 3: China's First 5G+4K Remote Ophthalmic Consultation

China Mobile cooperated with the Eye Hospital of Wenzhou Medical University to utilize high-quality 5G networks, the ViLin video conferencing system, and the remote outpatient platform CLEAR VISION, to hold a 4K HD video consultation with five hospitals and health centers. These included the Aksu First People's Hospital in Xinjiang, Wenchuan People's Hospital and Xiaojin People's Hospital in Sichuan, and Tengqiao Health Service Center and Xiangyang Health Center in Zhejiang. Remote medical guidance enables local doctors to check patients, solving problems such as unbalanced medical resources and difficult medical treatment. This encourages the sharing of high-quality medical resources with counties, towns, and villages, accelerates the development of remote outpatient services, and facilitates the "Healthy China" initiative.

Figure 12-11: 5G ViLin-based 4K remote consultation provided by the Eye Hospital of Wenzhou Medical University

Case 4: China's First 5G+ViLin-based Emergency Rescue Drill

In 2019, China Mobile worked with Fuzhou Emergency Management Bureau to complete an emergency rescue drill for major petrochemical accidents through the "5G+ViLin" system. This is the first case of joint dispatching and emergency rescue in mobility scenarios using 5G networks in China, marking the beginning of 5G application in emergency drills.

During the drill, the "5G+ViLin" system was used for the first time to implement seamless remote connection between multiple sites. The municipal emergency command vehicle was connected to each site through the 5G network. Mr. Lin Fei, deputy mayor of Fuzhou, gave a remote speech and announced the start of the drill. This achievement was highly recognized by municipal leaders.

Figure 12-12: Municipal emergency rescue using 5G+ViLin

Case 5: 5G Clairvoyance-based 4K UHD Video Surveillance in Shenzhen Airport

China Mobile and Huawei have jointly constructed a 5G+4K UHD video surveillance system for Shenzhen Airport. The system uses 4K UHD cameras and 5G networks to remotely capture HD images of aircraft takeoffs and landings and arriving passengers, transmit UHD video signals, and achieve 4K UHD video live broadcasting on UHD large screens in the terminal building, providing passengers with an improved experience.

Figure 12-13: 5G clairvoyance-based 4K UHD video surveillance in Shenzhen Airport

Case 6: 5G UHD Live Broadcast for the Cherry Blossom Festival in Jiangsu

With the 5G live broadcast solution, China Mobile integrates UHD live broadcast technology into smart scenic spots to implement remote live broadcasting in hotspot areas. The solution also uses social media channels such as WeChat and Weibo to promote scenic spots and encourage discussion. This is an important step in China Mobile's journey to upgrade smart scenic spots using 5G technology.

Figure 12-14: China Mobile Jiangsu first uses 5G technology to achieve live broadcasting of the cherry blossom festival on mobile phones.

Case 7: 5G AndLive-based 4K VR Live Broadcast at CAEXPO in Guangxi

5G edge computing and VR live broadcasting enable China Mobile to support 4K VR live broadcasts at the China-ASEAN Expo (CAEXPO). This live broadcast uses the 5G+4K VR technology to transmit 4K VR UHD videos through the 5G network in real time. The AndLive cloud platform performs cloud transcoding, cloud editing, and AI video processing, which greatly reduces live broadcasting latency and buffering, and creates an immersive VR live broadcasting experience.

Figure 12-15: AndLive-based 5G+4K VR live broadcast at CAEXPO in Guangxi

Case 8: 5G Video Convergence for "NPC and CPPCC Interactive Broadcast" by Henan Daily (NPC System's First Media Convergence Platform)

In March 2019, China Mobile supported Henan Daily in building a media convergence center for the National People's Congress (NPC) in Henan province. The goal was to achieve a holographic broadcast of the Henan delegation meeting at the second session of the 13th NPC. This was the debut of the NPC system's first media convergence platform, using video convergence to integrate technologies such as virtual live broadcast, 5G live broadcast, VR, and AR. 5G video conferencing and 5G live video broadcasting were utilized to implement 5G video convergence services. Through this live broadcast, the platform showcased the true power of 5G technologies and applications.

Figure 12-16: 5G video convergence for "NPC and CPPCC interactive broadcast" by Henan Daily

5G Smart Business Park

Smart Business Park is one of the key solutions for accelerating development mode transformation, adjusting industry structure, and accomplishing the national mission through informatization. Inspired by widespread entrepreneurship and innovation, Smart Business Park embodies the great vision of accelerating new economic growth and creating development momentum. The advent of 5G ushers in a new era of smart business park construction, enabling new technologies such as AICDE (Artificial intelligence, Internet of Things, Cloud computing, Big data, Edge computing) to be widely used in business parks.

China Mobile regards smart business park as an important field for promoting 5G deployment. The Smart Business Park platform is developed to integrate multiple capabilities with considerable 5G technological advantages and leading 5G essential resources. Application scenarios such as property management, business park security, and cloud office are eager to develop the next-generation smart business park solution in the 5G era.

5G Smart Business Park

1. Service Requirements

Business parks not only integrate industry developments but also reflect national and regional economic developments in China. The concept of "smart business park" has emerged in order to reduce costs and improve efficiency through informatization. Traditional business parks generally feature poor service experience, weak security protection, low operational efficiency, high management costs, and difficult service innovation. The Smart Business Park solution uses 5G+AICDE technologies to resolve the long-term difficulties faced by traditional business parks. It aims to provide customers with a comfortable service experience and help enterprises achieve innovative development through information-based transformation. The solution focuses on five requirements of business park customers:

Requirement 1: Complete Network Coverage

A smart business park requires a network that can quickly connect people, things, and environments. The network must achieve end-to-end O&M automation spanning planning, deployment, configuration, and optimization, to maximize system and data security.

