IP Network eBook Series

CloudCampus 3.0 Solution

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Preface

Author Introduction

Suqin Gu: Serves as documentation engineer for Huawei campus switches. After joining Huawei in 2006, Ms. Gu worked on software development and maintenance for Huawei data communications products until 2014. Since then, Ms. Gu has been dedicated to documentation development for Huawei campus switches. She has made significant contributions to developing the "All About Switches" series of articles and *Huawei Cloud Managed Campus Network Solution Deployment Guide*.

About This Book

This book begins by describing the challenges and typical characteristics of campus networks with the advent of the cloud era. Following this, the book explains what makes Huawei's CloudCampus 3.0 Solution ideal for building future-proof campus networks in the cloud era. Specifically, the book details its overall architecture, product components, high-value features, key technologies, and use cases across sectors such as education, finance, retail, and

manufacturing. After reading this book, you will have a clear picture of the next-generation cloud campus network solution.

Intended Audience

This book is intended for mid- and senior-level enterprise managers and network planning engineers, as well as anyone with a general interest in campus network solutions.

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Chapter 1
Cloud Campus Network Overview

Abstract

With the advancement of digital technologies, digitalization is accelerating around the globe, with almost all industries currently undergoing digital transformation. This, in turn, makes cloudification the obvious choice for enterprises of all sizes. Against this backdrop, campus networks are advancing from the traditional PC era to the cloud era. This chapter explains the enterprise cloudification trends and challenges, before analyzing the typical characteristics of campus networks in the cloud era, and finally introducing the overall architecture of Huawei's CloudCampus Solution.

1.1 Campus Networks Are Moving from the PC Era to the Cloud Era

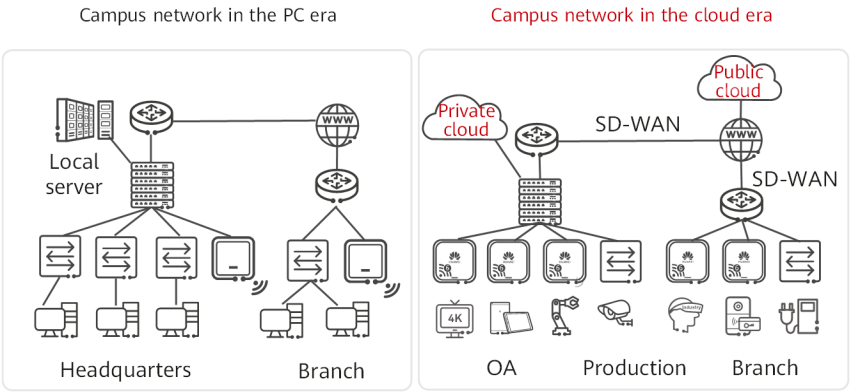
Over the past decade, cloud computing has changed enterprises' work and production beyond recognition. Countless services have been migrated from local servers to the cloud, empowering enterprises to quickly launch new services.

While electric power was the main driving force for industrialization, cloud is the key driver for digitalization.

According to consulting firm IDC, 80% of enterprises will accelerate their cloud migration by the end of 2021. At the same time, the multi-cloud access mode of the public, private, and hybrid clouds will serve as the preferred choice for these enterprises. As such, it is no surprise that enterprise campus networks are moving from the traditional PC era to the cloud era.

As shown in Figure 1-1, in the PC era, enterprise applications are mainly deployed on local servers. The campus network is primarily used to connect wired terminals for local office tasks, with the wireless network merely supplementing the wired network. However, with the advent of the cloud era, more applications are deployed on the cloud, and a growing number of terminals access the campus network wirelessly. Furthermore, the campus network is more than just part of the office infrastructure, extending out into production spaces and service areas. Alongside that, the roles of wireless and wired networks are reversed — the former becoming the primary network, and the latter the supplement.

Figure 1-1 Campus networks in the PC era and cloud era



The campus network in the PC era has clear boundaries and is generally confined to a physical or geographical scope. Cloudification of enterprise

services, however, breaks such boundaries, making the campus network borderless.

Specifically, enterprise services may be deployed on private or public clouds, and enterprise branches may be spread across multiple regions or countries. This expands the scope of the campus network to encompass interconnections between clouds and terminals, between clouds, between the headquarters and branches, and between branches. The result is a campus network that is borderless, sprawling across regions and countries.

1.2 Challenges Faced by Campus Networks in the Cloud Era

During the cloud migration process, enterprise IT systems have undergone great changes. Specifically, the number of mobile terminals has increased explosively, many of which do not have wired access capabilities. Furthermore, office applications, instant messaging, cloud computing, and other use cases are all carried as services on the Internet. Facing these changes, the campus network — serving as a bridge between terminals and clouds — needs to transform into a new architecture featuring multi-branch and multi-cloud interconnections.

Building a new digital campus network from the ground up is relatively easy. However, statistics show that 70% of enterprise campus networks are still built on traditional architectures, greatly hindering enterprises' digital transformation. Enterprises typically face the following four challenges during the cloudification of traditional networks:

- **Discontinuous wireless networking**: The wireless network merely supplements and extends the wired network, resulting in many network breakpoints and discontinuous wireless network coverage. This in turn leads to compromised services and low office and production efficiency.
- **Cross-domain fragile infrastructure**: Wide Area Networks (WANs), Local Area Networks (LANs), and Wireless Local Area Networks (WLANs) are independently planned and deployed, making it difficult to unify policies and centralize management between the headquarters and branches as well as between branches.

- **Cloud outpacing network**: Private lines are manually deployed, which is complex and time-consuming. This outdated approach cannot support fast service provisioning in the cloud era.
- **Trouble ticket-driven operations**: Network Operations and Maintenance (O&M) relies heavily on engineers' skills over long periods of time and lacks professional O&M tools. As a result, it is difficult to locate unexpected network problems, affecting the normal office and production operations of enterprises.

1.3 Typical Characteristics of Campus Networks in the Cloud Era

In the cloud era, enterprises need a new network architecture to support ever-changing digital services. Huawei believes that the campus network in the cloud era should have the following four typical characteristics:

- **Fully wireless access**: Wireless becomes the first choice, enabling access to the network anytime and anywhere to greatly improve office and production efficiency.
- **One global network**: Branches of all sizes around the globe are fully connected through one network.
- **Network-wide automation**: As network management is shifted from local to cloud, Software-Defined Networking (SDN) and Software-Defined Wide Area Network (SD-WAN) technologies are fully leveraged to automate management of the entire network.
- **Intelligent O&M**: Networks integrate big data-based intelligent analysis capabilities, thereby precisely locating potential network issues and providing predictive maintenance suggestions.

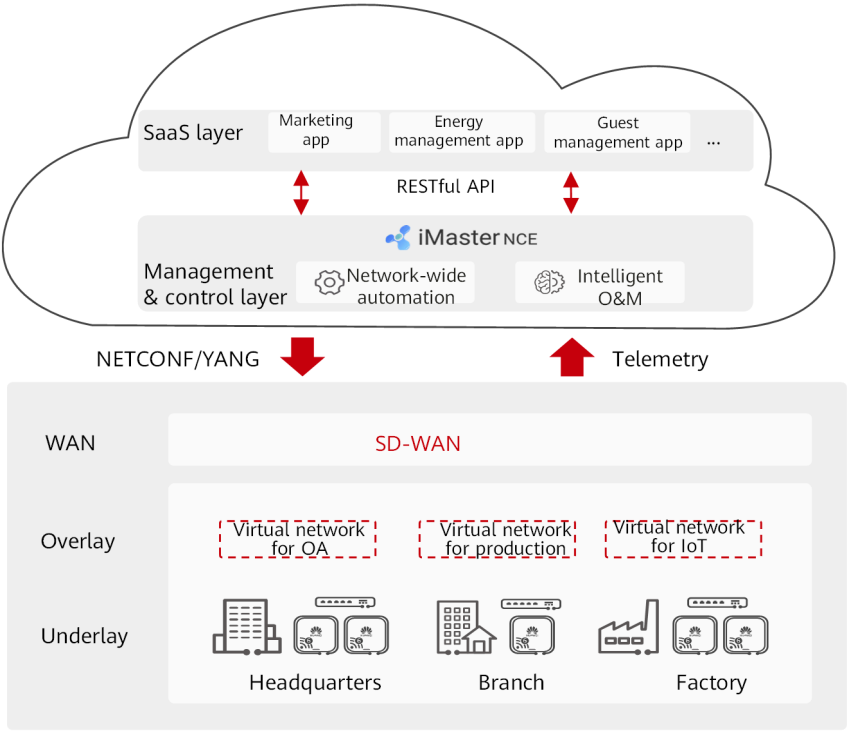
1.4 Overall Architecture of Huawei's CloudCampus Solution

To help address campus network challenges in the cloud era, Huawei released its CloudCampus Solution at the Huawei Industrial Digital Transformation Conference on March 25, 2021.

This future-proof solution draws on cutting-edge technologies, such as the Internet of Things (IoT), Wi-Fi 6, SDN, SD-WAN, cloud management, and Artificial Intelligence (AI), helping enterprises construct a future-proof campus network that features fully wireless access, one global network, cloud management, and intelligent O&M.

Figure 1-2 illustrates the overall architecture of Huawei's CloudCampus Solution.

Figure 1-2 Overall architecture of Huawei's CloudCampus Solution



With CloudCampus, enterprises benefit from ultrafast wireless, seamless communication and collaboration anytime, anywhere, agile provisioning of cloud applications, and guaranteed reliable application experience. In this way, organizations across sectors including government, education, healthcare, retail, transportation, and large enterprise can quickly seize new opportunities for digital transformation in the cloud era.

