5G-Advanced Technology Evolution from a Network Perspective (2021)

——Towards a New Era of Intelligent Connect X

Abstract

The commercialization of 5G networks is accelerating globally. From the perspective of industry development drivers, 5G communications are considered the key to personal consumption experience upgrades and digital industrial transformation. Major economies around the world require 5G to be an essential part of long-term industrial development. 5G will enter thousands of industries in terms of business, and technically, 5G needs to integrate DOICT and other technologies further. Therefore, this white paper proposes that continuous research on the follow-up evolution of 5G networks—5G-Advanced [1] is required, and full consideration of architecture evolution and function enhancement is needed.

This white paper first analyzes the network evolution architecture of 5G-Advanced and expounds on the technical development direction of 5G-Advanced from the three characteristics of Artificial Intelligence, Convergence, and Enablement. Artificial Intelligence represents network AI, including full use of machine learning, digital twins, recognition and intention network, which can enhance the capabilities of network's intelligent operation and maintenance. Convergence includes 5G and industry network convergence, home network convergence and space-air-ground network convergence, in order to realize the integration development. Enablement provides for the enhancement of 5G interactive communication and deterministic communication capabilities. It enhances existing technologies such as network slicing and positioning to better help the digital transformation of the industry.

Source Companies

China Mobile,China Telecom, China Unicom, China Broadcasting Network, SK Telecom, KT, CAICT
Huawei, Ericsson (China), Nokia Shanghai Bell, ZTE, CICT, Samsung, AsiaInfo, vivo, Lenovo, IPLOOK, UNISOC, OPPO, Tencent, Xiaomi

(The list above is not in any particular order)

Contents

01 5G Development

1.1 Progress

The global commercial deployment of 5G networks is in full swing. As of April 2021, 162 5G networks in 68 countries and regions have been commercially released [2]. On top of this, over a thousand industry-specific applications have been projected to benefit from the advantages offered by 5G, such as high bandwidth, low latency, and strong connectivity. In terms of connectivity specifically, GSMA predicts that 5G will boost the massive number of connections from 200 million in 2020 to 1.8 billion in 2025[3].

Overall, the global 5G industry is still in the early stages of network construction. The industry generally believes that "the future 6G technology" will not be applied until 2030. Therefore, whether in terms of business scenarios, network technology, industrial progress, deployment pace, etc., the next 3 to 5 years will still be critical for 5G development.

For this reason, 3GPP initially determined 5G-Advanced as the concept of 5G network evolution at the PCG #46[1] meeting held in April. In the future, all aspects of the telecommunications industry will gradually improve the framework and enrich the content for 5G-Advanced starting from R18.

In the process of end-to-end 5G-Advanced network evolution, the evolution of the core network plays a pivotal role. On the one hand, the core network is connected to various services and applications, which is the convergence point of the entire network business and the engine of future business development. On the other hand, the core network is connected to various standard terminals and access networks, the whole network topology. The center moves the entire body. Therefore, promoting 5G core network technology and architecture evolution based on actual business needs will help operators improve return on investment and help industry users better use 5G networks to achieve digital transformation.

1.2 Driving Forces

1.2.1 Industries Requirement

Unlike previous generations of communication networks, 5G is considered the cornerstone of the industry's digital transformation. The world's major economies have requested 5G as an essential part of long-term industrial development. For example, the European Union proposed the 2030 Digital Compass (Digital Compass) plan, which formulated outlines for commercial digital transformation and public service digitalization. It adopted 5G as the basis for Industry 4.0. As the first country to deploy 5G, South Korea has further strengthened the construction of a 5G+ converged ecosystem and promoted 5G united services. Japan continues to promote the value of B5G (Beyond 5G) to people's livelihood and society. China has also put forward a long-term goal for 2035 driven by insisting on scientific and technological innovation and deepening the "5G + Industrial Internet" as its important current goal.

Therefore, 5G-Advanced needs to fully consider the evolution of the architecture and enhance functions, from the current consumer-centric mobile broadband (MBB) network to the core of the real industrial Internet. However, it is currently possible to use network slicing, MEC (Multi-access Edge Computing), and NPN (Non-Public Network) to serve the industry. Whether it is network deployment status, business SLA (Service Level Agreement) guarantee capabilities, easy operation and maintenance capabilities, and some auxiliary functions needed by the industry, the current capabilities of the 5G network are still insufficient. Thus it needs continued to be enhancements in 3GPP R18 and subsequent versions.

First of all, in the future, XR (Extended Reality) will become the main body of business carried by the network. Not only will the definition of XR be upgraded from 8K to 16K/32K or even higher, AR (Augmented Reality) business scenarios for industry applications will also evolve from single-terminal communication to multi-XR collaborative interaction and it will develop rapidly beyond 2025. Due to the impact of business traffic and business characteristics, XR services will put forward higher requirements for SLA guarantees such as network capacity, delay, and bandwidth. At the same time, essential communication services still have a lot of room for development. Multi-party video calls and virtual meetings represented by telecommuting will become the norm. The current conference mode of fixed access and video and call will transform into a multi-party remote collaboration of mobile access and rich media and real-time interaction in business. For example, corporate employees can access the corporate office environment with virtual images at any time at home and communicate with them. Colleagues communicate efficiently. Therefore, 5G-Advanced needs to provide an upgraded network architecture and enhanced interactive communication capabilities to meet the business development needs of the existing clear voice-based communication methods evolving to full-aware, interactive, and immersive communication methods. It should also enable consumer experience upgrade.

Second, industry digitization has brought about a much more complex business environment than consumer networks. Businesses in different industries, such as the Industrial Internet, Energy Internet, Mines, Ports, and Medical Health, need the network to provide them with a differentiated business experience and provide deterministic SLA guarantees for business results. For example, the Industrial Internet requires deterministic communication transmission delays that are bounded up and down, and intelligent grids need high-precision clock synchronization, high isolation, and high security. Mines need to provide precise positioning under the surface, ports need remote gantry crane control and medical health needs real-time diagnosis and treatment information, synchronization and support of remote diagnosis with ultra-low latency. Therefore, 5G-Advanced needs to fully consider the deterministic experience guarantee for industry services, including real-time service perception, measurement, scheduling, and finally forming an overall closed control loop. For different industries, 5G needs to adopt public networks, local private networks, and various hybrid networking modes to meet the industry's business isolation and data security requirements. Therefore, 5G-Advanced should focus on the network architecture, networking scheme, equipment form, and service support capability that matches the diverse and complex business environment.

