HUAWEI

Striding Towards
the Intelligent World
White Paper

Cloud Core Network

Creating Better Business Value with Full Service Enabling

Building a Fully Connected, Intelligent World

Preface

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 paper outlines the development trend of core networks towards an intelligent world and systematically expounds the core network evolution approach. We hope this paper 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.

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Abstract

1 Trend 1: On-demand MEC,as a must for vertical industries,has entered a positive business cycle.

Compared with previous cellular network generations, 5G can better underpin distributed deployment and flexible service routing with an advanced network architecture and protocol-defined capabilities. It helps set up the shortest and most favourable paths from various devices to private networks, so as to deliver high-bandwidth and low-latency services (such as HD videos and AR/VR) to individual users, and also allows enterprises to build their own local networks. Coupled with MEC, 5G's potential can be further unleashed. The combination of MEC and 5G allows:

- On-demand edge deployment
  Thanks to the Control and User Plane Separation (CUPS) feature introduced in 5G, a network can be deployed in a distributed fashion, with the user plane nodes placed in close proximity to end users. These user plane nodes, coordinated with local compute resources, enable MEC to be deployed flexibly on demand. This allows operators to stretch their 5G networks to the edge, ensuring that service content and its required processing capabilities stay as close as possible to end users. Combined with service content resources, such as distributed Content Delivery Network (CDN), the edge nodes will constitute a distributed MEC network, providing large-bandwidth and low-latency services to users. This helps operators better capitalize on their networks.

- On-demand traffic steering
  With enhanced capabilities, as stipulated by protocols, 5G allows mobile devices to access both the Internet and local MEC services. The network can route service traffic to different targets — it directs generic Internet web access requests to central network nodes, while passing the enterprise data to the local MEC nodes. Enterprise services can be restricted to within campuses, yielding low latency and solid security. With flexible traffic steering, MEC-based private networks can fit into various industries, promoting organic growth of the MEC market.

2 Trend 2: MEC networks will become diversified and fully meshed.

On top of on-demand deployment and flexible traffic steering, MEC needs to be further enhanced to fuel the digital transformation of diversified industries. It needs to adapt to the ever-changing service scenarios with different deployment forms and enhanced connectivity. It also needs to facilitate wide-area roaming with full mesh networking, and allow application

integration above the carrier-class telecom cloud at the network edge. With connectivity synergized with compute, MEC will add new momentum to the development of telecom networks and vertical sectors.

- Industry-oriented multi-mode deployment

  As MEC further penetrates a greater number of industries, its capabilities need to be comprehensively strengthened to fulfill the varied service requirements from different sectors. For example, the User Plane Functions (UPFs) need to be enhanced for stronger connectivity to support new network access protocols, and to provide higher reliability to support auxiliary production and smart manufacturing. Another typical example is the integration of the IMS with the MEC system. Such integration can enable trunk resources to be appropriately scheduled for voice services in smart coal mines.

- Full-mesh networking for seamless access

  Disjointed MEC systems are expected to be fully interconnected in the future. With a wider MEC coverage, users can seamlessly access a campus even when they move out of it. Full-mesh MEC will be a key capability for digital upgrades of public services and campuses.

- Compute-network synergy for integrated deployment

  The telecom cloud platform will be built as a highly reliable network foundation featuring compute-network synergy and real-time resource scheduling, on which key applications of enterprise private networks can be efficiently integrated. This will simplify the deployment of enterprise private networks as well as help coordinate network resources with compute capabilities.

3 Trend 3: VoLTE is inevitable on the path to 5G.

As defined by 3GPP, 5G devices cannot recede onto a CS network to complete calls for 5G users. Therefore, VoLTE, which can ensure a consistent calling experience across 2G to 5G networks, has transitioned from an optional solution to a must-have for operators.

Since its birth ten years ago, VoLTE has delivered a host of benefits to the telecom industry. It significantly improved the calling experience, facilitated the smooth shutdown of 2G and 3G networks, and helped operators improve their brand awareness. It also laid a solid foundation for the construction of 5G networks. Currently over 95% of 5G operators worldwide have deployed VoLTE. In the first half of 2022, the number of global VoLTE users has increased around 30%, compared with the year earlier. Unquestionably, VoLTE has grown into the basic voice network. Leveraging VoLTE infrastructures, leading operators have become devoted to developing voice and video services to enhance their user loyalty. Furthermore, they are proactively collaborating with industry partners to unlock new applications for the emerging service scenarios. Together, they hope to utilize VoLTE to improve network efficiency, reduce costs, and expand the voice market space.

4 **Trend 4: New calling will redefine future-oriented voice services.**

VoLTE and VoNR will continue maturing under the concept of New Calling, to provide more enjoyable and immersive services, beyond voice and video services, to individuals and industries alike. To achieve this, Data Channels for empowering data-based interactions will be laid upon the existing IMS voice and video channels. The three types of channels will take user experience to new heights.

The innovative services that have emerged with New Calling will enrich the overall communication experience, along with creating social value and solving the pain points that plague users and industries alike. For instance, interactive video services can bring convenience to the elderly and disabled by intuitively showing the information they need, and remote collaboration services can simplify public and social services, such as insurance claims settlement.

5 **Trend 5: 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.**

Heightened 5G and mobile video services have boosted mobile data services, expediting the convergence of operators' video services with OTT applications. Users can enjoy video services not only on TV-based fixed large screens, but also on their mobile phones, tablets, and laptops, anytime and anywhere.

In addition to seamless access, 5G also features Ultra-Reliable Low-Latency Communication (URLLC) and Enhanced Mobile Broadband (eMBB), which guarantees the transmission of Ultra-HD (UHD) and high-bit-rate videos, and delivers crystal clear videos across different screens with OTT applications. It comes as no surprise that 5G features have rejuvenated operators' video business.

6 Trend 6: Spatial and social-interactive videos will become central to operators' video services.

5.5G and 6G will make ultra-high bandwidth possible over the air interface, removing the barrier for transferring spatial videos with ultra-high bit rates. Meanwhile, media technologies, from video stitching to modeling and rendering, continue to move forward, accelerating the technical readiness for developing spatial videos. In addition, as smartphones become more prevalent and feature phones are gradually phased-out, a greater volume of users will enjoy spatial videos on OTT-oriented multiple screens.

At the same time, operators are continuously improving their network capabilities to realize ubiquitous communications, which makes phone-based video calls available with TV-based large screens. The convergence of B2C and B2H pushes operators to combine their video platforms with video calling services. This enables home video services to be overlaid with calling and social-interactive services, delivering a richer experience to users, while at the same time improving service loyalty and stimulating B2H service innovation.

7 Trend 7: Telecom cloud is the optimal approach to develop telecom services, and will continue to fulfill operators' diversifying requirements.

After a decade of development, the telecom cloud has seen the steady growth and expansion of industry best practices, in line with operators' organizational capabilities, network architectures, and personnel skills. In the 4G era, Network Functions Virtualization (NFV) based decoupling of hardware and software on telecom networks has enabled the software to run on VMs. Currently, these NFV-driven networks are operating reliably. This is inseparable from a telecom cloud which provides rock-solid reliability and high performance, and also aligns with operators' organizations and processes by means of centralized deployment and intensive management.

In recent years, some operators have attempted to pilot their networks on hyperscale infrastructures, akin to a public cloud, but till now there are no viable cases. As such, operators need to remain cautious when deciding on whether to move their networks onto the public cloud. If they turn to the public cloud, they need to lease rather than build network infrastructures themselves, since the public cloud adopts an asset-light model. Furthermore, they also need to strengthen the supervision on network reliability and data security. It is worth noting that while the nature of the public cloud offers an open and flexible management style, it also poses high requirements on personnel skills. Though open to tenants, the public cloud is operating on siloed infrastructures. It is difficult to tell whether the public cloud can suit operators' needs for flexible decoupling of services from their underlying infrastructures.

To cater to operators' diversifying service requirements, the telecom cloud architecture needs to be more convergent and simplified, carry heterogeneous compute capabilities, and foster an open ecosystem. In addition, the telecom cloud needs to be strengthened to facilitate automatic deployment, to tackle the complex O&M brought on by thousands of edge sites. Thanks to the intent-driven configuration, the deployment efficiency can be enhanced by ten-fold. The telecom cloud will also be improved to proactively prevent issues by utilizing technologies such as AI and digital twins, yielding a ten-fold increase in the fault demarcation and locating efficiency.

8 Trend 8: AI is indispensable for developing an IntelligentCore.

5G has reshaped the core network with an all-new architecture — the Service-Based Architecture (SBA) — which added at least 33 network functions and 75 interfaces. 5G has also seen extensive application of Cloud Native in the core network, especially hierarchical decoupling, containerization, microservice, and service meshes. As the capabilities and flexibility of the 5G core network are significantly improved, the network has also become more complex than ever. As such, fault handling on the 5G core network is rather arduous and time-consuming.

At the same time, the ever-advancing network architecture and service capabilities will raise more and more requirements for the 5G core network. For instance:

- The ultra-distributed architecture of the 5G core network will give birth to numerous edge sites. 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 VM- and container-based ones, such as Smart Network Interface Card (SmartNIC) offloading and co-existence of heterogeneous hardware, like x86 and Arm. Correspondingly, the 5G core network needs to improve its Cloud Native capabilities, so as 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 Extended Reality (XR) and the metaverse. This requires the core network to be able to accurately sense services and intelligently schedule both the cloud and network resources.

- While 5G is empowering more and more vertical industries, the industries are also posing higher 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.

  To satisfy these requirements, AI must be positioned as a basic capability that constructs an IntelligentCore. Since AI technologies featuring foundation models are now in full swing, and their application in the telecom field is being standardized rapidly, 3GPP AI based network automation standards have been mature in Release 17. Gradually the technological shackles are being removed, thus fast-tracking the core network's move towards the IntelligentCore.

Overview

1.1 5G Enters a Virtuous Business Cycle

The rapid ascent of 5G networks has already added substantial value to industries with wide ranging applications and further room for further growth. 5G has entered a virtuous business cycle.

In the consumer market, 5G technologies significantly improve user experience and alter user habits. Since the commercial use of 5G, the proportion of HD video traffic on mobile terminals has climbed by 20%, and the duration of watching short videos has grown by 1.5 times. Such changes increase the Dataflow of Usage (DOU) of end users by 30%, accelerating the rollout of 5G service packages. By June 2022, the number of 5G package users in China reached 869 million. The popularity of 5G also drives the growth of VoLTE users. According to GSMA, the number of VoLTE users increased by 27% in the first half of 2022, which is remarkably higher than that in the 4G period.

