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CUBE-Net
新网络 新服务 新生态

White Paper

China Unicom CUBE-Net 3.0 Network Innovation System

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I. Overview

The world is undergoing the greatest changes in a century. Under such backgrounds that COVID-19 sweeps the globe, the uncertainty of international situation is intensifying, a new round of scientific & technological revolution and industrial transformation are rising up luxuriantly, all walks of life are thinking about and exploring the future direction of their development. As the leading force of a new round of scientific & technological revolution and industrial change, the ICT (information and communication technology) industry has profoundly influenced and changed the model of economic and social development, people's production and life style. It has become an important engine of scientific & technical innovation and economic growth. Especially in recent years, with the continuous innovation and wide applications of emerging ICT technologies represented by 5G, AI, Cloud Native, blockchain and MEC, the digital transformation of the whole society has been further accelerated. As the backbone of cyberpower, digital China and smart society, telecom operators shoulder the historical responsibility of better meeting people's yearning for a better life, helping to realize China's industrial transformation, upgrading and high-quality development, through technical & application innovation and integrated innovation.

China Unicom has long adhered to the innovation-driven development strategy, closely focused on the development trend of industrial technology and changes in customer demands, continued to promote network innovation and transformation and actively built a leading new-generation information and communication infrastructure. China Unicom released the new generation network architecture CUBE-Net 2.0 in 2015, proposed the network development vision of "New Network, New Services and New

Ecology” and “decoupled and intensive network architecture for dual centers of terminal and cloud”. CUBE-Net 2.0 is based on the networking principle of leading network service capability and optimal overall efficiency under multi-resource collaboration, serving the two centers of “subscribers” and “data”. It realizes network gene reconstruction by multidimensional decoupling in deployment, service and function. Base on the core technologies as SDN, NFV and Cloud and ultra-wide network and data center, it guides to construct a cube network which features cloud network collaboration, changes as per demands and flexibility, to realize “Network as a Service (NaaS)” through the cloud service plane and intensification network operating.

Under the guidance of CUBE-Net 2.0 in the past 5 years, China Unicom has deeply promoted the network transformations of SDN, NFV, Cloud and Intelligence, achieved a series of technology and application results. They are: (1) China Unicom Industrial internet (CUII),the first comprehensive SDN-WAN in China. (2) Cloud Bond, Cloud Lease line, SD-WAN and other cloud network collaboration innovation products based on CUII. (3) A high-quality network based on SD-OTN for government and enterprise customers. (4) 100% virtualized 5GC. (5) A series of intelligent operation products such as OSS 2.0. (6) The world’s largest co-constructed and sharing 5G SA network, which supports various network innovation practices such as 5G MEC, network slicing and virtual private network.

With the advancement of comprehensive digital transformation in recent years, customer demands are changing profoundly. Industrial internet has become the next wave of internet development. Industrial digitization has brought a great demand for high-quality and deterministic ICT services in

vertical industries. With the development of 5G, MEC and AI, computing power and intelligence will be everywhere, which provide intelligent services for the efficient collaboration of computing power in cloud, edge and terminal. Computing and network will be deeply integrated. Due to the all-round applications of AI in the network, the network will accelerate its transformation of automation and intelligence. Under the background of increasingly fierce international competition in science and technology, the emerging ICT has acquired strategic importance in the competition among great powers. To achieve self-reliance and self-control of science and core technologies is a necessity to ensure network information security and national security.

Based on the comprehensive study and judgment on international and domestic situations, trends of industry development and cutting-edge technology, China Unicom proposed to upgrade CUBE-Net 2.0 to CUBE-NET 3.0, build a new generation of digital infrastructure to support the high-quality development of digital economy through architecture innovation and integrated innovation. It provides intelligent integration services for ICT, building high-quality digital life and empowering the digital transformation and intelligent upgrading of various industries.

II. New trends and challenges

(I) Macro situation

Information and communication network has penetrated into all aspects of people’s lives and gradually expanded to the production field. More and more traditional service industries and vertical industries are becoming new territory of internet, information and communication services. 5G, cloud computing, big data, artificial intelligence and other new-generation

information technologies generate more and more influence on the economic and social development modes and the transformation of people's production and life style.

First, from the perspective of international situation, the competition between great powers will be largely reflected in the field of science and technology. Geopolitics has a far-reaching impact on the development of the communication industry and has brought many uncertainties to enterprises in terms of technology roadmap and decision-making related to industrial ecology. As the most important infrastructure of a country, the continuous safe and stable operation of communication network will always be the first priority, and the importance and urgency of independent and controllable core technologies are increasing day by day. In addition, the outbreak of COVID-19 in 2020, as a black swan event, has greatly accelerated the pace of social digitalization, profoundly changed people's production, way of life and learning and injected a stronger impetus to the development of network services and information communication industry.

Second, from the perspective of economic development, traditional economic development has encountered bottlenecks, and the potential of digital economy and data economy is releasing gradually. In 2019, the scale of digital economy of 47 global economies reached US $31.8 trillion, witnessing a year-on-year growth of 5.4% and 3.1% higher than the growth of global GDP in the same period. Digital economy has become the main engine of global economic growth, and digital transformation has been promoted as a national strategy by many countries. Digital industrialization and industrial digitization have been promoted in depth, and the virtual world and the physical world have been closely integrated. Industrial internet, IoV, smart medical treatment, smart city, etc. will become new

forces to promote economic development. The network needs more bandwidth to carry traffic, more types of business and more real-time responses to various needs. Reality virtualization and virtual reality have become the important boosters of the emerging digital economy. Their interaction and integration will bring huge potential and development space for business innovation, which requires that the new network infrastructure should fully adapt to these rapidly changing new forms of businesses.

Third, from the perspective of industrial change, the computing industry represented by cloud computing has produced a huge impact on the transformation of communication network in recent years. The speed of enterprise cloud is accelerating, and the cloud traffic continues to grow. While bringing development opportunities to operators, the prosperity of cloud applications has also brought huge operational and competitive pressure to the communication industry and driven the IT transformation of communication network. The digitization of economy and society will lead the ICT industry to a new growth track and the innovation of ICT technology to a “new territory” and “uncharted waters”. Local area service, local business and low delay service are emerging everywhere. The new generation of communication technologies represented by 5G gives new vitality to the communication industry. As a key link connecting the cloud network users, the network will change from merely a pipeline to a digital economic center carrying more value possibilities.

Fourth, from the perspective of Unicom itself, as the only central enterprise in the first batch of mixed reform pilot projects at the group level, China Unicom deeply cooperates with Tencent, Alibaba, Baidu, JD and other leading internet enterprises to provide integrated innovation services and accelerate its internet transformation and comprehensive digital

transformation, and it strives to become the creator of smart life trusted by customers. China Unicom adheres to the development concept of focus, innovation and cooperation, actively promotes 5G co-construction and sharing, vigorously develops innovative technology and business pilot project, serves various industries as a new innovator, leader and creator and comprehensively embraces the new digital era. In the next step, China Unicom will continue to give full play to the advantages of “mixed reform”. Based on the network with leading architecture, quality and services, it will actively build an ecosystem with complementary advantages and win-win cooperation. It will work with the upstream and downstream of the industrial chain to assist the digital transformation of the whole society, striving to become a leading digital service provider.

To sum up, the communication industry is facing new opportunities as well as many new challenges. Operators are at a critical period of transformation. The future development of information and communication network will need to explore more value possibilities while pursuing high bandwidth, low delay and high reliability. Operators need to satisfy the new demands of individuals and corporate customers, strengthen business innovation, build a more agile, efficient, secure, reliable, intelligent and basic service environment for the development of digital economy and achieve win-win cooperation with all parties in the industrial chain with a more open and inclusive attitude.

(II) Technical trends

Five years ago, the world’s major telecom operators started the next generation network transformation planning for the year 2020 and focused on cloud computing, and the realization of cloud network collaboration was the main theme at the stage of network transformation. Five years later,

operators have realized mobile access from 4G to 5G and wired access from EPON/GPON to the 5th Generation Fixed Networks (F5G) and built ubiquitous gigabit access networks for individuals, families and enterprises. Some leading operators and overseas mainstream Internet Exchange Point (IXP)have also built ultra-fast cloud-based data center interconnection (DCI) backbone network. Thanks to the structural transformation at this stage and during the COVID-19 outbreak, China's communication network has successfully supported hundreds of millions of users to work at home, realizing the significant improvement of internet service capability from supporting entertainment of video streaming to meeting the requirements of home video office. In the next 5 years, network will undergo the following major changes:

1. From cloud network collaboration to integration of computing and network, network will become the value center

In the past 5 years of cloud network collaboration, the network is located between the cloud and the end users, which solves the connectivity between the cloud and the end users. The rich contents on the cloud can be consumed on all kinds of smart terminals smoothly. The network supports the cloud interconnection (mainly downstream traffic), providing content services for terminals. With the emergence of a large number of real-time services in the next 5 years such as Cloud VR, machine vision and automatic driving, a large amount of data generated by the terminal needs to be uploaded to the edge and cloud computing nodes for processing, and the results will be sent back to the terminal in real time. The network needs to support the burst of upstream traffic to end, edge and cloud, and provide deterministic intelligent services for terminals.

