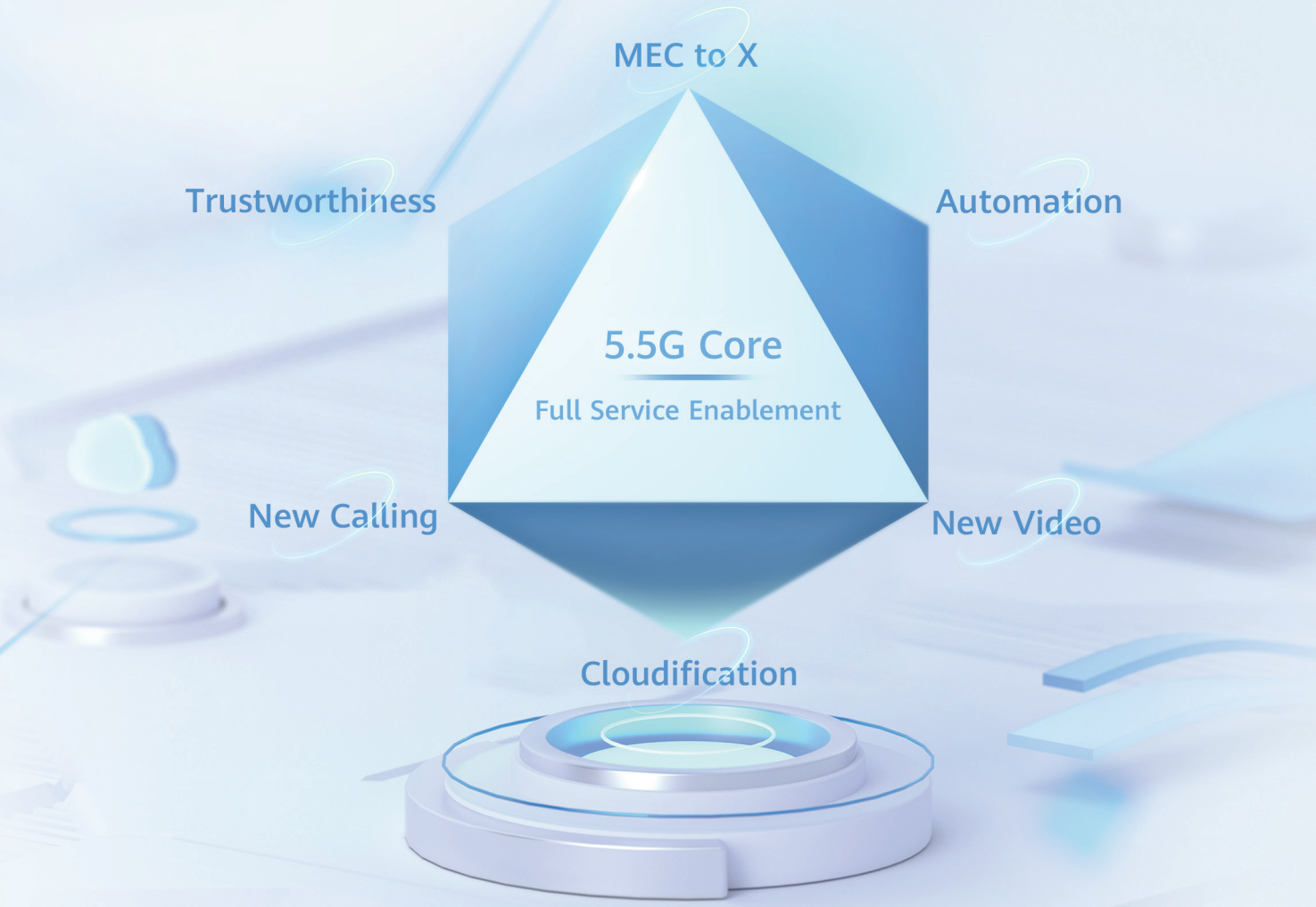
Striding Towards the Intelligent World

5.5G Cloud Core Network | Special Issue

INTELLIGENT CORE , INTELLIGENT WORLD



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HUAWEI

5.5G Core：from Connection to Service Enablement

The increased momentum in the development of 5G technologies is leading to a cornucopia of new services, which are simultaneously posing a multitude of new demands on networks that symbiotically drive the evolution of technologies, standards, applications and ecosystems. In light of such positive signs in the commercialization of 5G, this has already paved the way for the next phase of development, 5.5G. The 5.5G era will offer countless benefits across a myriad of industries and transform the ways in which we interact and work.

The 5.5G Core, as far as we can tell, is bringing an array of enhanced capabilities and will better serve various service sectors.

In the voice sector, 5.5G Core offers enhanced mobile network calling capabilities, revolutionizing the call service experience from mere audio and video calling, to intelligent and interactive communication. This serves as not only a bridge for communication, but more importantly, a capability platform for telecom operators to roll out new services.

A major highlight of 5.5G Core is that it introduces data channels to existing IMS voice and video channels, so as to enable interactive call experiences. Moreover, it integrates intelligent media content identification, rendering, and synthesis capabilities to call services, making them more intelligent and accessible across more scenarios, such as accessibility services and one-stop insurance claim settlements.

In the B2B sector, 5.5G Core offers enhanced "connection + edge computing" capabilities, expanding the industry private network from a limited scenario at a site to all scenarios anywhere, and transforming mobile networks into Data, Operation, Information, Communication Technology (DOICT) enablement foundations to serve all industries.

As for enhanced connection capabilities, 5.5G Core can guarantee ultra-high reliability and ultra-low latency in industrial scenarios by using the 5G LAN and OT-UPF technologies.

In addition, with the Mobile VPN solution, enterprise users can access enterprise intranets anytime, anywhere, and enjoy highly reliable and fast network services.

What's more, digital voice trunking services are integrated with existing data services, such as video content analysis and remote management, to better support enterprise production activities.

As for edge computing capabilities, edge computing is an absolute for certain enterprises who do not wish to go to the cloud. In the 5.5G Core, the telco cloud platform is built as a highly reliable network foundation featuring real-time resource scheduling. With such a foundation, key applications of enterprise private networks can be efficiently integrated.

In the video service sector, we will integrate mobile phones' communication capabilities with TVs' video capabilities. We'll build a video-based

"entertainment + social interaction" capability platform, to transform video services from single-screen entertainment to multi-screen social interactions. In this way, we can converge B2C and B2H services and explore more possibilities in the home audio-visual service scenarios.

Specifically, 5.5G Core will be integrated with Extended Reality (XR) and spatial video capabilities for new media. By introducing intelligent media content identification and scheduling capabilities, we can ensure an immersive experience, even with huge connections. By using technologies such as intelligent transcoding, intelligent stitching, and multi-stream synchronization, we can guarantee a Multi-Degree-of-Freedom (multi-DoF) spatial video experience. Also, we will enhance the multi-screen communication and video capabilities to provide better call and social-interactive video services, as well as improve service loyalty.

While developing voice, B2B, and video services, operators also need to couple the core network with Artificial Intelligence (AI) technologies to realize high stability, efficient O&M, and an improved experience.

As for stability, AI-based fault detection, diagnosis, isolation, recovery, and prediction can transform passive network issue handling into proactive prevention, improving network stability.

For O&M, intent-driven network provisioning, updates, and configuration, as well as intelligent traffic analysis, help achieve L4 Autonomous Driving Network (ADN), which thereby facilitates the advancement of network O&M.

For user experience, intelligent UPF selection and relocation, mobile VPN path optimization, and intelligent load-based slice selection help better fulfill SLA requirements of high-value users.

With all the aforementioned enhanced capabilities, the core network will facilitate the evolution for the entire range of services in the B2C, B2B, and B2H fields, creating new business models for an intelligent world. To better achieve these goals, we formulated this white paper, which is derived from Huawei's extensive experience in core network construction and evolution, including deliberations with industry partners. This special issue outlines the development trend of core networks towards an intelligent world and systematically expounds the core network evolution approach. We hope it will provide reference and inspire all involved parties to get together to evolve the core network. Huawei will collaborate with industry partners to tap into more possibilities, create more industry value, and move towards an intelligent world.

Richard Liu

President of Huawei Cloud Core Network Product Line

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5GtoC

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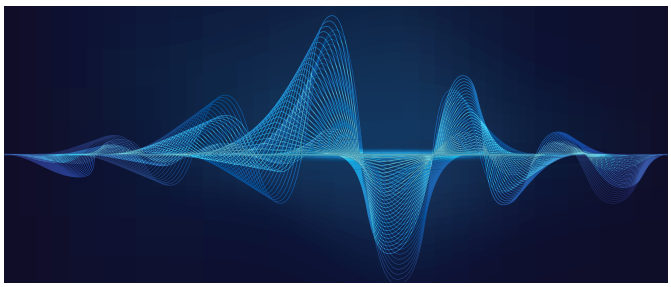

5GtoB

Hybrid Video

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MAE-CN

01

Securing the Longevity of Telecom Networks by Stabilizing Core Networks

Telecommunications form part of the lifeblood of modern-day society. However, in recent years incidents on various networks have repeatedly occurred around the world, which has been mostly attributed to core network issues. This has made the core networks the center of attention for the global mobile communications industry, and has also put industry players on high-alert. Corporates need to pay close attention towards core networks and continue to invest for the sustainable development of core network reliability.

A highly reliable core network is a prerequisite for any service innovation, and is essential to the entire socio-economic strata. It also needs to keep pace with the times in order to accommodate new network architectures and features, as well as maintaining a solid foundation along its evolutionary track.

Emerging technologies, such as cloudification and 5G, are also posing more stringent requirements on the reliability of the core networks. To address these challenges, industry stakeholders must join forces and design a systematic, hierarchical, and comprehensive reliability mechanism that can enable core networks to defend against incidents of varying severity. Only in this way, can core networks provide watertight reliability and prevent network-wide outages.

Huke Hu

Director of Huawei Cloud Core Network Marketing Execution Dept

Lessons learnt from network accidents: all industry stakeholders must continuously secure the lifeline of telecom networks — core network reliability.

In recent years, large-scale network outages have been commonplace, and many of them were as a result of core network faults. For example, Japan's KDDI and Canada's Rogers both encountered nation-wide network blackouts, which were regarded as critical accidents by local governments due to the resulting major socio-economic losses.

In the early morning of July 2nd, 2022, KDDI experienced the most severe communications failure in its history, and the failure was not resolved until the afternoon of July 4th. The accident took down the communications services for as many as 39.15 million users; it also froze fundamental public services, such as banking and transportation, causing significant inconvenience to people in Japan. Due to its far-reaching impact, KDDI's CEO had to apologize publicly. According to media reports, KDDI might have to possibly pay over tens of billions of yen in compensation damages. Worst of all is the reputation damage that KDDI encountered, which can hardly be recovered overnight.

No more than one week after this preceding event, Rogers was also thrown into a crisis with a nation-wide network outage in the early morning of July 8th, which lasted till the afternoon of the next day. During this period, at least 12 million users could not use telecom services as normal. This was also the most severe network accident that Rogers had encountered to date, topping the one that happened in the month of April 2021. Rogers had paid heavily for it. Its CTO was fired, and according to the media, the company might have to fork out US$70 million in compensation damages. At the same time, Rogers nearly doubled its investment to strengthen the core network.

What are the root causes for these serious large-scale communications failures?

According to KDDI's report (as disseminated by the media), the outage was caused by a core router, which was replaced in the early morning of July 2nd. However, the new router was faulty, and it could not correctly route voice traffic to the VoLTE switching node. Consequently, partial VoLTE services were interrupted for 15 minutes. After a rollback, the VoLTE registration signaling surged, leading to congestion on the core network switches; and the core network databases also encountered user data inconsistencies. As a knock-on effect, communications on KDDI's network further deteriorated, with the scope of affected voice and data services enlarged to the whole nation. Unfortunately, the downtime persisted for 86 hours.

Rogers has not explained the causes for its outage in detail. Nevertheless, its CEO revealed to the media that the outage happened after they carried out some maintenance operations and upgrades on their core network. Some core network elements were overloaded then, which eventually took down the entire network.

It is clear that the core network was most adversely affected in both KDDI's and Rogers' network accidents. As the nucleus of the entire

telecom network, the core network plays a pivotal role in empowering various services, and its reliability is essential for both operators and users. As fatal strikes to their business, these accidents that both KDDI and Rogers suffered have caused ripple effects in the industry, prompting major players to be more alert and astute in regards to the significance of core network reliability. This is strategically important in the 5G era. As the core network is being gradually cloudified, the industry must consolidate network reliability while developing new services. Otherwise, a single accident may cause immeasurable losses to people's lives, national economies, and even society as a whole.

Rock-solid core network reliability is the foundation for service innovation and the key for telecom networks to create social value.

Looking back at the development of core networks, we see a clear consensus in the pursuit of cloudification, which is leading the telecom industry toward broader horizons; however, it has somewhat proverbially opened Pandora's box in terms of the pressure to resolve both the reliability and stability of the network. Since operators shifted their eyes toward NFV and started to cloudify their core networks in 2015, many incidents similar to those of KDDI and Rogers occurred. As NFV is being deployed at an ever-increasing pace to advance network cloudification, there are also higher requirements on core network reliability and stability.

Moreover, the requirements are becoming more stringent with the advent of 5G. 5G core networks must provide watertight reliability to underpin 5G construction and service development. 2020 saw the debut of SA 5G commercialization, on which core network devices run with the functionality stipulated in 3GPP R15. From this year, 5G core networks have been further upgraded as documented in R16 and R17, to truly underpin eMBB, URLLC, and mMTC services, which act as the anchors for operators to navigate through new 5G markets. To achieve this, telecom networks must adapt to the ever-diversifying and differentiated services of various industries, such as industrial manufacturing, transportation, electric power, and finance. More importantly, the networks must satisfy extremely strict latency and reliability requirements from certain industries. The electric power industry, for example, demands a reliability of 99.9999% for differential protection. It's safe to say that 5G will be deeply integrated with the real economy and penetrate all production and operation phases in various industries. As a key driver behind this, 5G core networks must stay flexible as a service. Furthermore, it needs to leverage key technologies such as cloudification and virtualization to offer differentiated network capabilities and services to individuals and industries. However, signaling storms are likely to occur upon core network incidents, which adds to the possibility of outages. As such, in addition to the flexible system architecture, the 5G core network must stay highly stable and reliable as it empowers a greater number of industries.

5G is creating ubiquitous connections. In the near future, trillions of devices will be networked, serving all industries, as well as influencing industrial production and people's lives. This also means that a single point failure on a core network may bring about more destructive

impacts. To mitigate against such events, operators must team up with equipment vendors to develop new reliability mechanisms along with their innovation of network architectures and services, and standard organizations, industry partners, and analyst agencies should step up to the mark.

Maintaining a strong investment and innovation environment is key to building a highly reliable core network.

An ultra-reliable core network requires a systematic defense mechanism to reduce and even eliminate faults on network elements, while protecting each individual network element from the impacts of its peripheral network elements. If some network elements are faulty, the mechanism is expected to enable basic services to continue as normal, so that users can enjoy a seamless service experience. Additionally, the mechanism shall help efficiently prevent potential issues as well as locate and rectify faults. Such a mechanism must be built under a hierarchical framework with well-rounded defense lines.

Defense line 1: sound self-protection for zero downtime

As previously mentioned, KDDI's accident was caused by a router failure, and it worsened because the core network elements failed to stand the signaling surge that resulted from the failure of the router. Under such circumstances, core network elements must be able to protect themselves — they shall prevent themselves from becoming the sources of network-wide failures, while staying available and stable through faults caused by other components or systems. To achieve this, the defense mechanism needs to be highly refined from the aspect of architecture optimization, disaster recovery, and defense against signaling storms. In terms of the network architecture, stateless design can be introduced to decouple the service, data, and forwarding layers, so that multi-point disaster recovery can be implemented among service units. Such an optimized architecture can provide a higher reliability when faults frequently occur. For data backup and disaster recovery, databases of service units in different regions can be federated so that session data can be hot backed up across data centers. This, combined with technologies such as high-ratio compression and incremental backup, helps guarantee smooth disaster recovery among data centers. At the same time, the traffic allowed by the system shall be adjusted based on the system resource usage to maintain the success rate and stability of high-priority services. In this way, the network can survive extremely heavy signaling storms.

Defense line 2: protection over peripheral systems for a smaller impact scope

Under the signaling storms in KDDI's accident, the core network elements did not initiate protective measures for their peripheral components and systems, and therefore the entire network collapsed very quickly. This lesson taught us that core network elements, especially those responsible for signaling convergence and ingress control, must be able to look after their neighboring systems, so as to restrict the impact brought by service failures to the smallest scope. For example, the core network can implement intelligent flow control over the interfaces facing peripheral network elements, which mitigates the impact of signaling surging on back-end network elements. It can also intuitively carry

out collaborative flow control among network elements to accurately sense and control the loads on both front-end and back-end network elements. These measures jointly help the entire network defend against signaling storms.

Defense line 3: continuous services even under extreme circumstances

The HSS was the culprit of many severe network accidents that have happened recently. The HSS failures caused user authentication and authorization to be unavailable across the entire network, which then led to large-scale outages. In extreme scenarios where all network elements are down, the core network needs to keep services running by means of the bypass mechanism, so as to minimize any adverse impacts. For example, when a storage fault occurs, the core network shall initiate the system image downsizing algorithm to enable the local storage system, so that services can continue as usual. If all UDMs are faulty, the core network cannot serve the users whose accounts are newly created, but the online users and those with UEs having been powered off for less than 24 hours can still access the network as usual and enjoy both data and voice services.

Defense line 4: quick demarcation for timely service recovery

In KDDI's accident, it took experts a significant amount of time to locate the cause for the service interruption. It is obvious that a longer downtime will result in greater economic losses and social impacts. To minimize such impacts, the core network must be able to quickly demarcate faults and recover services. Especially after the core network is cloudified, its architecture complexity increases, causing the potential fault points to grow by over a hundred-fold. This requires that the system be capable of identifying fault points rapidly and providing effective rectification suggestions, instead of relying on several rounds of analysis by O&M experts. Thanks to the combination of expertise and AI technology, faults on cloud-based networks can be sensed more rapidly, and the faults at different network layers can be precisely correlated for intelligent diagnosis, so that services can be resumed in no time. More specifically, visualized object models can be utilized to integrate various resource data, analyze topologies, and associate different pieces of fault-related information, so that network conditions can be examined more comprehensively. Additionally, fault scenarios can be accurately identified through typical scenario modeling and intelligent model matching. With expertise incorporated into an online database, fault trees can be automatically sketched out, facilitating the system's self-analysis actions throughout the entire fault locating process, from self-check to self-derivation and self-diagnosis. Also, the knowledge graph can help generate the fault propagation chain, which makes it easier to demarcate faulty elements under a complex network architecture.

Defense line 5: proactive prevention for fewer potential risks

Powered by novel technologies such as AI, the core network can prevent misoperations and faults more proactively and effectively. For instance, the network interfaces in suboptimal health status now can be detected to prevent large-scale network faults. Users can perform potentially service-affecting operations only after they pass a secondary authorization. This helps

effectively avoid incorrect operations. In addition, the key data of all objects, including the transport network, infrastructures, and different network elements, is obtained in real time to form a digital twin network which presents the network conditions intuitively. On top of this, the indicators for different network layers are monitored in real time, and noise reduction, association, and aggregation of alarms, logs, KPIs, and traffic data help O&M personnel identify potential risks and carry out appropriate countermeasures efficiently.

In the near future, the core networks will become ultra-distributed and fully-interconnected. Under such an architecture, explosively growing edge sites will be fully meshed and empower more and more industries. Meanwhile, the telco cloud infrastructure will continue to diversify. In addition to accommodating VMs and containers, it must support more scenarios, such as iNIC offloading and heterogeneous hardware. All these will increase the number of potentially risky nodes and scenarios on the entire core network by hundreds of times. This must be taken into account during the reliability design of the core network. For example, the existing single-point disaster recovery must be upgraded to multi-point and multi-dimensional, and troubleshooting must be enhanced from a passive response to proactive prevention, and the current O&M which requires both manual intervention and automation shall be enhanced to AI-driven full intelligence.

As 5G shifts from network deployment to rapid service development, it poses higher and higher requirements on reliability. That said, an ultra-reliable core network cannot be constructed overnight. It requires equipment vendors' continuous investment while they are developing new features and reshaping the network architecture. Considering more and more operators have come to realize that they will incur heavy commercial losses if they do not consider the reliability-related factors when they are hunting for new features, closer attention is focused on the amount of capital going into these developments. Operators' investment on the core network construction only takes up 5% to 10% of their total network investments. However, once reliability-related accidents occur on the core networks, operators must pay much more. Therefore, as the core network reliability becomes more important than ever, it is better to increase the investment on reliability from the very go. Here we call for all industry stakeholders to collaborate to ensure the watertight reliability of the 5G core networks. Based on this, let's continue promoting service innovation and commercial practices, so as to boost 5G B2C and B2B business and cultivate a beneficial industry ecosystem.

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02

Growing Your 5G B2C User Base and Stimulating Service Innovation

5G networks have been rapidly rolled out across the world. Now, companies are shifting focus from building 5G networks to attracting 5G users and developing related services. Operators' revenue and profits rely heavily on B2C services in 5G. And, large-scale service rollout is a key indicator of an operator's capacity to operate and develop 5G. However, operators still face many challenges, particularly when it comes to user migration, creating attractive 5G service packages, and delivering a satisfactory user experience.

To address these challenges, operators need to develop a systematic core network solution featuring precise perception, 3D visualization, optimal service assurance, and closed-loop operations. These features will support user migration, stimulate traffic, and assure user experience. Such a solution will help operators grow their 5G user base while stimulating service innovation, and ultimately, maximize the value of 5G networks.

Zhao Wei

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In recent years, networks have seen a lot of pressure to support an exponential growth in video services, especially short videos. The 49th Statistical Report on Internet Development in China released by China Internet Network Information Center (CNNIC) estimates that there are currently 934 million short video users in China. Moreover, the Global System for Mobile Communications (GSMA) reports that about a third of all global 4G networks experience some degree of congestion.

Within this context, global operators are quickly building 5G networks to support the first wave of 5G services. According to GSMA, in the next five years, 5G networks

will account for over 80% of operators' total capital expenditure on network construction.

5G has already been deployed on a large scale around the world. In some leading regions like China, 5G coverage has nearly reached nationwide levels. GSMA reports that by Q2 2022, there were over 200 5G networks around the world. There are also 738 million 5G connections, a number that's predicted to exceed 1 billion by the end of 2022. China has the world's largest 5G network coverage, with 475 million 5G users, covering all cities and almost 90% of Chinese towns.

Now, companies are shifting focus from building 5G networks to attracting 5G users and developing related services. It is not enough to build high-quality 5G networks, they must also deliver, maximizing the value of 5G. Operators' revenue and profits rely heavily on B2C services in 5G. And, large-scale service rollout is a key indicator of an operator's capacity to operate and develop 5G. However, developing and scaling up 5G B2C services is still a challenging task.

Challenge 1: Users Are Reluctant to Use 5G Because They Are Unfamiliar with 5G Services

Encouraging users to embrace a new-generation network can be a challenging task. Operators need to actively advertise and incentivize users to switch to 5G and benefits must be clear. For example, some users may not know how they can access 5G services or enable them on their phone.

To target the right users, operators need precision marketing. But currently, many operator networks lack precision analysis systems based on terminals, service packages, and subscription information. This means they cannot classify or target the right users. At the same time, users want the most convenient access to 5G services at the lowest cost; complex operations frustrate them. For operators, this means a range of new requirements.

Challenge 2: Users Do Not Find 5G Service Packages Attractive

Even when users do migrate to 5G networks, another issue arises — they do not find the current service packages provided by operators attractive. In particular, when operators transition from 5G SA via 5G NSA, they need to offer users 5G service packages that deliver more than 4G. Otherwise, users do not see the value of upgrading their packages or increasing their 5G traffic usage.

This limits 5G DOU and ARPU growth, and many users even disable 5G on their phones to prevent battery drainage. This means that the new 5G networks may be underused, leading to an exceptionally long Return on Investment (ROI).

Challenge 3: Poor User Experience Deters Users from Switching to 5G and Limits Service Innovation

After switching to 5G, many users find little change in their experience, particularly on congested networks. Sometimes, services are even worse than 4G because of limited 5G coverage and unfinished construction. This

deters users from switching and slows the development of promising services such as live video broadcasting and video conferencing. As a result, the telecom industry cannot reach a state in which services and networks are mutually beneficial.

Meanwhile, we are seeing rapid development in metaverse, immersive, and all-sensing applications. Mixed Reality (XR) services are becoming more mainstream — Deloitte, a well-known international accounting and consulting firm, estimates that the XR market will exceed 100 billion dollars by 2025. Counterpoint, a global technology market research firm, estimates that over 100 million XR headsets will have been shipped by 2025.

Despite this growth, existing networks cannot provide the transmission speeds that XR services require. They just provide extensive pipelines, unaware of service packet forwarding rules. Plus, a 5G cell can only support high-quality concurrent access for about five XR devices, which is insufficient for commercial rollout. To improve service experience, operators need to expand network capacity. This is expensive both in terms of network construction and XR service costs.

To address these challenges, operators need to develop a systematic core network solution featuring precise perception, 3D visualization, optimal service assurance, and closed-loop operations. These features will support user migration, stimulate traffic, and assure user experience. Such a solution will help operators grow their 5G user base while stimulating service innovation, and ultimately, maximizing the network value.

User Migration: Quickly Migrate a Massive Number of Users Without Impacting User Experience

Operators can introduce a brand-new intelligent plane based on the Network Data Analytics Function (NWDAF) in the core network. With it, they can precisely identify target users and provide optimal policy suggestions to address their pain points.

For example, operators can proactively push 5G terminal discount information to 4G users, recommend 5G service packages to users whose terminals are 5G-capable, enable default 5G subscription for users who have not yet subscribed to 5G services, and instruct users who have not subscribed to 5G on enabling 5G on terminals.

In addition, operators deploy a fully convergent data management plane to automate 5G service provisioning. This way, users can enjoy 5G services with 5G terminals without changing their SIM card or phone number. This makes it extremely easy for users to subscribe to 5G services and accelerates user migration to 5G networks.

China Mobile in Zhejiang is an excellent example of this approach. After adopting NWDAF and by the end of April 2022, 40% of all traffic at the Zhejiang branch came from 5G services.

Traffic Stimulation: Improve Network Stickiness with Innovative Service Packages and Stimulate 5G Traffic

Global operators may choose different paths for the transition to 5G SA. No matter the path, operators need their new network capabilities to quickly attract more users and increase monetization. For example, in the 5G NSA phase, operators can only benefit from 5G's high bandwidth when they charge for 4G and 5G NSA services separately. For this, they need to design 5G service packages that are more attractive than 4G, for example 5G high-speed services or FWA services.

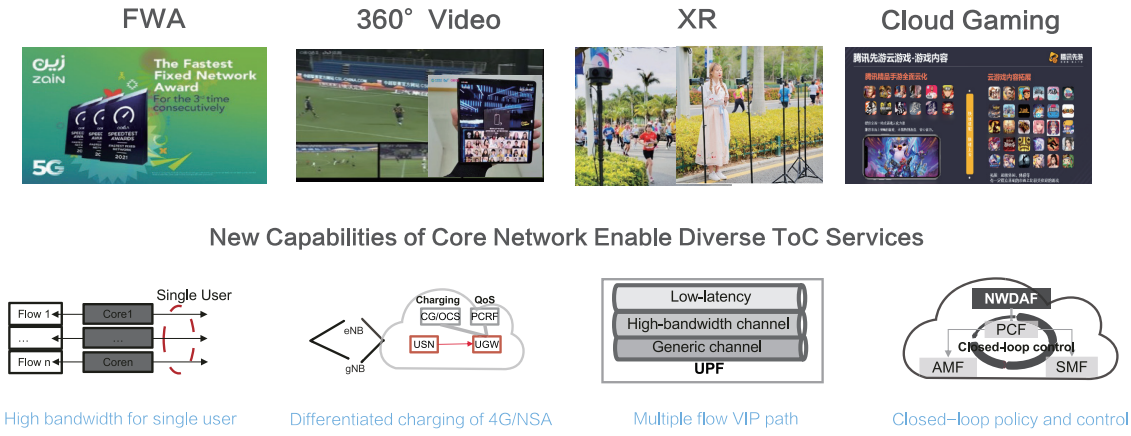

Figure 1: New 5G core network capabilities enable diverse B2C services

The 5G SA phase enables even more new capabilities on the core network. This provides operators with abundant opportunities to innovate 5G service packages and stimulate 5G traffic. For example, operators can deploy the Mobile VPN solution based on new capabilities like smart traffic steering and MEC. This solution enables end users to securely access enterprise intranets anytime and anywhere and increases service traffic.

In addition, operators partner with enterprises to design campus service packages based on the value-added experience brought by Mobile VPN. Then, users can add value-added packages to the basic ones. China Mobile in Guangdong was the first to use Mobile VPN. So far, it has applied the solution to diverse scenarios, like campus private networks, public services, healthcare, and remote offices.

What's more, diversified package innovation requires agile policies and faster rollout. If deployed in time, innovative service packages can improve the loyalty of 5G users, encourage them to upgrade packages or add new packages, and stimulate 5G traffic, thus increasing the 5G DOU and ARPU.

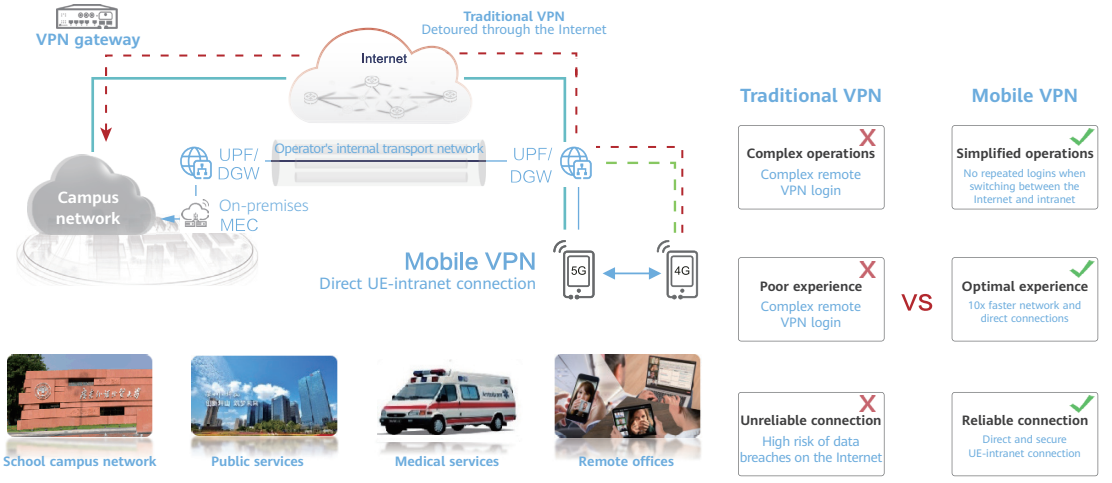

Figure 2 Campus package design based on the value-added experience brought by Mobile VPN

Experience Assurance: Improve Service Experience and Support Innovative Services

With the new capabilities of the 5G core network, operators can improve and monetize user experience and develop new services. In the 5G NSA phase, operators can use capabilities such as super uplink, 5QI, and dedicated channels for the core network to improve the experience of interactive services. For example, they can grow services such as live video broadcasting and video conferencing, increasing revenues. Such services require high uplink bandwidth and low latency.

The 5G SA phase enables even more new capabilities, so operators can differentiate services, making them comprehensive, visible, controllable, and operable. For example:

- AI-based service awareness implements precise awareness from service-level to flow-level identification.
- The NWDAF-based intelligent plane visualizes traffic statistics and experience in 3D.
- Dedicated channels for the core network and dynamic slicing optimize service assurance from preferential scheduling to dedicated channels.
- The NWDAF, PCF, and other 5G core network functions work together to realize closed-loop operations from pre-configuration to real-time closed-loop control.

What's more, these new capabilities can enhance experience assurance for new services, in particular the interactive ones. This will encourage users to try them and optimize experiences for users at different levels, promoting service growth.

