ZTE

Precise RAN Solution

White Paper

Contents

5G has great potential in vertical industry applications

At present, a new round of technological revolution and industrial transformation are emerging around the world. The new generation of digital technologies represented by 5G, big data, cloud computing, and AI are changing rapidly. The digital and intelligent transformation of traditional industries is inevitable. At the beginning of 2020, Chinese government explicitly proposed to accelerate the construction of 5G, industrial Internet, and other new infrastructure. As the core engine of new infrastructure construction, 5G has huge potential in supporting digital, network, and intelligent transformation of social-economic.

Leading operators around the world have begun to explore this field. China Mobile puts forward the concept of "5G+AICDE" with integration and innovation, promotes "5G+Ecology" ecological co-construction, and focuses on smart factories and other 15 industry categories. Relying on 5G+ cloud network integration infrastructure, China Telecom has made pioneering exploration in smart grid, machine vision and equipment manufacturing fields by building a digital capability platform with openness and cooperation as its core idea. China Unicom released the "5G+ Industrial Internet" action plan, which proposed comprehensive measures to service digital transformation and upgrade of traditional enterprises, including digital empowerment, innovation driving and ecological cooperation.

The vertical industries vary widely, and have diverse requirements for the communication network. There exists great differences in terms of latency, reliability, data rate and self-service capability compared with traditional ToC requirements. To cope with the challenges brought by vertical industry, ZTE has proposed Precise RAN Solution. Through precise planning, precise slicing, precise identification, precise scheduling, precise measurement and precise O&M, ZTE provides precise service guarantee for 5G applications in vertical industries, and provides visual presentation of service quality monitoring results and independent O&M capabilities to end users, laying a solid foundation for 5G application in vertical industries.

Vertical industries bring new challenges to 5G networks

At present, digital industries have swept the world, and various industries such as energy, industrial manufacturing, ports, and transportation are actively exploring digital transformation. From data transmission aspect, 5G technology, with its unique capability of high mobility, large bandwidth, low latency/high reliability, and wide coverage, is expected to become important infrastructure to support industry applications.

Industrial manufacturing

The industrial field has a huge output value. During the transformation of intelligent manufacturing, traditional wired networks cannot meet the requirements of collaborative manufacturing and flexible production, while the advantages of radio networks have begun to emerge. Applications such as machine vision, automatic transport vehicles, and collaborative robotic arms are closely combined with 5G networks to greatly improve production efficiency and reduce product costs. They are very valuable applications in the industrial manufacturing field.

Ports

The functions of modern ports are changing and upgrading constantly. Automation, network connection, and intelligence are the evolution trends. During the upgrade to Smart Port, many application scenarios have been emerged, such as unmanned trucks, remote control of shore bridges, and intelligent tally. 5G networks play an important role in all these processes.

Electric power

During the development of Smart Grid, the electric power communication network, as an important infrastructure of the Smart Grid, ensures the security, real-time, accuracy, and reliability of electric power services. Smart Grid is rich in service, including large-bandwidth video services such as drone and smart routing inspection, low-latency control services such as differential protection, and wide connections services such as advanced metering and new energy. The traditional power communication network does not cover all these areas, and its construction and maintenance costs is high. By relying on 5G public network, the electric power service can achieve fast deployment. In addition, a mature industry chain can greatly reduce the cost of using the 5G network in power grid.

Mining industry

The mining industry is undergoing transformation and upgrade towards informatization, smart mines and unmanned mines are its objectives. Due to the harsh environment, an efficient and reliable radio network is required to enable the interconnection between personnel and devices, improve operation efficiency, and ensure safe production.

Industry applications have different network requirements, and the challenges to 5G networks are as follows:

- Latency and reliability： Some high-end services in the industry require network E2E latency <12 ms, reliability >99.999%. For example, differential protection of smart grids and real-time industrial control. Traditional networks cannot meet this requirement.
- Data rate： The data transmission of industrial applications is typically uplink centric, such as machine vision in the industrial field, remote shore bridge applications of ports. Due to the transmission of image streams and video streams, the uplink rate of a single user is required to be 100 Mbps or higher. In addition, the network is required to provide a stable data rate, otherwise service interruption or production interruption may occur.

Precise RAN solution

Facing the challenges posed by industrial applications, operator's public network that provides basic communication services for public users is obviously not applicable. Communication operators are expected to provide private 5G networks that can be rapidly deployed, meet extreme service requirements, and have cost competitiveness. Precise RAN Solution is exactly the 5G private network technical solution provided by ZTE for industrial application scenarios.

Private network architecture selection

The development trends of 5G, such as NE (network element) virtualization, open architecture, and orchestration intelligence, provide a powerful technical guarantee for the flexible and customized service capabilities of 5G industry private networks. The 5G private network needs to be customized for different application scenarios to achieve differentiated capabilities in terms of latency, security isolation, reliability, bandwidth, uplink/downlink ratio, peak data rate, and meet service requirements of industrial users in production, office, and management applications.

To select a private network architecture, the isolation, deployment costs, deployment time, O&M modes, and other factors should be fully considered. When private network uses independent hardware and independent carrier resources, it is called physical private network. When private network shares hardware or carrier resources (including sharing both base station and carriers, or sharing base station only with carrier dedicated) with public network, it is called virtual private network. The virtual private network can be further divided into two types by service scope: wide-area virtual private network and regional virtual private network.

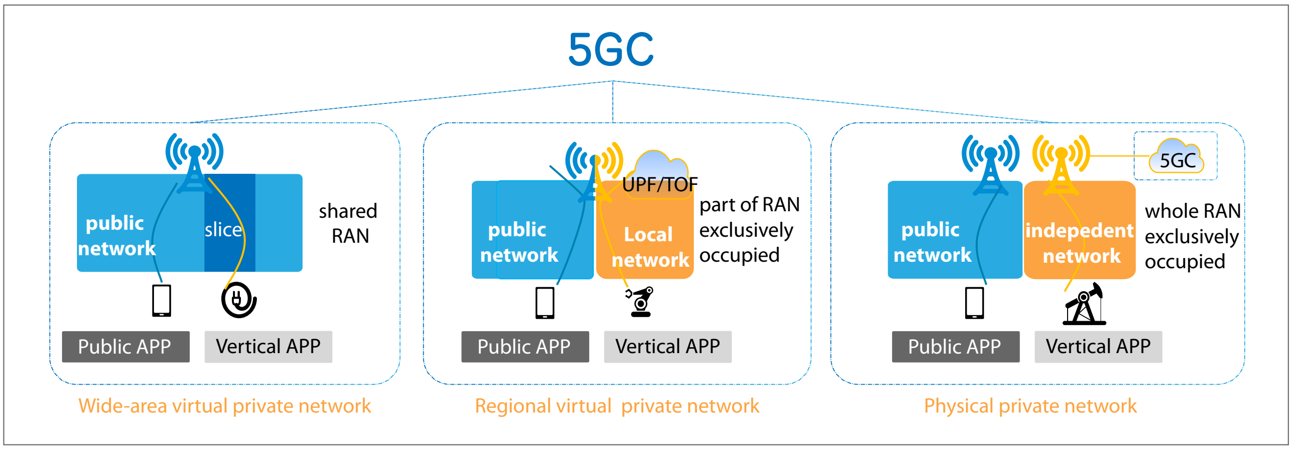

Figure 3-1 Three modes of 5G industrial private network

5G wide-area virtual private network

A 5G wide-area virtual private network is a virtual private network based on operator's public network, utilizing network slicing technology to provide customers with guaranteed latency, bandwidth, and isolation from ordinary user data in the public network. From radio access network, transport network to core network, wide-area private network and public network share an end-to-end 5G network infrastructure. By flexibly configuring network slicing, it can provide bandwidth guarantee, latency guarantee, and other network capabilities and services for private network users as required.

5G wide-area virtual private network is applicable to wide area private network services, including smart grids, smart cities, smart scenic spots, new media, and internet of vehicles, etc.

5G regional virtual private network

A 5G regional virtual private network is a network built for industry users to enhance bandwidth, achieve low latency, and keep operational data from leaving the campus through flexible customization of wireless functions and control NEs based on local data offloading technology. 5G regional virtual private network is deployed through distributed UPF or NodeEngine solution, providing part of dedicated physical 5G networks exclusively for industry users. 5G regional virtual private network meets the requirements of industrial users for large bandwidth, low latency, and no data out of the campus.

5G regional virtual private network is applicable to local parks, including industrial manufacturing, transportation and logistics, port terminals, high-end scenic spots, and urban security and protection, etc.

5G physical private network

By using 5G networking, slicing, and edge computing technologies, the 5G physical private network uses dedicated radio and mini core network equipment to build an physically closed network with enhanced bandwidth and low latency for industry users. User data is completely isolated from operator's public networks, and is not affected by public networks.

Under this mode, the service data and terminal/user behavior information of the industry users are completely confidential. The physical private network is completely isolated from the public network of the operators. From the radio access network, transport network, to the core network including both user plane and control plane, the end-to-end network is built independently by industry users, providing physically exclusive private 5G network to meet the large bandwidth, low latency, high security and high reliability data transmission requirements of industry users.

