中国移动 研究院 China Mobile CMRI | ZTE中兴

NodeEngine WhitePaper

Enabling 5G Digital Transformation of Industrial Parks

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Overview

At present, industrial technologies are evolving from the automatic control phase characterized by PLC and computer applications to the informatization and intelligence phase characterized by information communication technologies and Internet of Things. As a new production factor, information data is interacting with traditional technologies, business processes, and organizational structures to promote the development of industrial enterprises towards flattening, platformization, and federalization.

With the development of communication technologies, industrial sensors are evolving towards low cost, low power consumption, and miniaturization to construct a comprehensive, real-time, and efficient data collection system. Network communication technologies are developing towards 5G and Time-Sensitive Networks (TSN), to construct a data transmission system with low latency, high bandwidth, and wide coverage. New technologies such as cloud computing, big data, edge computing, and artificial intelligence are booming, and a system of efficient and rapid data storage, computing, and processing is being established. The new generation ICT is pushing the industrial society into a new era of all-round perception, reliable transmission, intelligent processing, and accurate decision-making. The digital transformation and upgrade of the industry is imminent.

Driving Force for Digital Transformation and Upgrading of the Industry

Enterprises are the most important economic organizations in today's society. Competition, essentially, is the competition of the allocation efficiency of enterprise resources in uncertain market environments. For industrial enterprises, they combine and configure social capitals, talents, equipment, land, technologies, markets, and other factors to create better products with less resources and higher efficiency for customers.

In today's digital and information era, data is a specific form and an important carrier of information, and information organization is a complete process of information collection, transmission, analysis, and processing. The traditional four-dimensional physical world based on time and space in any industry can be mapped to a multi-dimensional digital world. Massive data from the digital world collected by sensors can converge to the private cloud of enterprises through 5G network, and will be fed back to the physical world via data analysis and AI service, which greatly improves industry efficiency and reduces product costs. This is the basic paradigm: 5G changes the society! 5G empowers the industries!

Enterprise digitalization is to achieve automatic traffic of data through informatization. Scientific, efficient, and accurate decision-making, the core of resource allocation during competition, is relying more and more on automatic traffic of data, which drives the technology flow, capital flow, talent flow and material flow. It enables the digitization, networking and intelligentization of product R&D, production equipment, processes, and services, to reconstruct the entire production and manufacturing process, and to transfer the correct data to the target persons and machines in a correct way at a correct time. In this way, the uncertainties of complex manufacturing systems in the physical world can be manifested in the physical information system, so that resources can be optimized and configured in various ways, quickly, and efficiently.

5G Network is the "Nerve Center" of Digital Transformation in the Industry

The development of digital economy depends on new infrastructure, which supports key points such as data collection, transmission, processing, and application. The 5G network can be regarded as the "nerve center" that supports the industry digitalization, and plays the role of information data uploading and distributing. Artificial intelligence and big data are responsible for the storage, processing, and intelligent decision-making of data, which are the brains of the industry, while sensors and other components are the "sensing/executing organs". The brain must be connected with the sensing organs through the "central nervous system."

In the agricultural economy era, tools and human resources make the main production factors, which maximize the role of human beings. In the industrial economy era, the invention of steam engines and electricity has made us exceed the limitation of human physical strength. Now, in the digital economy era, information data is expected to function as new core innovation elements to make new combinations of key production factors possible, which eventually helps to exceed the limitation of human brainpower.

During the digital transformation of the industry driven by 5G networks, the following three aspects need more focus.

Strengthening Connections Through the 5G Private Network

In the four links of information data moving, the 5G network is mainly responsible for data transmitting, artificial intelligence and big data for data processing, and traditional sensors for data collection. From the perspective of entire industry digitalization, the capability improvement of these links requires iteration. In the previous industry, data collecting and controlling is the main focuses. Each device has sensors. After getting the data, the device makes a decision on which kind of actions (digital applications) will be executed through its locally defined calculation. In the traditional process, the intelligence and networking of data are not fully utilized, which results in a low level of the entire industry. Therefore, for the application of 5G, AI, big data, and other new technologies, the connection should be strengthened firstly from the original internal data cycle to the external data cycle of the entire system, to make the most of data.

Optimal solution to technology, performance, and cost

Network connections need to be adjusted firstly in the digital transformation of traditional industries. The major difficulty lies in data transmission and sharing. The reasons are as follows:

- **Inconvenient cable deployment**
  High construction costs, difficult cabling, and long deployment period, hard to adjust production lines flexibly on demand, and hard to meet the communication node requirements for rapid expansion in the industrial park
- **Unstable Wi-Fi network**
  Unlicensed frequency bands cause serious network interference and poor mobility. The requirements for AGV applications cannot be met.
- **Full-Scenario Access and Differentiated Processing Difficulties**
  Different industries have different requirements for data, performance, indicators, bandwidth, and responses.
  Differentiated solutions are required to solve different problems in the data transmission process, so that different industries can be flexibly configured to deal with the data connectivity. In addition, in terms of performance, simpler methods are required to reduce the cost of user deployment. The cost is a key issue for enterprises' digital economy transformation.

In terms of overall strategies, technical feasibility can be considered at the beginning, and then the optimization of effect and cost. Only through such cyclical iterations can digital economy develop more rapidly.

Step-by-Step Scenario Introduction

Considering the urgency of current service requirements, the maturity of products, and the frequency of use, it is feasible to introduce different scenarios step by step.

- **The first phase**

  The first phase focuses on the application scenarios that mainly improve user experience and video experience, including remote control, video, and AGV. These applications improve user experience and are consistent with the technical maturity of the first phase of 5G.

- **In the second phase**

  from the perspective of improving the capabilities of the entire industry, including application scenarios such as augmented reality, telemedicine, and smart transportation, the technology feasibility is fully verified through pilot trials, and maturity is promoted in terms of costs and performance, and the ecology and business models of the entire industry chain.

- **In the third phase**

  the application scenarios such as real-time control of factories and high-level autonomous driving can be considered. These applications have higher requirements for basic network capabilities, higher requirements for costs, and more mature technical and specification standards.

5G Network Requirements from Industrial Park Digital Transformation

Data local transmission in the industrial park

Industry services are generally divided into two types: intra-park production services and information interaction services outside the park. Enterprise customers are very concerned about the security and confidentiality of production data. Whether core production data can be held within the park is a basic requirement for the 5G network.