Table 1-1 describes the components and products integral to Huawei's CloudCampus Solution.

Table 1-1 CloudCampus components and products

Product/Component	Description
iMaster NCE-Campus	iMaster NCE-Campus is an intelligent management and control system for campus networks that can be deployed on premises or on the cloud. By fully leveraging cloud management and SDN technologies, iMaster NCE-Campus ensures consistent policies across WLANs, LANs, and WANs. It also automates management throughout the lifecycle, from planning, construction, O&M, and optimization, all the way to security.
iMaster NCE-CampusInsight	iMaster NCE-CampusInsight is an intelligent campus network analyzer that implements intelligent O&M. It uses telemetry to collect network metric data in seconds, enabling visualized experience for each user, in every application, at any moment. Drawing on AI and Machine Learning (ML) technologies, iMaster NCE-CampusInsight precisely identifies 85% of potential issues while efficiently locating faults and intelligently optimizing the network in minutes.
AirEngine Wi-Fi 6 series WLAN products	AirEngine series WLAN products comply with the Wi-Fi 6 (802.11ax) standard and fully leverage Huawei's innovative technologies, including 3D network planning and simulation, smart antenna, and smart roaming. These future-proof products are perfect for building a fully wireless campus network with ultrafast speeds, blind spot-free ubiquitous coverage, and interruption-free roaming.
CloudEngine S series campus switches	Huawei CloudEngine S series campus switches offer unique multi-GE options, hybrid optical-electrical access, and powerful 25GE/40GE/100GE ultra-broadband forwarding capabilities, helping to build an intelligent 10GE optical network for enterprises. Other differentiators include virtualization technology-enabled multi-purpose network, SDN-based automatic deployment and management, AI-powered accurate fault prediction, and zero-trust protection for the entire network through built-in security probes.

Product/Component	Description
NetEngine AR series routers	NetEngine AR series routers feature 5G ultra-broadband uplinks and boast a forwarding performance that's three times the industry average. Offering a wide range of features — such as support for SD-WAN, cloud management, Virtual Private Network (VPN), Multiprotocol Label Switching (MPLS), security, and voice — the series also excels at coping with uplink traffic surges and promoting diversified service development.
HiSec Insight	HiSec Insight (formerly CIS) uses the latest big data analytics and ML technologies to defend against advanced persistent threat (APT) attacks, as well as provide a comprehensive overview of the security situation on the entire network.
HiSecEngine series firewalls	HiSecEngine series firewalls integrate intelligent threat detection, handling, and O&M to provide comprehensive and integrated network security protection capabilities.

Chapter 2
High-Value Features of Huawei's CloudCampus Solution

Abstract

Campus network solutions have been evolving constantly over many years, and CloudCampus is the latest iteration of such evolution. What benefits can this solution bring to users? This chapter aims to answer this question from four perspectives: fully wireless access, one global network, cloud management, and intelligent O&M. After reading this chapter, you will have a clear understanding of how Huawei's CloudCampus Solution helps enterprises inspire further organizational innovation, maximize data value, improve O&M efficiency, and ensure stable and reliable services in the cloud era.

2.1 Fully Wireless Access

CloudCampus equips enterprises with a fully wireless network that features ubiquitous coverage, blind spot-free signals, interruption-free roaming, and continuous experience assurance. Such a premium wireless network is able to fully support bandwidth-hungry office applications such as Augmented Reality

(AR), Virtual Reality (VR), and 4K conferencing, as well as latency-sensitive production applications including Automated Optical Inspection (AOI) and warehouse Automated Guided Vehicles (AGVs).

In the cloud era, Wi-Fi is quickly becoming foundational to enterprise IT networks. However, conventional Wi-Fi technologies have various inherent issues and are therefore inadequate for meeting current and future application requirements. Two issues are especially prominent: The Wi-Fi network suffers from discontinuous coverage, and WLAN data transmission cannot achieve both long-distance Power over Ethernet (PoE) power supply and high-speed data transmission.

CloudCampus is specifically designed to address these issues. It draws on industry-leading Wi-Fi 6 technology and fully leverages innovations such as 3D network planning and simulation, smart antenna, and smart roaming to achieve high-density continuous coverage and offer industry-leading roaming performance.

- 3D network planning and simulation technology delivers full WLAN coverage without blind spots. This technology is perfect for all indoor and outdoor scenarios, and requires only 30 minutes to complete network planning for a campus with over 10,000 users. In addition, 3D signal simulation and roaming simulation visually present the planning effect, ensuring there are no WLAN coverage holes.
- Smart antennas are used to provide pervasive WLAN coverage, offering always-on signals for users while increasing the coverage range by 20%. The end result is more accurate WLAN coverage, smaller interference, and lower packet loss.
- Smart roaming technology ensures no interruptions during roaming. Through proactive roaming, this technology greatly improves the roaming success rate and enhances user experience.

To improve WLAN data transmission, Huawei is constantly finding new ways to enhance wireless network performance. In particular, Huawei has developed an innovative hybrid cable for high-quality transmission. The hybrid cable, combined with Huawei's hybrid optical-electrical switch, provides both PoE power supply at an ultra-long distance of 300 m and 10 Gbit/s data transmission for wireless Access Points (APs). What's more, the hybrid cable's lifespan is much longer than that of common cables. All of these traits make Huawei's hybrid cable the best choice for WLAN data transmission.

Table 2-1 compares the key performance metrics between hybrid cables and common cables. For example, hybrid cables offer 3x longer PoE distance, 10x higher transmission speeds, and 5x longer lifespan than common cables.

Table 2-1 Hybrid cables vs. common cables

Item	Hybrid Cable	Common Cable
PoE distance	300 m	100 m
Transmission speed	10 Gbps	1 Gbps
Cable lifespan	30 years	5-7 years

2.2 One Global Network

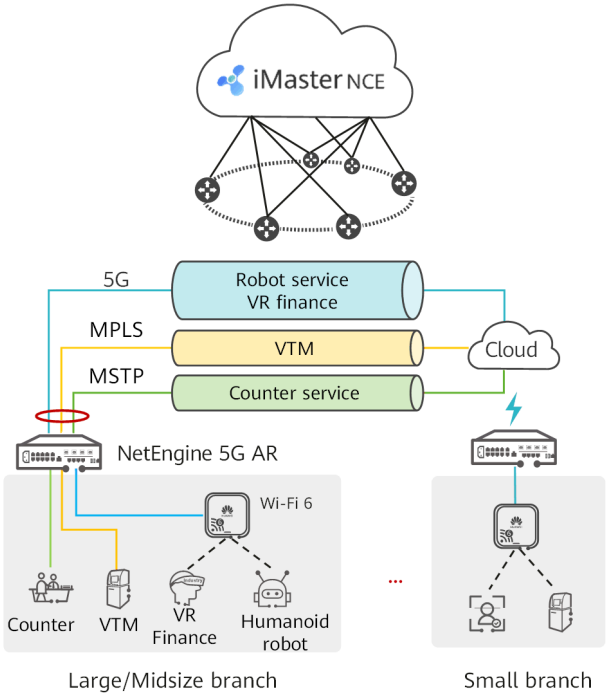
Today's enterprises face siloed construction and separate management between LANs and WANs. CloudCampus overcomes this by introducing the one global network feature. This feature enables one hop access to the cloud from any enterprise branch and in any network environment, and reduces private line interconnection costs by over 40%. It also greatly facilitates enterprise decision-making and collaboration across geographic locations.

With the widespread use of public clouds, a reliable and efficient data interconnection network is crucial. Designed for just this, CloudCampus is used to build a simple and efficient WAN. CloudCampus is built on 5G and SD-WAN technologies to enable high-speed interconnections between branches, the headquarters, and clouds, assisting enterprises to quickly expand services. CloudCampus also fully leverages multiple link types (e.g., 5G, Internet, and MPLS) and application-based intelligent traffic steering technology, to ensure optimal service experience.

Figure 2-1 illustrates SD-WAN enabled by CloudCampus. Multiple types of links, such as 5G and MPLS links, are available on the SD-WAN, through which enterprise headquarters and branches can flexibly connect as required. In addition, application-based intelligent traffic steering technology automates link

switchover for key applications upon poor link transmission quality, thereby ensuring optimal user experience.

Figure 2-1 SD-WAN networking



2.3 Cloud Management

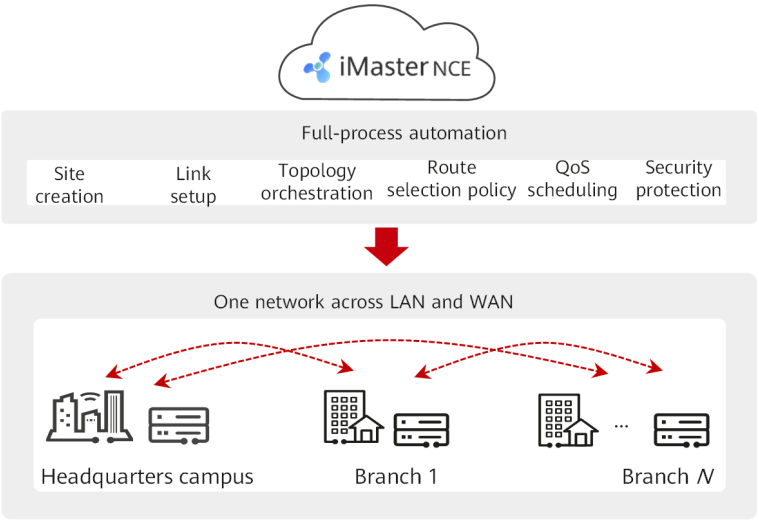
Today's enterprises expect service provisioning to be both rapid and agile. To this end, CloudCampus offers cloud management through iMaster NCE-Campus — an intelligent network management and control system. Specifically, enterprises can use one set of iMaster NCE-Campus to centrally manage WLANs, LANs, and

WANs, as well as to enable full-lifecycle automation, reducing O&M costs by 50%.