When it comes to self-operated services, operators can adopt the "1 platform + 3 capabilities + N services" architecture. This architecture uses a single real-time audio and video platform for an extraordinary communication experience. Plus, it delivers ultra-HD (UHD), intelligence, and interaction capabilities for fun, innovative, and interactive services, such as UHD video calling, intelligent translation, fun video calling, and remote assistance. As a result, operators deploy innovative business models and improve user stickiness.

Let's take short videos as an example of improving the OTT service experience. Short videos feature autoplay, which automatically adjusts video resolution based on network quality. As network quality improves, videos can be transmitted in UHD, positively impacting user experience.

Another area these new capabilities improve is innovation when it comes to experience-based operations. Operators have the flexibility to design experience-based service packages and multidimensional charging models (for example, based on bandwidth, latency, and service assurance). This helps them satisfy high-value users while upgrading the 5G B2C experience standards.

Last but not least, 5G SA capabilities can improve network resource utilization and optimally match network resources, user experience, and network value. This maximizes the network value per bit.

So far, companies like China Unicom in Guangdong, China Mobile in Shanghai, and China Telecom have launched innovative pilot projects using these new 5G capabilities. Their projects cover service experience assurance, such as Internet celebrity livestreaming, cloud phones, and cloud games.

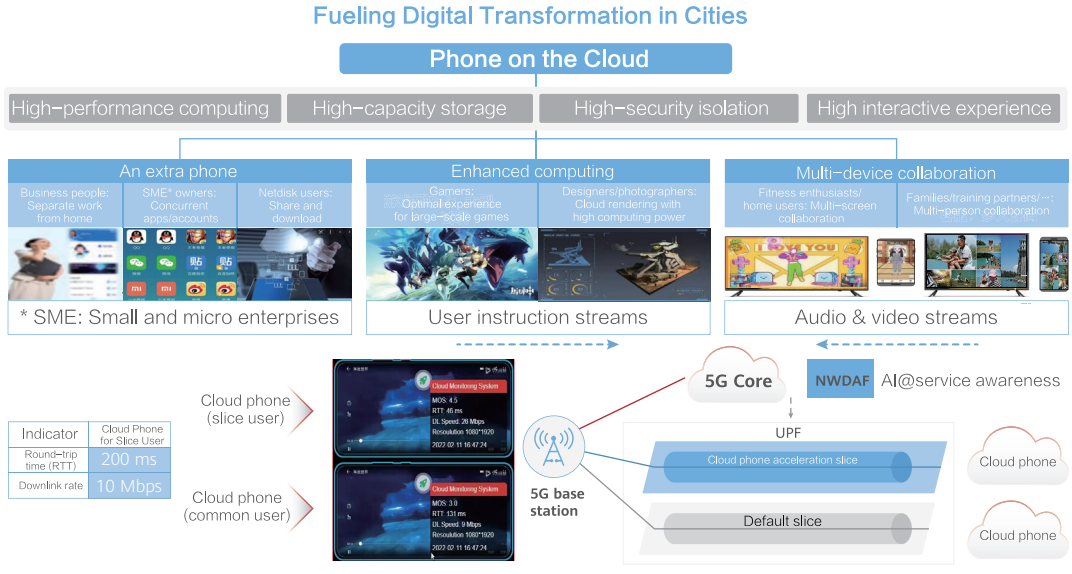

Figure 3 Shanghai Mobile and Huawei published the verification results of China Mobile's testing on cloud phones based on 5G network slicing

Currently, more users are adopting real-time video streaming and XR services. The core network needs to keep up through improved identification and scheduling capabilities shifting from flows to frames. This will enable a shift from real-time video streaming to immersive and interactive services. For example, precise identification and differentiated scheduling for key and non-key frames will allow a single 5G cell to support high-quality services for five times more XR devices, and ultimately, this will drive the large-scale commercialization of XR services and bring more profits to telecom operators.

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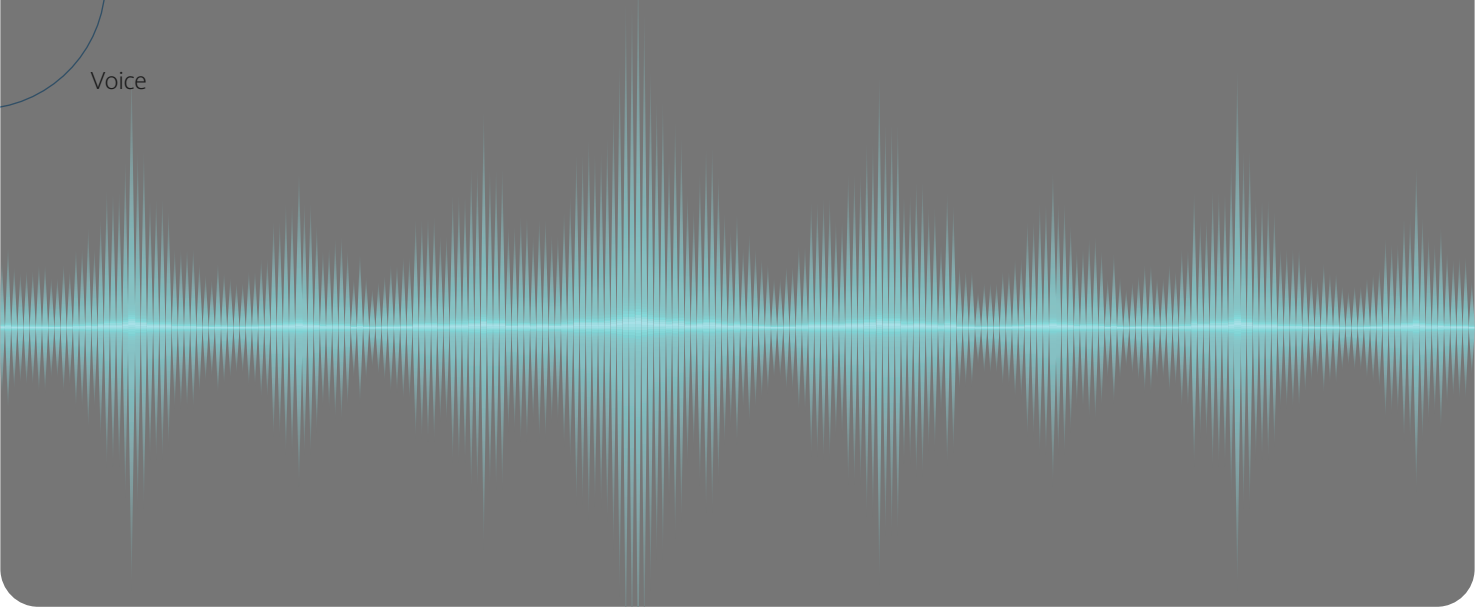
03

New Calling: Constructing Communications of the Future



Voice calling has traditionally been the most reliable and convenient communication method around the world, not to mention the most effective way to maintain customers' loyalty to operators. As times change and technology progresses, operators are considering what new functions and experiences can voice calling offer in the 5G era. To help operators minimize churn rates, Huawei leverages the audio, video, and data capabilities of IMS to roll out the 1+3+N New Calling solution. Utilizing this solution, operators can build networks with UHD, intelligent, and interactive calling capabilities, laying a strong foundation for innovative services. Such new services can significantly improve service experience, satisfy communication requirements in different industries, and build differentiated advantages in 5.5G.

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1. Leading Operators Leverage Voice and Video Calling Services to Maintain Customer Loyalty

5G lacks innovative B2C applications.

From the 1G to 5G range, each generation has had a unique service style, with 1G allowing voice-only calls, 2G enabling short message services, 3G supporting Internet access, 4G boosting video services, and now 5G empowering a wide range of industries. When greeting such limitless opportunities brought on by 5G, operators need to consider how the calling service will not only survive, but thrive.

Users have urgent demands on exchanging diverse types of information and improving

communication efficiency.

Individual users tend to use video calling because it delivers far more information than audio-only calling does, making communication more efficient. In addition, they desire that their privacy rights are well protected, and interactive functions are at hand during calls. Interactive functions, such as multi-party video calls provided by WeChat, background replacement and one-touch beauty settings supported by MeeTime, and AR emojis offered by TikTok, make calls more interesting, which ultimately attracts more users and increases the Minute of Use (MOU).

Enterprise users require efficiency-improving functions. For example, customer service personnel can deliver contracts to customers while they are on voice calls. Customers then can directly sign these contracts on their phones. Civil service staff also hope that survey forms can be filled in on phones whilst they are on voice calls.

Communication via calls is a fundamental and easy way to convey information, for not only individuals but also industries.

Operators leverage calling services to roll out new services and maintain customer loyalty.

OTT applications, to a certain extent, can improve communication efficiency and satisfy users' demands on interaction. However, OTT applications have several shortcomings such as unstable service quality and complex installation and registration processes. In contrast, operators provide services based on user numbers, freeing users from complex installation and registration processes. In addition, operators use dedicated channels on IMS to provide services. As such, users can enjoy services with a determined service quality.

As the bandwidth efficiency is significantly improved in 5G, some leading operators are moving markets by redefining the dial plates. They have empowered legacy voice calling with UHD, intelligent, and interactive capabilities. To achieve this, they have employed the following steps:

1) Making video calling affordable by common individual users: China's three leading operators have launched 5G UHD video calling in May this year and included video calling services in their service packages. Video calling shares MOU quota in the service packages with audio calling, and is not separately charged.

2) Making video calling intelligent: During voice calls in the B2C and B2B industries and between acquaintances, multimedia information, such as documents, images, and videos can be transmitted over data channels.

3) Making video calling interactive: By leveraging 3GPP-defined data channels, operators redefined users' dial plates and built up their leftmost screens. Operators now can offer interactive services, such as screen sharing and AR annotation on the leftmost screens, improving communication efficiency.

2. 1+3+N New Calling: Catering for Communication in the Future

Huawei launches the 1+3+N New Calling solution. The solution allows operators to build a platform with UHD, intelligent, and interactive capabilities. The platform brings services such as UHD video calling, speech recognition-based intelligent translation, and remote assistance into reality, accelerating service innovation and unleashing the power of communications across multiple industries.

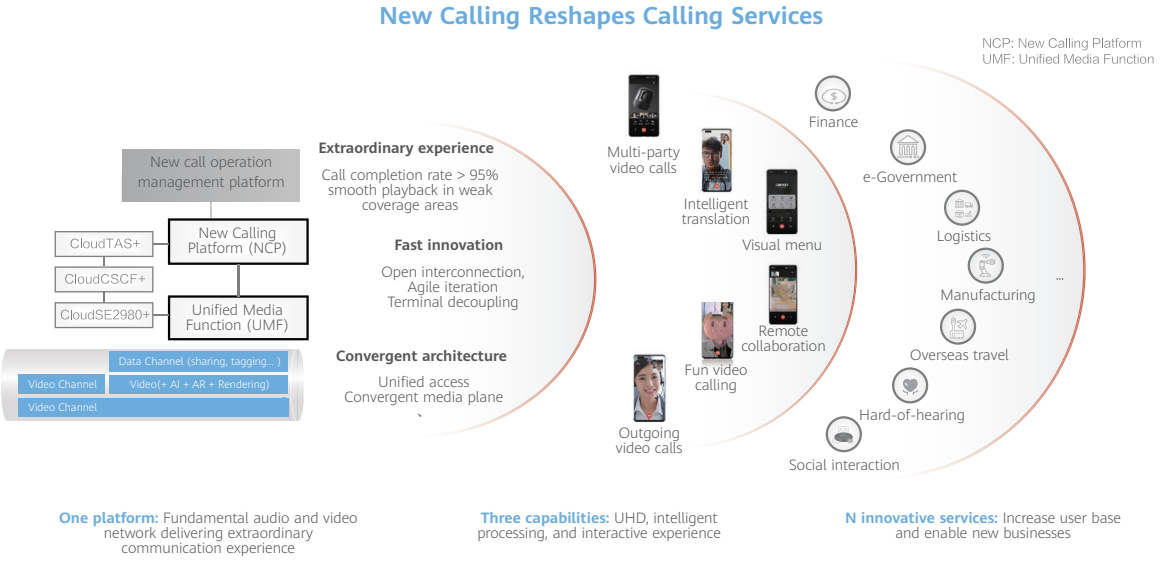

Figure 1 "platform + 3 capabilities + N services" architecture for New Calling

- **One platform:** Up until now, the VoLTE penetration rate has exceeded 80% in China, and over 75% of terminals on the market support video calling. China Mobile, China Telecom, and China Unicom deployed IBCFs in 2021, making cross-VoLTE network interworking possible. Currently, the video calling interworking rate is about 80%, which is advancing video calling services by leaps and bounds.

To boost service innovation, one platform is constructed with IMS as the base, coupled with the New Calling Platform (NCP), Unified Media Function (UMF), and corresponding operations support systems. On the platform, the UMF provides media rendering and composing capabilities, empowering service innovation such as XR and metaverse. The UMF enables AI media rendering and synthesis services, and empowers service innovation such as XR and metaverse communication. The NCP is a cloud-native platform for E2E service deployment. It provides functions, such as life cycle management and service orchestration.

- **Three capabilities:** UHD, intelligent, and interactive video calling capabilities are added to the basic network to cultivate user habits and allow video services to

organically grow.

a) UHD: The UHD video calling allows users to view videos without frame freezing, improving user experience.

b) Intelligent: Image recognition and media rendering functions are implemented through video channels to make calls fun and efficient. For example, users can choose from background replacement, AR virtual avatar, and speech recognition-based intelligent translation functions during calls.

c) Interactive: During a call, a data channel is established between the phone and network. In this instance, mini Apps are automatically established and run on the phone and users can complete multiple tasks by using just a phone. Mini apps that have been used can be displayed on the leftmost screen so that users can easily find them next time.

- **Multiple services:** The New Calling solution is an open enablement platform, fueling service innovation.

Operators, together with third-party partners, roll out new services tailored according to requirements of different users and industries.

3. Executing the New Calling Solution in Phases.

The rapid development of New Calling services relies on two aspects: popularity of VoLTE/VoNR networks and maturity of the ecosystem, which is comprised of chips, terminals, networks, services, and industries. The VoLTE and VoNR subscriber base in China are significantly large, with approximately 80% of users having already subscribed to the UHD video calling service. However, most terminals available on the market do not support this service. The entire ecosystem takes a long time to mature. Therefore, it is recommended that the New Calling solution be implemented in phases based on the maturity of the ecosystem.

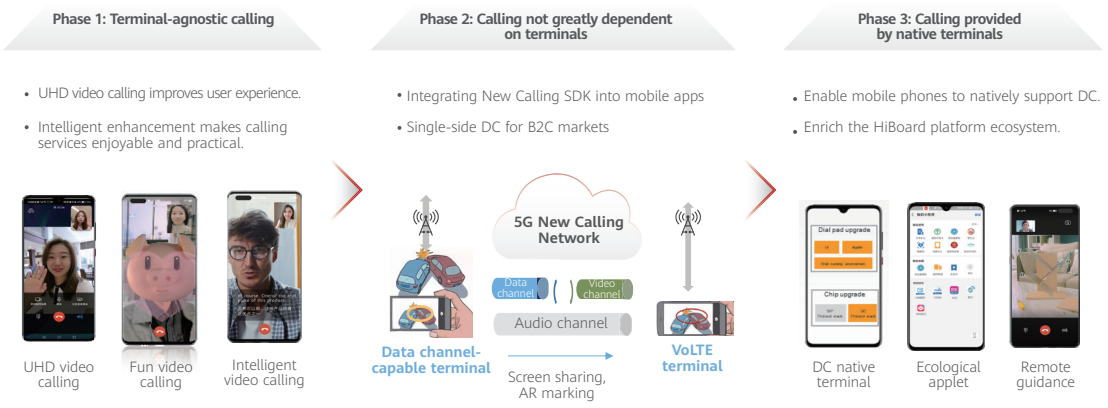

Figure 2 Three-phase strategy for implementing New Calling

Phase 1: Develop terminal-agnostic HD and intelligent video calling to meet the needs of B2C users, for diverse and enjoyable calling services.

Intelligent video calling

On the 3rd March 2021, Huawei together with operator C unveiled an intelligent translation service using the New Calling solution in Hebei. This service leverages speech recognition techniques by converting voice into text, and facilitates the communication between people with hearing difficulties.

Remote loss assessment

Currently, vehicle loss assessment is performed by loss assessors on site, which is costly and inefficient. To solve this issue, Jingyou Technology and Huawei jointly integrated New Calling into the claims assessment process for the insurance market. The system directly initiates a video call to the driver following an incident. After the driver answers the video call, the system can guide the driver to take photos of the damaged areas, upload certificates, and generate quotations. In this case, the insurance loss assessment process is shortened from two hours to five minutes, reducing costs and improving efficiency.

Phase 2: Enrich video calling applications and introduce interactive video calling that is not greatly dependent on content and terminals, to improve industry efficiency and increase value.

Embedded SDKs are installed on the network so that the network supports data channels (no retrofitting is required on terminals). As long as the network supports the data channels, it can establish data channels with the terminals.

Since 2021, Huawei has worked with operator C to pilot new New Calling at different sites and rolled out new services such as visual menus and remote maintenance.

Visual menu

In 2021, operator C, bank H, and Huawei signed a contract for deploying the New Calling-based visual menu service. The service was officially launched in February 2022.

With this service, customers can enjoy a more efficient service experience. During customer service calls, customers only need to select options displayed on their UE screens. In this scenario, services can be rendered quickly.

Remote maintenance

During the COVID-19 pandemic, remote office and remote classroom led to a sharp increase in the demand for home broadband services. To provide installation and maintenance services for customers in a timely and effective manner, operator C worked with Huawei to carry out a pilot remote maintenance project. After a customer answers a video call and activates the camera, the customer can share images of the broadband device with the installation engineer. The engineer makes marks on the screen and

remotely instructs the customer to install the device or rectify faults. This service effectively improves user satisfaction and reduces OPEX.

Figure 3 Remote maintenance

Phase 3: Develop all-round interactive calling, promote native terminals to support New Calling, build platform products, and roll out innovative services quickly, further allowing the application ecosystem to flourish.

Manufacturing of IMS Data Channel-capable terminals requires the collaboration of chip and terminal vendors. Currently, standard organizations and some leading operators are promoting this process. There are some mainstream chip vendors who plan to launch chips and terminal prototypes that support data channels in the second half of 2022. According to the pilot results of an operator, the first terminal that supports data channel is expected to be launched in 2023.

Using data channel-capable terminals will further improve the users' experience. Basic interaction functions such as screen sharing and AR marking will enrich service scenarios and boost New Calling development.

For B2C users: Interesting interactive services can scale up the usage frequency, increase the MOU, and promote users to upgrade service packages.

For B2B users: Services such as electronic signatures help improve transaction efficiency.

4. Industry Progress

Standards Progress

The development of New Calling depends on the maturity of the IMS Data Channel standards and the manufacturing progress of network devices, terminals, and chips. To help operators cope with these challenges, Huawei actively promotes a unified New Calling architecture in standard organizations, such as 3GPP, GSMA, and CCSA.

The 3GPP SA4 working group completed the standardization of IMS Data Channel in March 2020 and released the 3GPP TS 26.114 (V16.5.0) version.

In December 2021, 3GPP initiated NG_RTC in R18. This project conducts in-depth research on how to optimize the IMS Data Channel architecture and deploy IMS media plane as a service. The project clarifies that the media and control planes must be separated and a unified media plane must be adopted in the IMS Data Channel architecture. This architecture not only enables data channels, but also simplifies the IMS media network architecture. In GSMA, the IMS Data Channel PRD (NG.134) is being

drafted in an orderly manner. The initial version is expected to be released in the fourth quarter of 2022 to recommend the deployment solution for data channels and requirements on operator' networks.

In December 2021, GSMA released IMS Data Channel White Paper NG.129. The white paper describes the IMS data channel technology and its industry vision, and proposes requirements on IMS data channel-based C2C, B2C, and C2B communication services on operators, vendors, and device manufacturers.

The China Academy of Information and Communications Technology (CAICT), Institute of Technology and Standards, and Huawei jointly released a report on New Calling. This report analyzes the development and trend of call services, resolves the technical solutions and key capabilities of New Calling, and describes the typical application scenarios and important values of New Calling in B2B and B2C industries, and proposes suggestions as to how to expand service scenarios and collaborate between different industries.

Industry Collaboration

Unleashing New Calling values and boosting its development require the continuous and joint collaboration of all industries, including operators, equipment vendors, terminal and chip manufactures, and standard organizations.

In 2021, China Mobile and Huawei jointly proposed the establishment of the New Calling work group. At the 5G World Congress on August 30, this work group was formally established, aiming to promote the construction of the New Calling ecosystem. The work group includes over ten members, such as China Mobile, Huawei, Ericsson, Vivo, Xiaomi, and Zhanrui, etc. It is estimated that in the fourth quarter of 2022, chip vendors will launch chips that support data channels for pilot tests. Terminals that support data channels will be launched in 2023.

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04

Moving VoLTE-based Audio and Video Networks Toward a Bright Future

VoLTE was originally created on 4G networks and is characterized by both a wide coverage and polished service experience. Considering its commercial and technical values, VoLTE has become the inevitable choice for operators when rolling out 5G calling services. Further momentum will be granted to the development of VoLTE when operators shut down 2G and 3G networks in the not too distant future.

With the advent of 5G, networks are capable of providing Video over LTE (ViLTE) as one of the fundamental services. Leading operators running well constructed VoLTE networks are leveraging video calling to improve user experience, and in return an optimal user experience helps increase the subscriber base. Furthermore, operators can develop a multitude of innovative services on top of video calling, unlocking new business opportunities.

Huawei's Single Voice Core (SVC) solution can help operators build a solid audio and video network, and harness video calling capabilities and IMS Data Channels to roll out innovative services, ultimately achieving commercial success.

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VoLTE Is Mandatory in 5G

3GPP does not define the direct fallback from 5G to 2G/3G, and therefore VoLTE becomes mandatory.

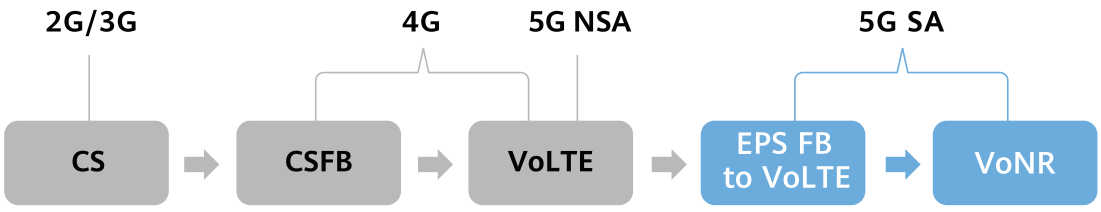

Figure 1 Voice solution transition

In 2G and 3G networks, the CS domain provides mobile voice services. As networks move to 4G featuring all-IP, users can access voice services in either CSFB or VoLTE. VoLTE is optional for 4G.

With the advent of 5G, mainstream operators still use VoLTE to provide calling services in NSA networking; in SA networking, though EPS FB and VoNR are available, VoLTE is an absolute necessity for EPS FB and an indispensable supplementary to VoNR.

5G mobile phones can only be used as 4G mobile phones if VoLTE and VoNR are not supported.

According to 3GPP, voice-centric UEs must continuously ensure that voice services are available. If a voice-centric UE cannot obtain voice services from a 5G network, the UE must disable the capability of accessing the 5G network and connect to a 4G network (if available) to ensure voice services.

Given this, if a 5G network does not support VoNR and EPS FB due to the lack of VoLTE, 5G mobile phones can camp only on a 4G network and need to fall back to a 2G or 3G network to obtain voice services. These 5G mobile phones can use only 4G data services. In this case, 5G user experience greatly deteriorates.

To guarantee voice and data service experience of 5G subscribers, operators demand a well-constructed VoLTE network when VoNR is not deployed in the early stage of 5G, or is being deployed.

VoLTE serves as an indispensable supplementary to VoNR to ensure user experience.

5G NR base stations use a higher frequency band. When 5G and 4G base stations are deployed at the same site, the coverage area of 5G base stations may be smaller than that of 4G. If a 5G mobile phone is under the 4G LTE coverage area only, and VoLTE is not supported, the mobile phone must fall back to a 2G or 3G network to initiate or receive a call and cannot use 4G data services until the call ends. If the mobile phone is under the 5G NR coverage area and then moves to the 4G LTE coverage area, an ongoing VoNR call drops because VoLTE is not supported by the 4G network and a PS handover cannot be implemented for the call.

Therefore, to commercialize 5G on a large scale, a well-constructed VoLTE network must be ready.

The winding down of 2G and 3G networks further promotes VoLTE development.

According to the GSA industry report, 135 operators around the world have shut down or plan to shut down their 2G and 3G networks, and by 2025 we will witness the peak. As VoLTE can provide a higher spectral efficiency, operators hope to migrate their 2G and 3G users to VoLTE networks and refarm spectrum resources to enhance LTE coverage and capacity, thereby promoting the development of both 4G and 5G.

Leading Operators Develop New Capabilities and Innovative Services to Retain Users

In 4G, operators' ViLTE services are not widely used. However, 5G brings great opportunities for operators to develop video calling services as essential services. Terminals that support video calls are becoming commonplace. In addition, operators can provide video calling services with the same package and the same price as voice services, and users can use video calls without worrying about incurring additional fees. Moreover, VoLTE roaming and cross-network interworking are gradually deployed. All of these changes lay a solid foundation for the large-scale commercial use of video calling.

Thanks to the popularization of the Internet, a greater number of individual users have already been accustomed to using video calls for communication. For example, the number of video call users in China exceeds 1.2 billion, and the average OTT video call duration over the mobile network reaches up to 300 minutes each month. In contrast with video calling services provided by OTT vendors, operators' video calling services have unique advantages, such as negating the process of adding friends and installing apps, and high quality calling ensured by dedicated bearers. All of these advantages will undoubtedly bring operators tremendous opportunities.

To boost operators' calling services, 3GPP TS 26.114 has defined the IMS Data Channel technique. In the IMS Data Channel architecture, a data channel is laid upon existing IMS voice and video channels and meets the requirements of data apps in terms of latency, bandwidth, and reliability. This technique will unleash the huge potential of native phone calling.

So, what should operators do to seize these opportunities?

Single Voice Core Helps Build a Future-oriented Fundamental Audio and Video Network

Huawei's SVC solution aims to help operators build a fundamental audio and video network, and transition their calling services towards 5G and all-cloud.

Build a high-quality VoLTE network.

Though there are more than 200 commercial VoLTE networks worldwide, they are not evenly distributed. Operators in different regions may be in different development stages and face different conditions.

First, operators need to accelerate the commercial use of VoLTE. VoLTE is a complex system, involving E2E network coordination among the terminals, wireless network, bearer network, core network, and signaling network. It consists of 21 types of NEs and 38 interfaces. Before the commercial use of a VoLTE network, many challenges, such as multi-domain adaptation, SRVCC handovers, and 2G and 3G voice service inheritance and consistency must be addressed. The SVC solution provides a highly converged voice network architecture, with all standard IMS NEs integrated into the CloudATS9900, CloudCSC3300, and CloudSE2980, greatly simplifying network deployment and interconnection. Furthermore, the SVC solution can help operators tackle issues in adaptation to peripheral NEs and IT systems and accelerate the commercial use of VoLTE networks. For example, the UMTS, LTE, CS, and PS networks of operator V in country S are provided by four vendors, and the entire network is extremely complex. Huawei's profound integration and delivery experience allowed it to leverage the SVC solution to interconnect different devices from different vendors at 120 sites on the entire network and helped the operator deploy a commercial VoLTE network within only 110 days.

Second, operators need to guarantee the service experience. At the early stage of commercial use, operators need to focus on improving the VoLTE service experience. In addition to optimizing networks and increasing coverage, operators need to be capable of efficiently locating and demarcating problems on VoLTE networks.

Voice services pose higher requirements on wireless coverage than data services. Before the large-scale commercial use of VoLTE, operators must ensure sufficient 4G signal coverage. To jointly align with the operators' VoLTE development pace and investment pace, Huawei defines network coverage standards for VoLTE in the basic, mature, and advanced stages. In 2021, Huawei helped operator T in country A build a VoLTE network according to these standards, and operator T has successfully put the VoLTE network into commercial use.

In addition, problem locating on VoLTE networks is more difficult than that on 2G and 3G networks, especially problems such as voice skipping, discontinuity, and one-way audio. Therefore, it is more difficult to achieve the SLA on VoLTE networks. According to a project, more than 50% of the customer complaints are related to voice calls at the early stage of VoLTE commercial use. To solve this problem, Huawei has established a Key Quality Indicator (KQI) system. This system helps operators set up a mapping between user experience, network indicators, and NE indicators from the dimensions of call connection delay, voice quality, and call continuity, facilitating operators to optimize VoLTE service experience. In 2016, Huawei helped China Mobile significantly improve key KQIs of its VoLTE network, paving the way for the rapid growth of the VoLTE subscriber base and building the world's largest VoLTE network.

Third, operators need to accelerate subscriber migration to VoLTE. After VoLTE is put into commercial use, operators need to wind

down 2G and 3G services as soon as possible and then focus on 5G construction. To achieve this, subscribers must be migrated from 2G and 3G networks to VoLTE networks.

The SVC solution provides manual and automatic VoLTE service provisioning modes for operators. In manual service provisioning, operators can obtain a list of potential VoLTE subscribers after scanning and analyzing terminals on the entire network. Operators can provision VoLTE services for these subscribers based on the network development pace. Manual service provisioning is commonly adopted in the initial phase of VoLTE commercial use.

In automatic service provisioning, SVC NEs automatically detect VoLTE-capable terminals and provision VoLTE services for these terminals. This process does not require any deployment tools and mitigates manual operations while ensuring accurate service provisioning. Automatic service provisioning drives the rapid growth of the VoLTE subscriber base and applies to the middle and mature stages of VoLTE commercial use.

With the help of automatic service provisioning, operator A in country B increased the number of VoLTE subscribers from 5.5 million to 25 million in 2021 alone and refarmed 10 MHz UMTS spectrum resources for expanding 4G network capacity. Currently, Huawei has helped global operators build more than 120 commercial VoLTE networks, serving more than 1.2 billion subscribers worldwide.

Leverage the fundamental VoLTE network to upgrade audio and video service experience and gain user loyalty.

Global operators have recognized that voice services alone cannot efficiently increase the Average Revenue Per User (ARPU). To this end, they are constantly trying to develop new services to monetize their VoLTE networks. A common consensus is that developing video calling services on VoLTE networks is a feasible way and may spur on more innovative services.

To shift from providing voice services to video calling services, operators must address several challenges. Firstly, they lack the technical ability and expertise in operating and maintaining large-volume video traffic. For example, video calls have higher requirements on network quality than voice calls. When the packet loss rate of a voice call is 1%, users are unaware of it. However, when the packet loss rate of a video call is greater than 0.1%, users will experience a poor call quality. In addition, operators do not have efficient problem demarcation and locating methods. Though VoLTE has been put into commercial use for several years, some issues like video artifacts, frame freezing, and black screen cannot be completely located and resolved.

In recent years, Huawei and China Mobile have completed a significant amount of work in advancing video calling as one of the basic services. They have built a system to refine basic audio and video indicators and systematically display video call KPIs, helping optimize video call experience. They have also tried to explore a proper Video Mean Opinion Score (vMOS) evaluation algorithm and promote its incorporation into standards to ensure that the algorithm not only supports 4G and 5G video codecs, but also can be integrated on the network side. The vMOS can reflect low-probability events such as artifacts, frame

freezing, and black screen in addition to showing video call quality in normal cases. Currently, Huawei and China Mobile are researching on how to improve problem locating capability for video calling services. With all of these efforts, a high-quality video network will be built.

In terms of service innovation, Huawei helped China Mobile develop the video RBT service on the VoLTE network. By the end of 2021, the number of individual users and enterprise users reached 200 million, achieving significant business success. Presently, Huawei is working with China Mobile to develop new services with New Calling. The New Calling solution provides ultra-HD, intelligent, and interactive capabilities for common video calls born on the fundamental network, thereby yielding more service scenarios and converting video calling into a basic service.

Wind down CS networks and build a simplified voice network.

Many operators in developing markets are still transitioning their services from 2G and 3G to 4G. In this phase, their 2G and 3G networks need to be in service and will coexist with 4G networks for a long period of time.