In the industrial market, 5G brings innovative private network models, opening up new business space for the industry. According to Communications Weekly, by the second quarter of 2022, 5325 5G industry private networks had been built. So far, it has achieved large-scale deployment in the manufacturing, mining, melting, electric power, and healthcare industries. Such networks have brought significant value to application scenarios like video backhaul, AGV management and control, AI-based quality inspection, and data collection. 5G's gravity-defying momentum is playing a pivotal role in supporting the digital transformation of industries.

1.2 New Scenarios and Services Impose Higher Requirements on Networks

Due to the evolutionary nature of 5G, with constantly new scenarios, content and applications, these impose tougher requirements on 5G networks. XR services are exploding with the emergence of metaverse applications. Statistics show that the growth rate of XR devices in recent years exceeds 60%, and by 2025, the number of VR headsets will exceed 100 million, and the number of AR glasses will reach 50 million. High-quality, large-scale XR services require networks to support layered encoding and scheduling of streaming media, as well as multi-stream collaborative transmission, closed-loop experience optimization, and real-time rendering and interaction.

According to Huawei's Intelligent World 2030 report, by 2030, the number of 5G industry virtual private networks will reach one million. Furthermore, a greater number of industry scenarios place higher requirements on 5G networks. As 5G industry private networks now extend to industrial production sites, in this aspect, networks must support industrial protocols and provide edge computing and ultra-reliable connections with ultra-low latency. In addition, networks also need to support full WAN connectivity and intelligent route selection for the access to industrial private networks anytime and anywhere.

To meet the requirements of diverse scenarios, 5G networks need to be continuously evolving and enhanced.

1.3 Continuous Evolution of the Core Network Towards 5.5G

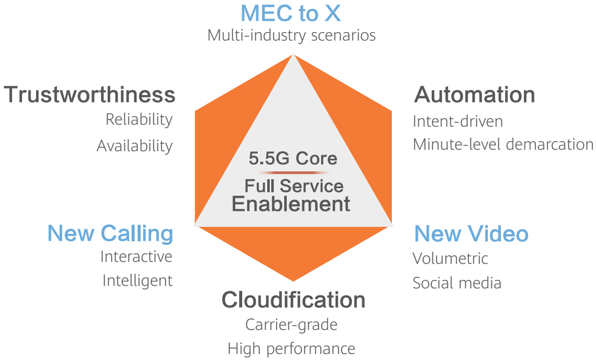
To meet the diverse requirements of 5G network capabilities for new services and scenarios, 3GPP officially established the 5G-Advanced project for the evolution of 5G on April 27, 2021. Since then, this network evolution has attracted substantial attention from operators, equipment, terminal and chip vendors, vertical industry players, and industry organizations. These parties have initiated about 50 projects on 5G-Advanced, 28 of which have been included in Release 18 by 3GPP in December, 2021, with key features defined for several important services.

- XR service: 3GPP defines media characteristic awareness, media transmission enhancement, and multi-stream transmission coordination. This in turn provides high bandwidth and low latency, and also prevents low capacity due to frame bursts, thereby improving XR service experience.
- Real-time audio and video communication: 3GPP-compliant Next Generation Real Time Communication (NG-RTC) defines the separation of the media plane from the control plane for the Data Channel as well as the objective of building a service-based media plane. The NG-RTC is dedicated to building an application platform based on operators' voice services, and reshaping the dial pad based on the basic voice experience.
- Industry private networks: 3GPP enhances the MEC function, with features such as roaming access and cross-domain Uplink Classifier (UL CL) added to support MEC in wide area networks. The URLLC capability is also enhanced to achieve high reliability and low latency for production intranets. In addition, other application-enabled features, such as positioning, are enhanced to meet the requirements for ubiquitous 5G industry private networks.
- Network automation: 3GPP enhances the data collection and analysis capabilities of the Network Data Analytics Function (NWDAF). More specifically, the NWDAF can now integrate multi-dimensional data through federated learning. Furthermore, it provides refined experience management by means of more fine-grained QoS analysis and prediction, and fulfills closed-loop

experience optimization based on the feedback from peers.

At the same time, ETSI proactively promotes the evolution of virtualization technologies. It has released the container-capable NFV architecture, and defines MANO-based container management specifications to support unified management of VMs and containers.

Based on the above enhancements in 3GPP and ETSI standards, Huawei proposed the concept of 5.5G Core and is fully committed to working with industry partners to promote the development and maturity of the industry ecosystem and technologies, paving the way for the core network's transition to 5.5G.



Key Capabilities of 5.5G Core

In light of the continuous evolution of the network, we believe that there are several key trends associated with the core network. Later on, we will present them and provide action plans accordingly.

01

On-Demand MEC, as a Must for Vertical Industries, Has Entered a Positive Business Cycle

2.1 Overview

In an era of automation and low-carbon emissions, multiple industries have decided to actively include 5G private networks as a part of their future-proof corporate technology strategies. A private network is integrated with the customers' enterprise applications, and a new digital infrastructure is built. This ensures added value on the balance sheet.

MEC-powered industry-specific 5G private networks act as a dedicated network service and can be deployed on demand for various business scenarios and connectivity requirements. It aims to satisfy industry customers' customized requirements for optimal service experience and a shortest transmission path. This will ultimately lead to a better production environment, and fuel the digital transformation of diversified industries.

2.2 On-Demand MEC Deployment at Network Edge

2.2.1 Scenarios

Industrial digital transformation requires applications to be designed to respond to large throughput, high bandwidth, low latency, and ultimate user experience. This continuously promotes network architecture evolution towards lower latency, higher bandwidth, and higher security. For instance, Augmented Reality (AR)/ Virtual Reality (VR)/Mixed Reality (MR) services require the latency to drop from 50 ms to 10-20 ms, in order to provide users with ultimate immersive and high-fidelity experience; HD video backhaul requires 1000 Mbit/s or larger bandwidth to carry more than 60 channels of 4K HD videos. Long-distance transmission results in large latency and high costs. Confidential data passing through a network needs to be forwarded in a more secure way, to meet the high standards for healthcare and industrial digitalization. For example, to protect enterprise data privacy, data needs to be processed and managed locally without making a detour to the public network. Any data transmission out of the enterprise network should be under strict control and requires prior approval.

In 4G, the control and user planes of a gateway are coupled and deployed at the edge, which poses security, charging, and O&M difficulties. Mostly notably, their application is limited. The majority of 4G private networks are deployed over dedicated spectrums for large enterprises, such as rail transportation, electric power, and public security. In this context, private network construction cannot be applied to diversified industries due to a small user scale.

2.2.2 Major Technologies

5G introduces new architectures, such as the SBA and CUPS, for the core network that plays an ever more important role. With the CUPS, the control plane and user plane are decoupled. There are multiple control-plane NFs, and only one user-plane NF, namely the UPF. This decouples centralized deployment and allows the user plane to be deployed in a core network equipment room or on the access side in the vicinity of users. The CUPS technology makes industry-specific 5G private networks simpler, more reliable, and more efficient.

The user plane is decoupled from the control plane and can be flexibly deployed as required, reducing E2E latency for services. As shown in the following figure, the UPF can be deployed in a distributed manner, either in a regional DC or an edge DC, which is closer to users, as required.

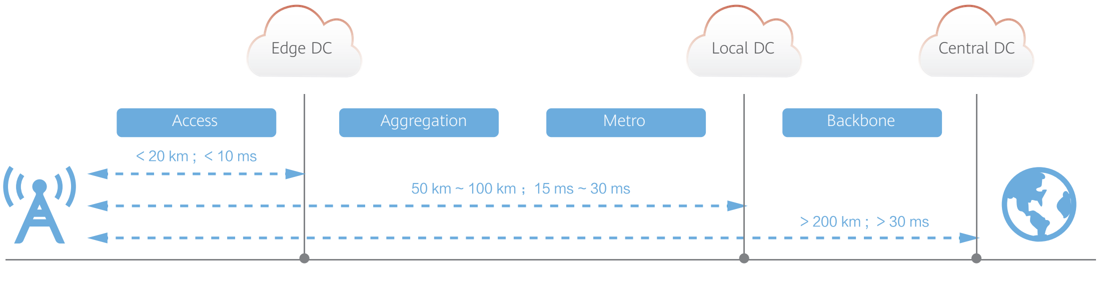


Figure2.2.2: On-Demand MEC Deployment

The UPF is gradually moved downwards from the central or local DC to the edge DC, reducing E2E latency by 10 to 20 ms. For example, remote office services always peak during COVID-19 and require a downlink bandwidth of 100 Mbit/s and an E2E latency of 50 or less ms. This will create seamless user experience and allow remote cloud desktop applications to run without distinct latency. 5G private line services offered on industry-specific 5G private networks tackle the bandwidth shortage of fixed networks in some areas with no optical fibers, contributing greatly to enterprise service continuity during COVID-19.

The aforementioned services are also expected in education and healthcare industries. Industry-specific data resources are stored locally. High-bandwidth services, such as HD and VR/AR videos, need to be accessed through the nearest edge DC. As a solution, MEC edge deployment is introduced. It helps conserve transmission resources on backbone networks between central DCs or regional DCs. This reduces network congestion, and offers services to UEs with the lowest latency after real-time rendering, thereby ensuring ultimate user experience.

Industry-specific 5G private networks are deployed using the CUPS architecture and at the edge closer to users, as required. In this way, a network with lower latency, higher bandwidth, and higher security can be constructed in advance, bringing major competitive advantages to operators.

2.3 On-Demand MEC-Based Traffic Steering

2.3.1 Scenarios

With the growth of 5G Virtual Private Networks (VPNs), an increasing number of users require access to both public (such as the Internet) and private (such as the campus intranet) networks. This poses a challenge about how to select the shortest service path to achieve the optimal user experience.

For example, applications (such as HD video conferencing, 4K video file transmission, and UHD rendering product presentation) pose strict requirements on the bandwidth and latency of a campus private network. In 4G, off-campus users' service flows for both Internet and intranet access cannot be steered locally, and all traffic needs to be carried on a secure VPN tunnel on the Internet and is then forwarded to the intranet. This increases the network resource overhead, lowers the bandwidth utilization, and prolongs latency. Therefore, without the implementation of traffic steering, applications that require high traffic and low latency will be adversely affected.

