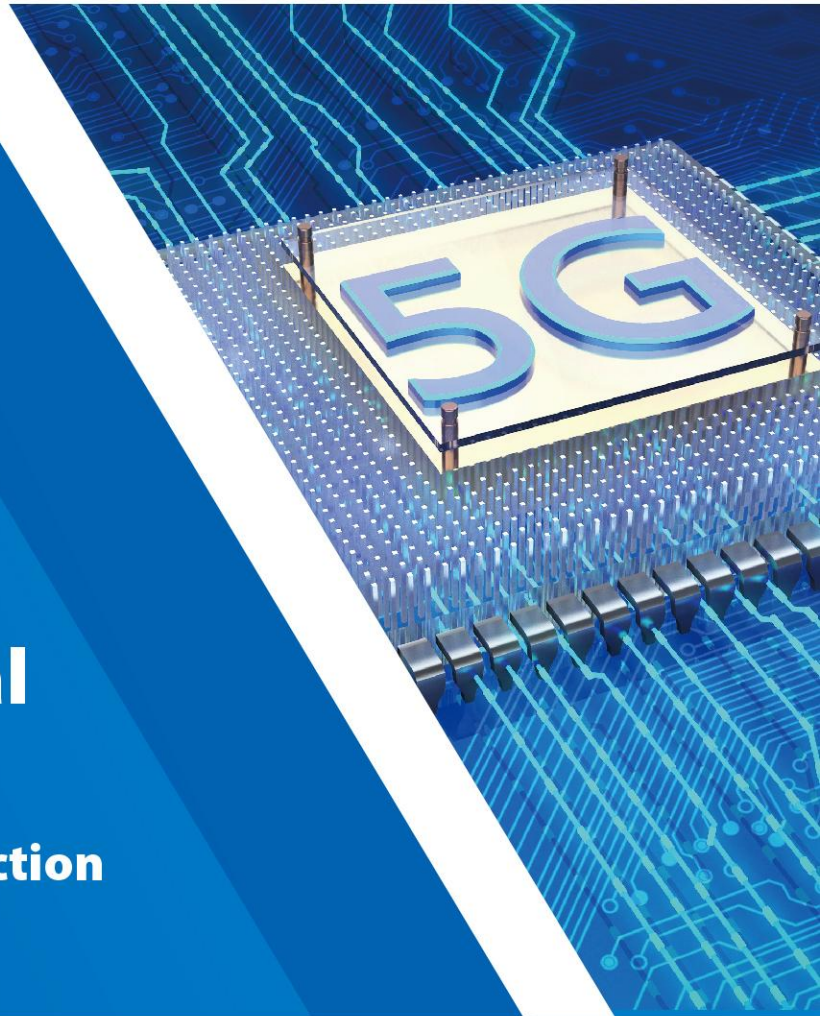


## **5G-based Industrial Field Network**

**-Private 5G for Critical Production**



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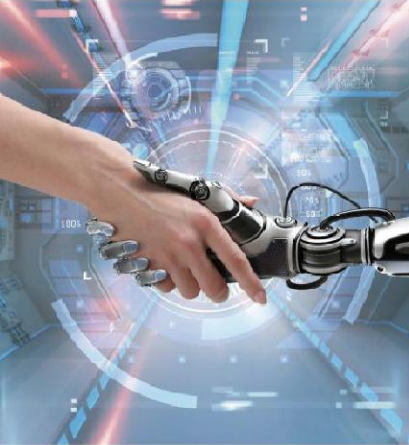
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## 1 Industry Development and Outlook for Evolution

Industry is not only the leading force of the national economy but also the foundation of social and economic development. Under the promotion of the digital economy boom in recent years, the innovative development of "5G + Industrial Internet" has made phased achievements, and even has been replicated and spread in some areas. ZTE believes that the 5G fully connected factory can make full use of the new-generation Information and Communication Technology (ICT) represented by 5G to integrate and build a new type of industrial private network for critical production. The "5G + Industrial Internet" will also move forward from the initial exploration to deep cultivation.



This white paper combines ZTE's extensive practice and optimized iteration with operators and partners in various industries to provide solutions covering converged computing networks, intrinsic determinism, and one-stop services, presenting to industry partners a detailed construction methodology and process of the critical production private network.

## 2 Demands and Challenges in the critical production

### 2.1 Industry Demands

The production site refers to a series of activity places with the completion of production tasks as the core. The production sites defined by the fully connected factory include production line level, workshop level, and factory level, corresponding to different scenarios and critical productions in different industries. Next, we will make scenario analysis on the critical productions of the following typical industries.



### 2.1.1 3C (Computer, Communication, Consumer) Manufacturing Industry

Generally, a 3C manufacturing workshop is deployed within a large factory building, with different production lines completing the component production, module packaging (SMT/LCM), product assembly, product testing, and product packaging processes according to the product process flow. Factories expect to use 5G to achieve networking and cloud-based management of robotic arms and PLCs, as well as utilizing applications such as data acquisition, AGV coordinated loading and unloading, and machine vision in multiple production lines in the region, further evolving towards digitization and intelligence.

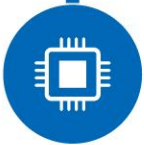
The demands of 5G network for automated production lines include:



Network interconnection and convergence of computer & networks: AGV, PLC, robotic arms, etc. require networking and cloudization, combined with data acquisition to achieve visual production and predictive maintenance of production lines. Therefore, wireless networking and cloudization promote the integration of computer & network solutions.



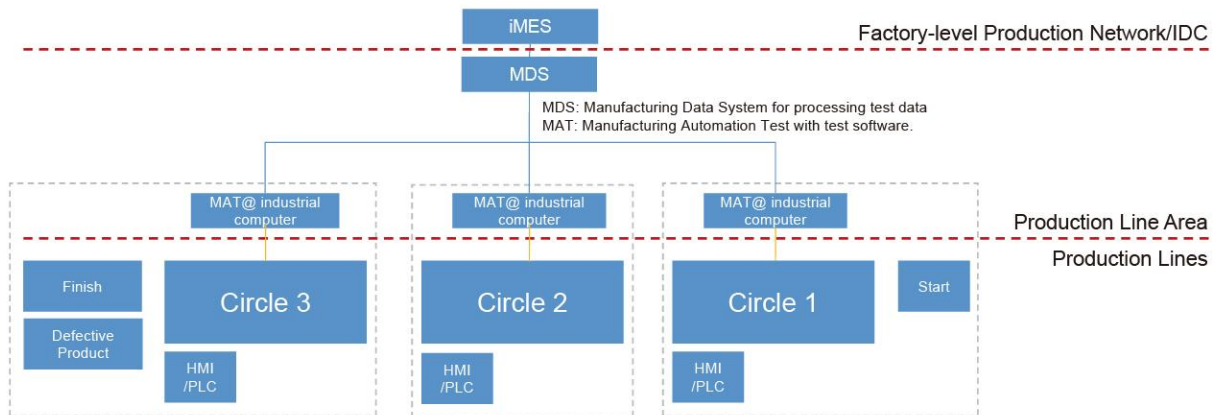
Connecting availability and network reliability: Network has high requirements on latency, jitter, and throughput for bearing industrial PLC protocols, AGV loading and unloading, and machine vision application business. Considering the actual situation in industrial sites, security is also an important factor that cannot be ignored in wireless transformation.



Integrated deployment and self-operation and maintenance: Enterprises have a demand to quickly achieve the deployment of 5G private networks in the critical production, in order to reduce the impact of construction on production. At the same time, factories also have a demand for IT transformation in their own operation and management, with urgent needs for self-operation and maintenance, maintenance prediction, and fault root cause analysis.



Figure 2-1 Example of a private network for an automated assembly and testing production line



### 2.1.2 Unmanned Cranes in the Steel Industry

Cranes are a key piece of equipment in the steel industry, with a huge stock, commonly used for lifting steel coils in hot and cold rolling production lines and finished goods warehouses. Traditional cranes rely on drivers to operate and requires coordination with ground commands, resulting in relatively low overall efficiency. Currently, cranes are at the forefront of unmanned transformation. Upgrades have been completed for crane clamps, distance and collision prevention laser sensors, limit switches, and ground reflectors. If vehicle-mounted PLC equipment can be connected to the WMS warehouse management system through a 5G private network, intelligent cranes can communicate with various production processes, warehouse materials, and factory management systems, comprehensively optimizing the logistics process and significantly improving the safety and overall efficiency of crane operations.





Figure 2-2 Remote control in steel industry



The demand of the steel industry for 5G network using unmanned cranes as an example:

- Availability of high bandwidth wireless connection: After the crane is refitted, high-definition cameras will be installed, and multiple cranes will be working at the same time. High-definition video monitoring will require a large bandwidth of several hundred Mbps from the network.
- One-stop wireless network refinement planning and design: A large amount of steel structures and large equipment inside the steel plant cause significant interference with electromagnetic wave propagation, resulting in network interference and multiple reflections. Some enterprises also have other wireless networks, such as WiFi, and require a convenient wireless planning scheme to achieve the network deployment quickly.

### 2.1.3 The Gantry Crane in the Port Industry

Figure 2-3 The gantry crane in the port industry



Traditional gantry cranes require on-site operation by staff around the clock, resulting in a high demand for labor, which is costly and can also lead to safety accidents. Remote control modification



is urgent for gantry cranes. Regarding the modification, the installation of a PLC control system and multiple high-definition cameras on each gantry crane comes first. In addition, a PLC control center, ROS remote control board, and multiple display screens must be installed in the central control room. The driver analyzes and judges the crane and its hoisting tools through video in the central control room to complete the operation of the gantry crane.

The existing remote control transmission is based on waveguide tube WiFi or fibers. Regular maintenance or signal conflicts may easily cause equipment downtime and affect business operation. In response to this problem, the 5G network can provide a transmission solution for remote control of cranes, completing the link connection from the cranes to the control center.

The remote control of the gantry crane proposes the following requirements for 5G networks:

- Availability of business connections for the video part: Each gantry crane typically requires 20 to 30 HD cameras, with each camera requiring around 30Mbps of upstream bandwidth and the transmission latency of around 50-100ms.
- Availability of business connections for control commands: Due to the large inertia of the gantry crane, the PLC control has very strict requirements for delay and reliability, often using heartbeat mechanisms to check the delay, which is around 16ms.
- Differentiated security guarantee in business connection availability: Due to differentiated QoS characteristics of video streams and control messages, intelligent QoS security guarantee solutions are needed.
- One-stop wireless network coverage planning and design: During the movement of the gantry crane, business performance cannot be reduced, which imposes high requirements on wireless coverage planning and deployment.





## 2.2 5G Capability Requirements for Private Network in Production Domain

Based on the typical critical production scenarios in different industries, we can summarize that in order to carry out 5G private network transformation, the following core capabilities are essential.