However, if an operator's CS network has been running for more than 15 years and is about to reach EOX or has reached EOX, the operator must reconstruct the CS network to ensure stable operations. Meanwhile, the operator needs to continuously invest in VoLTE to ensure network capacity and optimal user experience. In the near future, the operator will need to transition its voice network to VoNR.

This process brings some issues. Firstly, the operator needs to operate and maintain multiple voice networks, such as the traditional CS network facing EOX, traditional VoLTE network, NFV-based VoLTE and VoNR networks, and fixed network. This greatly complicates network O&M. Secondly, from the perspective of the evolution path, the traditional CS network needs to evolve to VoLTE, and then from VoLTE to EPS FB and VoNR. Such an evolution path covers multiple phases, which incurs high complexity in strategy, technology, and business. Thirdly, the operator needs to consider how to improve ROI when reconstructing the CS network.

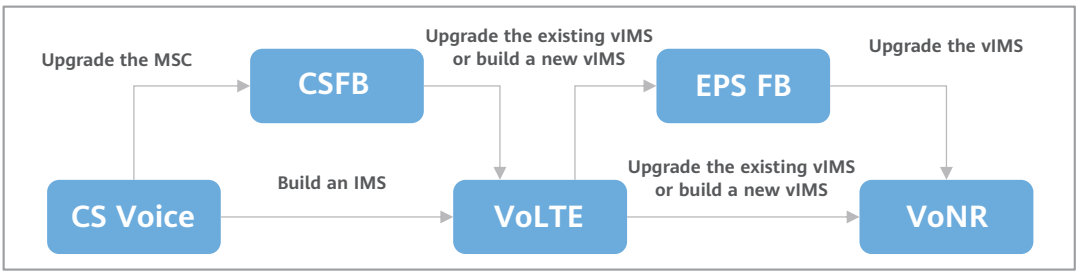

Figure 2 Voice network evolution in multiple phases

To tackle these issues, operators require a solution which can help them build a simplified voice network and facilitate the winding down of the CS network.

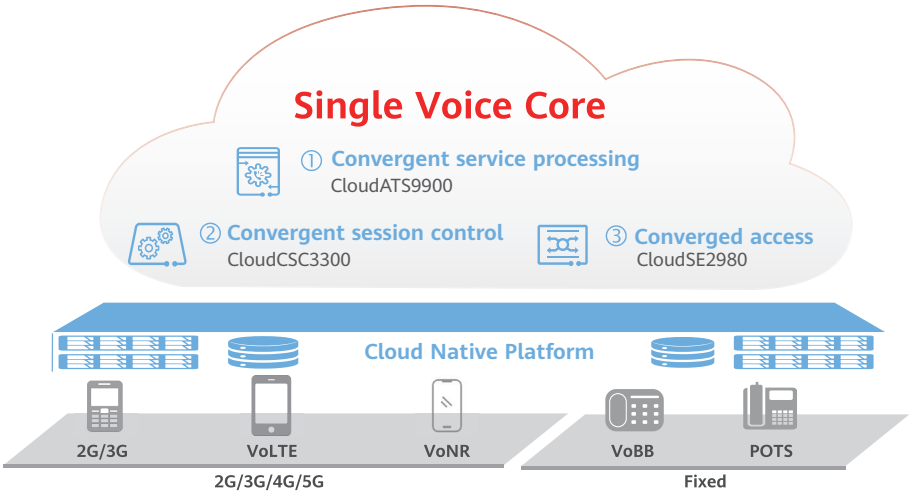

Figure 3 Huawei SVC solution

Huawei SVC solution complies with the SeDoc architecture defined in 3GPP R14. With the SVC solution, 2G, 3G, 4G, 5G, and fixed subscribers can access the IMS network and use services provided by the IMS. In this way, the outdated CS devices can be removed from the network, the network topology is simplified, the interfaces for peripheral systems are reduced, and the O&M cost is decreased by 40%. In addition, the SVC solution works on an all-cloud IMS network, which helps resource sharing. With the codec resource pooling technology, existing CS resources can be reused for VoLTE services, reducing hardware resource consumption by 30% on average.

Take operator T as an example. Since 2020, its traditional CS network has reached EOX and needs to be reconstructed. In addition, the operator planned to focus on VoLTE development in 2021 to pave the way for the commercial use of 5G SA. This gave rise to a high CAPEX. In this case, Huawei helped operator T deploy an SVC network to support both VoLTE and 2G/3G subscriber access and service processing, thereby allowing the operator to shut down the CS network. In addition, the number of NEs on the voice network is reduced by 40%, the power consumption is decreased by 55%, and the footprint is slashed by 60%. It has been proven that the SVC solution is the optimal choice for operators to evolve their voice networks.

Summary

In the journey to 5G and all-cloud, Huawei SVC can help operators build a high-quality VoLTE-based audio and video network. It not only incorporates traditional CS services to simplify the entire network but also helps convert video calling services into basic services and stimulate service innovation. The SVC solution, undoubtedly, will bring a bright future for phone calling services.

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05

Zhejiang Mobile: New Calling Services Unlock Future Communication

As technologies develop, calling services have become a part of our everyday lives. Today, calls are evolving from audio to video, a shift that Zhejiang Mobile has actively embraced. In fact, the company expects video calls to become as mainstream as audio calls. Taking it a step further, Zhejiang Mobile is adding intelligent and interactive calling capabilities to video calls. With these capabilities, operators can guarantee excellent user experience while helping enterprise users reduce costs and improve efficiency. Zhejiang Mobile is leading the way in normalizing video calling services and is piloting innovative add-ons, such as intelligent video calling and interactive video calling.

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Calling Services Need to Evolve Continuously to Satisfy Users' Ever-changing Demands

When it first emerged, voice calling was a game changer in the history of communication technology, having a profound impact on the architecture of mobile communications network. Then, 3G enabled video calling, which has since become part of everyday life. With 4G and widespread Internet access, online interactions and communication methods have become even richer.

Within this context, user expectations continue to evolve. So, Zhejiang Mobile asked the question: How can we satisfy the increasing user requirements? In particular, as operators roll out 5G, what are some ways to enhance user experience through ever-advancing technologies?

Video Calling Becomes a Standard Service, Building User Loyalty

Albert Mehrabian theorizes that human interactions rely heavily on non-verbal communication. According to his 7-38-55 Rule, 7% of meaning is communicated through spoken words, 38% through tone of voice, and 55% through body language.

Past attempts to integrate video calling into standard operator services have failed. Specifically, IMS-based native video calling was unpopular among users. It was expensive, incapable of cross-network calls, lacked network coverage, and relied on a few models of video-capable terminals. However, with 5G, these challenges are no longer an issue. In fact, IMS-based video calling can now be commercialized on a large scale.

On April 8th, 2022, Zhejiang Mobile became the first operator in China to commercialize 5G UHD video calling, providing 5G users with the ultimate interactive video calling experience. 5G VoNR facilitates stable, smooth, and crystal-clear video calling. Plus, 5G UHD video calling outperforms OTT services by using dedicated channels to ensure optimal user experience.

UHD video calling gives momentum to service innovation. In addition to helping operators retain users with an extraordinary service experience, UHD video calling paves the way for operators to develop new services, such as intelligent video calling and interactive video calling, to unleash the vast potential of call communication.

Zhejiang Mobile Is Ready to Pilot All-new Calling Experiences

China Mobile has added New Calling to its "8+5" user experience strategy, helping breathe new air into calling experiences and raise brand awareness. Zhejiang Mobile has taken the lead in verifying the E2E network architecture and service scenarios for New Calling.

Zhejiang Mobile and Huawei have made a host of improvements in the IMS network architecture and systematically optimized network indicators, such as latency and resolution, to ensure the best user experience. In addition, Zhejiang Mobile has gradually deployed strategies for product design, marketing, and user development. In the next phase, Zhejiang Mobile plans to commercialize New Calling services and rapidly increase their user base.

Zhejiang Mobile has drawn up a roadmap for the rollout of intelligent video calling services, the first of which will be the addition of fun video calling and intelligent translation.

Fun video calling enables callers to use virtual images to try on different outfits, which is achieved by synthesizing video streams on the network side. Users can also use gesture and voice commands to add fun facial expressions generated by the system to convey their emotions. For example, parents can use virtual images and funny expressions to engage with their kids while on a video call.

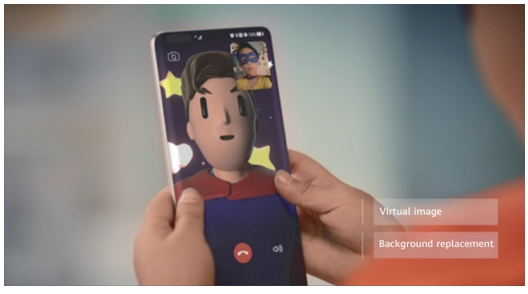

Figure 1 Interaction between parents and kids via fun video calling

Another option is for friends or partners to send cute images and facial expressions to show their emotions.

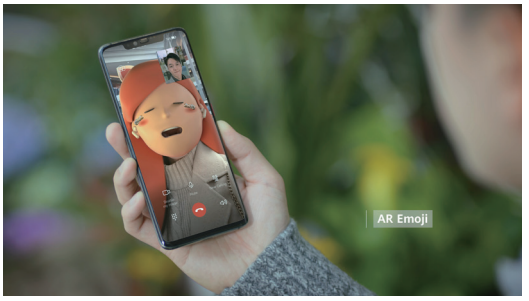

Figure 2 Interaction between friends or partners via fun video calling

On the other hand, intelligent translation recognizes and translates voice content and displays the translation on the video call interface in text. This is a powerful tool to facilitate communication across different cultures or for people with certain disabilities. Intelligent translation can even recognize and translate body language and sign language, facilitating smooth communication across different social and cultural groups.

Figure 3 Sign language translation

In addition, this feature can perform voice-to-text operations and close caption the call using a large font, facilitating communication for the elderly or people with hearing impairments.

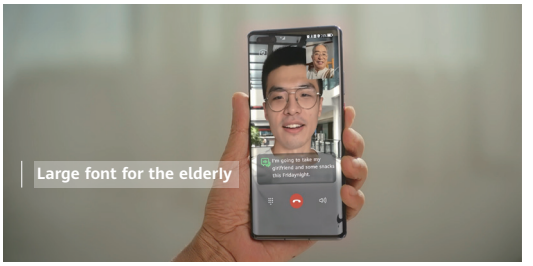

Figure 4 Large font for the elderly

Finally, intelligent translation can also translate across different languages while on the call in real time.

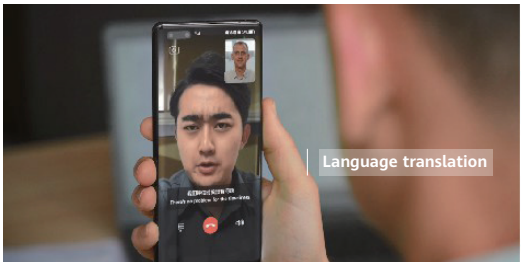

Figure 5 Language translation

Ultimately, features like these are taking a traditional service and bringing all-new commercial and social value. In the next phase, interactive video calling services will be rolled out and will undoubtedly take video calling to another whole new level.

New Calling Unlocks the Future of Communication

New Calling is still developing. New business models and features are bound to emerge. As such, Zhejiang Mobile will continue its tactical dive into New Calling, looking to optimize both business design and user experience. As the ecosystem for interactive video calling becomes well established, Zhejiang Mobile plans on integrating New Calling features to benefit millions of customers by offering helpful information services. Zhejiang Mobile will also restructure the B2B market and boost the growth of numerous industries with its all-new call services.

06

Building a Secure, Reliable 5G Signaling Network

Signaling, the language for inter-NF communications, acts like the nerve center of a communications network. Planning and managing signaling networks well are imperative for efficient, reliable, and secure communications. Huawei has launched the Unified Signaling Controller (USC) solution to offer simplified signaling networks with high stability, reliability, and security. It is dedicated to helping operators build and manage future-oriented signaling networks that are easily able to cope with diversified services and stringent requirements. This solution guarantees the secure and stable operation of a communications network and improves O&M efficiency.

Chen Weixian,
Marketing Expert for Convergent Signaling, Huawei Cloud Core Network Product Line

Operators are accelerating the construction of 5G, with the promise of high bandwidth, low latency, and immense connections. The advent of 5G brings service innovation and elevates user experience to new heights, enabling a more convenient and enjoyable life for those who are accessing its services.

Despite the above, several communication incidents have occurred around the world. These incidents affected the daily communications of the public and terminated services in many sectors such as the government and public services. We discovered that these incidents were closely related to operators' signaling networks, for example, services were interrupted due to unexpected signaling storms, and information leaked due to signaling security risks.

Therefore, we need to plan and build orderly and secure signaling networks to achieve reliable communications in the 5G era.

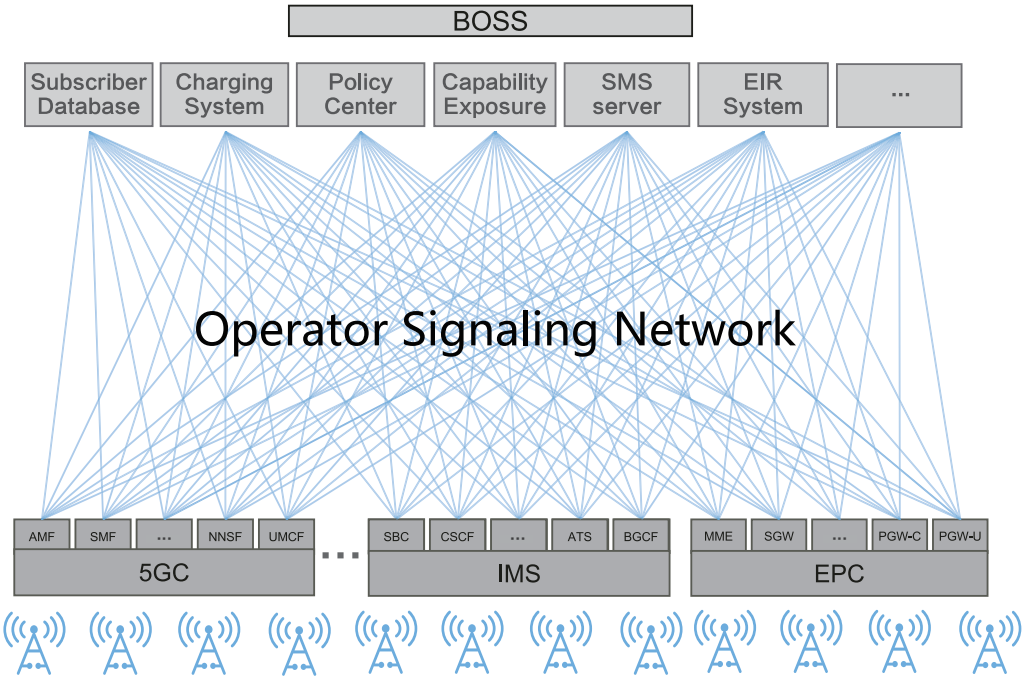

Figure 1 Signaling network — the nerve center of a communications network

To adapt to 5G networks, the signaling network faces the following challenges:

Challenge 1: complex network architecture and low O&M efficiency

Throughout the development of 5G, new services are emerging and continuously varying. An increasing number of subsystems and connections are added to the communications network, and all these combined factors make the network architecture more complex.

In terms of signaling protocols, HTTP/2 used on 5G networks is based on text parsing, which is less efficient than traditional SS7 and Diameter. In addition, the number of 5G NFs and service types increase exponentially compared with 2G, 3G, and 4G. As such, high network latency and congestion may surge in some service scenarios.

The 5G Core supports automatic signaling link establishment and route information acquisition. When the signaling traffic and number of links increase, the signaling network becomes disordered, making link troubleshooting and fault locating cumbersome.

Various vendors are active participants in the cloud era and have different understandings on communication protocols. They also execute the protocols in different ways, and sometimes even differ on network generations. These differences cause NF interconnection difficulties and hinder the service rollout progress. For example, an operator found that their charging system does not support Service Based Interfaces (SBIs) when

they want to deploy a 5GC network.

The practices of global operators have proved that the 2G, 3G, 4G, and 5G networks will coexist long into the future, and multiple protocols and subsystems further increase the complexity of the signaling network.

Challenge 2: unreliable network

In recent years, signaling storms occurred frequently, indicating that reliability risks exist in global communications networks. How to guarantee network reliability has always been a challenge the communications industry faces.

As network devices are transformed from traditional dedicated, to layered decoupled, and cloud-based, network agility increases, however on the flip-side, network reliability reduces. In particular, the robustness of networks deployed in collaboration with multiple vendors is more likely to be insufficient.

The signaling network is an end-to-end network and involves the design of each sub-module to be reliable, including dependable global assurance settings. As the communications network becomes large and complex, it is difficult to cover all aspects of reliability planning, which may bring potential risks.

More importantly, innovative services pose higher requirements on the number of signaling messages, packet length, and processing capabilities. Therefore, the reliability of the signaling network becomes more important. Although the Service-Based Architecture (SBA) has improved its route reliability, it still has disadvantages in real-time congestion management, real-time route load balancing, and reliability assurance.

The increase of new applications stimulates a traffic explosion. Signaling storms are more likely to occur due to reasons such as misoperations and NF exceptions. Service NFs, such as for user data storage, charging, and policy control, bear unprecedented signaling surge pressure. Once these NFs break down, services on the entire network are interrupted.

Challenge 3: absence of security protection

Compared with traditional communications networks, 5G networks evolved from a closed architecture to an open one. Various semi-open and fully open subsystems and even operators' internal networks are divided into different security zones, to fulfill isolation and differentiated management and control requirements. This is because a greater number of security risks were found with the widespread introduction of new network services and technologies. For instance, some security service providers discovered that 5G network slices had security vulnerabilities, and attackers may use terminals to snoop and tamper with user information in neighboring slices. Therefore,

the secure management of signaling network partitions has become a rigid requirement for preventing service loss caused by network vulnerabilities.

Some operators have taken measures to set up dedicated cyber security teams to strengthen the security check for NF and service rollout. If an NF or service does not meet the security requirements, they can veto the NF or service rollout. Henceforth, how to quickly construct signaling networks that efficiently support the service rollout, without sacrificing the security protection level has become a top concern for practitioners in the communications industry.

Huawei's Signaling Solution Helps Operators Build Simple, Reliable, Secure Signaling Networks

Huawei has launched the USC solution to address the challenges that face signaling. As a cross-generation fully-converged signaling management center, the USC provides logical NFs such as the STP, MNP, DRA, DEA, SCP, BSF, and SEPP. The USC can converge, route, analyze, and adapt to signaling, balance system traffic loads, prevent signaling surges, and protect signaling security. It helps operators build simple, reliable, secure 5G signaling networks.

3GPP defines four signaling communication models for 5GC networks: Models A, B, C, and D. Model D is used for indirect communications between NFs. The SCP with Model D provides functions such as link establishment, route information acquisition, traffic forwarding and control, and load balancing.

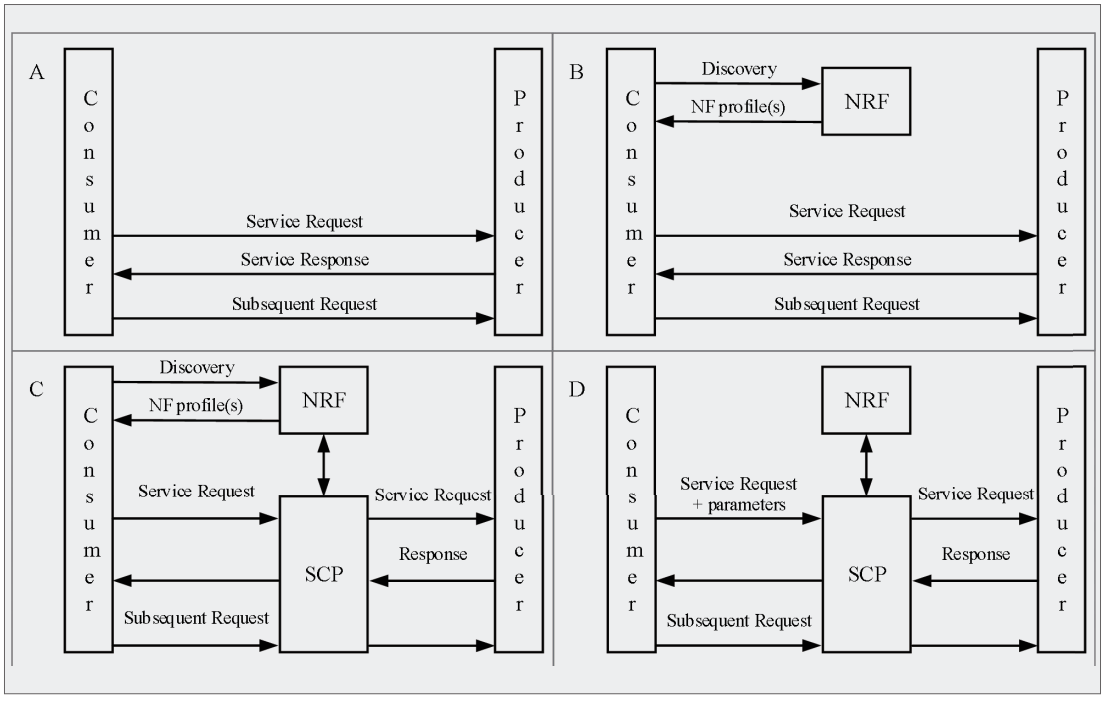

Figure 2 Four 3GPP-defined signaling communication models (A, B, C, and D) for 5G NFs [Note 1]

Model D is optimal for 5G signaling networks. Compared with Models A and B, Model D reduces the number of links by more than 90%, balances the real-time loads of each office direction, and simplifies network connections. Compared with Model C, Model D further reduces subscription and notification messages exchanged between NFs, reduces and balances network traffic loads, and implements centralized management of signaling routes on the SCP, expediting NF deployment and service rollout.

Model D Simplifies Networks and Improves Efficiency

For Model D, Huawei's USC helps operators simplify the signaling network to the maximum degree. The USC converges enormous links by two orders of magnitude, greatly reducing real-time network connections, as well as simplifying the network architecture and O&M.

In the star network structure, the USC provides the traffic visualization function to generate visualized control-plane traffic charts in real time. O&M personnel can easily learn about the global traffic overview and partial message trace. With the help of intelligent analysis tools, the O&M center can monitor the traffic of each office direction in real time and predict the traffic to locate bottlenecks and eliminate potential risks in a timely manner.

Furthermore, the USC implements flexible adaptation and interconnection based on Huawei's more than two decades of signaling interaction experience. This significantly reduces the workload of integration between NFs of different vendors, and provides onsite coding interface adaptation to accelerate the rollout of NFs and services of different vendors.

Huawei, as a unique vendor provides the 2G to 5G range of fully-converged signaling solutions, and helps operators manage resource pools for signaling NFs of different generations, making O&M agile and saving resources and OPEX. Huawei provides a unified lifecycle management platform to reduce the need to migrate and reconstruct networks, making signaling networks more secure and stable.

In 2021, an operator chose the USC to manage and route 5G signaling. This greatly simplifies the SA network architecture, eliminates the need to configure routes for 13,000 discrete number segments, and avoids incompatibility between charging interfaces of different vendors, boosting the rapid rollout of 5G services.

High Resilience, Intelligent Flow Control, and Quick Fault Recovery Make Signaling Networks More Reliable

Huawei's signaling solution is known for its high reliability. The USC's resilience is further enhanced in the all-cloud era. Based on the cloud-based architecture, the internal communication protocol stack is rewritten to support cloud-based load-balancing IP interfaces, and provide flow control on internal and external traffic. Reassuringly, normal message processing can be sustained even when the traffic is overloaded by 64 times, achieving the highest resilience in the industry.

According to recent statistics on signaling storms, 90% of the faults occurred on back-end NFs, such as for user data storage, policy control, and charging. In such a case, Huawei's signaling solution is introduced to adapt to the processing capabilities of the back-end NFs to perform intelligent flow control and peak clipping on front-end traffic, protecting the back-end NFs and ensuring service continuity on the entire network.

In 2022, an operator encountered a service interruption on the entire network due to signaling storms. Their O&M team took two to three days to locate the fault, which brought great troubles and losses to the public, government, and operator. To address such an extreme case, Huawei provides the USC solution for fast fault demarcation and recovery, traffic visualization, as well as intelligent analysis. It will help the O&M center quickly identify exceptions and shorten fault locating and service recovery to minutes, reducing losses for the public in a timely manner.

The implementation effect with Huawei's signaling solution is far superior than that without. As a prime example, an operator who does not use Huawei's signaling solution encountered a service interruption for more than 62 hours due to signaling storms, which deteriorated user experience and damaged the brand's image. In the same period, another operator faced similar signaling storms, but fortuitously with the help of Huawei's signaling solution, suppressed the surge within 15 minutes without service interruption or impact, achieving secure, stable, and reliable service running.

Multi-scenario Converged Protection Enables Signaling Networks to Be More Secure and Trusted

In addition to realizing 3GPP- and GSMA-compliant values, Huawei's signaling solution also provides the following unique values to help operators build secure and reliable signaling networks in multiple scenarios and dimensions.

The current network environment poses multiple security scenarios, which must be fully addressed and protected in order for Huawei to succeed in this field. Therefore, Huawei launches the USC solution to implement both internal and external security protection. It inherits external signaling security protection capabilities in traditional roaming scenarios, supports the 2G to 5G range of cross-generation roaming interconnection, and provides security zone isolation and protection capabilities. It also supports management and control functions such as topology hiding, access control, encrypted transmission, and signaling filtering. Huawei's signaling solution with the security protection functions helps operators easily mitigate against threats and attacks, regardless of whether they are from the outside or the inside.

Furthermore, Huawei's USC integrates the 2G to 5G range of fully-converged signaling firewalls and supports multi-generation joint defense. The O&M team can copy cross-generation defense policies by one click, avoiding incorrect or missing configurations. In the actual operation, the fully-converged firewall can share the 2G to 5G range of signaling attack pattern and signature database to realize optimal signaling

protection.

In addition, Huawei's USC implements light and fast defense. Compared with external firewall solutions, the USC solution implements protocol interface interconnection and firewall convergence, eliminating the need for traffic detour, reducing the latency, and shortening the service rollout. The statistics on project delivery of an operator show that the built-in firewall solution shortens the delivery time by more than three months.

Prospects and Suggestions for 5G Signaling Network Construction

Signaling is playing a pivotal role in operators' communications networks. In the 5G era, new applications are emerging one after another, and the signaling traffic of new services on the network increases exponentially. However, scattered management brings frequent occurrence of network reliability problems and security incidents, resulting in service interruptions and huge compensation payouts. Therefore, operators should focus on the construction of signaling networks as the underlying infrastructure. In the process of network evolution, the signaling network needs to be planned, constructed, and well managed to support the stability and long-term development of new services in numerous industries.

Note

3GPP classifies inter-NF communications on the 5GC into four models: Models A, B, C, and D. The NFs refer to the consumers and producers on the 5GC.

In Model A, NFs directly communicate with each other. Route information is manually configured and maintained, requiring a heavy maintenance workload.

In Model B, NFs directly communicate with each other. The NRF updates and obtains NF link establishment and route information, achieving automated routing. However, the entire network lacks capabilities of real-time traffic load balancing and control.

In Model C, NFs indirectly communicate with each other. NF link establishment and route information acquisition are the same as those in Model B. The SCP implements traffic forwarding and control.

In Model D, NFs indirectly communicate with each other. The SCP provides functions such as NF link establishment, route information acquisition, traffic forwarding and control, and load balancing. Model D has the minimum requirements on NFs.

07

Unlocking "MEC to X" New Businesses with Ultra-Distributed, Fully Connected 5G MEC

5G Multi-Access Edge Computing (MEC) will continue adapting to diverse industries as it further penetrates more sectors. It delivers varied connectivity and compute capabilities to integrate with different service scenarios. As such, it can be flexibly deployed at multiple locations, such as the operator's network edge, enterprise campuses, or production sites, to form ultra-distributed networking.

Cui Bin

Chief Marketing Expert for 5GtoB, Huawei Cloud Core Network Product Line

As 5G networks continue to proliferate, they will be fully backed by MEC to support the development of diverse industries, helping achieve business success and driving the evolution towards an ultra-distributed, fully connected network architecture. The golden time for diverse industrial development has arrived.

MEC has already been widely used across thousands of industries, and we are observing an explosive growth of brand new 5G industry-specific private networks. By the second quarter of 2022, there were over 6000 5G Virtual Private Networks (VPNs) in China. It is predicated that there will be one million 5G industry-specific private networks by 2030, with more specific applications. 5G MEC technology, which is at the core of 5G private networks, is playing a crucial role in the digital transformation of industries. In the early stage of 5G development, 5G MEC construction was driven by 5G industry policies and 3GPP specifications only. As the network construction scales up, enterprises benefit tremendously from 5G industry-specific private networks, due to improved production efficiency and reduced network construction costs, unlocking sustainable business value from 5G MEC. According to the annual reports published by three major operators in China, their

5G B2B services increased significantly in 2021. China Mobile generated a revenue reaching CNY¥137.1 billion in public services and enterprise services, with a Year-Over-Year (YoY) increase of 21.4%. China Unicom's industrial Internet services generated a revenue of CNY¥54.8 billion, with a YoY increase of 28.2%. China Telecom's industrial digitalization services generated a revenue of CNY¥98.9 billion, with a YoY increase of 19.4%.

Ultra-Distributed, Fully Connected MEC Helps Build Ubiquitous 5G Industry-Specific Private Networks

As 5G MEC continues to penetrate more vertical industries, we believe that 5G MEC will become a significant driving force for the uninterrupted development of enterprises, and 5G MEC will evolve towards an ultra-distributed, fully connected architecture. Ultra-distributed 5G MEC networking will take shape due to the fact that MEC with diverse connectivity and compute capabilities can be flexibly deployed at required locations, such as the operators' network edge, enterprise campuses, and production sites. Fully connected 5G MEC can be achieved as 3GPP-defined network interconnection interfaces are used to connect 5G MEC sites, so that local and wide areas can be reliably interconnected. This ensures that one-site innovation can be replicated network wide and single terminals directly access intended private networks anytime, anywhere. As such, 5G networks in future will evolve from a public network to an ultra-distributed, fully connected network that covers hundreds of industry-specific private networks.

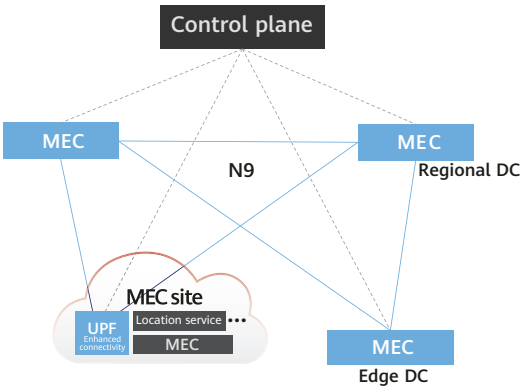

Figure 1 Ultra-distributed, fully interconnected MEC

5G MEC Will Continue Adapting to More Industries

As 5G commercial rollouts accelerate, 5G is being rapidly integrated into thousands of industries. According to data released by the Ministry of Industry and Information Technology (MIIT), 5G applications have covered up to 40 (such as manufactures, transportation, healthcare, education, culture, and tourism) of the 97 categories of industries relative to the development of the national economy. Several applications in typical scenarios have brought significant business value, contributing to a total number of 23,000 cases. 5G MEC will keep evolving to accommodate more sectors during large-scale application. "MEC to X" will be unlocked to enable new businesses.

- **From single- to dual-domains, Mobile VPN is an innovative application on private networks.**

5G industry-specific private networks are firstly deployed in local areas, then applied to wide areas, and eventually adopted to dual-areas. At the early stage, 5G private networks are deployed to ensure that enterprise data is processed locally, and at

this stage local private networks only fulfil the requirements of several industries, such as coal mines and healthcare. For campus, public, and enterprise services, 5G private networks must be able to provide dual-domain network access, so that mobile office users are able to access both public and private networks anytime, anywhere without changing their terminals and cards. This is aided by 5G that features wide coverage, large bandwidth, and high reliability.