In the cloud era, campus network boundaries are blurred. In this context, CloudCampus draws on SDN technology to implement cloud management of the headquarters and branches. Solution highlights include:

- CloudCampus adopts a Virtual Private Cloud (VPC)-like model to quickly integrate with cloud applications and automate configuration upon cloud resource changes, implementing quick service deployment.
- Industry-leading Data Plane Verification (DPV) technology slashes the network policy configuration verification time from hours to minutes.
- iMaster NCE-Campus enables end-to-end service deployment with one click across campuses, WANs, and virtual gateways. As illustrated in Figure 2-2, Huawei iMaster NCE-Campus implements end-to-end automatic planning and configuration based on applications, terminals, users, and networks, including site creation, link setup, topology orchestration, route selection policy, QoS scheduling, and security protection.

Figure 2-2 Full-process automation

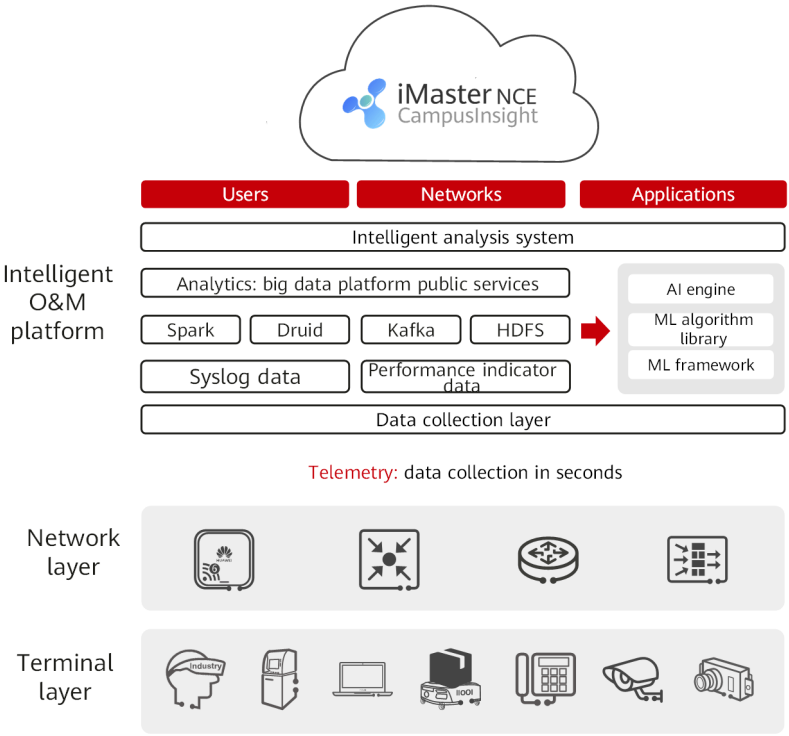


2.4 Intelligent O&M

As more enterprises go fully wireless and cloud-based, campus networks become too complex to be manually operated or maintained. CloudCampus combats this by introducing iMaster NCE-CampusInsight — an intelligent O&M platform that leverages big data and AI technologies to visualize user, network, and application experience. It revolutionizes O&M — which is traditionally passive — making it proactive and predictive. This helps enterprises avoid 85% of potential faults.

In this way, O&M staff are freed from traditional after-the-fact O&M, and instead can rest assured that their enterprise services will be stable and reliable. Figure 2-3 illustrates the intelligent O&M architecture enabled by CloudCampus.

Figure 2-3 Intelligent O&M architecture



iMaster NCE-CampusInsight offers a full picture of the user journey, helping quickly locate any faults. It visualizes user experience throughout the journey, from when the user accesses the network to when they disconnect. When a user access fault occurs, the protocol trace feature of iMaster NCE-CampusInsight quickly locates the fault and root cause and provides rectification suggestions accordingly, helping IT staff to quickly rectify the fault.

iMaster NCE-CampusInsight gives better insight into real-time network status by monitoring key indicators of devices. It collects and analyzes network data in real time and provides multi-dimensional network health evaluation, enabling IT personnel to easily understand the current network status and quality. Furthering to this, Packet Conservation Algorithm for Internet 2.0 (iPCA 2.0) can report real-time traffic and packet forwarding delay information of network devices to iMaster NCE-CampusInsight for intelligent calculation. Doing so helps quickly demarcate a fault that occurred. What's more, intelligent radio calibration technology uses big data analytics to optimize the wireless network quality and improve the wireless network performance.

iMaster NCE-CampusInsight also visualizes application experience by monitoring key application indicators. To elaborate, iMaster NCE-CampusInsight accurately identifies more than 1000 popular applications, collects multi-dimensional traffic statistics on applications, and displays the application statuses in real time to visualize application experience. Furthermore, enhanced media delivery index (eMDI) technology uses AI algorithms to periodically report the packet loss rate, out-of-order rate, and jitter rate of applications to iMaster NCE-CampusInsight. In this way, iMaster NCE-CampusInsight is able to detect application quality in real time, automatically identify poor-quality of experience (QoE) applications, and perform proactive O&M.

Chapter 3
Key Technologies in Huawei's CloudCampus Solution

Abstract

CloudCampus stands out with features such as fully wireless access, one global network, cloud management, and intelligent O&M, equipping enterprises of all sizes with future-proof campus networks for the cloud era. This chapter takes a look at the key technologies used by CloudCampus to achieve these four stand-out features.

3.1 Wi-Fi 6 Continuous Networking Enables Fully Wireless Access

Continuous networking means that users can access wireless networks anytime and anywhere, ensuring the entire wireless network provides seamless and continuous signal coverage when multiple APs are deployed simultaneously.

However, this can be difficult to achieve with conventional wireless networks, which have issues such as coverage holes, co-channel interference, and frequent

disconnections during roaming. Worse yet, wireless data transmission images are not clear due to excessively long cable reach and low transmission rate.

CloudCampus addresses these issues by using Wi-Fi 6 continuous networking technology to provide ubiquitous Wi-Fi 6 connections. It also adopts the hybrid cable and right-to-use (RTU) licensing to ensure long-distance and high-speed WLAN data transmission.

Wi-Fi 6 Continuous Networking

CloudCampus draws on unique 3D network planning and simulation, smart antenna, and smart roaming technologies to solve discontinuous coverage issues faced by conventional Wi-Fi networks. The end result is high-density continuous networking featuring zero coverage holes, zero blind spots, and uninterrupted handover during roaming, thereby delivering industry-leading roaming performance.

3D network planning and simulation

On a conventional Wi-Fi network, APs have to be manually commissioned during AP installation planning, often resulting in coverage holes. CloudCampus redefines this by introducing innovative 3D network planning and simulation technology, helping accurately determine AP installation positions while also visualizing network signal coverage through 3D signal simulation and roaming simulation. In this way, it is possible to quickly complete wireless network planning and ensure zero blind spots. Users can efficiently plan AP installation through 3D network planning and simulation and then install APs based on the simulation effect drawings. For added convenience and ease, such operations can also be carried out on a mobile application.

Smart antenna

In today's Wi-Fi network environments, three major challenges need to be overcome. The first challenge lies in providing coverage for stations (STAs) at the Wi-Fi network edge. Most APs use omnidirectional antennas with a limited antenna gain. Such APs can provide good services for short-distance STAs, but only low-throughput services or even no services for medium- and long-distance STAs. The second challenge is providing coverage around obstacles. It is difficult to provide high-throughput coverage services for STAs when there are obstacles in the way. The third challenge is high-density coverage, with multi-user

concurrency greatly increasing interference between links in high-density network environments. Despite downlink multi-user multiple-input multiple-output (MU-MIMO) introduced in 802.11ac, the downlink transmission throughput still needs to be increased.

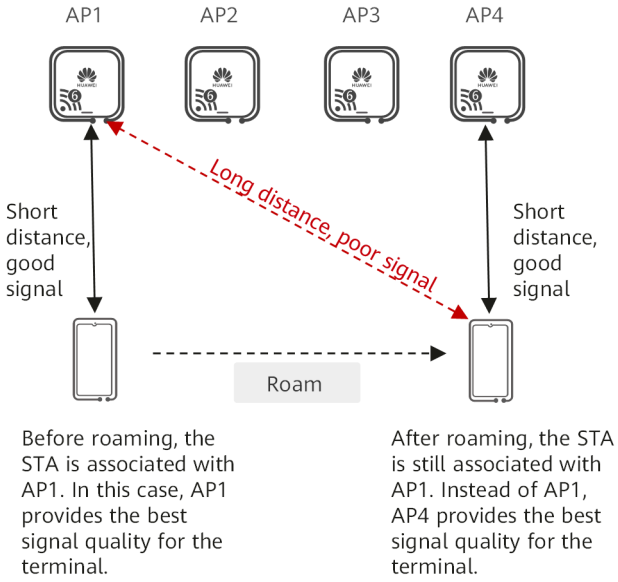
To address these challenges, Huawei innovatively developed the smart antenna technology. This technology introduces an antenna array consisting of multiple antennas. Antenna selection algorithms are used to select specific antenna elements for transmitting and receiving signals. Combining different antennas can form different signal transmission directions. In this way, optimal antennas are selected for STAs at different locations to improve received signal quality and system throughput as well as offer better coverage services.