1. Supports the interconnection of equipment in the industrial critical production and have the ability of 5G computing and network integration

The core business of the production field requires interaction with various surrounding devices, which requires the 5G network to support the interconnection of existing facilities and be compatible with traditional industrial buses and related industrial protocols. The networking and cloudification of various production also require the 5G private network to have computing power and platform components, providing owners/integrators with a complete solution of wireless network + computing power, to achieve application deployment and interaction of video optimization, cloud-based PLC, remote control platform, and integrated positioning, etc., through the convergence of computing and networking.

2. Provides business availability, network availability, and security solutions for industrial links

Industrial control businesses require networks to provide high availability, including low latency, large bandwidth, high deterministic communication, and SLA intelligent business assurance capabilities. These capabilities should not be affected by network load or interference fluctuations. At the same time, to ensure the continuity and security of production, network availability is also crucial. This includes network reliability, link reliability, and technical solutions such as isolation between production networks and B2C networks.

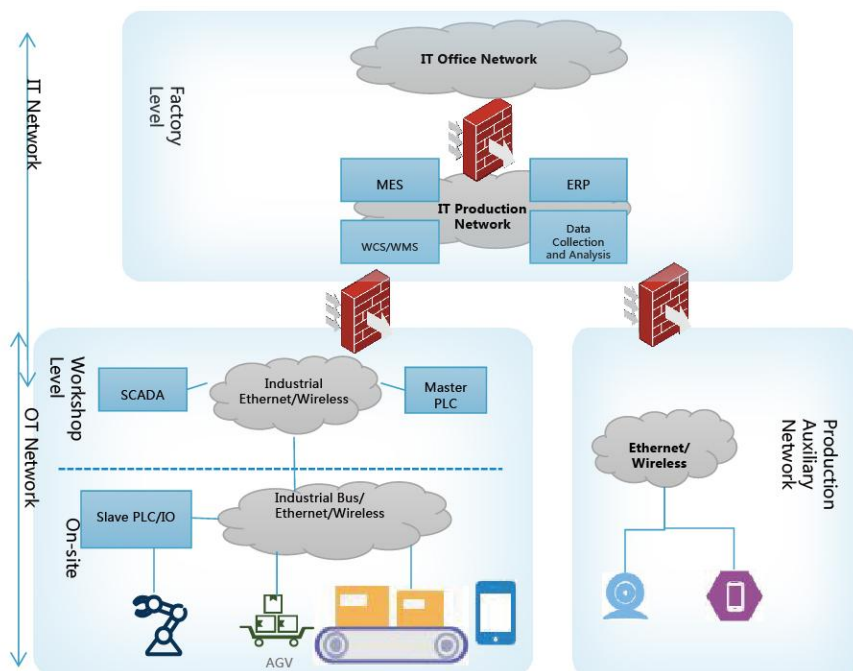
3. Supports one-stop network planning, deployment, and O&M, such as the "three-free" solution – free-of-planning, free-of-integration, and free-of-maintenance for critical production networks

Enterprise owners have demands for precise deployment within a shortest cycle, customized network debugging, and self-service to reduce the impact of network construction on production. Therefore, in addition to the excellent performance in business aspects, the 5G private network also needs to provide corresponding supporting technical solutions for network planning, network debugging, and network operation and maintenance, to reduce various problems encountered during the deployment process of the 5G private network. In the operation and maintenance stage, it provides operational status monitoring, low-threshold business deployment, and other content, such as service launch, service capability orchestration, flexible network adjustment, etc., to achieve local digital visualization, management, and control.

### 3 Deployment of 5G Private Network in Production Domain

Generally, enterprises outside of the 5G critical production connect their businesses with the cloud through operators' shared private networks. Compared with that, the 5G private network in critical production needs to better fit customers' production operations. The connectivity and computing deployment plan provided by the private network for the critical production is particularly important for its performance and cost. The figure below shows the network diagram for production-oriented enterprises, a 5G private network model more suitable for the OT network, especially for application scenarios under the industrial control network, while the 5G critical production peripheral network is more suitable for IT networks, production supporting networks, and other application scenarios.

Figure 3-1 Traditional industrial production network architecture

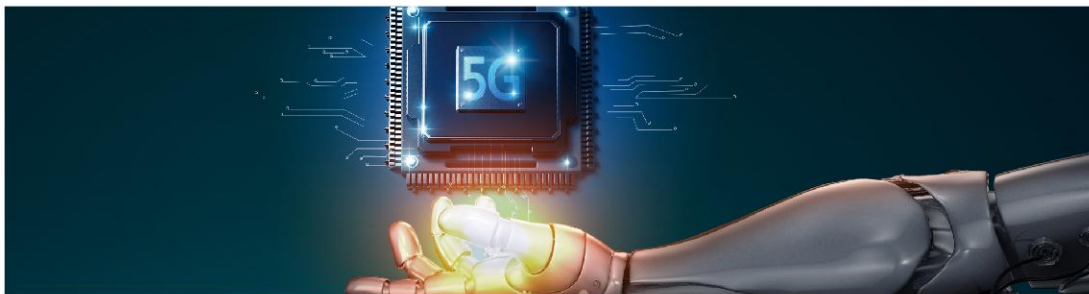




In the content below, we will combine typical industries and discuss two deployment modes for 5G private networks in the critical production, in order to express how they are implemented:

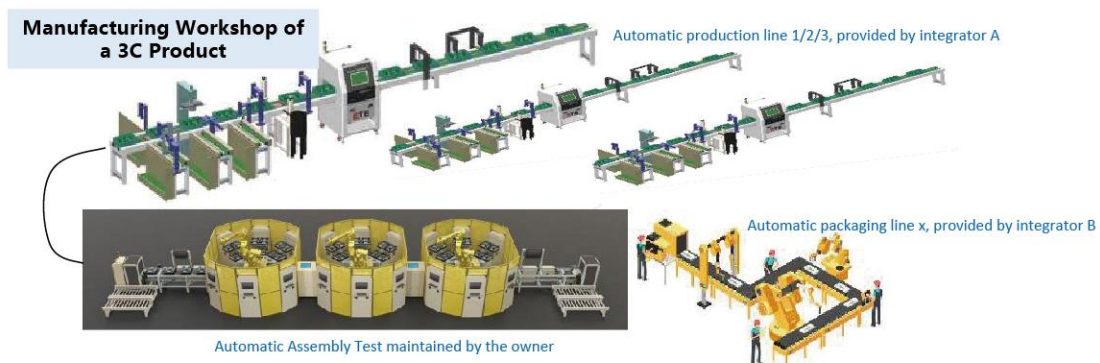
### 3.1 Independent Deployment Mode of 5G Private Network in critical production

Independent deployment mode is the most basic mode for 5G industrial private networks. When the performance requirements of industry customers, such as low latency and high availability, exceed the capacity limit of the public network and cannot be met with external network solutions for 5G industrial private networks, it is necessary to deploy an independent 5G industrial private network for industry applications. By using dedicated gateways, dedicated base stations/dedicated computing power services that match the requirements of industry applications, it ensures the transmission latency, processing capacity, and system availability of production flows.



Typical scenario: 3C electronics manufacturing workshop is as follows.

Figure 3-2 Diagram of typical 3C electronic manufacturing automation production line



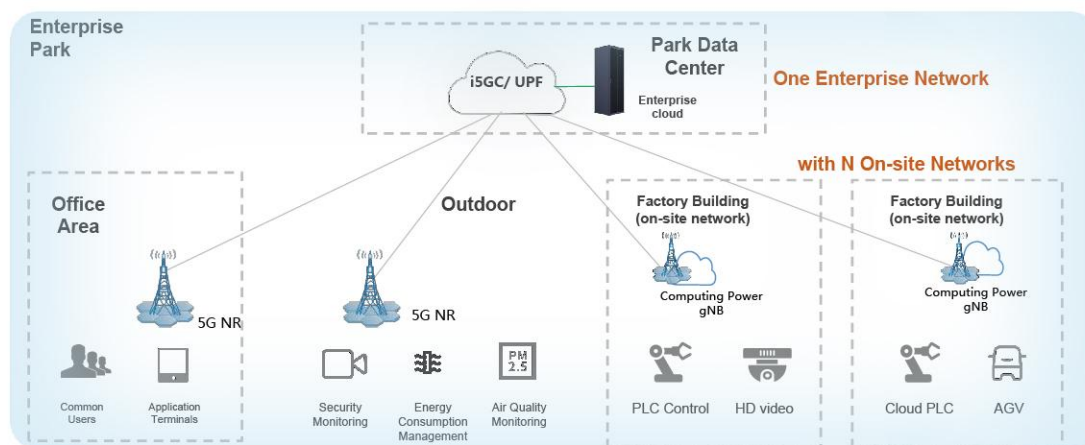
### 3.2 Joint Deployment Mode of 5G Private Network in critical production

The joint deployment model of 5G private network in the critical production, working with the peripheral network, is an extension of the independent one, targeting at industry scenarios with a certain scale. Cooperation and coordination are usually required between the private network and the peripheral network, and the following two joint deployment models can be adopted.

- Parallel deployment mode

With the support of the 5G production domain peripheral network, a parallel and independent deployment of the 5G private network is set up to provide collaborative services to manufacturing companies. Taking the steel industry as an example, the unmanned cranes in the workshop are covered by the private network. In addition, there are peripheral businesses such as air quality monitoring and security monitoring in the cross-workshop scope of the factory. These can be combined with the operators' shared network capabilities to serve the steel company together with the 5G private network.

Figure 3-3 Diagram of "1+N" networking architecture



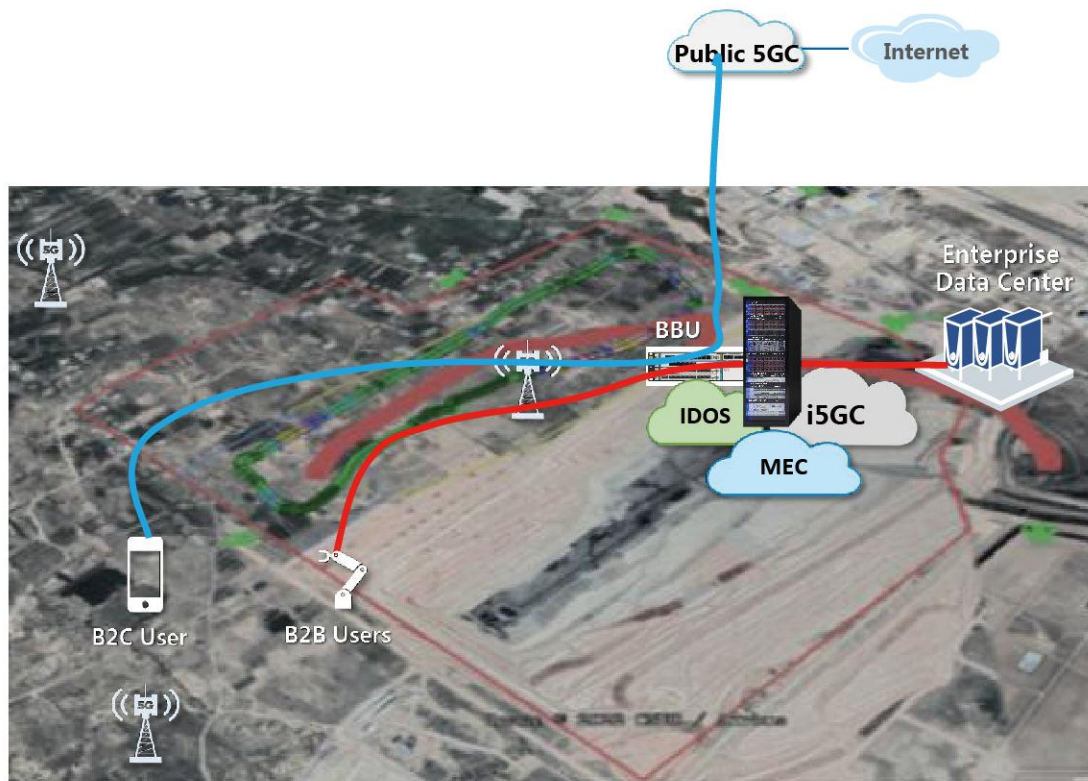




- Combined deployment mode

The 5G private network for the open-pit mine working area often adopts a deployment mode that combines the private network with the peripheral network. Its network architecture includes base stations (including BBU), edge computing, lightweight core network i5GC, enterprise self-service management platform, and is connected to the operators' public network 5GC and network management interface through the northbound connection. In special cases, public network services can also be allowed to access, and B2B and B2C dual-domain isolation technology is used to avoid mutual influence.