The 5G physical private network is applicable to closed local areas, including mines, oil fields, nuclear power, and high-precision manufacturing.

Precise service guarantee

Although there are many types of industrial applications with huge differences. For a single terminal or application, the deployment scenario, service flow characteristics, and service flow transmission requirements are very clear and stable. Therefore, to guarantee the services of industrial applications, radio network functions must be properly used, and wireless resources must be properly allocated based on clear scenarios, service attributes, and service transmission requirements. In this way, not only service experience can be guaranteed, but also radio resource can be utilized with high efficiency, making the 5G private network competitive for commercial use.

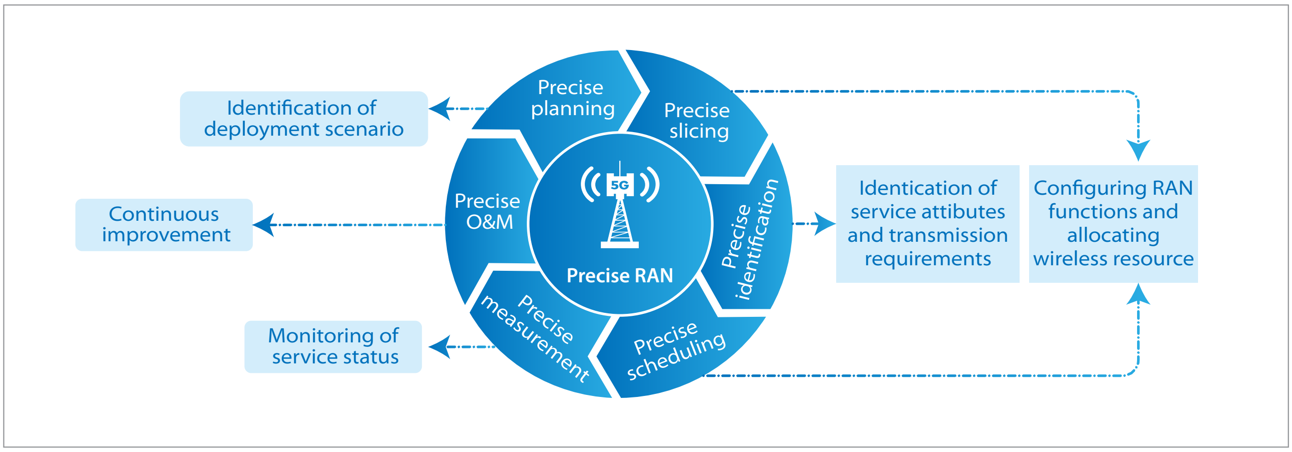

Figure 3-2 Six capabilities required for precise service guarantee

Precise network planning

Network capability design

Due to the wide range of industry application scenarios and various types of services, the ultra-high standards for network performance indicators are proposed, and network capability design and matching are required.

- **Ultra-low latency**

  Ordinary consumer applications are not sensitive to service latency, while industrial applications, including industrial control and remote control services, require a network latency of less than 20ms. For services with high requirements to latency, local offloading can be deployed on demand near industrial applications to implement local processing of industrial applications, reduce backhaul latency, and improve real-time response. In addition, the eMBB service cannot meet the extreme latency requirements of less than 10ms, and the 5G URLLC feature (such as mini-slots, low data rate MCS table, slot repetition) needs to be introduced to continue to improve the low latency capability of the network.

- **Ultra-high reliability**

  Industrial applications such as industrial production and remote control services, etc., put forward higher requirements for service reliability (99.99% - 99.9999%). To achieve the given service reliability, both system availability and link reliability needs enhancement to meet the requirements:

  System availability: Restricted by the availability of each node. If the hardware availability of a node does not meet the requirement, the availability of the equipment can be improved through hardware backup, such as active/standby CPE and active/standby BBU.

  Link reliability:Restricted by the reliability of each bearer, the corresponding technologies should be used to guarantee the reliability of each bearer, for example, dual-layer network for air interfaces and multiple redundant transmission for ground bearers.

- **Uplink large bandwidth**

  A large number of industrial applications, such as high-definition video monitoring and machine vision services, need to send real-time video streams or collected information back to the server. Therefore, high uplink capacity is required. To meet the large uplink bandwidth requirements of the industry, the frame structure that guarantees the uplink capacity such as 1D3U frame structure and carrier aggregation technology can be used preferentially to enhance the uplink capacity.

  Ultimate reliability and latency correspond to enhanced physical layer design of radio networks at the cost of decreasing the efficiency of the entire spectrum. Reliability, large bandwidth, and low latency can be interchangeable resources, meaning that the network capability is elastic in three dimensions: Latency, reliability, and bandwidth. In actual networks, precise network planning, precise resource allocation, and service orchestration are required. In this way, capacity optimization and efficiency improvement can be achieved.

Network planning

Unlike traditional eMBB network planning, the precise network planning for industrial applications is obviously different:

- **Performance from area to spots**

  Traditional eMBB network planning focuses on the overall network performance, while industry-specific network planning focuses on the performance of a single terminal at a specified location spot.

- **Requirement model from one dimension to three dimensions**

  The traditional eMBB network planning is based on the assumed service bandwidth as the traffic model, while the industry-specific network planning is based on the definite three-dimensional service bandwidth, delay and reliability requirements.

- **Scenario from assumed to specific:**

  Wireless coverage in traditional networks is classified by statistics of building height and density, while the wireless environment of the industry application is clear and definite.

As mentioned above, the 5G private network includes three modes: wide area virtual private network. regional virtual private network, and physical private network . For different network modes, the planning of the private network has different focuses. The differences and similarities between ToB network planning and public network planning are evaluated as follows:

planning factors analysis	ToC network	Wide area private network	Local private network	Physical private network
characteristics	public network for ordinary users	ToB service based on public network	Mxture of ToB/ToC, UPF/ NodeEngine goes to campus	physical isolation, customized private network
Frequency	ToC frequency	share freqeuncy with ToC	dedicated ToB freqeuncy or share freqeuncy with ToC	
wireless environment	dense urban, urban, suburb, rural, and special scenario	same with ToB	industrial campus, mines, tunnels, ports, ocean, high altitude	
service type	video, gaming, file transfer, web browsing, instant messaging, etc.	unmanned inspection, power differential protection, machine vision, video surveillance, driverless vechile, etc.		
QoS requirements	network level KPI, best effort for end user service	explicit QoS requirements, user level guarantee		
Criteria for coverage	uniform coverage criteria, requires continuous coverage	differentiated coverage based on QoS requirements, coverage for service area only		
Criteria for capacity	full area capacity requirements	capacity requirements from each terminal		
Sites number planning	Choose the maximum one from the results of capacity planning and coverage planning	calculates site number after merging the capacity and coverage requirements		
Planning tools	Simulation tools Atoll/Planet/CXP/Aircom, Big data platform			

Table 3-1 Differences between ToB network planning and public network planning

The work flow of precise network planning is as follows:

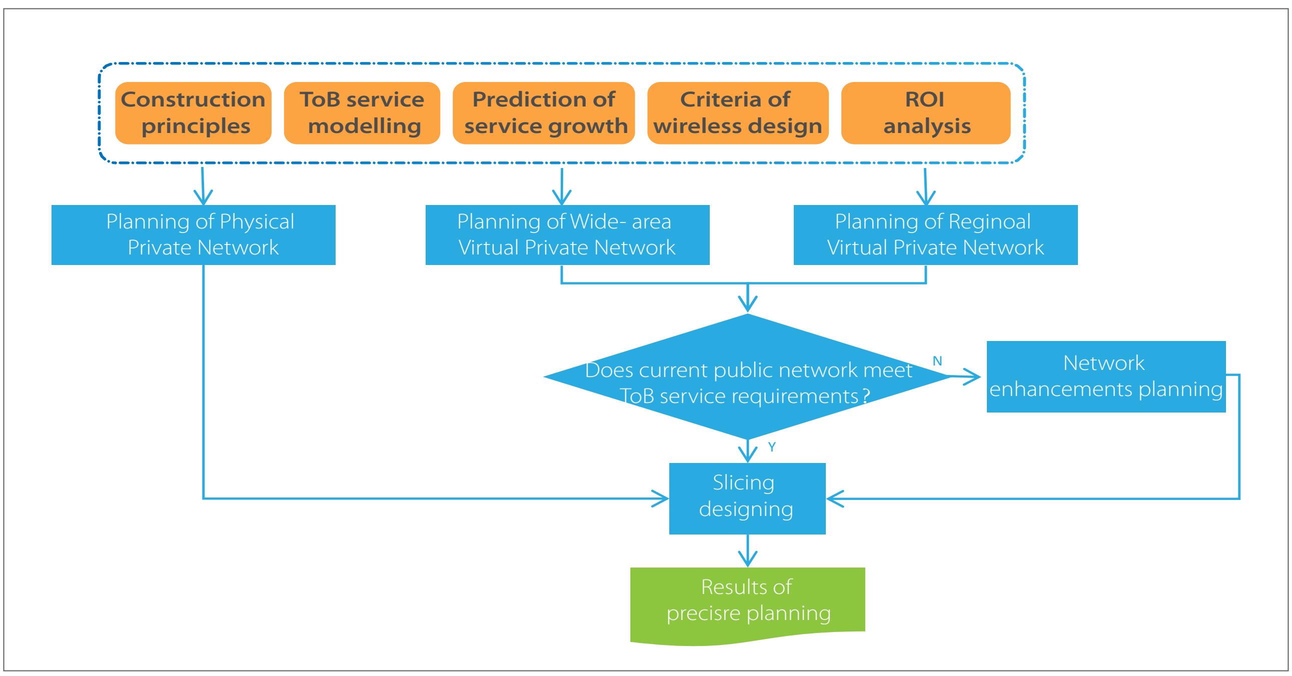

Figure 3-3 Flow chart of precise planning for vertical industry

The comprehensive analysis of accurate network planning includes network construction principles, accurate service modeling, service development prediction, wireless design criteria, and ROI analysis.

