

China Unicom's 5G Private Network PLUS One Telco Cloud for 5G PNI-NPN Use Cases



TABLE OF CONTENTS

1. 5G High-Reliability Private Network Transforms Yanjiahe Coal Mine

- 1.1 Overview
- 1.2 Challenges
- 1.3 Solution
 - 1.3.1 Highly Reliable 5G Connectivity
 - 1.3.2 Safety Monitoring
- 1.4 Summary

2. 5G LAN Empowers the Full-Connection Factory of Changan Automobile

- 2.1 Overview
- 2.2 Challenges
- 2.3 Solution and Benefits
- 2.4 Summary and Follow-Up

3. Smart Warehousing for Midea's Kitchen Appliance Factory

- 3.1 Overview
- 3.2 Challenges
- 3.3 Solution and Benefits
- 3.4 Summary and Follow-Up

4. Automatic Provisioning of 5G Network Slices for Live Broadcast at Dadu Dongnan Art and Technology Festival

- 4.1 Overview
- 4.2 Challenges
- 4.3 Solution and Benefits
- 4.4 Summary and Follow-Up

5. World's First Commercial 5G MEC Private Network for Cross-Region Campuses

- 5.1 Overview
- 5.2 Challenges
- 5.3 Solution and Benefits
- 5.4 Summary and Follow-Up

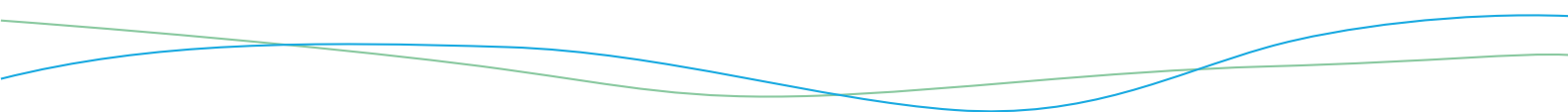
6. 5G Network Slicing + Edge Computing: Empowering Gree to Build 5G + Smart Factory

- 6.1 Overview
- 6.2 Challenges
- 6.3 Solution and Benefits
- 6.4 Summary and Follow-Up

7. 5G VPN Solution for Fudan University's Smart Campus

- 7.1 Overview
- 7.2 Challenges
- 7.3 Solution and Benefits
- 7.4 Summary and Follow-Up

8. China Unicom Guangdong and Huawei Completed DevOps-based Automatic NF Upgrades

- 8.1 Overview
 - 8.2 Challenges
 - 8.3 Solution and Benefits
 - 8.4 Summary and Follow-Up
- 



Preface

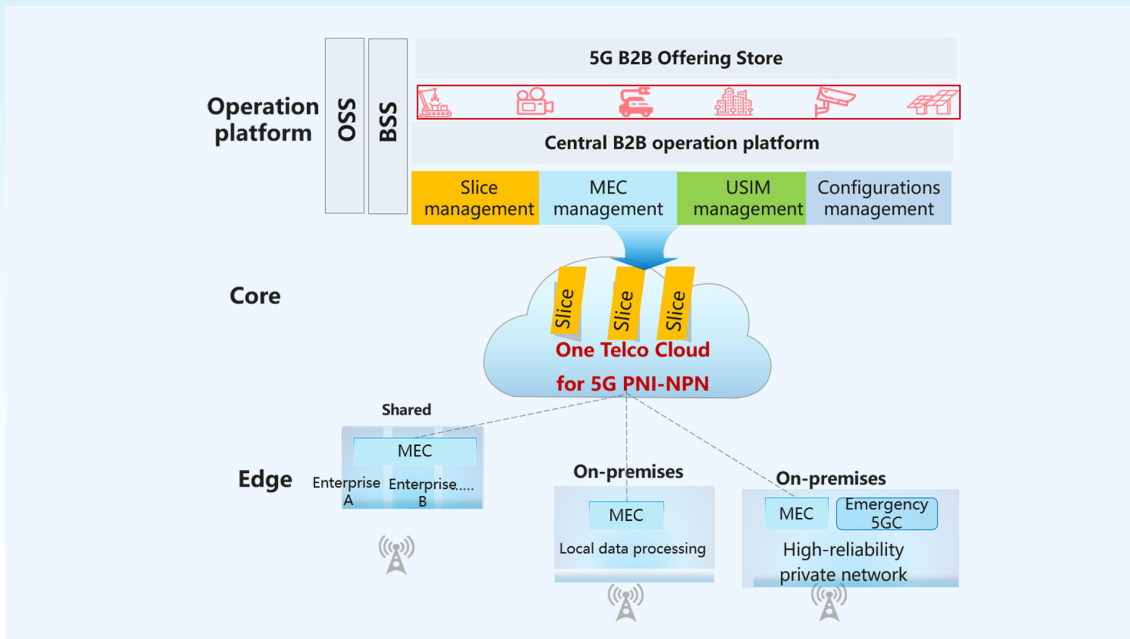
As an impacting force propelling industry digitalization, 5G is creating tremendous potential and great opportunities to redefine society as a whole. Along with its commercial scale-up worldwide, 5G now has found its first B2B residence in China, where it has been applied in a wide range of sectors, like the industrial Internet, smart port, smart mine, smart education, and smart healthcare. These successful applications would not be possible without the efforts of telecom operators. China Unicom is among those operators who recognize the value of 5G and taking the lead in tapping into the new 5G B2B market. To better utilize 5G to meet industry requirements, Huawei helped China Unicom reshape their network into One Telco Cloud for 5G PNI-NPN(hereinafter referred to as One Cloud) to coordinate all network nodes, facilitate O&M, and deliver benefits beyond those defined in the standards. This collection converges the benchmark use cases of the One Cloud. It can be used as a reference by 5G players, including operators and enterprises, and stimulate the innovation of 5G B2B applications.

Before diving into the use cases, we need to understand the architecture and technologies adopted by the One Cloud.

As 5G is penetrating industries, the industries are posing diverse and stringent requirements on the network. In addition, as 5G B2B is in full swing, the network can no longer fully meet requirements for B2B services:

- To provide a new service, O&M personnel need to centrally allocate numbers and then modify related data globally. Service provisioning overall could take as long as one or two months.
- Generally, three or four vendors are involved in each regional network, and the services provided by these vendors vary significantly. This hinders service innovation and vendor collaboration. Because of this, it is rather difficult to quickly roll out new B2B services across a country.
- Slice provisioning is complex and also takes a long time: Interfaces must be customized, and networks must be interworked by region. On average, it takes two months to provision a slice for each region.

The One Cloud perfectly addressed these issues. With a well-designed architecture, One Cloud enables B2B services to be provided in just one click, delivers a consistent service experience with a one-stop guarantee, and allows new services to be quickly replicated across regions.



One Cloud architecture

The solution's highlights:

- Fast slice provisioning

The solution's central operation platform integrates the OSS and BOSS and interworks them with MEC systems. With this as the basis, the platform streamlines the operation workflows for 5G private networks and enables a 5G Core slicing-based private line to be provisioned within just one day, both a first in the telecom industry.

- Fast network construction and service innovation

Under the One Cloud framework, Huawei and China Unicom have built up 5G Core networks in eight regions in China within just five months. Now, these networks are all serving industries stably and reliably. Huawei and China Unicom have also launched two innovation centers: one in Beijing and the other in Guangdong. With the two centers as bridges, the two hope to work with more and more industry partners to boost service innovation beyond the standards.

- Continuous Delivery and Continuous Testing (CDCT)

With CDCT, Huawei has helped China Unicom complete the industry's first automatic upgrade of commercial network functions, which took just a few hours. Such automation can help stabilize manufacturing activities in enterprises and facilitate the planning, construction, maintenance, and optimization of cloud-based networks.

Moreover, to better adapt to the continuously diversifying B2B services, One Cloud uses a series of cutting-edge technologies and provides viable solutions for different scenarios.

- Public Network Integrated Non-Public Network (PNI-NPN)
- By using Huawei's Kite-Like PNI-NPN solution and Rock-Solid Reliability solution, China Unicom's network can place MEC nodes close to the network edge (for example, in regional areas or even in enterprise campuses) and implements cross-DC N-way redundancy. In this way, the network can ensure service continuity even when network faults occur and extends connectivity across the network edge without the need for additional O&M personnel.