Figure 3-4 Diagram of 5G private network deployment in outdoor area







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## 4 Key Technologies for 5G Private Network in critical production

In this chapter, we take the perspective of key technologies to elaborate on how to better achieve the capability assurance and implementation of 5G private networks in the industrial domain from three aspects: network interconnection and convergence, reliability and security of the business availability network, and “one-stop, three free-of, self-service with three exemptions.



## 4.1 Interconnection and Computation Integration of 5G Private Network

### 4.1.1 Interconnection of Industrial Equipment (5G LAN and 5G gateway)

Essentially, the interconnection of private networks in the industrial critical production means linking systems and devices that are physically distributed across different levels and types via a private network, enabling the transmission and application of information/data. Most existing industrial equipment works in local area network environments, often using layer 2 networking technology and typical Ethernet messages for instruction and information transmission. With the construction of 5G private networks in the pcritical production, 5G LAN can be used to support unicast, multicast, and broadcast data transmission, as well as the interconnection of businesses distributed across different regions.

Figure 4-1 5G LAN Interconnection

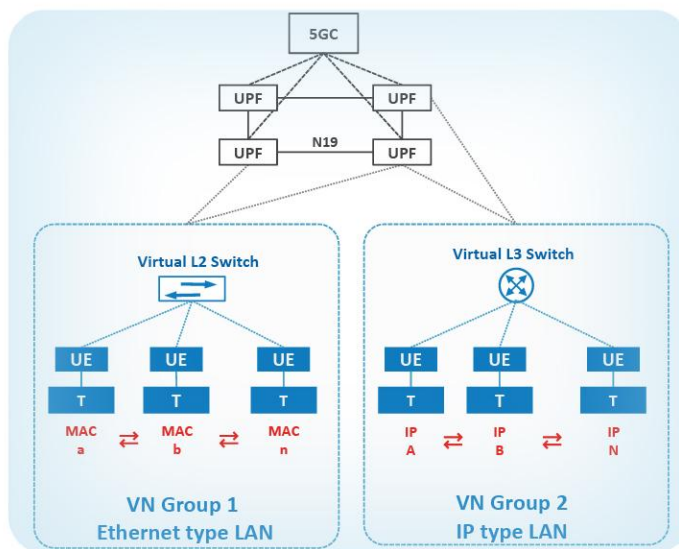
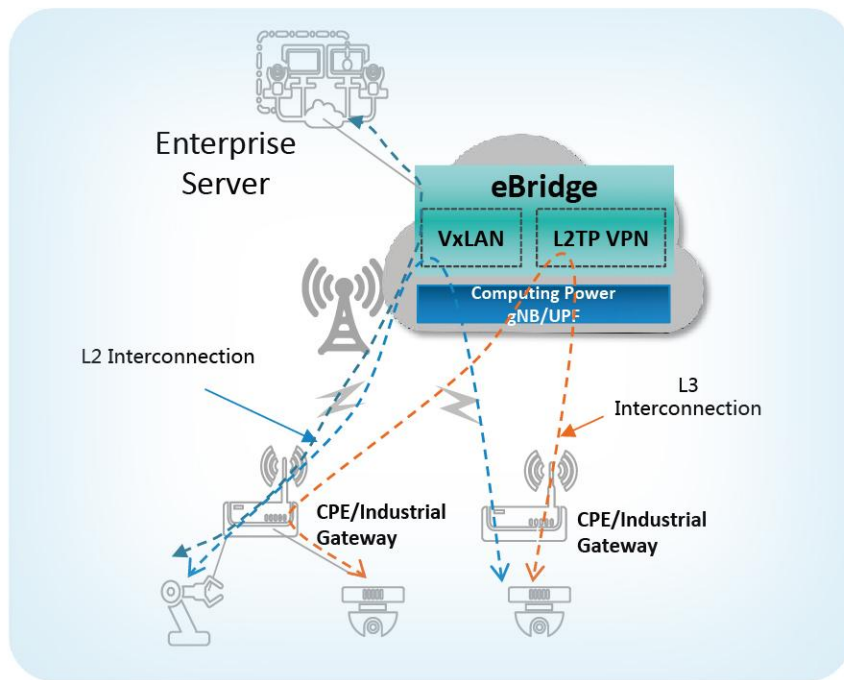
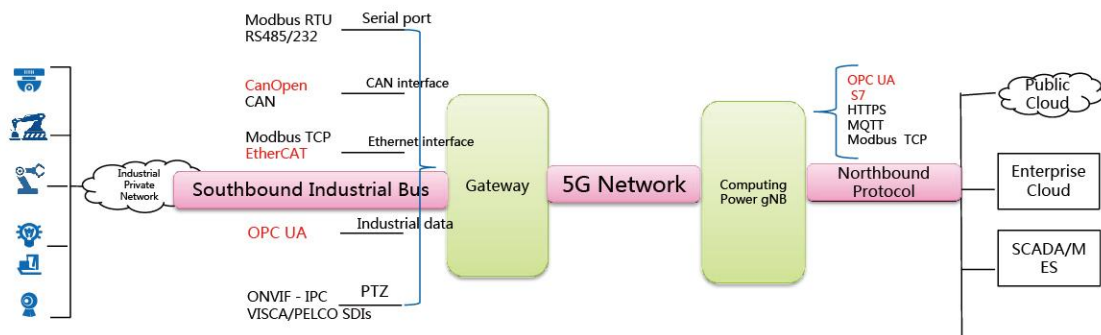


Figure 4-2 L2/L3 Interconnection



At the same time, there are a large number of different types of equipment in the industrial private network, such as PLCs, industrial robots, AGVs, CNC machine tools, etc., which can be flexibly accessed through 5G industrial gateways that support different physical interfaces/industrial protocols, thereby achieving wireless flat structure transformation to replace wired connection.

Figure 4-3 Multiple industrial protocols supported by 5G gateway





## 4.1.2 Integrated Computing and Network Solution for 5G Private Network

In order to better serve productions, the private network not only provides network capabilities, but also provides integrated computing resources to achieve synergy between the network and businesses. This is implemented through carriers of three levels: industrial gateways (terminals), computing base stations (edges), and MEC (cloud), using a container format to enable open computing and flexible deployment of enterprise businesses. Different computing resources have different characteristics. Generally, the closer they are to the cloud, the more abundant the computing resources, but the lower the real-time performance. The closer they are to the terminals, the more limited the computing resources, but the higher the real-time performance. Please refer to the comparison of several computing carriers in the table below:

Computing Power Location	Resource Situation	Available Services	Typical Cases
Terminal: Industrial Gateway	Computing power is strictly limited, such as CPUs typically having less than 10 cores.	Ultimate efficiency in coordination with production Take Time (TT).	Electronic fence, safety IO
Edge: Computing Power Base Station	Computing power is limited, such as having fewer than 100 cores in a CPU.	High efficiency that matches the production TT.	vPLC, AI visual inspection, low latency video.
Cloud: MEC Edge Cloud	Sufficient computing power, such as CPUs typically having 1000 cores or more.	The requirement for timeliness is not high when matching the production TT.	Video surveillance

In the industrial private network, many services terminate in the production line and workshop. These applications can be deployed on the local critical production edge/terminal computing platform. Local termination of services makes the operation more efficient and networking simpler.

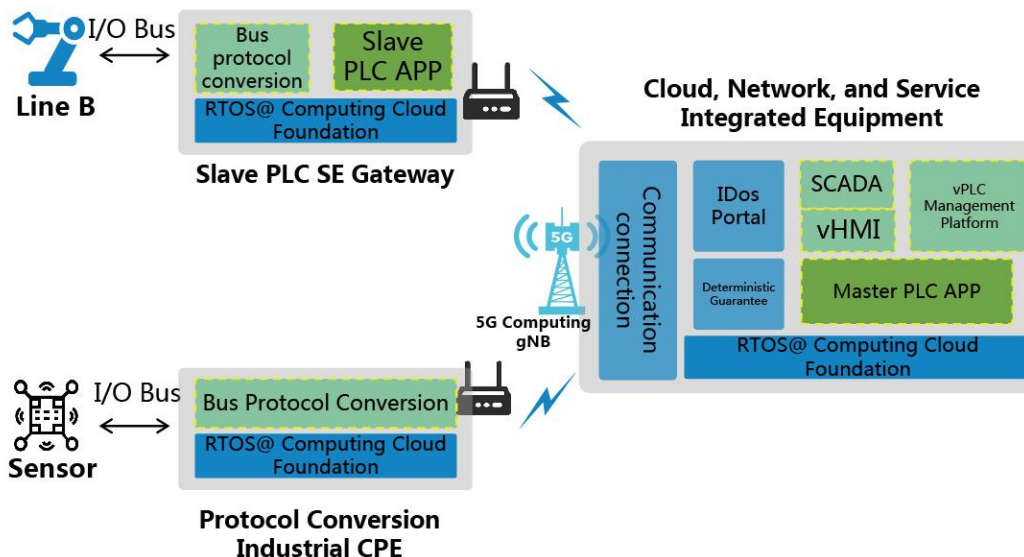
### 4.1.3 Typical Terminal/Edge-side Computing Services

Terminal/Edge-side computing power can support on-demand built-in cloud-based PLC, video optimization, front-end data acquisition, cloud-based AGV scheduling, and other key service applications. It can also be open to third-party applications for easy deployment. The specific details of these typical business capabilities are as follows.