Network construction principle: Industry customers determine whether to build 5G physical private networks or virtual private networks.

Precise service modeling: The AI learning and algorithm based on big data can implement precise modeling of the ToB service, and provide clear service bandwidth, delay and reliability requirements.

The following is the examples of service modeling:

	category	application	latency	bandwidth	reliability
Typical ToB service in industrial private network	smart manufacture	remote control	⩽ 20ms	UL ⩾ 50Mbps DL ⩾ 20Mbps	99.99%
		real time control	<10ms	>3Mbps	99.99%
		machine vision	<100ms	UL 100M~1Gbps	–
	smart grid	differential protection	⩽ 12ms	2–10Mbps	99.999%
	smart transportation	remote drive	2ms~20ms	–	99.999%
	AR/VR	remote expert support	< 200 ms	UL 25Mbps DL 25Mbps	–

Table 3-2 Typical cases of precise service modeling

Service development forecast: When planning the air interface capacity, more air interface resources need to be reserved for future network service development. The ToB service comes from the industry customers' planning of the types and quantities of services to be launched in the future. If the network carries ToC services at the same time, intelligent prediction can be made based on historical data.

Wireless design criteria: After the industrial coverage environment feature analysis, service modeling, and prediction are completed, the wireless network design criteria is clarified, that is, the coverage level, cell capacity, frequency strategy, and enhanced technology selection are clarified.

ROI analysis: To realize the investment value of the ToB network, based on the planning platform of the big data +AI, cost modeling accounting is carried out for the network construction investment of different SLA levels. The operation mode, benefit improvement, sharing mode and quantitative analysis are taken into account for the network benefit. The return on the network investment is clear, and the resources of the existing network are utilized to achieve efficient ROI.

Network implementation planning are classified into physical private network planning and virtual private network planning.

The physical private network only carries industry services. The planning includes network topology design, site selection, and site location selection based on industrial service distribution map (including QoS factors such as bandwidth, latency and reliability).

The virtual private networks are classified into wide-area private network and regional private network, and the planning is based on the existing ToC network. According to the ToB service distribution map (including QoS factors such as bandwidth, latency and reliability), the evaluation result of network resources occupied by ToC, analyze geographically with grid granularity whether the existing public network can meet the ToB service requirements. If not, it is necessary to carry out local network enhancement planning, product selection, topology design, site location planning and spectrum strategy, and implement precise calculation of slice resources.

Precise slicing

Network slicing is to divide network into multiple virtual logical networks . Then different levels of service data can be transmitted on network slices at different logical layers to meet differentiated requirements for data transmission rates, security, and reliability in different service scenarios.

With the environment where a physical network bears multiple logical slices, the key to achieve large-scale commercial use is how to precisely allocate, manage, and schedule system resources to better meet different slice requirements.

Slice resource management

Resource management of radio network slices involves the accurate calculation of the resources required by slices and the allocation and management of the corresponding radio resources.

- **Precise calculation of slice resources**

  Accurate calculation of slice resources based on the above network planning can accurately configure the radio resources required by each network slice.

- **Precise allocation and management of radio resources:**

  Radio resources are divided in accordance with the number of users, DRB, and PRB. The system allocates corresponding radio resources in accordance with the service resource requirements of each slice, thus guaranteeing the service requirements of the slice first and further improving the security of the slice network. In addition to the normal single-slice configuration, the system can also set multiple slices as one slice user group and reserve some radio resources for them. The resources reserve modes for radio slicing includes:

> **Private resources :** Only for the users in the slice user group.
> **Priority resource :** Preferential for the users in the slice user group. If there are remaining resources, the remaining resources are also available for the users not in the slice group.
> **Shared resources :** Fair to all the users based on QoS.
>
> In addition to static configuration, the above three types of slice resources can also use the calendar slice resource reservation mode to improve the overall resource usage in case of obvious periodical service characteristics.

To meet differentiated guarantee requirements of different slice groups, the system performs detailed management through admission control and resource scheduling of slice groups.

Slice service orchestration

The 5G slicing network carries a large number of different types of services, and the performance requirement of various services are different. The slicing network needs the help of intelligent slicing service orchestration to implement service-feature-based slice-level system parameter configuration and personalized service scheduling. In addition to defining the resource usage of each slice, the operator can also flexibly define the service types and the number of services that can be used by each slice. We can define service types through QoS templates. Each QoS template includes service descriptions and radio function descriptions:

- **Service description:**

  Service flow QoS attributes and required parameters

  Identifies service flow information, such as specific 5QI or IP 5-tuple and application type, such as video service, AR/VR service and control service.

- **Radio function description:**

  Set of radio resource scheduling functions that guarantee QoS and the corresponding parameter configurations..

Precise Identification

In industrial application scenarios, there are many involved different service types. In order to provide accurate service guarantee, operators need to match applicable radio resource scheduling functions and set appropriate parameters, and the first is to know service attributes and the requirements of each service for data transmission.

In the QoS framework of 5G (QoS flow-based), the QoS attributes and parameters indicating service attributes and transmission requirements are statically configured in the core network to ensure that users can obtain corresponding QoS guarantee when they initiate services. In the application scenarios of the industry, because there are so many service types, and there are great differences and the changes occur rapidly, the efficient and accurate service guarantee cannot be achieved by configuring the QoS attributes and parameters through the slice +5QI statically. Therefore, it is necessary to consider dynamic identification of service flow and further identification of packet features.

Service flow identification

Service flow identification includes two modes: Static matching and dynamic matching.

- **Static service flow matching :** For some service flows that have been explicitly configured in the core network subscription, a specific 5QI is usually used. The RAN can match the QoS template directly through the "slice +5QI" information of the QoS flow. It is generally applicable to the scenarios where the service attributes are clear, for example, the voice service attributes and guarantee modes in the ToC network are already clear, that is, they can be fixed through a specific 5QI. Static matching has the advantage of simplicity but it also has the following disadvantages:

Insufficient granularity:

In the 3GPP protocol, there are only 255 5QI identifying the service type. 1~127 is used for the standard 5QI clearly defined by 3GPP. 128-255 is used for the 5QI that can be predefined by the operator. In terms of latency and reliability, these 5QI are not enough.

Low efficiency increases O&M costs:

Static QoS attributes and parameters are configured based on user subscription, that is, the QoS guarantee provided by the network is bound to the SIM card. This requires the following:

When contracting and issuing SIM card, it needs to fully understand the actual services of the industrial applications, and determine and match differentiated QoS attributes and parameters, which is a great challenge to operators and industry customers.

When deploying services, it is mandatory to match the SIM card, wireless terminal and service equipment accurately. Any mismatch or change will affect the QoS guarantee of the service and raise high requirements for the operation and maintenance of the industry customers.

- **Dynamic service flow matching:** For the service flow that is not explicitly configured in the core network subscription, the default 5QI is generally used. By analyzing the data flow, the RAN could determines the IP 5-tuple and the application type, and then matches the QoS template. Dynamic matching is generally applicable. Especially in the early stage of private network deployment, the network and service are still in the running period. The main benefits that dynamic service flow identification and matching brings to operators and industry customers are as follows:

Extended service type

It supports the customization of QoS guarantee policies for each service, and is not limited to the 5QI defined by 3GPP.

Simplifying O&M and improving O&M efficiency

The QoS guarantee automatically matches the corresponding service flow, so that all SIM cards can be configured as the default 5QI when the operator subscribes to the service. During the service deployment, the QoS guarantee can be decoupled from the SIM card and wireless terminal, greatly reducing the operation and maintenance management work of the operator and the industry customers.