Requirement 2: Convenient Smart Operation

Traditional business park operational management is extensive and involves multiple management levels. Also, it is mainly performed by people, which leads to high costs. As the Internet mindset gradually penetrates into operational management, traditional business parks are in urgent need of an intelligent management system to implement smart and green operations.

Requirement 3: Intelligent Property Management

Business park property management is at the forefront of the AI era, in which traditional management is transforming to smart management. 5G technology applications will foster innovations in the property management mode and improve management quality to meet customers' requirements.

Requirement 4: Powerful Security Protection

With the expansion of business parks and the surge in the number of people, vehicles, and objects in the business park, original admission control and management system face many challenges. For this reason, a solution to quickly improve business park security capabilities must be found.

Requirement 5: Highly Efficient Production

Efficiency improvement is a common requirement of all enterprises. For business park administrators, this can be achieved by reducing the complexity of enterprise management processes and taking advantage of the industry aggregation advantages of business parks.

The advent of 5G provides a new solution for business park administrators: 5G Smart Business Park solution that will help business parks embrace the prime time of high-speed development.

2. Solution Overview

To make full use of 5G network advantages and better serve enterprise customers, China Mobile has developed a comprehensive solution for smart business parks. This solution provides brand-new interpretations for business parks in terms of network coverage, smart operation, property management, business park security, business park office, and smart accommodation. The following figure shows its architecture.

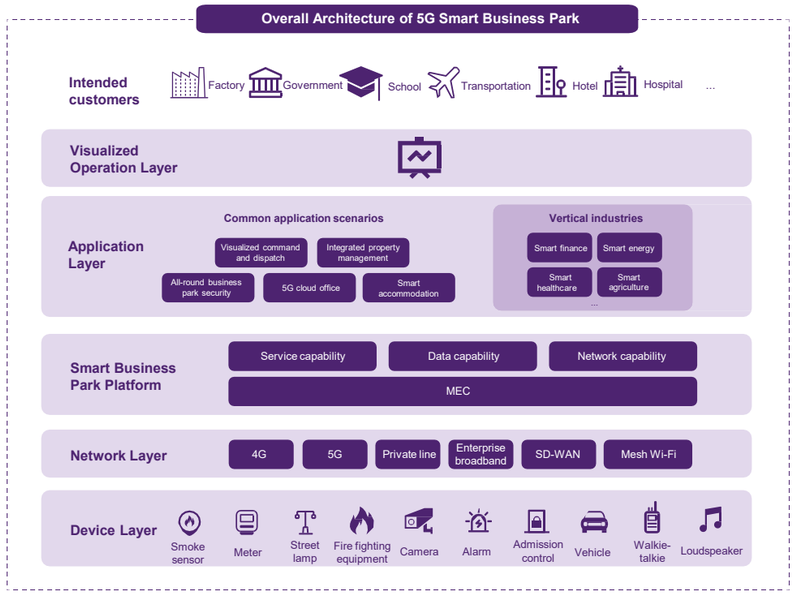


Figure 13-1: Overall architecture of 5G Smart Business Park

Device layer: Multiple access devices, such as security cameras and facial recognition admission control systems, are used to collect data at any time and send the data back in real time. The access devices can be directly connected to the 5G network through their built-in modules to provide HD images and video files.

Network layer: 5G and other access modes as well as different types of converged enterprise gateways are used to provide full network coverage in different scenarios. The user plane function (UPF) of China Mobile's 5G networks is deployed at a lower level, reducing the end-to-end latency of mobile services and improving user experience. With the MEC technology, services can be processed locally to prevent private data from being disclosed or transmitted on the public network.

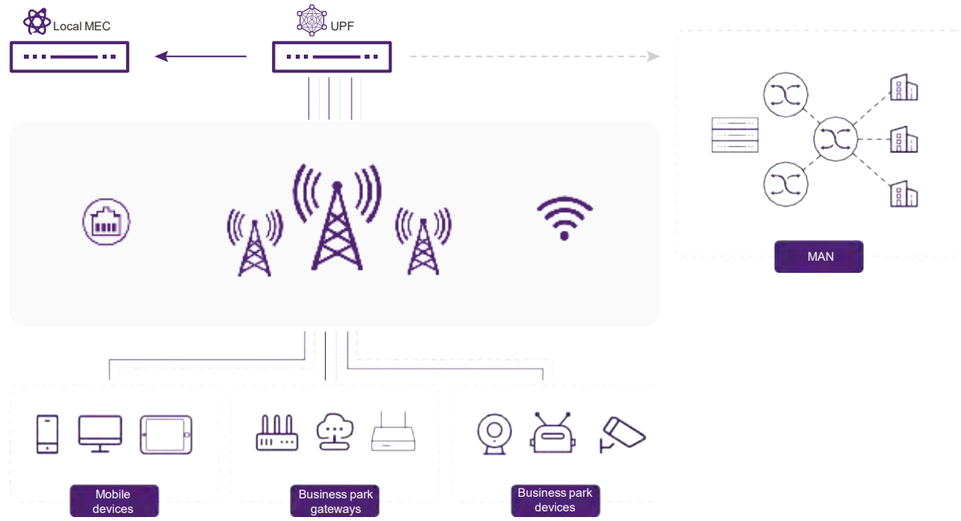


Figure 13-2: Overall architecture of the high-quality 5G private network

5G network features greatly increase the number of devices that can access the business park network, audio and video definition, cloud resource conversion efficiency, and the number of unmanned devices in business parks. 5G micro base station groups are deployed to enable high-density access of devices in smart business parks, achieving a massive number of connections. Business park devices can easily collect 4K to 8K HD audio and video data and upload the data to the platform in real time. In addition, the braking time of unmanned devices is shortened from seconds to milliseconds, and distance is shortened from meters to centimeters. Horizontally distributed base stations and vertically deployed gateways are used to transmit signals, achieving 100% wireless network coverage in business parks.