At the same time, there are different types of services in the industrial park, such as high-bandwidth HD video detection, low-latency remote control, and large-connection device information collection. Different services have different requirements for network performance, which requires the customized QoS guarantee while meeting the transmission requirements of various types of services.

In addition, to improve the utilization and to reduce the cost of using the 5G network in the same area, the 5G network should provide services for both public users and industry users, and public network services and enterprise services should be isolated securely. Moreover, there are also security isolation requirements for the Information Domain (IT) and Production Control Domain (OT) inside enterprises, and the two different services need to be transmitted independently and securely.

Multi-Type Terminal Access

The 2B market is a highly fragmented market, where industrial sites, equipment types, and equipment interfaces are diversified, and not all the terminals responsible for various data collection tasks are based on 5G terminal modules. And with the rapid development of the industrial Internet, the manufacturing industry's demand for local calculation is very urgent. The edge gateway is used to collect, filter, and clean local data in real time, and provide the cross-layer protocol conversion capability to achieve unified access to defragmented industrial networks, which has become a universal demand.

Precision Network Capability

In the industrial park scenario, there are a large number of time sensitive applications, such as motion control, and robot/AGV cooperative control. The data of these applications shall be sent to the target within a specified time limit to support the normal operation of industrial control devices and applications. In addition, the factory has a large amount of real-time switching production data, for example, the RT mode of Siemens PROFINET requires the response time to be less than 10ms. How to ensure the real-time performance of a large number of communications and ensure the continuous and stable operation of the production network is posing higher requirements for the private network solution of industrial parks.

Self-Service Portal

In the 5G era, industrial enterprise customers hope to have operations management rights for the network deployed within the enterprise. They pay more attention to the control autonomy, flexibility and convenience of the network, especially to the possibility of obtaining relatively independent self-service capabilities in the virtual private network of the industry, such as enterprise network monitoring information acquisition, service change and network parameter configuration information modification. On one hand, the network can be adjusted at any time in accordance with the service requirements. On the other hand, the network quality and operational status of devices can be viewed in real time. When the network is abnormal or the equipment fails to operate properly, the system can respond immediately and adjust production strategies in a timely manner to ensure the continuity of production to the maximum extent. In this case, complex network O&M processes need to be shielded to meet the simple O&M requirements of industry users on enterprise networks through the self-service portal.

Low-cost private network

The 5G network carries the core services of enterprises, so enterprises want to exclusively use the 5G network. On one hand, data security can be effectively guaranteed to meet the production service requirements. On the other hand, this can effectively guarantee the normal operation of services, with the probability of network congestion and packet loss greatly reduced.

However, the ultimate goal of an enterprise is to make profits. Although the 5G network is very good, if the construction and use costs are too high and the investment costs are obviously higher than the expected profits, the enterprise will not use the 5G network.

To ensure that the service data of factories transmitted in the park, some NE devices of the 5G core network need to be deployed in enterprises. These factors cause high costs of 5G network deployment and difficult maintenance. Low-cost 5G private network solutions are the core concern of industry enterprises.

Overview of the existing 5G private network solution

There are two kinds of private network solutions based on 5G. One is based on dedicated frequency bands (only for enterprise private networks), and the other is radio resource sharing between the private network and the public mobile network. In this white paper, only radio resource sharing mode is introduced, which can be suitable for most industrial park scenarios.

Based on Network Slices

The 5G network slicing technology is recommended for enterprises to serve specific local applications over 5G.

The network-slice-based solution is illustrated in the figure below:

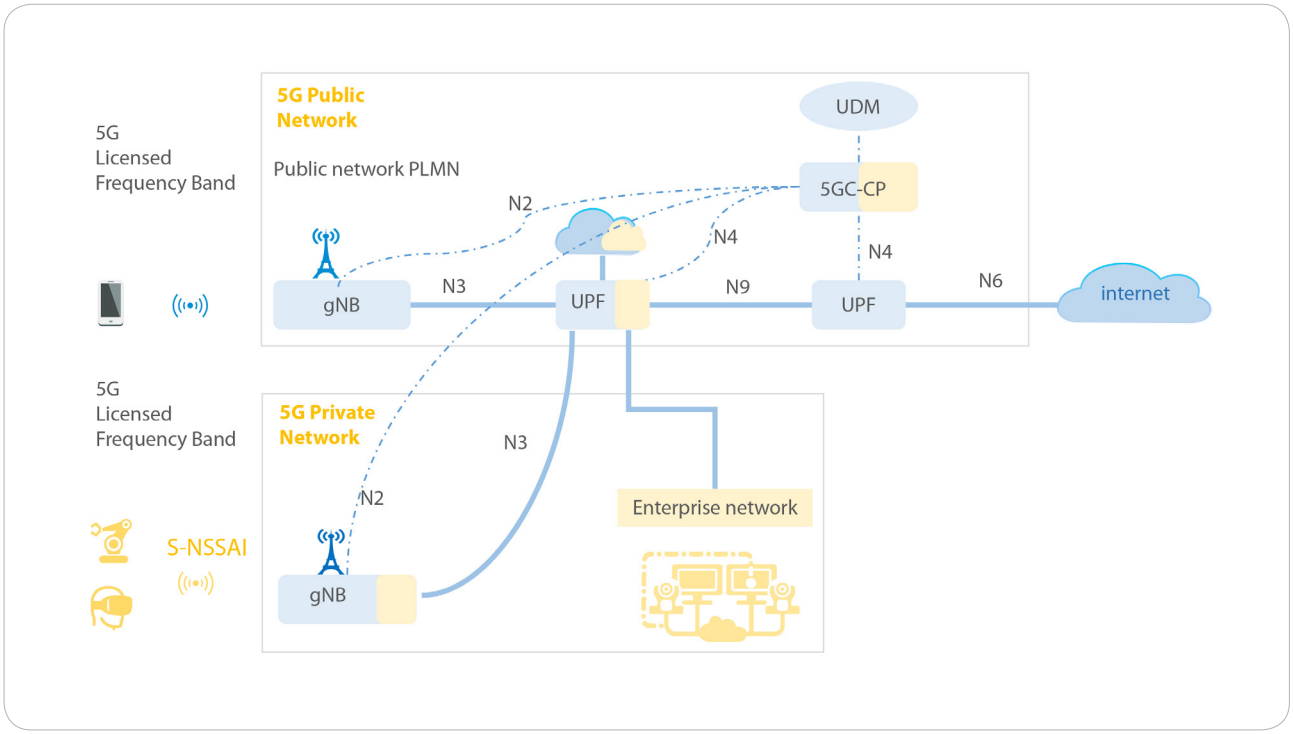


Figure 2-2 The private network solution based on Network Slice

This solution means that the enterprise's private network shares all resources with the public network with an E2E dedicated network subnet slice, including the resources of radio network, transmission network and core network. The capability of a private network depends on that of the network sub-net slice. The data transmitted locally with low-latency guarantee depends on the location of the UPF, which is one of the resources of the network sub-net slice.