#### 4.1.3.1 Cloud-based PLC

Traditional PLCs have various protocol forms that are not compatible with each other. In the process of industrial digital transformation, the critical production intranet can be optimized through cloud-based PLCs, making networking simpler. The cloud-based PLC based on 5G network is shown in the figure below. For conventional low complexity sensor and I/O control, the protocol conversion industrial CPE can be simplified by using the 5G gateway directly. For complex control PLC applications, the main PLC can be deployed on the edge, and the sub-PLC can be deployed on the 5G edge gateway at the end, thus achieving master-standby PLC control. The deployment of PLC based on edge and terminal cloudization is easy for intercommunication between different manufacturers and easy for customer technological upgrading, process adjustment for flexible manufacturing, etc. The 5G edge gateway supporting PLC at the end also enables direct extension of remote I/O, further reducing the cascading cost of a large number of I/Os.

Figure 4-4 Cloud-based PLC Architecture Based on 5G Network

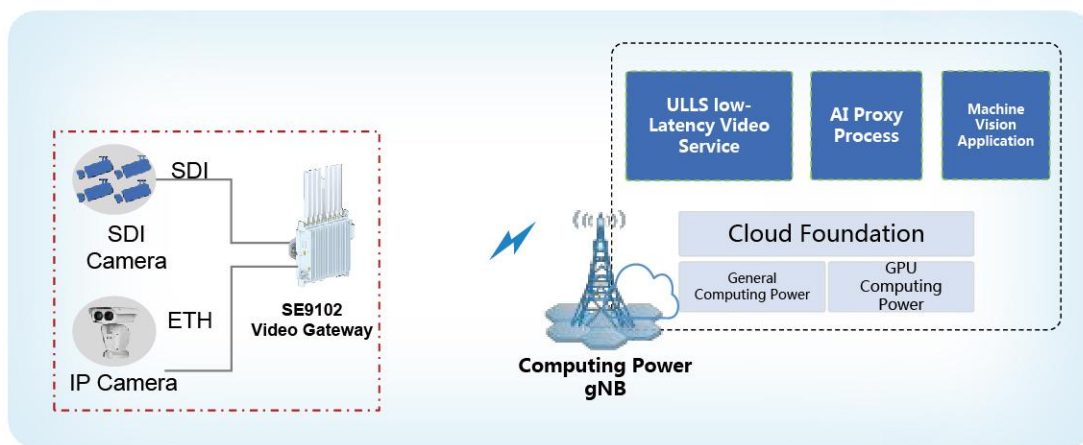




### 4.1.3.2 Video Optimization

There are various video-related services in the industrial critical production, which has high requirement on bandwidth. Given the limited resources of a 5G network, how can we ensure smooth video service for different scenarios? Taking machine vision as an example, machine vision uses intelligent analysis of collected image information to complete some industrial control applications. Generally, it consists of a visual system and a high-performance industrial computer.

Figure 4-5 Collaborative Edge Computing Solution

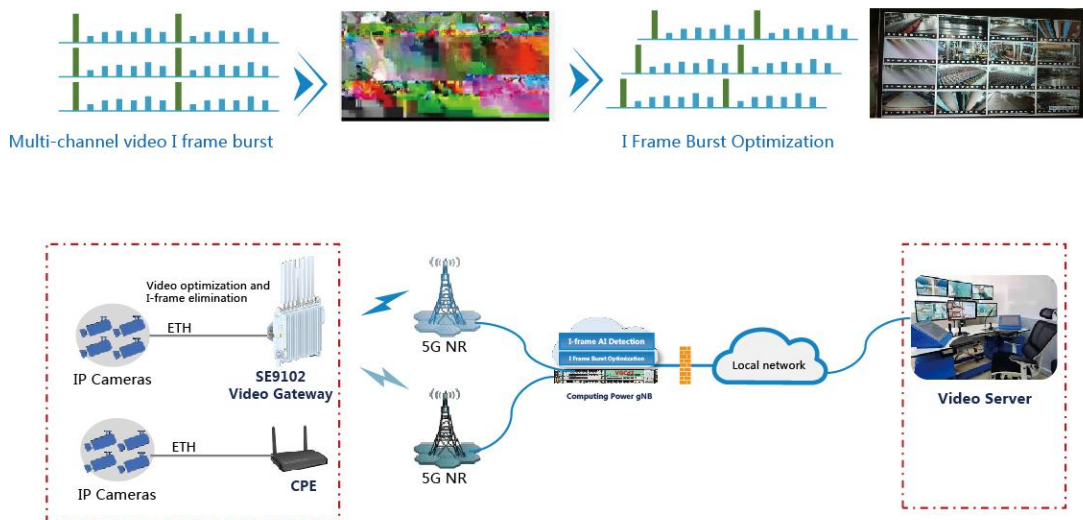


The typical architecture for edge-cloud collaborative machine vision application is shown in the figure above. At the edge, various camera interfaces are connected through a video gateway to complete image acquisition, compression, and protocol conversion, and upload via 5G network. On the cloud side, image support services are deployed on the computing platform, and customer developed or designated third-party applications are deployed on the edge computing platform. Through the configuration of application and distribution services, real-time video stream from devices to applications is established through RTP protocol.

For other scenarios, such as dense camera scenes, when multiple video streams are sent concurrently, multiple I-frames transmitted at the same time (known as I-frame collision) will result in several times more transmission bandwidth demand than the typical video flow rate, which exceeds the network transmission capacity, causing network transmission congestion and sudden increase in delay, resulting in video stuttering. In order to ensure the quality of video transmission and stable transmission of video services without stuttering, there are usually several solutions listed as following.

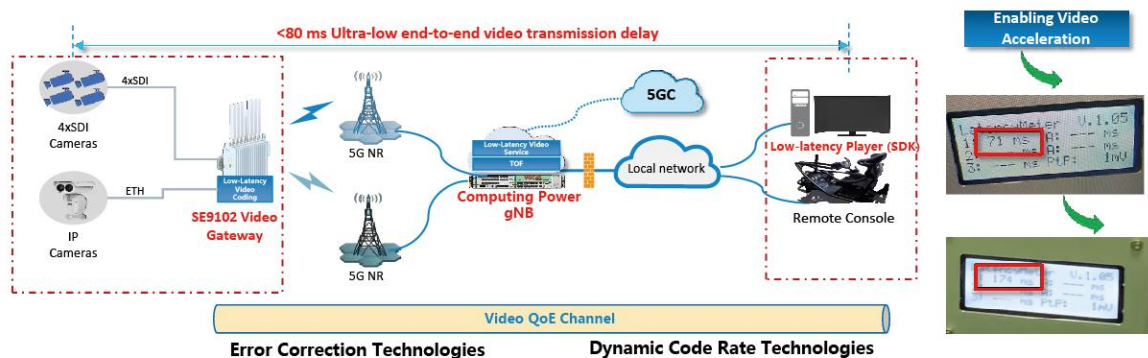
- Detect Video I-frame collision, adjust I-frame packet transmission interval to achieve traffic shaping

Figure 4-6 Video I-frame Collision Optimization



- By performing video encoding, eliminating I frames, and further introducing anti-packet loss low-latency transmission technology, network bandwidth requirements are reduced.

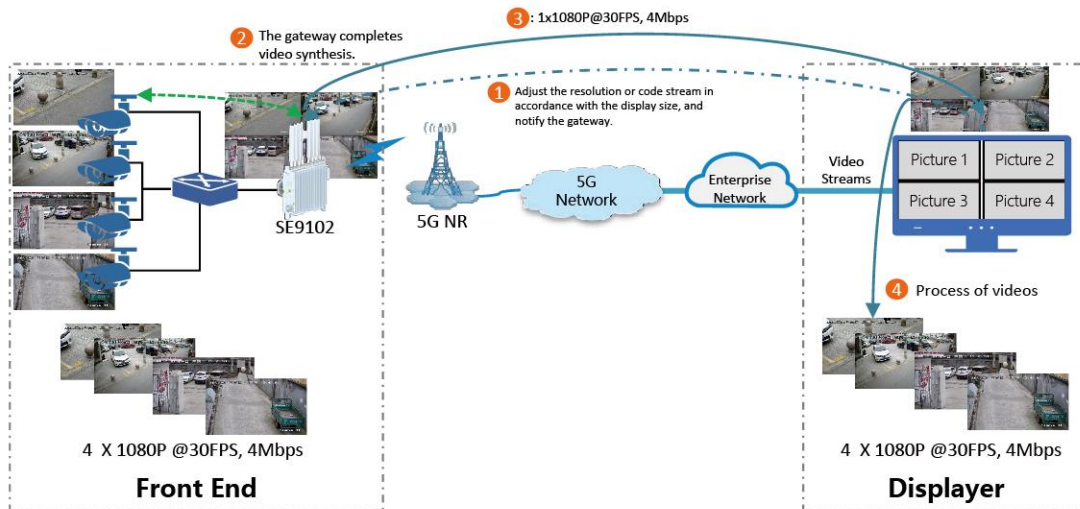
Figure 4-7 Anti-packet Loss Low Latency Transmission





- By splicing and synthesizing videos, multiple camera streams are combined into a single video transmission, reducing overall network bandwidth and achieving smooth video transmission.

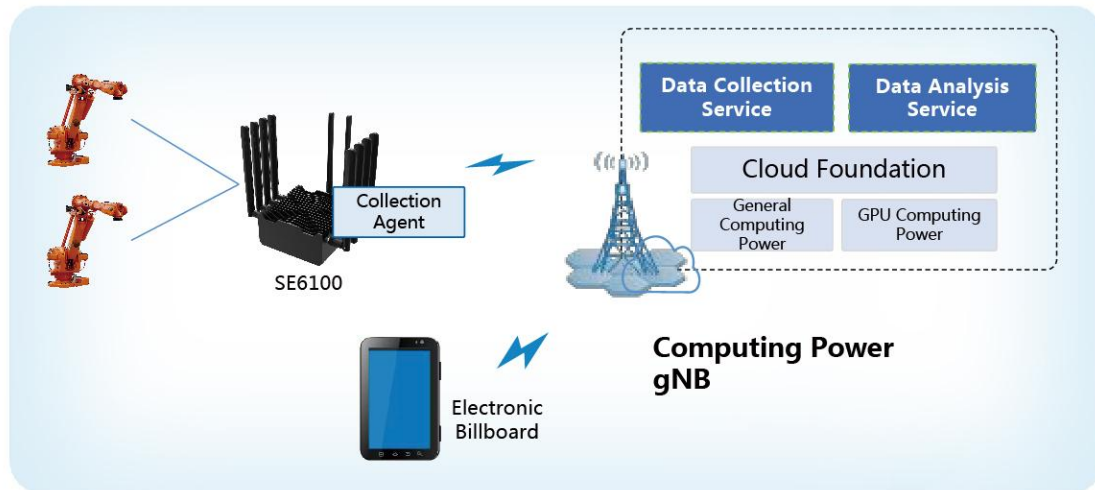
Figure 4-8 Video Splicing Solution



### 4.1.3.3 Pre-processing Data Acquisition

Digital information collection mainly involves collecting operation information of production line equipment through designated interfaces (such as RS232, 485 or Ethernet) and consolidating them into specified software systems for analysis. This is usually accomplished by using a front-end industrial control computer and deploying corresponding data collection and analysis systems. After upgrading, we can achieve the docking of end-side gateways with production line equipment, and deploy data collection and analysis systems through the cooperation of end-side computing power and edge-side computing power, thereby replacing the industrial control computer solution. This solution has obvious advantages in simplifying the environment and reducing costs.