2.3.2 Major Technologies

The UL CL function is defined for steering 5G user-plane data. A UL CL UPF steers uplink service data and aggregates steered downlink service data. The UL CL works with the Software-Defined Networking (SDN) technology to offer flexible routing policies based on domain names, user locations, and IP addresses. The MEC nodes deployed at the edge steer local service data to a local server and prevent any traffic detours to the core network. This reduces data transmission latency, and achieves efficient forwarding through a shortest service path.

As shown in the following figure, the edge UPF identifies a user based on the user's DNN/IP address and steers the user traffic according to traffic steering policies received from the SMF during an activation/update procedure. This achieves flexible traffic offloading, and local service flows can be forwarded locally or routed to edge apps.As shown in the following figure, the edge UPF identifies a user based on the user's DNN/IP address and steers the user traffic according to traffic steering policies received from the SMF during an activation/update procedure. This achieves flexible traffic offloading, and local service flows can be forwarded locally or routed to edge apps.

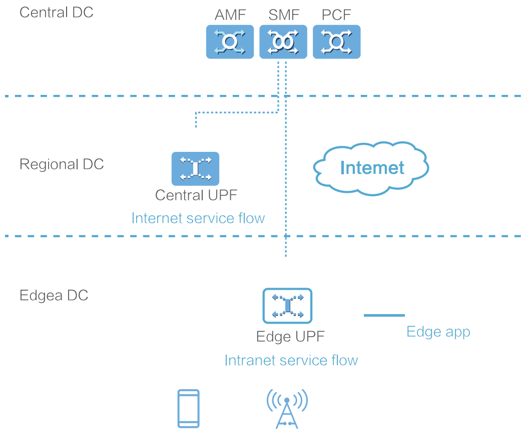


Figure2.3.2: On-Demand MEC-Based Traffic Steering

For example, traffic steering is commonly used in cultural and tourism industries. The industry-specific 5G private network improves local user experience for services, such as smart museums, VR intelligent navigation, stadium AR guides, and UHD video downloads. After purchasing a service package of a scenic spot, visitors use apps on their mobile phones to scan the pavilion, and view a magical scene alongside the pavilion's environment through AR. They can also use the apps to control the projectors, lights, sound, and other equipment, immersing themselves in a fantasy world. Specifically, the industry private network steers users' AR service flows to MEC nodes deployed in an exhibition hall and uploads service data directly to an edge intelligent analysis server instead of the remote central cloud. This server both updates algorithms and processes video data in real time, enhancing the timeliness and effectiveness of video analysis. By doing so, this ensures more than 100 Mbit/s bandwidth and less than 20 ms latency for AR content interaction, which offers users the ultimate experience. What's more, the industry private network steers users' traffic for accessing public networks, such as social media, to the central UPF, and users can switch between the private and public networks.

As 5G private networks develop, users are expecting to simultaneously access the public and industry-specific private networks in a secure way under various service scenarios. The on-demand service traffic steering function enabled on the industry-specific 5G private network will become a must for providing the shortest path and optimal experience for industry users.

2.4 5G Private Network Development Beyond Expectation

With the large-scale development of 5G, industry customers have already recognized the advantages of large bandwidth and low latency. The MEC-powered industry-specific 5G private network has built a solid infrastructure for various industries. Up to now, more than 30 operators around the world have taken on 5G private line products and offerings, covering tens of thousands of enterprises. In the China region, industry-specific 5G private networks have been deployed in more than 200 smart mines and more than 1000 5G smart factories that span over 40 industries, such as manufacturing, healthcare, transportation and logistics, and education.

According to related statistics, the Compound Annual Growth Rate (CAGR) is expected to reach 37.8% for the period of 2020 to 2027. The 5G private network market scale continues to grow rapidly in line with rising customer requirements in vertical industries.

02

MEC Networks Will Become Diversified and Fully Meshed

3.1 Continuous MEC Evolution for the Digital Transformation of Industries

The "Set Sail" Action Plan for 5G Applications jumpstarts the implementation of integrated applications and simultaneously promotes the transformation of industries into digital, smart, and network-based ones through 5G. "Set Sail" will accelerate the modernization of governance capabilities and improve the overall quality of public services. More than 3000 5G VPNs have been earmarked for construction. By 2030, the digital transformation will push enterprises into further upgrades, with Huawei predicting that up to one million enterprises will construct their own 5G private networks.

MEC plays an increasingly important role in the process of enabling thousands of industries through 5G. During the future digital transformation of a wide range of industries, MEC capabilities need to be continuously improved to fulfil the varied service requirements from different sectors.

3.1.1 Industry-Oriented MEC Nodes in Diverse Scenarios

MEC enables user planes to be deployed at the network edge and also provides traffic steering for services. However, as MEC further penetrates more diverse industries, its capabilities need to be comprehensively strengthened to fulfill the varied service requirements from different sectors.

1.Industry-oriented UPFs for stronger connectivity

As 5G is applied across diversified industries, it is challenging to fulfil such a wide spectrum of service requirements, based on the basic connectivity capabilities of MEC. Therefore, the connectivity capabilities need to be continuously powered by industry-oriented UPFs in diverse scenarios.

- New network access protocols: When MEC is adopted in enterprise workshops to assist auxiliary production and flexible manufacturing, network access based on IP networking at Layer 3 is unable to satisfy enterprise requirements. This is because most of the production control systems of enterprises access a network based on Ethernet networking at Layer 2. To address this issue with the help of 5G networking, the MEC solution must provide network access based on Ethernet networking at Layer 2.

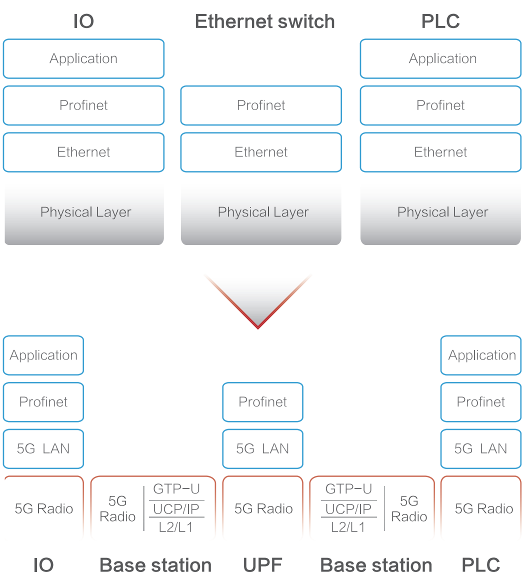


Figure3.3.1: Protocol Stack of Intelligent Manufacture

- Highly reliable connectivity: Enterprise applications require higher connectivity reliability than services of end users. Currently, the automatic production line of an enterprise requests system reliability of 99.999% and a service continuity probability of 99% within one to three years.

2.Multi-function integration for powerful service processing

For some industries, connectivity-only services will not suffice. In the future, an MEC node needs to be able to flexibly integrate more functions (such as voice services) to fulfil varied deployment requirements. Certain industries who have been using data services (such as video content analysis and remote management) also require the digital voice trunking service to support enterprise production. For example, enterprises use the digital voice trunking service to improve the communication efficiency of work groups, and to notify employees of daily information and evacuation information through the broadcast or multicast function of the dispatch system.

3.1.2 Full-Mesh Networking

Users in certain scenarios, such as government and school campuses, require consistent access to campus services even when they move out of the campuses. However, the network access solution in use still needs to be improved due to the following:

- Complex network access process: A dedicated VPN needs to be established for users off campus to access campus services, resulting in additional authentication, complex networking, and complicated O&M.

- Unsatisfied service experience: Due to restricted performance, it is challenging for a VPN to provide sufficient bandwidth when users off campus access intranet services.

Disjointed MEC systems are expected to be fully interconnected in the future. With a wider MEC coverage, users can consistently access campus services even when they move out of the campuses. Full-mesh MEC will be a key capability for digital upgrades of public services and campuses.

3.1.3 Compute-Network Synergy

In addition to the aforementioned connectivity enhancement and full-mesh networking, the telecom cloud platform will be built as a highly reliable network foundation featuring compute-network synergy and real-time resource scheduling, on which key applications of enterprise private networks can be efficiently integrated.

Several key applications of enterprise private networks need to be integrated into operator networks. This will simplify the deployment of enterprise private networks as well as help coordinate network resources with compute capabilities. To achieve this, the platform for running the applications and networks must be more reliable and able to schedule resources in real time.

3.2 MEC to X: Diversified and Fully Meshed MEC Nodes Enable Diverse Industries

3.2.1 MEC to Office

MEC is deployed on government and school campuses to provide seamless digital office access. Furthermore, fully meshed MEC nodes span wider WAN coverage, without the need to establish Internet-based VPN connections. As such, users in roaming scenarios can seamlessly access campus services, fulfilling increasing requirements for extranet access and remote office.

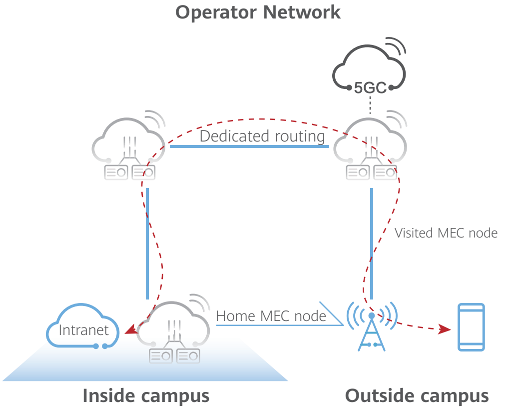


Figure3.2.1: Roaming Architecture of MEC to Campus

- Fully-meshed WAN: MEC nodes in different areas are fully meshed. When users move out of a campus, the visited MEC node outside the campus routes intranet access requests to the home MEC node, inside the campus. The users then access intranet services in the same way as if they were inside the campus, achieving seamless network access.

- Simplified networking: 5G's built-in security capabilities make it possible so that complicated VPN connections do not need to be established when users move out of a campus, simplifying networking and speeding up network access.

- Simplified authentication: The authentication function of mobile phones is used for centralized authentication during network access, without additional authentication required.