Advantages	Disadvantages
• The whole network resources are shared between the public network and private network. • No extra costs of deployment or O&M	• The location of UPF serving the sub-net slice determines the transmission patch and latency of the local traffic.

Based on Mini-5GC

The architecture of the private network based on mini 5GC is shown in the following figure:

In this way, the enterprise's private network shares the radio network resources with the public network.

he main functions of mini 5GC include user registration, identity authentication, terminal access and mobility management.
On the 5G base station, the mobile data traffic is distributed according to different PLMNs. The data traffic over the public network will be routed to the UPF while the local data of the private network is directly forwarded to the enterprise network through the mini 5GC.

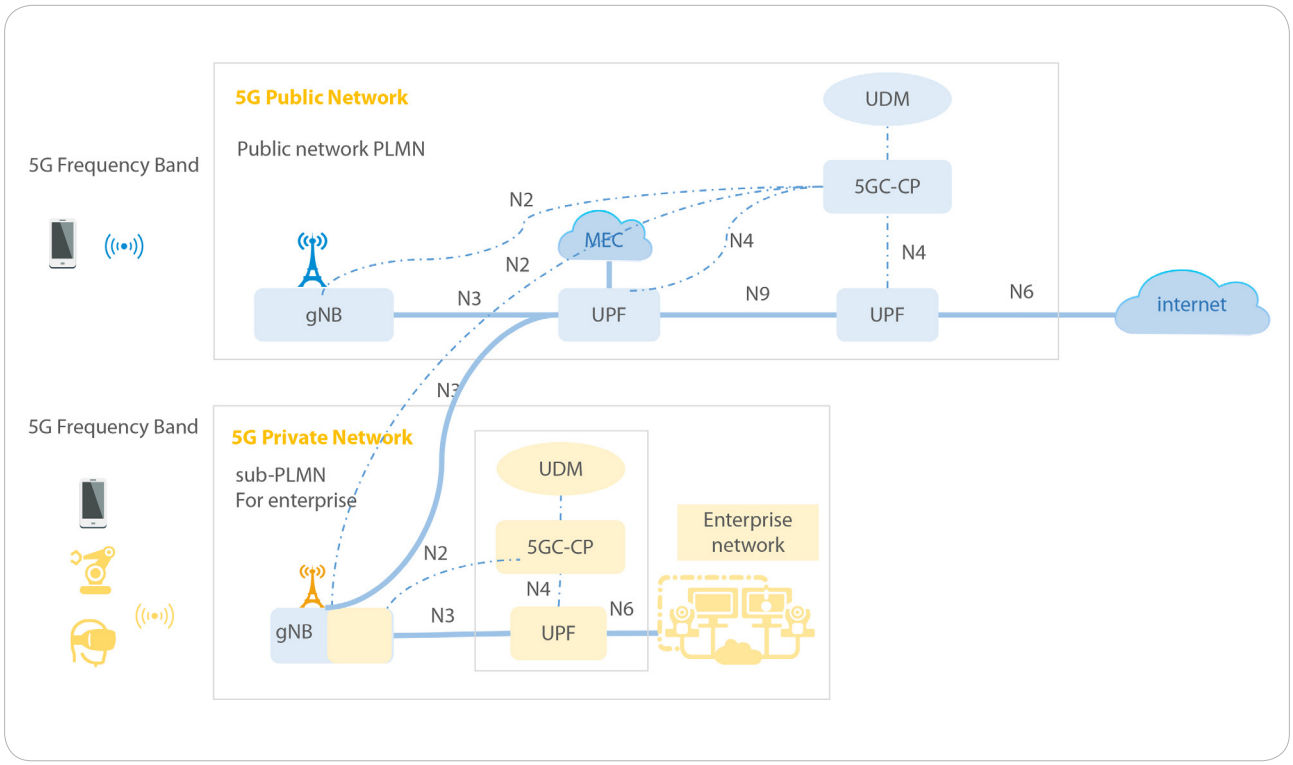


Figure 2-3 The Private Network solution based on mini-5GC

Advantages	Disadvantages
• User information and data information is kept within the industrial park. • Low service latency.	• For small and medium-sized enterprises, the cost of 5GC deployment is higher than expected, and the regular O&M is more complex with higher manpower cost. • The terminals serving in the private network cannot hand over to the public network.

Based on Edge UPF

The following figure shows the edge UPF-based mode.

In this mode, the enterprise private network and public network are sharing the control plane of RAN and 5GC. The management including user subscription, identification certification, service initialization and mobility is controlled by the public 5GC.

The base stations and edge UPF for the private network are handled by 5GC through N2 and N4 interfaces in the enterprise park. If there is an internet visiting requirement, the edge UPF is expected to connect core UPF through N9 interface.