For data flow forwarding, the UPF is deployed in the MEC equipment room in business parks to improve the local computing and data split capabilities of business parks. This is critical because the control plane and user plane are separated on 5G networks. All data on the business park intranet is split by the UPF to the local MEC for processing. Requests for accessing Internet are directly sent to the metropolitan area network (MAN) after being split and the internal and external data flows are separated to ensure security.

Smart Business Park platform: The platform is the business park decision-making center and the core component of 5G Smart Business Park. It has comprehensive operational management capabilities such as sensing, transmission, storage, collaboration, judgment, and decision-making. It connects to both the service platform and smart devices to integrate data and applications. The platform optimizes resource configuration, reduces business park operational costs, and improves business park operational quality and efficiency using scenario-based big data analysis.

Figure 13-3: 5G Smart Business Park platform GUI

Application layer: Capabilities such as smart operation, admission control, attendance check, video surveillance, virtual office, and partner application capability exposure are integrated through the platform. This provides application services in various scenarios such as visualized command and dispatch, integrated property management, all-round business park security, and 5G cloud office for business park administrators and enterprise employees.

Embracing Industry Partners with Open Ecosystem

As a next-generation business park solution, 5G Smart Business Park will comprehensively improve business park management and operations. Based on the Smart Business Park platform, we will actively promote ecosystem construction, and in collaboration with industry partners, jointly stimulate the development of the smart business park industry.

3. Application Scenarios

Scenario 1: Visualized Command and Dispatch

Visualized command and dispatch is an integrated video communications system that combines video conferencing and video surveillance. It allows users to perform visualized multi-level command and dispatch wherever they are through network-based onsite video surveillance, as well as hold remote meetings through video conferencing. This enables users in different locations to perform service dispatching, decision-making, commanding, and collaborative consultation.

The video-based command and dispatch system can be integrated with third-party data services, security alarm services, and voice-based dispatching to form a powerful comprehensive video application communications platform. The platform can meet the requirements of various service departments for video-based emergency command and dispatch. It helps leaders at all levels to quickly make decisions, perform instant command and dispatch, and improve emergency handling efficiency.

Figure 13-4: 5G visualized display

Scenario 2: Integrated Property Management

5G Smart Business Park redefines traditional human resource management through integrated intelligent management and control. Attendance checks, visitor management, and logistics will be completely upgraded in the 5G era. For attendance checks, the massive connectivity feature of 5G networks enables all access control data to be synchronously transmitted to the smart platform. Enterprise management personnel can directly use the attendance data sent by the platform to verify employee performance, making attendance checks simple, transparent, and efficient. For visitor management, AI-based facial recognition can directly verify identities, allocate permissions, and generate visitor passes. Visitors can then enter the business park without waiting. When a large number of people or vehicles enter the business park, the platform can analyze the road traffic based on the entrance data collected by business park devices, such as access control turnstiles, and subsequently divert pedestrians and vehicles to ensure efficient operations.

In terms of logistics, food and packages will be delivered by robots to improve the last-mile delivery in the business park. 5G's low latency feature ensures the accuracy and security of robot routes. The robot will scan the recipient's face and accurately identify the recipient based on AI-based HD facial recognition to avoid inaccurate delivery. In addition, the 5G network can help robots update their locations in real time. Business park administrators and users can track their locations at any time without worrying about missing deliveries.

Figure 13-5: Integrated property management

Scenario 3: Comprehensive Business Park Security

The next-generation smart business park will be equipped with a surveillance system featuring no blind spots, high definition, and real-time backhaul. Facial recognition based on AI cross-checks the collected data with employee data to identify visitors and unregistered vehicles in the business park, and cooperates with the security department to verify their identities, implementing trespasser warnings and blacklist alarms. 5G networks are combined with IoT technology to intelligently upgrade street lamps, manhole covers, electric meters, temperature control devices, and environment monitoring systems. In addition, business park devices are enabled to monitor the business park in real time, collect multi-dimensional environment data, and upload this data to the smart business park platform at a rate of several Mbps to some Gbps for subsequent big data analysis.

In such a highly data-oriented new business park, the management department can construct a VR business park to achieve multi-dimensional displays. Through this technology, the business park can be monitored 24 hours a day, 7 days a week in all aspects through HD video surveillance, video recording, and intelligent video analysis.

Figure 13-6: Video surveillance of a business park

Scenario 4: Smart Accommodation

A smart guest room is equipped with a smart TV, smart speaker, and wireless phone. Hotel guests can avail of room services, make internal and external calls, and reserve vehicles or meals through voice and simple operations.

The Smart Business Park platform proposes the digital guest room as a brand-new concept and profit-generating means for hotels, improving the image of the hotel industry in China through win-win cooperation.