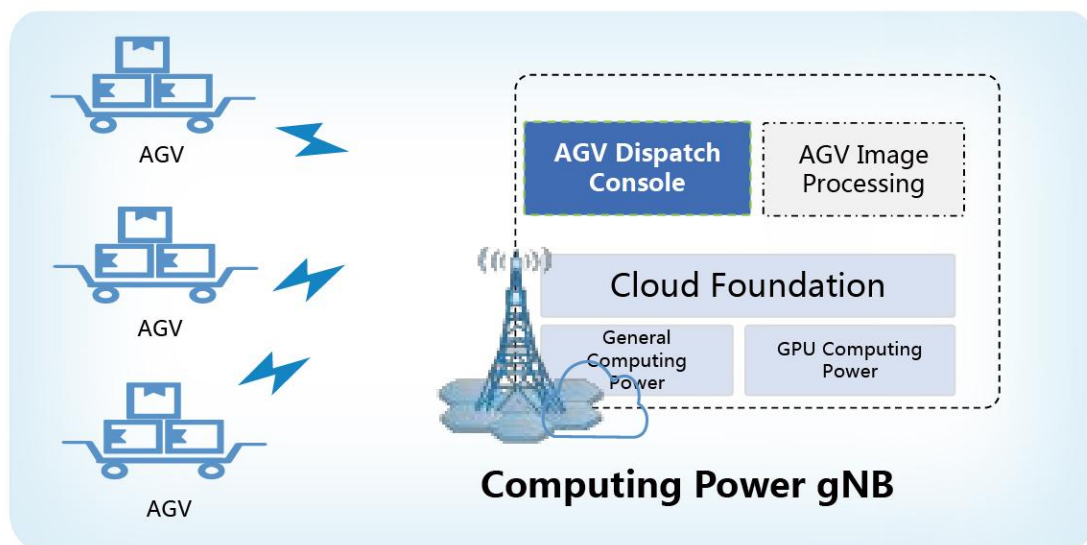
Figure 4-9 Pre-processing Data Acquisition



#### 4.1.3.4 Cloud-based AGV Dispatching Console

Edge computing can also support the cloudification of AGV and meet the real-time scheduling and coordination of AGV. The figure below shows a typical AGV software architecture. Cloudified AGV can be deployed on-demand on the edge computing power of the workshop/production line, improving system integration and achieving unified operation and maintenance, thereby reducing overall costs.

Figure 4-10 AGV Cloud-based Dispatching Console



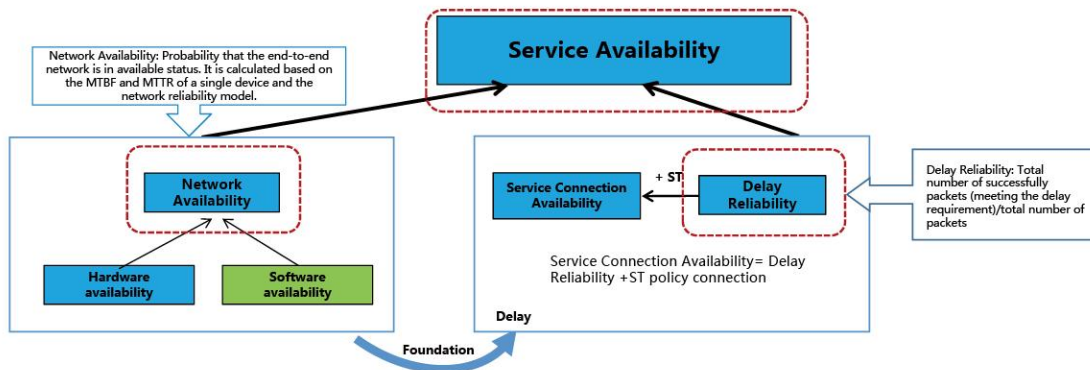


## 4.2 Service Availability, Network Availability, and Security of Private Network in critical production

The industrial critical production places high demands on the network reliability. The stable operation of industrial production networks is a crucial factor for enterprises to maintain stable production. Most unmanned intelligent manufacturing factories require production networks to guarantee at least 7\*24 hours of uninterrupted and stable operation. Once interrupted or if network performance decreases, it will seriously impact the normal production and operation of the enterprise.

In order to ensure the stable and safe operation of industrial production systems, we will describe the service connection availability, network availability, and security aspects in the following chapters.

Figure 4-11 Network, Connection, and Service Availability Relationship



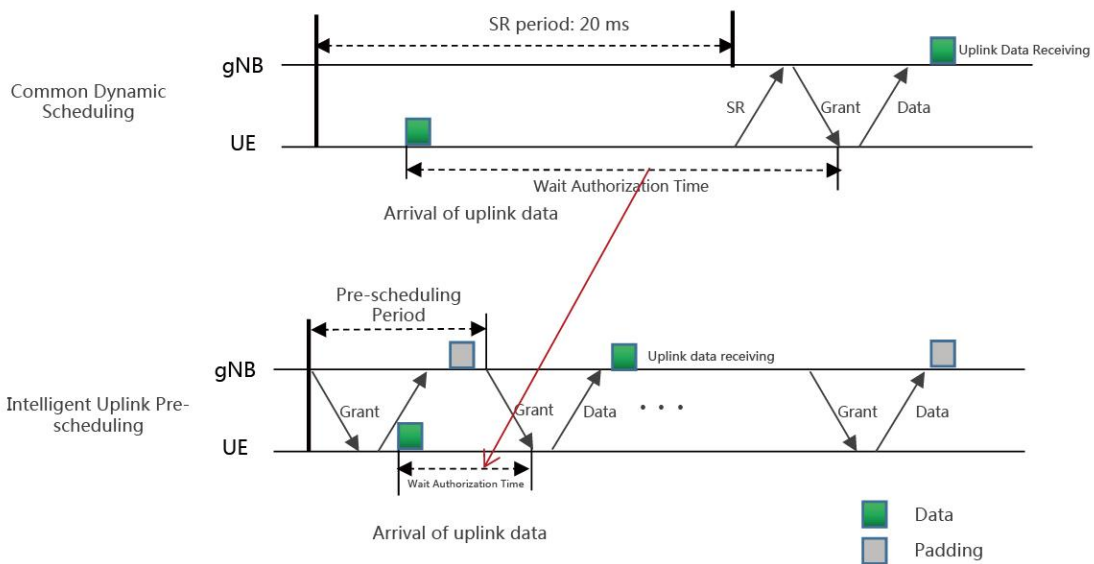
### 4.2.1 Service Availability

With industrial flexible production and digital transformation, vertical industries are increasingly demanding low latency, large bandwidth, high determinism, and other aspects. For example, remote control scenarios in ports and coal mines require a transmission latency of 20 ms to 50 ms and a latency reliability of over 99.99%. Industrial automation control requires a transmission latency of 4ms to 10ms and a latency reliability of over 99.999%. At the same time, applications such as machine vision inspection in industrial production and unmanned mining trucks have high requirements for real-time and concurrent uplink large bandwidth.

### 4.2.1.1 Basic Low-latency and High-reliability Solution

For a 20ms@99.99% SLA level: methods such as local diversion, PDCP out-of-order delivery, and intelligent pre-scheduling are used to reduce transmission latency in the link and air interface; conservative MCS, adjusted target BLER, and HARQ retransmission enhancement techniques are used to ensure the reliability of the air interface.

Figure 4-12 Latency Gain Brought by Intelligent UL Pre-scheduling



For 10ms@99.999% SLA level: DS frame structure, conservative MCS, adjusted target BLER, HARQ retransmission and other technologies can be used to reduce air interface delay; further reduction in air interface transmission delay can be achieved by using dual carrier complementary frame structure CA, or by using URLLC mini-Slot scheduling to save system processing delay and air interface transmission delay.

For 5ms (and below) @99.999% SLA level: utilize the multi-MO URLLC function of the ultra-short frame structure DS to achieve extreme latency assurance, and further enhance air interface reliability through mini-Slot repetition. At the same time, in the above-mentioned different latency reliability technologies, TSN technology can be used in combination to reduce latency jitter and enhance service determinism.



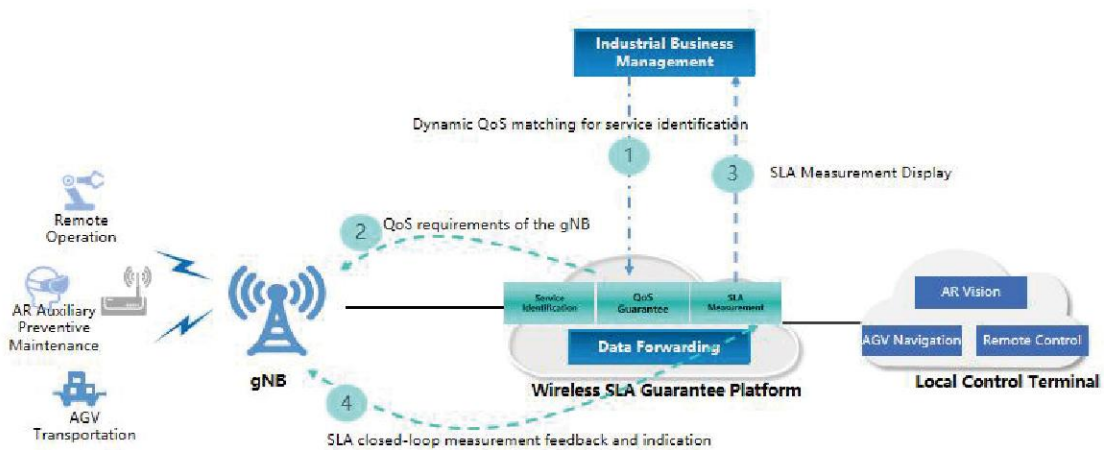
### 4.2.1.2 Wide Bandwidth Technology Guarantee

In addition to the demand for controlling latency in the production field, there are also some needs for wide bandwidth, such as image/video feedback and machine vision service in common scenarios such as ports, open-pit mines, unmanned steel cranes, and manufacturing lines. ZTE use technology such as overlay frequency bands, 1D3U frame structure, carrier aggregation CA, MU-MIMO, and SuperMIMO to improve network bandwidth to meet the bandwidth requirements of services in critical production.