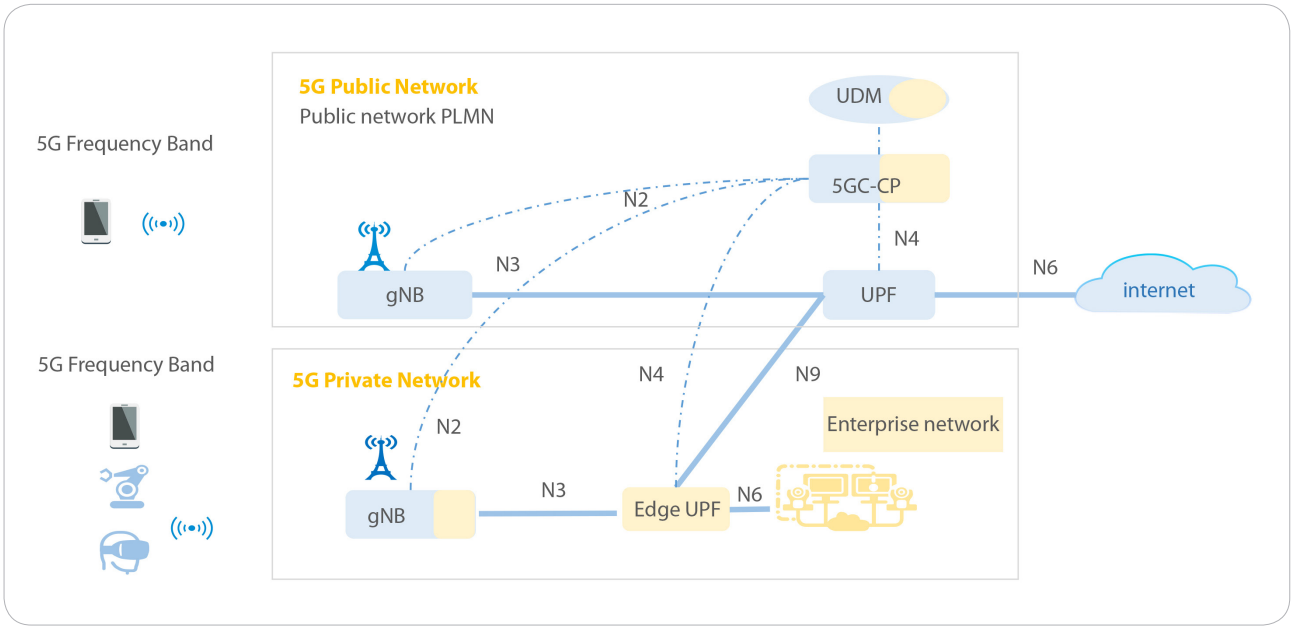


Figure 2-4 the private network based on Edge UPF

Advantages	Disadvantages
• The local data generated in the industrial park can be transmitted locally. • The radio network can serve the public mobile users and the enterprise terminals. • With edge UPF deployed closed to the enterprise, the latency of local data transmission can be guaranteed.	• To make a private network for an enterprise, the deployment cost of an edge UPF is higher. • The network planning for edge UPF deployment is more complex, because the transmission network is required to update to make an interaction with the core network. • As of now, it is not possible to make a commercial solution to N4 uncoupling between UPF and SMF. That means the vendor of the edge UPF is the same as that of the current 5GC network. • The edge UPFs may trigger security problems of core network since there is wide deployment in the industrial parks.

BTS-based local traffic offloading

The figure below shows the local traffic offloading solution.

On the existing gNBs, the Traffic Offloading (TOF) is introduced. This function can analysis the GTPU data traffic which is transmitted through the N3 interfaces, and distribute the data traffic to different destination according to the configured offloading policies. If it is the local traffic, then it will be routed directly to the private network of the enterprise. If it is not, then the traffic will be sent to core UPF through N3 interface. And this service can be deployed on an additional specific board, which co-exists with gNB in one BBU. Furthermore, it can offer the same traffic offloading service for other base stations simultaneously according to offloading policies, like PLMN id and slice id.

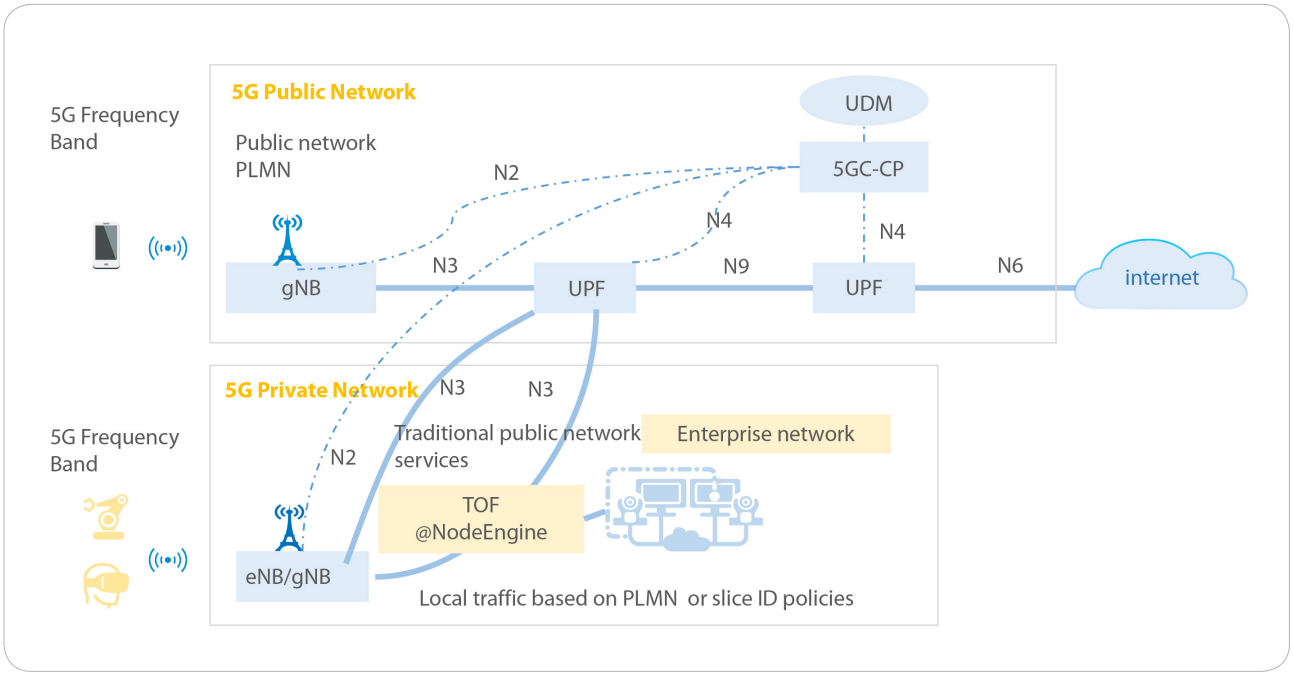


Figure 2-5 BTS-based Local offloading Mode

Advantages	Disadvantages
• It is convenient to deploy without additional positon of an equipment considered. Only one traffic offloading board is inserted to a BBU with plug and play mode. Besides, there is no cooperation with transmission network and core network, so the private network of an industrial park can be constructed in an hour. • Match the requirements of data security for the industrial park with local transmission. • The latency of local data transmission is lowest over 5G, because the local data is offloaded directly on the base station. It can effectively reduce the deployment cost of the private network for an enterprise, and accelerate the verification of local applications over 5G.	• The disadvantage is that only the monthly package of the private network is recommended with the management of bandwidth and traffic control, because it is not required to be cooperated with the core network.