Figure 13-7: Smart guest room

Scenario 5: 5G Cloud Office

The next-generation smart business park expands traditional offices with fixed terminals into ubiquitous cloud offices. With office files stored on the cloud, the edge computing platform builds an office software-as-a-service (SaaS) ecosystem integrating cloud storage, cloud collaboration, and video conferencing. Employees can directly connect to 5G networks through laptops, tablets, and mobile phones to access the cloud anytime and anywhere, improving office efficiency, enhancing office mobility, and applying cloud offices to the entire business park.

When an enterprise user accesses the office system, the UPF data split technology determines the message distribution path based on the user identity, access service type, and data receiving and sending addresses, and then forwards the data flow to the local MEC equipment room. This ensures data security by keeping internal data inside the business park.

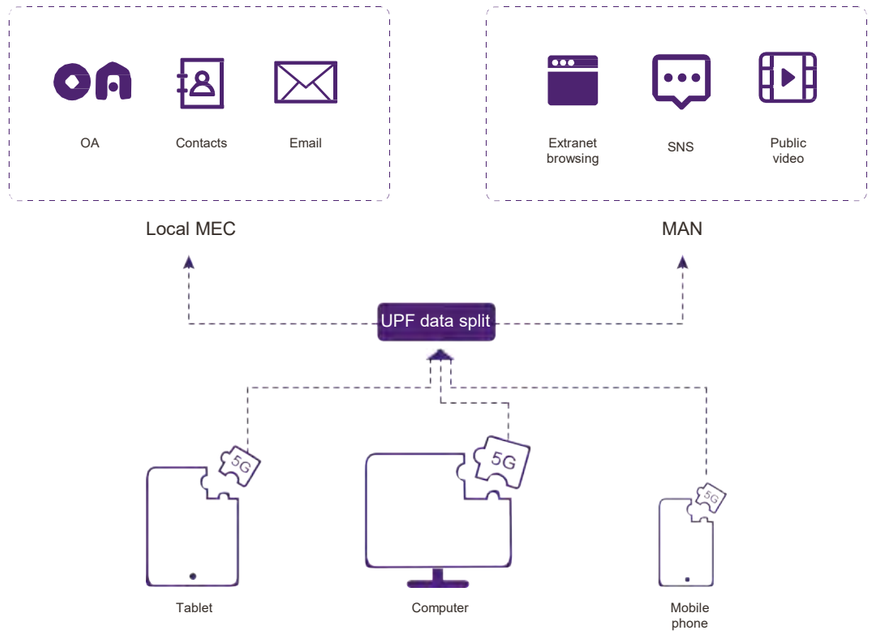


Figure 13-8: Mobile cloud office

4. Use Cases

Case 1: China Mobile Guangdong Builds 5G Smart Business Parks

China Mobile Guangdong has built 5G-powered smart business parks in multiple locations. 5G networks in these business parks enable next-generation cloud offices, property management, and business park security. The networks are accessible anytime and anywhere throughout the business park, enabling employees at different locations to work together on the cloud. For example, employees can access the cloud PC, participate in HD video conferences, watch VR live broadcasts of internal training sessions, and quickly upload or download internal materials using the cloud. Property management services facilitate employees both during and outside of working hours. Self-driving shuttle buses support the daily transportation of employees in the business park; sorting robots handle internal express items; and unmanned vending vehicles and coffee delivery UAVs cater to employee needs. Multiple measures are taken to build a safe business park, including high-positioned video surveillance, AR facial recognition, ground robot inspection, and low-altitude UAV inspection. In addition, the business park uses 5G MEC to achieve isolation and admission control for data security.

Figure 13-9: Smart business park deployed by China Mobile Guangdong

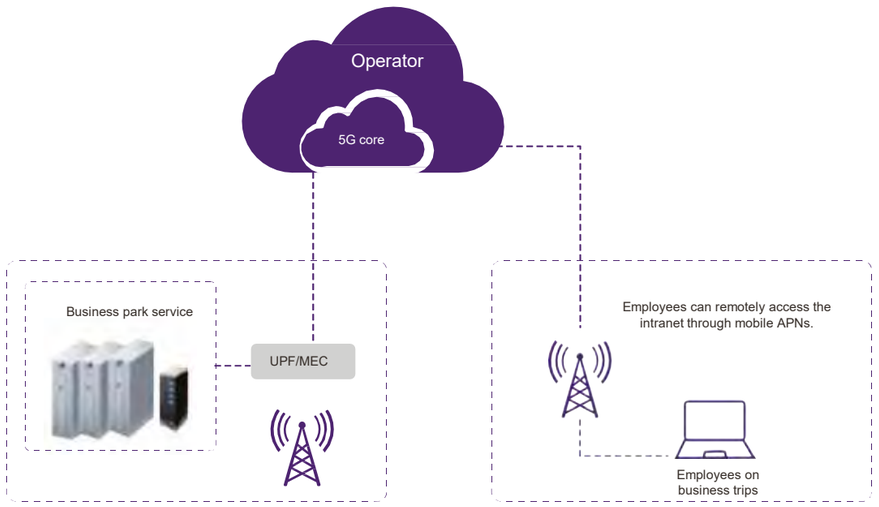


Figure 13-10: Smart business park architecture

Case 2: China Mobile Zhejiang Builds Hi-Tech Walkways for 5G Smart Business Park

China Mobile Zhejiang builds high-tech business park walkways based on 5G technologies and innovative applications. Property management services such as 5G facial recognition vending machines, unmanned sightseeing vehicles, VR glasses for musical fountains, and 5G connected UAVs for real-time coffee delivery enrich user application scenarios and improve lifestyle and entertainment experiences. In terms of business park security, 5G crowd monitoring and smart security/firefighting systems are deployed to help transport departments manage and control traffic situations in real time, ensuring security. Transport departments can implement remote all-time management in all areas without dispatching auxiliary police officers, enhancing security protection.