1.2.2 Network Technology Evolution

The 5G-Advanced evolution is technologically presented as a comprehensive integration of ICT technology, industrial field network technology, and data technology.

The communication network after 4G fully introduces IT technology, and the telecom cloud is generally used as the infrastructure. In the actual telecom cloud landing process, technologies such as NFV (Network Functions Virtualization), containers, SDN (Software Defined Network), and API (Application Programming Interface)-based system capability exposure have all received actual commercial verification.

On the other hand, the network edge is the center of future business development. Still, its business model, deployment model, operation and maintenance model, especially resource availability and resource efficiency, are pretty different from the centralized deployment of cloud computing. The Linux Foundation proposed that after introducing the concept of Cloud Native to the edge, it also needs to combine the various features of the border to form an edge native (Edge Native) application form [4]. Therefore, the evolution of 5G-Advanced needs to integrate the characteristics of cloud-native and edge-native, achieve a balance between the two through the same network architecture, and finally move towards the long-term evolution direction of and cloud-network integration.

For CT technology itself, 5G-Advanced needs to exert its network convergence capabilities further. These integrations include the integration of different generations and different models of NSA/SA, as well as the integration of individual consumers, family access, and industry networks. In addition, with the evolution of satellite communications, the 5G-Advanced core network will also prepare for a fully converged network architecture oriented to the integration of ground, sea, air, and space.

In addition to ICT technology, there will be more demand from production and operation in the future, and OT (Operational Technology) will bring new genes to mobile networks. For example, the Industrial Internet for industrial manufacturing is different from the traditional consumer Internet. It has more stringent requirements for network quality. It is necessary to consider the introduction of 5G while supporting minimal networking. Quality inspection scenarios based on machine vision require the network to keep both large bandwidth and low latency capabilities. Remote mechanical control requires the network to support deterministic transmission, guarantees the number of connections and bandwidth that can be promised, and the intelligent production line for flexible manufacturing also needs to be provided by the precise network positioning, data collection, and other capabilities. For this reason, wireless access networks need to have the reliability, availability, determinism, and real-time performance comparable to wired access. The integration of OT and CT will become an important direction for the development of mobile networks. 5G-Advanced networks will become the critical infrastructure for the comprehensive interconnection of people, machines, materials, methods, and the environment in an industrial environment, realizing industrial design, R&D, production, and management. The ubiquitous interconnection of all industries, such as services, etc., is an important driving force for the digital transformation of the industry.

In addition, DT (Data Technology) technology will also inject new impetus into network evolution. The development foundation of the digital economy is a massive connection, digital extraction, data modeling, and analysis and judgment. Combining 5G network with big data, AI (Artificial Intelligence), and other technologies can achieve more accurate digital extraction and build data models based on rich algorithms and business features. It can also make the most appropriate analysis and judgments based on digital twin technology and give full play to the digital impact which will further promote the evolution of the network.

In summary, the full integration of DOICT will jointly drive network changes and capacity upgrades and help the digital development of the entire society in all fields.

02 5G-Advanced Architecture and Technical Trends

To meet the needs of personal consumer experience upgrades and digital transformation of the industry. 5G-Advanced networks need to continue to evolve from the architectural and technical levels to meet diversified business demands and enhance network capabilities.

At the architectural level, the 5G-Advanced network needs to fully consider the concept of cloud-native, edge network, network as a service, and continue to enhance network capabilities and eventually move toward cloud-network integration and computing-network integration.

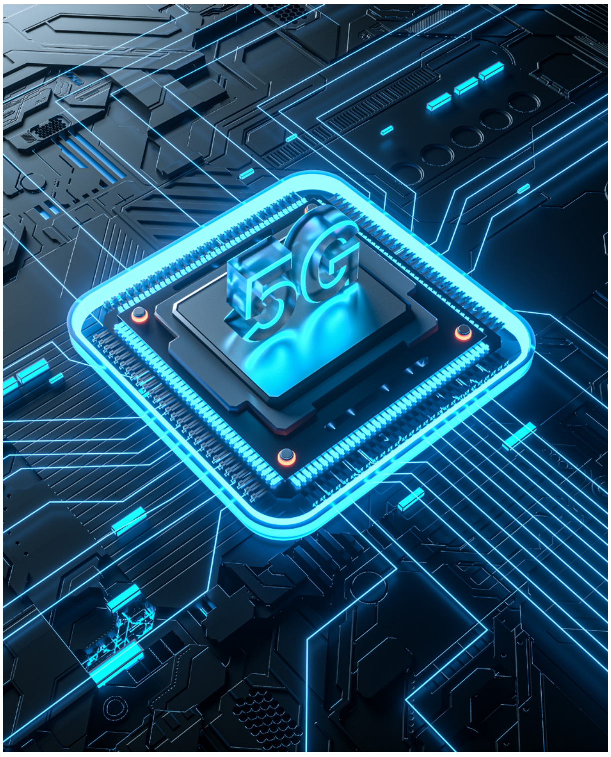
-Cloud-native is a further cloud enhancement based on the telecom cloud NFV to realize the flexible deployment of 5G networks and the flexible development and testing of functions more quickly. Cloud-native needs optimized software to improve the utilization efficiency of hardware resources, and a cloud-based security mechanism to achieve internal security of the infrastructure.

-Edge network is an efficient deployment form that combines distributed network architecture and edge services.

-The Network-as-a-Service model makes 5G systems highly flexible and can adapt to various customized solutions for vertical industry needs. The specific implementation form can be 5G network slicing or independently deployed networks. The SBA service-oriented architecture design of the 5G core network goes deep into the network logic, helping operators fully control the network and conform to the 5G network development goal of "network as a service."