The emergence of edge computing has changed the mutual independence

of traditional cloud and network. When computing enters into the network, the efficiency and reliability of edge computing will be deeply coupled with the bandwidth, delay, security and isolation of the network. Only the integration of computing and network can efficient services be achieved.

From cloud network collaboration to integration of computing and network, the role and value of network will change. For “cloud network collaboration”, network takes the cloud as the center. From the perspective of cloud, the main requirements of “one cloud and multiple networks” are connectivity and openness, the service quality should be provided with the best effort, and the network plays a supporting role. For “the integration of computing and network”, network is user-centered. From the perspective of users, network needs to support low-delay, safe and reliable communication. The service quality requirement is deterministic, and network becomes the value center.

2. Post-classic architecture innovation will support the sustainable development of network

Shannon’s law and Moore’s law, the classical theories guiding the development of information and communication industry in the past 70 years, will be confronted with bottlenecks. After the semiconductor process shrinks to 7 nm, it is difficult for the communication network chip to meet the requirements of reducing power consumption and improving capacity simultaneously. The network nodes will evolve from centralized architecture to distributed architecture, and the challenge of network traffic growth needs to be solved through architecture innovation. The information communication network will enter the post-Moore era.

The room for improvement of the coding efficiency of wireless and optical

systems is close to the limit. While increasing the capacity by adding new spectrum, communication equipment has begun to explore the use of semantic communication, knowledge-aided signal processing and other ways to improve the transmission efficiency of the system. Wireless and optical systems will enter the post-Shannon era.

In the post-Moore and post-Shannon era, network architecture innovation becomes the key. The continuous growing of network capacity depends on the innovation of network architecture; thus, the demands of massive data transmission in the information-based society can be fulfilled.

3. Wireless network will move toward full connection, full coverage and full spectrum

From connecting consumers to connecting various industries and in the next 5 years, wireless network will continue to evolve from 5G network supporting large bandwidth and featuring multi-connection and super reliability to post-5G network with real-time, large upstream and integrated perception. In the next 10 years, the wireless network will build a full-coverage network system integrating satellite and ground communication system from cities and villages to mines, oceans and aircrafts. From Sub-6GHz to millimeter wave, terahertz and visible light, the future wireless network will make full use of the spectrum resources to provide users with 100 times of network capacity to meet the long-term development needs of the information-based society.

4. With optoelectronic technology integration, optical communication will be applied in more fields

With the development of network towards high speed, frequency and cost performance, traditional electronic technologies will face the limitations of

distance, power consumption and sustainable development. In order to improve the high-speed processing capacity of electronic devices and reduce power consumption in the next 5 years, optical and electrical technologies will move from standalone technologies to optoelectronic integration, bringing new product forms such as chip light extraction and optoelectronic packaging. Optical communication technology will further enter various fields. For example: Coherent light communication technology will be introduced to improve the transmission distance of high-speed port of data communication equipment. In order to achieve gigabit-bandwidth coverage over households, optical access will extend from home FTTH to room FTTR. In order to realize 100 Gbps high-speed data transmission between LEO satellites, laser communication will replace microwave communication. In order to meet the communication needs of underwater mobile equipment, visible light communication with higher penetration will be used to replace wireless communication. In short, light will become the vehicle of information interconnection and empower the high-quality connection of various industries.

5. IP will enhance the perceptive ability to realize multiple services on a single network

From IPv4 to IPv6, the IP network will undergo institutional changes. By using flexible service definition capability based on locator and ID separation and defining different ID attributes, network can realize the perception of services, understand the needs of services and provide better services.

SRv6 will greatly reduce the complexity of cloud network collaboration. Compute First Networking (CFN) can sense the demand of services for computing and bandwidth resources simultaneously and dispatch the data

traffic to the most suitable computing power resources for processing so as to improve the efficiency of network and computing. In the future, new ID attributes can be defined in IPv6 network, the perceptive ability of IP network for services can be continuously expanded, and the links between any services can be supported according to the needs of different industries.

Based on the flexible address of IPv6, a new IP network at port level, tenant level and service level can be built under the same system. It is compatible with traditional network and can sense multiple service requirements upwards and use multiple optical and wireless underlying network resources downwards to realize multiple services on a single network.

6. AI will be integrated into the network to build the digital twin and move towards the automatic operation network

5G network will be more complex, operating cost pressure will be greater, and ToB new service demand for network will be more dynamic. This requires the network to quickly meet the diverse and differentiated needs of different users and services. With the continuous development of SDN and telemetry technology, the abstract thinking ability of software to hardware is gradually enhanced, which lays a foundation for the construction of digital twin network system. With the maturity of subsecond/millisecond-level fast real-time network data collection, modeling, emulation, prediction and control capabilities and combined with the new architecture of the integration of computing and network, a real-time online digital twin network system can be built for the physical network to enhance network operation capability and accelerate network service innovation.

Full stack application of AI technology in the network will drive the

development from network operation to automatic operation. Automatic operation network will provide customers with click-to-connect and superb experience, safe and reliable network services. For internal network operation and maintenance, it has the capabilities of self-configuration, self-monitoring, self-repair, self-optimization and enabling innovation. Operators can comprehensively use advanced automation and intelligent technology to reconstruct the existing network architecture and operation and maintenance model, or build a new network with full stack AI, automatic operation and maintenance that is hierarchically closed-loop and intention-driven to empower agile innovation of service and provide the ultimate user experience.

7. CT will be deeply integrated with IT/DT/OT to create new digital infrastructure capability

After the transformation of communication network from IP to cloud, the flexibility, agility and openness of the network will be greatly improved. In the next 5 years, the integration of CT and IT will be further deepened. The IT/DT technologies represented by cloud native, big data and AI will be deeply integrated with CT technology to promote the comprehensive IT transformation of the network.

With the deepening of digital transformation of the industry in the next 5 years, the OT technology featuring real-time and high reliability will be integrated with the ICT technology to provide 5G+TSN and other integration solutions to meet the application needs of vertical industries.

The new generation of digital infrastructure will be a technology infrastructure integrating CT, IT, DT and OT, which can cater for all kinds of needs of the development of information-based society and digital

economy.

8. Network security will be transformed from passive protection to endogenous active defense

With the evolution of network cloud/ubiquitous and the integration of ToB and ToC services, the exposure of network openness is increasing, the "boundary" of traditional network security is further blurred, and the means of network attack will be continuously upgraded. In the future, it will be difficult for the network to guarantee its security through the passive protection mode of boundary isolation and plug-in security capability, and more powerful security genes need to be injected into the network to promote the evolution of network security system towards the original embedded, safe and reliable, intelligent and flexible active defense mode and build a new network architecture of cloud network security integration.

(III) Development challenges

The telecom operation industry has completed its first transformation "from voice operation to traffic operation", and traffic operation has become the main service income source of operators. However, with the saturation of ToC users and the continuous decline of unit traffic income, the telecom operation is facing the challenge of increasing quantity without revenue increase, and the competition between operators has become rather fierce. In the face of new opportunities in the ICT industry, operators will also face challenges from internet enterprises, cloud service providers and industry system integrators. "A boat that sails against the current will be pushed backward if it does not move forward." Only when we actively embrace new technologies and maintain the advancement of the network can we

enhance our competitiveness, seize new opportunities, gain new growth and win the second transformation from “flow operation to digital ecological operation”. Therefore, the development of network needs to face up to challenges and be brave in innovation.

Challenge I: How to design a new network architecture for sustainable development?

With the rapid development of video service, network traffic will continue to grow at a high speed in the future. Meanwhile, new changes will appear in the network flow direction characteristics. Intelligent IoT devices such as cameras, intelligent cars and intelligent sensors will be dominated by upstream traffic. Moreover, the entertainment and office demands of any location and terminal impose higher requirements for the flexibility and intelligence of network operation.

Due to the limitation of the development bottleneck of Moore’s law, traditional network devices need to further improve their forwarding and processing capacity of traffic through architecture innovation, such as the introduction of distributed cloud architecture, optical and IP intelligent collaboration and other new architectures. The growth of upstream traffic also needs to further optimize the traditional network structure dominated by downstream traffic, such as the introduction of new edge computing nodes and new technologies for flexible adjustment of upstream and downstream access resources. In the face of the flexible network operation requirements of multi-scenarios and multi-services, it is necessary to introduce AI, software definition and other new means to realize automatic operation network.