Figure 13-11: Walkways in a 5G business park deployed by China Mobile Zhejiang

5G Cloud Gaming

Cloud gaming is made possible by the in-depth integration of gaming services and 5G technologies. That is, 5G technologies, such as edge computing and network slicing technologies, deploy the service processing capability of cloud gaming to the network edge closest to users. This reduces in-game latency, lowers the cost of devices, ensures user security, unifies versions for management, and prevents unauthorized plug-ins.

China Mobile leverages high-quality 5G network capabilities and closely collaborates with Internet enterprises to unlock the potential of 5G+AICDE (Artificial intelligence, Internet of Things, Cloud computing, Big data, Edge computing) capabilities. In this way, a 5G cloud gaming solution is developed which focuses on application scenarios such as edge cloud for gaming, gaming assurance for VIPs, gaming security protection, and cloud game workstations. This solution meets the requirements of cloud gaming services for high-speed transmission, cloud network security, slice assurance, and edge computing, providing smoother, safer, and better gaming experiences.

5G Cloud Gaming

1. Service Requirements

5G cloud gaming, as an important and innovative application within the entertainment field, relies on high-speed network channels and efficient edge nodes. With games deployed on the cloud, rendered images are transmitted to user terminals through the network. In general, a video resolution of 1080p with 60 frames per second (FPS) requires a bit rate of 40 Mbps and an end-to-end latency of 20 ms to 40 ms to ensure clear images and smooth video display. The latency and bandwidth of 4G networks have always limited the development of cloud gaming. As 5G networks offer high rates and low latency, mobile edge computing (MEC) and network slicing will completely remove the bottleneck for cloud gaming. The experienced rate of 5G users reaches 1 Gbps, while the air interface latency is 1 ms. This meets the network requirements for cloud gaming, and enables users to enjoy a high-quality gaming experience without high specification terminals.

Requirement 1: MEC Gaming Platform

Traditional game operators deploy servers in Internet data center (IDC) equipment rooms, introduce content sources into their equipment rooms, and use content delivery network (CDN) acceleration and other technologies to improve user experiences. For large-scale client-based games, players need to download clients on high-performance terminals. The cost is high, and frequent patch updates may result in user churn. Mobile games have even higher requirements on phone storage, network status, and user tolerance to updates. With 5G cloud gaming, games are deployed on the nearest edge nodes to implement local data breakout, computing, and rendering, as well as low-latency data synchronization. Users can enjoy a "thin client, zero wait time, and cross-platform" experience with versions managed on the cloud, no game plug-ins allowed, and lowered gaming thresholds.

Figure 14-1: 5G cloud gaming experience

Requirement 2: Network Guarantee for VIPs

Gaming experiences are affected by many factors, such as audio and video quality, interaction quality, and loading duration. 5G cloud gaming users can experience various client-based games, mobile games, and even AR/VR games as long as they have terminals with decoding capabilities. In densely populated areas or during peak hours, the heavy network load often results in poor user experiences, which can manifest as frame freezing, getting offline, delayed responses, and connection failures. e-Sports demand even higher requirements on network quality and stability, requiring dedicated network slices to provide exclusive network channels for optimal service experiences.

Figure 14-2: Network assurance for VIP acceleration in cloud gaming

Requirement 3: Cloud Game Workstation

The development and tests of games require expensive and high specification central processing units (CPUs) and graphics processing units (GPUs) for image rendering and engine testing. Such an initial investment poses great pressure on small- and medium-sized game developers. The cloud game workstation supports iterative development, quick deployment, and online testing of games, avoiding heavy asset investment in the early stages and reducing a company's financial pressure. The operations and maintenance (O&M) costs can also decrease if cloud game workstation or other external resources are used for subsequent maintenance.

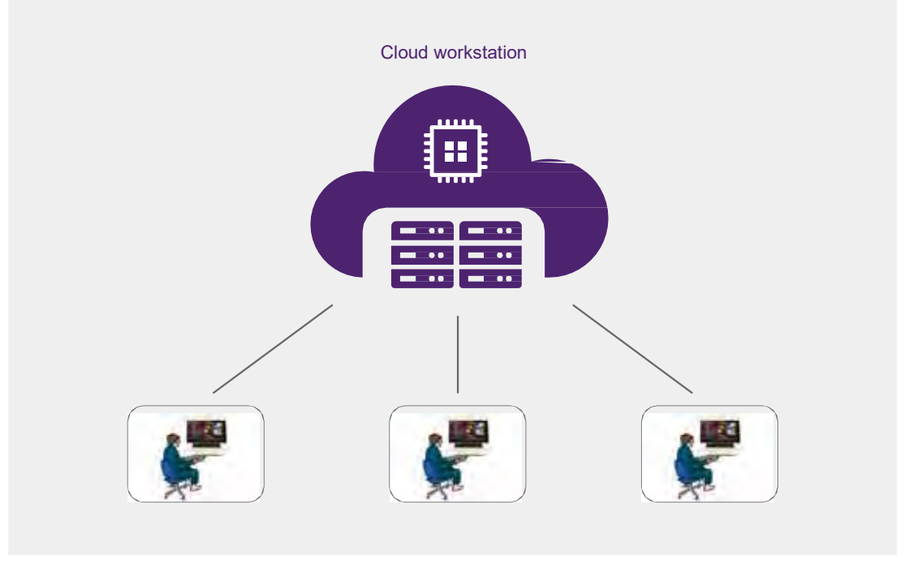


Figure 14-3: Cloud game workstation

2. Solution Overview

China Mobile builds a "cloud-pipe-device" integrated 5G cloud gaming solution based on 5G, edge computing, network slicing, and other technologies. The 5G cloud gaming platform aggregates capabilities such as network slicing for gaming, edge computing, network security, and big data, providing game vendors with products and services including quick game deployment, edge node management, slice operation and management, and game acceleration packages. Players can start games immediately after accessing the platform and obtain a cross-terminal and immersive gaming experience.