Summary of the 5G private Network Solutions

Items	BTS-based local offloading	Based on edge UPF	Based on mini 5GC	Based on network slices
Data of the industrial park transmitted locally	√	√	√	√
User Identification of the park	Public	Public	Private	Public
Network elements shared	RAN	RAN & UPF	RAN & some of 5GC elements	Slicing network
Deployment Period	hour	Week	Week	Week
O&M Cost	Low	Medium	High	Medium
Transmission latency	Lowest	Lower	Lower	Lower

Table 2-1 Comparison of the 5G private network solutions

According to the above table, each solution has its own highlights and is suitable for some certain scenarios, which matches some kinds of vertical industrial transformation over 5G network.

To satisfy the key requirements including data local transmission, fast deployment of the private network and cost orientation of small and medium-sized industrial parks, and to accelerate efficiently the digital transformation of the industrial parks the traffic offloading solution based on base stations is obviously far better.

Forging a Fine Private Network for Industrial parks

In order to meet the requirements of various applications scenarios in the industrial parks and achieve the ultra-low delay of less than 5ms, ZTE launches NodeEngine solution integrated with 5G base stations. Based on the public network architecture, the data generated by local terminals in the park can be transmitted and offloaded to the local server directly at the base station level. With the capabilities of computing, storage, switch, accelerator, etc. deployed in a BBU of the base station, the base station can provide the edge services, like mobile network controlling and local traffic offloading. The base station is transformed as an intelligent brain of the 5g virtual private network, which is able to perceive local applications' characteristics, make network performance coordination, provide SLA guarantee for local applications and self-service portal for the enterprise, etc. At the same time, centered on the intelligent base station engine, the computing capability can be extended to the sites and form intelligent tentacles at the side of data collectors. Then it will meet the requirements of connection, interaction, and computing for various application terminals in the industrial park. ZTE NodeEngine provides ultra-low latency solutions for industrial park services, and enables industrial digital transformation.

The overall solution of ZTE NodeEngine solution is shown in the following figure:

The NodeEngine solution based on the integration of 5G base stations adopts ZTE's new generation oIT BBU equipment ZXRAN V9200, with multi-band, flexible capacity configuration, convenient networking, small size (only 2U height) and easy maintenance, and so on. Furthermore, it has the strong ability of IT capability expansion since only additional VGC general processor board is required for NodeEngine deployment.

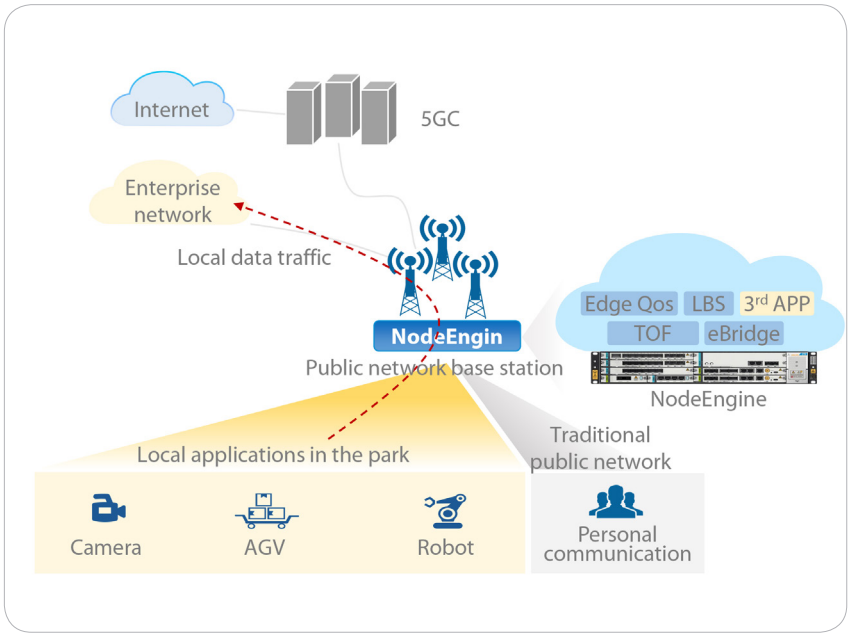
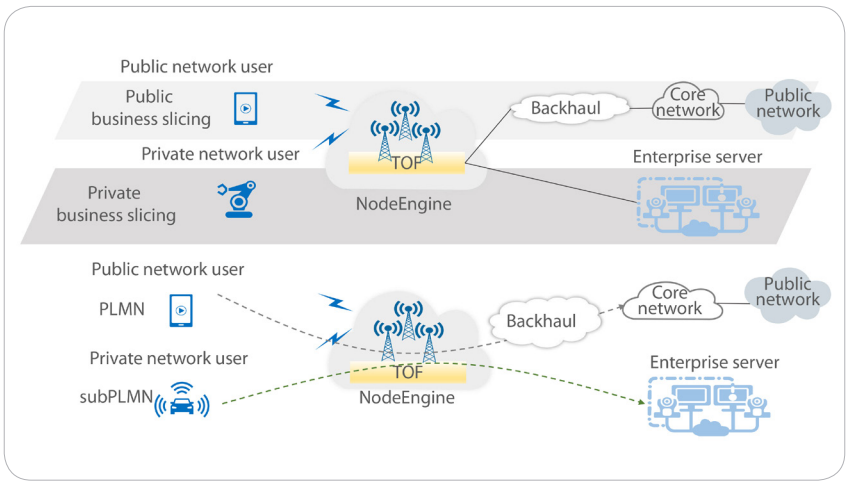


Figure 3-1 NodeEngine solution

Service Isolation and Guarantee

For the intelligent industrial park network, there are two different kinds of businesses, one is over the private network, and the other over the public mobile network and Internet. The industrial park private network requires higher network security, including authorized visiting and the isolation of private network from the public network. Business related to production of the industrial park is transmitted through the private network to ensure high isolation and security, such as data acquisition generated by sensors, control commands of industrial equipment, equipment monitoring information.