This is because SBA is designed so that 5G network functions (NFs) could be developed stateless. It allows the NFs to be modularized, flexible and more application-focused for efficient communication. One of SBA’s important role is to manage and control various communications between NF services efficiently, by using request/response and subscription/notification based methods. SBA’s framework also allows robust scaling, monitoring and load-balancing of NF services.

Operators use SBA as the network foundation, network slicing as the service framework, network platform as the core, and key network function APIs as the starting point to build agile and customized 5G capabilities to help users deeply participate in the definition and design of network services. Operators need an increasing number of network features accessible via APIs so that together with slicing they can provide possibilities for automated differentiated business experience and higher business efficiency for the users and makes the connection and computing a powerful booster for developing the 5G service industry.



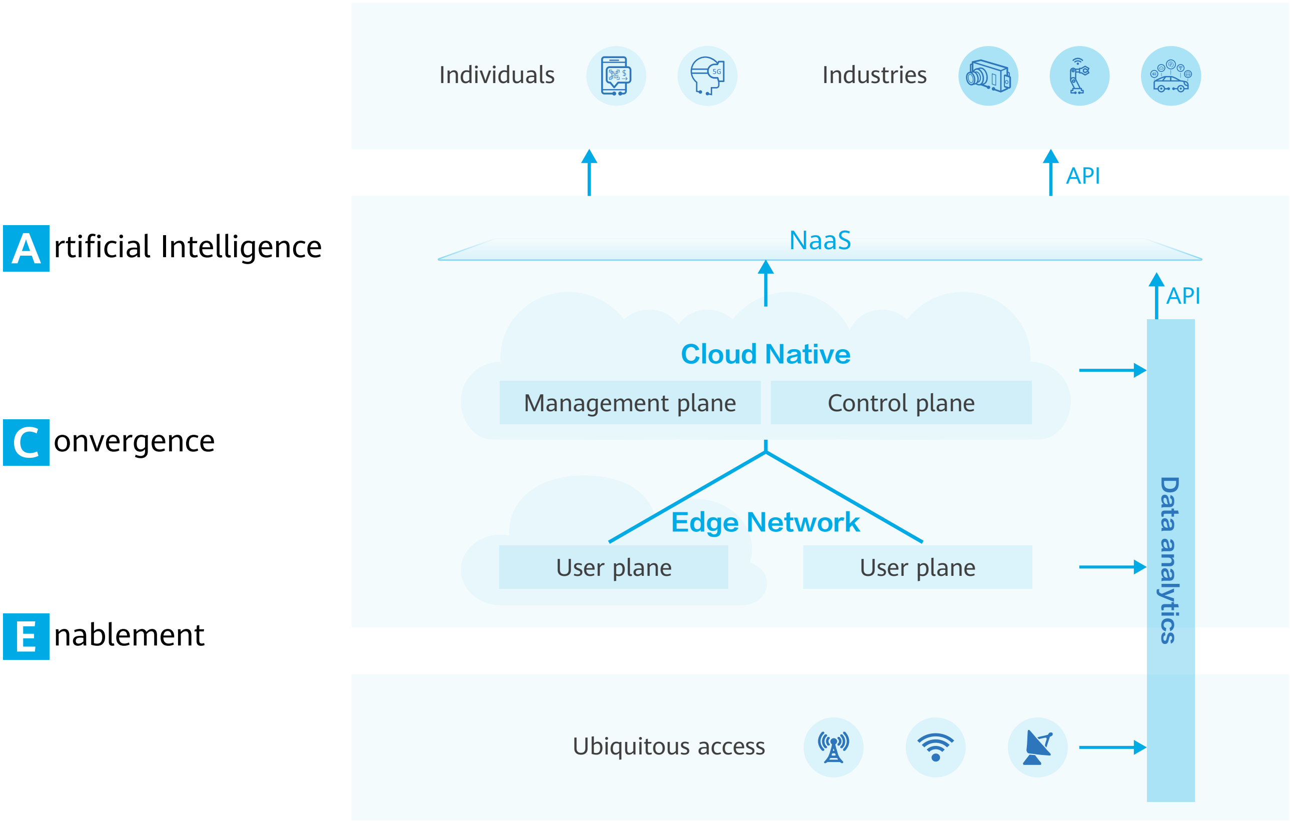


Figure 2-1: 5G-Advanced network architecture

Based on requirements that will be raised in the future, 5G-Advanced networks need to have the characteristics of an ACE: AI, convergence, and enablement.

• AI

As 5G develops, its applications and services are varying among industries. This leads to related network functions, management, and user behavior also becoming variable as well as complex. The network scale is continuously growing, but the conventional network needs heavy manual configuration, which is labor-intensive and prone to errors. Therefore, high management overhead has been added. It is necessary to introduce intelligent assistance to improve the capabilities and quality of services at all levels, from network functions to network management.

• Convergence

The convergence of different access modes and networks is the development trend of 5G-Advanced. Prior to the 5G era, various industries built independent networks, which were used for long periods, and diverse terminals, access modes, and transmission approaches emerged. However, the networks' low versatility led to the long iteration time of new functions, high cost of equipment, and slow development of technology. Therefore, the next-generation network, which should connect the air and ground and accommodate the IIoT, Wi-Fi, fixed networks, and other multi-industry and multi-protocol services, has become essential.

• Enablement

With 5G being used in industries, network capabilities continue to improve and gradually evolve from an infrastructure to enable services. Introducing new capabilities, such as deterministic networking, customization, high reliability, global control and management, and self-evolution to meet industry requirements, will facilitate the application of NaaS. This will enable 5G-Advanced to provide industries with customized networks featuring proactivity, flexibility, and resource isolation.