In other words, Huawei's smart antenna technology can flexibly and dynamically adjust signal coverage directions based on user access locations, ensuring always-on signals for users. This technology also concentrates multiple signals into one direction, similar to how a searchlight tracks an object. Doing so achieves stronger and more focused signals, more efficient obstacle penetration, and longer coverage distance. Compared to traditional omnidirectional antennas, smart antennas increase the signal coverage distance by 20% and reduce signal interference by 15%, delivering far better performance. With these traits, smart antennas are especially suitable for wireless network environments with many office partitions and frequent STA mobility.

Smart roaming

Smart roaming is a process of collecting STA information and steering STAs to APs with better signals, thereby improving user experience when STAs are moving. As illustrated in Figure 3-1, if a STA does not quickly switch to an AP with better signal quality, it will suffer from poorer Wi-Fi signal quality and lower transmission rate.

Figure 3-1 STA roaming failure

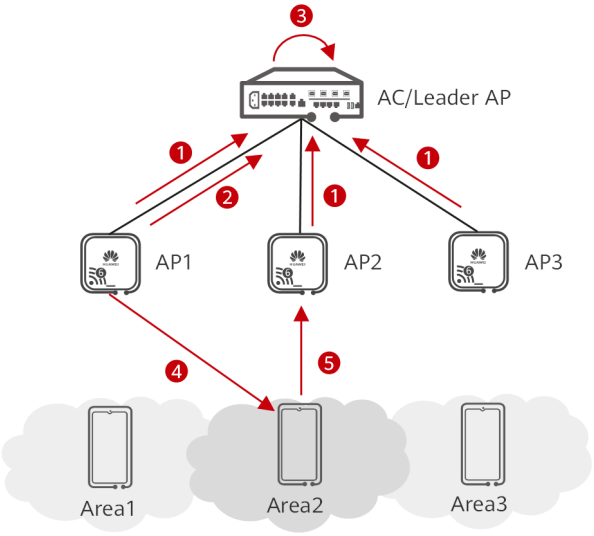


When a STA roams, smart roaming technology steers the STA to an AP with better signal quality. There are five steps involved, as illustrated in Figure 3-2.

1. All APs report the collected STA information to the wireless Access Controller (AC). (If no AC is available, an AP is automatically selected as the leader AP to take on the responsibility of the AC.) The AC then records information such as the neighboring APs of each STA and the corresponding signal strength.
2. AP1 reports STA signal information to the AC in real time.
3. When a STA moves from Area1 to Area2, the AC detects that the STA's signal strength is lower than the preset threshold and then determines that AP2 is the optimal AP for the STA to associate with.
4. The AC notifies AP1 that AP2 is the optimal AP for the STA. Then, AP1 forces the STA to go offline.

5. The STA then roams to the optimal AP2 to complete smart roaming and obtain better signal.

Figure 3-2 Smart roaming process



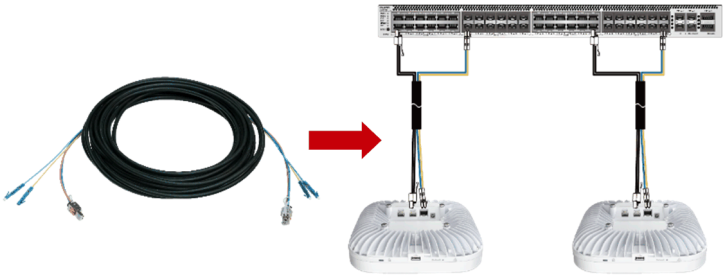
Wi-Fi 6 Data Transmission

When an AP connects to the campus network, an access switch generally provides PoE power for the AP through an Ethernet cable. However, the Ethernet cables generally cannot be used to supply power for distances over 100 m. In addition, the maximum transmission rate of a common Ethernet cable is only 1 Gbit/s, heavily restricting data transmission. To help overcome these two challenges, Huawei innovatively develops the industry's only hybrid cable.

As illustrated in Figure 3-3, a hybrid cable consists of optical fiber and copper cable, allowing it to provide both PoE power supply and high-speed data transmission for APs. The copper cable is used only for supplying power to APs from the switch, and does not transmit data. One end of the copper cable is connected to a multi-GE port on the switch, and the other end to the PoE_IN

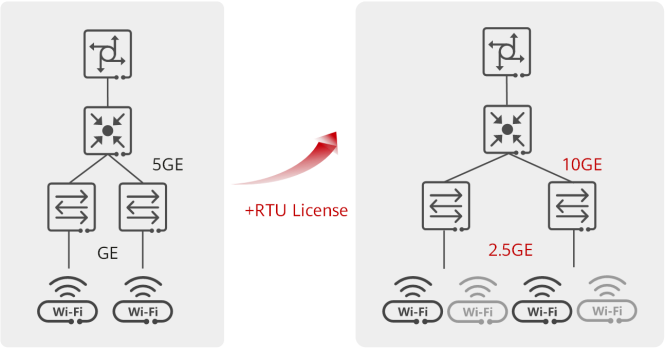
electrical port on an AP. The optical fiber is used for data transmission between a switch and APs, with one end connecting to the SFP+ Ethernet optical port on the switch, and the other end to the SFP+ Ethernet optical port on an AP.

Figure 3-3 Appearance and connection mode of a hybrid cable



Huawei also offers RTU licensing to upgrade AP spatial streams and port rates for Wi-Fi 6 data transmission. Instead of replacing hardware, customers only need to purchase RTU licenses, slashing Capital Expenditure (CAPEX) and bringing tangible benefits to enterprises. As illustrated in Figure 3-4, enterprise services currently require only GE wireless uplink ports and two AP spatial streams. With service upgrades, enterprises may need to upgrade to 2.5GE wireless uplink ports and increase to four AP spatial streams. In this case, enterprises can simply purchase RTU licenses, with no need to replace hardware devices.

Figure 3-4 Upgrading port rates with RTU licensing



3.2 SD-WAN Creates One Global Network

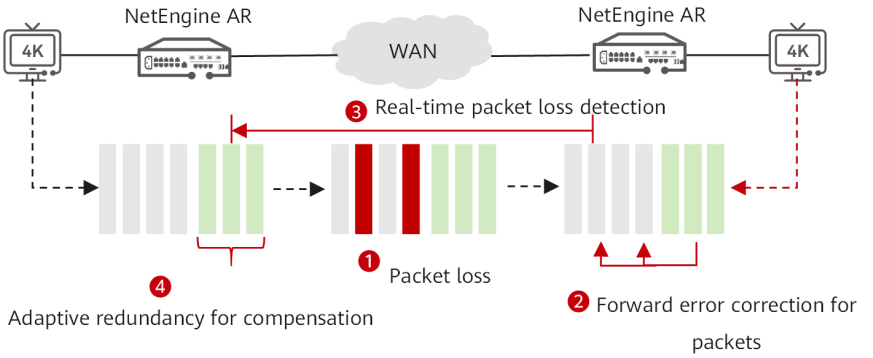
Enterprise applications are quickly migrating to the cloud, and they have varying requirements on bandwidth and link quality. For example, real-time video conferences have very low tolerance for packet loss, delay, and jitter on links. If packet loss occurs on a link, out-of-sync video and poor resolution may occur. Email and File Transfer Protocol (FTP) applications are insensitive to packet loss but require high bandwidth, so sufficient bandwidth must be available to transmit traffic of such applications as soon as possible. CloudCampus meets these expectations by creating one global network with SD-WAN. It provides optimal links for different applications, and also integrates Adaptive Forward Error Correction (A-FEC) and application-based intelligent traffic steering technologies to ensure optimal experience of key services.

A-FEC

A-FEC prevents continuous packet loss and ensures traffic transmission for key services by flexibly adding redundant packets at the transmit end. Figure 3-5 illustrates the A-FEC process. Upon detecting packet loss on the WAN, the

receive end performs Forward Error Correction (FEC) and adds packets to the location where packet loss occurred. At the same time, the receive end notifies the transmit end of packet loss on the network. Then, the transmit end performs adaptive redundancy to compensate for packet loss on the network. In this way, video quality is guaranteed, and video frame freezing or artifacts are prevented.

Figure 3-5 A-FEC process

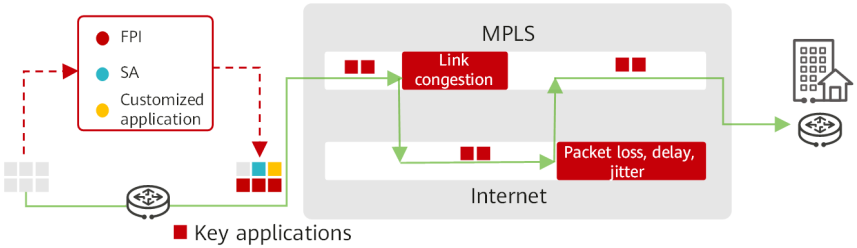


Application-based Intelligent Traffic Steering

Application-based intelligent traffic steering is a technology that is dedicated to achieving optimal experience of key applications. It draws on a dynamic multipath optimization mechanism to comprehensively optimize paths based on multiple key factors, such as application Service Level Agreements (SLAs), application priority, and bandwidth utilization. This helps achieve maximal bandwidth utilization without compromising experience of key applications. If multiple types of service packets are transmitted on the same link, this technology ensures that traffic of high-priority applications is preferentially processed upon link congestion, ensuring user experience of high-priority applications. In the case that voice, video, and file transfer services are carried simultaneously on the same MPLS link, if the link bandwidth is insufficient, the experience of the voice and video services is preferentially guaranteed.