How to define new network architecture cannot only protect original

investment but also smoothly introduce new technologies and capabilities in existing networks and maintain the advancement and farsightedness of the network. It is a challenge for network top-level architecture design.

Challenge II: How to build the new network capability to ensure end-to-end certainty?

With the development of communication services from connecting people to connecting everything, emerging services such as immersive videos (Cloud VR/AR/holography), automatic driving, smart manufacturing, robot and UAV impose higher requirements for the certainty of network services.

Certainty includes committed millisecond-level delay and variation, ultra-high reliability, isolation ensuring data security and user’s requirements on independent and controllable management.

Traditional network is composed of terminal, access (wireless and optical), transmission (IP and optical), core network, edge computing platform and other separate network elements. How to connect end, communication and edge, provide the deterministic network connection required by the services and guarantee the service experience is the challenge for the network service capability.

Challenge III: How to provide new network services featuring integrated computing and network and intelligent integration?

With the construction of 5G/F5G and WiFi-6 multi-gigabit network, broadband will become the universal and basic service of digital society like water and electricity. Meanwhile, the resulting digital flood needs powerful computing facilities to deal with. Most industries do not have the ability of "connection + computing" integration technology. Communication operators

can provide cloud and network integration and computing network integration services for them.

There are great differences between traditional network connection and computing services in terms of technical system and operation management mode. How to integrate the two, solve complex technical problems within operators, and present ultra-flat service experience of integration of computing and network to customers is the challenge of network infrastructure integration service.

Challenge IV: How to build a new network ecosystem that coordinates open-source with independent R&D?

With the rapid implementation of SDN/NFV/Cloud/AI and other technologies in the telecom industry, telecom operators are required to enhance their independent R&D capabilities and continuously promote the self-research and self-maintenance of network controller, communication cloud platform, service choreographer and some data analysis system software so as to realize agile development according to the rapid changes of market and services. Open-source has become an important trend of network software development. Operators can connect with the IT industry more effectively by participating in and leading the open-source projects in the network field and strengthen the robustness of software codes and advancement of function realization. However, compared with IT enterprises and internet companies, operators lack operation experience in open-source projects. Due to the changes in the international environment, some open-source projects led by foreign parties will face many uncertainties in their future development.

Technological ecosystem has become the key to industrial competition. There are many games and disputes between open-source and closed source and

between openness and closeness. How to choose or cultivate technological ecosystem, carry out open-source projects in the new situation, promote the opening of the industry while ensuring the network performance and improve the independent R&D capability and control the core technology is a challenge for operators to build the new ecology of the network industry.

III. Vision and mission

The vision of CUBE-Net 2.0, a new generation network architecture released by China Unicom in 2015, includes customer-oriented ubiquitous broadband experiencing network, content-oriented unlimited business ecological network and cloud-oriented ultra-flat brilliant elastic network.

CUBE-NET 3.0, as a network innovation system of China Unicom in the new era, aims to join hands with partners to build a new generation of digital infrastructure for the new demands of digital economy, enhance the endogenous capacity of the network and provide a new generation of digital infrastructure integrating "connectivity + computing + intelligence" services. Upgrading the new generation of communication network infrastructure to the new generation of digital infrastructure reflects the value pursuit of China Unicom to fully serve the economic and social digital transformation, the strategic thinking of continuously deepening the IT transformation of communication network and the vision and goal of accelerating the deep integration of digital technology and real economy. Based on the network development mission of "New Network, New Services and New Ecology" advocated by CUBE-Net 2.0, the mission connotation of CUBE-NET 3.0 is added with three new meanings as follows:

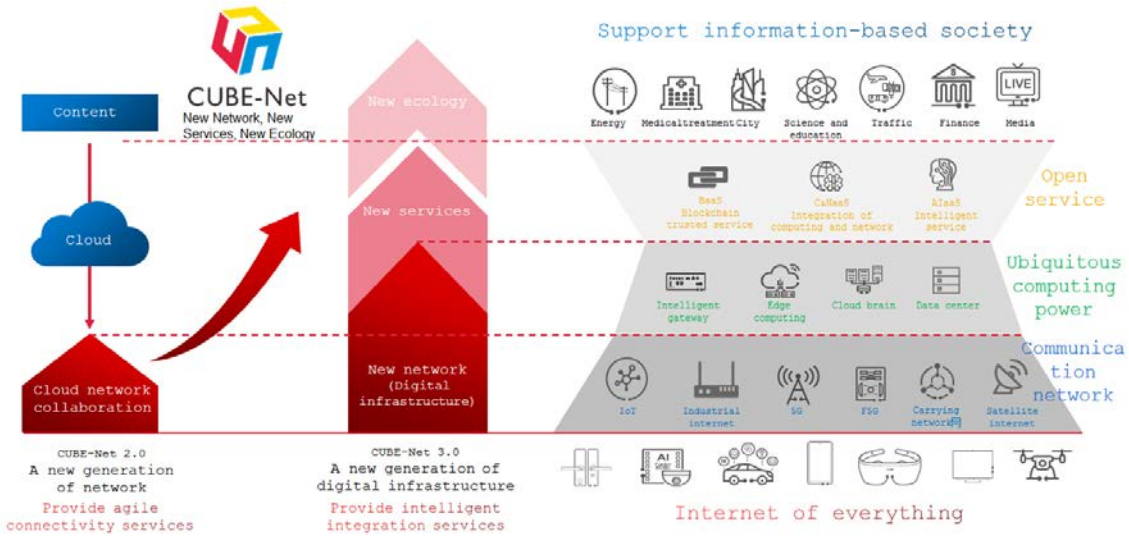

Fig. 1 New vision of CUBE-NET 3.0

(1) CUBE-NET 3.0 is the builder of "new network" based on digital infrastructure: It ranges from carrying personal communication service, providing voice, SMS and broadband services to carrier service and from providing IoT, industrial internet services to building a new digital infrastructure with connectivity and computing power by intelligently connecting everything and interconnected internet in the future. The new network not only includes the ubiquitous gigabit represented by 5G/F5G and the ubiquitous ultra-wide band with 10G-100G and deterministic **connectivity** based on 5.5G/6G/F6G in the future but also includes the network **perceptivity** of service and environment represented by IPv6+ and the network **endogenous computing power** represented by network AI, edge computing and endogenous security. The new network, which integrates connectivity, perceptivity and computing power, will become a new generation of digital infrastructure supporting the high-quality development of digital economy.

(2) CUBE-NET 3.0 is the creator of "new service" of deterministic intelligent integration: From providing single connection service of

broadband network for consumers to providing new service of “connection + computing + intelligence” with integration of computing and network and certainty and security for the needs of economic and social digitization and intelligence, it can meet the end-user’s ultra-flat brilliant service experience and improve the network value simultaneously. In order to support the new intelligent integration services, it is necessary to carry out unified classification, identification, atomization abstraction and intensive management for connection and computing resources, establish a virtual network based on digital twin, conduct real-time emulation and verification according to service requirements and conduct service choreography according to customers’ intentions.

(3) CUBE-NET 3.0 is a contributor to the “new ecology” of cloud network edge and end industry collaboration: From the era of “cloud network end”, the cloud and the end developing their own ecology and the network serving as only a dumb pipe to provide bandwidth to the new era of “cloud network edge and end”, network provides diversified capabilities including bandwidth, delay, variation, security, computing power, visual control, etc. Thus, it can deeply involve in the service logic of industry applications and intelligent terminals and achieve win-win cooperation with the end cloud industry ecology. New services call for new ecology. New services need to meet the integration requirements of customers for application, cloud, network and end. The open collaboration of industrial chain is an inevitable requirement. Internally, CUBE-NET 3.0 will rely on the access, transmission, core network, computing resources and data resources of operators and consolidates the basic service capacity of the new network through independent and controllable open-source industry ecology and developer ecology. Externally, it will extensively cooperate with cloud service providers, application service providers and terminal

providers and rely on external content services and intelligent application ecology. It provides individual and family consumers with the ultimate information life experience and vertical industries and governments with colorful intelligent integration applications.

IV. System architecture

(I) Top-level network architecture

The top-level architecture of CUBE-NET 3.0 is the inheritance and development of CUBE-Net 2.0 architecture. Based on 5G and taking a broad view on 6G, it integrates cloud native, edge computing, artificial intelligence, blockchain, endogenous security, deterministic services and other new technical elements on the basis of network SDN, NFV and cloud transformation and strengthens the deep integration of different technical and industrial elements.

The network architecture of CUBE-NET 3.0 consists of five parts: user-oriented network (UoN), DC-oriented network (DoN), computing-oriented network (CoN), all optical network (AON) and AI-driven control platform (ACP), as shown in Fig. 2.