03 Key 5G-Advanced Technologies

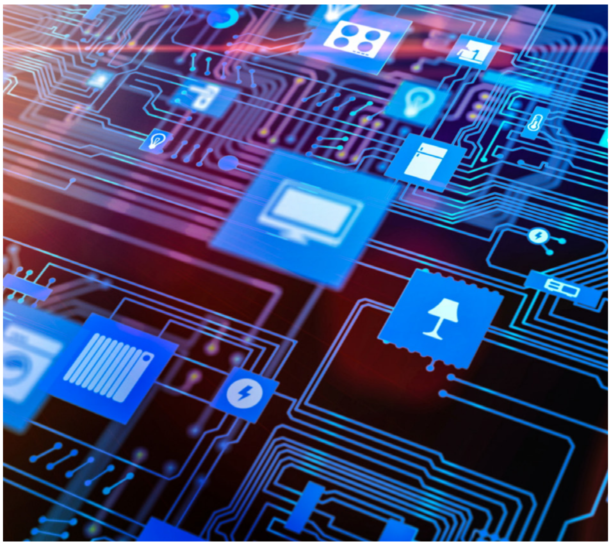
3.1 AI for Network

3.1.1 Key Technologies of AI for Network

The introduction of network resource virtualization, 5G service-oriented architecture, diversified services, and new 5G capabilities such as slicing and edge computing have brought challenges to 5G operations and commercial use. The application and integration of intelligent technology in telecommunication networks can improve network efficiency, reduce operation and maintenance costs, and improve the level of intelligent network operation.

Starting from 3GPP Rel-16, to promote network intelligence, continuous advancement has been carried out on the technical standardization of network infrastructure (SA2) and network management (SA5). NWDAF is a standard network element introduced by 3GPP SA2 in 5G. It is an AI+ big data engine. It has the characteristics of standardization of capabilities, aggregation of network data, higher real-time performance, and support for closed-loop controllability. 3GPP defines the location of NWDAF in the network and the interaction and coordination with other network functions and defines the flexibility of NWDAF deployment. NWDAF can be deployed in specific network functional units through function embedding and can also be coordinated across functional network units, to complete the closed-loop operation of network intelligence. 3GPP SA5 defined Management Data Analytics System (MDAS), which, combined with AI and machine learning, enables automation and cognition of the management and orchestration of networks and services. The MDAS can mine data value in network management by processing and analyzing network management data. It can also generate analysis reports and provide suggestions on network management and operations to promote the intelligence and automation of closed-loop network management and orchestration.

The evolution of 5G networks has increased the networks' complexity and, in turn, their O&M. Networks are required to be highly intelligent, automated, and autonomous. The networks need to automatically adjust to meet the rapidly changing service requirements according to changes in themselves and the environment. They also need to automatically perform the required network updates and management based on service and O&M requirements. To fulfill these requirements, the following AI technologies can provide reference for the intelligent development of 5G-Advanced network.



- **Machine learning**

As a basic network intelligence technology, machine learning can be widely used in various nodes and network control and management systems in 5G networks. Based on the large amount of subscriber and network data in the 5G system, combined with professional knowledge in mobile communications, a flexible machine learning framework has been adopted to build a network intelligent processing system that will be widely used and support distributed and centralized deployment.

- **Digital twin**

Digital twin technology can improve the monitoring and control of the network and prediction of its condition, for example its status and traffic, simulate and evaluate the necessary network changes in advance to help greatly improve digital network management.

- **Cognitive network**

Cognitive network technology uses algorithms empowered with mobile communications expertise and fully utilizes the big data analytics generated by the 5G network ,enhance the intelligence of network operations to enable complex and diverse services.

- **Intent-based network**

Intent-based network technology enables operators to define their network goals, which the system can automatically convert into real-time network operations. The network is continuously monitored and adjusted to ensure network operations remain consistent with the service intent.

In the future, a company can introduce advanced frameworks such as federated learning to support the joint learning and training of multiple network functional units. This can effectively enhance the training effect and protect data privacy. In addition, NWDAF can be deployed in layers, flexibly build a distributed intelligent network system, that responds better to different needs.

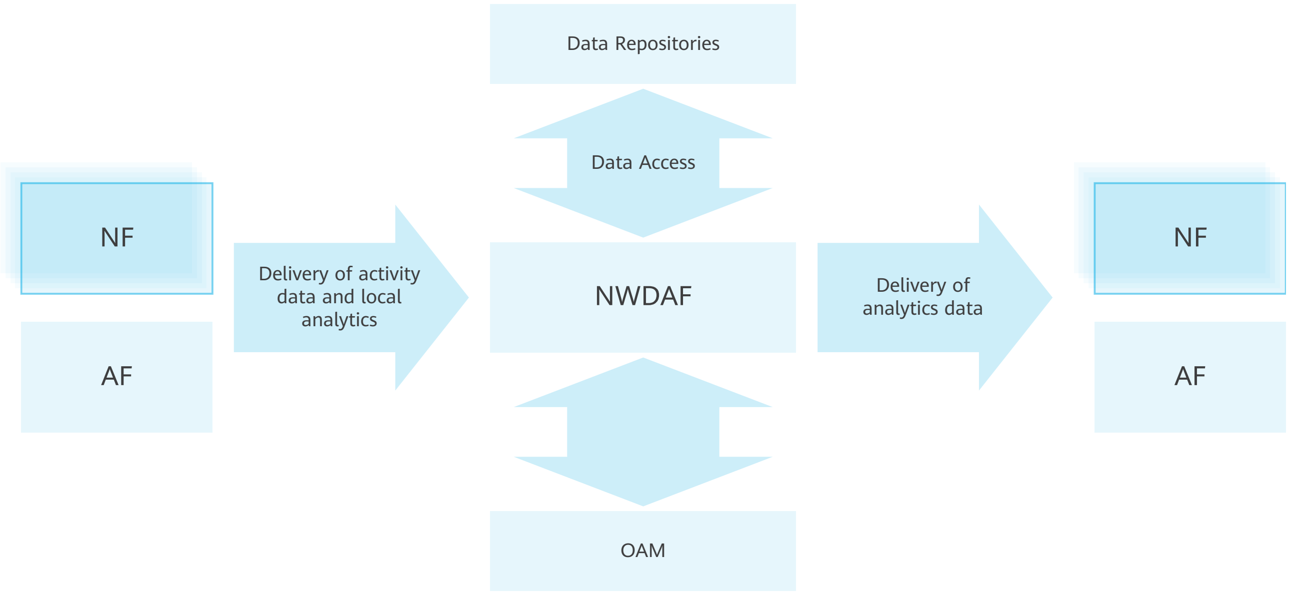


Figure 2.2.2-1: General framework for 5G network automation[5]

3.1.2 Application

To realize the construction of intelligent network, empower the digital intelligence transformation of the industry, 5G networks require the continuous introduction of AI Internally, it can better support connections, security, and management and utilize AI algorithms to transform cloud-based big data resources into intelligent planning, analysis, fault diagnosis, and adaptive optimization capabilities.