Figure 3-6 illustrates how application-based intelligent traffic steering works. There are two links for users to access the external network: MPLS and Internet links, where the MPLS link has better quality than the Internet link. After the transmit end detects key applications through First Packet Identification (FPI) and Service Awareness (SA), traffic of such key applications is preferentially transmitted on the MPLS link. When the number of services increases and the device detects that the SLA of the MPLS link drops below the tolerable threshold and the MPLS link becomes congested, the device dynamically diverts the traffic of key applications to the Internet link that is available and also meets the SLA requirements. After a period of time, if packet loss, delay, or jitter occurs on the Internet link, key applications are then automatically switched back to the recovered MPLS link to ensure user experience of key applications.

Figure 3-6 Application-based intelligent traffic steering



3.3 Full-Process Automation Facilitates Cloud Management

Integral to CloudCampus, Huawei iMaster NCE-Campus automates campus network management from end to end. This includes policies such as application policies, terminal policies, and user policies, as well as automating network deployment and management.

In particular, CloudCampus can intelligently identify terminals and apply control technologies to facilitate automation of terminal policies, automate terminal

access, and ensure secure terminal access. DPV — another technology setting CloudCampus apart from its competitors — automates network deployment and management and minimizes the impact of network changes.

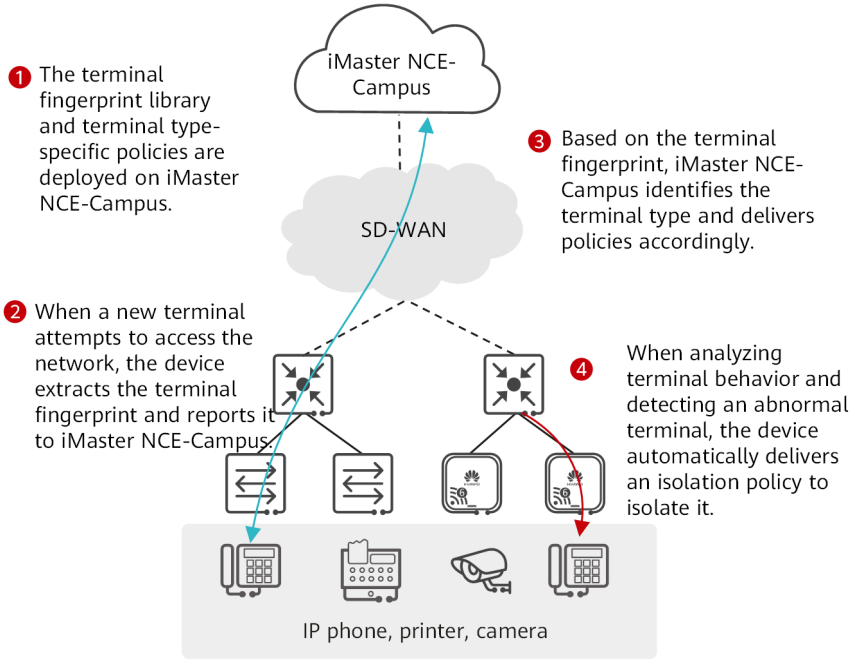
Intelligent Terminal Identification and Control

Figure 3-7 illustrates the intelligent terminal identification and control process. In this process, network O&M personnel have already deployed a terminal fingerprint library and type-specific policies for terminals on iMaster NCE-Campus.

When a terminal accesses the network through a device, the device automatically extracts the terminal fingerprint and reports it to iMaster NCE-Campus. iMaster NCE-Campus identifies the terminal type based on the terminal fingerprint and delivers a policy accordingly.

This method of access is more efficient than conventional solutions, and devices can detect terminal traffic in real time. As such, if terminal traffic is too heavy or the IP/MAC address of a terminal already exists while it is onboarding, the device automatically delivers an isolation policy to isolate the terminal. In addition, iMaster NCE-Campus intuitively displays the terminal access statuses and highlights abnormal terminals in red, helping maintenance personnel quickly identify and handle abnormal terminals to ensure secure terminal access.

Figure 3-7 Intelligent terminal identification and control process



DPV

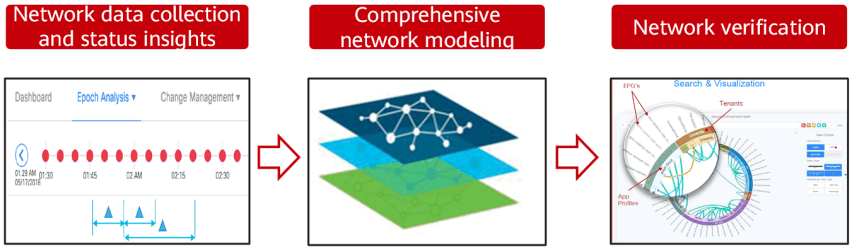
As shown in Figure 3-8, iMaster NCE-Campus uses protocols such as Simple Network Management Protocol (SNMP) to collect information from network elements (NEs) across the network, including the NE topology, configurations, routes, and table entries.

Based on such data, iMaster NCE-Campus comprehensively models the network, and uses this model to verify network expansion or reconstruction. This approach:

- Slashes the time it takes to verify network changes.
- Ensures a good outcome from network changes.
- Prevents network changes from causing faults.

The most notable DPV capabilities include snapshot management, subnet simulation, and access simulation. Snapshot management compares configuration files before and after a specific time point, and in doing so, checks whether the network configuration is abnormal, helping quickly locate faults. Subnet simulation verifies the connectivity of all paths on the network to prevent network changes from introducing connectivity faults. Finally, access simulation simulates user access and authorization to check whether user rights are correct and as expected when the user accesses the network.

Figure 3-8 DPV process



3.4 Big Data and AI Pave the Way for Intelligent O&M

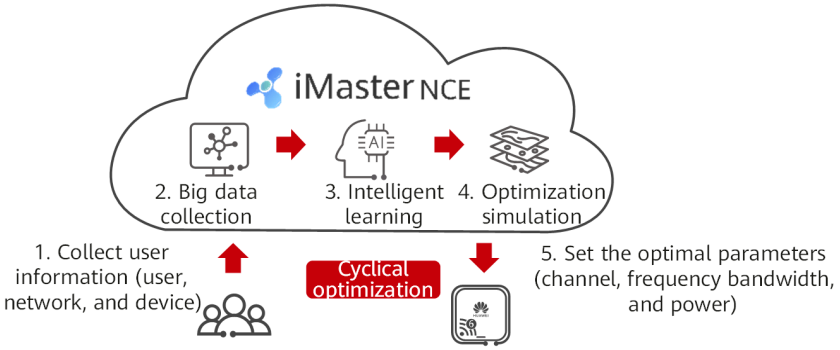
Network devices report information to iMaster NCE-CampusInsight in real time, including Key Performance Indicators (KPIs) as well as traffic and application data. iMaster NCE-CampusInsight uses AI and big data to analyze this data, intelligently optimizing the network, identifying potential network faults, and quickly demarcating faults as they occur. The end result is intelligent O&M.

Intelligent Radio Calibration

iMaster NCE-CampusInsight adopts intelligent radio calibration technology to cyclically optimize wireless network performance. As shown in Figure 3-9, iMaster NCE-CampusInsight is in a constant cycle where it collects user

information, performs big data-based intelligent learning and analysis, and simulates and calibrates the channels, frequency bandwidth, and power of wireless networks. In this way, wireless networks are automatically and continuously optimized.

Figure 3-9 Cyclical wireless network optimization



iPCA 2.0

iPCA 2.0 enables each device on the campus network to periodically report information regarding the traffic and packet forwarding delay to iMaster NCE-CampusInsight. Then, iMaster NCE-CampusInsight aggregates, compares, and analyzes the data to quickly determine which devices are encountering packet loss or forwarding delay issues. In this way, faults can be quickly demarcated, reducing O&M time.

Figure 3-10 iPCA 2.0

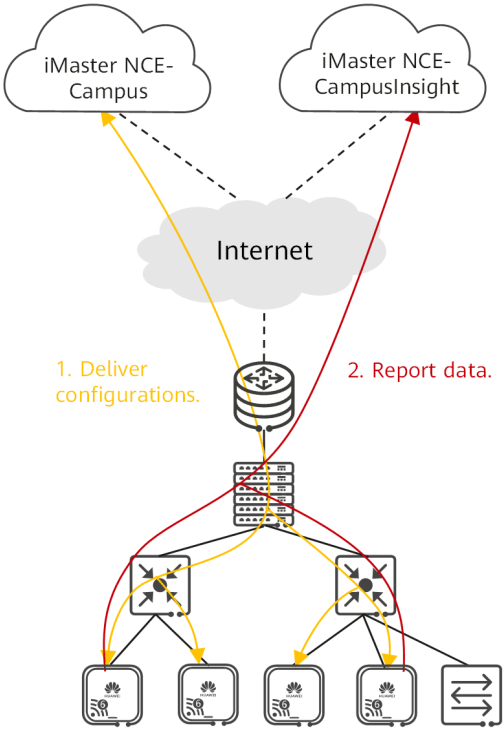


Figure 3-10 illustrates how iPCA 2.0 works. iPCA 2.0 is deployed on network devices through iMaster NCE-Campus. From here, network devices periodically report information regarding the traffic and packet forwarding delay of flows to iMaster NCE-CampusInsight. After processing, iMaster NCE-CampusInsight highlights problematic devices in red.