As the infrastructure of industrial network, 5G network provides solutions to meet the requirements of business isolation and network security for enterprises in different scenarios with application localization processing and end-to-end security isolation mechanism through network slicing. For example, different network numbers or slices are used to achieve isolation of various business in the industrial parks. NodeEngine can make a customized private network for an industrial park, to ensure that the local data is transmitted in the park and isolated from the public network.



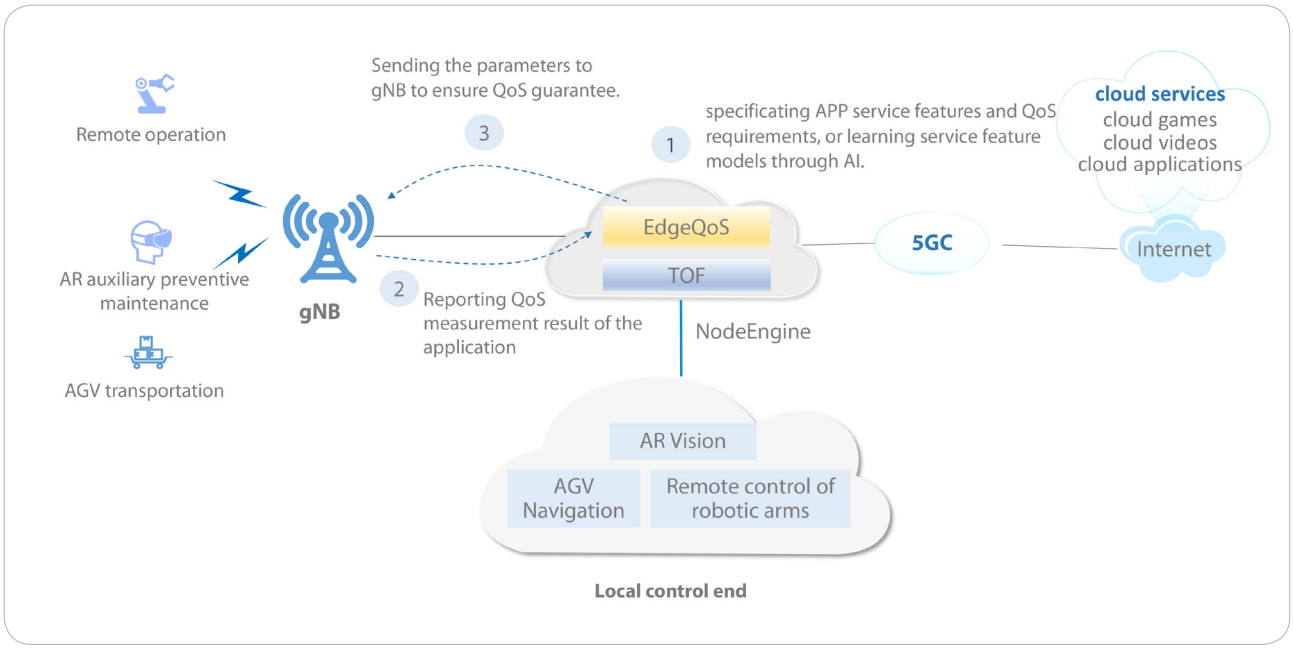
In the 5G base station-based industrial park scenarios, the local data traffic can be offloaded by NodeEngine at the side of base stations to ensure the local data transmitted within the park. Then it can isolate the services over the private network from the public mobile network for data security, based on different traffic offloading policies like subscribed PLMN IDs or network slices.

QoS Guarantee Capability for fine service

In the industrial parks, there are a large number of application scenarios that require high network performance, such as remote control, robot production, and AGV cooperative control. The relatively fixed bandwidth and stable time latency are required to support the proper operation of industrial devices.

The public 5G network cannot meet the requirements of industrial control because it is a best-effort network. To be suitable for industrial park scenarios, the network should match the characteristics of local applications.

In the 5G era, the access methods of devices and the kinds of applications are more than ever before. Considering the NodeEngine's position in the network, it is possible for it to offer near-to-real-time services for latency-sensitive, user-oriented, and service-oriented applications.

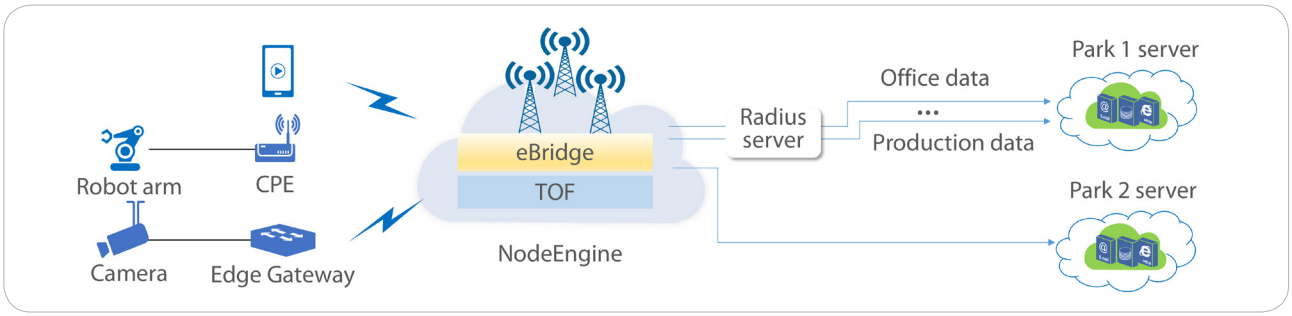


In industrial park application scenarios, especially remote control applications, edge QoS service offered by NodeEngine can detect the requirements and characteristics of the local applications, such as AR vision applications, AGV navigations and remote control applications, and the physical terminals which are connecting to one local application. Then it makes a QoS optimization for the radio network and sends the related parameters down to the base station, according to the QoS requirements of the application or the application characteristics through AI learning. The base station will make a corresponding resource allocation, to match the applications' requirements in the industrial scenarios.