- **From local to wide areas, multi-campus private networks ensure that one-site innovation is quickly replicated across multiple campuses.**

As 5G private networks penetrate into wide-area interconnection scenarios (such as electric power and multi-campus factories), large-area connections with flexible deployment and centralized O&M must be achieved. In this manner, wide private networks leverage the advantages of E2E 5G networks to deliver reliable connections within wide areas, facilitating network-wide replication of each innovation.

- **From campuses to industry fields, 5G is given a center stage in both enterprise production extranets and production intranets.**

5G private networks at the early stage are mainly intended for production supporting services, such as video monitoring, which is achieved through the basic connectivity capabilities of 5G. After 5G private networks are introduced to the production phase, their connectivity capabilities are unable to thoroughly satisfy the requirements of industrial applications. For example, industrial interconnection requires Layer 2 connections based on 5G networks. As such, enhanced connectivity capabilities, such as those provided by 5G LAN, become necessary for 5G MEC.

- **From connectivity to compute, MEC can be flexibly applied in surging industry applications that require ubiquitous compute capabilities.**

As industry scenarios multiply, enterprises demand compute capabilities such as service awareness and intelligent compute, in addition to connectivity capabilities. This requires 5G MEC to be able to integrate connectivity and compute capabilities so that edge computing can evolve to ubiquitous compute power.

Case 1: MEC to Manufacturing

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 joined forces with China Unicom and Huawei to build a fully-connected 5G factory based on the E2E "5G MEC+Slicing+Intelligent Applications" solution. This project has showcased numerous typical applications, including cloud-edge collaboration, converged positioning, Augmented Reality (AR)-based

remote assistance, machine vision, enormous device connections, and predictive maintenance, achieving the digital transformation of Midea.

For warehousing and logistics, the 5G MEC+Bluetooth Angle of Arrival (AOA) converged positioning technology helps accurately report location information about goods and fork lifts in finished product warehouses to the warehousing system, and associate such information with inventory information. This process effectively reduces warehousing costs. This is the first global smart factory project that adopts the 5G+Bluetooth AOA converged positioning technology provided by the 5G MEC platform. This technology resolves multiple issues in the conventional warehousing and logistics system, including ineffective tracking of personnel, machines, and goods, unstable industrial Wi-Fi networks in mobile scenarios, and complex maintenance of multiple networks. With this technology, 90% of positioning results can fall into a circle (centered at the origin) radius of 1 m to 3 m, helping Midea build an intelligent warehousing management system and improving warehousing and logistics efficiency, while simultaneously reducing warehousing costs.

For the assembly of finished products, the majority of assembly operations in the production line rely on automated devices. If one of the devices becomes faulty, the entire production line will be suspended. To address this issue, Midea introduces 5G+AR glasses to allow onsite engineers to send fault or device information to remote maintenance engineers in real time. Though not onsite, the maintenance engineers can give assistance, based on the AR images, to help quickly rectify the faults. For Automatic Guided Vehicle (AGV)-based logistics, 5G replaces Wi-Fi to eliminate Wi-Fi interference and prevent failures in handovers across Access Points (APs). For predictive maintenance, robots in the production line are prone to faults. Statistics show that the average fault duration of these robots is up to 36 hours in a calendar year. Once the robots become faulty, the entire production line has to be suspended. To address this issue, Midea connects their robots to a 5G wireless network, allowing the robots to collect and report required basic data in real time. The reported data is then analyzed to provide predictive maintenance suggestions by using the intelligent platform management algorithm. This ensures that the robot fault duration decreases by 40%, and the loss caused by production suspension is reduced by CNY¥560,000 per product line each year.

Case 2: MEC to Coal Mine

Yanjiahe Coal Mine of Shanxi Xiangning Coking Coal Group started to construct a highly reliable MEC-based 5G private network in October 2021 to fulfil production safety requirements and improve the coal mines operation efficiency. This network ensures that coal mine services run as usual even if the MEC system disconnects from the central 5G Core Network (5GC) due to unexpected optical fiber damage.

As most of us are aware, mining is a high-risk industry due to the harsh environmental conditions, and therefore safety is paramount for any mining operations. Workers underground are exposed to a wide range of risks, from explosions and structural

failures to gas poisoning. They also suffer from high humidity underground due to water penetration. Furthermore, it is rather difficult to monitor the status of multiple underground systems, including mining, excavation, ventilation, electromechanical, drainage, power supply, and transportation systems. An exception in a component or process may cause accidents. Furthermore, routine maintenance of certain devices, such as coal conveyor belts deployed in long coal mining haulageways, is labor-intensive and inefficient. To address these issues, Yanjiahe Coal Mine uses 5G to replace optical fibers and other connections. For coal mining, 5G MEC provides video stitching to allow workers to work aboveground and remotely control coal shearers underground. For coal excavation, 5G High Definition (HD) cameras are deployed at multiple key locations to collect and analyze onsite videos in real time, ensuring that coal mine risks are detected in a timely manner. In addition, an HD monitoring system is deployed for coal conveyor belts, helping intelligently identify potential risks, such as belt deviation, coal stacking, large objects, and staff sitting on belts. Once a risk is identified, the system reports and raises alarms to remind management personnel and onsite operation personnel to promptly handle exceptions.

5G MEC delivers secure and reliable production networks for coal mine enterprises, and its application in this case accelerates the sustainable development of energy enterprises.

Case 3: MEC to Electric Power

As the electric power industry develops rapidly, the communication needs of various power grid devices, power terminals, and power consumption customers multiply proportionally, opening up a wide range of applications for 5G MEC.

Electric power management mainly involves control and collection services. The control service covers differential protection for power distribution, power distribution automation (that is, telemetry, remote communication, and remote control), and precise fault locating for power distribution. The collection service is intended for intelligent inspection of power lines, power consumption information collection, and HD video backhaul for emergency communication. The electric power industry is a typical application where a VPN in a local area is used together with that in a wide area, both of which are powered by network slicing and edge computing. Network slicing enables E2E 5G VPN construction across multiple areas, ensuring logical or even physical isolation between VPNs and public networks. Edge computing (5G MEC) helps build dedicated or partially dedicated VPNs in certain areas, such as factories and campuses. The two technologies can be used together to better ensure the resources and quality of VPNs.

China Southern Power Grid, China Mobile (Guangdong), and Huawei jointly promote 5G smart grids in power generation, transmission, transformation, distribution, and consumption. Take power distribution automation as an example. Power distribution cabinets are distributed in a wide range of areas, including factories, office areas, and residential areas. Currently, conventional centralized protection

is mainly used for the cabinets, resulting in inaccurate control, severe impacts in case of power outage, and hour-level fault duration. Furthermore, routing optical fibers to power distribution networks and maintaining the optical fibers are very costly. As such, a 5G MEC site dedicated to power grids is deployed in a regional Data Center (DC) to provide ultra-reliable, ultra-low latency communication based on 5G. Distribution Terminal Units (DTUs) are installed between power distribution cabinets to establish a mutual protection mechanism in pairs or groups. The DTUs compare real-time current and voltage on both ends. Upon detecting that the difference exceeds the preset threshold or a fault occurs, the DTUs disconnect the corresponding circuit breaker or switch, achieving millisecond-level fault locating and isolation.

The 5G VPN project for China Southern Power Grid has significantly contributed towards 5G standards formulation, 5G network slicing verification, operation of the 5G slice management platform, MEC self-service, as well as MEC security, making it a shining example for entire industries. This project has won the "Best Mobile Innovation For Connected Economy" award at the 35th Global Mobile Award (GLOMO Award) ceremony hold by the Global System for Mobile Communications Association (GSMA) in 2021.

Case 4: MEC to Campus

Mobile VPN allows data to be transmitted through operators' mobile networks, without additional VPN connections. In this manner, users are able to securely and conveniently access campus intranets anytime, anywhere. Mobile VPN provides wide area coverage based on fully interconnected 5G MEC sites in multiple areas, allowing campus users in roaming scenarios to access campus intranets anytime, anywhere.

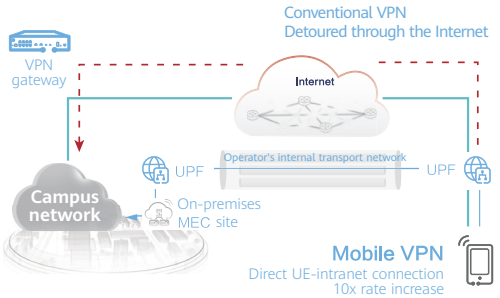

Figure 2 Mobile VPN and conventional VPN

Guangdong University of Foreign Studies (GDUFS) is a key globally-minded university. For the continuous improvement of its education informatization, rich resources are provided on the campus network to further assist the teaching, scientific research, and daily lives of the faculties and students. However, the campus intranet can only be accessed through VPN software once faculties and students are off campus, which is highly inconvenient. To eliminate this inconvenience, GDUFS, China Mobile (Guangdong), and Huawei formed a partnership and introduced a Mobile VPN as a solution to access the campus intranet. Specifically, 5G MEC is deployed on campus to allow service requests of specified users to be controlled and steered by using the Uplink Classifier (UL CL) technology. In this manner, users do not need to change their cards or numbers, or use the VPN dialup. Exclusively through a 5G terminal, they are able to access the Internet and campus intranet

simultaneously, which is seamless and efficient. Therefore, Mobile VPN makes it possible for campus users to quickly access public and private networks securely, further accelerating campus informatization. Mobile VPN provides a better service experience than conventional VPN solutions, as user traffic is not detoured through the public network, and the downlink service rate is improved by over tenfold. It also simplifies connections to campus intranets, so that users are able to switch between the Internet and intranet without repeated logins. Meanwhile, it leverages traffic steering on 5G networks to provide highly reliable and secure network access. Currently, Mobile VPN has been widely used for national 5G campus network construction to enable faculties and students to quickly and securely access campus intranets anytime, anywhere. Mobile VPN has been well acknowledged by and replicated in diverse industries, such as public services, healthcare, culture and tourism, and campus office, fulfilling the requirements for remote intranet access anytime, anywhere.

Unlock "MEC to X" New Businesses with Ultra-Distributed, Fully Connected 5G MEC

Looking into the future, 5G MEC innovation will be driven by both technologies and businesses, whereby technology innovation further accelerates the commercial implementation of 5G industry-specific private networks. For vertical innovation, 5G MEC is continuously evolved to deliver enhanced connection capabilities, such as high-precision positioning and simplified Layer 2 networking, and provides more reliable industry-specific private networks. For horizontal innovation, 5G MEC's application scenarios are expanded from local areas to wide areas. Specifically, 5G MEC in local areas is stretched from auxiliary production systems to enterprise production intranets, so that it can be used to process enterprises' core production services and manage the control system of production lines. Furthermore, fully interconnected 5G MEC helps enlarge network coverage based on operators' 5G Wide Area Networks (WANs). As such, 5G MEC can be used to build a compute-network synergy foundation for industry applications, giving full exposure to the unique values of 5G MEC's compute power. By doing this, 5G MEC can adapt to more industry service scenarios based on data service connections, voice service connections, and compute power. Ultra-distributed, fully connected 5G MEC not only enables private lines and private networks, but also fuels diversified new services. It is a platform and incubator for enabling new industry applications.

We believe that MEC will play an increasingly important role in enabling industry digitalization. Huawei will keep collaborating with industry partners to jointly promote 5G MEC in more industry scenarios, aiming to add more value through new 5G businesses.

08

Mobile VPN — an On-Demand and Direct Private Network

Huawei Mobile VPN is a solution that provides a private network which directly connects users with the campus intranet. Based on the 5G Multi-Access Edge Computing (MEC)+Uplink Classifier (UL CL) intelligent traffic steering technologies, Mobile VPN enables users to access the campus intranet and Internet securely, from any location at any time, without changing their cards or numbers. It also physically isolates data flows destined for the intranet and Internet. In this way, intranet data is not detoured through the Internet, ensuring intranet security; users can seamlessly switch between the Internet and intranet without repeated logins, facilitating mobile and flexible office work.

Guo Chuanguang

Senior Marketing Manager for 5GtoB, Huawei Cloud Core Network Product Line

Disadvantages of Conventional VPN Solutions

In the information era, demand has soared for remote office, online video conferences, online courses, and remote intranet access. Enterprises, as well as, governments and campuses want to protect information assets to the highest degree while facilitating users' access to information without any interruptions or delays. Therefore, they are in urgent need of a secure, fast, stable, and easy-to-use intranet access technology.

Before the use of Mobile VPN, Virtual Private Networks (VPNs) were, and are still commonly used to access the intranet, that is, using VPN gateways to establish data tunnels between the Internet to the intranet. Therefore, enterprises need to purchase VPN gateways and grant each user account permission to use VPNs. Apart from the difficulties of managing VPN accounts, data leakage may occur as intranet data is detoured through the Internet, posing data security risks. In addition, VPN gateways are vulnerable to hacker attacks if no security measures, such as firewalls, are taken. During peak hours, network congestion is likely to occur: service access is slow, user

experience is deteriorated, and repeated logins are complex. Conventional VPN solutions cannot meet users' requirements for fast and secure access to intranets.

Mobile VPN — an On-Demand and Direct Private Network

Mobile VPN uses operators' 5G mobile networks and adopts the 5G MEC+UL CL intelligent traffic steering technologies. It enables users to access intranets seamlessly without changing their cards or numbers and switch between the intranet and Internet. The traffic destined for the intranet is steered to the intranet through the locally deployed MEC, thereby physically isolating the intranet traffic and Internet traffic. Users can securely and conveniently access the Internet and intranet anytime and anywhere.

Take campuses as an example. If conventional VPN solutions are used, there must be wired broadband in classrooms, offices, dormitories, and libraries. Otherwise, users have to pass the login authentication through campus Wi-Fi. As such, users can only access the intranet in limited areas at uneven network speeds, which is affected by the volume of users. When off campus, faculty staff and students can only dial up through the VPN, posing certain stability and security problems, which affects the work output. However, with Mobile VPN, users can access campus intranet resources without hindrance using just 5G mobile phones or laptops with a 5G module.

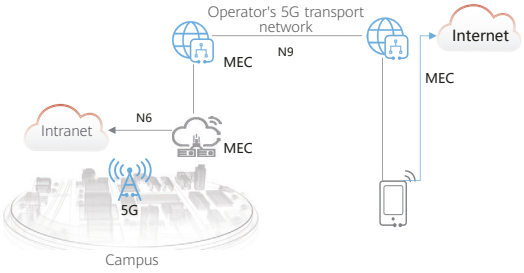

Figure 1 Mobile VPN solution

Take enterprises as another example. In recent years, the requirements of remote office have surged, with enterprises allowing employees access to more intranet resources and key service systems for service continuity. If a Mobile VPN together with the UL CL–based traffic steering technology is introduced, office, production, and other data is separated from each other, facilitating free and secure intranet access. Therefore, with just a 5G mobile phone, employees can access the intranet Office Automation (OA) system and production system.

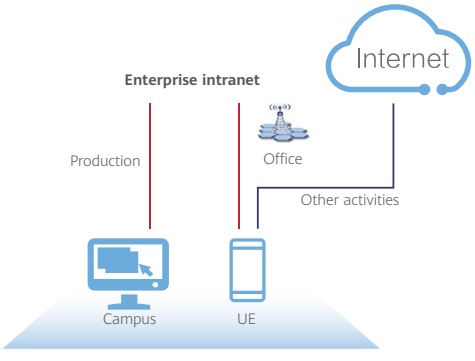

Figure 2 Mobile VPN Steering Enterprise Traffic

In regard to public services, the public sector aims to bring undifferentiated, inclusive, and convenient public services to everyone. One of their setbacks is that they lack a mobile, secure, reliable, and low-

cost network for assisting urban management. In Pingshan District, Shenzhen, a public health information system is required to improve social governance during pandemics; a secure and easy-to-use extranet is required to allow citizens to handle affairs online; and free access to intranets is required to help public officers work, hold conferences, and serve society. To address these requirements, the Government Services and Data Management Bureau in Pingshan district, together with Huawei and China Mobile (Guangdong), built the first 5G public service extranet based on Mobile VPN in China. Through this extranet, multiple public service platforms, such as the public service system, mobile OA system, self-service equipment, video management platform, and emergency management system, have been launched, greatly improving the work efficiency and bringing convenience to citizens.

Mobile VPN Is the Optimal Choice for Intranet Access

As mentioned above, Mobile VPN uses operators' mobile networks for data transmission. By this method, an on-demand and direct private network is provided to users. Compared with conventional VPN solutions, Mobile VPN is superior in the following ways: Firstly, Mobile VPN provides better user experience than conventional VPN solutions that detour user traffic through the Internet. It directly steers local traffic to the data center on campus over the N6 interface, increasing the downlink network throughput by more than tenfold. Secondly, Mobile VPN simplifies network connections, so that users can switch between the Internet and intranet seamlessly, without changing their cards or numbers, and are free of repeated logins. No VPN gateway or login authentication is required. After subscribing to the Mobile VPN service from operators, users can access both the intranet and Internet. Thirdly, it establishes a direct and reliable 5G connection that covers the (R)AN, transport network, core network, and campus intranet, fully protecting user data. In addition, to meet different security requirements in various industries, Mobile VPN can integrate particular functions, such as secondary authentication, terminal-card binding, terminal address allocation, IP address tracing, and private DNS server address delivery, allowing greater versatility.

In addition, leveraging Mobile VPN to access intranets can significantly reduce private network construction and O&M costs. Another shining example is the Guangdong University of Foreign Studies (GDUFS). When using the conventional VPN solution to serve a maximum of 2000 concurrent users with a bandwidth of 400 Mbit/s, it needs to invest about CNY¥908,000 for VPN construction and maintenance costs, spanning a period of three-years. If a Mobile VPN is adopted, only an investment of CNY¥805,000 is required, and this sum can serve up to 5000 concurrent users with a bandwidth of 1 Gbit/s.

Mobile VPN Helps GDUFS Build a Borderless Campus

During COVID-19, the process of campus informatization is accelerated in order to maintain online teaching during school closures. GDUFS is a prominent globally-minded university. For the continuous improvement of its education informatization, rich resources are provided on the

campus network to further assist the teaching, scientific research, and daily lives of the faculty staff and students. However, the campus intranet can only be accessed through VPN software once faculty staff and students are off campus, which is highly inconvenient.

To address this issue, 5G MEC is deployed on campus to allow service requests of specified users to be controlled and steered by using the UL CL technology. In this manner, users do not need to change their cards or numbers, or use the VPN dialup. Exclusively through a 5G terminal, they are able to access the Internet and campus intranet simultaneously, which is seamless and efficient. Specifically, through Mobile VPN, students can use campus applications, take online classes without freezing and disconnections, manage study affairs, register for popular courses that may be filled up quickly, seamlessly switch between the intranet and Internet for obtaining digital library resources, and so on. This ensures a fast, easy-to-operate, and secure system. Xie Jianguo, Director of Network Information Center in GDUFS, said that building a 5G campus private network based on edge computing technology is one of the key development goals for GDUFS. Mobile VPN helps them achieve this goal. It advances the efficient sharing of campus intranet resources, takes the campus IT construction to the next level, and facilitates the daily tasks and learning of the faculty staff and students.

Mobile VPN Upgrades Roaming Capability, Driving Specification Innovation

Industry customers are often on business trips and expect to access the campus networks in their home cities. However, their service traffic cannot be controlled through UL CL–based traffic steering in roaming scenarios, according to the 3GPP specifications. At present, the solutions for addressing roaming requirements are being explored. Operators are proposing various plans. China Mobile is attempting to construct dual DNNs on the network side, and China Unicom is introducing dedicated DNNs. We believe in the near future, Mobile VPN will be upgraded to 2.0, therefore allowing intranet and Internet access for all.

4G Networks Integrate 5G Capabilities, Rewarding More Users

5G developments are uneven around the world. 4G is still the mainstream in some regions. If operators in these areas want to introduce Mobile VPN to build mobile private networks, they have to solve the problem of 4G/5G compatibility. Huawei's fully convergent core network applies 5G technologies to 4G networks. This makes the UL CL–based traffic steering possible on a 4G network, which means that Mobile VPN is compatible on a 4G network, opening up its services to more users.

Mobile VPN provides high-speed, convenient, and secure intranet access services for enterprise customers. Currently, the solution has been successfully piloted and put into commercial use in more than 500 enterprises and institutions, covering campuses, public services, healthcare, and remote office. This greatly improves the capabilities and experience of enterprise mobile private networks. More and more users choose Mobile VPN as their optimal choice for intranet access. We believe this popular 5G application will bring more convenience to people's work and life, and enable the digital transformation of more industries.

09

Building New Infrastructure for "MEC to Manufacturing" to Upscale Industrial Digitalization

The widespread deployment of 5G is rapidly leading to the large-scale commercialization of new cutting-edge technologies. As a knock-on effect, traditional wired networks are being replaced by MEC at production sites such as factories, workshops, and production lines. MEC helps build the telecom cloud platform as a new network foundation through Huawei's "MEC to manufacturing" projects. The MEC-powered platform provides millisecond-level hot backup, 5G Local Area Network (LAN), and deterministic SLA capabilities, enables Operation, Information, Communication Technology (OICT), and promotes the digital transformation of industrial manufacturing enterprises through the flat network architecture and compute-network synergy.

Qian Hao
Senior Marketing Manager for 5GtoB, Huawei Cloud Core Network Product Line

In traditional sites, production lines are independent of each other and run different protocols, leading to information silos. Operational Technology (OT) and Information Technology (IT) systems are separated from each other and are unable to collaborate effectively. These issues pose challenges to the development of industrial manufacturing enterprises. 5G MEC can help build a flexible, simple manufacturing network with its enhanced Communication Technology (CT) network capabilities, deterministic network capabilities, and Information and Communications Technology (ICT) convergence featuring compute-network synergy. This further drives OICT and helps build a new platform for industrial digital transformation.

The "Set Sail" Action Plan for 5G Applications, released by the Ministry of Industry and Information Technology (MIIT) together with 10 other departments, accelerates the upgrade and reconstruction of industrial manufacturing infrastructure networks. According to data released by MIIT in April 2022, there were 2400 "5G+industrial Internet" projects being built

for production services such as video content analysis, AR-based remote assistance, and quality inspection in machine vision. Naturally, 5G MEC can support auxiliary production on industrial extranets now.

To build new infrastructure for industrial manufacturing and enable digital transformation, it is imperative that 5G MEC is expanded from auxiliary production to production intranets, and then to the production lines onsite to replace wired industrial control connections. However, this presents many challenges in network reliability, stability, adaptability to OT, and deterministic SLAs. As such, it is recommended that manufacturing enterprises adopt 5G MEC gradually using the following approach.

1. Build a reliable, stable CT network. In addition, use 5G LAN for adaptation to OT, in order to drive 5G application to enter Programmable Logic Controller (PLC) northbound industrial intranet. With 5G LAN, MEC replaces the wired workshop production network, and processes production data sent to and from the Management Execution System (MES) and Supervisory Control and Data Acquisition (SCADA).

2. Build deterministic network capabilities and integrate industrial protocols to meet strict SLA requirements of industrial sites, and expand 5G to production lines onsite to process PLC southbound services, enabling the collaboration between CT and OT.

3. Use 5G MEC to integrate the industrial Internet platform and applications, facilitating in-depth IT and OT convergence. This requires 5G MEC to support ICT convergence for compute-network synergy.

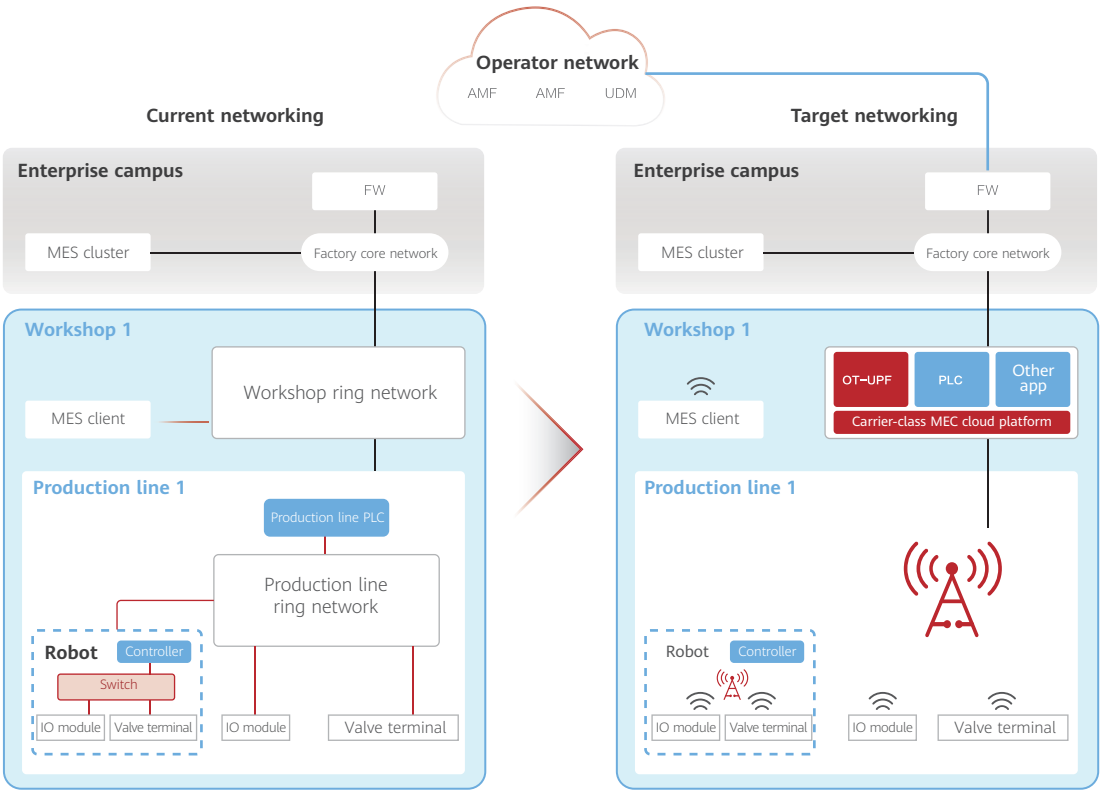

Figure 1 5G MEC Gradually Used in Workshop Production Intranets and Production Lines Onsite

Huawei must work with industry players in using MEC to build the telecom cloud platform as a foundation for running all industrial applications, and to promote OICT in terms of the following three aspects.

Case 1: Enhancing CT Network Capabilities to Expand 5G to Industrial Intranet

The requirements posed for network reliability, stability, and adaptability to OT must be met before 5G is applied to industrial intranets. Huawei MEC is expected to be expanded to more industrial intranets of manufacturing enterprises in 2023, by building UPF's millisecond-level hot backup and the capabilities of 5G LAN.

Reliable network connections are paramount for industrial applications. The Ethernet ring network in workshops can achieve self-healing within 300 ms to avoid production interruption. Therefore, the UPF hot backup capability is indispensable for 5G to replace the wired network in workshops. On a Huawei industrial manufacturing private network, two UPFs are used to create two sessions, which synchronize forwarding policies to ensure that the remaining UPF can take over services within 200 ms when one UPF becomes faulty, ensuring service continuity.

Assuming that devices on a 5G network are interconnected and run smoothly, 5G network system suppliers should modify and adjust the internal operation mechanism of the 5G network to meet diversified OT adaptation requirements. Conventional industrial networks widely use Layer 2 Ethernet protocols. In light of this, to reconstruct the wired industrial network as a wireless 5G one, AR routers are necessary for converting Layer 2 packets to Layer 3 packets and for virtual Layer 2 network configurations, before 5G LAN was introduced. This solution results in complex networking, and requires new devices, leading to high reconstruction costs.

As such, 5G LAN must be used for Ethernet Layer 2 access to help apply 5G in industrial intranets. No AR routers or tunnels need to be configured on the operator network, decoupling operator networks from enterprise networks. As such, 5G LAN simplifies the network structure, reduces deployment costs, as well as relieves devices from complicated cabling and facilitates a seamless production line adjustment.

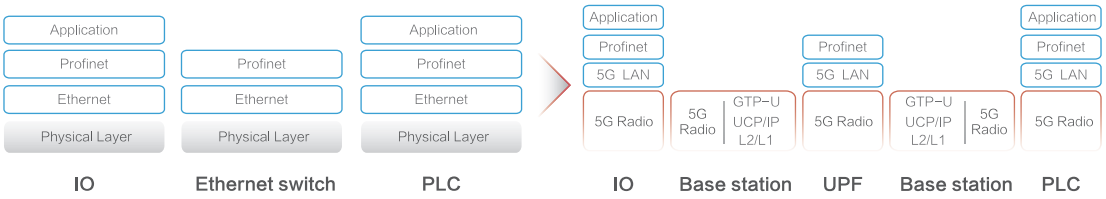

Figure 2 Protocol Stack of Intelligent Manufacture

Case 2: Building Deterministic Network Capabilities to Achieve CT and OT Collaboration

The interaction between onsite devices in production lines is independent from resource scheduling on a 5G network. This makes it difficult for 5G MEC to ensure deterministic low latency. To address

this issue, Huawei's "MEC to manufacturing" integrates CT communication protocols and OT industrial protocols on a 5G network to achieve CT and OT collaboration for industrial applications, achieve deterministic low-latency, and expand 5G MEC to production intranets.

On the one hand, the scheduling queue in a UPF is optimized based on service characteristics, so that the UPF can forward important information in real time. On the other hand, through coordinated scheduling between the core network and (R)AN, the network scheduling pace is synchronized with the communication pace between industrial devices. This ensures deterministic latency, fulfilling SLA requirements of the production lines. It also provides Ultra-Reliable Low-Latency Communication (URLLC) capabilities with an ultra-low latency of 4 ms and ultra-high reliability of 99.9999%.

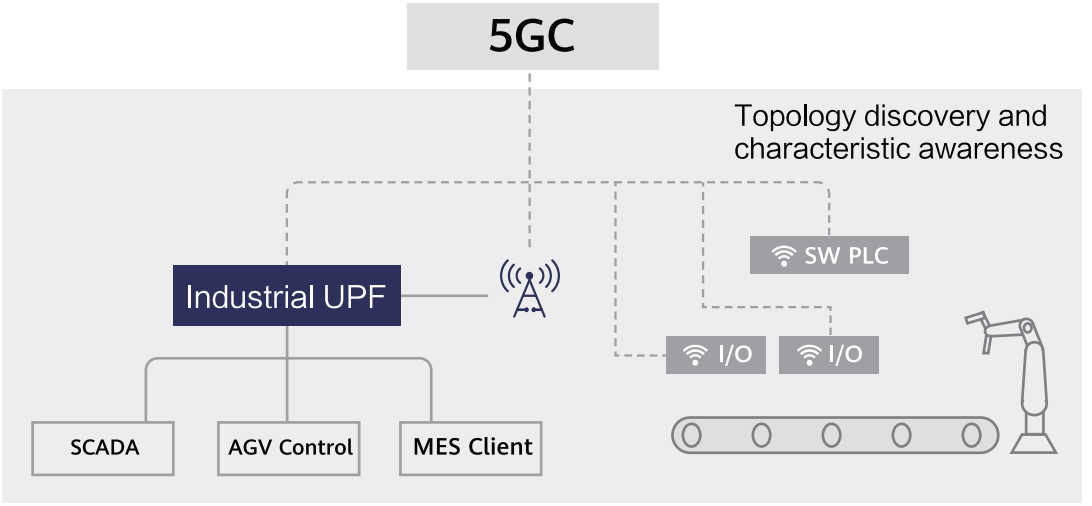

Figure 3 Deterministic Reliability and Latency Through Inter-Domain Collaboration

A 5G production network can therefore be constructed to process all industrial services. Controlled terminals connect to the PLC via one hop. This case completely changes the current industrial Ethernet architecture, replaces the industrial Ethernet wired network, and radically improves the operation efficiency and flexibility.

Case 3: Building a Convergent ICT Foundation for Compute-Network Synergy and In-Depth IT and OT Convergence

Production lines in the current industrial control system are independent of each other. The upper-layer IT system is unable to directly touch data from onsite production lines as it centrally receives data from controllers. As such, it is difficult for production lines to thoroughly collaborate with each other. The 5G MEC-powered convergent ICT platform interconnects production management, monitoring and warning, and industrial control networks, providing flat access to onsite terminals. This platform featuring compute-network synergy integrates all applications, and converges OT and IT systems.