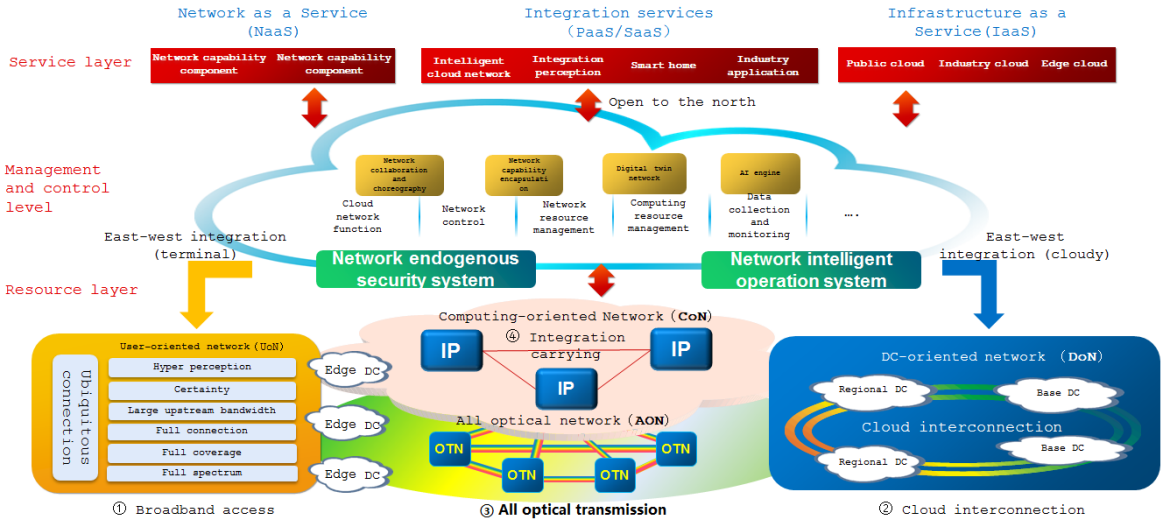

Fig. 2 Top-level architecture of CUBE-NET 3.0

CUBE-NET 3.0 network based on this architecture can provide a variety of innovative services, including:

(1) As a configurable networking as a service (NaaS), network connection is provided to users and business partners on demand.

(2) As a configurable computing infrastructure as a service (IaaS), network endogenous computing power is provided to users and business partners.

(3) The connection, voice, message, computing power, data, intelligence, security and other atomic service capabilities in the network are choreographed and coordinated through the intelligent management and control system and provided to users and business partners as the optional platform integrated service (PaaS/SaaS).

(II) Main components

1. Customer-oriented network

With the deployment and promotion of the national 5G, gigabit optical network (F5G) and other “new infrastructures”, broadband network will continue to provide consumer entertainment services for individual and family users and undertake the important task of supporting the industry’s digital transformation and empowering the information-based society in the future. The mission of broadband will expand from connecting everyone to connecting everything and from supporting telecommuting to empowering smart manufacturing.

In the CUBE-NET 3.0 technology architecture and in order to achieve the goal of intelligently connecting everything, we will greatly improve the guarantee capability of user experience through the collaboration between mobile broadband and optical broadband, enhance the access capacity through the efficient use of full spectrum and meet the full-coverage requirements of the integration of sky, earth and ocean through the combination of heterogeneous networks. We meet the access requirements of diverse terminals through differentiated network protocol mechanism innovation. We realize the access capability of large upstream through flexible physical resource allocation. We meet the requirements of industry certainty through real-time and reliability innovation in the transmission layer. We achieve the super perceptivity of access network for service and environment and meet the requirements of service experience guarantee through the combination of intelligent technology and network algorithm.

In order to ensure that the broadband network can meet the demands of differentiated services and have the economical efficiency of scale of the network, the new broadband network will also have the new capability to support end-to-end network slicing and SLA grading services on the public network.

2. DC-oriented network

At the stage of CUBE-Net 2.0, China Unicom has built a DC-oriented network, providing cloud and network integration services and supporting the development of consumer entertainment internet and telecommuting internet.

With the extensive use of cloud computing and the transformation of cloud computing industry in the deep end, enterprise cloud will go deep from IT office system to OT production system. As a key element of cloud service, network has a more prominent role and value. Due to the rigid requirements of low delay, high reliability and strong data privacy protection for enterprise production system cloud, the traditional data center is usually far away from users, which cannot meet the requirements of economy and timeliness. Cloud will move from centralization to distribution and from center to edge.

In the technical architecture of CUBE-NET 3.0 and in order to match the new demands from central cloud interconnection to cloud edge interconnection, the cloud interconnection network will extend from the core to the metropolitan area. Taking non-blocking, low delay and large capacity as the key elements, it builds a new cloud interconnection network with wider coverage and more interconnected nodes.

3. Computing-oriented network

With the rise of “edge computing”, the end-edge cloud network computing infrastructure composed of intelligent terminal, edge computing and cloud data center will become a new hot spot of ICT development driven by 5G.

At the stage of CUBE-Net 2.0, China Unicom introduced SDN technology

to realize the opening of cloud and network integration and provide corresponding services. In the technical architecture of CUBE-NET 3.0, we will continue to consolidate the integration of cloud and network, explore new business-class compute first networking technologies in combination with new business demands such as 5G+AI, edge computing, smart home and industrial cloud network and provide users with real-time and efficient computing and network integration services.

In the technical architecture of CUBE-NET 3.0 and in order to realize the efficient utilization of network computing power and provide the services of the integration of computing and network, a new IP network with one network and multiple platforms including port-level physical network, tenant-level cloud network and service-level compute first networking will be built through the collaborative innovation of computing and network technology.

4. All optical network

Optical network has become a national strategic public infrastructure, which is the foundation and premise of the development of 5G, cloud computing, big data, artificial intelligence and other information technologies. Its development level has also become one of the important indicators to measure the comprehensive competitiveness of a country.

However, as optical network plays a role “behind the scenes” for a long time, there are some problems such as complex architecture, poor flexibility and low intelligence. This is far from the positioning requirements of strategic public infrastructure in the new era.

In the technical architecture of CUBE-NET 3.0, we will combine the choreography and service ability of intelligent management and control

function to give full play to the super bandwidth supply ability, optical layer networking ability, performance guarantee ability and green energy-saving advantages of optical network, push optical network from “behind the scenes” to “in front of the stage”, build an optical service network, provide bandwidth resources for other professional networks, provide industry customers with deterministic quality lines, realize cloud and optical communication integration service and build an open, intelligent, flexible and reliable new all-optical network.

5. AI-driven control platform

At the stage of CUBE-Net 2.0, China Unicom gradually realized the transformation of network management and control system through the large-scale deployment of SDN/NFV. It carried out life cycle management for cloud virtual network functions, centralized control for network forwarding devices and introduced an end-to-end collaborative choreography layer to decompose and allocate service demands to SDN controllers and NFV management units according to the service logic and achieve service agility and automation.

In the technical architecture of CUBE-NET 3.0, artificial intelligence will be introduced on the basis of the existing network cloud and combines with the collection and analysis of network element status, network operation and service characteristic data so as to realize the capability upgrading of network element status from perception to cognition, network operation and maintenance from passive to active and service guarantee from disorder to predictability and promote the network operation from local intelligence to independent automatic operation network.

Based on the choreography layer of automatic operation network,

computing and network resources can be coordinated to provide customers with the service of the integration of computing and network such as 5G+MEC+AI and new security service of cloud and network security. In the future, the physical network can be logically abstracted based on the closed-loop of real-time data collection, analysis, emulation, prediction and choreography, and the digital twin network system can be built to accelerate the iteration of network innovation functions while reducing the impact on the existing network.

(III) Evolution of technical system

Like the image description of CUBE, CUBE-Net 2.0 defines a three-dimensional network technology system, which is divided into access layer, convergence layer and core layer according to the deployment dimension. According to the logical dimension, it is divided into resource level, control level and open level. According to the service dimension, it is divided into user domain, switch domain and data domain. CUBE-NET 3.0 inherits CUBE-Net 2.0 three-dimensional technical system and develops its technical connotation. The relationship between them is shown in Fig. 3.