Perception layer: This layer consists of various gaming terminals, including AR/VR devices, mobile phones, computers, TVs, and tablets. Users can log in to the game with the same account on different terminals. Edge computing reduces hardware configuration requirements on these gaming terminals.

Network layer: This layer provides services such as edge cloud for gaming, network slicing, and quality of service (QoS) assurance based on various gaming service requirements to ensure stable, high-speed, and secure transmission of data, audio, and video streams.

Platform layer: This layer offers a big data and slicing platform with open capabilities to game developers and operators. They cannot only manage versions and resources based on the edge cloud, but also perform user management, authentication, certification, and interface management on the platform. Such a platform provides standard interfaces and self-service pages as well, facilitating the interconnection of vendors on the gaming platform.

Application layer: This layer boasts value-added services such as edge cloud management, gaming slice management, game acceleration packages, and game security protection for game developers and operators.

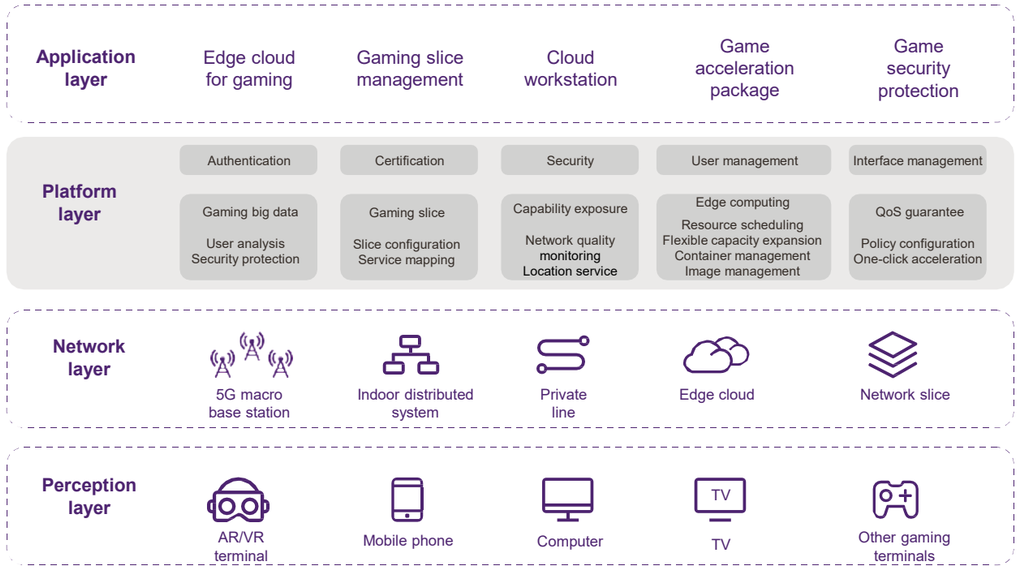


Figure 14-4: 5G cloud gaming solution

3. Application Scenarios

Scenario 1: 5G Edge Cloud for Gaming

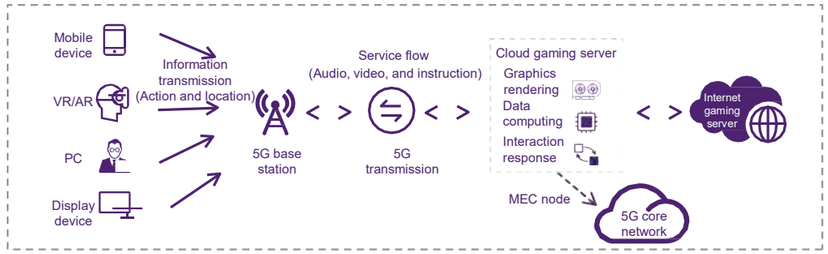


Figure 14-5: 5G edge cloud for gaming

Given the requirements on high specification devices, network bandwidth, and latency, players are often unable to enjoy their favorite client-based or mobile games carelessly with families or friends in leisure time. To overcome this problem, China Mobile has launched the 5G edge cloud for gaming solution based on 5G networks, edge computing, and slicing technologies. This solution allows game vendors to move cloud gaming servers to the edge cloud to implement local data breakout, rendering, computing, and other functions. The slicing technology enables logically isolated network channels to reduce frame freezing, getting offline, and connection failures. The unified management of cloud gaming versions based on the edge cloud enables access-and-play, prevents piracy and plug-ins, and optimizes the overall experience, maximizing the number of players. Cloud gaming provides a new entertainment experience for fragmented time.