3.2.2 MEC to Manufacturing

MEC powered by enhanced Operation Technology-UPFs (OT-UPFs) can be deployed in enterprise workshops. In this manner, flexible manufacturing can be used on production lines based on wireless network control, and production capacity loss caused by faults in wired connections can be reduced, based on the wireless control of mobile components.

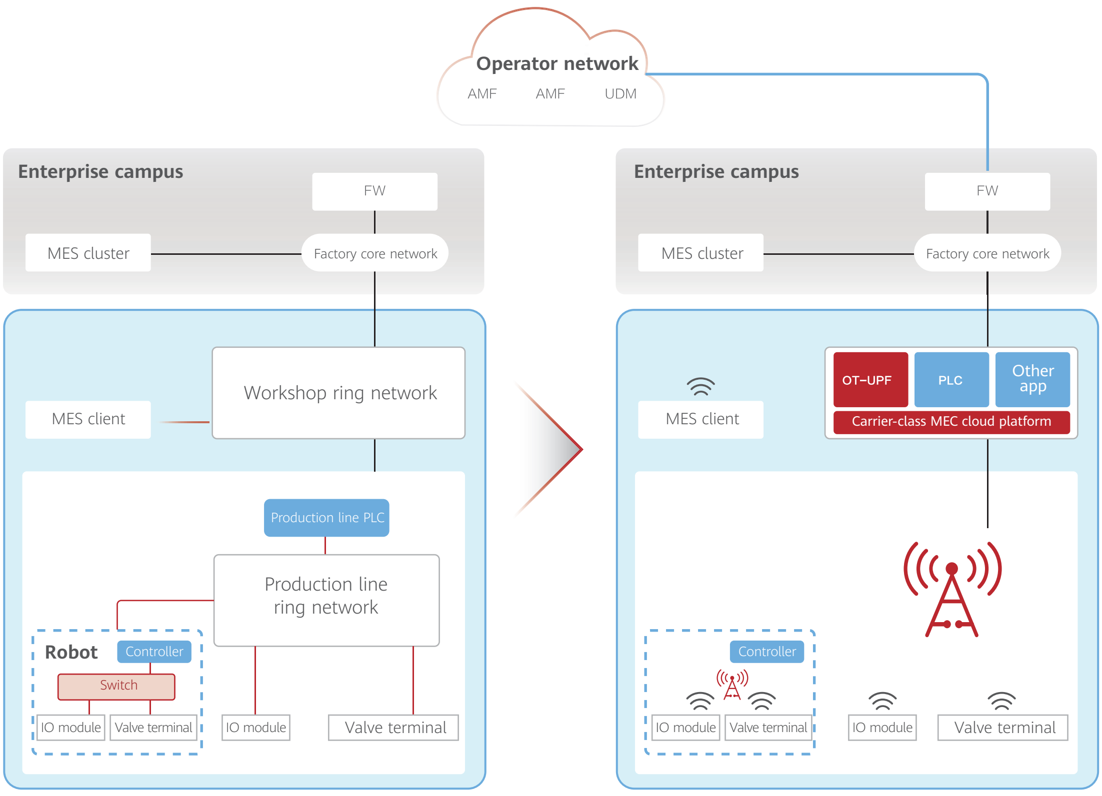


Figure3.2.2: General Network Architecture of Intelligent Manufacture

- Seamless 5G LAN access: 5G LAN provides industrial Ethernet access, allowing industrial control terminals to directly access mobile networks through Ethernet interfaces.

- Ultra-high reliability networking: 99.999% or even 99.9999% networking reliability can be achieved based on multiple features, such as dual-system hot backup or dual fed and selective receiving, providing continuous online connections.

- Compute-network synergy: The carrier-class MEC cloud platform is built based on Operation, Information, Communication Technology (OICT), features real-time resource scheduling, and can be integrated with industrial applications, such as Programmable Logic Controller (PLC).

3.2.3 MEC to Coal Mines

An all-in-one 5G core network and an IP Multimedia Subsystem (IMS) are integrated at an MEC node at the network edge so that resources can be scheduled for the digital voice trunking service under and above grounds of coal mines. The node is fully meshed with public networks to allow users to use only single SIM/USIM cards to access both voice and data services under and above grounds, regardless of whether they are inside or outside coal mining areas.

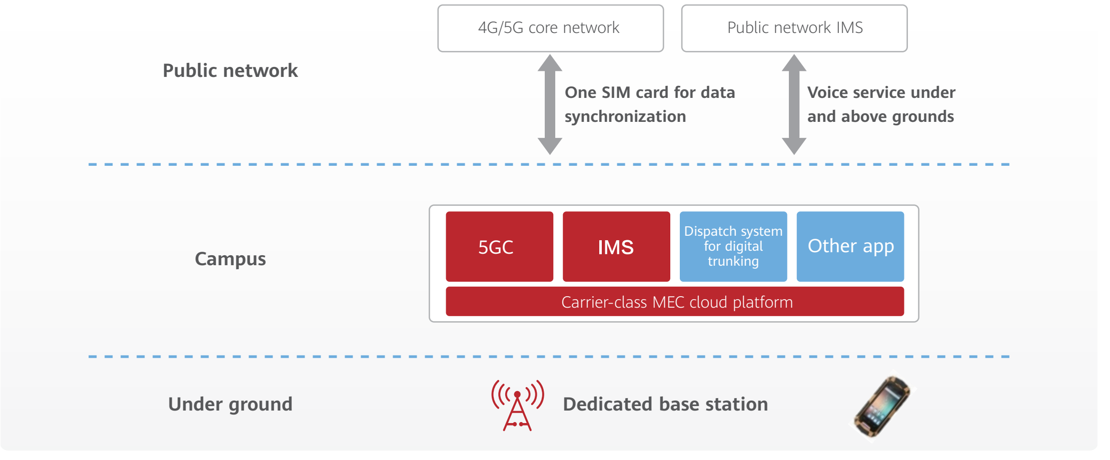


Figure3.2.3: General Network Architecture for Intelligent Coal Mine

- Data and voice service integration: An all-in-one 5G core network and an IMS are integrated in the vicinity of the coal mine to provide the digital voice trunking service underground as well as above, based on 5G highly reliable wireless connections.

- Seamless convergence with public networks: The 5G core network and IMS in coal mining areas are fully meshed with those on the public network so that users can use single SIM/USIM cards to access both voice and data services, both underground and above, regardless of whether they are inside or outside the coal mining facility.

- Compute-network synergy: The carrier-class MEC OICT-based cloud platform features real-time resource scheduling, and can be integrated with third-party application systems or the dispatch system for digital trunking.

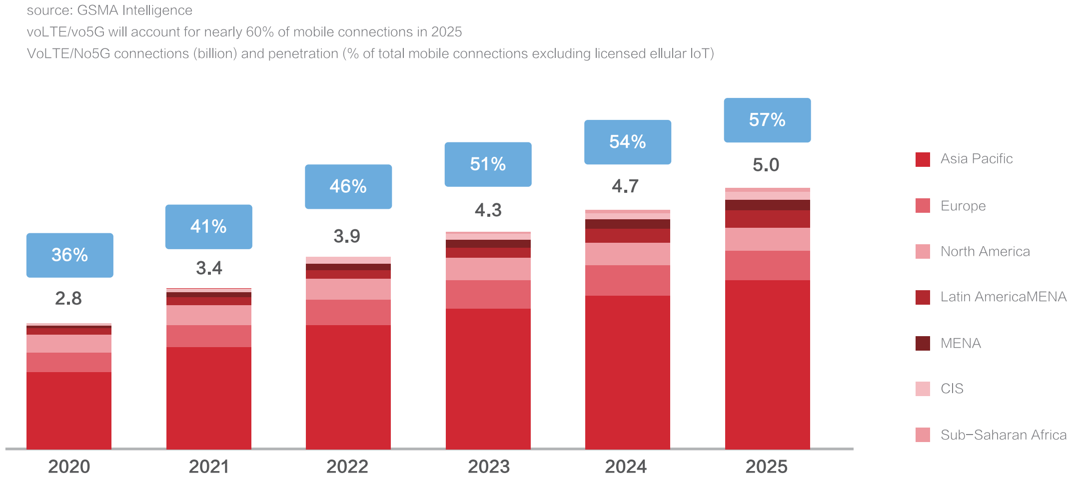
As described in this chapter, MEC needs to be continuously evolving to provide stronger connectivity for diverse industries, support full-mesh networking for seamless access, and enable compute-network synergy for integrated deployment. The connectivity+compute solution will promote the digital transformation of diverse industries.

03

VoLTE Is Inevitable on the Path to 5G

4.1 Accelerating VoLTE Development Globally

In recent years, VoLTE has made significant progress around the world. Currently, more than 220 mobile operators offer commercial VoLTE services in about 100 countries. In 2012, operators in South Korea took the lead in launching VoLTE services. The U.S. and Japan were following closely, launching their own in 2014. European operators embarked on VoLTE services the following year. Three Chinese operators launched VoLTE services from 2015 to 2018. Currently, the penetration rate of VoLTE users in China has exceeded 80%. The VoLTE user base is on the rise — by 2021, the number of global VoLTE users had reached 3.3 billion. According to GSMA intelligence, the number of global VoLTE and Vo5G connections will exceed 5 billion by 2025, accounting for nearly 60% of mobile connections. In addition, VoLTE connections will encompass about 75% of all 4G and 5G connections.



4.1-1 GSMA's prediction about VoLTE/VoNR connection quantity

The past 10 years witnessed the gradual recognition of VoLTE services by operators. About 96% of leading operators around the world have deployed VoLTE services, and here's why:

- **Enhanced spectrum efficiency:** The spectrum efficiency of LTE networks is 2-3 times that of 2G/3G networks. That means, with the same spectral bandwidth, LTE networks can support more users. For example, if the spectrum is 5 MHz, a 2G cell supports about 32 users, a 3G cell supports about 50 users, and an LTE cell supports over 119 users. Developed and many developing countries have set a clear schedule for 2G/3G network sunset. They plan to shut down them broadly or build light-weighted voice networks before 2024 or 2025 and use the precious medium- and low-frequency spectrum resources for 4G/5G networks.

- **Better experience:**

1.The VoLTE call connection delay is greatly shortened. It takes only 1 to 3 seconds to connect a VoLTE call. The call connection speed is 2 to 3 times faster than a CS call.

2.VoLTE calls leverage HD audio and video codecs, providing high-fidelity audio services for users.