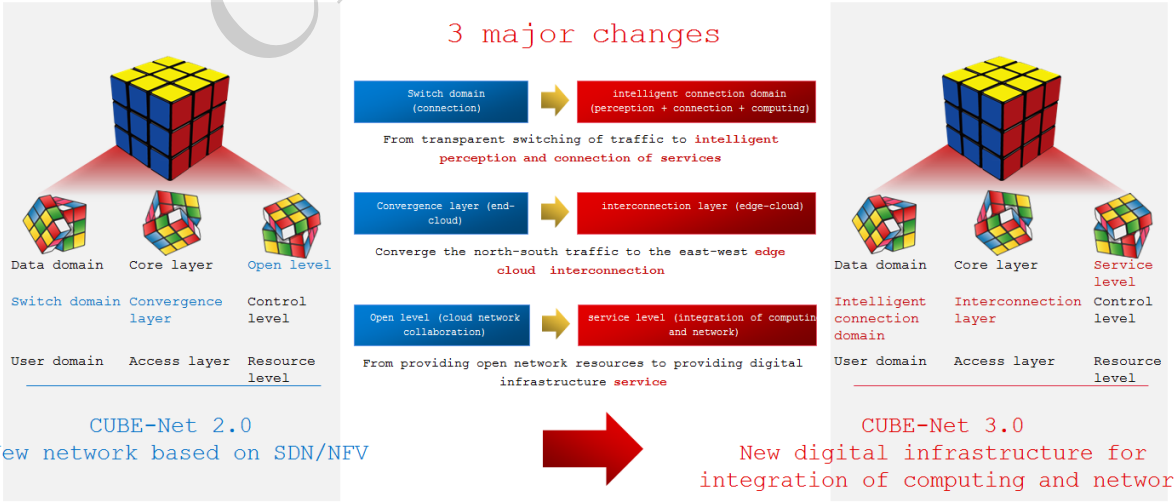

Fig. 3 Comparison of CUBE-NET 3.0 and 2.0 technical systems

The changes of technical system under the new architecture of CUBE-NET 3.0 are mainly reflected in the following three aspects:

(1) "Switch domain" is expanded as "intelligent connection domain": In the new architecture, network has the new capabilities of perception, intelligence and experience guarantee by supporting the integrated services of "connection + computing", which are combined to form intelligent connection. Network does not only provide transparent data switching but also provide edge computing services for industry customers, intelligent service experience guarantee for families and high-precision positioning and other integration perception services for individuals.

(2) "Convergence layer" evolves into "interconnection layer": In the new architecture and with the extension of the cloud to the edge, the metropolitan area network will evolve from the end-cloud south-north traffic convergence to the edge-cloud east-west traffic non-blocking interconnection.

(3) "Open level" is upgraded as "service level": In the new architecture and with the transformation of the new network to the new digital infrastructure, network service capability is not only the open service of basic network resources but also the intelligent integration services based on integration of computing and network for industries, families and individuals.

V. Technical characteristics

CUBE-NET 3.0 has the following ten technical characteristics, which are based on CT enhancement, it endogenous and integrated innovation.

(I) New connection of CT enhancement

1. Flexible broadband

With the deployment of 5G mobile network and 10G PON, WiFi 6 commercial use, mobile network, fixed network, WLAN access broadband generally reach a gigabit capacity. Information and communication services are also changing from “internet of people” to “IoT”. The deep combination of IoT and industry digital transformation imposes more differentiated demands for access services and bandwidth quality, and broadband network services need to evolve to a more flexible and intelligent direction.

(1) Provision of elastic bandwidth: CUBE-FLEX AIR technology will provide flexible dynamic spectrum sharing, system bandwidth and frame structure, beamforming and interference elimination based on artificial intelligence and flexible air interface collaboration (including macro-base stations and micro-base stations collaboration and high and low frequency collaboration). Cloud core network will provide elastic and scalable network processing capacity. Ultra 10G PON provides continuously enhanced fixed network bandwidth access capability, flexible upstream and downstream bandwidth and QoS configuration capability on demand as well as customized broadband and quality solutions for special scenarios. The IP network will realize the unified carrying of multiple services, provide real-time stepless bandwidth adjustment, QoS scheduling, programmable routing, flexible slicing and other elastic capabilities. The combination of optical transmission network and packet-based technology

provides flexible, elastic and extended physical isolation bandwidth capability (OSU, etc.) from Mbit/s to Gbit/s and realizes on-demand elastic network expansion through hybrid networking of optical and electrical nodes (OTN, OXC/ROADM, etc.).

(2) Intelligent real-time elastic configuration: The network will be based on AI technology to complete real-time demands and resource identification, realize real-time elastic resource configuration, service chain configuration, end-to-end slice-level service configuration (bandwidth + cloud + security) to achieve dynamic resource optimal configuration and maximum utilization efficiency.

(3) Integration of multiple access technologies: A single broadband access technology has been unable to meet the application requirements of complex scenarios, and multiple broadband access technologies will help provide ubiquitous access and senseless switching.

2. Ubiquitous connection

Ubiquitous connection is the basic pursuit of network development, which is developing towards “Pan micro” and “Pan macro”.

(1) In terms of “Pan micro” (micro-level machine connection), 5G network has expanded the blue sea of ToB IoT market, FTTR and other home network technologies have opened up smart home IoT, and machine connection will gradually be expanded to industrial production, family life, social life, etc.

(2) In terms of “Pan macro” (macro-level coverage), the air-sky connection technology is gradually mature. Air, sky and earth are integrated to form a three-dimensional network structure, breaking through the

limitation of surface coverage. 3GPP and non-3GPP systems (fixed network broadband, satellite broadband, WiFi, etc.) will be fully integrated or coordinated to provide more extensive and flexible access capabilities, realize real-time, low-cost and undifferentiated broadband access over oceans, high mountains, deserts, sky and other areas and make broadband resources ubiquitous and available on demand.

3. Deterministic connection

The rapid development of connection quantity and bandwidth promotes the prosperity of information application and accelerates the digital transformation of vertical industries such as industry/energy/medical treatment/IoV/videos/games. The resulting emerging businesses such as telemedicine/smart manufacturing/online VR/cloud games will drive the network to change from the best effort service for connection to “the real-time, accurate, rapid” and high-quality services. This requires communication network to have more deterministic connectivity.

(1) Stable ms-level timeliness: The delay requirement of LTE service is generally 100ms, and that of a large number of new services at the 5G stage is increased to 10ms. The delay requirement of URLLC service has reached ms level. The sensitivity of government and enterprise services to delay has reached ms level, and some financial transaction customers are willing to pay higher fees for shortening delay per ms. The customers’ demands for the stability of delay are also improved, and the delay variation in the process of signal transmission will obviously affect the user’s experience of real-time services.

(2) Precise μs-level synchronization: Most of deterministic network applications require time synchronization between terminal stations, and

some queue algorithms also require network node synchronization. The precise time synchronization requirements of services require more network devices and hosts to synchronize the end-to-end clock accuracy of the network to be within 1μs by using precise time protocol (PTP).

(3) Ultrahigh reliability: The increase of network connection quantity and the deployment of distributed computing power greatly increase the complexity of the network. The impact of network failure will be more extensive. As services impose more stringent requirements on reliability, network needs to enhance the reliability in an all-round way.

(4) Diversity and isolation: Industry users have a strong demand for their own data security. Isolation is the most basic means to ensure the data security of customers. Edge computing and other technologies can provide customers with an isolation guarantee that the data will not leave the park. A variety of isolation technologies and their combinations based on slicing concept will provide customers with end-to-end flexible and diverse service isolation services and ensure customers' network performance such as bandwidth and delay, which will not be affected by other slices.

(5) Global visualization: Based on massive network real-time data collection and integrated AI data processing, communication network will evolve to real-time visualization operation and service modes. Network topology, performance, fault, service bandwidth and routing as well as customer bandwidth, topology, routing, performance, network status and history, network and service deployment, configuration, maintenance and management will be presented in a visual way.

(II) New IT native capabilities

4. Cloud native

Cloud native is a new trend of cloud computing, which has many advantages such as automation, standardization, consistency of multi-environment delivery and easy expansion. It simplifies operation and maintenance, supports heterogeneous hardware, reduces complexity and operation cost, improves utilization and cost performance and shortens TTM so as to promote service innovation and so on.

(1) Cloud native network: In terms of architecture design and technology selection, cloud native technologies (such as containers, microservices, lightweight API interfaces, hardware and software decoupling, DevOps, etc.) will be directly used for cloud network functions, which will be directly deployed to the cloud platform and provide greater flexibility, elasticity and portability across cloud environments.

(2) Cloud native operation and maintenance: Based on cloud native online operation and maintenance tools, online timely and accurate network operation and maintenance can be realized. The operation and maintenance for cloud native can be managed and distributed by KubeEdge and other tools to maximize the advantages of rapid deployment of containers and meet the requirements of operation and maintenance.

(3) One network and multi-cloud: From the 5G era, cloud has been moving from data center to integration of cloud, edge and network, connecting multiple cloud resources with a carrying network and using the native advantages of cloud to realize hybrid cloud, cloud-cloud collaboration, cloud edge collaboration and edge autonomy.

5. Intelligence native

With the development of artificial intelligence, the application of AI technology in the field of communication network has become increasingly

prominent, which promotes the network to move towards the automatic operation network. Network intelligence native is mainly reflected in three levels: service + AI, network +AI and network element +AI.