- 5G VPN

5G VPN technology enables customers to securely access enterprise private networks through the N19 interface between the UPFs in different regions, eliminating the need for conventional VPNs and the detour through the public network.

- Carrier-class reliability

The carrier-class reliability of industrial networks ensures high security for enterprise production activities.

- Efficient industrial networking

Network switching capabilities are moved to the network edge, so that industrial networks with a simple architecture can easily be set up whenever required.

- Simplified O&M

The network edge can be easily and quickly deployed, and its O&M does not require additional personnel. Enterprises can even enjoy self-service O&M.

- Tailored E2E solutions

Connectivity, computing, and applications can be flexibly combined to create baseline solutions for typical service scenarios, standardizing and accelerating 5G applications in various industries.

Thanks to One Cloud, all network nodes are coordinated for agile services across all network domains, network operations have become simpler and more flexible than ever, and benefits beyond those defined in standards are delivered to customers.

As of now, Huawei has helped China Unicom utilize One Cloud to build up over 800 5G industry private networks and launched more than 4000 5G commercial projects, 300 of which are flagship projects. The two have also effectively expanded the network edge, where more than 300 MEC edge nodes are already in place.

Furthermore, the new applications born out of One Cloud have promoted the development of everything involved in the 5G industry chain, from 5G standards to devices. This is just the beginning of what One Cloud will do for industries.

Huawei will continue to work with China Unicom and deliver larger, more powerful private networks to more enterprises, integrating 5G capabilities into key production activities and empowering more service scenarios. In addition, Huawei will help China Unicom explore better approaches to plan, construct, maintain, and optimize 5G private networks. All of these will contribute to a better One Cloud, and the One Cloud will unleash better value in 5G B2B.

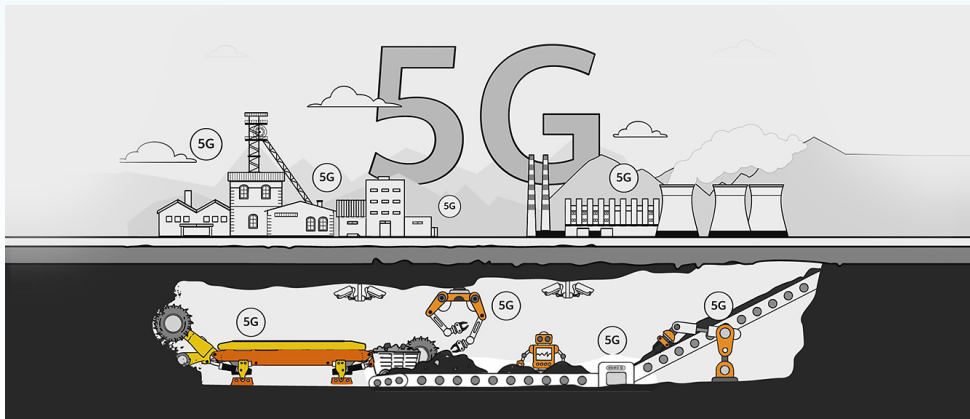
Now let's find out more about how One Cloud has redefined 5G B2B through the selected use cases.



5G High-Reliability Private Network Transforms Yanjiahe Coal Mine

01

Co-contributors: Yanjiahe Coal Mine of Shanxi Xiangning Coke Coal Group, China Unicom, China Unicom Industrial Internet (Shanxi), Huawei



1.1 Overview

5G is being used in more and more industries. The mining industry is no exception. After seeing the pivotal role 5G played in reshaping the mining industry, Yanjiahe Coal Mine started to build their 5G private network together with China Unicom Industrial Internet (Shanxi) and Huawei in October 2021. This network empowers all the major mining operations, eliminating the safety risks in previous manual production operations and promoting sustainable development of the industry.

The coal mine's 5G private network was built with the help of China Unicom's One Cloud. In this network, MEC nodes are placed in the mine. This placement enables all data to be processed locally, eliminating the need for data to be sent to China Unicom's public network. An on-premises emergency 5GC control plane has also been deployed in the mine. If the local forwarding plane fails to communicate with the public control plane, the emergency control plane can take over services immediately to ensure production continuity. In addition, by deploying explosion-proof base stations, mobile phones, and CPE underground, all the operations and devices there, like excavation and belt conveyors, can be efficiently monitored thanks to the highly reliable network connections. This ensures that any hazard could be efficiently identified.

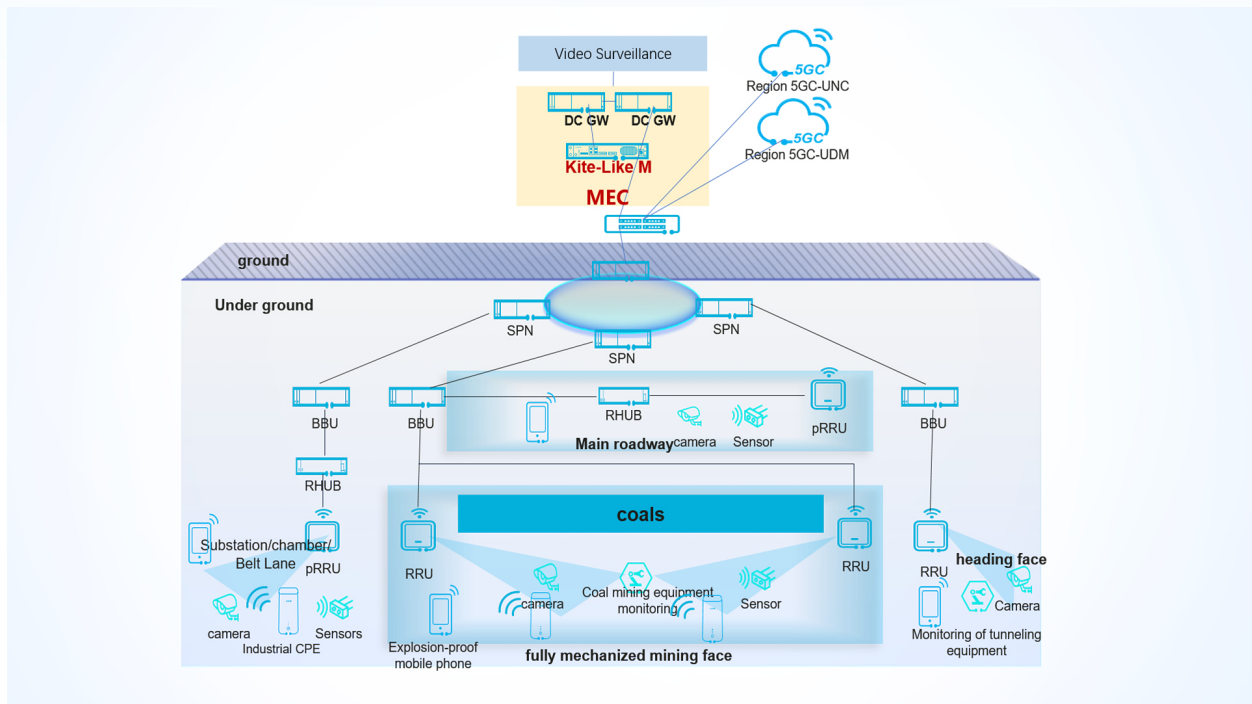
1.2 Challenges

Safety is critical in all mining operations. However, conventional mining is inadequate in this regard. Workers underground are exposed to a wide range of risks, from explosions to structural failures, gas poisoning, and extreme heat and humidity levels. In addition, it is essential but rather difficult to monitor underground devices and personnel. If any safety risk in mining, excavation, ventilation, electromechanical systems, drainage, power supply, and transportation is missed, severe accidents may occur. The underground environments are also very complex. For instance, the main haulage passage may span hundreds of kilometers, so it is also rather difficult to monitor the operating statuses of devices there, like the long conveyor belts. This makes routine equipment maintenance labor-intensive and time-consuming, crippling work efficiency.