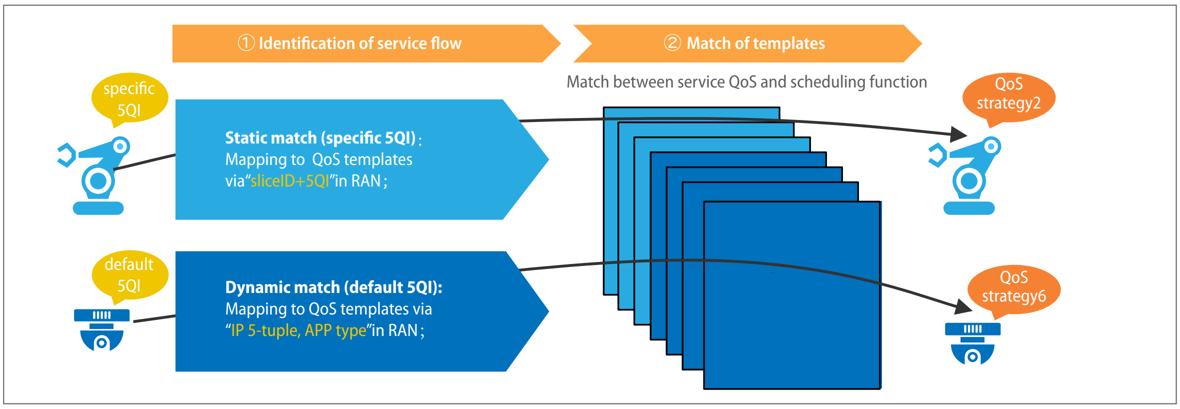

Figure 3-4 Service flow identification and QoS template matching

Packet characteristics identification

In industrial application scenarios, although multiple service types are involved, application data carried by a single service stream is more simple. From the perspective of packet characteristics, the features are more clear, and there is more room for targeted optimization. Therefore, in order to further improve the utilization efficiency of radio resources, the radio network needs not only to identify service streams, but also to identify the packet features of streamline, and to match the radio resource scheduling function and parameters with the packet features.

- **Packet identification methods:**

  Based on DPI: Analyzes, extracts, and identifies various protocol features of data packets.

  Online-based reasoning: Offline learning is performed in advance for packet features of specific services to obtain a model that can identify packet features, and then online deployment and online reasoning are performed to obtain packet features.

- **Packet identification result:**

  Packet attributes:

  Packet interval/packet size/upper-layer protocol type

  Packet type: I frame or P frame of video service, control-control command or task information of remote control service

  Packet requirements:

  Packet delay: Packet delay is determined based on the packet interval.

  Packet reliability: Packet reliability is determined based on packet types. For example, the I frame packet loss rate in the video service is 10^{-6}, and the P frame packet loss rate is 10^{-3}.

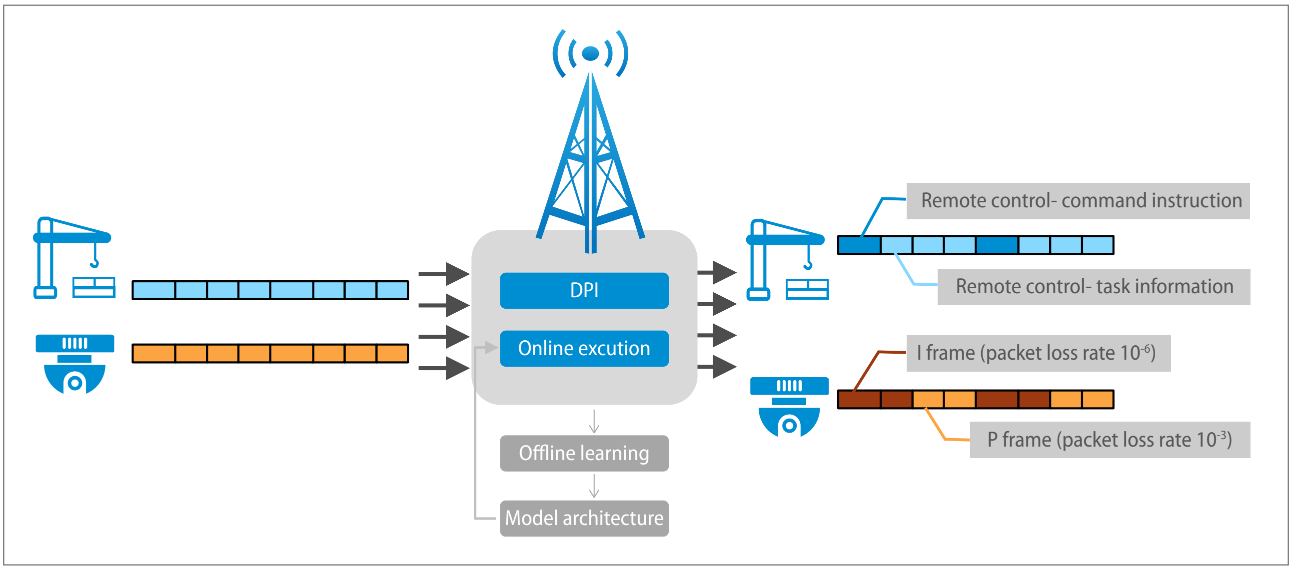

Figure 3-5 Packet feature identification

Precise scheduling

In industry application scenarios, key services often have high requirements for transmission delay and reliability, radio networks must provide commercial competitive precision assurance solutions. In addition to accurate identification, radio networks must also improve scheduling capabilities and scheduling orchestration to achieve efficient service guarantee.

Scheduling enhancement

In industrial application scenarios, some services require high reliability in data transmission and latency because of the security and efficiency of production operations. Therefore, radio networks are required to further enhance radio resource management and scheduling capabilities, and effectively guarantee low latency and high reliability of services. The main functions include:

❶ Dynamic conservative scheduling

Based on the service reliability requirements, adjust the modulation coding parameters in accordance with the air interface status. For example:

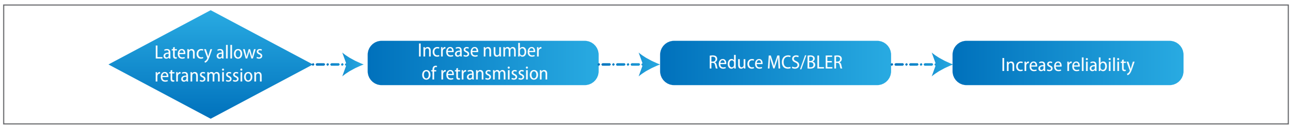

Figure 3-6 Flow chart of dynamic conservative scheduling

The reliability requirement of industry application is 99.999% or even higher. Completely relying on conservative modulation coding parameters will lead to the radio spectrum efficiency to be too low and the commercial value of the radio network to be affected.

❷ Pre-scheduling enhancement

On the basis of the accurate configuration of pre-scheduling period and data volume, the start time of pre-scheduling is dynamically adjusted to match the actual uplink transmission time of service data to further reduce the uplink data transmission delay.

❸ Delay-Based Scheduling

As shown in the following figure, the system dynamically selects queuing by priority or directly schedules and allocates resources in accordance with the waiting time. This feature ensures service delay and optimizes radio resource utilization.

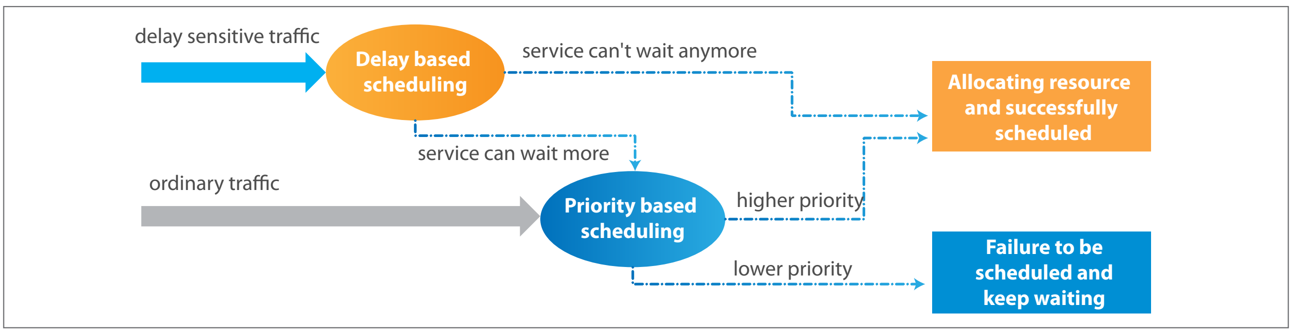

Figure 3-7 Flow chart of delay based scheduling

Scheduling orchestration

Scheduling orchestration is precise matching between "service attributes and transmission requirements" and "radio resource management and scheduling functions and configurations" based on radio environment perception to implement QoS guarantee efficiently. It can be divided into the following types based on application scenarios and implementation mechanisms:

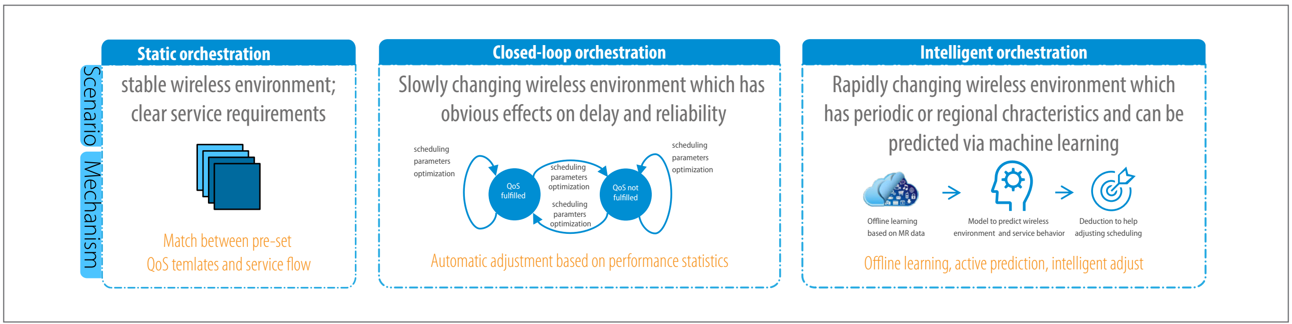

Figure 3-8 Scheduling orchestration classification

Precise performance measurement

In industry application scenarios, the communication body is a machine, and the service QoS achievement directly determines whether the machine is operating properly. Therefore, industry customers pay much attention to service experience and the reliability of data transmission. This requires that radio networks not only need to guarantee service transmission requirements through precise scheduling, but also need to refine the granularity of performance statistics to each service flow. In particular, they need to provide more elaborate presentation of delay, so that industry customers can better monitor service status.