(1) Service + AI: from disorder to manageability

Using AI technology, network can learn about the service attributes and provide differentiated transmission and services by learning the characteristics of service flow message, build a new guarantee capability for internet or industry applications from disorder to predictability and manageability and enhance user experience. For example, it provides guarantee and optimization services for games, Cloud VR and other services that require low delay or packet loss probability and improves the service experience of terminal consumers. By analyzing the characteristics of hacker attack message, the security risk can be identified without touching content privacy, and the intelligent security guarantee can be provided.

(2) Network + AI: from passive to active

Based on CUBE-Net 2.0 system, CUBE-NET 3.0 digitizes a large number of experts' experience in communication network, uses the AI technology to improve network analysis and decision-making abilities and realize network flexibility, high efficiency and super automation, such as automatic deployment, fault pre-emulation, post verification, preventive prediction and active optimization and improve operation and maintenance capability from passive to active.

(3) Network element + AI: from perception to cognition

By introducing AI technology into network elements and upgrading them to digital intelligent network elements, each network element can have multi-

dimensional and real-time perceptivity, including service flow, resources, topological state, operation and maintenance events, its energy consumption, etc. In this way, the whole network can be more sensitive to perception, processing and reasoning execution. It has the closed-loop ability of independent perception and decision-making and can also achieve more efficient collaboration together with the cloud and network management and control level.

6. Blockchain/DLT native

Blockchain/DLT technology is characterized by multi-party participation, tamper proof, traceability and decentralization. Blockchain/DLT can provide important technical means for native trust, heterogeneous collaboration and value delivery of CUBE-NET 3.0 network.

(1) Enhanced native trust based on Blockchain/DLT

Trustworthy network infrastructure: Based on the blockchain/DLT enabled decentralized identity mapping/resolution management and resource catalog system such as domain name, IP/AS, DID, certificate and device tag, it can improve the network autonomous management and natively trusted. Through the unified catalog of network (entity) status such as MSI (machine state integrity), the transparency, consistency and verifiability of network (entity) status can be improved.

Distributed trust and network micro unit autonomy: The internetwork collaboration based on distributed trust such as international roaming settlement, number portability and heterogeneous network data collaboration can reduce operation and maintenance costs and improve user experience. The collaboration of heterogeneous edge autonomous micro units helps provide distributed network services.

Trusted access of network entities and trustworthy behavior: Zero trust network access under the background of fuzzy trust boundary and identity-driven trusted behavior verification.

(2) Trustworthy decentralized network resource sharing and value delivery

Network resource sharing and value delivery such as computing power sharing, spectrum sharing and content sharing improve the efficiency of resource allocation and economic benefits.

Distributed trusted data sharing and privacy computing, network digital twin and intelligent trusted digital infrastructure can protect data ownership and privacy meanwhile mine the data value.

(III) New system of integrated innovation

7. Endogenous security

Network endogenous security refers to the technology of native creation and symbiotic evolution of security protection capability and network communication capability. It injects an endogenous security gene into the network so that the network can take more responsibilities of security trust and protection supervision and reduce the security pressure of application side and terminal side. Network endogenous security capability has the following characteristics.

(1) Embedded native: Security capability is concomitantly designed with the network, the security and trust attribute is added to the underlying protocol of the network, and the security function is integrated in the network devices and chips so that the network has an active defense capability and meets the service security requirements effectively.

(**2) Collaborative aggregation:** Network and service security situation can be fully sensed, cross-domain and cross-system interconnected response is achieved, and end-to-end secure communication is provided for services.

(3) Flexible intelligence: Security capability can be intelligently adjusted and rapidly deployed with the changes of network and system, continuously guarantee the security of network, service and data and have the ability of self-adaptation and self-growth.

(4) Pervasive and open: It can adapt to multi-scenario and heterogeneous networks, and its unified interface can output security to the third party.

8. Technical integration

(1) Integration of CT and IT: With the evolution of communication network to cloud, NFV and SDN, IT elements are extending from the management layer of communication network (EMS, NMS) to the service layer of network (NaaS, PAAS, SaaS, etc.), the control layer (SDN controller, collaborative choreographer, etc.) and the network element layer (5GC, vSwitch, vBRAS, etc.) and have gradually become the endogenous components of the communication network.

(2) Integration of CT and DT: Network will strengthen the real-time perception for users' service needs and changes, network resource capacity and load, network operation status and service quality. DT technology is fully utilized and artificial intelligence is introduced to realize the intelligent maintenance and operation of the network and predict the development of the network. The digital twin of the network is built to digitally restore the running state of the cloud network and realize the traceability, predictability and easy adjustment of the network.

(3) Integration of CT and OT: Service-oriented architecture is the key to planning highly complex enterprise resource system. The data layer and the transmission layer of the traditional field bus OT network need to be decoupled. The data layer will be open and shared. The transmission layer will adopt new industrial network carrying technologies such as 5G URLLC, TSN and industrial PON which support timeliness and reliability.

(4) Integration of connection and computing: With the integration of IT, DT and CT technologies and the development of edge computing, the connection capability provided by traditional communication network and the computing capability provided by IT/DT technologies will be more closely coordinated and integrated. The cloud and network integration service of network + central cloud will gradually evolve into the integration of computing and network, and the compute first networking is becoming a new direction of network technology development.

9. Architecture simplification

Reducing the cost of network construction and operation is not only the basic demand for operators to reduce cost and increase efficiency but also an important guarantee for the future sustainable development of network and the digital transformation of empowering social digital transformation. “The greatest truths are the simplest”. The construction of ultra-flat network has become an important pursuit of network planning and design.

The basic technology of electronic information has entered the post-Moore and post-Shannon eras. The most direct and efficient way to optimize the network cost is the intergenerational evolution of network and the innovation and optimization of network architecture. For example, 5G network is constructed in C-RAN mode, and the architecture optimization

such as decoupling of control level and user level of core network directly promotes cost reduction. The realization of dynamic flexible resource scheduling and scaling based on AI technology will optimize resource utilization under the condition of ensuring network service quality, and measures such as shutting down and standby for idle resources will be taken in real time to further reduce network OPEX cost.

10. Open capability

Based on the open architecture design, CUBE-NET 3.0 network of China Unicom promotes the opening of capability and will aggregate the industrial ecology with an open attitude to achieve a win-win pattern in the industry.

(1) Provide open capability for multi-cloud scenarios: Include the opening of network infrastructure capabilities and IT basic capabilities such as public cloud, private cloud, edge cloud and industry cloud.

(2) Provide open capability for industry applications: On the one hand, it provides industry applications with higher quality and more differentiated digital infrastructure services than traditional internet. On the other hand, it promotes the deep integration of CT and OT and opens the interface, resources and capabilities of CT network for OT applications, and OT uses CT capability to implement digital transformation of enterprises.

(3) Provide open capability for developers: Network is built as a capability platform to attract more developers to develop applications and services based on network capabilities and provide more valuable and characteristic services to customers. Meanwhile, it will reduce the R&D threshold and costs of developers and accelerate service innovation through

open-source in the field of network software.

VI. Service characteristics

The main purpose of building a new generation of CUBE-NET 3.0 digital infrastructure is to provide new infrastructure services required by the digital transformation of economy and society. CUBE-NET 3.0 has the following six new service characteristics.

(I) Integration services

Through the combination of CT and AI, IT, DT and OT technologies, we provide integrated service products, including:

(1) Intelligent, supportable and choreographable network connection and service chain service;

(2) Integration of network and computing power;

(3) Integration of optical transmission and cloud service;

(4) Collaborative service of “cloud network edge and end industries”.

(II) Intelligent service

With the development of SDN, NFV, edge computing and other technologies, 5G network application scenarios will be more diversified, business models and processes will be more colorful and complex, and service objects are changing from ToC to ToB. ToC extracts universality from individuality, while ToB mainly serves individuality. Different service objects lead to different demands for network services. CUBE-NET 3.0 will be based on multi-source heterogeneous integration data and

AI technology, actively learn users' behavior characteristics, automatically perceive demands, automatically allocate network resources, realize agile and accurate service scheduling and optimization and provide the best service experience for users with intelligent service means.

(III) Value service

CUBE-NET 3.0 hopes to change the traditional business model of network traffic and measure the value of network services by creating value for customers. Network architecture will reinforce the perception, openness and empowerment of services and especially help government and enterprise customers to make full use of the network endogenous ability to achieve digital transformation and create greater economic benefits. China Unicom has developed high-value network products for government and enterprise customers such as Cloud Networking and private network for governments and enterprises. In the future, it will also use technical means such as URLLC, 5G slicing private network and endogenous security to realize win-win values with customers based on the innovation of business and service models.

(IV) Deterministic service

The "best effort" service capability provided by traditional network can no longer meet the multi-dimensional, differentiated and customized requirements of vertical industries digital transformation and smart manufacturing applications. Based on the smooth evolution of the original network, CUBE-NET 3.0 network architecture will continue to enhance the end-to-end deterministic service capability of the network, including high bandwidth guarantee, deterministic delay, bounded delay variation, high-

precision positioning and network lossless transmission. Based on the deterministic and stable basic network capabilities, it provides controllable, safe and reliable deterministic services for the demands of industry customers.