1.3 Solution

1.3.1 Highly Reliable 5G Connectivity

Yanjiahe Coal Mine's 5G private network is connected to China Unicom's regional 5GC, the software of which has been updated to support highly reliable connectivity. The network covers mine areas both above and below ground and can transfer the videos captured underground to the equipment room aboveground for content analysis and risk identification. In addition, the MEC system deployed on this network provides not only UPFs, but also the emergency 5GC control plane. If the local forwarding plane fails to communicate with the regional 5GC, the emergency 5GC control plane can take over the processing of service requests and allow new access from various 5G devices.

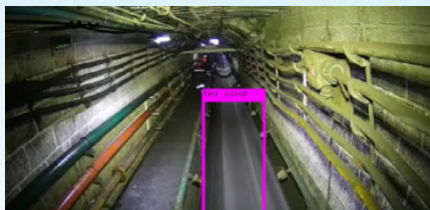


5G Kite-Like High-Reliability Network solution at Yanjiahe Coal Mine

1.3.2 Safety Monitoring

The network has replaced the optical fiber network previously used for the work and excavation in Yanjiahe Coal Mine. It can efficiently transfer the video streams captured by the 5G HD cameras installed around the tunneling devices, transportation transfer points, and vehicle yards, facilitating monitoring of mining devices and personnel. Once the video streams are transferred the network's video content analysis system can quickly identify safety risks on coal conveyor belts, like belt misalignment, large or stacked coal pieces on the belts, and personnel on the belts, and generates alarms so that these risks can be quickly resolved.

Belt tear monitoring



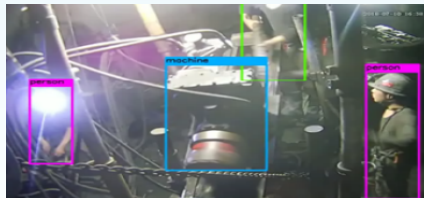
Belt deviation monitoring



Belt coal stacking monitoring



gas monitoring



Water Permeability Monitoring



Safety helmet monitoring



1.4 Summary

One Cloud can be used to build private networks that meet the stringent reliability requirements of high-value industries. This solution benefits both the operator and enterprises:

For China Unicom:

- The NFs on the public 5GC network can be fully utilized.
- The O&M approaches, teams, and experience are inherited, reducing OPEX.
- The 5G private network can be quickly set up. Only the user plane needs to be deployed and commissioned in enterprise campuses.

For enterprises:

- The 5G private networks stabilize production operations.
- Enterprise data is kept within campuses, ensuring high security and low latency.

5G LAN Empowers the Full-Connection Factory of Changan Automobile

02

Co-contributors: Chongqing Changan Automobile, China Unicom, China Unicom Chongqing, and Huawei

2.1 Overview

Chongqing Changan Automobile, a leading automobile company in China, is rewarded as the first smart manufacturing demonstration enterprise in the automobile industry. As the 5G momentum continues, it introduces the 5G industry private network to the automobile manufacturing and builds a 5G full-connection factory, speeding up its digital transformation. In this project, China Unicom's 5GtoB One Cloud innovation center, which features agile innovation, provides the 5GC control plane functions; and MEC is deployed at Changan Automobile campuses. 5G LAN is a major technical achievement of 5GtoB One Cloud. Through the 5G LAN-based Layer 2 networking, the industrial cameras and servers in multiple campuses can be centrally managed, meeting Changan Automobile's requirements for simplified networking and intensive management.

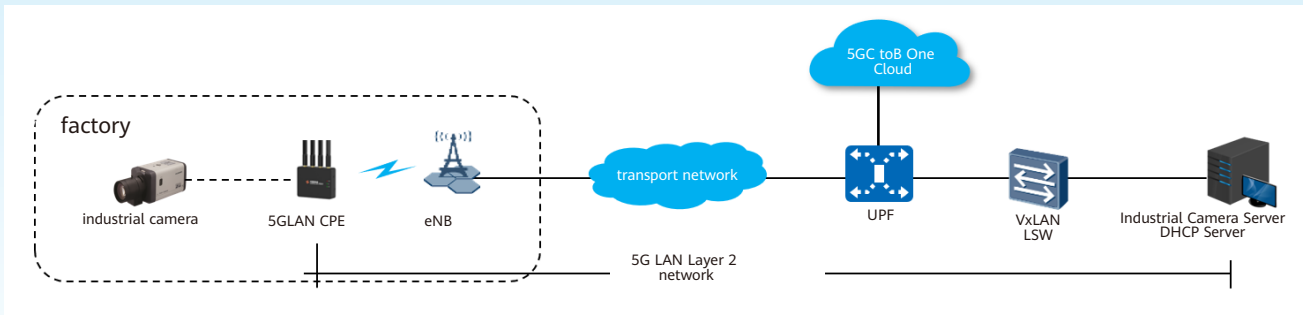
2.2 Challenges

Currently, the automobile industry faces challenges in digital transformation and carbon emission. Meanwhile, the competition in the automobile industry is becoming increasingly fierce as new competitors rise from Internet companies. As such, digital transformation is a must for automobile manufacturers, and the Industrial Internet is an important field where they can explore and conduct practices. They require new technologies for integrating 5M1E factors (Man, Machine, Material, Method, Environment, and Measurement) during the manufacturing, to obtain comprehensive production data and achieve intelligent decision-making. This helps to implement efficient, lean, flexible, and visualized production.

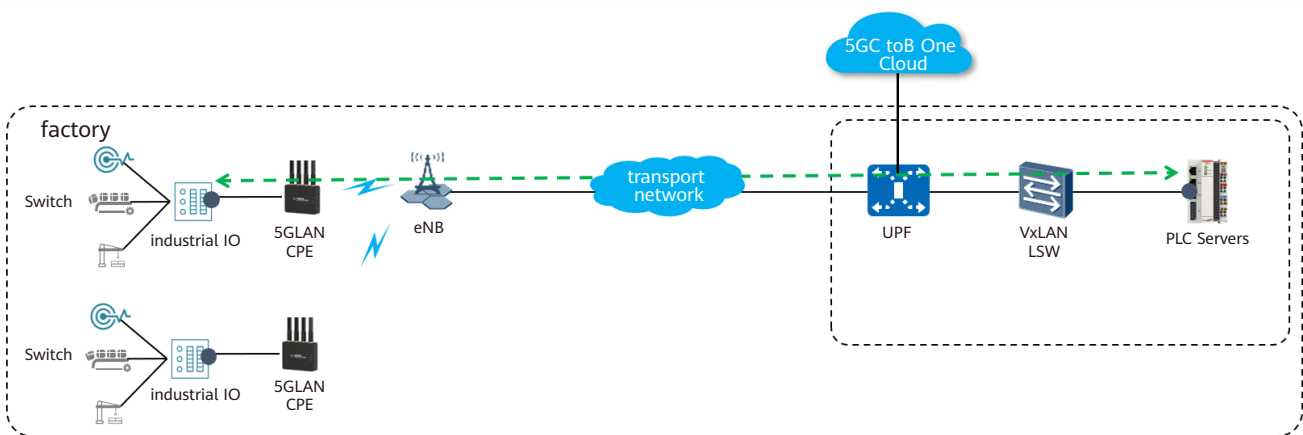
Changan Automobile launches new vehicle models at a quick pace and the production lines need to be adjusted frequently. However, it took a long time to rearrange wired devices on these production lines due to their complex cabling. The original 5G access can address the preceding problem but requires tunnel data configuration with the help of operators. The network deployment difficulties are then compounded, not satisfying Changan Automobile's requirements.

2.3 Solution and Benefits

Generally, machine vision and PLC devices communicate with each other at Layer 2. However, 5G supports only Layer 3 communication, and in this case, AR routers must be deployed to convert Layer 2 packets to Layer 3 packets, increasing device costs and delivery difficulties. To address such issues, Changan Automobile introduces the 5G LAN technology into its automobile production intranet. 5G LAN is a new feature introduced in 3GPP Release 16. It provides LAN and VPN services through 5G access, with no AR routers or tunnels required on the operator network, decoupling the operator network from enterprise networks. This simplifies the network structure and reduces deployment costs. In addition, network devices can directly communicate with each other at Layer 2 without AR routers; and intranet applications, network topologies, and configurations do not need to be changed. This relieves limitations on the devices, with no additional configuration and maintenance needed. The following figures show the 5G LAN application in Changan Automobile.