Taking the remote control scenario as an example, the production scenes are captured by industrial cameras deployed in the dangerous workhouses and uploaded to the central control room through the video server system. Thus an operator can control remote cranes to load/unload cargos or excavators to make the field excavation in the central control room by the videos. In traditional scenarios, optical fibers are used between remote cameras and a central control room. But in 5G era, the optical fibers are expected to be replaced by 5G network for convenient deployment and management. However, 5G network is an uncertain and best-effort network, it is hard to detect the characteristics of applications. This weakness is obvious in video remote control scenarios. For the different strategies of scheduling and transmission are required for I frames with important information and P frames with minor information. Based on the Edge QoS of the NodeEngine, the corresponding scheduling of a base station can be supported to match the requirements of remote control applications, according to analysis of the video services.

Terminal Interworking Capability in the Park

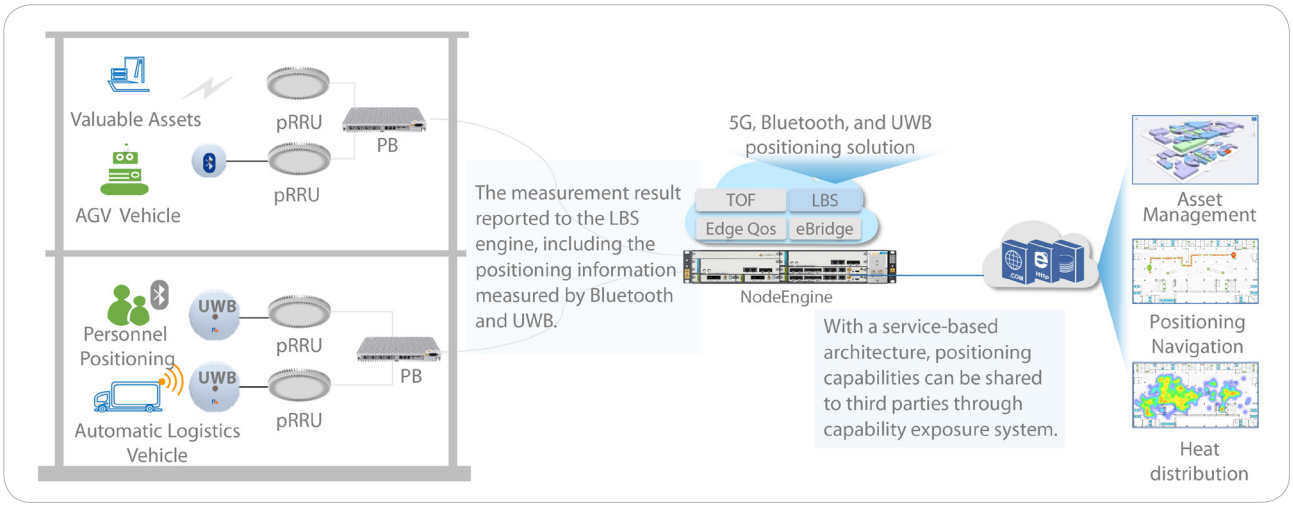
During the digital transformation of industrial parks, one of the primary problems is how to connect different kinds of devices in the park through 5G. The current solution is by CPEs or edge gateways to be connected with 5G network. And the second is how to make intra-communication between devices in the parks. eBridge service of NodeEngine is recommended to build a bridge through L2/L3 tunneling functions between the devices or devices and local application platform in the park. Then the network topology can be ignored and the original configuration and working mechanism are kept. In this way, it replaces the traditional cable network and makes a convenient intra-communication, which is active from a device to the local application platform or vice versa, and between devices in the park.



High-precision Positioning Capability

There are strong indoor/outdoor positioning requirements in industrial scenarios, such as robots cloudification, positioning and navigation of AGVs, positioning management of personnel in production areas and important assets. With the integration of 5G networks and traditional positioning technologies, indoor and outdoor high-precision positioning can be achieved in industrial park scenarios.

The combination of 5G network and satellite-based wireless positioning technologies is for outdoor positioning requirements. With the large bandwidth and low latency of 5G and dense deployment of pRRUs, the indoor positioning technologies, like Bluetooth and UWB, can be integrated with 5G QCell for multi-level indoor positioning solution. It improves the positioning accuracy and coverage area. Simultaneously, it facilitates the access of a large number of sensors to upload the massive data and location information of devices. The following figure shows the overall architecture:



Integrated with the Bluetooth Low Energy (BLE) and the Ultra Wide Band (UWB), 5G intelligent indoor QCell solution will share the cascading power supply capability and support the cascading deployment of non-3GPP positioning equipment. A loose coupling deployment mode is formed between the 5G indoor QCell and the other positioning base stations. Or a tight coupling mode is formed, simultaneously sharing cascading power supply and data channels with non-3GPP positioning equipment. These two modes can be deployed at the same time, to support 5G communication and high-precision positioning. And the cost of deployment and maintenance can be reduced.

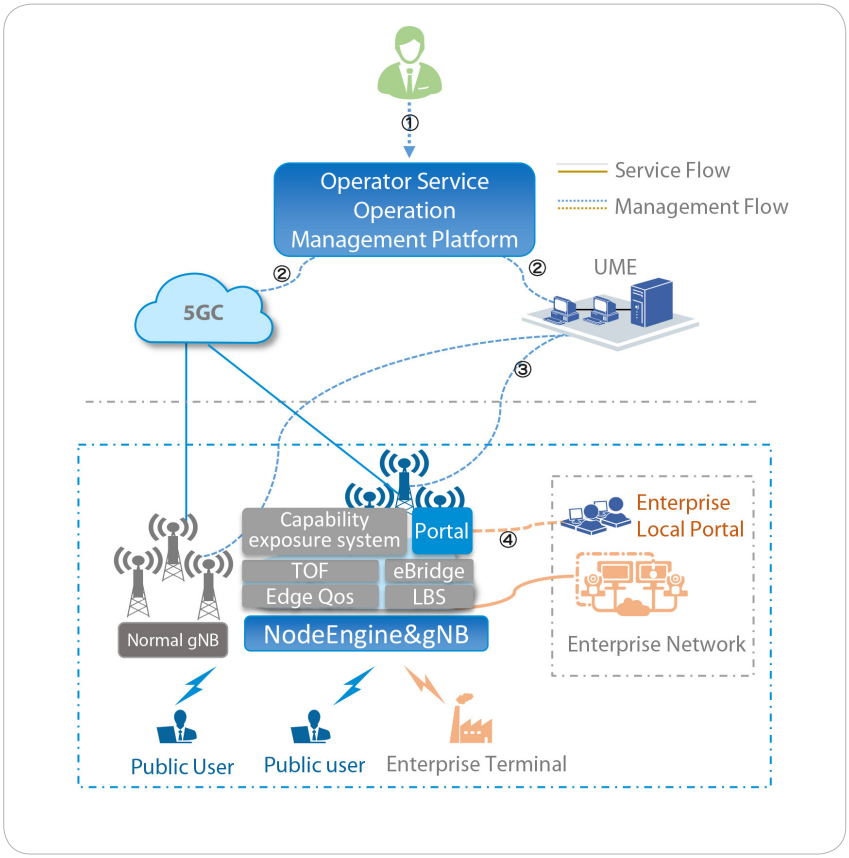
The indoor LBS service provided by NodeEngine integrates various positioning technologies. It can get the dynamic positioning results according to prediction of the moving path and moving direction. Furthermore, this service can be encapsulated and shared to the vertical applications though local API of NodeEngine. Then the third-party location applications provide diversified location-based services, with atomic capabilities such as real-time map information, track & navigation, electronic fence and target location.