### 4.2.1.3 Service SLA Close-loop Guarantee

Based on the SLA assurance platform, which automatically identifies the characteristics of service data flow, ZTE performs closed-loop and precise network-service collaborative scheduling based on service characteristics, and ensures the reliability of delay and service bandwidth. The SLA assurance architecture is shown in the figure below:

Figure 4-13 SLA Close-loop and Low Delay



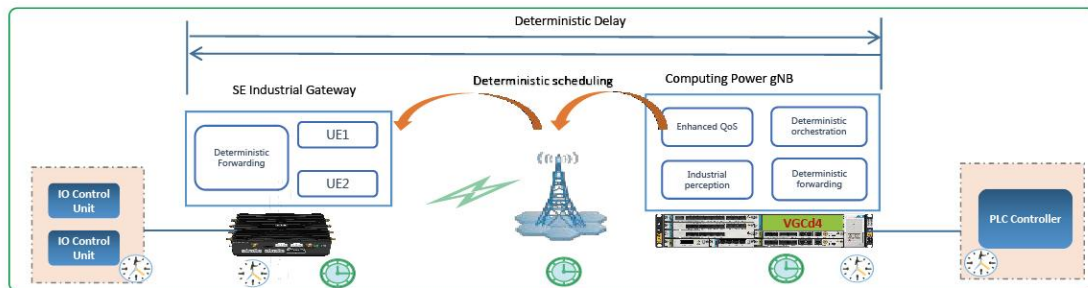
The SLA closed-loop guarantee function introduces AI service feature recognition technology to the data forwarding aspect, deeply understanding and perceiving service features, collaborating with base station scheduling, and providing feedback on SLA measurements. Based on the measurement results, further adjustments can be made. This scheduling mechanism matched with the business ultimately achieves the goal of service assurance, while effectively utilizing spectrum resources, gaining benefits for multiple terminal concurrency and reducing interference.

#### 4.2.1.4 TSN Ultra-low Jitter Guarantee

Combined with the low latency capabilities inherent in 5G networks, ZTE TSN solution utilizes deterministic orchestration technology to create an end-to-end deterministic solution, providing jitter guarantees at the  $\pm 1\text{ms}$  level. The 5G TSN solution includes the followings:

- Hardware: SE industrial gateway and computing power base station that supports TSN.
- Software: Supports 802.1as/1588 clock synchronization; supports deterministic forwarding technology 802.1Qbv; supports frame preemption technology 802.1Qbu; also supports endogenous deterministic scheduling to ensure the determinism of 5G network transmission.

Figure 4-14 TSN Solution



#### 4.2.2 Production Domain Private Network Availability

In the 5G system, network availability is used to describe the proportion of time that the network element composed of the network operates normally. The availability plan of the 5G industrial critical production private network mainly includes the following three aspects.

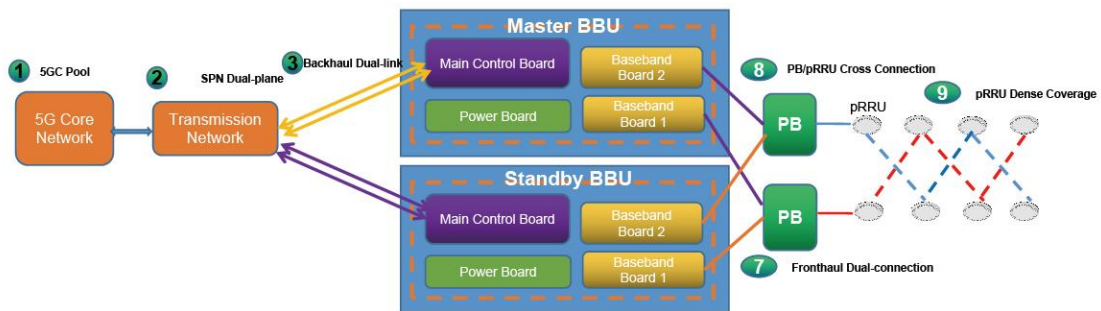
##### 4.2.2.1 Highly Reliable Network Device Backup

For industrial production scenarios, 5G private networks in the critical production can increase network reliability and reduce the impact on industrial production networks



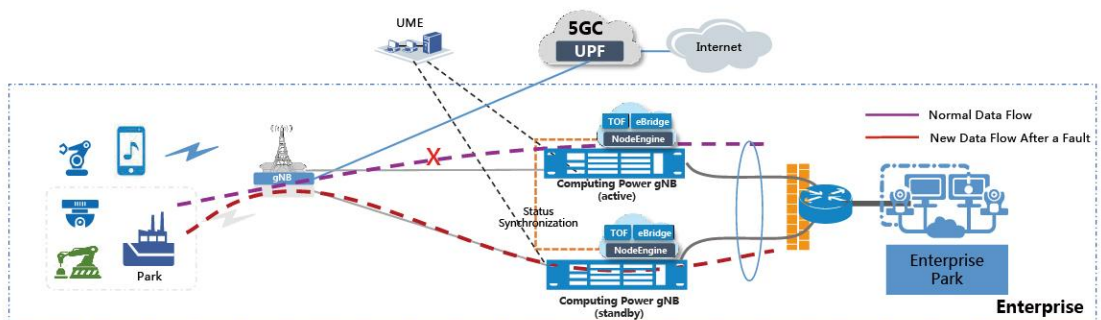
through methods such as dual BBU backup, dual pBridge access, RRU overlapping coverage technology, 5G core network pooling, and dual-plan SPN carrier. When a single device fails, rapid recovery of the network can be achieved through backup network element nodes, thereby improving network reliability and reducing the impact on dedicated networks for industrial production.

Figure 4-15 Multi-level Network Backup Improving Network Reliability



5G critical productio private network enhances service reliability by backup based on user services data offloading anchor points. When using computing power base stations as data offloading anchor points in the industrial production domain, a 1+1 backup solution is employed for computing power.

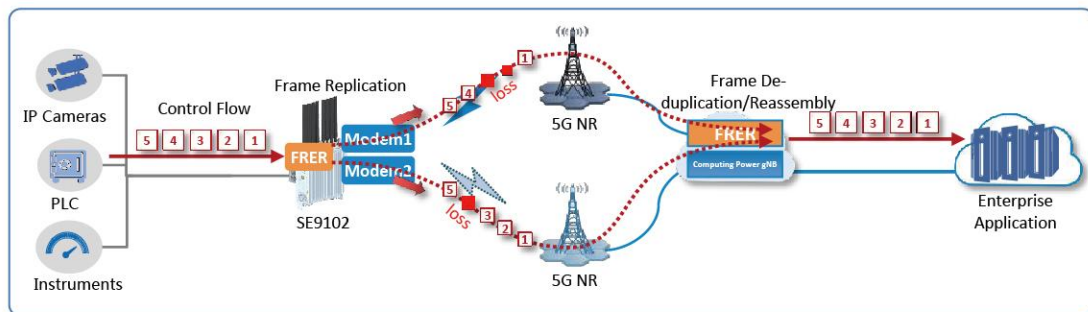
Figure 4-16 Computing Power Base Station Mutual Backup Solution



### 4.2.2.3 Highly Reliable FRER Link

End-to-end link reliability, supporting FRER functions of IEEE802.1CB, can guarantee zero delay switchover and zero packet loss in case of single link failure. This technology can not only be used for 5G dual links, but also for heterogeneous network dual link backup, such as 5G+WIFI, 5G+wired, 5G+4G, and other dual-link FRER functions.

Figure 4-17 FRER High Reliability Solution

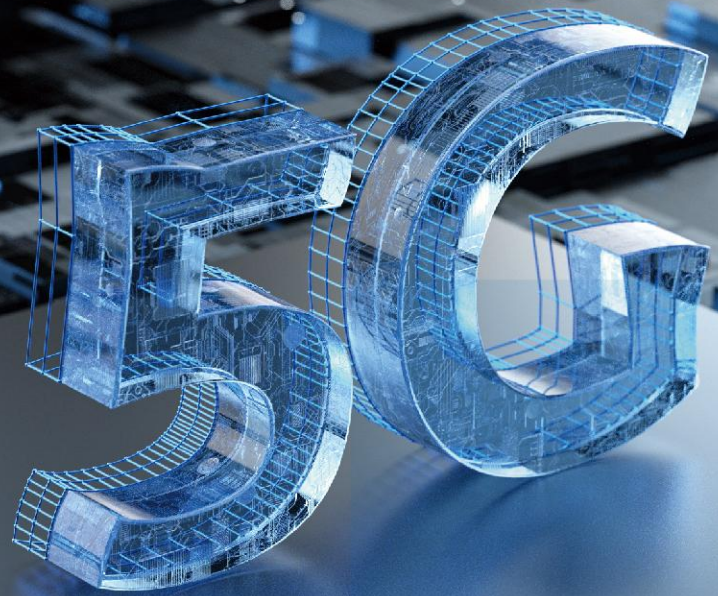


### 4.2.3 B2B/B2C Network Isolation Technology

In individual cases, in addition to B2B service, there are also various B2C services in the critical production private network. For the computing power base station scenario, B2B adopts slice-based traffic splitting to ensure that B2B service data is locally distributed to the industrial park, ensuring data security. As for B2C services, a base station traffic splitting and isolation solution based on RFSP is used, controlled according to RFSP. Public network users who are not employees of the company cannot access the industrial park private network because they do not have a signed RFSP agreement. At the same time, the user authentication mechanism of the 5G network and the isolation mechanism between 5G LANs also ensure the security of the network and data.

In addition, the private network supports the overlay of enterprise independent certification, initiates secondary authentication to DN-AAA, realizes the identification of the identity of the enterprise docking terminal, and avoids non-trusted terminals from accessing the enterprise dedicated network, further ensuring the security of private network access.