Compute-network synergy takes shape based on the convergent edge compute platform. This platform manages multiple heterogeneous compute servers, uses a unified resource pool that integrates VMs and containers, as well as provides independent cloud service capabilities. Additionally, it supports flexible deployment of convergent 5G applications to provide one-stop compute-network synergy services to fulfill enterprise customers' requirements for a convergent experience. In fact, MEC deployment on edge networks has been significantly scaled up in China on top of distributed user plane deployment. With connectivity and compute synergized, 5G MEC integrates third-party applications to help simplify infrastructure, provide unified O&M, and implement compute-network synergy. The connectivity+ compute+application solution will promote the digital and intelligent transformation of diverse industries.

GSMA Intelligence also estimates that there will be 13.8 billion industrial IoT connections by 2025, 65% of which will emanate from China. Operators, enterprises, equipment suppliers, and application suppliers need to collaborate further to continue to leverage CT advantages, promote in-depth convergence of OI, CT, and IT, based on industry requirements to deliver URLLC capabilities. They must also team up to strengthen the construction of a solid infrastructure, characterized by reliable connections and deterministic SLAs.

10

5G Private Network Solution Brings "MEC to Coal Mine" and Improves Mining Workplaces

The intelligent transformation of the mining industry aims to reduce the possibility of accidents and increase production efficiency. Intelligent mine construction requires full coverage both above and below ground, interconnection with external networks, and high network security and reliability. Huawei has resolved this by launching the Public Network Integrated Non-public Network (PNI-NPN) Kite-like solution. In implanting this solution, Shanxi Mobile has built a 5G working prototype private network for Sanyuan Coal Mine. The private network touches various scenarios and processes relevant to coal mine production and application, personnel communications, and unified dispatching. It helps improve the environment of the workplace and ensures safe production, cost effectiveness, and high-quality operations. It is undoubtedly a gamechanger for the move towards intelligent mines.

Zhang Bin
Sanyuan Coal Mine of Jinneng Holding Shanxi Coal Industry Co.,Ltd.
Xue Jun
Shanxi Branch of China Mobile
Wang Hua
Huawei Technologies Co., Ltd.

Over the past several years, the coal mining industry has been looking to move towards clean and intelligent business models. Mining intelligentization is imperative for such a transformation. New technologies such as 5G, edge computing, and computing power network are jointly accelerating the construction of intelligent coal mines.

Mining Intelligentization in Diverse Scenarios Poses Three Concerns for the Base Network

Coal mine intelligentization in China is undergoing three distinct phases. In 2021, intelligent pioneering coal mines of various types have been successfully constructed. By 2025, intelligentization will be completed for large coal mines, as well as coal mines with a high accident profile. By 2035, intelligentization will be completed for the majority of coal mines in China. Nowadays, intelligentization has penetrated the entire work process from digging, extraction, machinery operations, transportation, to communications. It spans panoramic video stitching and remote control on the fully mechanized mining face, 5G excavator remote control, inspection robots in 5G chambers, intelligent monitoring for 5G main transport, and 5G convergent communications (including centralized scheduling of wireless, wired, and broadcast resources). This poses higher demands on network reliability and data security, service coverage and interconnection, as well as the capability of the base network to carry multiple types of services such as voice, video, and data.

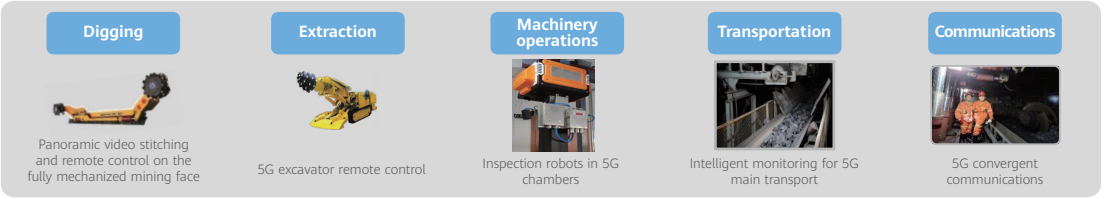

Figure 1 5G intelligent coal mine service process panorama

Reliability and data security are the top concern for the mining community. For example, it is required that shearers and excavators be remotely controlled via 5G to reduce operation risks. The devices under remote control can run stably and reliably with a low failure rate. What's more, mining efficiency can be significantly improved, with little or no personnel required. Remote control applications rely on the 5G private network. Data recorded by sensors and video copies generated by HD high-density cameras need to be uploaded to the network side. As such, the private network must run with consistency into the future, with the promise of large uplink bandwidth, and 20 ms or less latency.

Furthermore, intelligent inspection robots comprehensively monitor the underground working environment and devices, transmit monitoring results to the aboveground Dispatch and Command Center (DCC), and collect big data for visualized management and warning. In this manner, onsite exceptions can be handled promptly through man-machine interaction. The aforementioned sensors record sensitive mining security data, and therefore the data cannot be transmitted to public clouds nor can any related applications be permitted to do the same. In this context, preventing unauthorized access to these sensors is vital when establishing the base network.

The second concern is about the convergence of voice, video, and data services. As the penetration rate of mobile communications above ground exceeds 99%, 5G-based video calling has become a common service. When miners are working, they also expect to use mobile phones to make voice or video calls with other workers below ground and keep in contact with the DCC and other staff on both the fully mechanized mining face and excavation face. In addition to basic communications, real-time voice and video interaction and production scheduling are also required on the base network.

The third concern is about continuous coverage above and below ground and service interaction with on- and off-campus systems. As new 5G applications begin to multiply at mine sites, deploying 5G only below ground cannot fulfil the diversified communication requirements of 5G intelligent mines. Service applications such as intelligent inspection, unstaffed ferry vehicles, and rubber wheel vehicles require continuous coverage both under and above ground so that they can be centrally accessed through the mining core network. In addition, internal data and voice services at mine sites need to interact with those outside of the area, and workers need to make calls to external numbers and access external service data, under specified security control. Therein, a new demand is posed, namely, the demand for convergence between the intelligent mine private network and operator public networks.

In response to the aforementioned concerns, the 5G coal mine private network is designed for two purposes: one is to avoid safety risks, and the other is to improve communications and work efficiency.

Purpose 1: Avoiding Safety Risks

Conventionally, there are a large number of miners working on the fully mechanized mining face. They work under harsh conditions and are exposed to high safety risks. Therefore, safety is paramount for any mining operations. However, mine safety inspection is labor-intensive, inefficient, and dependent on inspection personnel's experience. Through mechanization, automation, and intelligentization, the number of workers required for high-risk operations is reduced by more than 50% as the fully mechanized mining face can be remotely controlled and mining inspection robots are available. These measures free workers from a wide range of underground high-risk operations and reduce safety risks to a large extent.

Purpose 2: Improving Communications and Work Efficiency

Without 5G-based communications, it is difficult for mining personnel who work up to dozens or even hundreds of meters below ground to contact others above ground in emergency situations. They are prevented from making video calls, placing calls to specified personnel, or making calls anytime anywhere. Instead, they can only make voice calls through fixed-line phones, which is inefficient and leaves unwanted risks. Currently the only means to detect underground incidents rely on wired networks. Due to limited wired

network coverage, instructions cannot be delivered from aboveground to underground personnel promptly. The 5G private network solution and convergent voice and video mobile applications now come to make real-time underground communications realistic. With this solution, personnel, vehicles, and things are coordinated effectively, achieving extensive interconnection, data visualization, intelligent detection, and efficient scheduling. Furthermore, it helps reduce misoperations and improve mining efficiency by 30%.

About the 5G Coal Mine Private Network Solution

5G network architecture and protocol capabilities are enhanced, enabling Multi-Access Edge Computing (MEC) nodes to be deployed at network edges for traffic steering as required. The rising pace of digital transformation is gaining a strong foothold across diversified industries, accelerating the execution of "MEC to X", which creates fully meshed MEC nodes, enabling thousands of industries.

In this context, Huawei has been working with Shanxi Mobile to launch the 5G coal mine private network solution for Sanyuan Coal Mine based on its PNI-NPN Kite-like solution, introducing MEC to coal mines.

The 5G coal mine private network solution uses MEC and IMS as its foundation. To offer this solution, Huawei designs a three-layer application system architecture, covering the operator network, mine area, and underground working area. This architecture provides centralized O&M, centralized registration, and local processing of signaling and service data. It also integrates a 4G and 5G convergent voice and video dispatch system using 3GPP-defined interfaces.

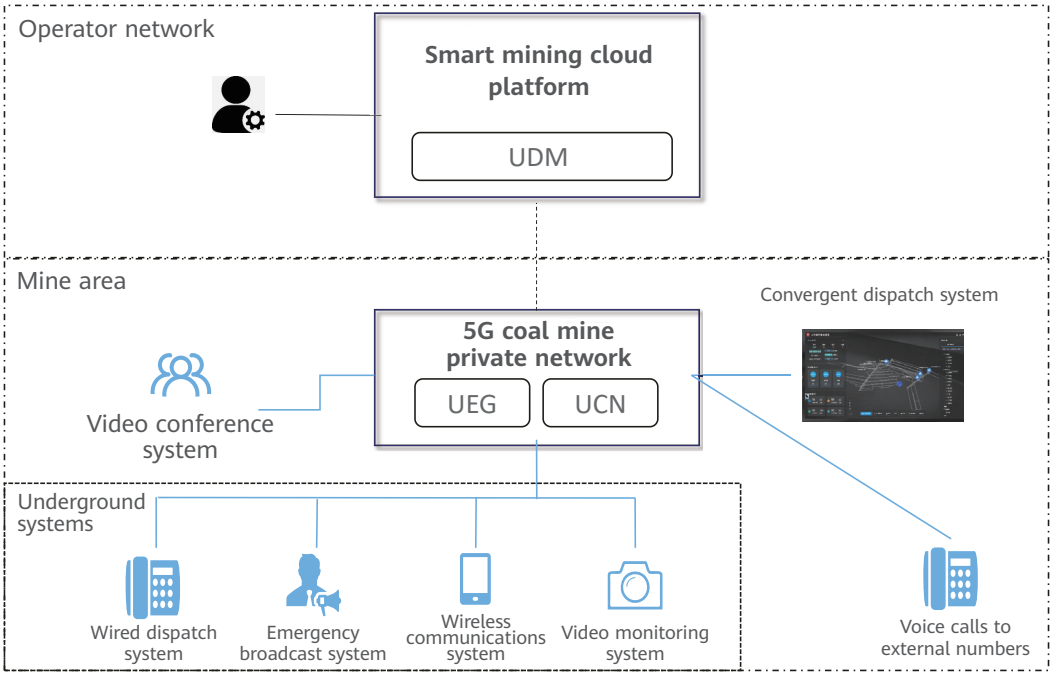

Figure 2 MEC to coal mine three-layer application architecture

As shown in the figure, the 5G coal mine private network deployed at the mine site connects directly to the operator's smart mining cloud platform. The Unified Data Management (UDM) is deployed on the smart mining cloud platform and manages subscriber data in 4G and 5G convergence scenarios. Over the northbound direction, the UDM connects to an O&M system to centrally provision services and store data for 4G, 5G, and IMS subscribers. In this manner, card numbers and UE numbers can be centrally maintained on the operator's network for network-wide service interaction. This fulfils the third concern about continuous coverage above and below ground and service interaction inside and outside the mine area. Over the southbound direction, the UDM connects to the 5G coal mine private network and synchronizes subscriber data to the Unified Edge Gateway (UEG) and Unified Communication Node (UCN) at the mine site.

As a mandatory component of the MEC solution, the UEG provides the Multi-access Edge Platform (MEP) and user-plane functions defined in ETSI. When being deployed with a Kite-like solution on the coal mine private network, the UEG provides MEC user-plane functions as well as 4G and 5G convergent control-plane functions to offer voice and data services for mine workers. The UEG controls services and connects calls locally without exchanging signaling with the central network. As for service redundancy, two UEGs are deployed on site; local services continue to run even if a central network exception occurs. In extreme situations, for example, if optical fibers connected to the campus network are damaged, the UEGs ensure that services can still run as usual. In summary, the UEG features high bandwidth, large throughput, optimal performance, and high integration, catering to the first concern for network reliability and data security and advancing coal mine intelligentization.

The UCN provides a simplified, highly integrated, and carrier-class IMS solution. It adopts dual-site redundancy and connects to the same EMS as the UEG. The UCN provides standard VoLTE and VoNR services and real-time HD voice and video services, fulfilling convergence of voice, video, and data services as mentioned in the second concern. It uses standard interfaces to connect to the convergent dispatch system dedicated to the mine for real-time voice and video interaction. The convergent dispatch system provides advanced functions for the coal mine, including emergency broadcasting, wireless communications, video monitoring, external line voice, wired dispatching, and intelligent event-triggered 5G terminal dispatching.

Based on the 5G coal mine private network solution, intelligentization-oriented construction aims to avoid production safety risks and improve communications and work efficiency. This solution has been successfully used for Sanyuan Coal Mine.

5G Coal Mine Construction Example

The 5G coal mine private network is jointly constructed by Sanyuan Coal Mine of

Jinneng Holding Shanxi Coal Industry Co.,Ltd, Shanxi Mobile, and Huawei. It covers major production areas below ground. The operator provides a unified network management system and centrally provisions numbers on the private network. Local data is not transmitted out of the campus, ensuring campus data security. The private network supports various types of 5G devices, including 5G intrinsically safe cameras, 5G explosion-proof mobile phones, smart mine lamps, 5G CPE, and 5G inspection robots.

The 5G coal mine private network solution offers different types of services covering the following processes and scenarios:

- Production and application: panoramic video stitching and remote control on the fully mechanized mining face, 5G excavator remote control on the excavation face, and inspection robots in 5G chambers

- Personnel communications: remote device diagnosis, video and voice calling, individual intelligent equipment, and intelligent mine lamps

- Convergent dispatching: voice dispatch services (P2P voice calls, P2P video calls, and group calls), conference services (video and voice conferences), SMS services, and user mapping and grouping (temporary group creation by region)

At present, the 5G coal mine private network solution has been successfully put into commercial practice for Sanyuan Coal Mine. It applies 5G to convergent mining communications systems for the first time. This solution is designed for major service requirements, such as multi-network access, convergent voice, convergent data, unified dispatching, centralized network management, and seamless access to the integrated management and control platform. After this solution is deployed, personnel below and above ground can communicate with each other in real time, improving dispatch efficiency. It flexibly adapts to most mining processes and service scenarios and provides key mine services such as remote control, intelligent inspection, and HD intelligent monitoring, elevating safe mining to new heights and setting a benchmark for 5G private network construction in the coal industry.

Prospect: 5G Coal Mine Private Network, Improving Mining Workplaces

Digital technologies are fast tracking their integration with traditional industries to amplify, promote, and multiply economic development.

5G, edge computing, and computing network technologies are introduced to the coal industry chain for safety and efficiency and the intelligent management of coal mines. With these technologies, underground mechanization, automation, and remote control become possible, making it easier to centrally schedule office and production processes below and above ground.

Below are voices from frontline coal miners:

"In the past, the white towels we wore during mining were likely to become black towels."

"We don't have to go mining underground now. We are more willing to wear white shirts every day."

"Nowadays, 5G-assisted technologies make coal digging much easier and more efficient."

As intelligent mine construction accelerates, the 5G coal mine private network solution will help gradually build a new digital foundation of "connectivity+compute+capabilities" for coal mine intelligentization, and make production "intelligent, real-time, least-staffed, and unstaffed". It promotes smart mining, intelligent transportation, security self-assurance, and the intelligent operational management of coal mine resources. As digitalization and 5G industrialization penetrate the coal mine industry, the 5G coal mine private network encourages the coal industry to develop towards an intelligent and high-quality direction, improving mining workplaces below and above ground and benefiting millions of coal miners.

11

5G Brings New Development Opportunities for Operators' Video Services

5G will accelerate the development of operators' Fixed Wireless Access (FWA) services. However, if operators provide only connections without services bound, there can be no doubt that they will eventually fall into homogeneous competition. From global experience, FWA predominately serves residential dwellings, so it is the optimal choice for operators to bind video services to FWA. After 5G is introduced to provide deterministic services and flexible charging modes, wireless home broadband services will continuously innovate according to the future trends and requirements of the family.

Song Xuzhao

Senior Marketing Manager for Hybrid Video, Huawei Cloud Core Network Product Line

1. FWA Is Developing Rapidly from the 4G Era to 5G; However, Operators Are Still Facing Several Service Pain Points.

5G brings new opportunities for FWA.

FWA was first proposed in 2015. It utilizes wireless technology for the last mile of broadband access and uses Customer Premises Equipment (CPE) as terminals. FWA was first proposed during the 4G era as an inexpensive technology to implement access at the last mile. At that time, wired connections incurred high costs and required a long Time to Market (TTM), therefore a window of opportunity was opened for wireless connections.

Even back then, FWA experienced a successful development; however, it still encountered some restrictions concerning bandwidth, spectrum, QoS assurance, and O&M. Stepping into the 5G era, the network is significantly enhanced in capacity, which brings new opportunities for the development of FWA. By the end of 2021, more than 400 4G FWA networks and dozens

of 5G FWA networks have been deployed worldwide. Over half of mobile operators have launched FWA services. The number of 4G and 5G FWA users has exceeded 100 million globally. According to Ovum, an independent global analyst and consultancy firm based in the UK, the number of FWA users will reach 165 million by 2025.

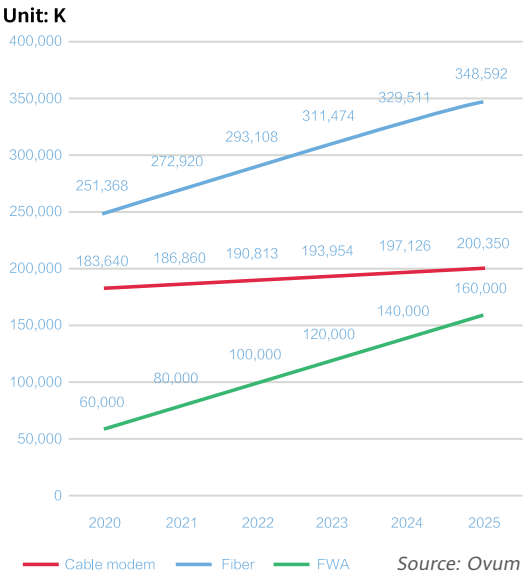

Figure 1 Forecast for global FWA user count

It is inevitable to bind services to FWA.

FWA, a beneficial supplement to Fixed Broadband (FBB), expands the value of fixed users. At the early stage of 5G development, it plays a vital role for creating value and driving growth. It is also among the first wave of 5G applications. These have been commonly admitted by most operators. Despite the rapid growth of FWA, operators are still facing a service pain point — FWA provides only data, with a lack of user loyalty. Operators leverage FWA to allow users to gain access to the Internet, but it is only the first step of users' network access activities. Due to FWA's intrinsic defects, such as high costs, as well as limited and unstable bandwidth, FWA providers may face competition from FBB vendors in the same city. Once user churn occurs after FWA services are put into use over a certain period of time, the operational costs increase and the ROI period is prolonged. Therefore, there seems to be only one right choice for operators, which is to develop their own core services based on basic data connections, to enhance user loyalty and achieve a higher Average Revenue per User (ARPU).

2. The Bandwidth Cost of FWA Determines that Operators Will Not Use the Same Business Model for Optical Fibers in Which No Services Are Bound. Binding Video Services to FWA Becomes the Optimal Choice.

FWA brings operators' connections to the home. On this basis, it is considered the best choice for operators to bind video services to FWA.

FWA uses CPEs to enable access at the last mile. In this scenario, the service object of operators changes from individuals to home users, and the user type changes from mobile users to fixed home access users. So, what types of services should be carried over home connections, which best serve home users? It must be video services. Due to video services being one of the most mature services of operators, video services are available at any time. Therefore, it is considered the best choice to bind video services to FWA.

- In countries and regions where FBB develops rapidly, many operators have bound broadband and video services upon provisioning. Statistics have demonstrated that about 70% of broadband users are bound with video services, and the data is on the increase.

- Such examples include Verizon in the United States and Etisalat in the United Arab Emirates, who are among the earliest movers that provisioned FWA services together with video services to increase the ARPU.

The challenges facing FWA+Video services in the LTE era no longer exist in the 5G era.

In fact, Etisalat had trialed the business model of binding video services to FWA early in the LTE era. In 2017, Etisalat launched IPTV over WTTx. Possessing a market share of 80% of the fixed network, Etisalat aims to attract at least 100,000 WTTx users and obtain an additional 14.3 million dollars in annual revenues from IPTV services. Considering this, Etisalat still faces challenges in the following aspects:

- Capacity over LTE air interfaces

- IPTV QoS

- O&M problems, such as IPTV problem demarcation, locating, and monitoring

In the LTE era, these issues became the main obstacles hindering the development of Video over WTTx; however, they no longer exist in the 5G era. Thanks to the following factors, we believe that video over 5G FWA is about to blossom and grow even stronger in the not too distant future:

- The price of 5G FWA CPEs has decreased significantly. By 2022, the price of a single CPE has reduced to less than US$100, and there are nearly 200 models of CPEs that support FWA available worldwide.

- The air interface capacity of 5G is greatly improved compared with that of 4G. The maximum capacity exceeds 1 Gbit/s, making FWA a replacement for optical fibers and greater value for money.

- A new slicing framework, and the Communication Service Management Function (CSMF) and Network Slice Management Function (NSMF) are introduced to 5G to ensure end-to-end user and service experience.

- The Network Data Analytics Function (NWDAF) is introduced to 5G to provide a comprehensive O&M and monitoring mechanism based on slices, service types, and users.

Currently, there are dozens of 5G networks around the world, and more and more operators are deploying 5G. The FWA+Video model will become an important value creation point and main strategic choice for operators at the early stage of 5G development.

5G will help evolve videos to ultra-HD, spatial, and social ones.

In addition to convenient access, 5G also provides large-bandwidth and low-latency data transmission capabilities, laying a foundation for the transmission of ultra-HD and high-bit-rate

videos. The development of MBB opens up a new horizon for operators to vigorously develop video services.

The transmission bandwidth of 5G air interfaces will be significantly improved, no longer limiting the transmission of ultra-high-bit-rate spatial videos. The continuous development of video stitching, modeling, and rendering technologies provides a technical foundation for spatial videos. The popularization of smartphones and phasing-out of feature phones will further accelerate the large-scale application of spatial videos on OTT multi-screens. The ubiquitous communication capability of operators' networks has also significantly improved. Video calling previously available only on mobile phones will be gradually available on large TV screens, driving the combination of operators' video platforms and video calling services. This will further enrich the video experience for users and increase loyalty.

New business model: 5G FWA+Video

5G FWA is similar to home broadband; however, it is essentially an intermediate form between wireless and wired connections. Therefore, when designing the business model for 5G FWA, we cannot directly emulate the business model for fixed networks. The characteristics of wireless networks should also be taken into consideration.

Household size changes in China: Families with 1 to 2 members improved

Source: National Bureau of Statistics of China, Guosen Securities Economic Research Institute

Figure 2 Household size changes in China

5G FWA mainly serves home users; therefore, the characteristics of home users and average household size must also be considered. Taking China as an example, most families have an average of two to four people per house. Based on this, we can conclude that:

- The business model for optical fibers providing a pure high rate is not suitable for FWA, nor is it cost-effective, especially when you consider current trends where families are getting smaller.

- Before video services are bound, 8 Mbit/s bandwidth is sufficient in most cases. This is due to the fact that mainstream home services provide 480p or 720p OTT videos, and 8 Mbit/s of bandwidth will suffice. In the coming three to five years, 100 Mbit/s bandwidth will meet the general requirements of most households. After video services are bound, taking popular 1080p videos as an example, the designed 20 Mbit/s home bandwidth can also meet the requirements in such main scenarios.

Video Resolution	Bandwidth Requirement
1080p @ 60 fps	4.5–9 Mbit/s
4K @ 60 fps	20–50 Mbit/s
8K @ 60 fps	100–200 Mbit/s
AR-VR	150–200 Mbit/s

Figure 3 Bandwidth requirements for different video resolutions

- If an operator does not have a dedicated FWA spectrum, it can provision large-volume packages to meet the service requirements of the video. At the early stage of 5G development, the MBB network is relatively idle due to the low penetration rate of terminals. The peak hours of Enhanced Mobile Broadband (eMBB) and FWA do not completely overlap. Therefore, effective utilization of MBB resources during off-peak hours to develop FWA can bring more benefits to operators and shorten the ROI.

3. Technical Advantages of 5G FWA+Video

The combination of 5G FWA and video services ensures user loyalty after connections are established. It also offers a myriad of native technological advantages.

Unprecedented QoS guarantee

When FBB or FWA is employed to provide home broadband services through optical fibers, the downlink rate of large-screen users is essentially unlimited. When switching to 5G access, users are more sensitive to the service experience and less tolerant to QoS problems. Once these users are conditioned to their original service experience, they will be lost quickly if those standards are not maintained or exceeded. In some triple-play scenarios, voice services need to be added to FWA. The requirement on delays in such scenarios is higher than that when large bandwidth is used. However, the capacity of 5G air interfaces is significantly improved, which can fully meet the experience requirements of most families after being properly planned.

More importantly, QoS guarantee on 4G networks can be implemented only at the bearer level with high costs, while 5G uses QoS flows as the carrier for QoS control and introduces technologies such as the Service Data Adaptation Protocol (SDAP) for QoS guarantee, which is more flexible and comprehensive. The

use of 5G slices introduces new technical means such as end-to-end resource reservation, security assurance, and end-to-end reliability to ensure a seamless user experience.

Service-based differentiated charging

For fiber users, the charging structure is simple, with monthly subscriptions placing users firmly at the center. In this case, operators' revenue is entirely dependent on the number of users, with no other variables.

In 5G FWA, multiple home services are added to basic connections, allowing differentiated charging modes and flexible business scenarios for operators.

1. Basic data services can be charged by rate or traffic package.

2. Video services can be charged based on independent charging policies by service type. User type and content can be further monetized, for example, by providing value-added services for VIP users, charging users based on content, and supporting post-payment in cooperation with OTT providers.

Real end-to-end O&M

After a service is launched, such as the video service, it poses O&M requirements on the network. In the 4G era, the wireless, transmission, and core networks are independently maintained and lack unified O&M. After slicing is introduced to 5G, users can access the network through CPEs that support slicing. In this case, O&M, network quality monitoring, and lifecycle management are performed on the network as a whole, including wireless, transmission, and core networks, based on slices. This reduces O&M costs, improves O&M efficiency, and ensures an optimal user experience, creating additional revenue streams for operators.

4. In the Future, Operators Will Upgrade and Transform Video Services Towards Large Screens and Develop New Smart Home Scenarios.

Each industry follows an objective, periodic cycle to develop, from mature technology R&D, to mature manufacturing capabilities, and then to a mature market for new commodities. FWA technology started its development in the 4G era. In the current market, there have been several 4G and 5G FWA success stories. This indicates that FWA has completed the industrial infancy phase led by technology R&D, and the industrial cultivation phase led by technology application, and has consequently entered the rapid development phase led by the market. It is foreseeable that FWA will develop even faster over the next two years.

5G FWA extends operators' connections to people's homes. However, it is only the first step. Operators need to further bind FWA with services such as video services to improve user loyalty, explore more value, and grow the market space. In the future, one CPE can be applied in N scenarios in a home covered by

one Wi-Fi module, namely, the 1+1+N mode. In addition to video services, many other service scenarios like voice, home cloud, cloud gaming, 4K/8K video, and VR/AR, as well as mobile home guard, smart home, and smart healthcare and elderly care centered on an all-in-one smart home can be developed depending on the industrial development phases in different countries and regions. Operators will continue to extend services based on large screens, deploy the Holistic, Diversified, Intellectual, Connected, and Terrific (HDICT) strategy to explore the next growth point, and turn 5G FWA into the source and foundation for service innovations.

Broadband connections are the cornerstone of the digital economy. According to an ITU report, nearly half of the world's population and 900 million households are not connected to the Internet, and 300 million of the connected households use copper or cable connections. Considering the trend of replacing copper cables with optical fibers, and the evolution of wired and wireless networks, 4G and 5G FWA will be able to provide reliable and affordable broadband Internet connection solutions more quickly, helping bridge the digital divide. During the global pandemic, 4G and 5G FWA played an important role in supporting online shopping, distance education, and remote office, and became an important infrastructure for normal social engagements. More than 20 operators around the world released FWA service packages in response to the pandemic. However, there is still a long way to go for operators, industry organizations, CPE vendors, chip vendors, and analyst institutions to work together to promote the rapid deployment of 4G and 5G FWA and wireless home broadband.

12

Operators' Video Services Are Converging with OTT Applications and New Video Services Are Spearheading the Trend Towards 5.5G

Improved 5G and mobile video services have boosted mobile data services and upgraded video services from Standard Definition (SD) to Ultra-High-Definition (UHD), expediting the convergence of operators' video services with OTT applications, so that users can enjoy video services not only on large TV screens, but also on their OTT devices. As we steam towards the 5.5G and 6G era, there will be no obstacles for transferring spatial videos with ultra-high bit rates, and a greater volume of users will enjoy spatial videos on various OTT devices. At the same time, operators are continuously improving their network capabilities to realize ubiquitous communications, which also enables phone-based video calls to be placed on large TVs, allowing home video services to be overlaid with calling and social-interactive services. These new video services will promote the convergence of B2C and B2H services, and bring new opportunities for operators' video services in the 5.5G era.

Yan Shifu

Senior Marketing Manager for Hybrid Video, Huawei Cloud Core Network Product Line

1. Operators' Video Services Are Converging with OTT Applications at Lightning Speeds, Stretching Out from TV-Based Single Large Screens to OTT-Oriented Multiple Screens, and Delivering a Better UHD Video Experience with Enhanced Network Capabilities

Mobile network technologies are a powerful driver for change and innovation in video technologies. The high-quality 5G networks featuring high bandwidth, low latency, and wide connections, are opening new pathways, experiences, models, and opportunities in the video industry. Today, 90% of global operators have commenced their video service transformation, with OTT and UHD becoming mainstream.

1.1 5G Helps Operators Extend Video Services from Large TV Screens to Various OTT Device Screens

As a type of B2H service, operators' video services have been stably growing in terms of users and traffic over the past years. Omdia reports a total IPTV service revenue of US$35.9 billion among all global operators in 2021. Video services represent an important revenue source, accounting for 20% to 25% of the total home services revenue.

Meanwhile, operators find new opportunities as 5G deployment ramps up. They are shifting focus toward OTT multi-screen video services, where they can expand video services from TVs to various mobile OTT devices, such as mobile phones, tablets, and laptops. This allows users to enjoy video services anytime and anywhere.

For telecom operators, statistics show that 89 of the world's top 100 operators provide OTT video services. For users, Nielsen reports that adults in the U.S. have added about 40 daily minutes on video content through mobile phones, tablets, and laptops each year between 2018 and 2020. These indicate the increasing use of OTT multi-screen video services.

1.2 UHD Video Experience Is Available on Various OTT Device Screens, and High Interaction Facilitates Spatial Video Service Application

Higher resolution, higher frame rates, and wider color gamut deliver a better video experience. However, these also require higher network bandwidth for video transmission. The good news is that 5G is up for the task. 5G networks deliver significantly higher transmission bandwidth compared with its predecessors, reaching a 1000 Mbit/s downlink rate. This guarantees the high-quality transmission of video content, enabling UHD video services on various device screens.

In addition, increasingly advanced touch screen technologies on mobile terminals like phones and tablets enable smoother human-machine interaction and improve the interoperability across multiple OTT device screens. This delivers a better interaction experience than large TV screens, creating the foundation for highly interactive spatial video services delivered through various OTT devices.

We have already achieved a UHD experience in flat videos. Now, 5G is gradually enabling immersive spatial video services with VR, free viewpoint, and glasses-free 3D. For example, the Kungfu act *Heroes* performed at the CCTV New Year's Gala 2021 used the 360-degree free-view feature, driving viewership up by 5% to 7%. Another example is the Tokyo Olympic Games in 2021. During the event, free-view technologies were used to live broadcast some sports competitions, allowing audiences to look at athletes' performance from a range of viewpoints. These new experiences were very popular among viewers and serve as examples for the large-scale application of spatial video services.