The NodeEngine indoor LBS service meets the diversified positioning requirements in various industrial park scenarios with integrated 5G indoor key technologies.

Enterprise self-service management capability

There are personalized requirements for enterprises to use, adjust and maintain the private network of the park. That means they can modify offloading policies of the network at any time in accordance with the requirements of local applications, and simultaneously they can get the network quality and operational status of devices in real time.

So when a private network is to be deployed in an industrial park, there are two aspects to be considered. One is unified maintenance in the mobile network operated by the operator, and the other is self-service, self-maintenance and self-management for enterprises. ZTE's BTS-level NodeEngine solution offers self-service portal service for enterprises. The following figure shows the overall architecture:



An enterprise initiates the service subscription of the private network for his/her industrial park through the operator operation management platform. And the network capability services of 5G RAN and 5GC, like slice, can be subscribed through northbound interfaces in the network management system. Then the subscription will be sent to NodeEngine to activate the services automatically through southbound interface of UME, the unified O&M management system for base stations and NodeEngines.

The authorization and scope of self-service for the enterprise can be defined by the operator on demand through UME. And enterprises can make visual monitoring and management of the private network of the park, such as network operation status, network performance, network faults, traffic statistics, and edge gateways.

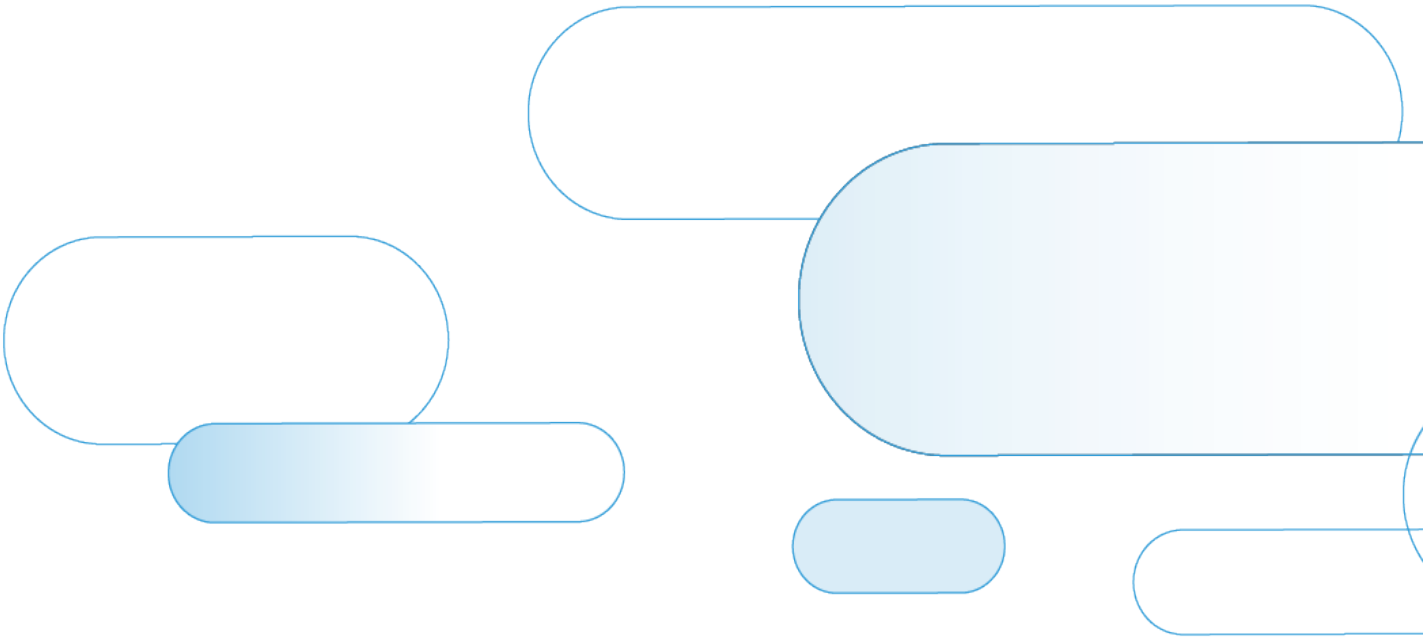
This self-service management is separated from the management of public mobile network to ensure the security of the network operation.

Summary

Overviewing the development history of the industrial society in the past 300 years, it is an essential process of continuous improvement of the production methods and optimization of the level of labor division and cooperation. A new era of digital economy is launched with large-scale manufacturing, retailing and circulating. The division of labor and cooperation is transforming from closed to open and from localization to globalization.

The trend of digital economy is bringing a lot of development opportunities for the transforming and upgrading of various vertical industries. The key of catching the opportunities is how to accelerate the digitalization for enterprises as soon as possible with a flexible and convenient solution. At the present stage, fast deployment of the private network and application is the fundament to achieve success. With success cases accumulating, it is accelerating the development of digital economy in the whole industry.

ZTE BTS-level NodeEngine solution is committed to forming local intelligent 2B nodes for operators and their enterprise customers, which is oriented to vertical applications and deployment on demand. And it is accelerating the incubation of 5g local applications and promoting the digital transformation process for industrial parks.



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