Chapter 4 Typical Use Cases for Huawei's CloudCampus Solution

Abstract

With the onset of cloud technologies, digitalization is extending from campus workspaces to production spaces and operations. This chapter describes how CloudCampus has proven valuable in various industries such as education, finance, retail, and manufacturing.

4.1 Smart Education

China has attached great importance to education informatization and Internet technologies since the 1990s. Key initiatives in the early days included Education informatization 1.0 and "Three Links and Two Platforms", which were aimed at providing broadband access for each school, quality resources for each class, and online learning spaces for each student, as well as building an education resource platform and an education management platform.

In 2018, China stepped forward, proposing "Education Informatization 2.0". According to this initiative, by 2022, China will deliver teaching applications to all

teachers, extend learning applications to every student, ensure digital campus construction for any school, improve the level of informatization and the information literacy of teachers and students, and put in place an "Internet + education" platform.

Networks have fortunately made great strides during this process, as they are the primary infrastructure required to press ahead with informatization in education.

Wi-Fi 6 and All-Optical Ethernet Maximize Outcomes Under COVID-19

The outbreak and resurgence of COVID-19 adversely affected education all over the world since 2020. Educators have realized the urgent need for education that persists everywhere we go. In other words, education must go beyond current expectations and allow students to learn anytime and anywhere.

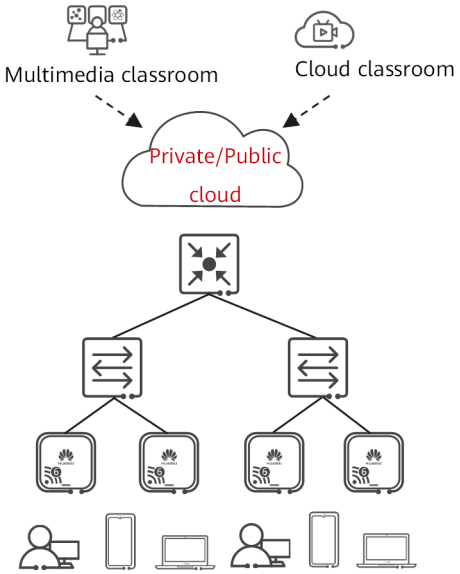
For example, while some students can take online courses and Massive Open Online Courses (MOOCs), and download teaching resources remotely from their dormitories, we have not gone far enough. Immersive teaching — powered by state-of-the-art network and VR/AR technologies — should be available, providing a highly interactive and engaging experience to students and teachers alike.

These expectations, however, are hard to meet given the outdated construction and lack of informatization that still persists in some schools. One of the key reasons is that wired networks are still predominant, and wireless networks are at most used as a supplementary network. Problems such as connection failures, video buffering, and artifacts occur frequently, and the IT department receives one complaint after another. In short, legacy networks cannot meet the demands required to suspend class attendance while still providing equal learning opportunities for students.

Facing this challenge, many schools have decided to introduce cutting-edge network technologies that can stably and reliably support teaching, research, and administration. Doing so helps comprehensively improve network experience and accelerate the construction of smart education campuses.

To keep up, CloudCampus offers a "Wi-Fi 6 + all-optical Ethernet" solution for the education industry to upgrade and reconstruct school wireless networks. Figure 4-1 illustrates the network architecture enabled by this solution.

Figure 4-1 Smart campus network architecture



Innovative full-10GE hybrid optical-electrical switches can be used together with hybrid cables at the access layer, supplying both PoE over 300 m and 10 Gbit/s access bandwidth for APs. This combination of optical and electrical not only overcomes the inability of a Passive Optical LAN (POL) solution to supply power to APs, but also the inability of an Ethernet cable access solution to upgrade bandwidth. Therefore, it proves ideal for constructing a Wi-Fi 6 transport network in this instance. For student accommodation, Huawei's flagship campus core switch — CloudEngine S12700E — can be deployed at the core of dormitory networks. The switch can manage up to 10,000 Wi-Fi 6 APs, implementing wired and wireless convergence and eliminating the need for standalone WLAN ACs.

It should also be noted that the access and core switches support network virtualization with Virtual Extensible Local Area Network (VXLAN). With VXLAN, multiple isolated data services can be deployed on the current transport network on demand, creating one multi-purpose converged network while reducing network construction and management costs.

Cloud Management and Intelligent O&M Make Managing Numerous Devices Easy

When it comes to achieving high-quality networks, 30% lies in the construction and 70% in O&M. Effective O&M is of the utmost importance for education campus networks. For example, at a top-ranked university in China, nearly 10,000 APs and 1000 switches are deployed in a single dormitory area. Tens of thousands of students need to access the network, and so do hundreds of thousands of IoT endpoints, including video surveillance, energy saving management, asset management, and environment monitoring endpoints.

In face of this, smart campus construction must consider how to efficiently deploy and manage such a vast number of network devices, how to secure access for numerous users and IoT endpoints, and how to guarantee network quality for multiple services, such as remote education, video conferencing, and pandemic prevention and detection.

In response, Huawei has developed a "cloud management + intelligent O&M solution. This solution is purpose-built to manage numerous network devices and endpoints and ensure the network access experience for massive numbers of users in real time. The dashboard at the information control center presents device statuses and service experience across the campus network in an intuitive manner, as shown in Figure 4-2.

To maximize the operational and management efficiency of campus networks, Huawei also offers iMaster NCE-Campus, an intelligent network management and control system. This system integrates network management, control, and analysis functions and facilitates centralized management and control of devices, users, and services. Conventional solutions require devices to be manually configured and commissioned one by one onsite. iMaster NCE-Campus offers automated underlay network deployment, allowing switches and Wi-Fi 6 APs to automatically initiate registration requests and synchronize service configurations from iMaster NCE-Campus once powered on. This provides true

plug-and-play for devices and networks, slashing device deployment costs and shortening device provisioning time.

Figure 4-2 Example of the dashboard at the information control center

Huawei's AI-powered platform — iMaster NCE-CampusInsight — has completely transformed the way we do network analysis. It collects and analyzes Wi-Fi network data and user data in real time, evaluating network health from multiple dimensions and then presenting IT personnel with insights into network status and quality. It allows teachers and students to enjoy seamless access to the network whenever they are connected. However, if a user does fail to access the network, the platform can trace the protocol to rapidly locate the fault as well as its root cause, providing IT personnel with suggestions to rectify it. More importantly, iMaster NCE-CampusInsight constantly learns network models and can predict service trends using big data and AI technologies. Based on these predictions, it intelligently calibrates the radio for Wi-Fi networks, creating better

Wi-Fi services for teachers and students alike and transforming an administration-oriented education campus network into a service-oriented one.

4.2 Smart Bank

With the growing popularity of mobile payments, digital currency will replace cash as the long-term means for performing transactions. Digital currency is just one example of the direction the finance industry is taking, and digitization is no doubt a megatrend for the industry.

For financial institutions worldwide, digital transformation is a must given today's policies and fierce market competition. Especially with the rise of Internet finance, people's access to financial services has changed greatly, resulting in fewer touchpoints between traditional brick-and-mortar financial institutions and customers.

Indeed, banks, specifically their local branches, are hit the hardest by this change.

5G + SD-WAN: Building a "Bridge" for Smart Connectivity in Bank Branches

What direction should bank branches go in as they look to evolve? That is the question for industry players to consider.

Smart bank applications are constantly emerging; for example, Smart Teller Machines (STMs), home banking, live streaming, interactive customer engagement, and even humanoid robots. These new use cases make financial services more convenient, and reshape service processes across the entire customer experience.

Smart banks integrate online and offline banking services, such as mobile banking, social banking, and traditional banking at branches, and offer multiple fun interactive games. Financial services are more engaging than ever, and smart banks are becoming a front line for engaging and productive customer marketing services. The end result is significantly improved transaction handling efficiency, minimized queuing time, and more engaging financial services and transactions.

But none of this is possible without the WAN infrastructure. While smart banks continuously optimize the financial services experience, they also drive exponential growth in traffic. As such, bank branches have more urgent demands for real-time data transmission performance and high bandwidth.

MSTP private lines are the conventional solution for branches, and are seemingly mature and stable, but offer bandwidths of only 2 to 4 Mbit/s. This falls far short of the ultra-large bandwidth required by the wide range of smart applications emerging in finance.