3.VoLTE users can use data and voice services at the same time, improving user experience. For example, a user can make a call while playing a game or using the navigation service. Statistics show that operators providing VoLTE services can gain higher scores in P3 network tests.

- **Diversified services:** A VoLTE network provides HD audio and video capabilities, allowing operators to roll out diversified multi-media services like Video RBT (VRBT) in addition to voice services.

- **Easy access to VoLTE-capable terminals:** Through the joint promotion and efforts of the entire industry chain, all terminals delivered after 2017 support VoLTE functions. As the industry chain matures, VoLTE-capable terminals become more and more affordable, providing a favorable development environment for VoLTE.

- **Standard network access authentication:** GSMA together with mainstream operators align their network access parameters and reduce required parameters from 100 to about 50. After completing authentication tests with GSMA, terminal manufacturers can launch new terminals in markets, reducing test workload and accelerating the rollout of new models.

- **Necessity for 5G:** The popularization of 5G boosts VoLTE development. 3GPP stipulates that voice calls cannot fall back from 5G to 2G/3G networks. At the same time, some operators are planning to shut down 2G or 3G networks. In this case, VoLTE becomes a must to ensure voice continuity for 2G, 3G, 4G, and 5G users. According to GSMA, an excess of 95% of 5G operators have built VoLTE networks to improve 5G user experience.

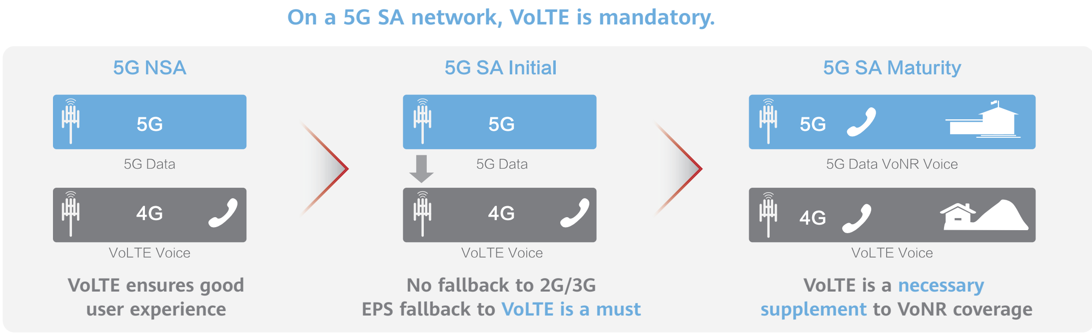


Figure4.1.2: Basic network for 5G voice services

4.2 Relying on Audio and Video Services to Increase Stickiness of Customers

In 5G, voice services are still the core of telecom services for operators and play an indispensable role in people's communication. With the continuous development of technology, users have strong demands for interactive communication. Statistics reveal that 80% of mobile users in China use video calls, most of which happened when they are attached to mobile networks. Beyond this, industry users hope to complete transactions on phones to reduce communication cost and improve service efficiency.

To satisfy these requirements, some operators are rolling out innovative New Calling services. Compared with legacy video calls, New Calling services provide UHD images and interactive capabilities, facilitating communication and enriching service experience. Take certain Chinese operators as an example. In 2021, three major operators implemented all-IP interconnection and built the world's largest and forerunning VoLTE network. Currently, the number of video call users in China exceeds 1.2 billion, and the penetration rate of video calls increases year by year. Currently, the three major operators have included video services in their service packages, encouraging users to use the native video services on operator networks. For home scenarios, Set-Top Boxes (STBs) have integrated audio and video call functions. In this case, users can watch videos online with their friends or use STBs to make video calls.

It is estimated that by 2025, there will be 400 VoLTE networks worldwide, and the penetration rate will reach 50%. Operators, vendors, and industry analysts have reached a consensus that it is crucial to accelerate VoLTE construction and develop New Calling services.

04

New Calling Will Redefine Future-Oriented Voice Services

5.1 Users Chase Intelligent Interactive Communication Methods Beyond Voice and Video Calls

Telephone calls fulfill the communication needs of 7 billion people worldwide, the most reliable and convenient communication method humanity has enjoyed to-date. However, as the Internet becomes commonplace thanks to 4G, people desire more enjoyable and efficient communication methods beyond basic voice and video calls. From 1G to 5G, 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 the great opportunities brought by 5G, operators need to consider how the calling service will survive and thrive.

Conventional voice calls can no longer satisfy modern, ever-changing communication needs. People tend to seek more enjoyable and interactive calling modes. Statistics show that the number of video call users in China exceeds 1.2 billion, accounting for about 80% of mobile Internet users nationwide, and their average video call duration reaches up to 300 minutes each month. To cater to this trend, OTT players have made many enhancements to their calling services, 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. These new features enrich communications and help increase Minute of Use (MOU).

For enterprises, they expect to be able to seamlessly complete an entire transaction process over a call. They don't want their customers to have to download various apps and go through long and complex processes like registration and authentication; it impedes service efficiency. New Calling can help achieve this. For example, through video calls, car insurance companies can receive settlement claims and perform loss assessment without an onsite inspection, and device vendors can provide remote installation and maintenance guidance, helping them reduce costs and improve efficiency.

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

5.2 Standards Introduce Data Channel to Support Service Innovation

The 3GPP SA4 working group completed the standardization of the IMS Data Channel in March 2020 and released 3GPP TS 26.114 (V16.5.0). In December 2021, 3GPP initiated NG-RTC in Release 18 to further clarify the separated architecture of the IMS Data Channel and its unified media plane. To promote the IMS Data Channel and New Calling, GSMA released the NG.129 IMS Data Channel White Paper in December 2021.

In the IMS Data Channel architecture, a data channel is laid upon existing IMS voice and video channels to meet the requirements of data apps in terms of latency, bandwidth, and reliability. One or more data channels can be added to an IMS session to transmit any type of data for any purpose. All the data transmitted is synchronized with voice and video traffic. The standardization of the IMS Data Channel paves the way for operators to develop innovative calling services.

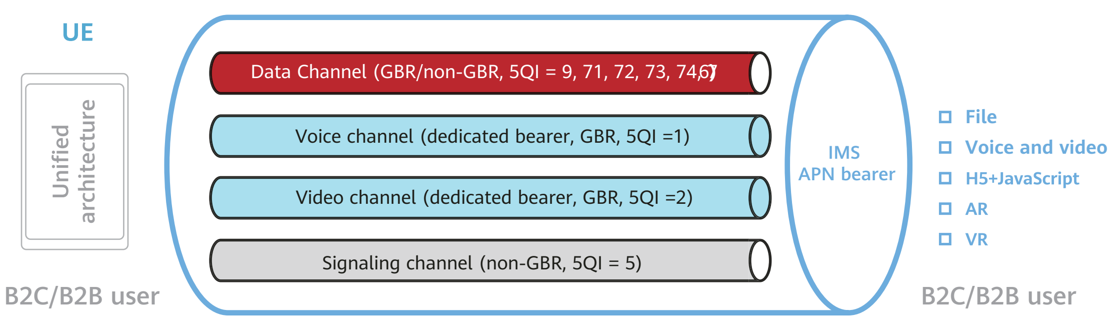


Figure5.2: IMS data channel

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

The calling service plays a fundamental role in maintaining customer loyalty and the operators' social value. Since 3G, VoIP services have ramped up, and OTT services have come to center around call communication between acquaintances. Even so, native phone calls made by dialing numbers are still the main means of daily communication because of their high availability and reliability. Due to the restrictions of uplink bandwidth and video call interconnection between different networks, operators' calling service is limited to voice and unable to take advantage of features provided by terminals, such as a large screen and HD.

Promoting video calling by reducing package fee and developing more service scenarios

With the advent of 5G, China's three leading operators have included video calling in their packages, with the same package fee as voice services. This drives more users to make video calls. With video calling services hosted by operators, strangers can call each other without the need to add friends. In addition, dedicated video call bearers guarantee high quality and reachability. The video calling service can be used not only in daily communication, but also in business activities. Operators are now gearing up to provide video calls on a large scale. In China, an operator launched its video calling service in October 2021, and the video user penetration rate increased from 4% to 10% within only half a year.

Enhancing network capabilities

In addition to the basics, individual users hope to experience fun video calls in HD; industry users hope to exchange information and accomplish business transactions over a call. Though there are advantages for operators in providing reliable HD video calling services, they are limited by the following factors:

- Operators provide only basic video calling services, which cannot meet users' diverse requirements.
- Information can only be conveyed through voice and video images. Screen sharing as well as file and picture transferring are not allowed within a video call.
- Business transactions cannot be accomplished over a call, and users must use third-party apps to process transactions.

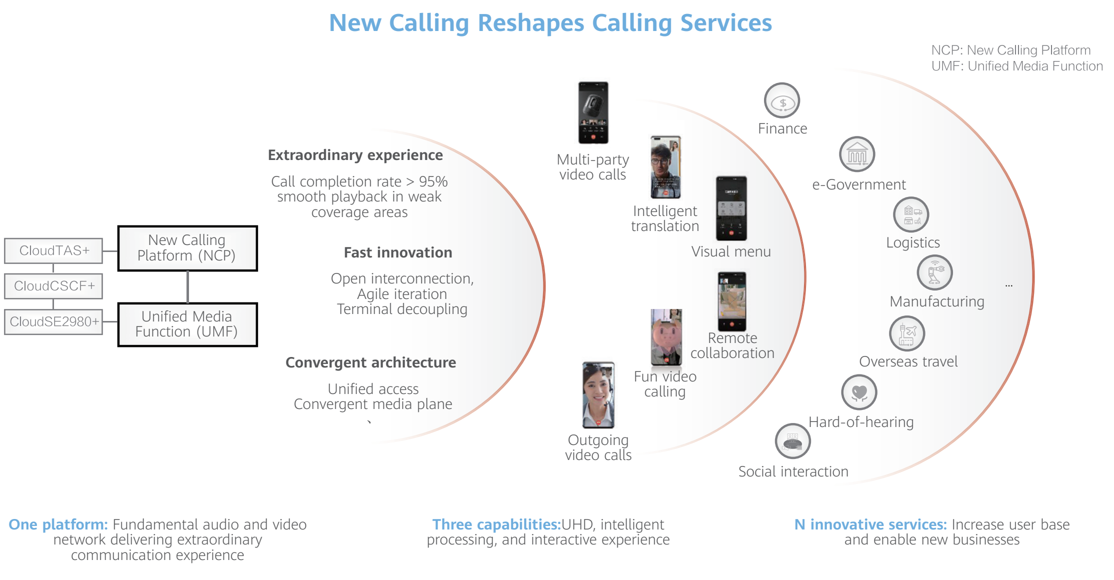
Leveraging calling services to develop new products and maintain customer loyalty

To meet user requirements and break through conventional calling service limitations, some leading operators in China have launched brand-new 5G products. Through this, they have managed to empower communication with UHD, intelligent, and interactive calling capabilities, unleashing new business monetization opportunities in the process. These calling capabilities bring operators the following benefits:

- First, they help increase the video call user base and improve user experience.
- Second, in addition to voice and video channels, a data channel is provided to transmit multimedia information, unleashing great business value.
- Third, they enable business transactions to be processed within a call, thereby helping enterprises reduce costs and improve communication efficiency.