Per-flow performance statistics

In industry application scenarios, the radio network needs to provide service-level performance statistics to meet the service monitoring requirements of industry customers, because:

1. Industry customers require that the data transmission requirements of each service are met, and the measurement granularity is precise to each service flow to effectively monitor service experience.
2. Many industrial applications are used for the communication between machines. The service flow performance statistics provided by the radio network can effectively present the service status.

Under the flow-based QoS framework of 5G, the service flow level performance statistics are provided for each QoS flow. The main indexes are as follows:

- Service rate (uplink and downlink)
- Number of packets (uplink and downlink)
- Packet loss rate (uplink and downlink)
- Packet delay (uplink and downlink)
- Packet delay jitter (uplink and downlink)
- Service time

Delay performance measurement

In industry application scenarios, the transmission delay of many services directly affects the efficiency and safety of the production process. If the delay measurement result only shows the average value within a statistical period, it cannot accurately reflect the service status or effectively optimize the delay. Therefore, delay measurement needs to support other statistical indicators, including delay distribution and delay jitter distribution.

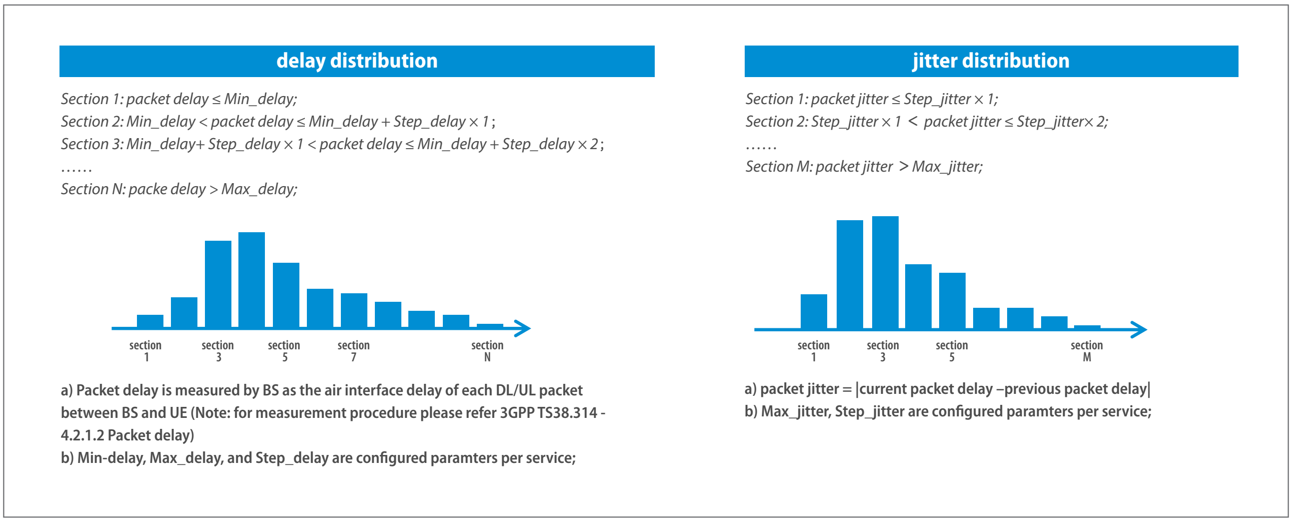

Figure 3-9 Delay distribution and delay jitter distribution

Precise O&M

Based on the scenarios and requirements of ToB, ZTE has enhanced various functions in the existing O&M system to improve the O&M effectiveness and efficiency of ToB.

Slice self-configuration

The ToB service has six typical types: Uplink large bandwidth service, low delay and jitter service, low delay & large bandwidth service, high reliability service, wide area uplink large bandwidth service and massive connection service. Due to the variety of service types, the slice configuration strategy is changeable, the slice parameters are complicated, and the requirements for personnel skills are high. However, at the early stage of ToB network construction, there is no engineers familiar with the ToB service. How to effectively solve the slice configuration task must be completed with efficient slicing tools.

The slice management tool will convert the SLA requirements of the slice subnet into the configuration parameters of the NR, and deliver them to the NR through UME to complete independent commissioning, greatly reducing the skill requirements of the personnel and effectively improving the efficiency of slice deployment.

Delay troubleshooting

The sensitivity of ToB services to delay is much higher than that of ToC services. How to perform effective end-to-end troubleshooting for delay problems, and the proportion of delay problems of each network element should be described in different sections. This is the key to the troubleshooting of delay problems.

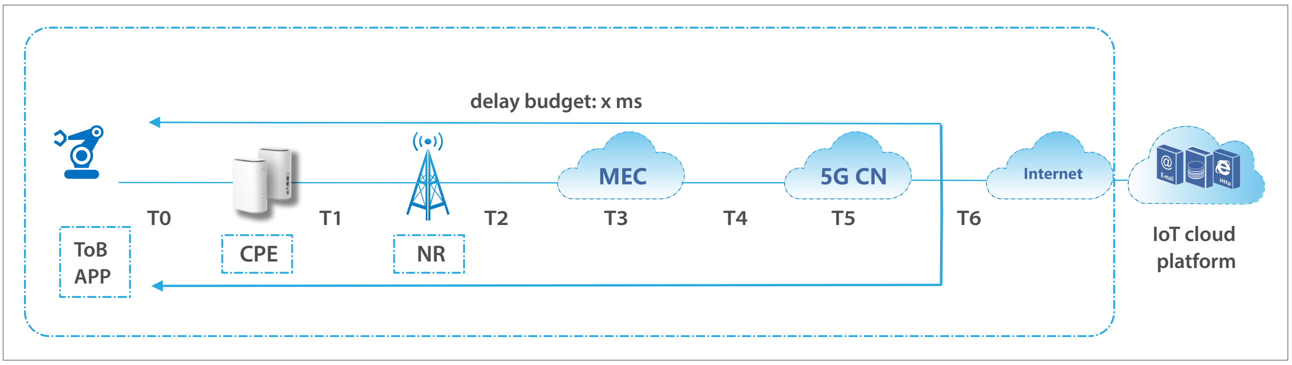

Figure 3-10 Per segment analysis is required for delay troubleshooting

ZTE provides various delay troubleshooting solutions, such as:

In the NodeEngine solution, the service delay within access cells and links can be monitored with millisecond (ms) precision as required. The monitored delay jitter can be further measured and processed, reported to the network management platform, and further interconnected with the capability exposure platforms such as the operator NSMF.

The solution of QoS Monitoring measurement can help industry users locate end-to-end delay problems, and provide slice-level and user-level slice delay management.

Antenna weight self-optimization

AAPC (Antenna Automatic Pattern Control) employs artificial intelligence search algorithm to implement automatic optimization of the whole process of automatic data collection, automatic optimization analysis, automatic distribution of weight value and automatic verification result based on the test report data. This makes it possible to optimize the weight values of over 10,000 antenna parameters of Massive MIMO, greatly improving the network optimization efficiency. It can also optimize it with the UE location, track and movement period of the ToB service, thus improving the flexibility and pertinence of the ToB network.

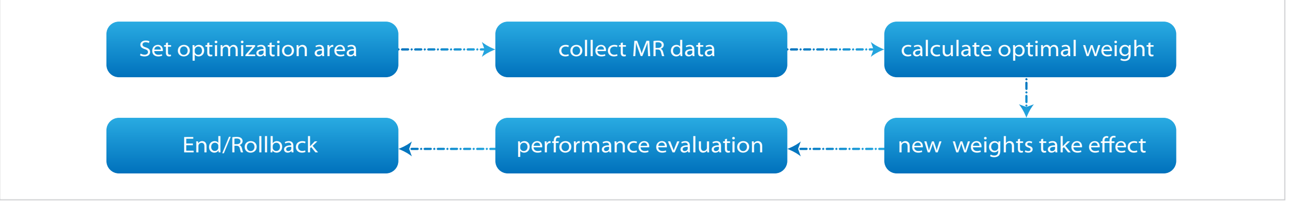

Figure 3-11 AAPC Antenna Weight Self-Optimization flow chart

Abnormal KPI detection

KPI inactivity often indicates that a problem occurs on a layer of the network. The O&M engineer handles hundreds of KPIs and alarms every day. Many times, KPIs cannot be monitored accurately and rapidly. The O&M engineer does not start the processing flow until the user complains about KPIs. ZTE radio intelligent operation and maintenance system uses AI, machine learning and expert rules to realize the automation of abnormal detection and fault diagnosis of radio network KPIs. It is equivalent to a "network health monitoring and diagnosis instrument" which is running 24 hours everyday, providing network doctors with data analysis and root cause diagnosis. In the ToB scenario, the system can provide the service flow level-based KPI detection and analysis function.