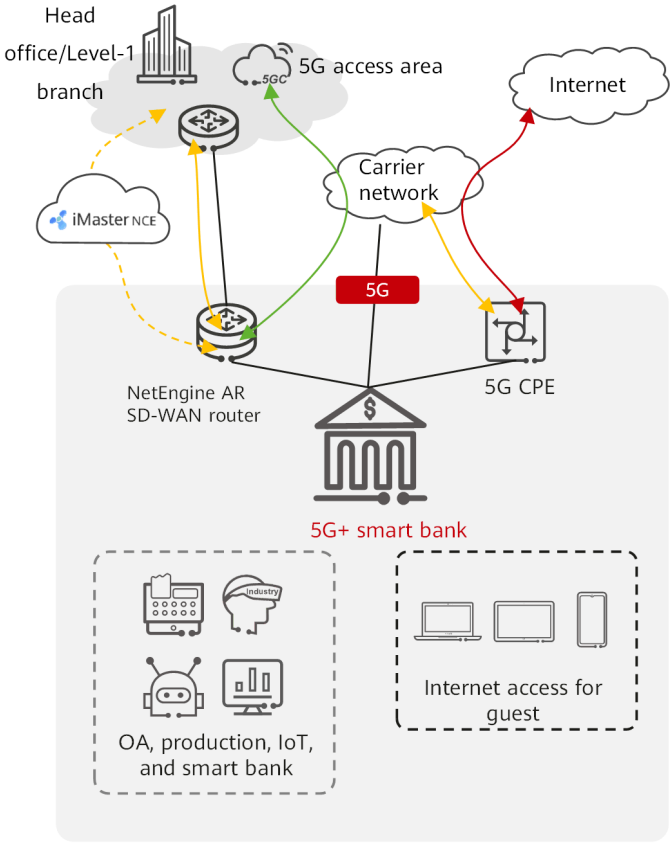
Compounding this problem, branches have more stringent requirements on mobility and provisioning speed to cope with ever-changing business environments. With more than 10,000 branches across the globe, banks need to find a new way to improve O&M and management efficiency on such large, complex WANs.

As shown in Figure 4-3, Huawei's CloudCampus Solution uses "5G + SD-WAN" technologies to provide high-speed interconnections between branches and headquarters and to deliver the ultra-high bandwidth required by smart applications.

Huawei NetEngine AR enterprise routers are deployed to build dual service channels at the network egress, namely, a 5G link and MSTP private line. This improves the bandwidth of smart branches by 100 times. The 5G link functions as the underlay network, providing the network infrastructure with ultra-high bandwidth and ultra-low latency for smart banks. SD-WAN is used on top of this 5G link and the legacy MSTP private line to build an overlay network. In this way, high-speed channels can be quickly set up to interconnect branches at all levels with the financial cloud. The cloud-based iMaster NCE-Campus efficiently manages and schedules a variety of applications and automates complex configuration for branches.

The 5G link can be deployed fast and has high mobility. This means that smart banks can be quickly rolled out and demonstrative services that require mobility can be provisioned. For example, community banks and call centers can be connected through 5G/LTE and the Internet, and temporary financial service branches can be deployed at large event venues to provide onsite financial service assurance.

Figure 4-3 Smart bank networking

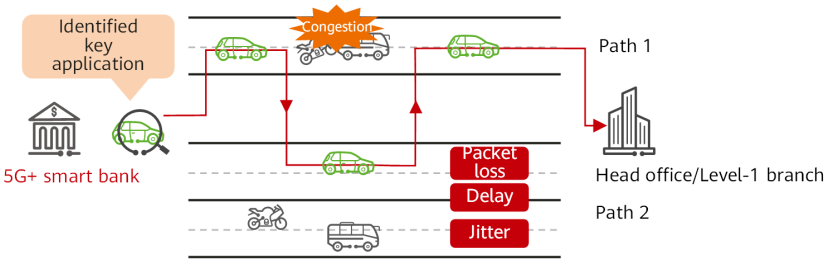


Application-based Intelligent Traffic Steering for Preferential VIP Assurance

SD-WAN builds an end-to-end overlay network to logically eliminate intermediate network nodes. 5G implements one-hop access to the cloud for smart banks. Together, these technologies greatly simplify the network topology.

By fully leveraging the 5G link and MSTP private line, SD-WAN provides reliable access to the cloud. SD-WAN accurately identifies key applications and detects application quality in real time. Doing so facilitates intelligent multi-factor optimization of network paths and ultimately ensures that key applications always run on the optimal links. As shown in Figure 4-4, smart banks often have dozens of financial applications. SD-WAN can quickly identify key financial applications, monitor their path statuses in real time, and dynamically schedule their traffic over optimal paths.

Figure 4-4 Intelligent traffic steering



Intelligent O&M and Unified Cloud Management

SD-WAN orchestrates and schedules link and bandwidth resources for applications network-wide. SD-WAN can accurately and intelligently identify a broad range of applications such as key financial applications, IoT applications, and Internet applications in real time; it also presents real-time key indicators including the status and bandwidth usage of applications, links, sites, and devices. This facilitates capacity expansion, link optimization, and branch adjustment, thereby optimizing network investment and planning.

What's more, iMaster NCE-Campus centrally manages LANs and WANs. It automates the entire process from network provisioning, service deployment, and fault locating, all the way down to routine inspection. iMaster NCE-Campus also provides insight into the network topology using Geographic Information System (GIS), and delivers multi-dimensional visualized reports (on the basis of links, applications, users, sites, and devices). As such, it helps quickly locate

network faults while optimizing network policies. These benefits mean financial services can be carried on one simple and reliable network.

4.3 Smart Retail

Driven by new technologies, such as AI, IoT, and big data, the retail industry — represented by shopping malls, supermarkets, and retail chains — is undergoing profound transformation to adapt to diversified and personalized requirements of consumers. A viable way to improve retail efficiency is to digitalize it by integrating technologies with the Internet. To this end, two areas need digitization: operations and consumer experience.

Plug-and-Play for Fast Provisioning

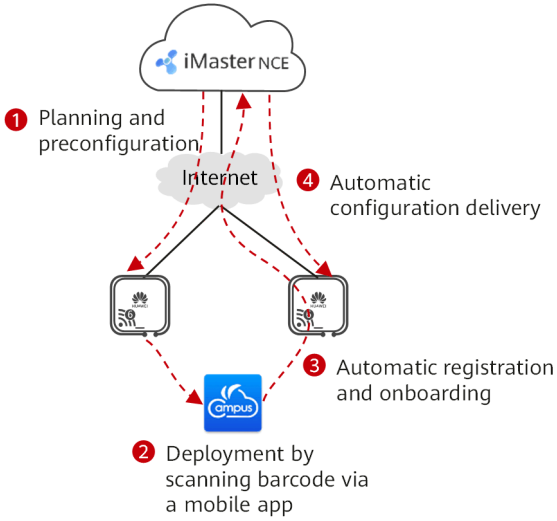
As competition in the market heats up, retailers are finding it increasingly difficult to succeed while basing their entire business on only one store. For this reason, many retailers prefer to operate multiple stores. Since its emergence in the last century, retail chains have quickly grown with a strong momentum. This new business pattern has a profound impact on the consumption habits and life style of modern society. The key to success for retail chains lies in their unmatched replication. They can quickly replicate into multiple stores and expand reach into global markets. For example, a famous milk tea brand in China saw a 4-fold increase in the number of stores in two years. Undoubtedly, the key strategy and top priority for retail chain development is to quickly open new stores.

In response, Huawei launched its Cloud-Managed Network Solution tailored to retail chains, as illustrated in Figure 4-5. This solution slashes network deployment time and the error rate. With it, retail chains are able to quickly open new stores and implement digital operations.

Once devices arrive at stores, engineers simply need to scan device barcodes to record the device information in iMaster NCE-Campus. Devices can be onboarded in minutes, and once onboarded, they do not require manual configuration. Instead, preset configurations are delivered directly from iMaster NCE-Campus. This implements Zero Touch Provisioning (ZTP) for onsite devices and shortens store provisioning time from weeks to just days. Faster rollout and

operations in the new store translate into accelerated Return on Investment (ROI).

Figure 4-5 Cloud-managed network



Unified Management of Global Stores

Retail chains often have to face a range of management and O&M issues. One reason for this is that IT and IP devices are not centrally managed. The internal network of a store and the headquarters network belong to different departments, resulting in decentralized management. Heavy on-site O&M requires high skills and leads to high costs. If a network fault occurs, IT engineers need to locate and rectify the fault on site. However, faults are difficult to locate and the network takes a long time to recover.

Huawei iMaster NCE-Campus is a good fit to help address these issues. It centrally manages stores all around the world through the Internet and cloud. It also offers comprehensive automatic management from end to end.

The iMaster NCE-Campus interface gives users a clear view of information such as the online statuses of devices and users, as well as user traffic usage status and device faults. Users can also search for devices by tenant, device, or device group to view their status in real time. GIS and the CloudCampus APP help O&M engineers quickly pinpoint network devices. A graphical dashboard is also provided.

Application Integration for Precision Marketing

In recent years, e-commerce has grown to an enormous scale, and it has taken a toll on offline retail. Brick-and-mortar retailers need to innovate and transform, and they need to start now. While they realize the need to move into online marketing, they lack effective online operation and business models.

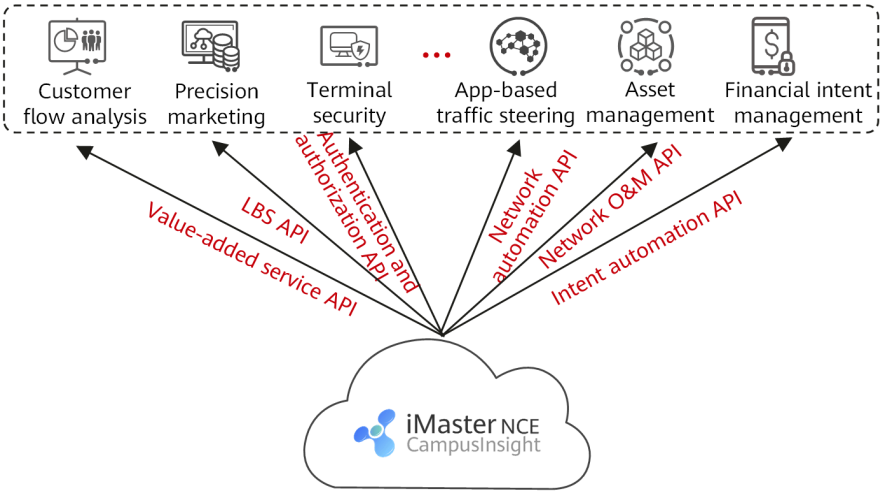
To this end, most retailers implement wireless networks in the hopes of improving customer experience. Specifically, they seek to provide coupons with a low level of entry; that is, supporting multiple authentication modes such as social media, SMS, and a mobile app to attract customers and increase sales.