Scenario 2: Gaming Assurance for VIPs

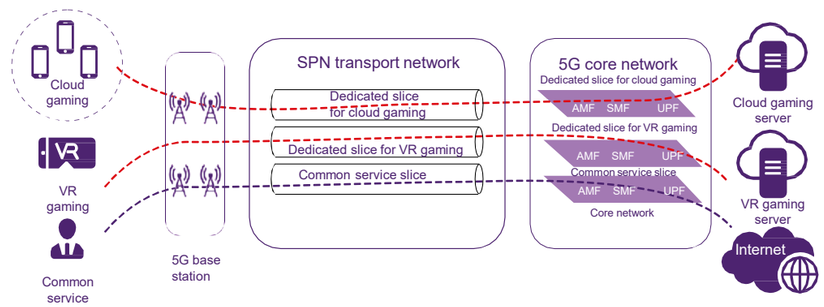


Figure 14-6: Slicing assurance for VIPs

Based on 5G network slicing and QoS assurance technologies, high-quality network assurance is available to cloud gaming VIPs. There are two types of VIPs. The first are players who have a strong willingness to pay or have invested a large amount of money in games. The second type are e-Sports players of competition games such as League of Legends, Dota 2, and PlayerUnknown's Battlegrounds (PUBG). e-Sports features a large number of players, global competition scale, and high requirements on network environments.

China Mobile provides dedicated gaming slices, customized network channels, and acceleration services to ensure the gaming experience of the first type of VIPs during cloud gaming peak hours with inferior and unstable network quality. e-Sports competitions may suffer from interruptions caused by long latency, hop ping, and network fluctuations. Game operators can submit slicing requirements on network specifications on the slice operations platform, and then the slice management platform configures dedicated gaming slices to provide end-to-end logically isolated channels. This ensures short network latency, large bandwidth, low packet loss rate, and other specifications complying with high Service Level Agreements (SLA). Dedicated gaming slices also provide flexible charging modes, guaranteeing network quality and ensuring a level playing field for e-Sports.

Scenario 3: 5G AR/VR Gaming

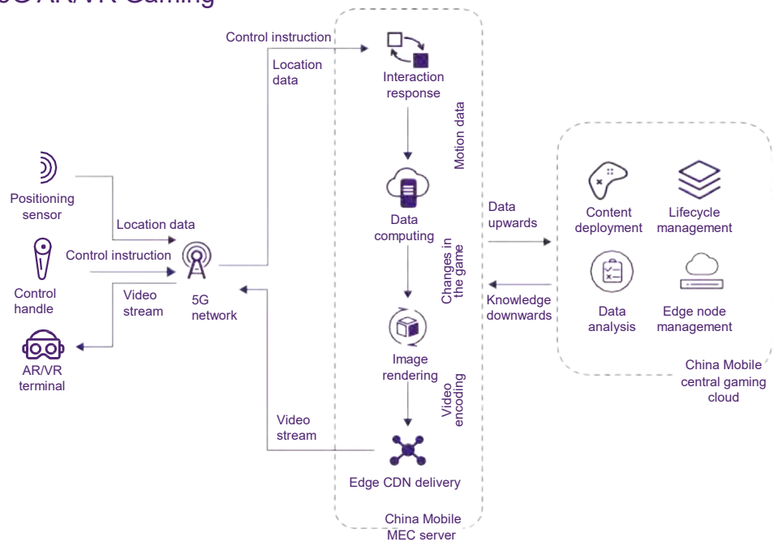


Figure 14-7: AR/VR gaming scenario

Immersive gaming experiences with AR glasses, VR headsets, and kinetic devices requires ultra-high bandwidth and ultra-low latency. However, insufficient device resolution, screen-door effect (SDE), motion sickness, and heavy devices have limited the development of AR/VR gaming. Enhanced Mobile Broadband (eMBB) and Ultra-Reliable Low-Latency Communication (URLLC) application scenarios of 5G remove the limitations that have plagued AR/VR gaming for many years. China Mobile's 5G AR/VR gaming solution combines 5G and MEC technologies to effectively solve problems such as long latency, frame freezing, and insufficient resolution, and greatly reduces the threshold for players with light but powerful VR/AR devices. The immersive user experience is also greatly boosted.

Scenario 4: Gaming Security Protection

Traditional game operators usually face three industry pain points: copyright security (game piracy), content security (game cheating), and operation security (network attack).

Thanks to the high rates, low latency, and edge computing technologies of 5G networks, traditional client-based game content can be placed on the cloud. As such, cloud gaming effectively prevents traditional piracy actions such as cracking, replication, and the spread of copyright protected standalone games.

Game cheating includes tampering with game data and using illegal plug-ins (such as automatic aiming, lock-on, and mouse macros in shooting games). However, cheaters cannot tamper with data when the game content is stored on the cloud. In addition, machine learning and other AI technologies interwork with edge computing to establish a detection model for abnormal behaviors. Cheaters using illegal plug-ins are automatically blocked in real-time, reducing the time and operation costs of the entire process of cheating detection, reporting, and manual verification in traditional multi-player online games.

Regarding protection from network attacks, the cloud gaming technology widely used in 5G networks perfectly integrates with China Mobile's cloud-based network security protection products to provide network-wide traffic cleaning, web page protection, and domain name system (DNS) anti-hijacking.