5.4 Building a "1 Platform + 3 Capabilities + N Services" Architecture with Voice, Video, and Data Channels on an IMS Network to Implement New Calling in Three Phases

Huawei coordinates with world-leading operators, standards organizations, and industry partners to build a "1 platform + 3 capabilities + N services" architecture that provides New Calling through voice, video, and data channels on an IMS network. Through this, user loyalty and service innovation gain exponential room for growth.



5.4-1"1 platform + 3 capabilities + N services" architecture for New Calling

One platform refers to the New Calling Platform (NCP) and Unified Media Function (UMF) constructed with voice, video, and data channels on an IMS network.

Three capabilities — UHD, intelligent, and interactive video calling — are added to the basic network to cultivate user habits and make video services more popular.

Multiple innovative services are provided by operators with the New Calling solution. Operators, together with third-party partners, flexibly innovate services with advanced network capabilities, quickly meeting the requirements of various users as well as industry scenarios.

- UHD video calling

IMS dedicated channels ensure video calls are sustained without frame freezing in poor network coverage. Almost all video calls can reach target users with a high video resolution, taking user experience to new heights.

- Intelligent video calling

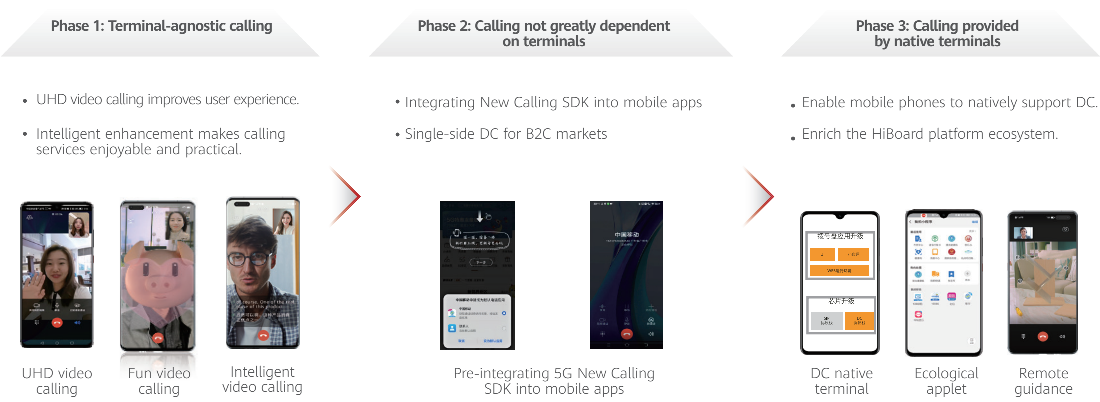
Intelligent video channels provide capabilities such as image recognition and media rendering. Let's imagine, for example, an operator plans to launch fun video calling. This would entail enabling users to replace calling backgrounds, use AR virtual images, and send emoticons during video calls. They also plan to launch an intelligent translation service. This service would bring convenience to the disabled and elderly by intuitively showing the information they need, and vastly reduce the difficulties of language barriers with real-time translation in the case of multi-cultural communications.

- Interactive video calling

- Interactive video calling can close service loops during calls, making calling services more useful.

To sum up, New Calling makes calling services easy to use, practical, and beneficial.

New Calling also introduces Data Channel to reshape the dial pad, build operators' own HiBoard, and provide interactive calling capabilities like screen sharing and AR annotation. Moreover, New Calling closes service loops for industry users, which in turn improves industry efficiency and enables new avenues of business monetization. However, the development of New Calling depends on the maturity of upstream and downstream industry ecosystems, including chips, terminals, networks, services, and industries. For instance, terminals need to support interactive Data Channel, which cannot be achieved overnight. Accordingly, we propose a terminal-oriented three-phase strategy for implementing New Calling.



5.4-2 Three-phase strategy for implementing New Calling

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

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.

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.

In short, it has become a common consensus among leading operators to build a New Calling platform based on voice and video channels to enhance user loyalty. Some operators are piloting and practicing New Calling in the industry already. 5G New Calling will bring brand-new calling experience to users and inject new vitality into the entire industry. Huawei is willing to work together with global partners to build standards and specifications, promote the maturity of native terminals, and conduct iterative service innovation. The future of the industry is sure to be prosperous.

05

Operators' Video Services Are Converging with OTT Applications, and Will Deliver a Better UHD Video Experience

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 directions, experiences, models, and opportunities in the video industry.

6.1 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.

However, this is changing. As 5G deployment ramps up, the video industry is shifting focus toward OTT multi-screen video services, where operators are gradually expanding 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, estimates 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.

6.2 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.

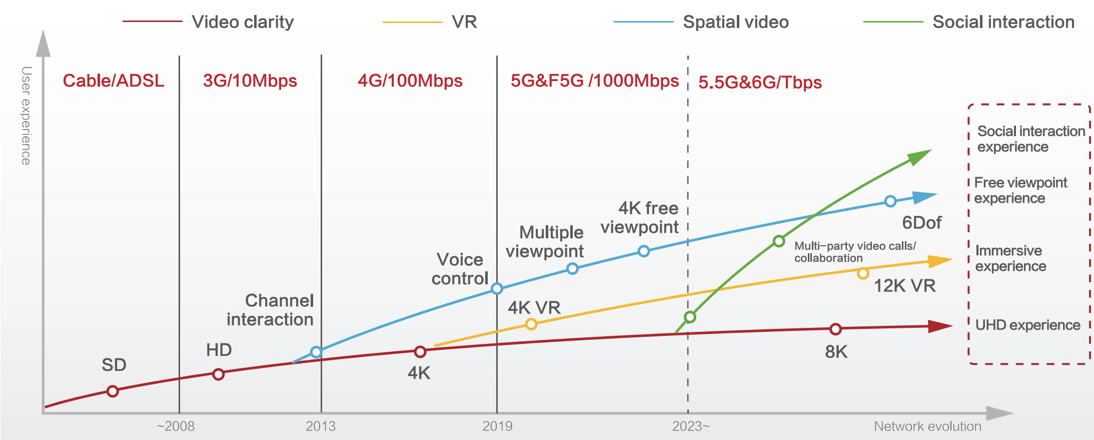
We have already achieved a UHD experience in flat videos. Now, 5G is gradually enabling immersive spatial video services with VR, free viewpoint, and naked-eye 3D. For example, the Kungfu act Heroes performed at the CCTV New Year's Gala 2021 used the 360-degree free-view feature, driving viewership up 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 evolve, operators' video services are evolving from TV screens (fixed broadband) to diverse OTT device screens (mobile broadband). Plus, mobile phones and tablets work on high-quality networks and offer highly interactive capabilities, promoting spatial video services, delivering innovative experiences, and creating opportunities for fast, high-quality development of operators' video services.

06

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 spatial and social-interactive video services, which will in turn become an important source of opportunity for operators.



7-1 Future Trend of Operator Video Service

7.1 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 naked-eye 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 Storm 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 an immersive experience both on large TV screens and various 5G OTT device screens.

7.2 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 as the global video and broadband penetration rates continue to increase. This signals incredible opportunities and most probably very fast growth for spatial and social-interactive video services on both large TV screens and small OTT device screens.

07

Telecom Cloud Is the Optimal Approach to Develop Telecom Services, and Will Continue to Fulfill Operators' Diversifying Requirements

8.1 Telecom Cloud Has Become a Best Practice in Telecom Network Virtualization

The telecom cloud has experienced a decade of development since the NFV concept emerged in 2012. It has seen the steady growth and expansion of industry best practices, in line with operators' organizational capabilities, network architectures, and personnel skills.

In the initial NFV white paper released by ETSI, 13 operators representing the entire industry suggested the design and deployment of telecom networks by decoupling software from hardware. The main objectives were to use NFV and Commercial Off-the-Shelf (COTS) servers to reduce network construction costs and power consumption, accelerate the TTM of new services, provide elastic and agile capabilities for telecom networks using IT, and drive telecom services through a more open ecosystem. In addition to supporting these objectives, telecom networks needed to maintain high performance, reliability, and security.

The white paper also highlights the unprecedented challenges telecom network devices were to face with NFV. These include compatibility issues caused by device decoupling, performance deterioration due to virtualization, difficulties in the evolution of legacy devices and in introducing a new management and orchestration system, and potential risks to security and reliability. The industry also recognized that deploying NFV requires transformation in terms of organization, culture, and processes.

With the joint efforts among operators and vendors, the telecom cloud has gradually overcome both technological and organizational challenges. In the standard 5G network architecture launched in 2017, the NFV-based SBA architecture became the norm for telecom networks. Except for a few legacy 2G/3G networks left unreconstructed, telecom cloud is largely the most popular choice for today's core networks.

However, the telecom cloud has not yet fulfilled all the original NFV objectives due to a gap between IT and CT technologies. There is still room for improvement in TTM, elasticity, and agility. Even so, the telecom cloud has overcome many challenges, including network reliability issues caused by hardware-software decoupling, fault diagnosis and O&M efficiency issues across different layers, and system integration challenges posed by the hierarchical NFV architecture.

Reliability: NFV is designed based on software-hardware decoupling and COTS IT servers, but IT hardware cannot meet carrier-class reliability (99.999%) requirements due to cost considerations. In response, telecom cloud reliability has been enhanced on the basis of the OpenStack framework, which enables targeted prevention, diagnosis, and recovery designs against different fault scenarios.