5G LAN enables industrial cameras to connect to the industrial camera server through the 5G network, so that they can collect product image data. The average latency between the cameras and the server reaches 15.42 ms. In addition to the industrial cameras, Changan Automobile also works on the interworking of industrial PLCs through 5G LAN and explores the possibilities of other edge interworking scenarios.



China Unicom's 5GCtoB One Cloud incubates the 5G LAN technology and enables agile innovation through DevOps. 5G LAN can then be quickly provisioned on the entire network. Its commercial use is six months ahead of the industry.

2.4 Summary and Follow-Up

With the continuous evolution of 3GPP specifications, 5G LAN, owing to its technical advantages, will be broadly applied in various fields such as industrial manufacturing, power grid, and campus network. Traditionally, to build a new campus, enterprises usually need to construct multiple physical networks, including the Wi-Fi network and wired LAN for production, and Wi-Fi network for office work. Such siloed networks are expensive and increase the burden on O&M. Now with 5G LAN, enterprises can construct a 5G physical network and divide it into multiple virtual local area networks (VLANs) used for production, management, and office work, respectively. In this way, one 5G network can meet multiple purposes, reducing network investment and O&M burden.

Smart Warehousing for Midea's Kitchen Appliance Factory

03

Co-contributors: Midea Group, China Unicom, China Unicom Guangdong, and Huawei

3.1 Overview

Midea Group Co., Ltd. (Midea) is a leading home appliance manufacturer, which ranks first in China and No. 288 in Fortune Global 500 list with its annual revenue of over USD 40 billion in 2020. Midea believes in humanizing-technology. Leveraging its 53-year expertise in robotic, automation, and manufacturing, the company provides solutions in smart home, building technology, industrial technology, robot and automation, and digital innovation sectors, and is serving about 400 million users in more than 200 countries and regions.

Since 2020, Midea has started its 5G journey to go digital and intelligent. It has joined forces with China Unicom and Huawei to build out an E2E "5G+MEC+Slicing+Intelligent Applications" solution based on the 5GctoB One Cloud. In the solution, the 5G network provides ultra-high bandwidth, low latency, and massive connection capabilities, and the multi-access edge computing (MEC) serves as an open platform that converges telecom network, computing, and storage capabilities. These made it possible to deploy diverse industrial applications to meet the key requirements of the manufacturing industry on real-time control, intelligent assistance, data aggregation and interoperation, security, and privacy protection, helping the industry go digital. Additionally, the slicing technology is used to build service-differentiated enterprise private networks for Midea, for secure isolation of different service flows. Based on China Unicom's 5G private network+MEC architecture, Midea deployed four platforms — converged positioning, 5G private network self-service, slice management, and intelligent analysis — for its factory to ensure connections and process services for over 300 access points in 16 scenarios. The solution uses outdoor and indoor micro base stations to ensure full 5G coverage, and uses the UPF deployed in the campus to process service data locally.

3.2 Challenges

As the competition in the home appliance industry grows fiercer and the warehousing costs spike up, a new warehousing and logistics mode with high efficiency and low costs will absolutely make Midea — a discrete manufacturing enterprise — more competitive.

Currently, the warehousing and logistics sector faces problems in efficiency, visualized management, and operation tracing, and an E2E digital transformation is demanded to address these issues. 5G converged positioning, leveraging China Unicom's 5GctoB One Cloud featuring intelligent O&M and private network, is an optimal way to do so. The One Cloud can be further used to build 5G full-connection factories, and address the pain points of the factory in terms of logistics management efficiency, flexible manufacturing costs, quality control, and production security.

3.3 Solution and Benefits

1. 5G converged positioning

The 5G+bluetooth angle of arrival (AOA) converged positioning technology used by China Unicom and Midea in the smart warehousing project is adopted in smart factories for the first time. This converged positioning solution uses China Unicom's 5G indoor base stations and MEC+VPN architecture, and the converged positioning engine deployed locally to provide the 5G+AOA converged positioning capability, and interconnect properly with Midea's production system. Specifically, the project uses an integrated 5G converged positioning platform, where the AOA data of terminal robots' uplink signals towards the base stations is collected and reported to the 5G converged positioning engine, which then calculates the real-time terminal positioning based on the data. The platform aggregates and processes the positioning data based on 5G, Wi-Fi 6, bluetooth low energy (BLE), and BeiDou realtime kinematic (RTK), so it can provide meter- and submeter-level positioning services for high- and low-density coverage, no matter indoor or outdoor. The positioning services are readily available to position multiple targets (vehicles, logistics containers, and personnel) in complicated factory or warehouse scenarios.



2. 5G remote O&M assistance



Dish washer manufacturing relies on automated equipment, for example, the dish racks need to be powder-coated using automated equipment, and the washer housing needs to be made out using sheet metal stamping equipment. However, the automated equipment is prone to faults — the total number of faults on various equipment can be up to 40 in just one day. At night or weekends, there are not many engineers on duty and the limited personnel resources have to deal with multiple tasks. Besides, there is no timely troubleshooting guidance

available for them. All these make it difficult for the one-duty engineers to quickly rectify the equipment faults. So once a fault occurs in such a case, the production will be suspended, which is often. But now, these issues can be solved by using 5G+AR. The 5G network guarantees a large bandwidth (uplink bandwidth > 10 Mbit/s) and low latency (< 50 ms) for the AR glasses. Wearing the glasses, onsite engineers can transmit equipment conditions to the remote maintenance engineers in barely real time. Though not onsite, the maintenance engineers can give assistance, based on the AR images, to help quickly rectify the faults. This approach also ensures that the data is recorded and uploaded in real time. In this way, a remote engineer can assist multiple onsite engineers, which brings 70% travel cost reduction and 40% training efficiency improvement.

3. 5G intelligent logistics robots



AGVs used to use Wi-Fi for communication. However, Wi-Fi signals may be interrupted by doors, walls, and loaded shelves, resulting in packet loss; and the connection may be down when the Wi-Fi access point changes. These problems will cause a 5-to-10-second pause to the AGVs, which in some cases requires even a manual restart to restore moving. Connecting the AGVs to the 5G private network helps solve the above Wi-Fi interference and disconnection issues. The 5G private network can accommodate a large number of intelligent AGVs for logistics operations, greatly reducing manpower cost.

4. Predictive maintenance platform

Midea has introduced KUKA robots using 5G to its kitchen factory for automated operations, but this does not eliminate fault risks. The robots are prone to faults — statistics show that the average fault duration of these robots is up to 36 hours in a year; and once the robots are faulty, the production has to suspend. To solve this problem, Midea has upgraded their robots using the 5G smart warehousing solution. The 5G wireless network, leveraging its massive connection and high reliability features, enables the robots to collect required data in real time. Additionally, with the wireless network, cables are greatly reduced, and operations can be more flexible. The solution also provides an intelligent predictive maintenance platform, which can analyze the data backhauled and provide predictive maintenance suggestions. Using this approach, the robot fault duration decreases by about 40%, and the loss caused by production suspension can be reduced by about USD 88,000 per product line each year.



3.4 Summary and Follow-Up

Based on 5G+private network and cloud-edge collaboration, this project can provide multiple application services, including converged positioning, AR remote assistance, industrial vision, massive device connection, and predictive maintenance. Thanks to the 5GctoB One Cloud featuring fast network construction, quick network access, as well as rapid innovative collaboration and replication, Midea is deploying the edge cloud to replicate this practice across its factories nationwide. With the "5G+MEC+Slicing+Intelligent Applications" solution deployed across all its factory campuses in China, Midea will definitely hold the lead in the digital transformation of the home appliance industry.