AI can help 5G networks realize closed-loop optimization of service experiences. First, user experience is intelligently monitored and then evaluated. Then, the optimal strategies are recommended through intelligent comprehensive analysis based on service requirements and network capabilities. Finally, policy adjustment and closed-loop tracking are implemented through the service experience feedback mechanism to balance network costs and service experience. For example, a relationship model between user experience indicators and QoS indicators is built through intelligent data analysis and, based on this model, user experience of current services is monitored and evaluated in real time. In addition, differentiated QoS parameters that best match users, services, and networks are generated by analyzing and mining users' communication habits. Moreover, network slicing resources and services are intelligently scheduled and optimized through reinforcement learning and other optimization algorithms to ensure premium experience of services delivered by network slices. What’s more, AI-based multi-access collaboration can ensure that multi-access resource is fully utilized with improving user experience.

Externally, network intelligent technology makes full use of the computing power, data and scene advantages of the telecom industry to redefine the end-tube cloud ecology and build a new business model of the telecom industry. Many 5G applications require the cloud, the edge, and end devices to work together to implement and orchestrate services with the assistance of data collection, model training, and intelligent inference. To better use the available and ever-changing computing and networking capabilities, AI needs to be introduced to predict the computing and network loads, as well as optimally schedule the computing, storage, and network resources across the cloud, the edge, and devices. Domain twin models can be used to simplify multi domain orchestration problems which would ensures that services can be practically and flexibly deployed and migrated on heterogeneous cloud-edge-device resources to provide the required service quality with optimal resource utilization.

3.2 Industry-Specific Networks

The integration of 5G and industry networks will become a key scenario for 5G-Advanced networks for vertical industry customers. In the industry network, 5G network can bring more business value, such as personnel protection, production flexibility, and advantages in wireless and mobility. From the perspective of networking, it can not only greatly reduce the complexity and labor cost of wired networking but also help industry customers realize the ideal of "one network at the end." For example, in the field and workshop networking in the industrial manufacturing field, 5G can simplify the multi-level wired network level at the vertical level to achieve network flattening. Based on the differentiated guarantee of 5G deterministic capabilities, 5G can realize the IT network of the field network (Such as equipment operation and maintenance data collection) and OT network (such as PLC control) into one.

The characteristic of the private industry network is to provide third-party customers with a flexible and on-demand customized network within the scope of their operation and management. The 5G industry private network can integrate the enterprise's network system with the 5G network to build unified management and seamlessly integrated industry networks.

Convergent industry-specific networks have been enhanced in the following three aspects:

1) Enhancement of network intercommunication

5G-LAN technology can use 5G networks to replace local area networks in the current industrial field. Solve cable mobility limitations and high optical fiber laying costs in existing industrial networks, and provide industry users with the ability to quickly and flexibly build private mobile networks. 5G-LAN defines a virtual network through the concept of a group and supports point-to-point and point-to-multipoint communication within the group. The 5G-LAN group can deploy one UPF or multiple UPFs and supports local exchanges within UPFs and intra-group communication across UPFs. The open API interface enables third parties to create or modify communication groups flexibly, thereby realizing dynamic group management. 5G Advance can enhance 5G-LAN technology in the following aspects:

-Further study the new requirements in industrial networks, enhance the layer 2 data transmission of mobile networks and expand the application scenarios of 5G-LAN in industrial networks. For example, factory complex scenarios require group communications with service continuity among networks, dynamic group communications in 5G LAN, and 5G LAN group QoS support.

-At present, 5G-LAN only supports one group to be served by a single SMF. In the future, it will be expanded to one group spanning multiple SMFs, thus realizing wide-area interconnection.

-Convergence of fixed network and mobile network, 5G-LAN needs to communicate and converge with traditional industrial wired LAN.

In addition, in the 5G industry private network networking, enterprises can conduct unified management and plan for terminal addresses. Constructing the N3IWF network function can also support the integration and switching of the industry's existing networks and 5G private networks.

2) Management

A central network management monitoring system replaces the siloed management systems, simplifying network management.

3) Security

The networks will meet enterprises' requirements for security and reliability. The network for enterprise can be deployed isolated from the public network and one possible way is to support industry-specific network(e.g. PNI-NPN). In terms of security, they will further support the network topology hidden. An enterprise can also incorporate a firewall to filter all data in its private network to ensure that confidential data remains in the campus. The reliability of access, dedicated resources, and connections is also improved.

3.3 Home Networks

Home networks will be a focus for developing 5G-Advanced. Already now, many operators see a peak in mobile data traffic when people are at home. This is likely to be even more so with new services for consumers (e.g. mobile gaming, or high definition mobile TV) that require every higher data rates.

High data rate services such as interactive applications are best served at higher frequency bands, where more capacity is available. However, these higher frequency bands make providing indoor coverage a challenge. It may not be possible to provide enough indoor capacity with outdoor base stations, relaying or indoor base stations may be needed to give consumers an ubiquitous coverage experience.

Unlike other areas where networks are deployed, there are more devices of different types in home networks, though they move around in much smaller areas. In addition, home network users do not require extremely high reliability, but have stringent requirements on protocol conversion and bandwidth.

In the future home intelligent IoT network, there will be various devices and types of collected data. Finding the optimal way to synchronously transmit this data, use AI algorithms to pre-judge user behavior accurately, predict device status, and implement intelligent adjustment will become the focus for the next-generation home network.