The telecom cloud uses the affinity and anti-affinity design for VMs to prevent faults on some hardware devices from affecting the whole system. Plus, Host Aggregate (HA)-, Availability Zone (AZ)-, and Data Center (DC)-level backup enables quick switchover upon system faults. To eliminate the risks of potential fault points in the system, the telecom cloud adopts automatic load balancing and automatic bypass of faulty components. These designs ensure carrier-class reliability.

Performance optimization: Telecom network applications are "heavier" than IT applications, and only a limited number of applications can run on a telecom network. To overcome performance deterioration caused by virtualization, the telecom cloud has integrated CT experiences (such as CPU core pinning, huge page memory allocation, Single-Root I/O Virtualization (SR-IOV), Data Plane Development Kit (DPDK), and interrupt coalescing) into IT technologies, which has significantly improved service performance at the cost of certain flexibility.

Centralized deployment and intensive management: Network scales vary across operators. On some large-scale operator networks, the telecom cloud supports centralized deployment and intensive management of tens of thousands of servers in a single DC. This is a best practice in the industry, enabled through the efforts of various stakeholders.

All these outcomes are not just the result of technological advancement, but represent successful vendor-operator collaboration that uses their talent and skills to help operators succeed.

In recent years, several hyperscalers have encouraged operators to deploy network functions based on the public cloud. However, it is too early to tell whether the public cloud can be a good choice. Migrating the networks onto the public cloud poses many challenges to operators, in both technical and non-technical fields. Firstly, the public cloud adopts an asset-light model which requires operators to lease rather than build network infrastructures themselves. It is difficult to tell whether these advantages outweigh the disadvantages. Secondly, the public cloud adopts an O&M mode based on automation tools. This provides a certain reference for telecom networks, but poses high requirements on personnel skills. Operators need to invest more in training and organizational development. Thirdly, there are challenges with the supervision on network reliability and data security. Although the public cloud can provide several security capabilities, there may be political barriers in terms of industry regulatory policies and sovereign data protection. Last but not least, the public cloud is unable to meet operators' needs for the flexible decoupling of services from their underlying infrastructures. This is because it is operating on siloed infrastructures. Take AWS and Google as examples: they both use self-designed and developed hardware, which cannot meet operators' requirements on procurement flexibility.

8.2 Telecom Cloud Evolution Technologies

Since the beginning of the 5G era, operator networks have been serving not only individual consumers, but also vertical industries. Nevertheless, the business models of industries differ dramatically, which demands diversified service evolution requirements for the networks and the telecom cloud. For example, machine vision applications require large uplink and downlink bandwidths. As such, the telecom cloud must be able to provide continuous high performance. Applications such as remote management require E2E low latency, and the telecom cloud needs to further reduce the latency at the platform layer. Meanwhile, the telecom network needs to further accelerate the integration of cloud computing. To cater to operators' diversifying service requirements, the telecom cloud will not only improve its carrier-grade capabilities, but also provide the following evolution technologies.

8.2.1 Heterogeneous Compute Capabilities

NFV allows services to run on COTS hardware, which is interchangeable with other hardware of its kind. The telecom cloud must be able to fully leverage heterogeneous hardware capabilities. The telecom cloud must also support co-deployment of x86 and Arm servers to meet service requirements. MEC is one of the main focal points for the evolution of operators' networks, which may require the deployment of Arm servers at the edge.

In addition, the telecom cloud also needs to support co-deployment of VMs and containers for the transformation from virtualization-based 4G to container-based 5G.

8.2.2 Convergent and Simplified Networking

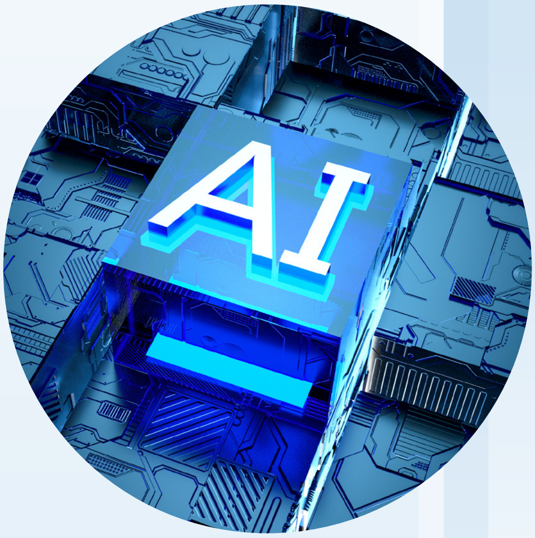
To cope with heterogeneous computing capabilities, the telecom cloud must support different physical infrastructures, and manage and orchestrate these hardware resources uniformly. Therefore, the telecom cloud architecture needs to be more convergent and simplified to support VMs, containers, or other new computing capabilities. It will be a unified management and orchestration system that complies with the ETSI standards.

8.2.3 Automatic Management and Deployment

Currently, manual intervention is still required for complex operations on cloud-based networks. However, 70% of network faults are caused by manual errors, according to Huawei statistics. For example, recent wide-scale network outages in Canada and Japan were caused by human errors. Therefore, E2E automatic deployment is required to protect the networks from manual faults. Although the telecom cloud has certain centralized and automatic deployment capabilities, it needs to enhance its automatic capabilities in hot patching, hot replacement, and hot migration for capacity expansion and upgrades. Specifically, the telecom cloud needs to simulate operations such as upgrade and capacity expansion, based on digital twins, to achieve low-cost trial and error. In addition, the telecom cloud is expected to provide full life cycle management capabilities such as automatic deployment, configuration, and upgrades, including blue-green deployment, to ensure that O&M operations do not compromise services. Furthermore, the telecom cloud needs to tackle the complex O&M brought on by a thousandfold increase in edge sites. Thanks to the intent-driven configuration and E2E automatic tools, the deployment efficiency can be enhanced by ten-fold.

08

AI Is Indispensable for Developing an IntelligentCore



9.1 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.

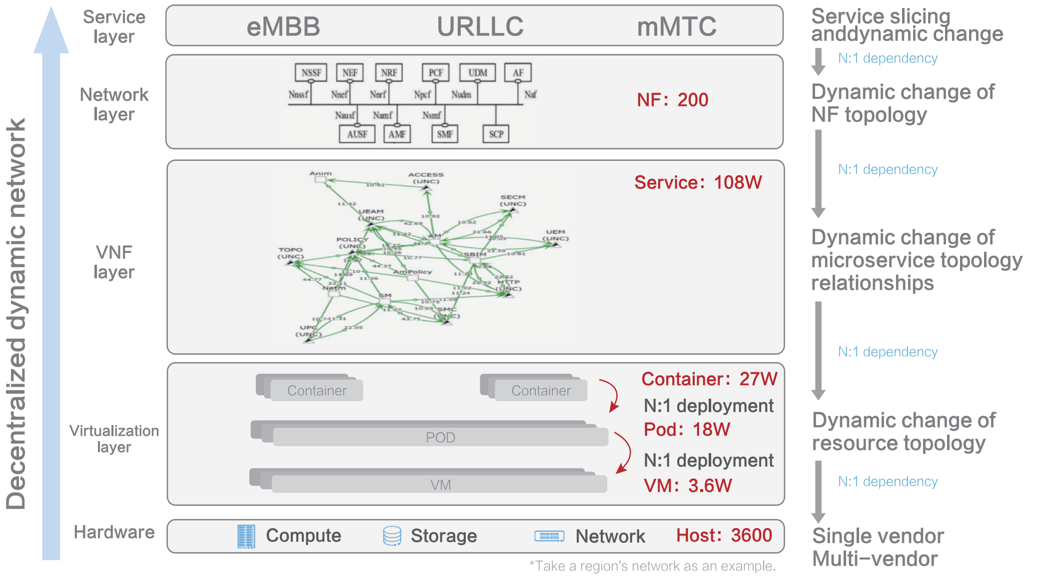


Figure9.1.1: Evolution and challenges of Cloud Native in the core network

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.

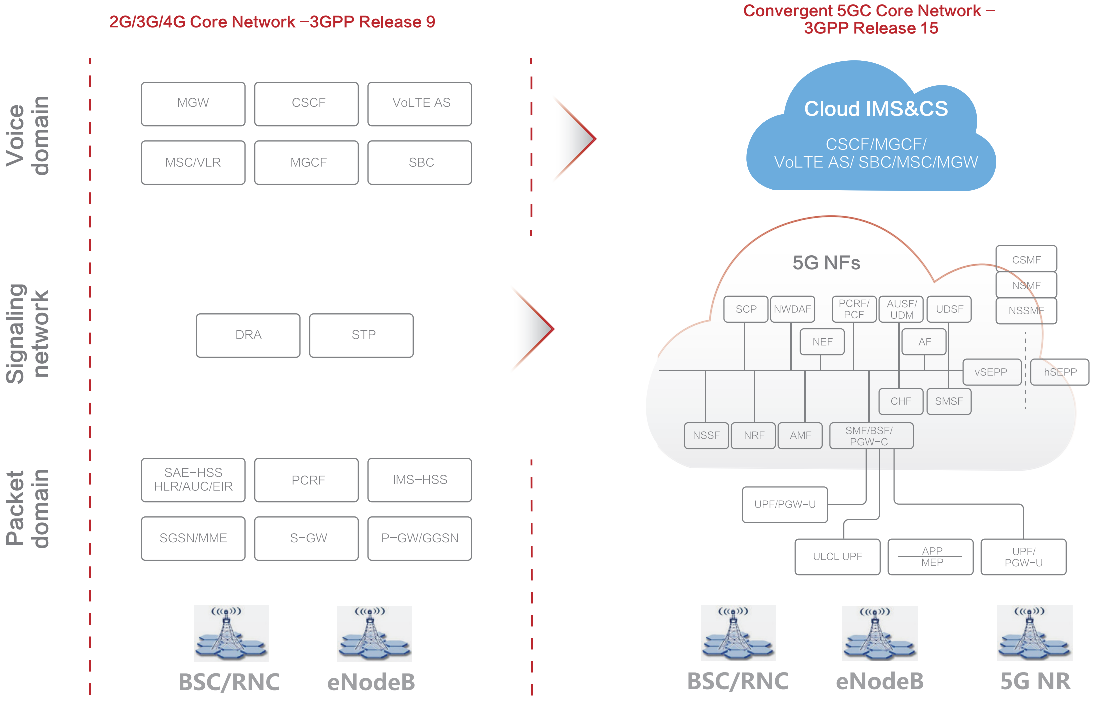


Figure9.1.2: Evolution and challenges of Full Convergence in the core network

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.