Automatic Provisioning of 5G Network Slices for Live Broadcast at Dadu Dongnan Art and Technology Festival

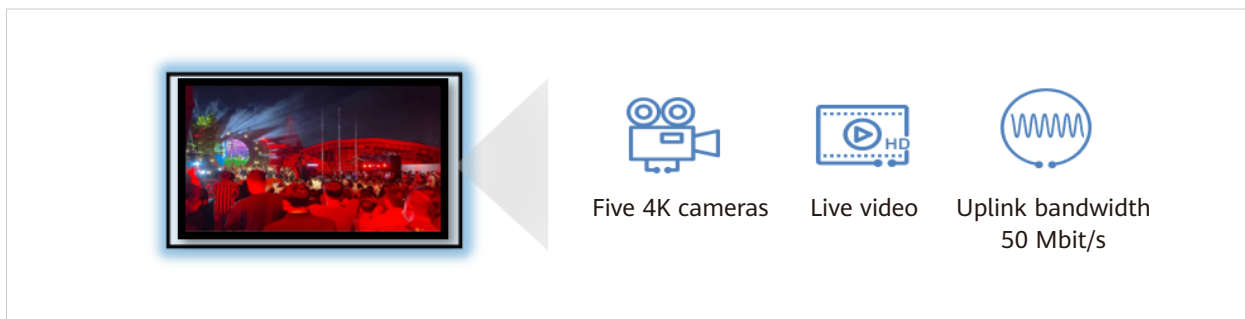
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Co-contributors: China Unicom Beijing, Huawei

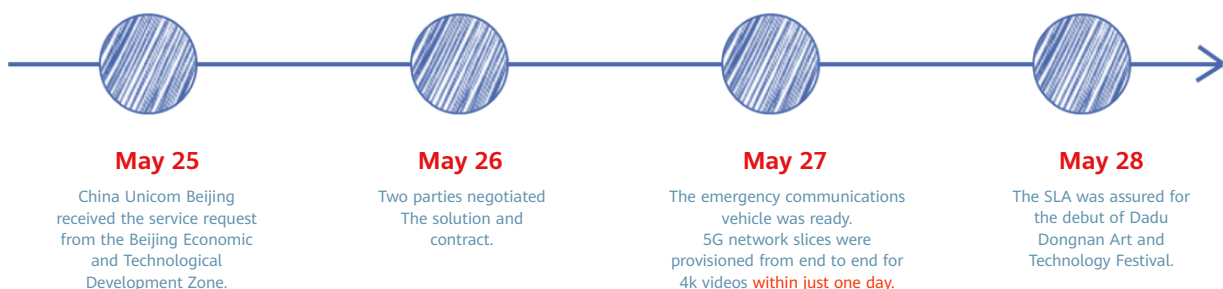
4.1 Overview

On the evening of May 28, 2021, the debut of Dadu Dongnan Art and Technology Festival was live broadcasted in the Beijing Economic and Technological Development Zone.

The successful broadcasting is inseparable from joint efforts of China Unicom Beijing and Huawei. The two utilized China Unicom's One Cloud and designed and provisioned 5G network slices within just one day, and fulfilled the SLA requirements for the 4K live videos, delivering an enjoyable experience to the festival audience.



4.2 Challenges



One-day slice provisioning above One Cloud

On May 25, 2021, China Unicom Beijing received an urgent service request from Beijing Economic Development Zone, that is, to provide network support for 4K live video broadcast of the Dadu Dongnan Art and Technology Festival, with an uplink bandwidth of 50 Mbit/s. In response to the requirements for high bandwidth and low latency, China Unicom Beijing attempted to create a network slice for the festival.

The attempt could be rather challenging under the conventional network architecture:

- Poor collaboration between platforms

The platforms for provisioning a slice are disjointed, and each slice provisioning step must be manually performed. In addition, the operations and maintenance of network slices are independent of each other.

- Slow slice provisioning

Network slice topologies need to be manually designed, and then slice services must be manually configured. Generally, as long as more than one month is required for provisioning a network slice.

- Lack of slice resource estimation

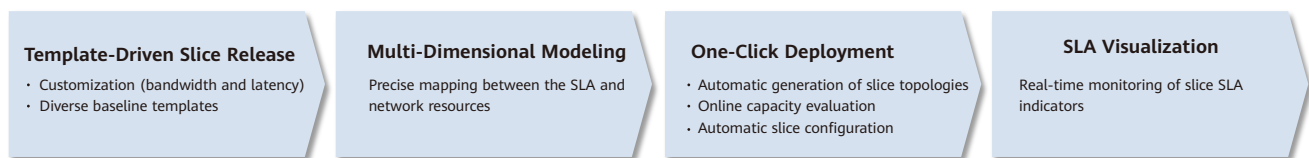
In the slice design process, the required service resources cannot be estimated and as a result, network resources are probably not enough for network slices, which may lead to slice provisioning failures.

- Inadequate SLA assurance

As network slices cannot be auto-provisioned from end to end, it is impossible to estimate network resources before the slice deployment; the slice SLA then cannot be ensured. After slices are deployed, the network status cannot be monitored in real time.

4.3 Solution and Benefits

The One Cloud enables network slices to be provisioned within just a few days, from slice offering release to subscription, provisioning, and operations.



E2E automatic slice provisioning

Template-driven, flexible slice release

Drawing on the delivery experience in diverse industry service scenarios, Huawei already developed more than 10 baseline network slice templates, which can be customized on demand, helping operators flexibly release slice offerings.

Multi-dimensional modeling and precise mapping

Enterprise tenants only need to enter their service requirements when purchasing network slices. Additionally, by means of One Cloud's unique multi-dimensional modeling, slice SLA indicator requirements can be converted into network resource requirements (such as VMs, storage resources, and microservices), achieving precise mapping between the SLA and network resources.

Dynamic orchestration and one-click deployment

One Cloud enables network topologies to be automatically generated based on resource requirements, with slice-relevant VNFs selected properly. It evaluates whether current network resources meet slice SLA requirements before slice deployment. What's more, network slices can be deployed in just one click, with all configurations automatically issued.

- Automatic generation of slice topologies

One Cloud automatically selects slice-relevant VNFs based on VNF attributes such as the location, slice type, and resource capacity. It then uses VNFD files to generate NSD files for slice resource deployment, and generates slice service configuration scripts.

- Automatic network resource estimation

One Cloud allows designing and orchestrating core network slices through the NSSMF, which estimates system resources for the slices. The NSSMF uses the SLA to evaluate VNF resources (such as the number of VMs) required by network slices and whether the available network resources are sufficient. If resources are insufficient, operators will be notified. This helps prevent slice provisioning failures.

- One-click network slice deployment

One Cloud supports one-click slice deployment and automatic slice instantiation, significantly improving the slice rollout efficiency. After a customer order is placed, the CSMF translates the service request into a slice SLA requirement and delivers it to the NSMF. The NSMF then breaks down the requirement for the AN, TN, and CN, and passes the requirement separately to the AN NSSMF, TN NSSMF, and CN NSSMF. Then NSSMF converts the SLA requirement into slice configuration data and delivers the data to VNFs in its network domain. The entire slice deployment process is automated, eliminating the need for manual collaboration between different platforms and vendors.

SLA visualization

One Cloud visualizes SLA fulfillment. Slice SLA indicators are intuitively displayed, facilitating slice status monitoring. For example, the number of slice users as well as uplink and downlink network rates are presented in real time. This ensures that SLA problems can be efficiently identified and handled.

4.4 Summary and Follow-Up

Based on the automatic slice configuration of One Cloud, China Unicom Beijing completed the E2E design and provisioning of 5G network slices within just one day, providing strong network assurance for the smooth online video live broadcast of the Dadu Dongnan Art and Technology Festival. Furthermore, One Cloud will implement timely fault detection as well as SLA visualization of more slice indicators, and provide 5G slice-based live video broadcasts with optimal technical support for real-time visualized monitoring and timely fault handling, expanding China Unicom's 5G slice footprint in vertical fields.