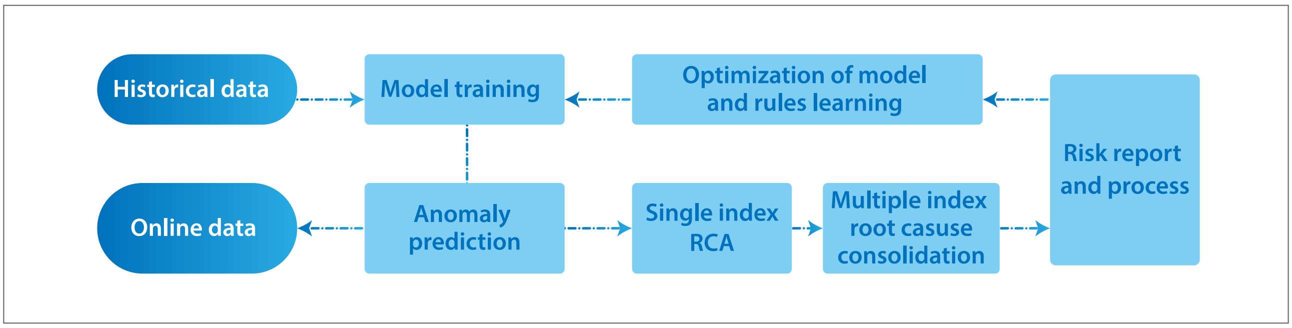

Figure 3-12 KPI abnormal detection flow chart

Precise RAN solution practice

China Southern Power Grid

5G applications of power include "power generation, transmission, transformation, distribution and usage", which covers wide areas, varieties of businesses, and large difference in QoS. The number of terminals also reaches 1 billion. At the same time, the power system has the requirement of physical isolation of safe partition. How to identify and guarantee all services separately in the 5G commercial network of operators is a big challenge.

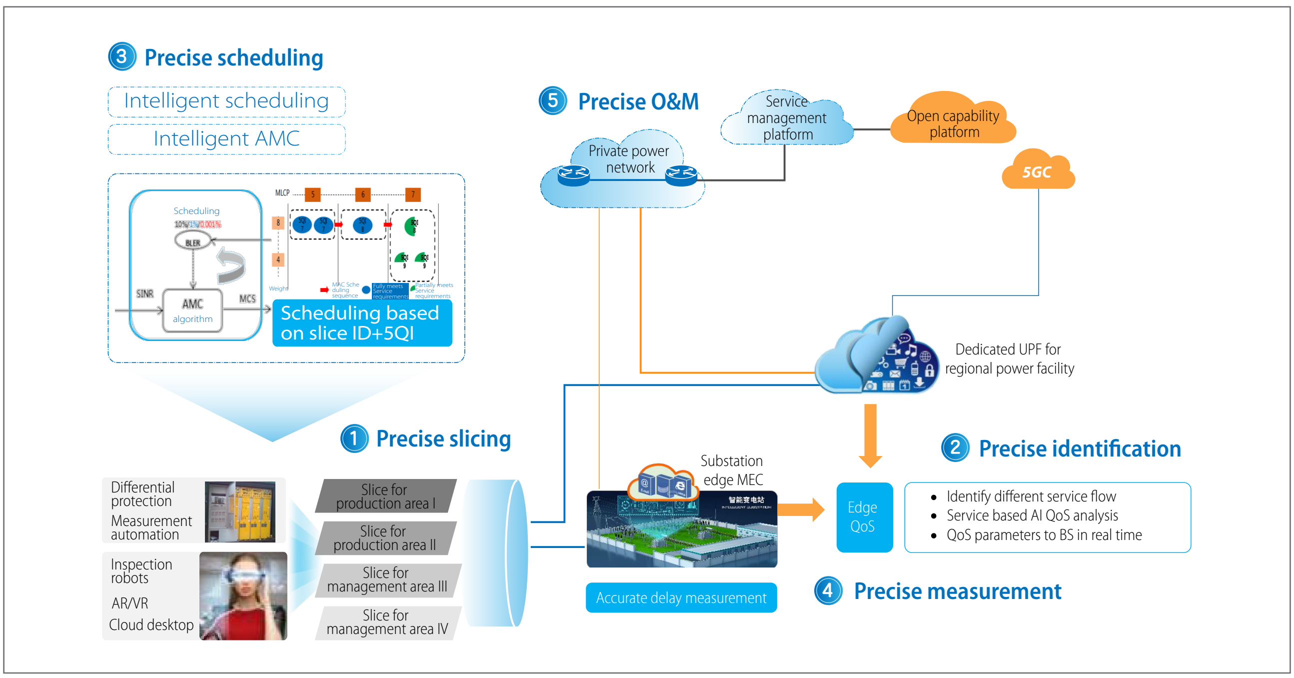

Figure 4-1 Application of Precise RAN solution in power private network

Cooperating with Operators, China Southern Power Grid Co.,Ltd. has set up a demonstration area of 5G+ smart grid application in Nansha district which covers the most comprehensive use cases in the world.

As a vendor in this area, ZTE has verified that Precise RAN Solution can support the power scenarios. Using precise slicing, the communication network of power grid can be sliced according to the security partition, and the parameter granularity combining the slice ID and 5QI can meet the multi-service requirements in a single slice. Precise scheduling can ensure the requirements of Line Current Differential Protection in power distribution grid service that the unidirectional delay between 2 UEs is 15 ms and reliability is 99.99% in the operator's commercial network. Precise measurement can provide the measurement methods of ms-level delay distribution for the delay-sensitive power services. Precise identification can reduce the resource consumption of the power wide-area virtual private network. Precise O&M can provide the operational status of network channels and terminals for the power platform.

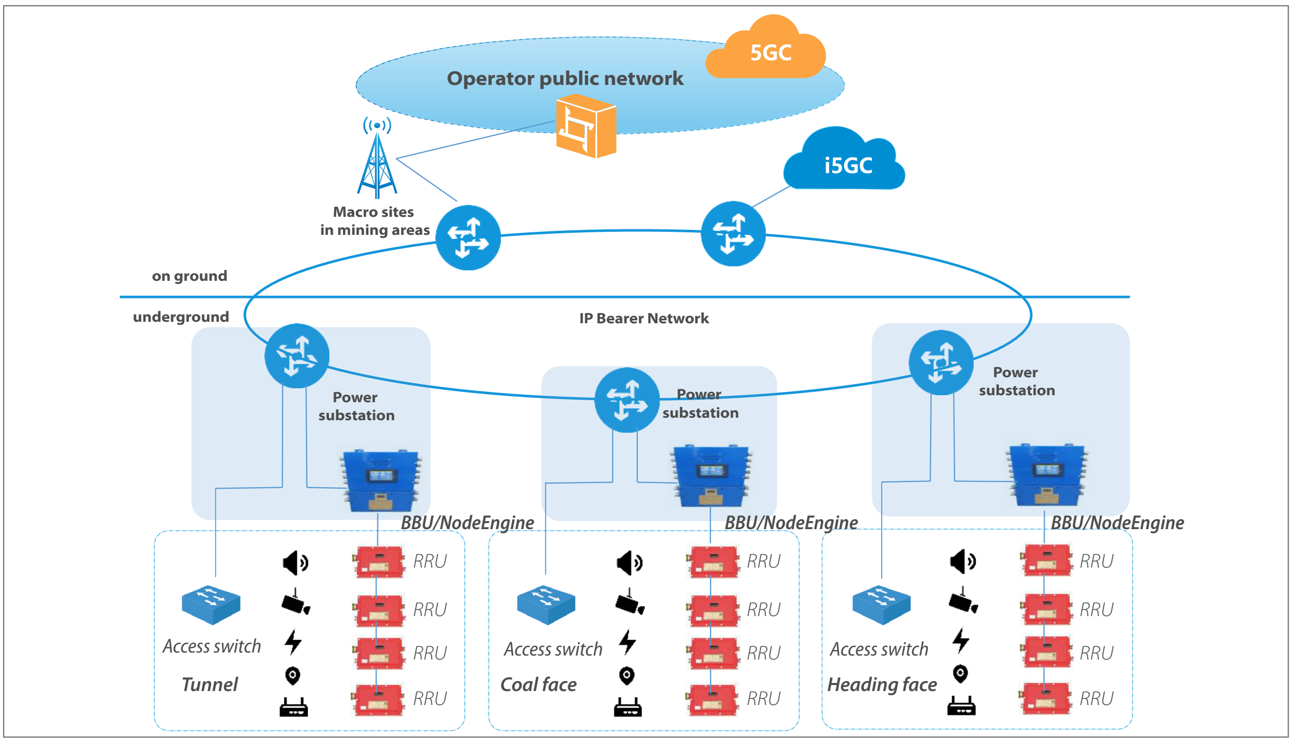

Figure 4-2 5G private network architecture in mining industry

Shaanxi Coal and Chemical Industry Group

Mining industry has urgent requirement for intelligent transformation due to the complex and dangerous environment and the priority of production safety. Cooperating with Operators and ZTE, Shaanxi Coal and Chemical Industry Group has built a 5G demonstration area to verify the capabilities of Precise RAN solution for smart mines.