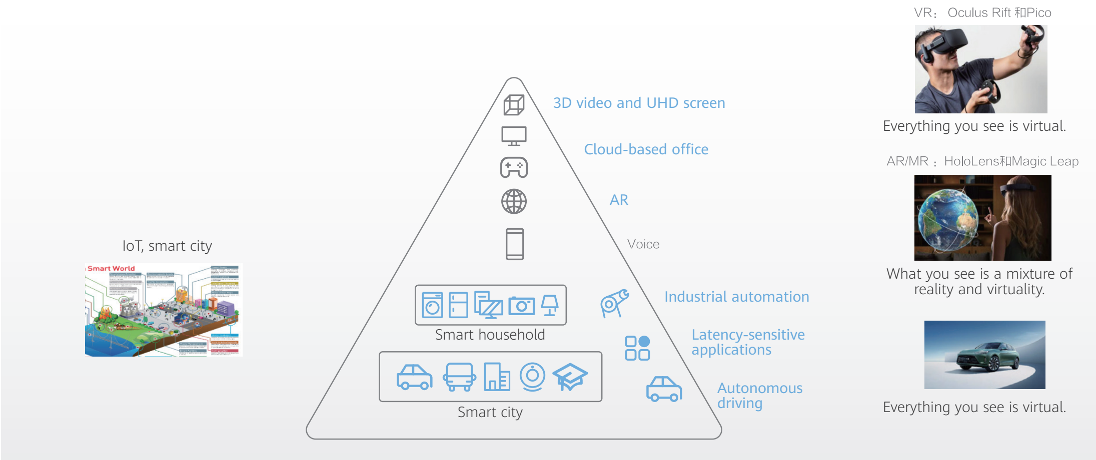


Figure9.1.3: New services provided by the 5G core network

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.

To satisfy these requirements, intent-driven technologies such as AI must be positioned as the basic capabilities that make up an IntelligentCore.

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 customer 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

9.2 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.

Through its intelligent functions, the O&M system of the 5G core network can obtain cloud-network data across layers and DCs, which it then uses to create 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 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 E2E 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 E2E 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.

9.4 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:

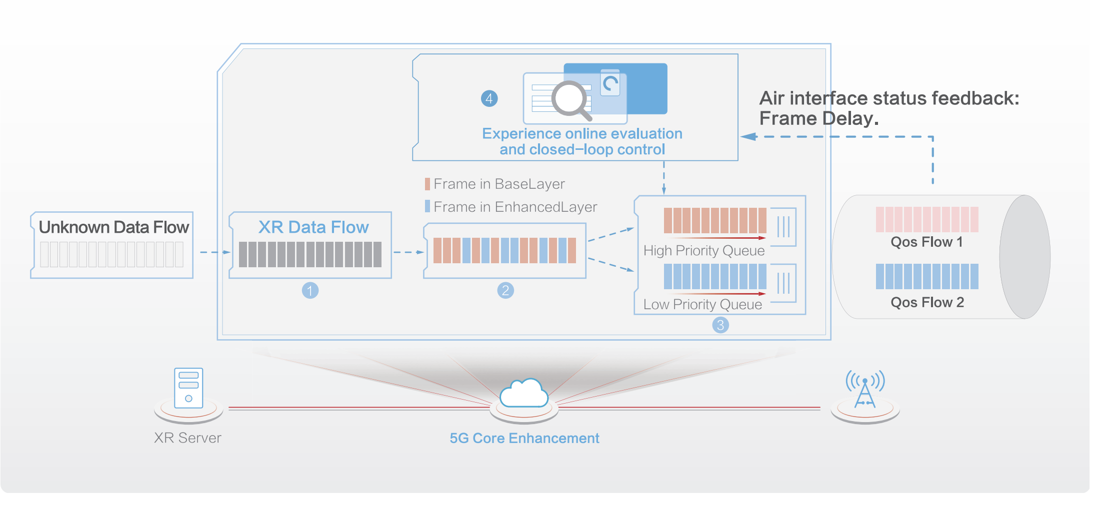


Figure9.4: Improving XR service pipe efficiency based on AI

1.Intelligently identifies XR data flows.

2.Associates packets based on the behavior model and intelligently identifies frames at the basic and enhancement layers.

3.Implements differentiated frame-level scheduling through 5QI priorities to ensure no packet loss at the base layer.

4.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.

9.5 Overall Architecture of an IntelligentCore

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

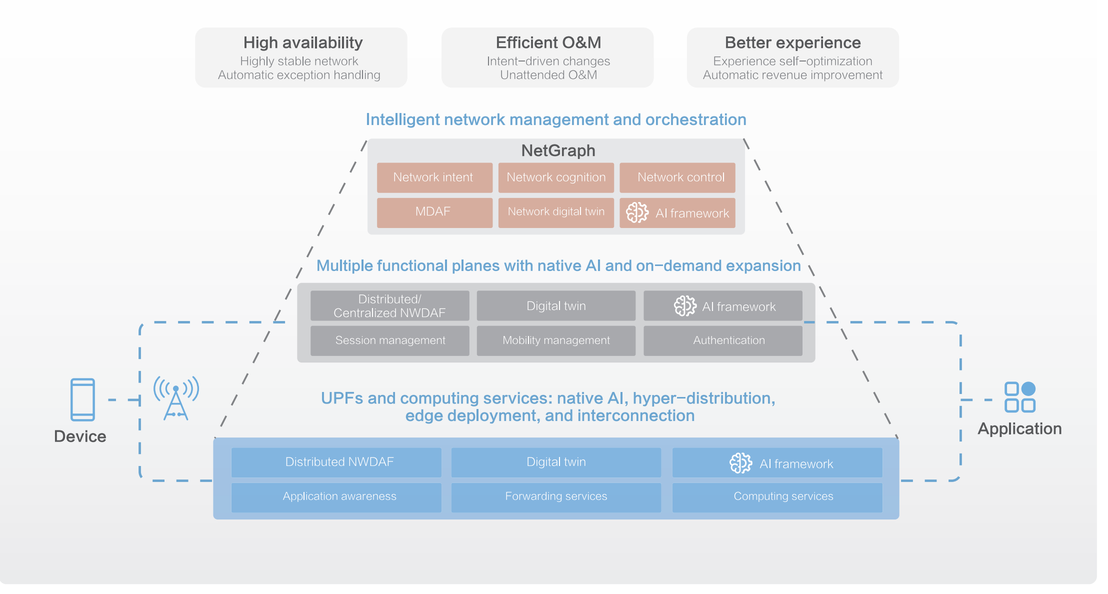


Figure9.5: Overall architecture of an IntelligentCore

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.

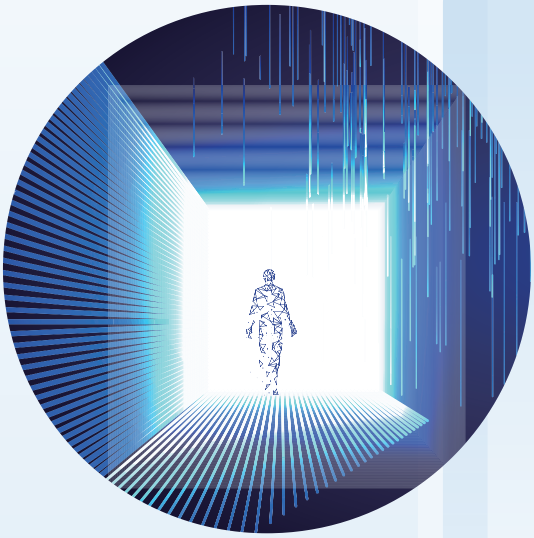
3.The core network is the service experience management center. AI must be able to improve the service experience of end users and industry customers.

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.

09

Summary and Prospect



Driven by best business practices and technological innovations, the telecom network and applications are advancing at a blistering pace. While we are busy mapping the future for 5.5G, industry pioneers have already begun to research 6G. We can clearly see that intelligence will be essential to the development of both networks and services. This will catalyze the technology-business synergy, creating more business opportunities and beneficial value for all industry stakeholders.

As progress is made towards an IntelligentCore, the 5G core network will empower B2C, B2B, and B2H services. In the B2C field, New Calling will upgrade audio and video calling to intelligent, interactive, and immersive communications. In terms of B2B, MEC to X will enable industry private networks which used to serve limited scenarios and areas to exert their effectiveness in any scenario at any location. As for B2H, New Video will revolutionize video services, bridging the virtual and real worlds, and upgrading user experience from single-screen entertainment to multi-screen social interactions. These are all built on agile, reliable, and efficient network infrastructures which combine the strengths of the telecom cloud and autonomous driving technologies, as well as continuously evolve to enable a full range of services.

Focusing on both network architecture and key technologies, as adopted by the core network, this white paper will provide guidance for the next phase of the 5G core network, accelerating us towards an intelligent world. We hope this paper can promote consensus in the industry, and with concerted efforts, we will open a new chapter for the mobile communications network.

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Abbreviations

Aabbreviation	Full Spelling
2C	To Consumer
2H	To Home
3D	Three Dimensions
5G NSA	5G Non-Standalone
AR	Augumented Reality
AR	Augmented Reality
CP	Content Provider
CS	Circuit Switching
DC	Data Channel
DOF	Degrees of Freedom
EPS FB	Evolved Packet System Fallback
FBB	Fixed Broadband
HCS	Harmonized Communication and Sensing
IMS	IP Multimedia Subsystem
IPTV	Internet Protocol TV
MBB	Mobile BroadBand
MBB	Mobile BroadBand
MDAF	Management Data Analytics Function
MMTC	Massive Machine Type Communication
MOS	Mean Opinion Score
MOU	Minute of Usage
NEF	Network Exposure Function
NG_RTC	Next Generation Real Time Communication

Aabbreviation	Full Spelling
NWDAF	Network Data Analytics Function
OTT	Over the Top
OTT	Over The Top
QoS	Quality of Service
RTBC	RealTime Broadband Communication
SBA	Service Based Architecture
SLA	Service Level Agreement
TV	Television
UCBC	Uplink Centric Broadband Communication
URLLC	Ultra-Reliable Low Latency Communications
VM	Virtual Machine
VoIP	Voice over IP
VR	Virtual Reality
VoLTE	Voice over Long-Term Evolution
	5G Standalone

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