World's First Commercial 5G MEC Private Network for Cross-Region Campuses

05

Co-contributors: Ferrotec, China Unicom Zhejiang branch and Huawei

5.1 Overview

Ferrotec (China) is an internationally renowned supplier of semiconductor products and solutions. It has a total of 30 campuses in China. Among them, six campuses are scattered in Hangzhou, Quzhou, and Dongtai, spanning two provinces Zhejiang and Jiangsu. These campuses need to be interconnected to work together, the networks need to be managed in a unified manner, and customer self-service and cross-region service replication need to be enabled. However, the existing wired network is complex in structure, making O&M difficult; adding new devices and workshops often takes a long period of time, giving a low flexibility of production lines; workshops are not fully interconnected, causing information silos and unavailability of cross-system operations. Overall, the current campus network cannot fulfill requirements of flexible manufacturing and intelligent transformation.

Given that, China Unicom, Ferrotec, and Huawei jointly built the industry's first 5G+MEC private network that covers multiple campuses locating in different regions. This project connects cross-region campuses to a unified operations platform through 5GtoB One Cloud, enabling agile service deployment on edge MEC nodes and facilitating centralized and efficient operations.

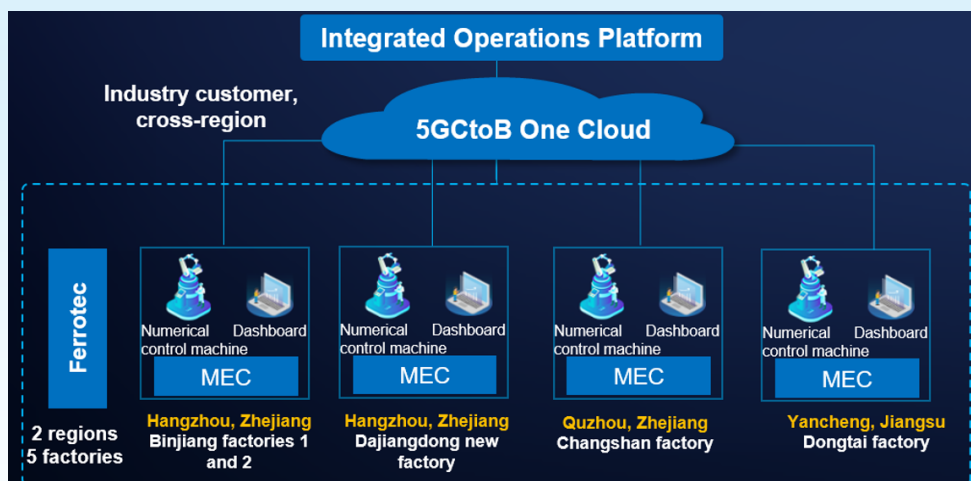
5.2 Challenges

Ferrotec faces two challenges on the way to digitalization:

1. The six campuses are scattered in different regions, which brings difficulties to campus interconnection and collaboration, unified network management, customer self-service, and cross-region service replication.
2. The existing wired network is difficult to cable, maintain, and upgrade. In addition, as the wired network structure is complex, workshops cannot be fully interconnected, and cross-system operations are not supported. These issues hinder campuses from realizing flexible, digital, and intelligent production.

5.3 Solution and Benefits

By considering the challenges faced by Ferrotec, China Unicom and Huawei built MEC resource pools for campuses in different locations and established an operations platform to schedule and manage these edge MEC nodes in a unified manner. In this way, services in one campus can be promptly replicated by other campuses.



Under this architecture, services can be rapidly provisioned to edge MEC nodes through the integrated operations platform, ensuring simultaneous rollout of services at multiple sites. In addition, the cross-region 5G industry private network helps Ferrotec standardize production operations and accelerate their digital and intelligent transformation, and campus networks can also be managed in a unified manner.

In this project, the two campuses in Binjiang, Hangzhou share the same MEC node, and dedicated MEC resource pools are deployed for the other three campuses. Service data (such as OT data collector traffic and dashboard access traffic) is locally processed on the MEC nodes. In addition, a 5G wireless network with adequate signal coverage is deployed to connect terminals. The network then can deliver both connectivity and compute capabilities to the terminals in a shortest route, thereby greatly shortening the latency from data collection, transmission, processing, to result feedback.

Besides, to ensure data security and completely isolate the traffic of industrial data collectors from that of other enterprise users, this project uses technologies such as 5QI and FlexE to slice the transport network to physically separate different OT and IT service flows at the timeslot level.

The cross-region 5G+MEC private network delivers low-latency and high-bandwidth wireless connections. This frees terminals from wired connections and solves problems such as difficult network deployment, O&M, and upgrade in industrial production, making flexible production possible. Moreover, the edge MEC nodes can leverage compute power and intelligence technologies to process data locally and in real time, which promotes the implementation of various industrial applications, such as digital workshop, AR-assisted maintenance, and unified AGV scheduling, greatly improving production efficiency and quality.

5.4 Summary and Follow-Up

This project adopts 5GctoB One Cloud and China Unicom's operations platform to enable fast rollout of campus services and connect 1,200 processing lathes and 300 industrial dashboards to the 5G network. As the MEC nodes support plug and play, its deployment duration is shortened from 2 weeks to 1.5 hours, and the time spent on the integration of machine data collectors and control applications is shortened from 2 weeks to 1 day.

Since the commercial use of 5G, 5G industrial applications are generally applied to a single campus. However, many large enterprises usually have more than one campuses across a country or even around the world. Coordinating these cross-region campuses and efficiently completing digital upgrade have become the top priority for these enterprises. 5GctoB One Cloud can help them address these issues.

5GctoB One Cloud provides an ideal solution to cross-region campus interconnection and collaboration. It enables fast service replication and unified network management, promoting the use of 5G in cross-region campuses and accelerating digital transformation of enterprises.

5G Network Slicing + Edge Computing: Empowering Gree to Build 5G + Smart Factory

06

Co-contributors: Gree Electric Appliances, Inc. Of Zhuhai, China Unicom and Huawei

6.1 Overview

Zhuhai Gree Electric Co., Ltd. is a global industrial manufacturing group, mainly engaged in household air conditioners, central air conditioners, intelligent devices, household appliances, air water heaters, mobile phones, refrigerators and other products. Gree owns nearly 90,000 employees scattering in 15 production bases and 6 renewable resource bases. Its products are sold in more than 160 countries and regions, providing professional services for 400 million users worldwide.

By leveraging the 5GtoB One Cloud, China Unicom, Gree, and Huawei took the lead in putting 5G E2E hard slicing into commercial use in the manufacturing industry in April 2021.

Gree and China Unicom won the bid for the industrial Internet innovation and development project of the Ministry of Industry and Information Technology (MIIT). In this project, Guangdong Unicom and Huawei jointly put forward the private network solution harnessing 5G + MEC edge cloud + network slicing after considering requirements of different manufacturing phases and in diverse smart manufacturing scenarios. In this solution, the dedicated MEC edge cloud is deployed close to users to physically isolate enterprise services from public user services, ensuring that enterprise data is not transmitted out of the campus and safeguarding production data. The 5G network slicing technology is used to implement E2E 5G hard slicing based on service scenarios. In this way, traffic of different services, such as video surveillance, paperless first article inspection (FAI), and AGV logistics, are streamed through dedicated channels.

6.2 Challenges

The household appliance manufacturing industry faces three challenges. First, traditional production lines lack flexibility. Currently, wired connections are used for communication, and some devices use Wi-Fi communication that is neither reliable nor stable. Second, the household appliance manufacturing industry is labor-intensive. Faced with challenges caused by gradually increased labor cost, it is important to enhance automation and digitalization capabilities and substitute repetitive manpower with machines and intelligent technologies. Third, the competition in the household appliance manufacturing industry is intensified. To control the cost and achieve a high yield rate, the production process needs continuous improvement.

6.3 Solution and Benefits

China Unicom helps Gree build a 5G+ smart factory, improving management efficiency by over 10% and operation accuracy by 30%, and reducing the response time of the control and scheduling system by 50% and annual production cost by over CNY 15 million.

What's more, 5G intelligent technologies are used to assist behavior analysis. Without 5G intelligent technologies, manufacturing operations cannot be monitored and managed. The production line layout depends on experience and lacks data support. 5G AI technologies monitor and help standardize manufacturing operations in real time. The collected big data is periodically analyzed to support production line reconstruction and optimization. In this way, the production line reconstruction period is reduced by 2 days, and the operation standardization is improved to 95%.