(V) Customized service

With the integration of CT network and IT/DT technologies, communication network has evolved into an intensive digital empowering platform, which has stronger, more flexible, real-time and open business service capabilities and can provide customized services centered on customers, including:

(1) Optional network service contents: Based on the operator's end-to-end automatic choreography layer, customers can choose one or more standardized network services (such as cloud service, ICT service, cloud access, internet access, network slicing, network security, etc.) according to their own requirements.

(2) Dynamic adjustment of network services on demand: Customers can independently initiate dynamic adjustment demands including connection quantity, bandwidth, PaaS resources, IaaS resources, etc. Customers' requests are directly sent to the network choreography control layer through the service center to adjust the services in real time.

(3) Visual, manageable and controllable network services: Operators can provide visualization of ordered network resources and services to upper applications, open certain network control rights according to customers' demands and allow customers to control the network independently based on the visual network service.

(4) Private network service: In addition to providing standard network

capabilities and services, it can also provide customized private network construction and operation services for VIP customers.

(VI) Endogenous security service

Network endogenous security capability can provide external security services and open interface calls to customers.

(1) Collaborative and integrated security services: Network endogenous security injects a variety of security genes into the network, the security boundary is more detailed, the security capability coordinates better with the edge resources of cloud network, the security strategy further fits the service requirements and integrates the native and plug-in security capabilities to provide end-to-end integrated protection services.

(2) Pervasive and open security service: The network has a strong endogenous security adaptation capability and can provide different security services for 5G, home broadband, dedicated line, IoT, etc. according to different network characteristics. Meanwhile, it has an open interface, which can provide a security capability for partners to call from the third party.

(3) Elastic on-demand security service: Network endogenous security can flexibly schedule security resources, provide different security protection levels and security service combinations according to customers' appeals.

VII. Innovation direction

In order to promote the realization of CUBE-NET 3.0 architecture, China Unicom will launch the following series of network technology innovation work, aggregate industrial chains and innovation chains and accelerate the construction of a new generation of digital infrastructure through technical

R&D, experimental verification and commercial practice.

(I) Ubiquitous and flexible mobile broadband

With the steady promotion of 5G network construction and application, 5G service is characterized by differentiation, integration and diversification. Large upstream bandwidth will become the new bottleneck of 5G network development, and mobile broadband needs to evolve to higher spectrum and larger bandwidth. IoT brings a large number of medium and low rate services and large bandwidth services coexist for a long time, which will require more intelligent, flexible and elastic bandwidth resource management. In the next 5-10 years, mobile broadband will evolve to be ubiquitous, elastic, intelligent and green.

FLEX AIR is a wireless network technology system under the CUBE-NET 3.0 system, including:

(1) Flexible bandwidth technology

Spectrum resource is the foundation of wireless communication system, and full spectrum 5G reconfiguration will become the basis of 5G network continuous evolution and development. The first is large bandwidth capability. In millimeter and terahertz frequency bands, the bandwidth of single carrier is more than 400MHz, and the operation bandwidth is more than 1GHz. The second is the spectrum resource pooling, and high, medium and low frequency resources are efficiently coordinated and accessed on demand so as to realize the pooling management of cross-band resources. The third is the bandwidth resource allocation is intelligence, which can match the bandwidth resources intelligently according to users' service demands. More intelligent, flexible and refined BWP technologies are utilized to meet the requirements of different bandwidth services and

improve resource efficiency.

(2) Flexible time slot technology

The upstream and downstream requirements of a large number of ToB services are completely different from those of ToC networks. It is urgent to adopt flexible slot configuration scheme to solve the upstream bandwidth demands on the basis of interference avoidance and achieve optimal resource utilization and user experience. The first is to accurately predict the trend of service demands based on AI and determine the time slot configuration requirements. The second is to realize the real-time adjustment of time slot configuration according to the service requirements and achieve the flexible configuration of symbol level. The third is to use artificial intelligence to identify and avoid interference features and match service with performance.

(3) Smart upstream technology

Based on “smart time slot” + “carrier aggregation” + “exclusive terminal” and through the integration with AI technology, upstream enhancement can be achieved in time, frequency, power and antenna concurrency, and the upstream network capability of ultra-gigabit can be created to meet the demands of upstream bandwidth enhancement in the future.

(4) Deterministic technology experience

5G network will adopt a variety of schemes to meet the differentiated and deterministic service guarantee demands of industry applications. The first is to build an end-to-end QoE standard system and AI-based real-time service guarantee scheme through service perception, service experience collection and real-time service guarantee schemes so as to realize certainty

of service experience. The second is to achieve millisecond-level precision time certainty through 5G low delay technology, 5G+TSN integration, end-to-end service delay perception and core network, transmission network, wireless network segmented delay control and other technical solutions. The third is to achieve a high-precision positioning capability based diversified positioning technologies defined by 3GPP and by combining with positioning technologies such as Beidou, ultra-wideband (UWB) and Bluetooth and create the spatial deterministic service capability

(5) Wireless access to cloud network

Wireless access to cloud network is a key link in the deep integration of IT and CT. It is necessary to gradually promote wireless cloud base station which feature hardware white-box, software virtualization, resource pooling, open capability, intelligent management and flexible deployment. The first is to promote the underlying universal hardware reference architecture and support the flexible deployment of RF on demand. The second is to promote the virtualization and containerization of base station functions, realize wireless resource pooling and improve system efficiency. The third is to build a wireless network cloud platform, introduce wireless network intelligent network element and empower intelligent computing power.

(6) Wireless AI

The integration of 5G and AI will become the key direction of wireless technology evolution in the next 5-10 years, which can be based on scheduling algorithm for the integration of service demand, user grouping, scheduling prediction and network MCS/RANK quality and accurately match the wireless resources for users. Meanwhile, service intention can be thoroughly understood through network perception, user perception, service

perception and other technologies. We can intelligently select and coordinate the resources between networks, optimize mobility management, interference management, load balancing and other processes and realize intelligent service navigation.

(7) Intelligent trusted technology

Under the background of 5G co-construction and sharing, the intelligent trusted demands of resource management and use of sharing parties becomes the key to the future refined network operation. In the future, the intelligent trusted scheme of co-construction and sharing can be realized through federated learning + blockchain technology, meeting the refined operation requirements of trusted resource use data, trusted and visual resource allocation, trusted billing and settlement data, etc.

(II) Ultra-wide and high-quality optical access

The wired access network is evolving from 1G PON and WiFi 5 to 10G PON and WiFi 6, achieving the access capability of gigabit to homes. In the next 5-10 years, the optical access network will develop in the following directions.

(1) All optical access extends to the end users

OLT needs to support a variety of forms and flexible networking so as to meet various service demands in the future. Optical fiber continues to extend to the end users, and FTTR ultra-gigabit is connected to rooms to realize stable large-bandwidth and low-delay access in the room. FTTM supports optical fiber to extend to the machine, and FTTD supports optical fiber to extend to the desktop.

(2) Slicing differentiation and capability open to all

OLT supports end-to-end slicing to meet the differentiated carrying demands of services such as applications of home broadband, governments, enterprises and industries. OLT upstream supports VxLAN, VLAN, ODU/OSU, SRv6 and other forwarding routing modes. It adopts technologies such as HQoS, chip physical isolation, PON port physical isolation and WiFi air interface slicing to realize end-to-end slicing in combination with carrying network slicing. According to the services and applications, the diversion of different slices can be conducted, supporting synchronous interconnection with cloud side service.

(3) Ultra-wide access

50G PON: Single wavelength TDM-PON architecture is adopted, and its rate is 5 times faster than XGS-PON. Meanwhile, it supports different ONU rate combinations: 50G/12.5G (domestic customers), 50G/25G (domestic customers and government and enterprise customers) and 50G/50G (high-end government enterprise customers). With the same PON port, 50G PON ONU can coexist with 10G GPON ONU or 10G EPON ONU.

WiFi 7: Focus on 320MHz bandwidth, Multi-RU, 4K QAM, Multi-link and Multi-AP collaboration technologies, provide the rate above 30Gbps and improve the delay and variation indexes of extreme scenarios.

(4) Openness of embedded computing power

End and edge deployment of computing resources helps achieve application perception and real-time pipeline optimization and support application scenarios such as experience management, potential customer mining, intelligent operation and maintenance by using the AI capability of cloud edge and end collaboration.

The embedded computing capacity of OLT and ONT is opened and coordinates with the cloud side ecosystem to realize optimized cloud of video optimization, video surveillance return, industrial IoT and other application scenarios.