As networks continue to evolve, so do the operators' video services, from TV screens

(fixed broadband) to diverse OTT device screens (mobile broadband), and from SD to UHD. They are also expanding from single TV playback to multi-screen collaboration between various devices such as TVs, mobile phones, and tablets. Moreover, a new immersive spatial video experience is made possible compared with traditional flat videos. Factoring in the changes as described above, user loyalty will be enhanced, followed by an increase in competitiveness, and new business models will come to life based on the video services provided. To achieve these goals, operators need to add a lightweight solution to their network or build a new video service platform to quickly upgrade services and operations.

2. Spatial and Social-Interactive Videos Will Become Central to Operators' Video Services

Content transmission and video communications will continue to evolve as mobile networks move toward 5.5G and 6G. We will also see a rise in popularity of new video terminals, namely smartphones, VR headsets, and AR glasses. These will serve as the technical foundation for the large-scale rollout of new video services such as spatial and social-interactive video services. Such new video services will become an important source of opportunity for operators to converge B2C and B2H services, and deliver an upgraded experience to 500 million global TV users, which will in turn bring significant growth and revenue opportunities.

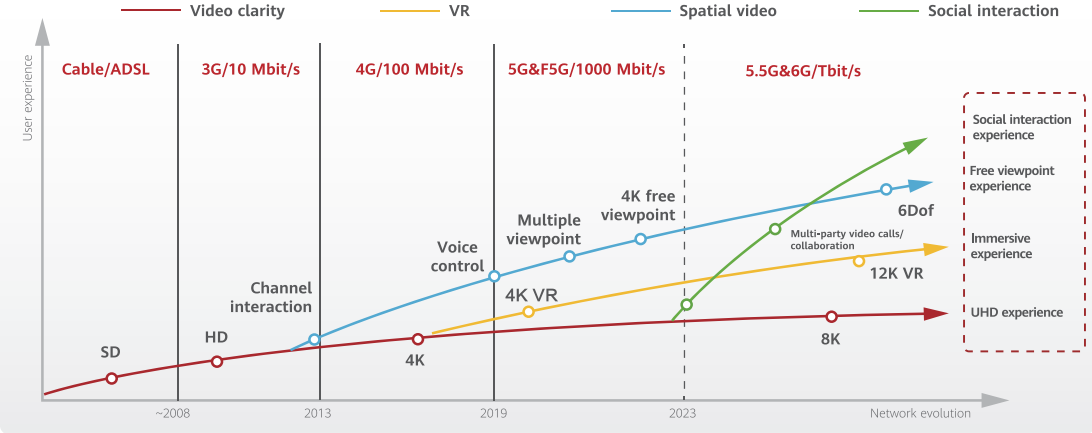

Figure 1 Development trend of operators' video services

2.1 With Smarter Devices and Higher-Quality Networks, Spatial Video Services Are Shifting Toward Large-Scale Application

5.5G and 6G are around the corner. Already today, 5G has significantly improved the air interface transmission rate, driving it up to Tbit/s. New network capabilities, such as on-demand scheduling, multi-stream collaborative transmission, closed-loop experience optimization, and real-time rendering and interaction, ensure the deterministic transmission of spatial video content.

Media technologies, such as video stitching, modeling and rendering, and low-latency transmission, are also developing, so video services

are providing 3D, immersive, free-view, and interactive experiences. To date, multiple video service forms have already emerged, including glasses-free 3D, multi-view, free-view, VR, and 6DoF videos. These deliver high-quality spatial video and interaction experiences to users.

5G is enabling the large-scale rollout of spatial video services. The novel experience is popular among many stakeholders in the industry, including content producers (like TV stations), content copyright owners (like sports event organizers), and content aggregators and distributors (like telecom operators and online streaming media platforms).

For example, operators (such as LG U+) in North America, Japan, and South Korea, work with sports media to launch free-view live streaming of basketball, hockey, and baseball games. LG U+ has also combined this with 5G packages for commercial promotion. In addition, some leading sports media use 6DoF video modeling to model and livestream basketball games in real time.

In China, *Dance Smash* Season 2 (a Chinese dance competition show) used 360-degree free-view technologies in 2020. Since then, spatial video services have become a hit and the industry has widely adopted free-view technologies. For example, Shaanxi Telecom and Shaanxi Mobile used free-view to livestream the table tennis competition during the 14th National Games of China in Shaanxi. Users enjoyed a brand new immersive experience on both large TV screens and various 5G OTT device screens.

2.2 B2C and B2H Services Converge, Enabling New Home Video Services Like Social Interaction

Today, many households have large TV screens for home entertainment along with other smart home services. As networks and communication services evolve, we will see video calls stretch out from mobile phones to large TV screens. These smart home applications will begin the integration of B2C and B2H services.

As B2C and B2H services converge, so will operators' video and video call services. Technological platforms will need to evolve accordingly. By integrating video calling and video platforms, operators will be able to enrich video service experiences, improve user stickiness, and capitalize on the development opportunities of social-interactive video services.

Omdia estimates that there were 117 million IPTV large screen users outside China in 2021. In China, this number exceeds 300 million, according to China's National Radio and Television Administration. Even so, there is still a growth space of over 100 million users, considering that there will be over 500 million IPTV users by 2025 as the global video and broadband penetration rates continue to increase. Such a large user base creates vast opportunities and new video services such as spatial video and social-interactive video can be fully leveraged by telcos. By upgrading video service platforms to implement new video services, deliver improved experiences, and facilitate operations, telecom operators can provide high-quality smart home video services including spatial video and TV-based calling for more than 500 million large-screen users, bringing a better service experience to people whilst opening up a wider market space.

13

Huawei Vivision Solution Debuts: Zhejiang Mobile Becomes the Number One Player

Huawei Vivision solution has been adopted by Zhejiang Mobile. This solution can automatically and intelligently convert 2D Video-on-Demand (VOD) and live TV content to 3D in quasi real time, significantly reducing 3D content production costs. It also supports many other functions such as glass-free 3D on mobile phones and 3D projection. Considering all these innovative features, this solution can help operators deliver innovative experiences and gain more revenue with their video services.

He Yanjuan

Senior Marketing Manager for Hybrid Video, Huawei Cloud Core Network Product Line

1. Immersive Video Experiences Such as 3D Form The Development Direction of Next-Generation Video Services. However, Content Insufficiency Remains a Hindrance

Industry Development Trend

End users have an unquenchable thirst for better video experiences. With the development of 2D video technologies, an 8K UHD video experience is readily available. In this case, people are setting their focus on emerging technologies for more interactive, real-time, and real video experiences. The rise of Extended Reality (XR) technologies is a right exemplification of this trend.

At the same time, the evolution of the network is in full swing and 5.5G and 6G are already around the corner. Today, 5G has significantly improved the air interface transmission rate. New network capabilities, such as on-demand scheduling, multi-stream collaborative transmission, closed-loop experience optimization, and real-time rendering and interaction, together ensure a high-quality immersive video service experience. On top of that, emerging technologies such as Virtual Reality (VR), Artificial Intelligence (AI), and motion capture are bridging the virtual world with the real world.

The world must look further into the future, with 3D being an optimal development direction for the video industry as far as we can tell. Facing this trend, many video service sectors like social media and video entertainment are both exploring new opportunities in 3D, and more and more technology players are engaging. Factoring in the above, a 3D industry framework has been established, covering 3D device technology development, product manufacturing, market growth, and product delivery. However, the 3D content sector seems to be holding back the development of the entire industry.

Challenges and Solution

In contrast to the rapid development of 3D devices, the 3D content sector is experiencing a somewhat muted growth.

The reason is quite obvious: 3D content production is complicated. It is costly and time-consuming to shoot 3D videos, and the range of lenses are limited. Manually converting existing 2D content to 3D is a pragmatic alternative, but it also requires a significant amount of time, labor, and expenditure. These pose great hurdles to 3D content generation.

To address these challenges, Huawei has creatively proposed a 2D-to-3D video conversion solution named Huawei Vivision solution. Developed based on the company's extensive video technologies, the Vivision solution streamlines the entire process covering 3D video conversion, distribution, and playback, enabling operators to make full use of existing 2D content.

This solution also brings much lower costs and higher efficiency. For example, it may take 100 personnel three months to manually convert a 2D video to 3D, conversely, the Vivision solution may take just one person only one week to convert the same content, resulting in a 1000 times greater efficiency. With this high level of efficiency, Huawei Vivision solution can be utilized to quickly roll out more 3D content with existing 2D videos, helping operators improve user experience and gain more revenue with their video services.

2. Huawei Vivision Solution Unleashes Greater Value of Operators' Video Content

Key Features

- Lightweight; add-on deployment mode

Huawei Vivision solution is a lightweight solution and can bedeployed as an add-on. With the intelligent transcoding server deployed beside the IPTV platform, 2D-to-3D conversion services can be rolled out quickly. After receiving 2D video streams, the transcoding server can automatically output 3D video streams and then ingest them to the IPTV platform. By doing so, this solution can make full use of existing 2D video content and generate 3D videos easily with low costs.

- 3D depth estimation based on AI deep learning

The key to implementing 3D video content conversion is to determine the depths of different objects and render them in videos. Based on AI deep learning, Huawei Vivision solution can estimate the depths of objects in the video images. It first extracts objects in a video image and obtains their boundary information. Then, it generates a depth image based on the extracted objects, and builds a stereoscopic model to generate left- and right-eye images. At the end, it fine-tunes the 3D image based on the comparison with previous and next frames.

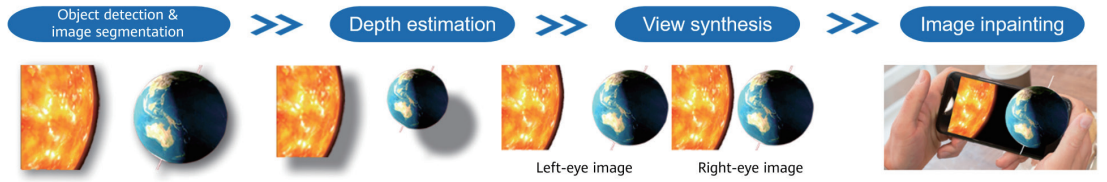

Figure 1 3D video generation process

- Well-trained 3D visual effects

The more powerful the 3D model is, the finer the 3D visual effects are. Being trained with more than 500,000 hours of animation, movie, TV series, and sports videos covering over 3000 scenarios, the 3D model of this solution is powerful and can deliver optimal 3D visual effects.

- World's only solution for converting 2D live broadcast content to 3D

Huawei Vivision solution is now the world's only one that can convert 2D live broadcast content to 3D. It can be used for live broadcast channels or event live broadcast such as sports events and galas. The conversion adds only a five-second delay to the live broadcast, and can provide operators with differentiated competitive advantages.

- Glasses-free 3D and real-time focus tracking

The 3D content generated using Huawei Vivision solution can be enjoyed with VR headsets, 3D glasses, and 3D displays, akin to regular 3D videos. Notably, it can also be played on mobile phones. Huawei 3D solution integrates the intelligent transcoding server with the SDK and mobile phone protective film to build an end-to-end 3D solution, allowing users to enjoy 3D content using only their phones.

The glasses-free 3D effect is achieved based on binocular stereo vision. With the lenticular lens sheet structure of the 3D protective film, the light reflected off the 2D image will be refracted to the user's eyes when passing through the film. Due to that, binocular disparity occurs, and the left- and right-eye images will be captured by the left and right eyes, respectively, and will then collaboratively produce a 3D effect. In this way, users can enjoy 3D videos using only their phones with their bare eyes.

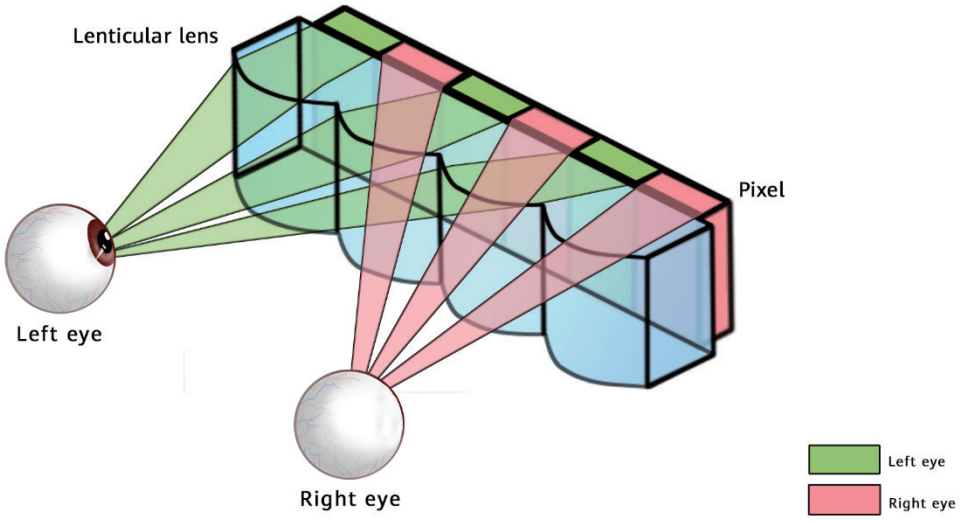

Figure 2 Lenticular lens technology

However, there are still some limitations. To obtain an optimal glasses-free 3D effect, the user needs to maintain their viewpoint and view angle, and any subtle shifts in the viewpoint or view angle may affect the video experience.

To address the aforementioned issue, the Vivision solution adopts real-time focus tracking technology. Such a technology can accurately capture and calculate the eye position and pupil distance of a user, with which it can obtain the line-of-sight direction and generate a proper angle of view. The video will then be adjusted through SDK within 300 milliseconds based on the analysis result, ensuring a comfortable watching experience.

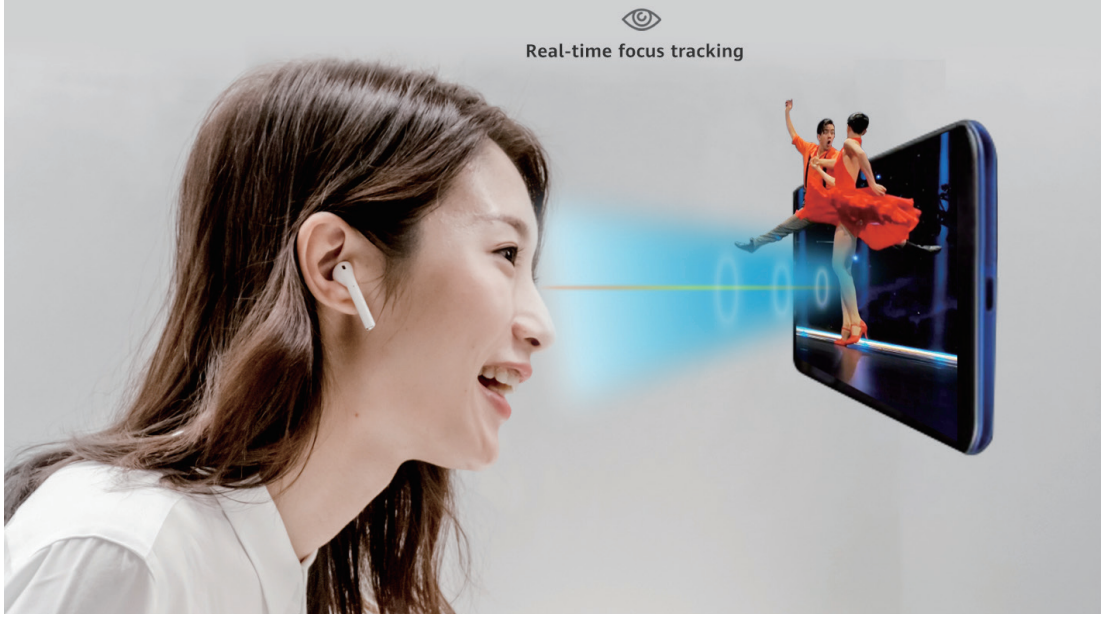

Figure 3 Focus tracking

3. Zhejiang Mobile Takes the Lead in the Commercial Use of Huawei Vivision Solution

As user dividends are disappearing and the IPTV industry is undergoing inter-generational evolution, it is vital for operators to lead the transformation of industry, upgrade their services, and better monetize users. 3D video, as a differentiated video experience, will certainly bring new opportunities for operators' business innovation and vast market possibilities for the video industry.

To facilitate its IPTV service transformation, Zhejiang Mobile introduced Huawei Vivision solution for their 3D content services. By creating a differentiated service, Zhejiang Mobile will bundle Mobile Broadband (MBB) service packages with video content. It has collaborated with partners in the video industry chain, such as video platforms, content providers, and terminal device vendors, to build a new service and revenue mechanism, aimed at driving its IPTV service growth.

With the Vivision solution, Zhejiang Mobile provides high-quality 3D content to high-value package users so that they can enjoy a 3D experience with projectors and 3D glasses at home. It also delivers 3D content to mobile phone users, with the SDK and protective film of the Vivision solution. Moreover, Zhejiang Mobile is inviting a greater number of content partners to provide more valuable content services for users and achieve an all-round win.

The 2D-to-3D conversion feature provided by the Vivision solution can bring many benefits to operators. It not only brings more high-quality and personalized video content, but also enriches the hierarchical member service system of operators' video platforms, allowing operators to create more differentiated member privileges and new business models.

On the one hand, it can help operators gain additional revenue with existing 3D content. For example, if a blockbuster 3D film is put online after finishing in the cinema, this would capture a greater variety of audiences who choose to enjoy the 3D film on their phones. On the other hand, it allows operators to convert existing 2D video content into immersive 3D video content, and gain more revenue from users with pay per view streaming.

3D live broadcast is another powerful feature for operators. It can be widely used for the broadcasting of large-scale activities such as sports events, concerts, and launch events, delivering a more vivid experience. It also drives bandwidth consumption as the broadcast requires higher bandwidth.

Outlook

As the video industry moves forward, there will be more video service forms besides immersive video, and video services will eventually be more refined. Huawei will innovate and collaborate with more industry partners to deliver an optimal video experience to a wider range of users, and help operators explore new opportunities in this field.

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Building a Reliable, Optimal-Performance, Secure, Maintainable Telecom Cloud as the Cloud Base for the 5G Core

When it comes to cloudification, building cloud infrastructure with telecom cloud technologies is the optimal choice. An excellent telecom cloud platform for the core network has the potential to feature rock-solid reliability, optimal performance, high security, easy O&M, and openness, thereby ensuring ultra-low latency, always-on ability, and zero interruption of 5G services. After overcoming all kinds of technical challenges, Huawei Telco Cloud has brought these features to life, enabling agile services and reliable upgrades. With Huawei's help, operators can gain technical advantages among fierce market competition and achieve business success.

Yao Yunyun

Senior Marketing Manager for Telco Cloud, Huawei Cloud Core Network Product Line

5G core networks are built over cloud infrastructure. Operators are accelerating their construction of cloud infrastructure to reach their own 5G era. After 10 years of telecom cloud development, core network devices are being switched from legacy dedicated devices to Commercial Off-The-Shelf (COTS) servers, and NEs are evolving from virtualization to cloudification. Currently, cloud core networks bear the basic characteristics of cloudification. To build a hyper-distributed 3D 5G core network, the control plane must be convergent and centralized to implement highly stable, agile, centralized management through Internet-based operations, and the user plane must be distributed from cities to campuses and industrial sites in order to achieve ultra-low latency, secure, efficient campus networks. To accomplish these goals, the telecom cloud must feature rock-solid reliability, optimal performance, high security, and easy O&M. In addition, the telecom cloud must provide an open network platform in compliance with industry standards.

A core network carries key telecom services and the data of hundreds of millions of users.

Some operators centrally manage users through regions, so a single fault can cause widespread disruption. Therefore, a highly reliable core network is required to ensure that user services are always online and that voice and data services are not interrupted.

Core network users include communications service users (B2C), campus users (B2B), and government and enterprise users (B2B). Data security is essential. In normal communications activities, user privacy must be guaranteed. For B2B users, data must not be transferred beyond the campus. The availability, integrity, and confidentiality of network data are all top-priority. The core network must ensure high security.

5G networks must fully meet the network service requirements of applications with different characteristics to implement ultra-reliable and low-latency communications services (such as AR/VR). An optimal-performance 5G core network must guarantee high-quality 5G user experience.

In comparison with 2G/3G/4G networks, 5G networks have experienced an explosive growth of mobile data traffic, massive device connections, and emerging new services and application scenarios. As such, forwarding and O&M costs are much higher. To cope with this, we must implement cross-layer O&M collaboration and build a core network that is easy to maintain, helping operators greatly reduce costs and develop the enterprise market.

Huawei Telco Cloud solution integrates both concepts & technologies in the IT field and technical advantages in the CT field. This solution provides multiple innovative functions, such as carrier-grade enhancements, batch upgrade, and enhanced defense, to fulfill rock-solid reliability, optimal performance, high security, easy O&M, and openness. This helps operators build open cloud-based telecom networks.

Rock-solid reliability: keeping hundreds of millions of users always online, with no interruption in voice and data services

- Commercial use of large clusters: Huawei Telco Cloud supports the highly reliable commercial use of large clusters (each with up to 2000 servers). So far, Huawei has helped China Mobile build a telecom cloud with the largest number of users in the world. This cloud covers eight regions and 31 provinces to provide communications services for hundreds of millions of users.

- Cross-DC DR: Huawei Telco Cloud supports cross-DC DR to ensure service continuity.

- Carrier-grade stability: The CT storage bypass function is supported. If all storage devices were to become faulty, the memory can function as temporary storage to ensure the service continuity of applications. The IaaS layer can be restored within 3 hours after the entire cluster is powered off and on. Service flow isolation ensures service continuity even if faults occur, and users remain unaware of the faults.

Optimal performance: providing ultra-

reliable and low-latency user experience

- Kubernetes (K8s) enhancement: Huawei has greatly enhanced the reliability and performance of K8s. For example, the dynamic huge page, unlike the static huge page used by most vendors, flexibly adjusts the page size for different scenarios; NUMA anti-affinity avoids cross-NUMA access to reduce latency; and multi-tenant security supports full-path subhealth detection and VNF fault rectification. All these enhancements greatly improve performance. The overhead on a disk configured with K8s enhanced scheduling is 20% less than that of a same-capacity disk without this function. In addition, image compression is optimized, reducing the IOPS (in loading state) of PaaS by 80%.

- Efficient forwarding: Telecom networks support Layer 3 MAC address forwarding. The forwarding performance is higher than that of Layer 2 IP address forwarding. In addition, DPDK/SR-IOV scheduling is used to improve the forwarding performance.

High security: ensuring network and user data security and meeting compliance requirements

- Enhanced defense: Security is critical. K8s CIC security is hardened at the PaaS layer of Huawei Telco Cloud by using compute isolation (HA isolation, multiple clusters, and security containers) and network isolation technologies (plane-based isolation, firewalls/DMZs, management and service isolation, three-plane isolation, and microsegmentation).

- Agile awareness: Host intrusion detection (malware, information damage, behavior anomaly, and security configuration), VM/container escape detection, and container intrusion detection all help operators easily handle network security risks and detect hacker intrusion behaviors in real time. This ensures network and user data security while also meeting compliance requirements.

Easy O&M: cross-layer synergy and fast upgrade

- Batch upgrade: The Huawei NFVI batch upgrade solution is unique in the industry. This solution requires neither the traditional live VM migration approach nor redundant hardware. All operations, such as batching, upgrading, and resetting hosts, are automated. Services are not affected during such an upgrade. The batching algorithm built into the upgrade tool is associated with MANO and VNFs to minimize the number of batches, greatly improving the upgrade efficiency. For a telecom cloud that serves tens of millions of users, the NFVI layer must be upgraded fast with zero downtime. To achieve this, batch upgrade is the smart move.

- Heterogeneous capacity expansion: Huawei Telco Cloud supports both x86 and Arm servers. These can co-exist for further capacity expansion.

- OpenStack+Kubernetes converged architecture: The Telco Converged Cloud (TCC) platform uses this architecture to provide carrier-grade enhancements in compute, storage, and

network management. VMs, VM containers, and bare-metal containers can be combined as required to meet the differing requirements of industry applications. The Unified Resource Management (URM) is used to properly invoke VM and container resources, greatly improving resource utilization. In addition, a lightweight TCC is also provided to meet small-scale and fast deployment requirements in edge scenarios.

Openness: an open ecosystem in compliance with the standards

- Heterogeneous hardware management: Huawei Telco Cloud can centrally manage different hardware devices at the IaaS layer, greatly improving O&M efficiency.

- Third-party app integration: Huawei has been establishing ETSI standards with other members to build a telecom cloud ecosystem. Huawei always adheres to openness and supports third-party applications and hardware that complies with ETSI standards. Northbound interfaces support integration with third-party VNFs, CNFs and apps, and southbound interfaces support interconnection with diversified third-party hardware devices, ensuring ecosystem compatibility.

For operators, a reliable, optimal-performance, secure, maintainable telecom cloud not only supports the central network, but also helps operators quickly launch and upgrade software at edge sites. This implements quick service innovation and trial-and-error while at the same time greatly reducing O&M costs. It also provides full-service and differentiated SLA assurance, offers innovative services for industries, helps operators develop B2B markets, and quickly responds to the requirements of various industries.

Huawei has been leading the way when it comes to telecom cloud technology and industry development, making significant contributions to various standards organizations. It is a CNCF platinum member (primary contributor), has two chairmen and two vice chairmen of 3GPP, and is also a founder and primary contributor of ETSI NFV ISG. Huawei is also a leader in open-source communities around the world. It is an OpenStack platinum member (the first platinum member in Asia), Linux platinum member, and OPNFV platinum member. Huawei has been committed to providing mature and advanced technologies for customers to help them achieve business success. In addition, Huawei brings customer requirements and business practices to the community to boost the open-source ecosystem.

By the second quarter of 2022, Huawei ranked No. 1 in terms of all-cloud core network contracts signed globally. Huawei Telco Cloud has supported the commercial use of NFV for many operators. For example, Huawei provided STC Saudi Arabia with leading cloud architecture and technologies. TestCraft, one of the tools in the tool chain for automatic delivery, improves the test efficiency and cutover quality; this enables quick service rollout and smooth cutover on the live network. Huawei Telco Cloud ensures 99.999% reliability. Fault isolation and self-healing help

rectify faults in just a few minutes. The efficiency of health check is enhanced. The average time required for event recovery is reduced. The cooperation between STC and Huawei optimizes STC's platform resources, reduces service-oriented TTM, improves the performance and efficiency (by 30%), and optimizes the space. Huawei also deployed its Telco Cloud for a variety of customers including China Mobile, China Telecom, China Unicom, Smart in the Philippines, and América Móvil in Latin America. It is remarkable that, in August 2021, Huawei and China Mobile Zhejiang jointly completed the FOA tests on the Telco Cloud & 5GC batch upgrade solution on the live network. This is the first commercial use of the Telco Cloud & 5GC batch upgrade solution in the industry. During the FOA tests, the cloud OSs of about 1000 servers in a single resource pool were upgraded in just four time windows within two weeks. Before this solution emerged, cloud OSs were usually upgraded using the live migration method in the industry, which required 10 to 30 time windows across several months. Huawei's batch upgrade solution improves upgrade efficiency by over three times and reduces the workload and night shifts of O&M personnel. This capability has been put into commercial use globally.

Huawei has been continuously making efforts and innovating to help operators smoothly make their move to 5G SA. To cope with challenges in network complexity, reliability, and O&M efficiency, Huawei helps operators build telecom cloud networks featuring rock-solid reliability, optimal performance, high security, easy O&M, and openness, which enables more agile services and reliable upgrades. This helps operators gain technical advantages among fierce market competition and achieve business success, lays a solid foundation for future 5G network development, and promotes the digital transformation of the 5G industry.

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Reasons Why Operators Should Remain Cautious When Deciding Whether to Move to the Public Cloud

The cloud-based evolution of the core network has entered a critical phase. Operators now stand at a fork in the road and must choose which path to pursue: the telecom cloud or the public cloud. The telecom cloud, featuring rock-solid reliability, optimal performance, high security, and easy O&M, is an immensely popular choice for today's cloud-based core networks. The public cloud has also been a solid choice for some Tier 2/3 operators because of how cost-effective it is. However, the public cloud is unable to provide carrier-grade reliability, has hidden costs, and locks operators into a hyperscaler's public cloud. Operators should remain cautious when choosing which path they will take. In 2020, Microsoft announced their agreement to acquire Affirmed Networks, a virtualized mobile network startup. This marked the advent of the public cloud's involvement in telecom networking. Since then, the public cloud has become another option for core networks. 2021 saw massive cooperation between the public cloud and operators including Dish, AT&T, and Deutsche Telekom. However, AWS experienced three outages in December 2021. "So, still want to put your network core into the public cloud? #suckers," commented the chief architect of UK's BT. It is difficult to tell whether the public cloud really is a good choice for operators.

Peng Yue

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Core on Cloud: Telecom Cloud vs. Public Cloud

The Cloud-Native-empowered telecom cloud can meet communications networks' requirements for rock-solid reliability, optimal performance, high security, and easy O&M. Its 5G architecture is an

evolution of the 4G cloudification architectures but based on a Service-Based Architecture (SBA), developing into a hyper-distributed 3D core network. It is capable of handling the sharp increase in network traffic brought about by the emergence of the 5G era, facilitating enterprise innovation and industry transformation.

Public cloud vendors have provided one more option. Operators can migrate their core networks onto the public cloud, consuming its infrastructure to provide 5G public or private network services. Using this method, Dish deployed the first 5G standalone core network on the public cloud with AWS. "This cooperation will optimize our network operations and allow us to launch new software and services rapidly and efficiently, enabling the integration of countless innovative use cases for customers," said Dish's Chief Network Officer. This reflects the expectations of many operators for the public cloud. They want to achieve faster expansion and replication by leveraging the public cloud's cost-effective services. However, whether they can reduce costs and get the results they want by using the public cloud is yet to be verified. COVID slowed down global 5G SA network deployment, and some cost-sensitive Tier 2/3 operators trailblazed their way onto the public cloud. Take AT&T as an example. AT&T publicly expressed its tendency to cooperate with the public cloud in 2019. Then in 2020, it announced a cost-cutting program aimed at trimming $6 billion from its budget by 2023. This plan undoubtedly accelerated its migration of services to the public cloud.

In fact, it will still take more time and success stories to tell whether public cloud advantages can live up to expectations. Whether or not to migrate core networks onto the public cloud remains a pressing question for many operators. The reasons below, why and why not, provide some food for thought.

Reason 1: Carrier-grade Requirements Cannot Be Met

Reliability is the cornerstone of the core network. Once a network failure arises, tens of millions of users will be affected. The evolution of the 5G core network also brings new reliability challenges. On the one hand, the 5G core network architecture will become more complex. On the other, the adoption of 5G in enterprise markets will require zero service interruption. The fact is that the public cloud cannot deliver a satisfactory solution for rock-solid reliability, optimal performance, high security, and easy O&M. This is because:

- **The public cloud cannot provide carrier-grade reliability.**

The core network requires the highest possible stability and availability. However, the public cloud cannot guarantee this, which imposes networks to interruption risks.

- **The public cloud has lower service-level agreement (SLA) than carrier-grade standards, and does not promise short service recovery duration.**

Generally, carrier-grade services need to achieve 99.999% uptime. However, the SLA of public

cloud services ranges from 99.9% to 99.99%. For example, Alibaba Cloud offers 99.975% SLA, and AWS EC2 offers 99.99%. This means that the maximum annual service interruption on the public cloud is about 50 minutes, which is far longer than the carrier-grade requirement of 5 minutes. In addition, the public cloud does not promise a short fault recovery time. Once an interruption occurs, the public cloud does not proactively compensate for the interruption unless a major incident ensues.

- **The network architecture of the public cloud makes cross-region DR difficult.**

The public cloud architecture consists of Central Cloud Regions and Edge Locations. For example, AWS has 25 Regions, including 81 Available Zones across limited countries, and AWS can be deployed only in these places. Therefore, if operators choose to migrate networks onto AWS, they must build Edge Locations by themselves. In countries where there are Regions, the control and management planes are deployed in that Region, and the forwarding plane is deployed at Edge Locations. The distance between AZs is less than 100 km, which cannot meet carrier-grade remote DR reliability requirements. To cope with severe natural disasters, multi-region/cross-region DR is required, which means at least two Regions must be deployed in a country. Currently, this standard is still far from being achieved and it is not very cost-effective. In countries with no Regions, local user and control planes still need to be set up, however the management plane needs to be deployed in an existing Region of another country, and the user and control planes need to be deployed in the local country. Although the local sites support remote DR with a distance of over 200 km, multinational private lines will cause difficult network fault demarcation and locating, uncontrollable fault rectification times, and lengthy service recovery time. What's worse, the network failure of a Region in a certain country can cause all linked edge outposts to become unreachable since a local site can be connected to only one Region and edge sites do not have infrastructure autonomy.