3.4 Space-Air-Ground Networks

The 5G network was built not only to provide high network speeds, but also ubiquitous mobile network access. However, in remote areas such as mountainous areas, deserts, and the ocean, building and maintaining a 5G terrestrial network is extremely expensive, which makes it impossible to provide 5G network coverage in those areas. Fortunately, the development of aerospace technology enables the satellite-based broadband communication system to provide radio coverage to large or even global areas at a much lower cost. As such, the 5G network will deeply integrate with the satellite communication system to constitute a convergent communication network that provides seamless coverage on the planet, meeting various service requirements anywhere in the world.

Current 5G networks supports the base station to adopt 5G NR system, allowing terminals to access the unified 5G core network through the satellite base station , and satellite base stations working in transparent mode, but there are some limitations on the support of voice service and higher data rate. In the future, the 5G-Advanced network will comprehensively integrate with satellites and provide the following features:

- Support for the integration of the terrestrial 5G network with satellite networks in orbit at different altitudes, for example, different mobility management strategies for low, medium and high orbit.

- When providing wireless access, the satellite can work in bent-pipe or re-generative modes to forward data transparently and process on-board data, respectively. The 5G-Advanced network can support networking for satellite-ground and satellite-satellite, in order to support terminals to use both satellite access and ground access to optimize data transmission no matter whether the satellite access and terrestrial access belong to a single operator or different operators. The 5G network can support enhanced mobility management mechanisms for terminals connecting via satellite access , such as access control based on terminal location to meet regulatory requirements, terminal seamless switching between satellite access and ground access, , policy and QoS control based on the type of satellite access, and network-based positioning to enable positioning of non-GNSS terminals and to fulfill reliable UE location requirements for regulated services.

- When the base station uses the back-haul service provided by the satellite network or satellite enabled NG RAN, the core network shall be able to perceive the status of the satellite network (such as time delay, bandwidth, etc.) to facilitate policy and QoS control considering the movement of satellites and the entire constellation. This can also help to expose the back-haul capability to the application layer to assist the application adaptation.

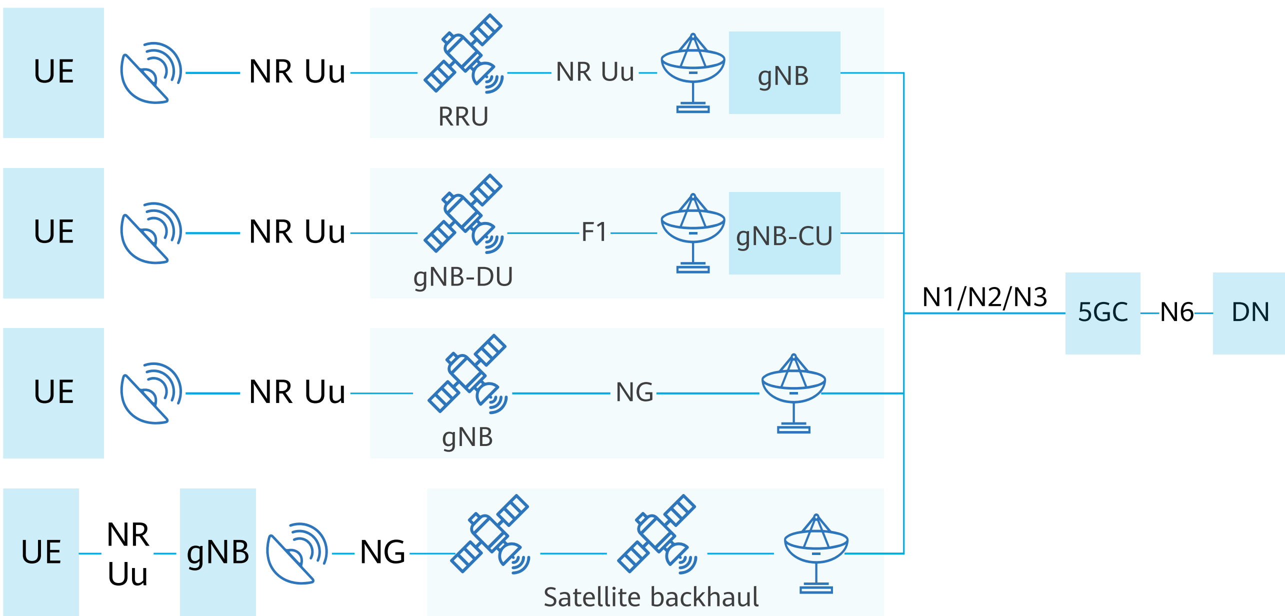


Figure 3.4-1: 5G network integrated with a satellite system

3.5 Interactive Communications

As 5G coverage expands, the screens of smart terminals increase in size, and AR/VR/XR devices develop rapidly. Consumers expect more than the conventional voice and video services and are increasingly anxious to experience digital, highly interactive, and multisensory experiences[6].

In this context, real-time communications are becoming more immersive, represented by HD video, AR/VR, and other emerging technologies. This shift not only enhances individual services, such as personalized calling, remote collaboration, AR social media, and VR communications, but also helps enterprises establish their image and carry out marketing more efficiently. For example, enterprise information can be displayed to consumers in calls from enterprises, improving the call connection rate, and interactive menus can replace audio instructions in customer services, helping customers select service options. Moreover, exposing network capabilities help enable a new wave of application innovation. Applications like ride-hailing, enterprise campus communications, and remote education have been influencing people's work and lives.

3GPP Rel-17 defines new requirements, 5QI and other QoS parameters for cloud games and XR and other interactive services. In the 5G-Advanced stage, interactive communication also needs the following key technical support:

- **IMS data channels**

Existing real-time communications networks are overlaid with IMS data channels, which enable screen sharing, AR effects, and enhanced interactions with environments and things in them.

- **Distributed convergent media**

A unified convergent media plane is established to upgrade basic audio and video services and facilitate new media services like collaborative activities and AR/VR. The media plane is deployed in a distributed manner, so that the nearest media resources can be scheduled for services to ensure the lowest possible latency and largest uplink bandwidth.

- **Programmable call applications**

Terminals are enhanced so that their web browser engine can process service data in the IMS data channels in real time and display the results on terminal UIs. This increases the flexibility of services to an unprecedented level.