Mines can be divided into ground mines and underground mines. The ground mines adopt the 5G virtual private network and use network slicing for isolation. The underground mines select the 5G physical private network architecture which needs dedicated network infrastructure. In order to guarantee service experience, the frame structure of 1D3U is used for the video monitoring scenario with intensive cameras, which can satisfy the requirement of large uplink bandwidth in the complex mining environment. In addition, for control applications in the mine, such as remote control and automatic driving, the 5G Precise RAN solution can provide precise guarantee of delay and reliability , reducing the demand for human resource on the production site.

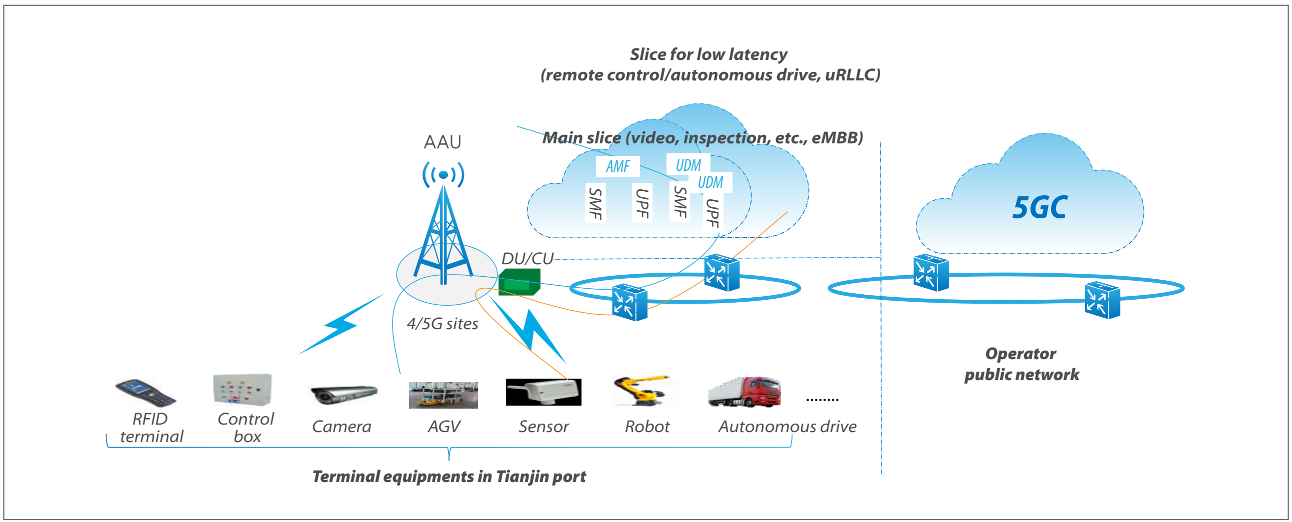

Figure 4-3 5G Precise RAN solution in Tianjin Port

Tianjin Port

Intelligent applications, such as unmanned trucks, intelligent tallying, remote shore bridges, and tire cranes, can greatly improve the capability and efficiency of port collaboration. However, these applications have encountered many problems when using traditional communication networks like optical fibers or Wi-Fi. Therefore, cooperating with Operators and ZTE, Tianjin Port has deployed the infrastructure of 5G physical network.

Services in port are geographically centralized. There are multiple services in a 5G cell , such as remote shore bridge, intelligent tallying, and unmanned trucks. Using precise planning, sites can be accurately planed and parameters can be configured by modeling various port services. Precise scheduling can ensure that the end-to-end latency of the operation for remote shore bridge is lower than 20 ms and can provide stable rate guarantee for multi-view video backhaul. With the support of 5G network, 25 self-driving trucks in the port area can automatically drive. Currently, the pilot acceptance of Tianjin Port 5G network has been completed and put into commercial operation, which preliminarily achieves the objectives of automatic and intelligent port area and continuously improves operation efficiency.

Zhanjiang Iron and Steel

To implement the national program of China Manufacture 2025, Baowu Zhanjiang Iron and Steel Co., Ltd. cooperating with operators and ZTE in 5G technologies, hopes to achieve intelligent upgrade and transformation of factories and equipment in the steel industry, improve the efficiency of production and management, and reduce human resource investment.

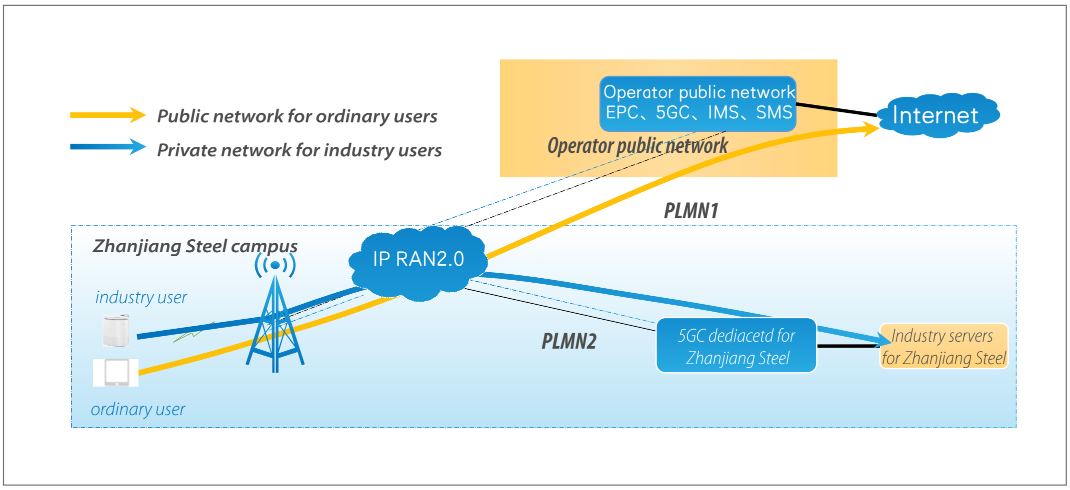

Figure 4-4 Architecture of 5G private network in Zhanjiang Iron and Steel

The 5G private network of Zhanjiang Iron and Steel Corporation uses dedicated core networks and the sharing transmission and radio networks with the public networks. The pilot service of the private network is the intelligent monitoring of belt machine in the blast furnace. In this scenario, the online monitoring and malfunction diagnosis of key devices is implemented through the following technologies: online monitoring of belt machine rotation device, patrol robot of belt machine track and stall detection of tail wheels.To meet the service requirements, ZTE deployed default slices of public network, default slices of private network and dedicated robot slices by precise slicing, which can isolate the services on public and private network and satisfy differentiated requirements. In this project, after data monitoring and intelligent reconstruction of the equipment for steel making, steel rolling, coke oven are completed, the personnel investment in dangerous positions will be reduced and management efficiency will be improved.

Guangzhou Metro

In 2019, ZTE, together with operators and Guangzhou Metro, has launched a demonstration project of 5G smart Metro, which aims to solve the pain points in metro O&M, such as frequent congestion of surveillance videos, large delay of emergency response, insufficient flexibility of network , low accuracy of traffic prediction and delayed traffic monitoring.