- **Long public cloud switchover time impairs telecom services.**

Telecom services require the highest possible continuity. If the user plane times out for 4 seconds, telecom services will be interrupted. The standard networking of the telecom network cloud supports bidirectional forwarding detection (BFD). As such, the service interruption caused by the overall switchover process can be controlled within 2 seconds. However, in the public cloud networking architecture, services will be interrupted for 8 to 10 seconds, which cannot meet telecom service requirements.

The doubt about the reliability of the public cloud does not come from nowhere. The outages of the public cloud have made headlines around the world. Take AWS as an example. Since 2011, there have been at least 18 critical outages. The latest one occurred on December 7, 2021. Millions of users were affected by this extended outage, which took down major Amazon online services such as Prime Music, Prime Video, and Alexa. The outage also took down services hosted by Amazon cloud services, such as

Netflix, Disney Plus, and Coinbase, the biggest cryptocurrency exchange in the United States, affecting tens of thousands of users. After the accident, BT's chief architect commented angrily: "So still want to put your network core into the public cloud? #suckers."

For over-the-top (OTT) services, public cloud system breakdowns may be manageable. The rapid expansion of public cloud services indicates that IT services are not sensitive to reliability to a certain extent. From the perspective of telecom services, a system breakdown can wreak havoc. For one thing, as opposed to IT services which do not have high requirements on continuity and availability, CT services require the highest possible continuity. They cannot tolerate minutes or even seconds of interruption, regardless of end user services or enterprise production systems. The consequences of a breakdown are difficult to estimate. For another, the communications network carries services critical for the national economy and people's livelihood. Once a serious outage occurs, the financial system breaks down and emergency calls are rendered offline; this naturally can beget dire consequences. KDDI Corp., one of Japan's top three cellular operators, said on July 2, 2022 up to 39.15 million mobile connections had been affected by a nationwide network disruption that continued for over 48 hours. As a result, public services like bank cashiers, payment machines, and logistics were interrupted. The breakdown caused their emergency call system to become unavailable and government officials urged KDDI users to dial 110 or 119 using other operator networks or fixed-line phones. Japan's communications minister criticized KDDI Corp. over its handling of the network disruption, saying the company failed to provide sufficient information to customers in a timely manner and that it had not fulfilled its responsibility as a telecommunications operator. On July 29, the president of KDDI publicly apologized for the fault at a press conference. Operators' decision makers are to be held responsible if accidents occur. In telecom networks, every detail counts. In July 2022, the CEO of Rogers Communications sent a letter to apologize for the outage caused by the core network upgrade and promised to compensate. Faults occur more frequently on OTT services than on telecom services every year. However, there are few cases where the company's executives apologized.

Reliability is the lifeline of telecom operators and is a top priority when it comes to network construction. Unless carrier-grade requirements of rock-solid reliability, optimal performance, high security, and easy O&M can be guaranteed, it is too early to migrate networks onto the public cloud.

Layer 3 forwarding of the public cloud deteriorates performance, increases IP address consumption, and reduces forwarding efficiency.

VNFs have multi-plane communication requirements. In addition to Layer 3, the telecom cloud also supports Layer 2 interconnection based on MAC addresses and equal-cost multi-path routing (ECMP), ensuring fast distribution. However, the public cloud does not support ECMP. The VNFs, if to be migrated onto the public cloud, need to be reconstructed to use

the multi-IP address solution. The bandwidth of multiple access methods is limited, and the IP address consumption doubles. Calculation shows that the L3 forwarding solution of the public cloud reduces the forwarding efficiency by 30% compared with the L2 forwarding solution.

Core on public cloud also needs to resolve security issues related to digital sovereignty.

The Region-based architecture of the public cloud inevitably involves international scenarios. Political barriers also emerge as many places have issued policies on digital sovereignty. Take Europe as an example. In July 2020, the European Parliament released Digital Sovereignty for Europe, which clearly defined digital sovereignty. In 2022, the European digital sovereignty protection system was preliminarily established with the enactment of multiple laws and regulations on data strategy and cyber security, including the Digital Services Act, Digital Markets Act, Data Governance Act, and Data Act. These acts further supplemented General Data Protection Regulation, released in 2016. Due to the mandatory specifications of digital sovereignty and the sensitivity of information in the communications field, operators must carefully examine potential digital security risks before choosing the public cloud.

Reason 2: Hidden Costs May Weigh on Operators

Although the public cloud can reduce costs due to its asset-light model, the following potential additional costs must be carefully considered to avoid falling into a cost trap further down the line.

Additional costs caused by the inability to over-committing of telecom services:

The public cloud can reduce costs by overcommitting CPU resources to different applications. In non-CPU-pinning scheduling mode, although CPU resources are not guaranteed and the computing performance fluctuates when the load is heavy, the resource utilization is greatly improved and the cost is reduced. Generally, overcommitment is used for entry-level Internet applications that do not have high requirements and can allow services to run in off-peak hours. On the contrary, telecom's resonance services are highly consistent. This makes it difficult to stagger peak hours. Emergency plans must be provided in advance so that full services can be taken over for DR, preventing the system from breaking down due to traffic bursts. Measures such as CPU pinning and isolation must be taken to ensure resources can cope with a 100% load. This means that the core network cannot take advantage of the cost reduction brought by overcommitment; its requirements on performance are much higher. Currently, the price of enterprise application services pinned to CPU cores is 1.5 to 2 times higher than those not pinned to CPU cores.

Additional costs brought by DR construction:

The coverage of public cloud Regions is limited. Most countries do not have Regions and need to build their own Edge Locations. A single disaster has the potential for a huge area of impact. As such, the number of central and edge sites must be increased substantially. This costs time and money. The public cloud does not provide direct

interconnections between edge sites. Operators need to build or lease bearer networks with all edge nodes interconnected to ensure continuous availability, especially when there is no Region in the country. This will inevitably increase construction costs.

Additional costs caused by separate O&M of the application and infrastructure layers:

Infrastructure as a Service (IaaS) on the public cloud is provided by different vendors. As opposed to the unified O&M structure of the telecom cloud network, the public cloud does not support cross-layer demarcation, the coordination between organizations is time-consuming, and the recovery duration is uncontrollable. Cloud security is a responsibility shared between the cloud provider and the customer. The public cloud vendors are only responsible for cloud security, such as hardware, software, network, and devices. The operators are responsible for service security, including data, configuration, operation, access, and network security assurance. Having to coordinate layered O&M costs operators more.

Hidden costs caused by network failures:

Once a serious fault occurs on telecom services, it has the potential to render significant financial losses or irreparable damage to an operator's reputation. Mobile operators suffer from an average of five network outages or degradations that impact subscribers each year, costing them around $15 billion annually, according to an analyst in 2013.On July 8, 2022, Rogers Communications Inc. acknowledged it has work to do in building customer trust after its massive network outage that lasted for 19 hours and affected 12 million users and that it expects to spend $150 million on customer credits related to the outage. If operators choose to migrate their core networks onto the public cloud before carrier-grade performance and reliability are achieved, they will have to bear huge hidden costs.

Reason 3: Cloud Vendor Lock-in Dilutes Operators' Control

The public cloud takes over the cloud infrastructure, which ostensibly reduces the burden of operators. However, this means an operator's control over the infrastructure will be significantly reduced and they may end up trapped in a case of cloud provider lock-in.

The public cloud architecture dilutes operators' control rights.

Core on the public cloud weakens operators' control over the cloud infrastructure. Operators have to rearrange their VNF architectures to be compatible with the IaaS and PaaS architectures of the public cloud and change their ways of O&M and management to adapt to the transition of the cloud services. Operators' networking and capacity expansion requirements are subject to the network planning of the public cloud. For the operators that do not have Regions in their own countries, the unified infrastructure management plane is deployed in Regions of other nations. Resource application and provisioning, elastic scaling, upgrade, and

O&M are all also implemented abroad.

Cloud vendor lock-in makes it difficult to switchover services.

The direction of public cloud architecture evolution is different from that of telecom services. Clouds are private and do not have unified standards. Operators will be locked into specific vendors. Discussions about cloud vendor lock-in are common. In 2017, Snapchat said in its last annual filing with the US Securities and Exchange Commission that "any transition of the cloud services currently provided by either Google Cloud or AWS to the other platform or to another cloud provider would be difficult to implement, and would cause us to incur significant expense in both money and time." In October 2020, the U.S. House of Representatives said that when a customer decides to move any of its operations to a different public cloud vendor, it often comes up against significant financial barriers and must overcome technical design challenges. The global IaaS market share reveals the vendor lock-in problem. According to Gartner statistics, the top three IaaS providers (Amazon, Microsoft, and Alibaba) accounted for 70% of the market. Amazon continued to lead the worldwide IaaS market with a market share of 38.9% in 2021.

Although core on the public cloud has shown its unique advantages, there are still various challenges: it cannot guarantee rock-solid reliability, optimal performance, high security, and easy O&M; it poses hidden cost risks to the operators; it brings vendor lock-in problems. Operators should be cautious about their move onto the public cloud until these obstacles can be overcome. After weighing the advantages and disadvantages of the public cloud, operators can then select the most suitable cloudification solution for their own development.

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AI Is Indispensable for Developing the IntelligentCore

A Cloud Native service-based architecture is introduced to the 5G core network, coupled with a large number of network functions and interfaces, which in turn adds to the complexity of the core network whilst improving both its capability and flexibility. Over the next few years and beyond, the network architecture and service capabilities will continue to push technological boundaries, which in turn will raise more requirements and pose more challenges. Huawei believes that AI must be positioned as the basic capability that makes up the IntelligentCore, in order to meet the requirements of efficient O&M and service development. AI technologies are now immensely popular and their application in the telecom field is being standardized rapidly. As such, the core network has embarked on its journey to become the IntelligentCore.

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1.1 AI Has Become a Must for the 5G Core Network

In the 5G era, Cloud Native and Full Convergence are advancing constantly, greatly increasing the scale and complexity of the cloud-based core network. This poses a great challenge to O&M. At the same time, services provided by the 5G core network are expanding from MBB to eMBB, Massive Machine-Type Communications (mMTC), and URLLC. The 5G-Advanced phase

further introduces Uplink Centric Broadband Communication (UCBC), Real-Time Broadband Communication (RTBC), and Harmonized Communication and Sensing (HCS). The Service Level Agreement (SLA) and user experience of these emerging services have become top priorities for operators.

The 5G core network has two distinguishing features. The first is the evolution of Cloud Native. Following the extensive application of Cloud Native, especially containerization, microservice, and service meshes, the core network has been decentralized to become a dynamic network.

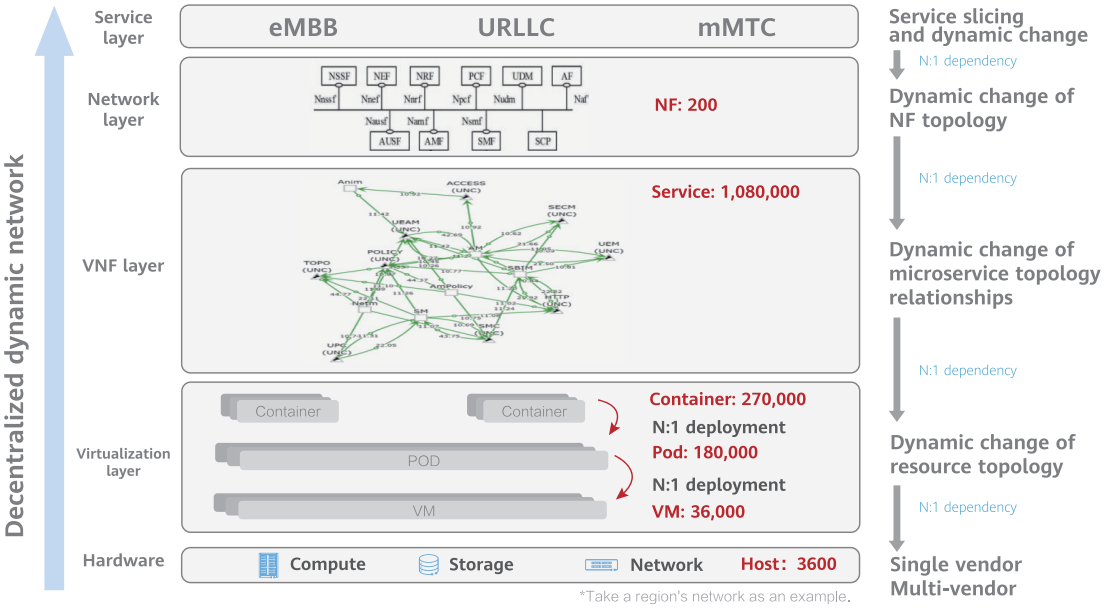

Figure 1 Evolution and challenges of Cloud Native in the core network

As shown in the above figure, tens of thousands of servers can be deployed in the hardware resource pool of a certain region. A large number of VMs, pods, and containers are deployed on these servers. Microservice-based NFs are dynamically scheduled to the resource objects to flexibly provide differentiated services like eMBB, URLLC, and mMTC on demand. As the Cloud Native architecture significantly improves the capabilities and flexibility of the 5G core network, fault locating and rectification have also become more arduous than ever.

The second distinguishing feature is the convergence of the 2G/3G/4G network and SBA-based 5G network, centralization of control planes, and distribution of forwarding planes.

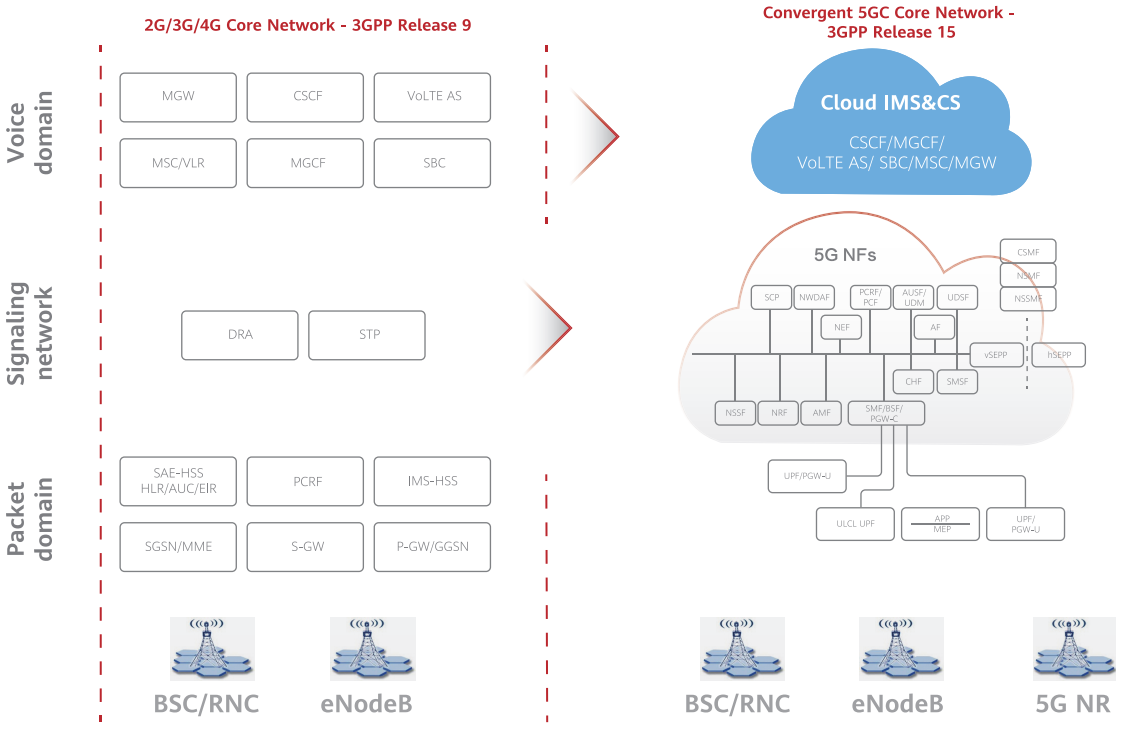

Figure 2 Evolution and challenges of Full Convergence in the core network

As shown in the above figure, if multi-generation core networks are separately deployed, the networking and O&M becomes more complex. To simplify the network topology and O&M, full convergence is required. Core network convergence poses some challenges to O&M. For example, if a convergent NF is faulty, the access of all RATs may be affected. In addition, the forwarding planes and edge computing of the 5G core network are massively deployed in close proximity to end users. This deployment also presents serious challenges to O&M.

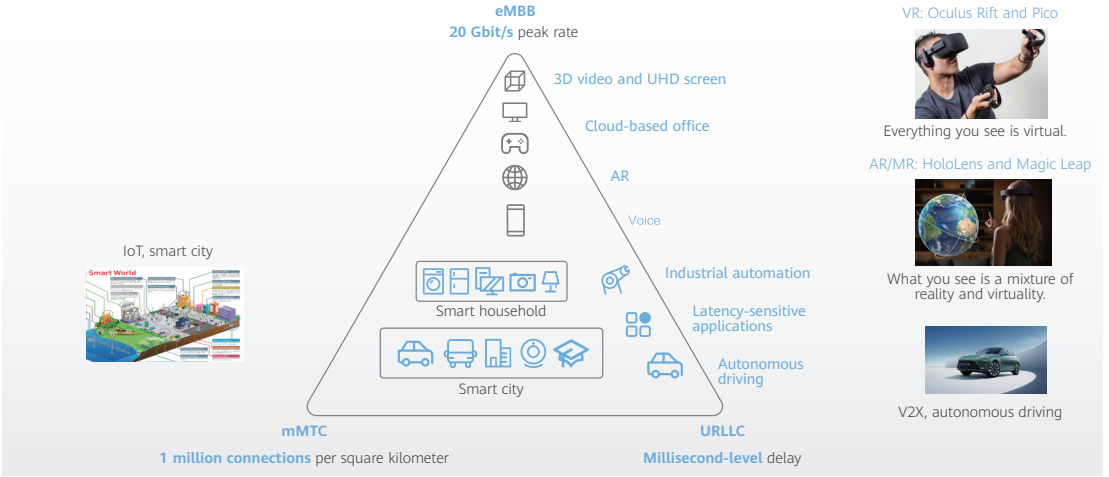

Figure 3 New services provided by the 5G core network

As shown in the above figure, the 5G core network provides a wide range of new services, which poses higher requirements on the QoS. Operators face the great challenge of meeting the SLA of these new services.

In the 5G-Advanced phase, the core network provides more services, such as UCBC, RTBC, and HCS. The 5G core network has ever-advancing architecture and service capabilities and is required to support more complex and diversified software and hardware platforms. This means more and more requirements are being raised for the 5G core network. For instance:

- The ultra-distributed architecture of the 5G core network will beget the massive deployment of edge sites close to end users. Operators must find an efficient and cost-effective way for the O&M, including deployment and scaling, of these sites.

- As Cloud Native continues to advance, it will drive more service scenarios beyond being VM- and container-based, for example SmartNIC offloading and the co-existence of heterogeneous hardware like x86 and Arm. Correspondingly, the 5G core network needs to improve its Cloud Native capabilities to flexibly adapt to more complex and diversified software and hardware platforms.

- To deliver an ultimate experience, the 5G core network is expected to be paired with cutting-edge technologies and concepts, such as XR and the metaverse. This requires the core network to be able to accurately sense services and intelligently schedule both cloud and network resources.

- While 5G is empowering more and more vertical industries, these industries are also posing stringent requirements on the 5G core network. They expect always-on services, fully secure data, rock-solid reliability, as well as visualized, manageable, and controllable O&M.

As the core network becomes increasingly complex, conventional management and O&M become more cumbersome. For example, when a fault occurs on the network, it will take several hours to manually locate it and even several days to resolve. To satisfy these requirements, intent-driven technologies such as AI must be positioned as the basic capability that makes up the IntelligentCore, which automatically learns core network rules, detects network exceptions, and optimizes network configurations.

AI technologies with foundation models are now immensely popular and their application in the telecom field is being standardized rapidly. As such, 3GPP AI-based NWDAF standards have been mature in Release 17. Gradually, technology, standards and industries are gaining their footing, and the core network has embarked on its journey to become the IntelligentCore.

AI must be intensively applied in the following high-value scenarios to facilitate certain network benefits. Some of these scenarios will be described in further detail in following sections.

- Stable network: fault diagnosis, isolation,

bypass, rectification, prevention, and prediction

- Efficient O&M: Intent-driven network provisioning, change, and configuration; intelligent sense and paging; UE mobility prediction and traffic exception analysis

- Optimized experience: SLA for XR and B2B users, intelligent UPF selection and reselection, experience assurance based on mobile VPN, and load-based intelligent slice selection

1.2 Intent-Driven Configuration and Digital Twins Enable Efficient O&M and Highly Stable Networks

The 5G core network is becoming increasingly complex as more and more cloud-based networks are deployed. Currently, many scenarios still require manual operations, reducing operational efficiency. Take an operator in China as an example. Each year, engineers need to perform over 5000 network operations, like upgrading, expanding capacity, and modifying configurations. An upgrade alone takes three months per region and involves 33 manual breakpoints. At the same time, 70% of network faults are caused by manual misoperations. Routine O&M also faces challenges, such as labor-intensive inspections, inefficient multi-department collaboration, and a lack of real-time DR plan evaluation.

The root causes for these challenges include the lack of visualization across network layers and DCs as well as the inability to acquire NF status in real-time. As such, it is imperative to roll out intent-driven configurations and core network O&M based on digital twins.

By utilizing the intelligent functions, the O&M system of the 5G core network obtains cloud-network data across layers and DCs, uses the data to build a model through machine learning, and creates a digital twin for users to visualize the network. The O&M system also restores the physical network through an 8-level network model and defines golden KPIs. It collects streaming data and can report golden KPIs in just 1 minute (4 minutes faster than before) without affecting system performance.

Besides network visualization, core network automation focuses on efficient O&M and high network stability.

High network stability is universally deployed across all network O&M scenarios including fault detection, troubleshooting, service survival, and service recovery.

If a network fault occurs, the highly stable network can use AI and a knowledge graph to automatically generate a fault propagation chain and quickly demarcate faults horizontally. It also uses intelligent algorithms obtained from the expert experience library to vertically demarcate faults. In this way, faulty NFs can be diagnosed within 5 minutes and the network can soon be restored.

For a regional DR switchover, the highly stable network provides an end-to-end intelligent tool chain to simulate and evaluate tens of millions of real-time network surges in 15 minutes, optimize the flow control parameters

in 5 minutes, and enable one-click automatic switchover. Machine attendance makes monitoring more comprehensive and accurate and ensures successful switchover on the first try. Ultimately, the network becomes both stable and controllable.

Efficient O&M is implemented during upgrade and capacity expansion. An automatic orchestration engine enables one-click automatic NF upgrades, resulting in three times more efficient upgrades. In 2021, Huawei and an operator in China completed the world's first end-to-end automatic upgrade of 5GC commercial NFs. Before the upgrade, more than 400 preparations and checks were completed automatically, reducing the number of human-machine interactions from over 100 to 10. This upgrade provides valuable technical and practical experience for global operators, laying a foundation for future cooperation in maintenance and upgrades.

1.3 AI Provides SLA Assurance for High-Value Services

5G core networks are constantly evolving, supporting more and more services. It is therefore urgent to find ways to ensure differentiated Service Level Agreement (SLA).

Service providers are most concerned with the Mean Opinion Scores (MOSs) of services. They are uniquely positioned to fully understand service characteristics and use their application processing servers to monitor and measure service MOS in real time.

If the 5G core network uses only fixed QoS parameters to guarantee services, service experience requirements and network resources may not match. As such, the 5G core network needs to collaborate with third-party service providers to ensure service SLA with the help of AI models and optimization algorithms. The following describes the assurance process.

First, the 5G core network collects historical user-plane KPI data (including throughput, delay, packet loss rate, and jitter) from the UPF along with historical service MOSs from a third-party service server.

Then, it draws on the acquired data to establish an MOS-KPI experience model by using machine learning. In addition, it obtains real-time KPI data to infer the service MOSs. In this way, the 5G core network can analyze subscriber-level service MOSs in real time and evaluate the Quality of Experience (QoE) of a slice based on its service MOS distribution.

Experience can be further optimized. For VIP subscribers whose service MOS is lower than the service SLA, the Policy Control Function (PCF) adjusts their QoS policies to ensure service experience. Similarly, for slices whose QoE is lower than the SLA, the Operations Support System (OSS) or Network Slice Management Function (NSMF) dynamically allocates slice resources.

1.4 Improving 5.5G-Oriented XR Service Pipe Efficiency Based on AI

Amidst the development of metaverse

applications and immersive, all-sensing communication, new media models like XR have become commonplace requirements. According to Deloitte Global XR industry insight, December 2021, the market size of XR is estimated to exceed 100 billion dollars by 2025. Not only this, but XR headset shipments are expected to exceed 100 million by the same time, as predicted by the Counterpoint Global XR (VR/AR) Forecast in December 2021.

Existing networks are only providing extensive pipelines, unaware of service packet forwarding rules. This significantly decreases XR forwarding efficiency. A single 5G cell can only provide high-quality access for about five XR devices concurrently. To improve service experience, E2E capacity expansion is a must. However, this greatly increases network costs and reduces XR cost-effectiveness, affecting the penetration rate of XR services.

To optimize XR experiences, the XR service layer uses a Scalable Video Coding (SVC) mechanism in which the base layer can restore complete video images with low resolution. The video can then be restored to high-resolution after data at the enhancement layer is added.

On existing networks, the basic and enhancement layers cannot be distinguished. Therefore, extensive E2E capacity expansion needs to be performed to accelerate transmission speeds at both layers. This will minimize packet loss at the base layer and avoid artifacts caused by partial image loss.

As of yet, 3GPP has not provided an adequate solution. Operators need to formulate enterprise standards that require network equipment vendors to provide a frame scheduling function and support the high-quality access of over 25 XR devices in a single 5G cell. The frame scheduling function must meet the following requirements:

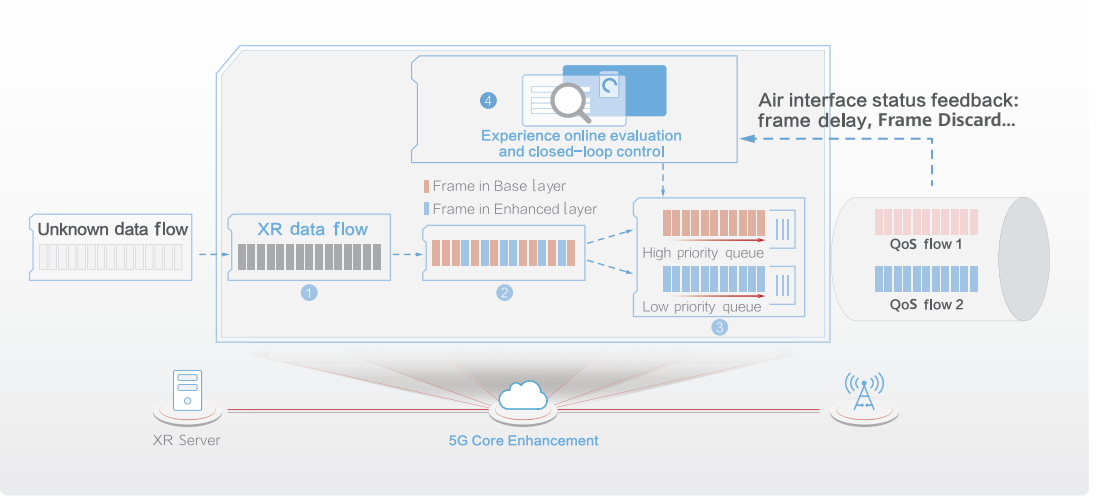

Figure 4 Improving XR service pipe efficiency based on AI

- Learns service feature changes based on AI, updates the packet identification signature database, and intelligently identifies XR data flows.
- Associates packets based on the behavior model and intelligently identifies frames at the basic and enhancement layers.
- Implements differentiated frame-level scheduling through 5QI priorities to ensure no packet loss at the base layer.
- Intelligently evaluates MOS values for XR experiences online and adjusts scheduling policies to implement intelligent, closed-loop control. This ensures that more XR devices can access the network without frame freezing or artifacts.

1.5 Overall Architecture of the IntelligentCore

The core network boasts a highly stable network, efficient O&M, and experience optimization. The IntelligentCore takes AI as the core and uses the native distributed intelligent plane to monetize this. The following figure shows the overall architecture of the IntelligentCore.

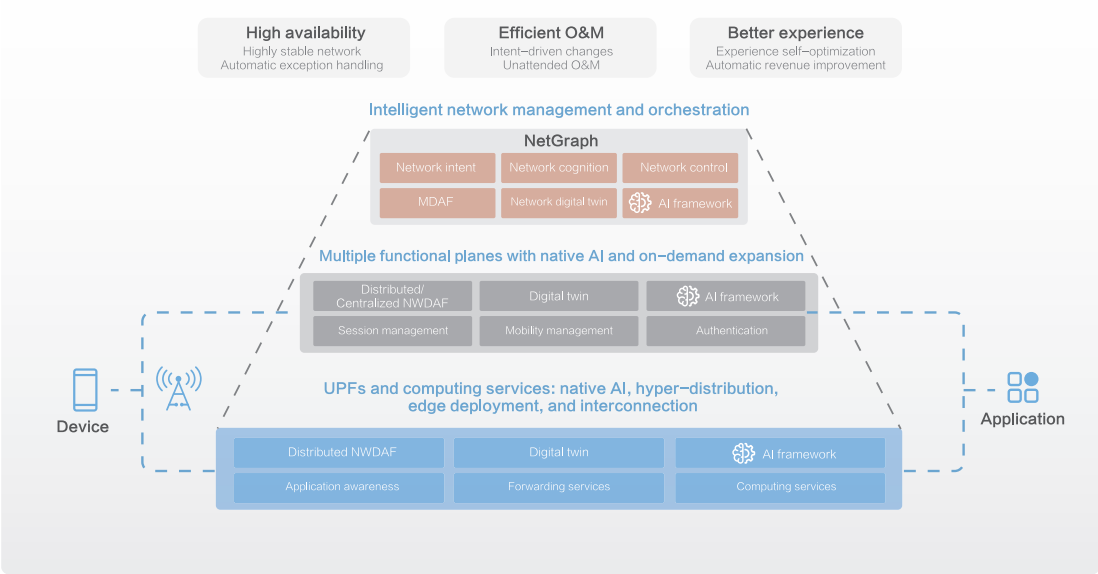

Figure 5 Overall architecture of the IntelligentCore

The architecture was designed based on 3GPP specifications for the NWDAF and Management Data Analytics Function (MDAF) while taking subsequent continuous evolution into consideration. The architecture has the following capabilities:

1. Two-level DAF: The MDAF and NWDAF form a two-level architecture, enabling on-demand scheduling between intelligent services and continuous enhancement of network stickiness.

2. Distributed NWDAF: The native NWDAF function of NFs supports centralized and distributed deployments.

3. Function decoupling and model sharing: The training and analysis/inference functions can be flexibly deployed. The native NWDAF supports the analysis/inference function. The centralized NWDAF and MDAF support both training/retraining and analysis/inference functions. Data and models can flow and be shared on demand.

4. In-depth cloud-pipe-device synergy: The device/AF provides analysis data input for the NWDAF/MDAF through the Network Exposure Function (NEF), implementing in-depth cloud-pipe-device synergy.

For EMSs and NFs in the core network domain, the IntelligentCore will introduce the digital twins and three collaborative frameworks-network intent, network cognition, and network control-to continuously improve the intelligence of the core network and finally achieve automation, self-healing, self-optimization, and autonomy.

To implement the IntelligentCore, four basic AI models need to be constructed: the knowledge, perception, performance, and control models. These together can implement the intelligent extraction of inventory knowledge on the core network, real-time convergence perception and cognition of the core network, intelligent analysis and prediction of core network performance and user experience, as well as continuous intervention on the core network based on predefined objectives. This enables the continuous optimization and autonomous running of the core network.