- **Enhanced QoS**

Multi-flow services are coded and transferred at different layers, and the QoS of each layer is assured based on a specific 5QI. Moreover, QoS control is implemented for different data packets at a finer granularity, such as latency- or reliability-based control. In addition, new QoS parameters, including latency, reliability, and bandwidth, are introduced to help ensure that all types of data, including that from tactile sensors, is efficiently transmitted.

- **Collaboration of multi-media communication data flows**

All data representing service features is collected, facilitating smooth coordination and central scheduling of different service flows. This ensures that data packets synchronously arrive at servers or terminals.

- **Enhanced network capability exposure mechanism**

For strong interactive business scenarios such as AR/VR, the 5G system and AF directly support better user experience and more efficient use of network resources by exposing more and more real-time information.

3.6 Deterministic Communications

3GPP has defined deterministic communication capabilities since Release 15. In Release 16, the deterministic capabilities were further enhanced for the air interface, CN, networking and integration, SLA assurance and URLLC. 3GPP Release 16 defined a 5G system as one or more bridges which can be integrated transparently into an TSN architecture. On top of this, 3GPP Release 17 sketched the deterministic communication architecture for independent 5G TSN to adapt to more networking scenarios. That being said, an overarching architecture buttressing deterministic SLA fulfillment and QoS from end to end has not been ready yet. This architecture must be enhanced in the following aspects:

- **Management and deployment**

The management and deployment of deterministic network services rely on accurate requirement conversion — translating all service KQI requirements from industry players into network KPI requirements and splitting all the KPI requirements among different network domains and mapping these KPIs to deterministic network capabilities.

Operators can utilize modeling and simulation to predict and verify whether the conversion results can satisfy the service requirements on a specific network. In this way, they can adjust the network deployment and configurations in advance to facilitate service rollout and mitigate the risks of service losses.

- **Measurement and assurance**

Applications that deliver deterministic performance need to send packets at millisecond-level intervals, and thusly network resources need to be scheduled highly flexibly and efficiently. To ensure this, the KPIs related to latency, bandwidth, and jitter cannot only be measured based on average values, but also must be accurately guaranteed on the 5G-Advanced network.

- **Scheduling and coordination**

To ensure predictable, attainable QoS and SLAs for deterministic services, every part of the transmission must be scheduled flexibly and coordinated collectively.

- Applications need to notify the network of their access; whereas the network needs to sense the formats and coding approaches of various application data and recognize the characteristics and priorities of related service flows, be it from periodic services or those featuring random bursts.

- Once an application has been sensed, the network needs to schedule resources on demand, at an intra-flow, inter-flow, or service level. In addition, the network quickly establishes a closed-loop service assurance approach based on the services' characteristics and priorities. With bidirectional interfaces, the network controls data packet exchanges and coordinates them harmoniously with the E2E resource scheduling. Meanwhile, the network influences the application, pushing it to adjust traffic to adapt to the network, and thereby avoiding congestion caused by concurrent services.

- In addition, the network needs to better serve terminals by using its enhanced features, such as providing active/standby connections and supporting dual feeding and selective receiving to set up reliable transmission paths.

• Based on the vertical' s requirement, 5G-Advanced will enhance the bridge integration approach:
- In addition to the centralized TSN deployment model stipulated by IEEE, 5G-Advanced shall support more models, such as distributed deployment, to make networking more flexible and deploy more new applications. and to make services highly controllable and scalable.

• Timing service: Currently, most industries that require precise time synchronization rely on the Global Navigation Satellite System (GNSS) to manage their system time. To address the problems of malicious attacks, electromagnetic interference, weak indoor signals, and high power consumption of receivers, the 5G system needs to provide more flexible time services and serves as a backup or supplementary system for the GNSS to ensure continuous and accurate time synchronization for both individual users and industry players.

3.7 User Plane Customization

UPF should be able to support different kinds of 5G services from eMBB, URLLC, mMTC. As UPF is separated from control plane functions, the architecture is now more focused on for optimized packet-processing.

With the deployment of 5G networks, vertical industries have increasingly clear requirements for 5G in edge scenarios.. 5G UPF can be deployed and expand capacity according to market demand, which requires 5G UPF to have flexible and exposure capabilities, support function customization on demand and be able to quickly go online.

Based on the SBA design, the invocation of user-plane capabilities by other network functions can be supported. Information such as precise location information, user planeload conditions, network delays,slice related information, billing, and additional specific information that industry customers are concerned about can be exposure by 5G UPF.

3.8 Network Slicing

Network slicing is a technology that enables networks to be deployed on demand. It isolates multiple virtual E2E networks above a unified infrastructure to meet various service requirements. It is one of the key features of 5G SA. Many standards organizations such as 3GPP, ITU-T, ETSI, and CCSA have conducted standardization related to network slicing, and the network slicing-related functions and technical specifications have essentially reached maturity. To enable network slicing to be commercially used in industries, the following three areas need to be improved:

• Intelligent configuration
Network slicing-related configuration has been gradually improved through standards. For example, 3GPP defines the parameters and interfaces related to the Network Slice Management Function (NSMF) and the Network Slice Subnet Management Function (NSSMF) of each sub-domain. However, these parameters still need to be manually configured. Further work is required to find the optimal way to implement automatic, intelligent closed-loop control for these parameters to fulfill SLA requirements.

• SLA guarantee
Standards have defined the process for tenants to subscribe to their target network slices from network administrators. After subscribing to a slice, the tenant needs to be informed of QoS conditions and the slice resource usage.

• Integration with vertical industries
To better serve vertical industries with network slicing, vertical industries' typical requirements need to be considered, for example, industry customers wish to manage their slices themselves, such as self-service monitoring and data query. If a vertical industry has deployed a private network, industry users may need to access the 5G network slice for the industry and then be directed to the private network. To ensure smooth user experience, the 5G network slice and private network must be concertedly coordinated.