5G also empowers visual inspection during manufacturing of air conditioners, improving inspection efficiency and accuracy and reducing workload. During 5G-empowered inspection, photos of air conditioner appearance are automatically taken. Then, the inspection system invokes related device parameters and automatically generates inspection results. 5G intelligence helps reduce inspection cost by CNY 1.2 million per year and increase the inspection fulfillment rate to 100%.



In the past, logistics for line warehouses require manual intervention. 5G smart warehousing enables customers to use a cloud-based scheduling system to automatically plan AGV routes, manage AGV traffic, and monitor AGV activities, reducing the operation cost by CNY 1 million each year and improving the logistics scheduling efficiency by 15%.



During inspection in the past, workers must write down the results and cannot synchronize the data to the online system in real time. 5G paperless FAI facilitates inspection and improves inspection efficiency. In addition, inspection results can be synchronized to the online system in real time for analysis and comparison. With 5G paperless FAI, the cost of consumables is reduced by CNY 1.5 million annually, and the FAI accuracy reaches 100%.



The 5G hard slices leverage technologies such as RB reservation on the access network, FlexE on the transport network, and dedicated UPF to allocate bandwidth for dedicated services in different scenarios. In this case, the latency of transmitting data from a 5G device to Gree campus network is reduced by 55% (from 20 ms to 9 ms). The hard slices effectively ensure the independence, security, and stability of campus services.

During onsite service verification, the 5G hard slicing technology ensured that the uplink bandwidth reaches 60 Mbit/s for video surveillance in Gree. During the packet injection test (160M), the bandwidth was stable at about 60 Mbit/s, and the onsite video was clear and smooth without frame freezing. The onsite verification results meet the expectation.

6.4 Summary and Follow-Up

By harnessing the 5GtoB One Cloud, China Unicom builds a unified operations platform and takes the lead in streamlining the CSNF/NSMF on the live network, realizing automatic orchestration of access, transport, and core network resources, and deploying network slices at one click. In the Gree project, E2E network slices can be automatically provisioned in days and quickly replicated to 150 production lines.

In the future, to achieve large-scale replication of the 5GtoB innovation projects, China Unicom will continue collaborating with enterprises to develop solutions applicable to different scenarios, using the unified operations platform to manage scripts for deploying private networks and network slices, and inspiring 5G innovation across the country.

5G VPN Solution for Fudan University's Smart Campus

07

Co-contributors: Fudan University, China Unicom Shanghai branch and Huawei

7.1 Overview

With the development of next-generation information technology, such as big data, 5G, and virtual reality (VR), colleges and universities are entering a critical period of digital transformation and posing higher requirements on information infrastructure to construct digital campuses. Fudan University, a top university in China, has built up the first cross-domain and cross-region campus network in China through collaboration with China Unicom and Huawei. The campus network deeply converges the 5G network and traditional campus network and is the first one fully covered by the operator's network.

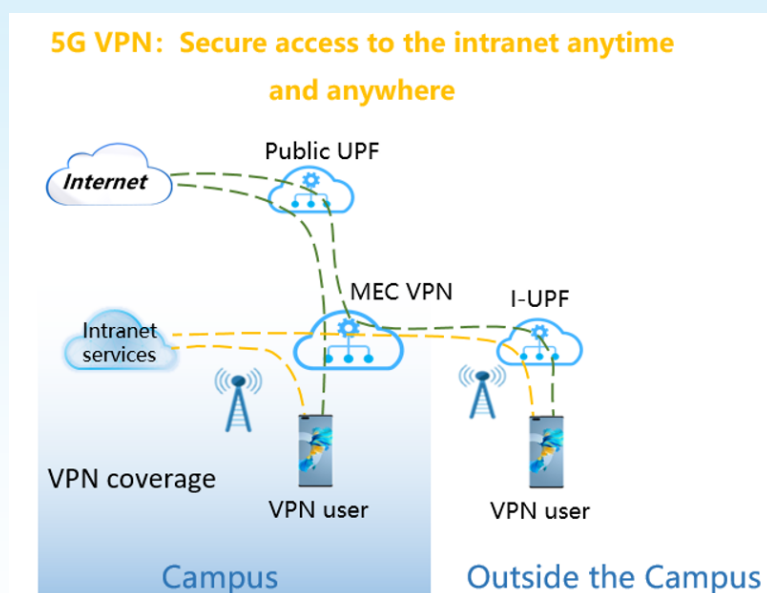


7.2 Challenges

Traditional campus networks mostly use WLANs or optical broadband. Teachers and students access the networks through Wi-Fi or wired connections. When outside campuses, they need to use VPN dial-up to connect to campus networks. VPN access has low security, unsatisfactory bandwidth, and long latency, and can only support a limited number of users, resulting in poor user experience. In addition, it is capital- and time-demanding to deploy VPN gateways to allow campus intranet access from outside the campus. As the education industry is going digital and intelligent, campus network users expect to access campus networks at high speed anytime, anywhere. However, the traditional VPN access mode cannot meet the requirements.

7.3 Solution and Benefits

The 5G VPN solution, in compliance with 3GPP specifications, uses the uplink classifier (UL CL) function for local traffic distribution, allowing campus network users to simultaneously access the Internet and campus intranet services within campuses. The solution also goes beyond 3GPP specifications. When the users are roaming, the 5G VPN solution enables inter-city and inter-province node communication to backhaul the users' service data back to their campus network through the 5G campus VPN. In this way, the bearer load of campus WANs is reduced, the campus network users' ubiquitous access requirements are met, and user experience is improved.



To implement Internet local break-out (LBO), the operators in the home and roaming areas should coordinate to perform relevant configuration on the core network in roaming areas to allow network address translation for roaming users. Therefore, before constructing a campus network, operators need to consider cross-city and cross-province network deployment.

China Unicom and Huawei have jointly built the One Cloud. With a well-designed architecture, One Cloud enables B2B services to be provided in just one click, delivers a consistent service experience with a one-stop guarantee, and allows new services to be quickly replicated across regions. One Cloud provides services across all network domains. It connects the UPFs in different provinces to build a national VPN and enable campus network users to use intranet services when roaming across provinces or cities in the country.

Benefits

1. Flexible traffic distribution for cross-province roaming services

When campus network users are concurrently accessing the Internet and intranet services via a campus network, the UL CL function defined in 3GPP specifications can be used to implement LBO for the users. However, the service data backhaul when the users are roaming across campuses, cities, or provinces are not defined in 3GPP specifications. The 5G VPN solution goes further. It uses a 5G campus VPN, instead of traditional VPNs, to enable campus network users to securely access campus intranet services and the Internet through mobile devices, no matter they are in the campus or a roaming area.

2. Better service experience at higher performance and lower costs

The 5G VPN solution uses a 5G campus VPN, other than the Internet, to backhaul users' roaming service data. This restricts service data to within the campus, and significantly enhances data security. Using the 5G VPN solution, customers do not need to deploy application-layer VPN devices, saving the costs for software authorization and maintenance. Traditional VPNs have performance bottlenecks when encrypting and decrypting data while data backhaul over the Internet has latency and packet loss. The 5G campus VPN, in contrast, provides better service experience through QoS. One project has proven that the 5G campus VPN can enable nearly two times the download rate compared with application-layer VPNs.

7.4 Summary and Follow-Up

To guarantee more secure, convenient, and flexible network access for users, the 5G VPN solution must be deployed on the One Cloud platform, which enables services to be provisioned upon rollout and replicated widely across regions.

As technology develops, government, education, and medical customers are more likely to use secure channels to access industry intranets. To meet customer needs, China Unicom has customized the 5G VPN solution to deliver secure, reliable, and ultra-low latency services anytime, anywhere. Based on China Unicom's nationwide One Cloud network, the 5G VPN solution can be quickly deployed across the country to provide smart networks for campuses, governments, and healthcare institutions, accelerating their digital transformation.