## 5G-based Industrial Field Network

### -Private 5G for Critical Production

Figure 4-18 Isolation Solution Based on User DNN/Slicing and Signing

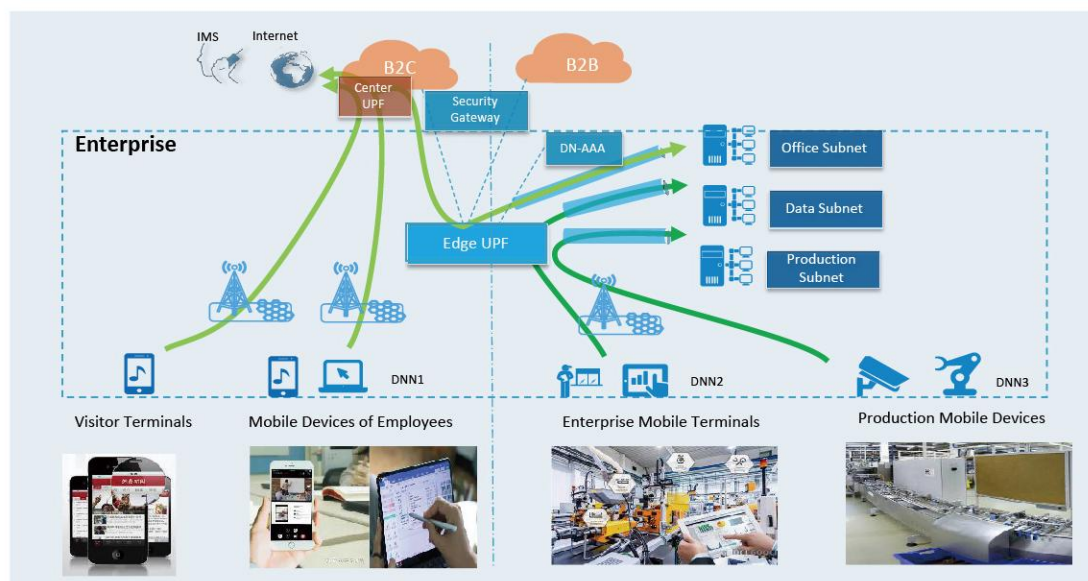
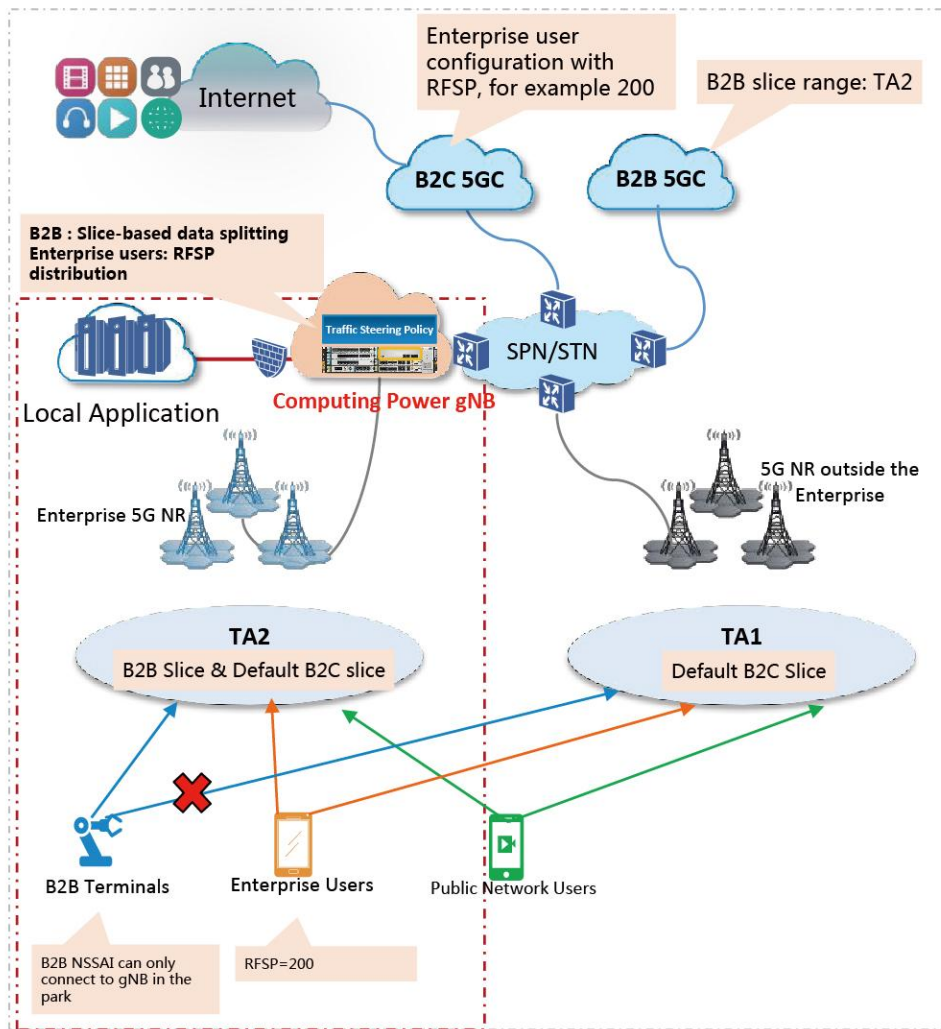




Figure 4-19 Isolation Solution Based on the RFSP Computing Power Base Station



### 4.3 One-Stop Self-Service

In order to reduce the industry entry barriers for 5G private networks, ZTE has innovatively proposed one-stop three self-service solutions, including free-of-planning, free-of-integration and free-of-maintenance, thus achieving a simplified network delivery solution.

#### 4.3.1 Free-of-Planning, Precise Modeling and Network Planning

For network coverage in workshops with limited space, more precise deployment plans are often needed. For the 5G wireless critical production private network, we can introduce 3D

map modeling, which extends from signal strength coverage to service location coverage. Based on the actual differentiated service SLA requirements, scenario-based precise modeling can be carried out to form a network design centered on overall users. In terms of network planning, on-site engineers require no skills. 3D laser scanning is used to model and generate maps, and site simulation planning is implemented based on digital twins, increasing planning efficiency by more than 6 times.

### 4.3.2 Free-of-Integration, Quick Provisioning

Multiple network forms coexist in B2B network construction, with different service levels also coexisting, and facing the following challenges in practice: long activation time, high skill requirements, and inaccurate business acceptance. For 5G devices in the industrial critical production, a solution of pre-installation on the assembly line and on-site configuration can be adopted to shorten the activation time and achieve plug-and-play capability, achieving activation within hours.

After the network is activated, the "5G Industrial Deployment Emulator & Analyzer (IDEA)" can be used to simulate business acceptance in the B2B sector, solving pain points in the acceptance process and supporting visualized perception of service KQI, achieving precise acceptance of SLA. The typical features and acceptance process diagram are shown below.

Figure 4-20 Typical Features of 5G IDEA

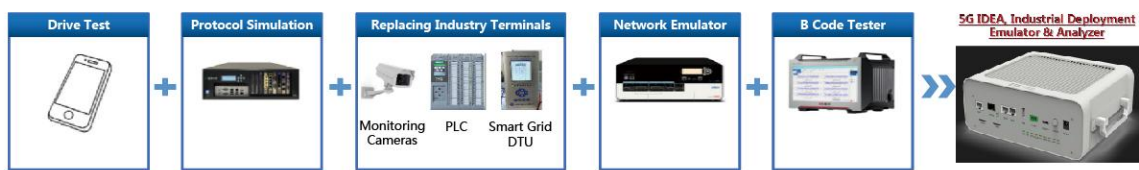


Figure 4-21 How to use 5G IDEA



### 4.3.3 Free-of-maintenance, automated operation and maintenance from service perspective

In the field of industrial private network, facing the simple operation and maintenance demands of enterprises, both the provision of rich specialized communication network operation and maintenance means and the consideration of diversified production and operation needs of enterprises, ZTE provides the IDOS product that supports collaborative network operation and maintenance, which has the following main capabilities.



#### Device Management

Supports management and operation and maintenance of network equipment, providing unified topology, alarms, performance, resource configuration, inspection, and security functions, combined with intelligent fault prediction and root cause analysis, to achieve quick problem demarcation and localization. Support monitoring the status of computational resources, including the distribution and utilization of resource locations and the total quantity.

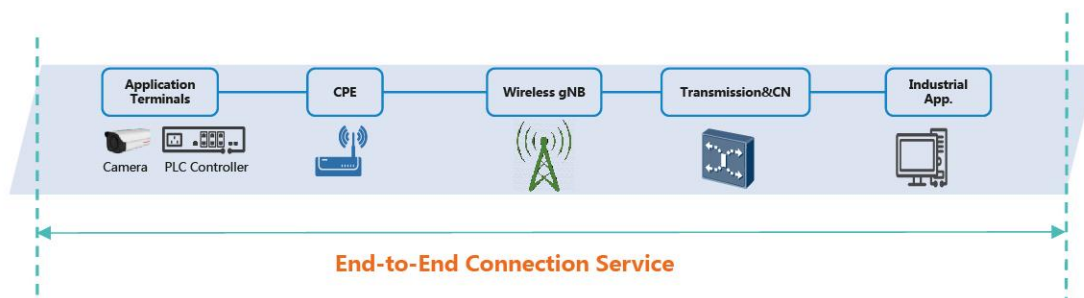
#### Terminal Management

Supports for CPE, industrial gateways, video gateways, AGV equipment, 5G Industrial Deployment Emulator & Analyzer (IDEA), and IoT devices (such as production equipment), including third-party terminal devices, for access and management.

#### Service Operation and Maintenance

Supports management and control of private networks in the industrial critical production from the perspective of business process, complemented by perspectives of network equipment, terminal, and industry-specific APPs. Real-time observation of the status of business process assurance, alarms for network equipment and terminal devices, network performance indicators, and other data to achieve rapid problem localization and resolution.

Figure 4-22 Service Operations and Maintenance Perspective





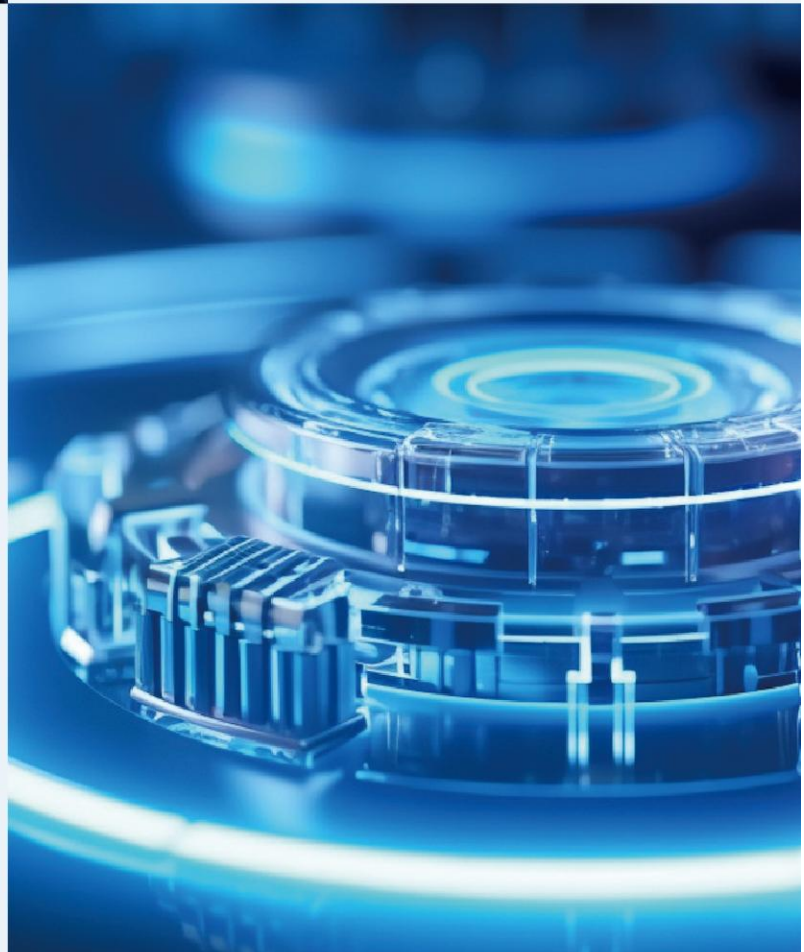


### Capability Openness

The enterprise operation and maintenance platform needs to provide more open management and maintenance capabilities and data to meet customized demands and support the upper-level comprehensive applications of various industries. By opening up capabilities, the common core technical capabilities can be formed into a component library, and through the platform, they can empower industry customers and ecosystem partners, helping to promote innovation incubation and ecosystem construction for upper-level applications. For example, providing a visual API console as an API management portal, as well as functions such as API creation, subscription, consumer management, and control.