3.9 Positioning, Ranging and Perception Enhancement

5G positioning facilitates personnel and vehicle locating, logistics tracking, and asset management. As an increasing number of services are gravitating towards MEC, positioning capabilities are increasingly important at the network edge and need to have ultra-low latency and high precision. For instance, Vehicle to Everything (V2X) requires positioning accurate to a centimeter level with a confidence of over 90%. The 5G Automotive Association has been carrying out extensive research on reducing the transmission delay of location information based on MEC-based deployment of the location management function (LMF) and gateway mobile location center (GMLC), as well as using reference UEs to improve the accuracy and confidence of the location information.

With the development of 5G network, new network capabilities based on ranging and Perception are emerging. For example, in some scenarios of smart home, smart city, smart transportation, smart retail and Industry 4.0, there are requirements of obtaining the relative position and angle between objects, as well as perceive the distance, speed and shape of the target object. 5G-Advanced network should be further enhanced to assist the wireless network in ranging and sensing capabilities.

3.10 Multicast and Broadcast Services

5G multicast and broadcast services can transmit multimedia streams or data to various general 5G devices, which is conducive to improving the efficiency of wireless resources and the realization of innovative services. NR MBS is very important for the realization of ARVR broadcast and multicast, public safety local broadcast, V2X applications, transparent IPv4/IPv6 multicast transmission, IPTV, wireless software transmission, and Internet of Things applications.

5G networks need to consider the flexible and dynamic allocation of resources between unicast and broadcast/multicast services through 5G NR-MBS, providing substantial improvements and new capabilities in terms of system efficiency and user experience. In addition, the use of artificial intelligence technology can achieve efficient resource allocation according to the actual user experience. The 5G network could further enhance the ability to support a flexible mechanism for the ability of terminals to access broadcast services.

3.11 Policy Control Enhancement

5G supports flexible policy adjustment by introducing UE policy and user-based AM (access and mobility) policy management functions. This function can already provide the UE with capabilities such as user routing selection and access network discovery, and provide the network with capabilities such as wireless access mode, radio frequency selection priority (RFSP Index), access area restriction, and UE AMBR.

In the follow-up 5G-Advanced research, operators need to further explore the market application prospects of UE and mobility management strategies. For example, user access policy control under roaming conditions, Policy Control can support a better QoS management by utilizing a fine-grained QoS Monitoring, which effectively improves a service assurance of UE sessions. Per-slice specific QoS control helps efficient bandwidth management for supporting various network deployments such as B2B and B2C. There is also need to ensure user policy consistency between 4/5G systems under the current 4/5G interoperability situation. To better respond to requirements of high precision and low latency in industrial applications, the granularity and distribution process of existing policy management parameters need to be further optimized.

04 Conclusion

Mobile communication is always in a state of innovation and development. Today, with the first phase of 5G standards commercially deployed, the technology continues to evolve and 3GPP officially names the 5G evolution as "5G-Advanced" on April 27.5G-Advanced network will define new goals and capabilities for the 5G evolution to enable the generation of greater social and economic value through network evolution and technological enhancements. At this point, industry partners jointly publish this white paper, hoping to provide reference for the development of 5G-Advanced network.

This white paper mainly introduces the 5G-Advanced oriented network architecture and key technologies and guides the next 5G network evolution stage. The network architecture will develop along with the concept of cloud-native, edge network, and network as a service to meet the demands of rapid deployment of network functions and on-demand iteration. In terms of network technology, the 5G-Advanced network capability will continue to be enhanced along the three aspects of "Artificial Intelligence, Convergence and Enablement". Artificial Intelligent will focus on improving the level of network intelligence, reducing the cost of operation and maintenance, further promoting the application and integration of intelligent technology in the telecom network, carrying out the research of distributed intelligent architecture, and the collaborative intelligence between terminals and networks.Convergence will promote the coordinated development of 5G network with industry network, home network and space-are-ground network. Enablement will support the 5G network serving the vertical industry. While improving the representative capabilities i.e.network slice and edge computing, 5G-Advanced network will also support interactive communication and broadcast communication to make network services "more diversified". The network will become "more certain" based on the end-to-end quality measurement and guarantee, and scheme simplification.The network capabilities can be"more open" in terms of time synchronization, location services, etc.

This white paper is expected to provide reference scenarios, requirements and technical directions for the development of 5G-advanced network, in order to motivate the industrial consensus, and jointly promote the development of 5G network.

Acronyms and Abbreviations

Abbreviation	Full Spelling
AF	Application Function
AI	Artificial Intelligence
AM	Access and Mobility
AMBR	Aggregate Maximum Bit Rate
API	Application Programming Interface
AR	Augmented Reality
B5G	Beyond 5G
CT	Communication Technology
DOICT	DT, OT, IT and CT
DT	Data Technology
E2E	End to End
GMLC	Gateway Mobile Location Center
GNSS	Global Navigation Satellite System
LMF	Location Management Function
MBB	Mobile Broadband
MBS	Multicast and Broadcast Services
MDAS	Management Data Analytics
MEC	Multi-access Edge Computing
N3IWF	Non-3GPP InterWorking Function

Abbreviation	Full Spelling
NF	Network Function
NFV	Network Functions Virtualization
NPN	Non-Public Network
NSMF	Network Slice Management Function
NSSMF	Network Slice Subnet Management Function
NWDAF	Network Data Analytics Function
O&M	Operation and Maintenance
OSS/BSS	Operation Support System/ Business Support System
OT	Operational Technology
PLC	Programmable Logic Controller
QoS	Quality of Service
RFSP	Radio Frequency Selection Priority
SBA	Service Based Architecture
SDN	Software Defined Network
SLA	Service Level Agreement
V2X	Vehicle to Everything
XR	Extended Reality
5G-LAN	5G Local Area Network

References

[1] https://www.3gpp.org/ftp/PCG/PCG_46

[2] GSA 5G Market Snapshot, April, 2021

[3] GSMA Global 5G Landscape Q1 2021

[4] LF Sharping the Edge: Overview of the LF Edge Taxonomy and Framework

[5] TR23.791 Study of Enablers for Network Automation for 5G

[6] 5G VoNR+ Whit Paper, China Mobile Research Institute, November, 2020

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