Once a customer has bought in to this experience, personalized advertisements can be pushed to customers depending on their region and assigned category, along with discounts and promotions.

With network statistics, activity planning and shop layout can also be adjusted on the fly to take advantage of where consumers tend to walk and dwell. This facilitates effective marketing and decision-making.

Figure 4-6 illustrates open Application Programming Interfaces (APIs) supported by iMaster NCE-Campus for easy integration into retail applications. iMaster NCE-Campus offers more than 680 open APIs across more than 50 industry solutions and 30 application scenarios. APIs include value-added service APIs, location-based service (LBS) APIs, authentication and authorization APIs, network automation APIs, and network O&M APIs. With this range of open APIs, enterprises have the freedom to integrate partner applications and precision marketing however they choose.

Figure 4-6 Open APIs



To explain how this may apply to the real world, we can look at value-added service APIs. These APIs provide third-party partners with terminal-related data, with which they could profile customers, assign tags to customers, and personalize services accordingly. This could include pushing targeted information or marketing to the customer. As another example, LBS APIs aggregate terminal location data collected by APs, and periodically send such data to the partner's LBS analysis platform. This platform parses and analyzes LBS data with a series of algorithms, ultimately offering value-added services such as heat maps, path tracing, and customer flow analysis for end customers.

4.4 Smart Factory

In 2018, the Ministry of Industry and Information Technology (MIIT) in China released a first-of-its-kind *Industrial Internet Development Action Plan (2018-2020)*. Over the past three years, industrial Internet has been frequently discussed in the industry and even featured in four of the government's work reports in a row, highlighting its significance at the national level. Networks are

foundational to the development of industrial Internet. The first step towards industrial Internet is to achieve fully wireless inside factories and transform factory terminals into IP-based ones. CloudCampus keeps up with this change by leveraging industry-leading Wi-Fi 6 technology to reconstruct wireless networks and unify the many different protocols used by industrial terminals into IP.

Wi-Fi 6 and Lossless Roaming Get AGVs Free from Interruptions

Annual shopping events like Black Friday and Double Eleven are really challenging for logistics, warehousing, and e-commerce. To improve goods sorting and transportation efficiency, many industry players are turning to automated guided vehicles (AGVs) for help. Although AGVs can transport things with a higher efficiency, they often get "stuck" due to network packet loss and delay. Once stuck, collisions, accidents, and even chaos can ensue.

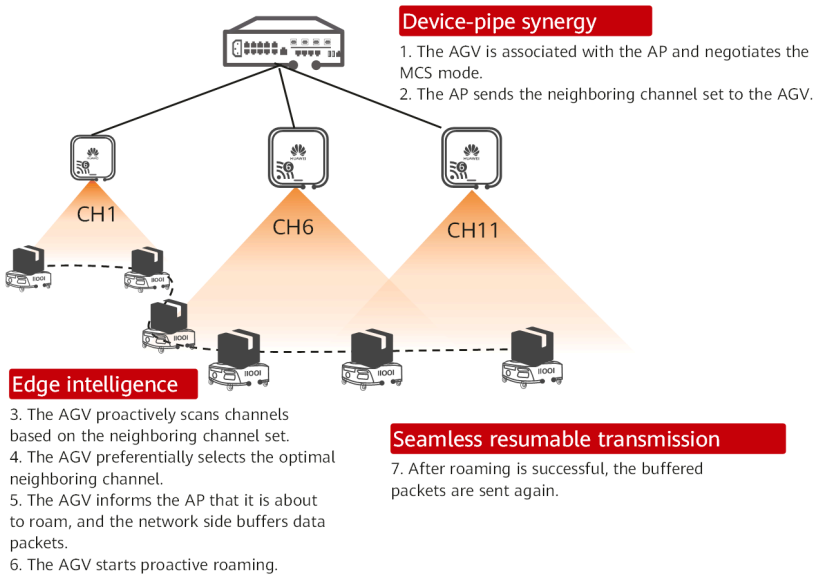
Network delay or packet loss is the main issue causing AGV interruptions, especially during roaming. AGVs need to obtain key instructions from the network when moving at high speeds. This includes questions such as:

- Where I am
- Where I will go
- How will I go there

Even a small rate of packet loss (probably over 1‰) may sometimes cause AGVs to become disconnected or stop responding.

To change this, Huawei proposes the "Wi-Fi 6 and lossless roaming" solution, as illustrated in Figure 4-7.

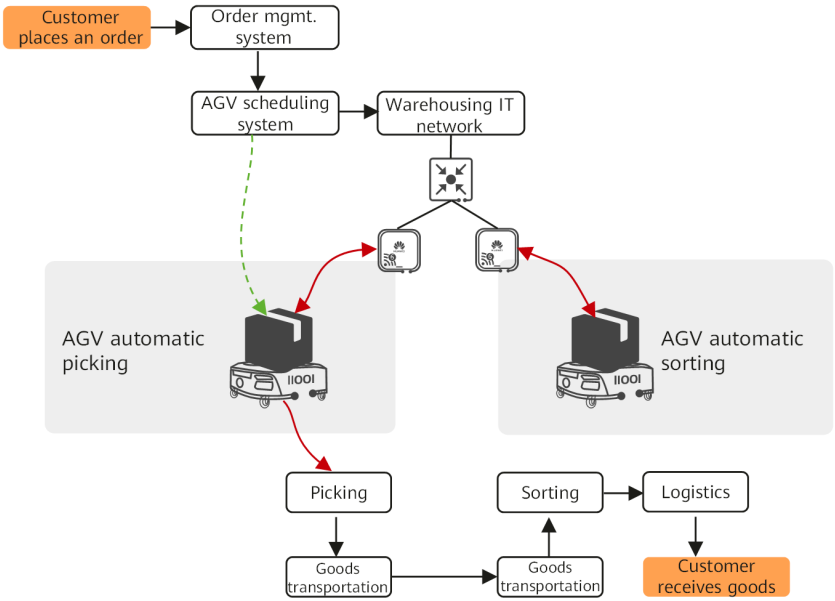
Figure 4-7 Wi-Fi 6 and lossless roaming solution



With conventional wireless networks, the packet loss rate of AGVs is usually greater than 1%, and roaming only works about 90% of the time. Huawei's "Wi-Fi 6 and lossless roaming" solution outperforms this by integrating key technologies such as lossless scanning, lossless roaming, and reliability guarantee mechanisms. It reduces the packet loss of AGVs to zero during roaming, ensuring that the production network can run stably 24/7.

Figure 4-8 illustrates the AGV workflow at a typical automated warehouse. Customers place an order online, and the generated order information is immediately reported to the warehouse IT system. Then, goods are automatically picked up and packaged under the control of the AGV scheduling system. The automatic sorting system then instructs AGVs to deliver the packages according to their labels to a specified logistics box and then to vehicles for delivery.

Figure 4-8 AGV workflow at an automatic warehouse



Huawei's "Wi-Fi 6 and lossless roaming" solution improves terminal roaming reliability, reduces network latency and packet loss rate, and greatly enhances network service capacity. The resulting benefits include dramatically reducing AGV interruptions caused by poor network quality, scheduling AGVs in an orderly fashion, and significantly increasing network loads.

For example, this solution has proven highly productive at a warehousing enterprise. Specifically, the number of AGVs that the Wi-Fi network can accommodate increased from 550 to 750, the number of work orders generated per day grew from 30,000 to 40,000, and overall efficiency was improved by 30%. More importantly, the entire network is basically O&M-free.

Wi-Fi 6 Industrial CPE Makes Equipment Wireless for Flexible Manufacturing

The manufacturing industry is facing many challenges, including more complex production environments, fiercer competition, stricter supervision, and more demand for comprehensive security risk management.

To address these challenges, manufacturers have begun to transform towards intelligent production. They are looking for an all-in-one solution that integrates planning, operation, and monitoring to achieve secure production and protect its people, environments, assets, and intellectual property rights.

However, a key challenge lies ahead — ensuring that legacy factory equipment can be operated smoothly in the next-generation system.

Figure 4-9 Wi-Fi 6 industrial CPE

The Wi-Fi 6 industrial CPE illustrated in Figure 4-9 is the ideal solution for this challenge. Built on broadband capabilities offered by the intelligent edge computing system, the Wi-Fi 6 industrial CPE offers the most comprehensive assurance for E2E production traffic. This means production is easier to manage and enterprises can quickly respond to internal, external, and market changes. In particular, Wi-Fi 6 technology assists the manufacturing industry with interoperability to interconnect devices across systems, production zones, and regions. This translates into higher efficiency and drives the arrival of more intelligent manufacturing and service systems.

In factories, the Wi-Fi 6 industrial CPE helps transform production lines and their equipment into intelligent and fully wireless equipment. With the Wi-Fi 6 industrial CPE, production line deployment is more convenient than ever. Its wireless access features comprehensively cover user requirements for wireless access and help enterprises flexibly and conveniently embrace intelligent devices and new industry use cases.

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