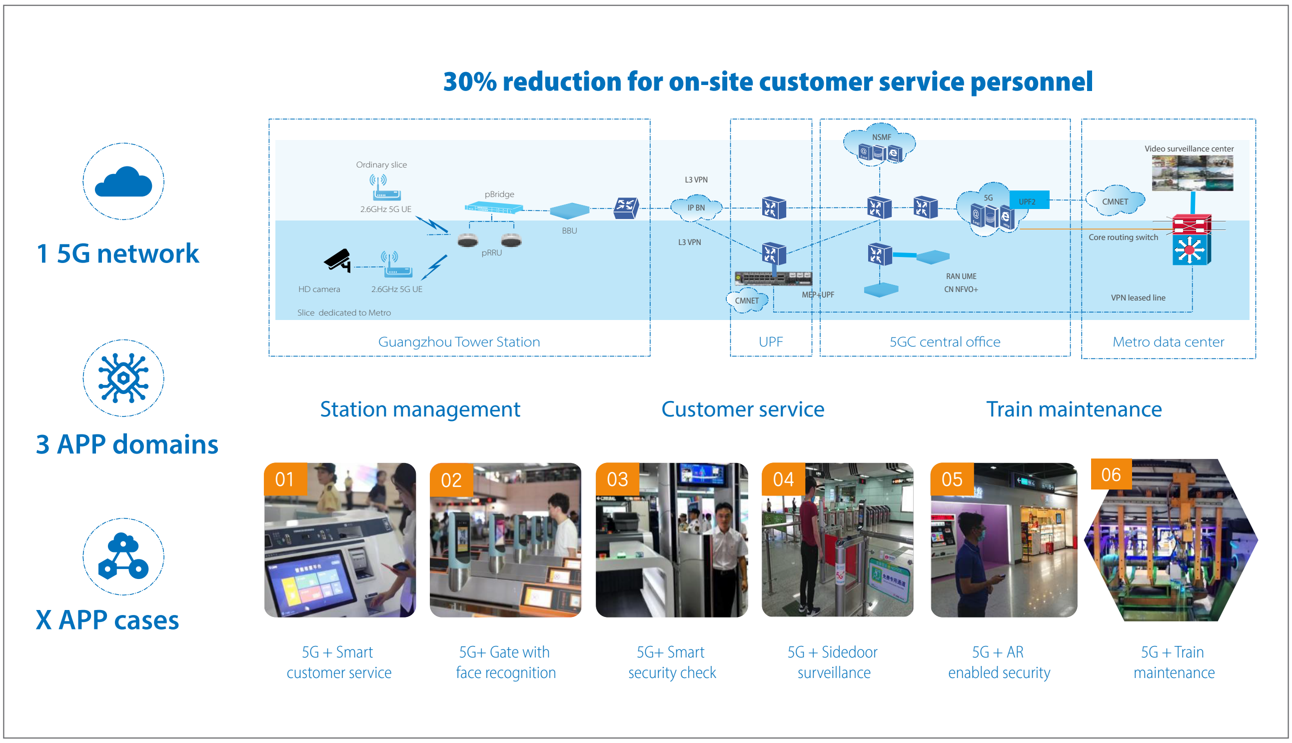

Figure 4-5 1+3+X architecture of 5G+ Smart Metro

The project adopts the "1+3+X" overall architecture, including:

A customized 5G private network based on Metro services: Based on the 5G Mobile network of Guangzhou, the dedicated MEC + UPF, the precise coverage of 5G QCell in the station hall and end-to-end precise slicing of Metro services are deployed, which achieves integrated bearing of multiple services and precision guarantee of differentiated network performance requirements of different services.

Demonstrations of X application scenarios in the three major application fields: The project focuses on the following three fields: station O&M, passenger travel service and train base maintenance. Multiple Metro application scenarios have been verified and demonstrated, including 5G smart security inspection, 5G mobile HD video surveillance, 5G AR glasses security, 5G subway side door help, 5G high-precision indoor positioning and 5G train base maintenance.

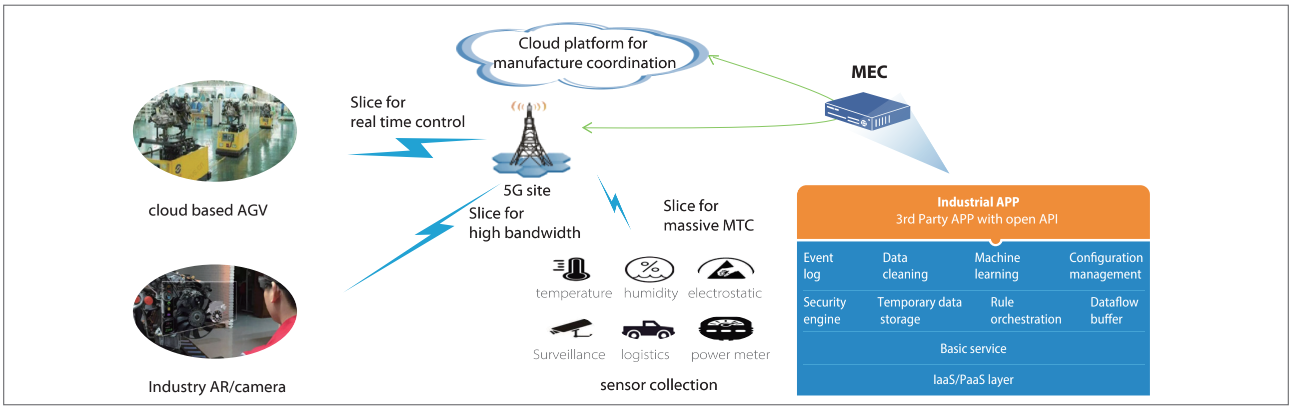

Figure 4-6 5G intelligent manufacturing in Binjiang, Nanjing

Nanjing Binjiang 5G manufacturing

When 5G is applied in the industry, there still exists a series of problems, such as network security, reliability, delay jitter, and uplink bandwidth. Cooperating with operators, ZTE has built a 5G virtual private network based on Precise RAN solution in Binjiang 5G intelligent manufacturing base, which practices the concept of "using 5G to manufacture 5G."

Using ZTE's advantages in 5G technologies, the project has build some pilot application scenarios. Based on the 5G virtual private network, the integration of 5G technologies with industrial networks, industrial software, and control systems are promoted and the 5G industrial applications in specific scenarios are built, such as factory data collection, 5G robotics, 5G cloudified AGV, 5G cloud-based visual quality inspection, 5G production monitoring, 5G-based industrial AR/VR, 5G-based digital twin, 5G smart campus and other innovative applications.

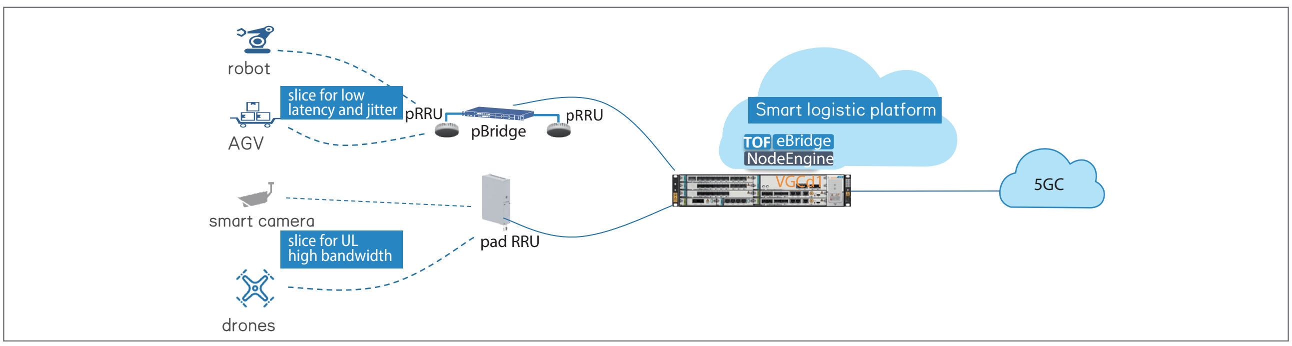

Figure 4-7 Unmanned warehouse in Jingdong Logistics

Unmanned warehouse for Jingdong Logistics

Unmanned warehouses are an important junction in the logistics and transportation process. There are multiple typical service scenarios in the warehouse, such as multi-dimensional storage, high-density deployment of cloud-based AGV, warehousing visualization and digital twin, and intelligent sorting based on robotic arm. Each scenario has great differences in environmental features, number of terminals, and QoS requirements. Therefore, customized radio network solutions are required. Cooperating with operators and ZTE, Jingdong Logistics has customized a dedicated logistics radio network solution for the unmanned warehouse.

According to the shape of the unmanned warehouse operation area, the service requirements of terminal and the quantity and operation tracks, the site type, antenna specifications, site deployment and configuration parameters can be precisely planned . Using precise slicing, AGV can be configured with a low-latency and high-reliability slice template and drone can be configured with a uplink large-bandwidth slice template. Precise Scheduling can guarantee the high-density handling of hundreds of AGV Vehicles. Precise O&M can monitor all 5G terminals in the warehouse in real time. And as the intelligent upgrade of unmanned warehouses continuing, 5G networks can also continuously expand capabilities to meet higher requirements.

Summary

In the generation-to-generation transition of mobile communications, 5G is the first generation whose focus is turned to support for applications in vertical industries. 5G can deeply empower vertical industry applications with brand-new air interface capabilities, service-based network architecture, end-to-end network slicing and edge computing, which can fulfill differentiated and definite service requirements from industry. Based on the design philosophy of Precise RAN solution, 5G can provide deterministic guarantee for various vertical industry applications through precise planning, precise slicing, precise identification, precise scheduling, precise measurement, and precise O&M.

At present, the development of 5G has entered a key stage of integration and innovation, and there is a trend of multi-entities collaboration among communication service providers, equipment manufacturers, and vertical industries. More 5G application scenarios are emerging, and smart grid, intelligent mining, smart ports, smart factories, smart rail transit have become hot sectors. 5G is becoming the engine of digital transformation, and will open a new era of comprehensive digital transformation of the economy and society.

Abbreviation

Abbreviation	Full Name
5QI	5G QoS Identifier
AAPC	Antenna Automatic Pattern Control
AGV	Automated Guided Vehicle
BBU	BaseBand Unit
BLER	Block Error Rate
DPI	Deep Packet Inspection
DRB	Data Radio Bearer
eMBB	enhanced Mobile Broadband
FDD	Frequency Division Duplex
KPI	Key Performance Index
MEC	Multi-access Edge Computing
NSMF	Network Slice Management Function
PRB	Physical Resource Block
ROI	Return on Investment
SLA	Service Level Agreement
TDD	Time Division Duplex
UPF	User Plane Function
URLLC	Ultra Reliability Low Latency Communication

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