AI is an emerging technology and is still developing rapidly, whereas core network services have their own unique requirements. When introducing AI into the core network and making it a basic capability, we need to define basic design principles to guide the implementation. Based on the service attributes and requirements of the core network, we formulated the following five basic design principles that, we think, must be upheld:

1. The network position of the core network is very important: AI must be able to improve the security and reliability of the core network.

2. O&M has a great effect on the core network: AI analysis and decision-making must be explainable and verifiable.

3. The core network is the service experience management center: AI must be able to improve the service experience of end users and industry customers.

4. The core network is the cloud-network resource scheduling center: AI must ensure the equity of cloud-network resource allocation and significantly improve cloud-network resource utilization.

5. Sensitive user data is managed by the core network: AI must meet user data privacy protection requirements.

References

[1] ETSI, 3GPP TS 29.520

[2] ETSI, 3GPP TS 23.288

[3] ETSI, 3GPP TS 29.522

17

Autonomous Driving Network Reconstructs O&M Transformation on the Cloud Core Network

The core network functions as the "brain" for the telecom network, which is responsible for scheduling and managing network resources. The rapid development and large-scale commercial use of 5G all-cloud core network with all kinds of emerging services have complicated the core network. Surging maintenance objects and frequent change operations call for cutting-edge solutions to fulfill the network O&M requirements in this new cloud era. With technologies such as AI and big data, Huawei Autonomous Driving Network (ADN) solution implements automatic and intelligent O&M of cloud core networks in all scenarios, helping operators cope with the O&M challenges of cloud-based networks.

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Senior Marketing Expert for MAE, Huawei Cloud Core Network Product Line

With 5G Core Network Powering All Industries, Cloud-based Transformation Faces New O&M Challenges

The past ten years have witnessed comprehensive cooperation and practices among operators and vendors around the world and they have reached a consensus that the core network requires a Cloud Native-based transformation. Owing to key technologies such as the cloud-based layered architecture, microservice- and container-based architectures, and Continuous Integration Continuous Delivery (CICD), the core network becomes agile and efficient, empowering diversified communications as well as complicating the system on a large scale. Compared with 4G, 5G features high bandwidth, ultra-low latency, and immense communications and provides a new infrastructure for the digital economy, which will further bolster numerous industries that are associated with this. As the key driver, the 5G core network schedules and manages global resources and manages network topology, access data, user data as well as industry requirements.

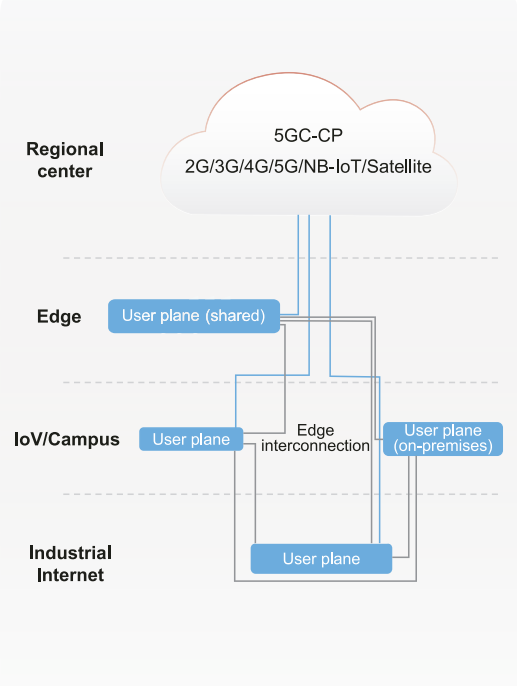

Figure 1 Ultra-distributed cloud core network

Cloud-based transformation along with 5G new services brings new challenges for operators and vendors:

Challenge 1: More Complicated Network

The microservice architecture lifts O&M complexity. Network function modules are encapsulated into different services. Each of them, independently developed and deployed, is running in an isolated process. Any service updates will not affect the running of other services, reducing the upgrade or scaling impacts, and making quick service iteration and agile release possible. However, system complexity also comes with this distributed architecture. Its features, such as the smaller granularity of routine operations, association between microservices, and horizontal fault demarcation, have made O&M much more cumbersome.

Super-distributed networking increases edge deployment costs. Compared with 4G's infrastructure, 5G will require 100- or even 1000-fold increases for MEC sites, which need to be deployed for super-distributed networking — a future-oriented network architecture. Under these conditions, operators and vendors have to tackle the difficulties on how to efficiently deploy and expand the capacity of vast MEC sites at lower costs.

Challenge 2: More Complicated O&M

E2E automation capabilities are essential for all-cloud flexible deployment. With static methods to plan hardware, devices are added phase by phase according to user growth on the traditional core network, fulfilling the sustainable service development. The up-to-date core network, based on an all-cloud flexible deployment, aims to build cloud-based resource pools and deploy the user-oriented software system in a timely, dynamic, and flexible manner. This further meets the requirement for fast, flexible, and cost-effective services, whilst at the same time requires higher-level E2E automation for O&M management.

Complex cloud-based configurations pose higher requirements on operation reliability. Immense parameter settings concerning IP routers, SDN, VNFs, and others have complicated core networking. These parameters are coupled and associated with each other. As such, to ensure that the parameters are correctly configured, multiple tech departments need to collaborate effectively. Even a tiny error in changing ports may lead to a chain reaction in the entire system, with disastrous results. Over the past few years, there has been a multitude of major network accidents caused by incorrect configurations. For example, a configuration fault arose in KDDI (a

Japanese telecommunications operator) during router replacement on the core network. It took the company 86 hours to recover and affected 30 million subscribers. Rogers in Canada and NTT in Japan have all observed similar accidents.

Challenge 3: More Complicated Services

Always online is an absolute necessity for customers. From the perspective of commercial potential, 5G's access capability featuring broader bandwidth, more connections, and lower latency, compared with 4G, has enriched opportunities for operators to dive into various industries, where 5GtoB becomes a new revenue pathway. To cope with the market demands, operators need to provide not only higher-quality basic network capabilities but also agile technology iteration, round-the-clock services, and fast recovery from network faults.

Refined and differentiated service experience forges a new path for operators. The traditional time- and traffic-based charging methods for B2C-oriented services no longer fulfill operators expected ROI. Instead, they expect optional and more refined business models, which can continuously boost revenues. In the meantime, new concepts, such as extended reality (XR), metaverse, and others, have made the headlines, with related industries entering their investment peak. However, as XR and metaverse have higher requirements on network quality due to their technical features, new charging methods for operators have materialized. According to this, the core network must be able to accurately optimize the network quality based on users, service types, and even message frames, so as to provide an ultimate user experience.

Suggestion: Automation and AI Enable O&M Transformation on the Cloud Core Network

To address the challenges posed by O&M transformation and the new requirements that are generated as a result, Huawei with its three decades of experience has taken the lead in proposing the ADN. This is a measurable and practical path for operators' evolution from their existing network to the ADN, which takes user experience, manpower reduction, and network complexity into account. Practices in key scenarios require gradual development, where single-scenario automation (such as automatic deployment, upgrade, or fault locating) needs to be evolved into all-scenario automation (covering network planning, construction, maintenance, optimization, and operations) so that the E2E autonomous network can be formed. To achieve this goal, Huawei believes that the O&M on the cloud core network needs to be transformed on the basis of three capabilities.

Network Maintenance Capability: Building Telecom Cloud Networks with High Stability Based on Cloud Native and AI to Provide Always-Online Services for Customers and Enterprises

High stability of always-online services: Based on the expert experience, knowledge graph, AI self-learning, and digital simulation, single-domain fault maintenance of the telecom cloud and core network VNFs is implemented in a closed-loop manner. VNF/module-level fault management capabilities are designed to implement subhealth prediction, precise fault demarcation, and rapid self-healing.

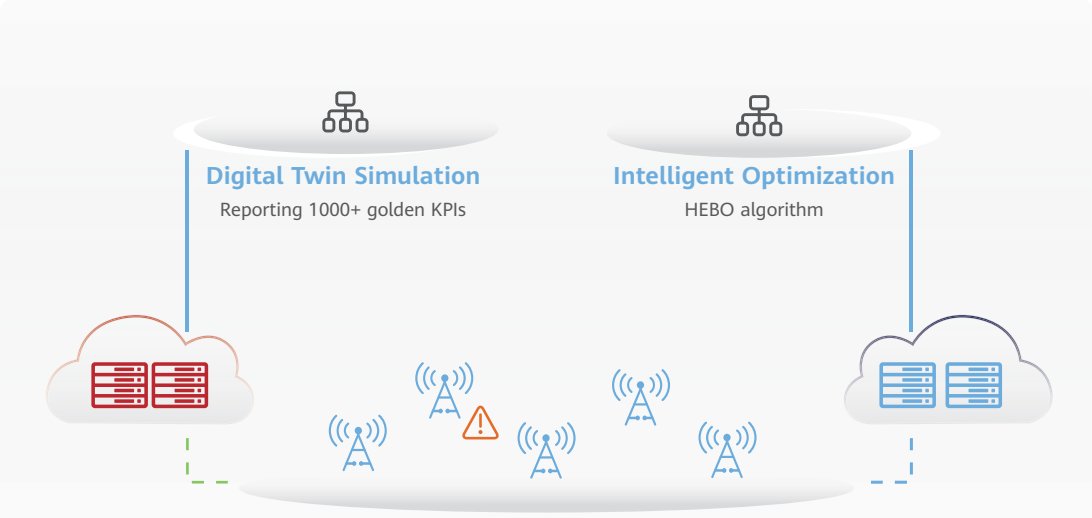

Figure 2 Precise simulation and intelligent optimization securing redundancy switchover

Operation Delivery Capability: Exponentially Reducing the Complexity of Routine Operations on Cloud-based Networks on the Basis of the Digital Twin Technology and E2E Automatic Tool Chain

E2E automation capability on network operations: Based on the digital twin technology and cloud-based CICD tool chain, an intelligent and simplified delivery capability is built for routine operation scenarios, such as upgrade, capacity expansion, cutover, and testing. Driven by user intent, the solution streamlines the delivery process, achieves automatic delivery throughout the entire procedure based on the pipeline, and ensures hitless and secure change operations.

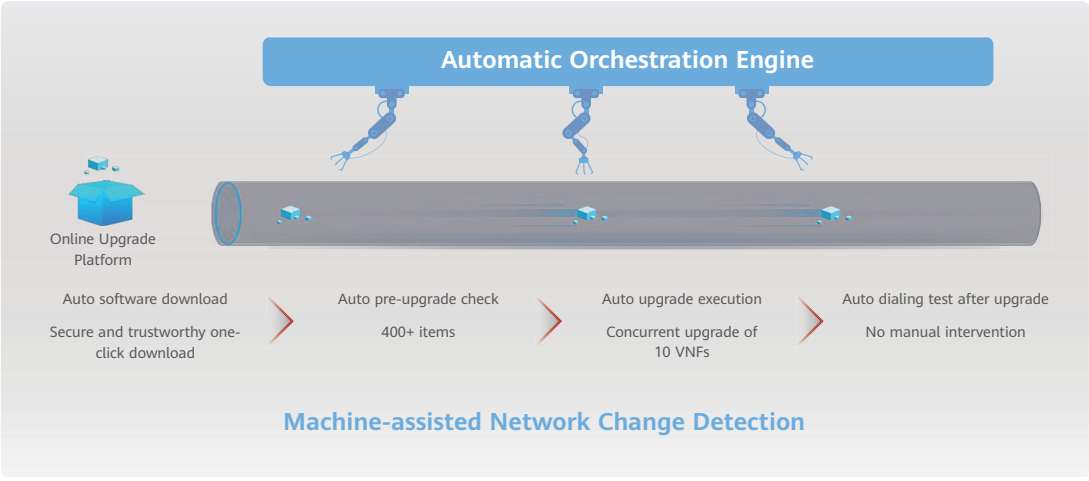

Figure 3 Full-process automatic upgrade of the ADN

Closed-Loop Capability: Providing Personalized Service Experiences with Native AI

Optimization capability for refined and personalized experiences: A transformation from managing network quality to managing personalized user experience (service standard, awareness, and closed-loop experiences) underpins the experience monetization for operators, providing enterprise-level SLA assurance for customers from different industries.

Huawei Core Network ADN Solution Starts a New Era for O&M on a Cloud-based Network

As a world-leading provider for 5G commercial solutions, Huawei has released a series of intelligent network O&M products and solutions in ADN. Adhering to the concept of "highly stable network, intelligent and simplified O&M, and optimal user experience", Huawei, relying on its leading technical advantages in the 5G core network and in-depth understanding of O&M services, has integrated technologies like AI, big data, automation, and others into the communications field and launched the ADN solution for the core network.

This solution incorporates a batch of products and professional service tools in the core network management domain, and streamlines data assets, making network-wide data visualized, manageable, and traceable. It pairs intelligent technologies such as data native, intelligent analysis, model training, AI inference, and intent insight, with workflows that can be orchestrated, presenting an E2E autonomous core network and helping operators build the ADN.

To cope with cloud-based O&M transformation and demands posed by 5G new services, the Huawei ADN solution focuses on building the following capabilities:

Highly stable network

- Health check: The solution evaluates network reliability, ensures that key resources are always available, and handles emergency faults with ease.
- Routine drills: The entire process is visualized and the redundancy drill efficiency is high.
- Diagnosis from experts: Rapid fault detection and accurate demarcation and locating are provided. Faults can be demarcated to the minimum operational unit to quickly recover services.
- Health prevention: From passively handling faults to proactively preventing faults, the health management ensures that subhealth issues can be prevented without intervention.

Intelligent and simplified O&M

- Automation: The E2E tool chain streamlines the manual operations and reduces manual intervention, lifting the delivery efficiency in all scenarios, including upgrade, capacity expansion, and cutover.
- Hitless operation changes: With simulation capability, low-cost trial-and-error of operations such as dynamic elastic scaling is implemented, achieving

hitless operation changes.

Optimal user experience

- Optimized experience: To optimize user experience on key services, such as VoNR and ViNR, the tool chain is optimized along with the use of native AI to ensure connectable calls, quick call setup, clear voice, low churn rate, and stable sessions without a call drop.

Huawei core network ADN solution focuses on building these three key capabilities on the basis of intelligence and automation to secure network and improve O&M efficiency throughout the lifecycle covering network planning, construction, maintenance, optimization, and operations, bringing about new experience opportunities for business. In the future, Huawei will create intent-driven and digital twin capabilities, so that the core network can add policies based on operators' needs and dynamically and flexibly adjust them. In addition, network issues (such as network faults, SLA exceptions, and performance deterioration) can be detected in real time. Its policy-driven closed-loop control helps achieve network autonomy.

Success Story: Huawei ADN Solution Plays a Key Role in Helping Zhejiang Mobile Hit a World First in Rectifying NFV Cross-layer Faults

Whilst expanding service boundaries and facilitating the digital transformation of various industries, 5G also brings new challenges to the holistic process of network planning, construction, maintenance, optimization, and operation. Operators urgently require the construction of a brand-new network operation support system to ensure efficient network O&M and service support. To meet the increasing network O&M requirements, Zhejiang Mobile, as a pilot site, cooperated with Huawei to develop the 5GC fault O&M capability. They built a fault handling center that secures fast discovery, accurate demarcation, and quick response, ensuring an optimal network access experience for hundreds of millions of users.

The traditional fault demarcation that relies on expert experiences and manual checks can no longer fulfill today's O&M requirements in NFV scenarios. Cross-layer fault demarcation on the core network has become one of the most intractable conundrums in the telecommunications field and one of the most urgent tasks for the fault handling center to resolve.

Zhejiang Mobile partnered with Huawei to build efficient NFV cross-layer demarcation capabilities. These capabilities, which rely on Huawei ADN solution, combine expertise and AI to enhance the most rapid possible awareness on network faults, as well as accurately match and intelligently diagnose faults, helping operators secure automatic, intelligent, fast, and precise O&M.

Fast fault awareness depends on the process that starts from monitoring all metrics in real time and filtering data like alarms, logs, KPIs, and traffic for aggregation and association analysis, to finally obtaining the root cause of the fault according to the expertise library. In addition, this solution helps O&M engineers detect network subhealth risks in a timely manner and secure sufficient maintenance

windows for troubleshooting before the metrics deteriorate. For the first time, O&M for Zhejiang Mobile is transformed from traditional passive O&M to proactive prevention.

The solution provides the first visualized 8-layer topology object model in the industry. It integrates resource data such as modules/resource units (RUs), containers, VMs, hosts, and transport networks, and performs topology analysis and fault information association for more than 80 objects, ensuring all-around network analysis. In addition, the solution sorted out nine types of typical faults in NFV cross-layer demarcation to intelligently and accurately match a fault.

This joint innovation project uses online expertise to form a fault tree, implementing self-check, self-deduction, and self-diagnosis. The core capability for diagnosing over 1000 NFV cross-layer faults is formed based on the comprehensive analysis of alarms, configurations, KPIs, and logs as well as the NFV cross-layer fault handling experiences on the live network of Zhejiang Mobile in the past two years plus Huawei's NFV O&M experiences over the past five years. Through cooperation with Huawei, Zhejiang Mobile has become the world first in the global telecom field to rectify NFV cross-layer faults. Faults on the live network can be identified within 5 minutes and NFV cross-layer faults can be accurately demarcated within 15 minutes.

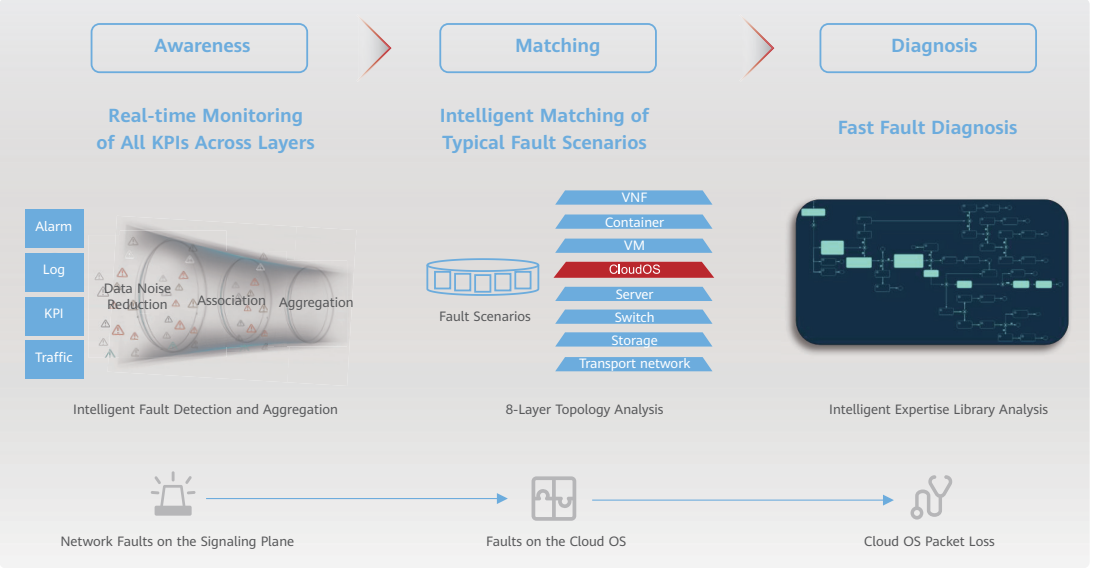

Figure 4 Efficient NFV cross-layer fault demarcation

Huawei and global operators jointly carry out a series of O&M innovation projects, marking a milestone in the digital transformation of building a brand-new O&M system. These projects help customers achieve efficient and accurate O&M, as well as quickly rectify network faults, providing innovative experiences and achievements for global operators' cloud-based O&M. Huawei would like to join hands with global operators to move towards an intelligent future core network.

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Thoughts on and Practices of Zhejiang Mobile's O&M Transformation Towards Regional Cloud-based Core Networks

The booming digital economy has brought China Mobile a sea of opportunity and accelerated its digital transformation. Following China Mobile's plan for constructing autonomous networks and the philosophy of "venturing and pioneering, leading the way", Zhejiang Mobile proactively carried out a systemic reform not only of its internal O&M process and personnel management but also its O&M methods through the cooperation with Huawei. As such, it has made significant progress and a great headway into its digital-intelligent transformation. Zhejiang Mobile will continue to increase investment and strive to achieve its strategic goal of L4 autonomous networks in 2024.

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1. Construction of the Cloud-based Core Network and O&M Challenges Faced by Zhejiang Mobile

Complying with China's 14th Five-Year Plan, China Mobile has formulated the goal of 100% cloudification of core networks by 2025. Zhejiang Mobile, the pacesetter in the company, has migrated core network services to the cloud. Its cloud-based service volume ranks highest in China. Cloudified core networks, however, entails more complex network architecture and a dramatic increase in managed objects. The question remains: how do we effectively realize cross-layer cross-DC network visualization, real-time NE status acquisition, real-time fault detection and precise demarcation, and fast service keepalive? These issues cannot be addressed by simply adding manpower or relying on expert experience. The O&M of the regional cloud-based core networks is facing a potentially backbreaking burden.

During the trial and explorations of regional cloud-based core networks, the following problems are emerging:

- **The O&M process does not match the new organizational structure.** Traditionally, a core network was constructed and maintained by a province. Now, it is constructed by a region, with its routine O&M, cutover, and Disaster Recovery (DR) collaboratively completed by the headquarters, region, and related provinces. In this case, traditional guide-based and cooperation-dependent processes are no longer applicable.

- **O&M personnel are still adjusting to the new network O&M.** As more regional cloud-based core networks are constructed, O&M personnel are facing higher requirements than ever before. A good training system is urgently needed to help O&M personnel rise to the challenge.

- **O&M methods cannot keep up with network evolution.** Current O&M methods are still oriented towards the early stages of digitalization and automation and are inadequate for already cloudified and intelligent networks. Massive alarms, performance data, and logs on cloud-based networks exponentially lift the complexity of fault locating and demarcation. Consequently, it takes a long time to troubleshoot, and the investment remains high.

2. Thoughts on and Practices of Zhejiang Mobile's Digital-Intelligent Transformation for Core Network O&M

Mr. Yang Jie, Chairman of China Mobile, has repeatedly emphasized the need to push forward with cloud-based and intelligent network transformation and to accelerate evolution to the L4 autonomous driving networks. During the 2021 China Mobile annual group meeting, he expressed the goals for the network cloud, which included strengthening O&M management, improving network experience to a higher level, and accelerating network diagnosis and fault self-healing. **Zhejiang Mobile proactively answers the group's call and dares to take the lead. It optimized the O&M system based on the O&M characteristics of regional cloud-based core networks, and it worked with Huawei to explore effective O&M methods for autonomous networks. The preliminary results are already starting to show.**

2.1 O&M Process: From Independent Single-Province O&M to Multi-level Collaboration

Due to the continuous evolving nature of the network architecture, routine O&M, troubleshooting, and DR cannot be completed within a single department, however, the work requires collaboration between the group, provinces that access services, regional provinces, and cities. In addition, the complex cloud-based network architecture makes it more difficult to ensure service SLA. To meet the cross-level and cross-layer O&M requirements, Zhejiang Mobile optimized responsibility divisions of services, cloud, and cities, reshaped the troubleshooting and service collaboration processes, and defined a cross-layer SLA metric system. As such, routine

O&M is fully coherent and exceptions are handled collaboratively and quickly, paving the way for continuous development.

2.2 O&M Personnel: From Traditional O&M Personnel to Digital Intelligent Talent

To adapt for intelligent O&M, Zhejiang Mobile launched the "three domains and six types of engineers" talent development plan made for the transformation to Site Reliability Engineers (SREs) and other. For example, traditional monitoring and maintenance personnel have been trained into O&M designers, who tailor O&M scenarios and processes and specify required O&M capabilities. Many have also been sculpted into orchestration engineers, who put together O&M processes and standardize digital O&M experience. As such, O&M becomes agile and proactive. Zhejiang Mobile is building an intelligent team capable of both R&D and O&M by refining the responsibilities and roles of O&M personnel, constructing a 5G innovation training base, and promoting the "excellent teachers leading the way" training model.

2.3 O&M Methods: From Computer-assisted Manual Operations to Expert-assisted Automated Operations

In terms of O&M methods, Zhejiang Mobile and Huawei have conducted research together on autonomous cloud-based core networks and have built an intelligent end-to-end fault defense system involving fault prevention, awareness, demarcation, and recovery. Expert experience in conjunction with AI boosts full-process troubleshooting capabilities including proactive prevention and prediction, quick network fault detection, accurate fault demarcation, and hitless fault recovery. This brings operators an automatic, intelligent, fast, and accurate core network O&M experience as well as reduces the Mean Time to Repair (MTTR) and prolongs the Mean Time Between Failures (MTBF). The two parties analyzed O&M pain points, determined areas to innovate, and incubated new digital O&M capabilities. With continuous optimization and iteration, they have achieved fruitful results.

- **In terms of risk prevention and fault awareness, the O&M system has changed from passive fault handling to proactive risk prevention.** Traditional static threshold detection applies only to stable metrics. An intelligent KPI anomaly detection solution has now been introduced to learn and train from a large amount of historical data based on multiple machine learning algorithms, such as BoxPlot, RRCF, and LOF. As such, the system can infer the dynamic threshold range of many types of metrics, including those that are periodically or continuously fluctuate. It can also detect 100,000 metrics and over 1000 golden metrics at the same time with an accuracy of 85%. On top of that, the system can automatically reduce noise for, associate, and aggregate KPIs, alarms, logs, and MML commands to form various "incidents". In this way, fault information can be quickly and accurately reported, and preliminary fault

diagnosis can be completed swiftly.

- **In terms of fault diagnosis, manual analysis is replaced with automatic diagnosis, reducing the fault demarcation duration and improving accuracy.** Conventionally, once a fault occurs, multiple departments need to work together to locate the fault, resulting in poor efficiency. In addition, manual troubleshooting and DR are slow, and services are therefore interrupted for a long time. To address this problem, Zhejiang Mobile introduced an intelligent fault diagnosis solution which analyzes fault symptoms based on online expert experience, knowledge graphs, time, and space topology. Through this information, the solution can find the diagnosis rule and process that is best for the specific type of fault detected. If a fault matches a predefined fault type, the system automatically analyzes and demarcates it based on the inferred diagnosis rule and process. Both horizontal and vertical fault scenarios can be covered. Nine categories and over 500 diagnosis rules for NFV fault demarcation have been sorted out and integrated into the workflow. This means that the system can automatically diagnose faults and deduce fault causes based on the collected NE and NFVI component data. The workflow derivation process is visualized and can be backtracked. Precise demarcation for NFV cross-layer faults, IMS/5GC network faults, and process errors is completed within ten minutes, which has been fully tested.

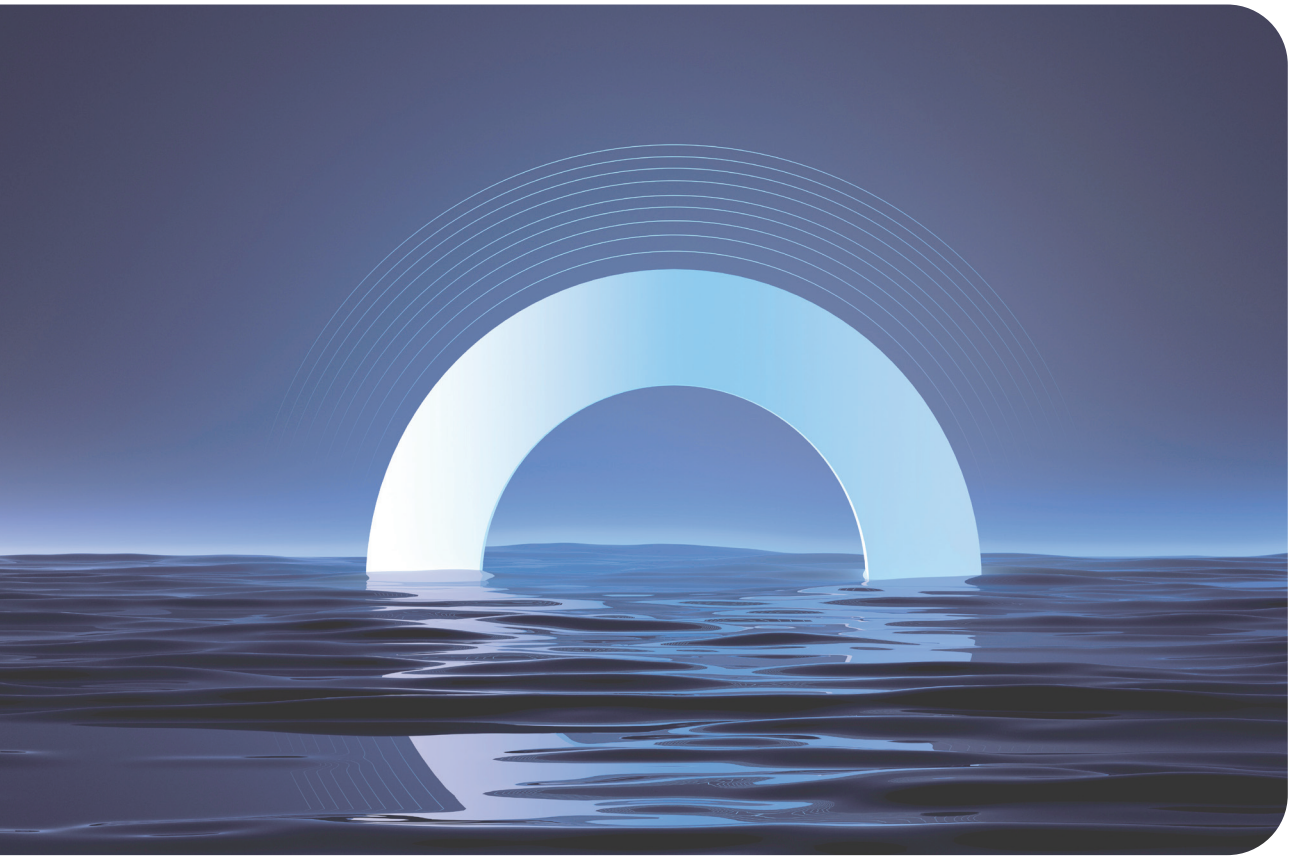
- **In terms of fault recovery, Zhejiang Mobile ensures a 100% DR switchover success rate with intelligent DR assurance instead of blind switchovers.** Zhejiang Mobile and Huawei jointly conducted two DR switchover drills for millions of subscribers. Conventional DR switchover evaluation depends on manual operations, which is time-consuming and labor-intensive. Once a fault occurs, only basic checks like alarm checks can be performed due to the tight timeframe. Risks are unknown and service impact is uncontrollable. In addition, the switchover process is invisible, traditional monitoring data such as traffic statistics is required, and key service metrics, such as the number of subscribers and sessions, cannot be obtained in a timely manner, which may cause secondary disasters such as surges. Zhejiang Mobile and Huawei proposed an intelligent DR assistance solution, which can automatically identify events, evaluate simulation results, and help operators visualize a disaster recovery process. By using the HEBO algorithm before a switchover, the system can precisely simulate a DR signaling model, predict post-switchover traffic surge based on the redundancy NE's capabilities and the flow control parameters, and evaluate the impact on users to aid the switchover decision. Moreover, a large screen is provided where O&M personnel can view DR topology relationships and routing policies online and monitor the defined golden KPIs.

The whole DR process is taken under control.

3. China Mobile Accelerates to L4 Autonomous Driving Core Networks

The booming digital economy has brought China Mobile a sea of opportunity and accelerated its digital transformation. China Mobile has taken the lead by proposing "L4 autonomy of intelligent networks by 2025". The goal is to build full-lifecycle automation and intelligence to achieve "zero wait, zero fault, and zero contact" as well as "self-configuration, self-healing, and self-optimization".

Zhejiang Mobile ranks No. 1 among the group branches for an intelligent network. It will continue to venture, pioneer, and cooperate with Huawei comprehensively to accelerate intelligent core networks. Zhejiang Mobile also looks forward to strengthening its cooperation with industry organizations and endeavors to contribute to the formulation of standards, inject new vigor into intelligent networks, and fast-track the realization of L4 autonomous driving networks by 2024. Though the road ahead may be arduous, all the hard work and perseverance will pave the way for some fantastic accomplishments and a bright future.



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