### Service Management

ZTE provides support for collaborative network operation and maintenance products that support industry APP management. In the field of industrial production, there are various industry APPs in the private network domain and Operational Technology (OT) domain, and the operation and maintenance system needs to deploy and manage them. The operation and maintenance product can deploy the appropriate computing platform according to the needs of the services and resources, and at the same time, it can monitor the network resource usage and services operation status of the app in real time. It also supports enterprise users to have a certain degree of autonomous management and control ability for terminal number cards, including operations such as number allocation, signing, and account cancellation for terminal number cards. It also provides capabilities such as traffic monitoring, quality monitoring, abnormal interruption identification, and illegal terminal isolation for terminal number cards.



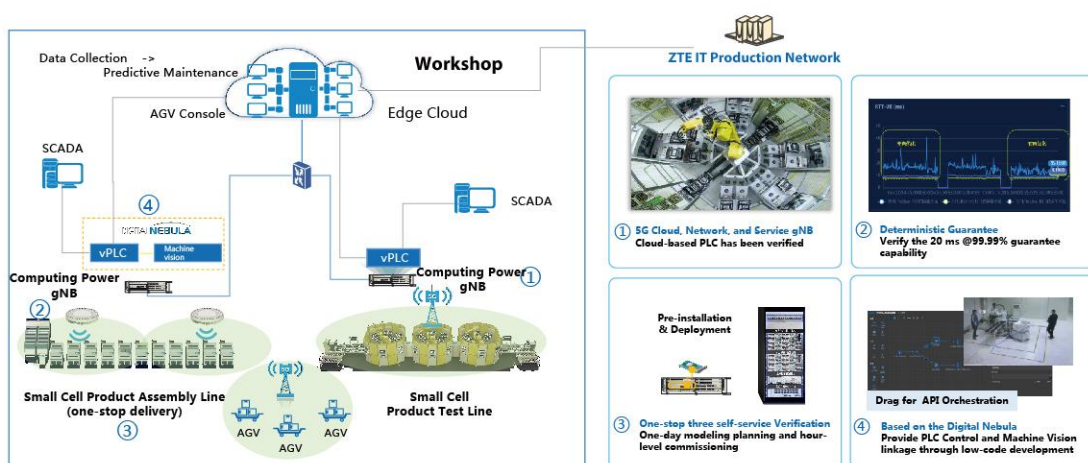
## 5 Case Study

With the deepening of industry practices, ZTE has accumulated experience in constructing specialized networks for several typical industries. We will introduce specific technical solutions through some implemented projects for your reference.

### 5.1 Application of Digital Automated Production Line in ZTE Nanjing Binjiang Factory

The digital modernization of the base station manufacturing workshop at Nanjing Binjiang Factory is a typical case of a specialized network in the electronic manufacturing industry at the workshop level. The workshop uses digital distributed antenna equipment combined with super cell technology to achieve 5G private network coverage, carrying out services such as AGV, data acquisition, machine vision, and cloud PLC, and thus achieving wireless cloud migration of all workshop data. The cloudification and networking of the PLC workstation for testing production lines, specifically the MAT/MDS service of the PLC workstation, has led to a centralized cloud deployment and maintenance of the PLC, promoting the industrial digitalization process and achieving a 50% cost reduction.

Figure 5-1 BinJiang Factory Workshop Network Deployment





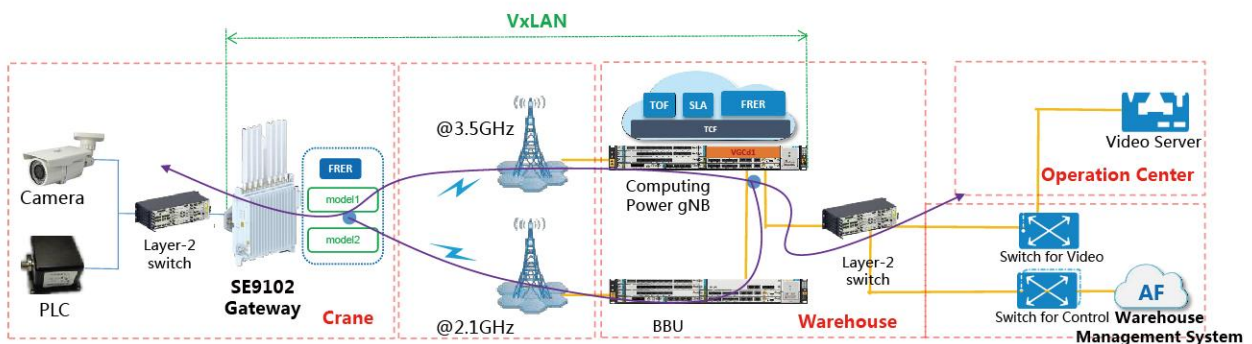
The modernization process adopts 5G network integrated devices, the network uses 20ms@99.99% deterministic latency enhancement technology, achieving real-time and reliable production line control. At the same time, it is deployed based on specialized frequency and dedicated network using free-of-planning/integration/maintenance strategy, bringing the following advantages:

- A single production line can be transformed and quickly put into production within one day.
- The SLA closed-loop control reduces the optimization demands for the critical production private network.
- Production line users use IDOS to maintain the network on their own and adopt the ZTE Industrial Internet platform architecture to achieve the interaction between PLC control and electronic fences.

## 5.2 WISCO Unmanned Crane Modernization

Wuhan Iron and Steel Corporation (WISCO) has been gradually promoting industrial smart manufacturing since 2019. Currently, the Wuhan Steel Park has completed the deployment of 5G unmanned cranes in three areas: the steel coil warehouse, slab warehouse, and main rolling line emergency area. The project modernizes the cranes by adding equipment such as cameras, sensors, and PLCs, and establishes interconnectivity between the control systems and the warehouse management systems through 5G networks, achieving unmanned control of critical production cranes.

Figure 5-2 Unmanned Crane Control Solution





Considering that there are many steel structures in the factory building, the 5G signal reflection is severe, which can easily cause signal interference and frequent inter-cell handover of terminals. To address this issue, the factory building adopts small cell and activates the super cell feature to avoid the handover problem of terminals inside the factory building. At the same time, ZTE adopts a 5G dual-frequency network of 3.5GHz+2.1GHz to create a dual-link channel, fully utilizes the features of ZTE's 5G edge gateway single-terminal dual-mode module, and constructs an FRER 2T2R to ensure that the network's average latency remains stable at the level of 10ms.

In addition, the project utilizes the local offloading technology and computational extension capability of the computing power base station to connect with the WMS management system of unmanned cranes and adds IDOS enterprise business operation and maintenance service, achieving efficient application of direct scheduling for enterprise business and optimization of implementation monitoring and operation maintenance.

## 6 Summary and Outlook

As the core driving force, industry promotes the development of real economy. Currently, the innovation and development of "5G+Industrial Internet" has entered the fast lane. ICT industry, sectors, and ecosystem partners are continuously innovating and exploring how to utilize digitization, networking, and intelligence to achieve a leap development in efficiency and effectiveness, enhance total factor productivity, and have achieved remarkable results. Next, the focus of applying 5G fully connected factories in the industrial field will accelerate from the peripheral links of the critical production to the dedicated network links of the critical production. This white paper is a practical summary of the 5G entering the dedicated network solution in the critical production, it is applicable to various vertical industries including logistics, manufacturing, ports, and steel.

In the future, with the deepening of "5G+Industrial Internet," the private network solution will continue to be promoted hand in hand with the entire industry, ultimately helping various industries build more abundant fully connected applications.

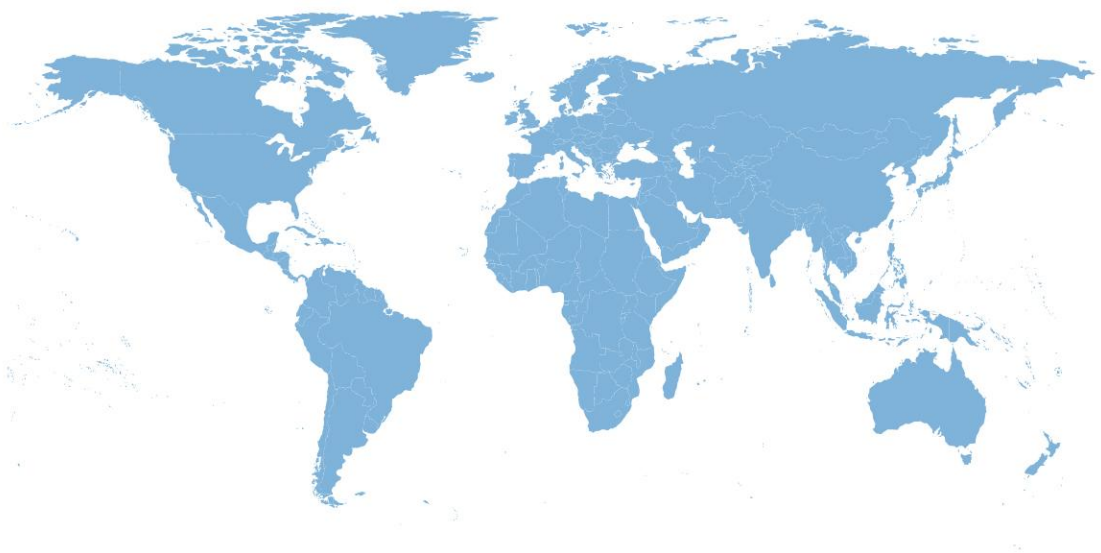
## 7 Appendix: Acronym

Acronym	Full Name
3C	Computer, Communication, Consumer
5G	5th Generation
5GC	5G Core Network
5QI	5G QoS Identifier
BLER	Block Error Rate
HARQ	Hybrid Automatic Repeat Request
HMI	Human and Machine Interface
MCS	Modulation and Coding Scheme
MES	Manufacturing Execution System
miniUPF	mini User Plane Function
MIMO	Multiple Input, Multiple Output
MU-MIMO	Multi-user, Multiple Input, Multiple Output
MO	Monitoring Opportunity
MDS	Manufacturing Data System
MAT	Manufacturing Automation Test
OPC UA	OLE for Process Control Unified Architecture
PDCP	Packet Data Convergence Protocol
IDOS	Intelligence Digital Operational Service
SMT	Surface Mounting Technology
AGV	Automated Guided Vehicle
RTP	Real-time Transport Protocol
FRER	Frame Replication and Elimination for Reliability
API	Application Programming Interface
PLC	Programmable Logic Controller
QoS	Quality of Service
RB	Resource Block
RFSP	RAT/Frequency Selection Priority
ROS	Remote Operation System
SDMA	Space-Division Multiple Access
SLA	Service Level Agreement
SCADA	Supervisory Control And Data Acquisition
TTI	Transmission Time Interval
TSN	Time Sensitive Network
WMS	Warehouse Management System
URLLC	Ultra Reliable Low Latency Communication



## 8 Reference

1. IEC 61508 (all parts), Functional safety of electrical/electronic/programmable electronic safety-related systems
2. IEC 61784-3, Industrial communication networks - Profiles - Part 3: Functional safety fieldbuses - General rules and profile definitions





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