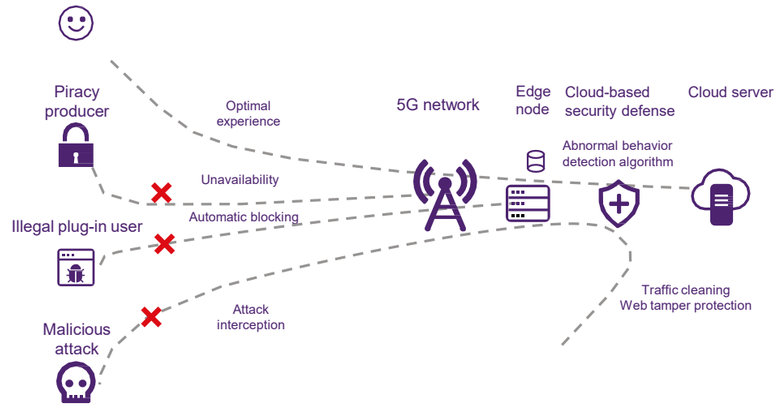


Figure 14-8: Gaming security protection

Scenario 5: Game Development Workstation

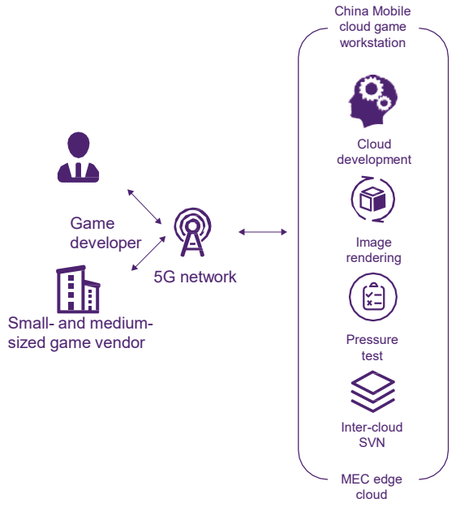


Figure 14-9 Game development workstation

Image rendering, pressure tests, and version iteration during game development require workstations to have advanced computing processing capabilities, high durability under frequent use, and large bandwidths. China Mobile uses 5G edge computing technology to build game development workstations on the cloud, providing easy access to computing and image rendering services for small- and medium-sized game vendors. Game developers can perform image rendering, pressure tests, and version iteration on the cloud, which effectively reduces the hardware investment and greatly improves game development efficiency.

4. Use Cases

Case 1: Industry's First MEC-based 5G Game Application

From May to October 2019, China Mobile worked with Tencent to apply 5G edge computing to Tencent games, achieving an optimal combination of 5G+MEC and cloud games for the first time. The high rate, low latency, and edge computing technology of the 5G network enabled game services to be deployed at edge nodes, reducing latency from approximately 100 ms to 20 ms. Such capabilities easily deliver high-quality gaming experiences. 5G greatly enhances Tencent's cloud gaming development.

Figure 14-10: Latency comparison between the traditional game and 5G+MEC cloud game (5G+MEC cloud game shown in the following figure)

Case 2: 5G Cloud Gaming Application Exploration

In November 2019, China Mobile, together with the Application and Platform Business Department of NetEase Games, demonstrated the 5G-powered NetEase cloud gaming application platform, achieving the integration of 5G networks and cloud gaming platforms. 5G networks enable cloud deployment of traditional mobile games, delivering high-quality and low-latency gaming experiences on 5G networks without the need to download the game.

Figure 14-11: Title screen of a 5G cloud game

Appendix

Acronyms and Abbreviations	
Acronym or Abbreviation	Full Spelling
3D	3 Dimensions
4G	4th-Generation
5G	5th-Generation
AGPS	Assisted Global Positioning System
AGV	Automated Guided Vehicle
AI	Artificial Intelligence
AICDE	Artificial intelligence, Internet of Things, Cloud computing, Big data, Edge computing
AP	Access Point
API	Application Programming Interface
APN	Access Point Name
AR	Augmented Reality
ATG	Air to Ground
AVC	Advanced Video Coding
CDN	Content Delivery Network
CPE	Customer Premise Equipment
CPU	Central Processing Unit
CRM	Customer Relationship Management
CT	Computed Tomography
DNS	Domain Name System
DTU	Data Transfer Unit
eMBB	Enhanced Mobile Broadband
ERP	Enterprise Resource Planning
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GPU	Graphics Processing Unit
HEVC	High Efficiency Video Coding
IDC	Internet Data Center
IoT	Internet of Things
I/O	Input/Output
LIDAR	Light Detection and Ranging
MEC	Mobile Edge Computing
MES	Manufacturing Execution System
mMTC	Massive Machine Type of Communication
MR	Mixed Reality
MRI	Magnetic Resonance Imaging
NB-IoT	Narrow Band Internet of Things
NFV	Network Function Virtualization
NR	New Radio
OA	Office Automation
OCR	Optical Character Recognition
OCT	Optical Coherence Tomography
ORP	Oxidation-Reduction Potential
PC	Personal Computer
Ping	Packet Internet Gopher
PLC	Programmable Logic Controller
PMU	Phasor Measurement Unit
POC	Push-to-Talk Over Cellular
PSVN	Public Switched Voice Network
QAR	Quick Access Recorder
QoS	Quality of Service
RTK	Real-Time Kinematic
RT-TCP	Real-Time Transmission Control Protocol
SaaS	Software-as-a-service
SCADA	Supervisory Control And Data Acquisition
SDN	Software Defined Network
SD-WAN	Software-Defined WAN
SLA	Service Level Agreement
SMF	Session Management Function
SVC	Scalable Video Coding
UAV	Unmanned Aerial Vehicle
UPF	User Plane Function
URLLC	Ultra-Reliable Low-Latency Communication
UWB	Ultra Wide Band
V2X	Vehicle to X
VoLTE	Voice over Long-Term Evolution
VR	Virtual Reality
VTM	Video Teller Machine

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