China Unicom Guangdong and Huawei Completed DevOps-based Automatic NF Upgrades

08

Co-contributors: China Unicom, Huawei

8.1 Overview

5G B2B services have penetrated a wide range of sectors, like industrial Internet, autonomous driving, and smart city. These outcomes bring the B2B market onto a fast track, deeply changing the way we live and the way the society develops. The conventional NF upgrade with complicated process and long duration no longer fulfills the agile and fast rollout required by massive 5G applications. Automatic NF upgrade is at the core of the One Cloud for 5G B2B services. China Unicom and Huawei have dived into the discussions and carried out innovative practices, aiming to automate the telecom network and O&M system. The Continuous Integration Continuous Delivery (CI/CD), driving such large-scale automation, helps reshape the O&M concept and the partnership between operators and vendors, as well as helps deploy cutting-edge automatic workflow engines. With the vision of building a future-oriented telecom network, the One Cloud enables the large-scale and E2E rise in efficiency, so as to implement fast service provisioning and simplified O&M with low costs.

Under the One Cloud framework, Huawei has helped China Unicom complete the world's first automatic upgrade of 5GC commercial NFs based on the iMaster MAE-CN workflow engine, bringing quality 5G services for subscribers. The upgrade process is automated and provided in a consistent manner with just one click, requiring no manual intervention. The successful practice lays a solid foundation for agile innovation and reliable rollout of 5G services and sets an excellent example for the autonomous driving of network applications.



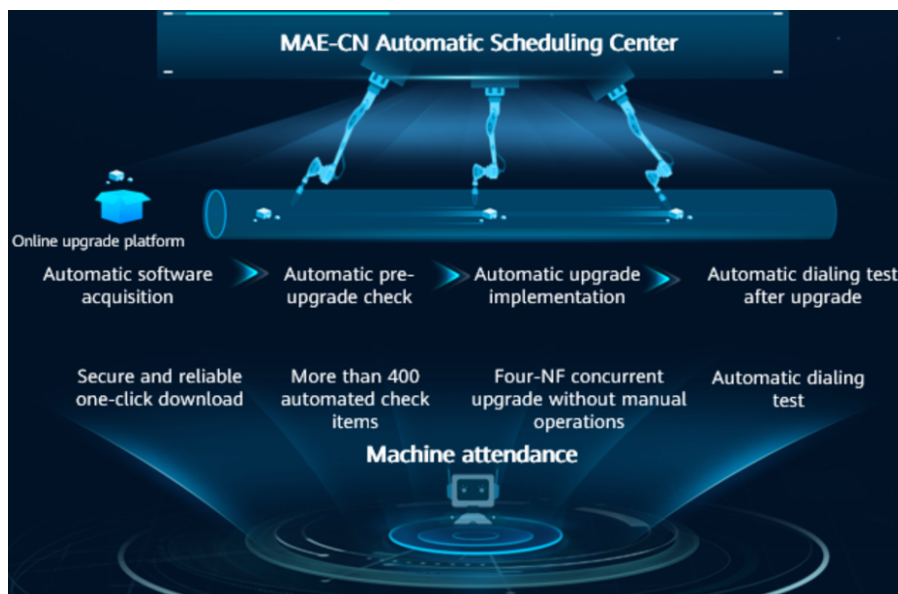
8.2 Challenges

With the rapid construction and large-scale commercial use of 5G all-cloud networks, the core network becomes more complex and vertical industries boom. Operators face many O&M challenges, such as high O&M complexity, serious network security risks, and slow service rollout. China Unicom's 5G core network in the South China region covers Guangdong province and four access provinces, including Fujian, Hunan, Hainan, and Guangxi. The network scale is large with more than 100 5G Core NFs involved, including level-1 NRFs, level-2 NRFs, NSSFs, AMFs, SMFs, CHFs, PCFs, UDMs, and UPFs. In each network upgrade, these NFs need to be divided in more than 20 batches. The whole upgrade takes more than three months. This is not fast service rollout. In addition, an NF upgrade involves many aspects, such as software acquisition, pre-upgrade preparation, upgrade operations, post-upgrade dialing tests, and upgrade attendance. More than 100 manual operations are required, which are prone to errors. This poses a big challenge for both O&M engineers and network security. Conventional upgrade methods can no longer meet the requirements for agile innovation and reliable service provisioning of 5G applications in various sectors of industries.

The 5G network architecture has evolved from centralized to distributed. NFs are becoming decoupled, and they are upgraded, expanded, and maintained separately. In this context, operators are ideally suited to refer to Internet vendors' use of CICD to make their networks more agile and efficient for small and secure changes, explore the value of cloud-based networks, and better serve tremendous industries. CICD enables telecom operators to become more competitive, helping them transform in technologies, processes, and corporate culture in the 5G era.

8.3 Solution and Benefits

To resolve the problems in conventional upgrades and further accelerate the large-scale commercial use of 5G applications, the South China Region Operations Center of China Unicom Guangdong Branch and Huawei Cloud Core Network Product Line have set up a joint work group with DevOps introduced. The two sides jointly formulated the automatic upgrade standards, secure software download mechanism, and software version management mechanism, to flexibly schedule resources based on the Huawei iMaster MAE-CN workflow orchestration engine.



Leading Technical Solution

- **Zero manual breakpoints, reducing manual misoperations:** 27 manual breakpoints are removed through flexible scheduling by the workflow orchestration engine, automating the full-process core network upgrade. One-click download of software packages, automatic risk check, and automatic upgrade operations are implemented on a unified WebUI. The number of man-machine interactions is reduced from over 100 to 10, greatly reducing risks caused by manual misoperations. During an upgrade, the intelligent machine-assisted system is used to automatically monitor and compare various metric items and alarms, identify exceptions in advance, and take corresponding measures to prevent network faults from escalating. In addition, a rollback can be performed with manual intervention if an exception occurs, which supports one-click suspension and ensures reliable upgrade results.
- **4-NF concurrent upgrade, improving O&M efficiency:** Four NFs can be concurrently upgraded. In the conventional mode, one person upgrades one NF in one operation time window. The upgrade in a region requires more than 20 batch operations for three months. However, iMaster MAE-CN enables four NFs to be upgraded concurrently in one operation time window. The upgrade in a region requires only eight batch operations for one month, ensuring the agile rollout of 5G applications.

Leading O&M

The project uses the iMaster MAE-CN workflow orchestration engine to change the conventional way of upgrading NFs and standardize as well as automate repetitive and high-risk operations. The entire upgrade process implements one-click automatic scheduling with manual breakpoints removed. All upgrade operations are automatically performed without manual intervention. The transformation from manual operations to automatic O&M lays a solid foundation for agile innovation and reliable rollout of 5G core networks.

Leading Project Achievement

The South China Region Operations Center of China Unicom Guangdong and Huawei Cloud Core Network Product Line successfully completed the automatic upgrade of commercial 5G core network NFs based on the iMaster MAE-CN workflow orchestration engine, which marks the world's first verification in this regard. So far, China Unicom Guangdong has implemented automatic upgrade of 5GC commercial NFs with the help of the Huawei iMaster MAE-CN workflow. Moreover, the project introduces the capacity for concurrently upgrading multiple NFs, which greatly improves the upgrade efficiency and ensures the agile rollout of 5G applications.

Leading Cooperation

China Unicom and Huawei have cooperated in the upgrade and O&M. The two sides participate in the end-to-end process of automatic upgrade through tight coupling, from network and process to collaboration, providing excellent examples for the industry.

8.4 Summary and Follow-Up

The digital-intelligent network O&M transformation cannot be achieved overnight. It requires the joint exploration and efforts of the entire industry. The success of China Unicom Guangdong and Huawei's automatic upgrade project greatly improves the reliability and efficiency of 5G core network O&M. It provides valuable practical experience and technical reserves for the industry. However, this is only the first step of China Unicom's digital-intelligent O&M transformation. In the future, China Unicom will work with Huawei to carry out joint innovations in gray upgrade, automated testing, automatic capacity expansion, and intelligent O&M, explore and consolidate O&M processes and activities, and continuously optimize the way to cooperate. Moreover, we will further apply and promote the project achievements, continuously build leading competitiveness, and build an industry model.