(III) Intelligent and open all-optical foundation

New services in the cloud era require stable connections of “three lows and four highs”, namely, low delay, low variation and low packet loss; high bandwidth, high reliability, high security and high availability. Due to its rigid pipeline characteristics, it naturally has the capability to provide high-quality connections and has become a solid foundation for new infrastructures and ubiquitous networks. However, the current optical network has such problems as complex architecture, poor adaptability and low intelligence. It is urgent to evolve from a bandwidth-driven pipeline network to an experience-driven cloud service network and provide automatic, intelligent, high-quality capabilities and ultra-wide capacity base. China has gradually formed a basically independent and controllable optical network industry, which provides conditions for continuous innovation and low-cost sustainable development of optical network and lays a solid foundation for a network power.

China Unicom proposes the architecture and network construction concept of all-optical base to build an all-optical network oriented to quality service and cloud transformation. The overall architecture is shown in Fig. 4.

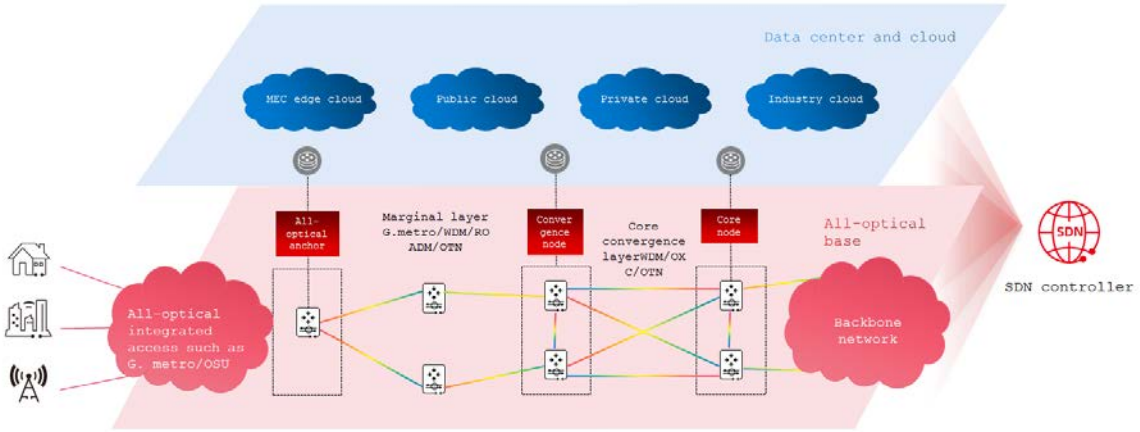

Fig. 4 Overall architecture of all-optical base

The all-optical base of CUBE-NET 3.0 has four key features: (1) Stable architecture, all-optical switching, large bandwidth and scalability; (2) All-optical anchor, all-service access, service into the cloud with a jump; (3) Intelligent management and control to realize automatic operation and maintenance; (4) The end-to-end slicing provides differentiated SLA services for multiple services in one network. The key technologies include:

(1) High-speed transmission

200G/400G/800G high-speed transmission technologies are gradually mature and will be introduced into the network, and the cost and power consumption per bit of optical transmission will be further reduced.

(2) Optical fiber spread-spectrum communications

At present, optical fiber spectrum is still dominated by C-band, so we should make full use of optical fiber resources, spread spectrum to C-band, C+L band and even the whole band so as to greatly improve the system capacity at a low cost.

(3) Optical cross-connect (OXC)

Optical cross-connect equipment with wavelength selection switch and optical backplane and other technologies is adopted to realize zero fiber connection, plug and play, flexible scheduling, smooth capacity expansion and ultra-large capacity wavelength scheduling in the station and thus greatly save machine room space and power consumption.

(4) Flexible optical service unit (OSU)

Service-oriented flexible optical service unit (OSU) can carry low-speed services efficiently, provides an all-optical base slicing solution and is the potential evolution direction of the OTN technology.

(5) All-optical integrated access

G.metro, a wavelength-tunable DWDM optical module, has the characteristics of wavelength adaptation and large system capacity and can realize all-optical integrated access (λaaS) and greatly simplifies the network construction, operation and maintenance.

(6) Multi-scenario adaptation and open networking

Based on the standardized north-south interface and unified management and control, the open network construction of optical network is realized, and the open all-optical base with multiple suppliers and diversified equipment forms is built.

(7) FlexO interface technology

Based on FlexO interface technology, inter-domain and intra-domain interconnection of ultra 100G OTN network is realized.

(8) End-to-end high-precision clock

OSC single-fiber bidirectional compensation free high-precision clock synchronization transmission scheme of the WDM system is adopted to improve the network maintainability.

(9) Centralized + distributed control-level protocol architecture

Centralized SDN realizes the optimized service path calculation with global resources. The advantage of distributed control protocol lies in agile and efficient execution, millisecond-level fault perception and rapid response. The all-optical service network control protocol based on centralized + distributed architecture provides the ability of massive connection, ultra-high reliability and intelligent operation and maintenance.

(10) Hierarchical intelligent control and end-to-end choreography

Based on the standardized ACTN interface, hierarchical architecture is adopted to realize the end-to-end automatic choreography and collaboration across domains and manufacturers and provide open, fast and hierarchical optical network service delivery, operation and maintenance capabilities, including fast service delivery, delay management and service availability management.

(11) Intelligence of all-optical base

Intelligent technology is introduced to realize AI-based service path calculation, fault location, performance analysis and prediction and performance optimization of optical network and create a full life cycle and end-to-end automatic closed loop which is centered on service experience.

(IV) Carrying network under the integration of computing and

network

At present, SDN/NFV is the main technical feature of operators' cloud and network integration practice. Multi-cloud connection is carried out in the convergence layer in advance, and the network control system is interconnected with the cloud side management system to realize rapid opening and collaborative services of cloud network service. This stage can be called as cloud and network integration 1.0. In the future, IP network will evolve to the integration of computing and network. Based on the cloud and network integration, it focuses on the integration of network and computing power and injects capability components related to computing power into the network framework.

Under the integrated architecture of computing and network, network senses computing power, realizes collaboration among cloud, network, edge, end and industry and serves the final commercial services with more flexible, elastic and reliable capabilities. The integrated architecture of computing and network is shown in Fig. 5, including the following key technologies.

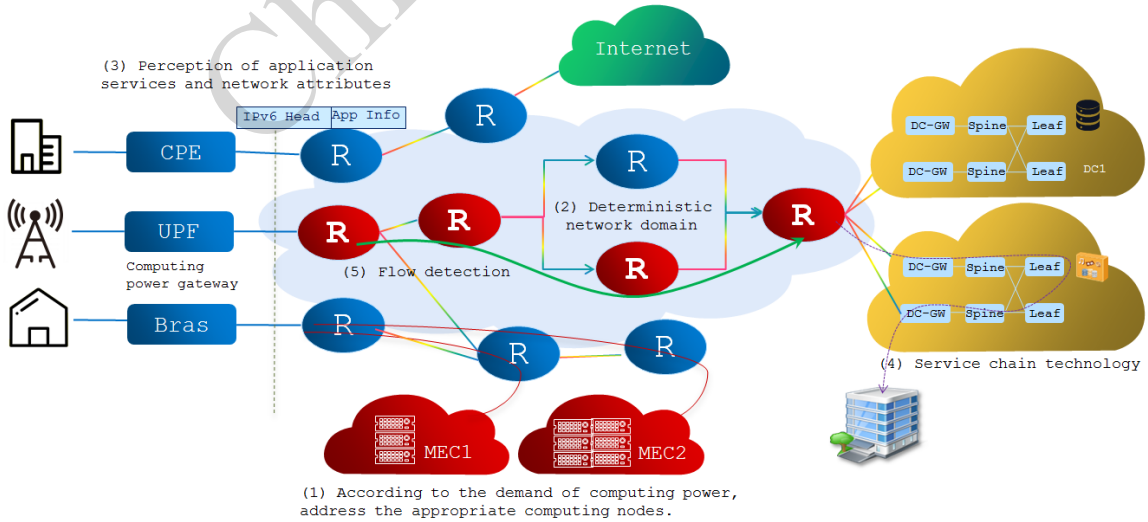

Fig. 5 IP network architecture for the integration of computing and network

(1) Information perception technology of computing resources

Compute first networking integrates computing resources to provide computing power for users in the form of services. Similar to the network routing protocol based on link metrics and in the compute first networking, the path is calculated based on the computing power metrics, and the computing power metrics come from the whole network computing resource information and the bandwidth, delay, variation and other indicators of the network link.

The realization of compute first networking cannot be accomplished overnight. The computing power-oriented network should follow the principle of “consistent goal and phased construction”. To build a “thin layer” of computing power between MEC nodes through DC gateway networking, SRv6 and CFN protocols can be introduced at the overlay level, and then it is gradually expanded to computing power perception and network joint optimization at the underlay level of the carrying network.

(2) Enhanced deterministic network technology

DIP (Deterministic Internet Protocol) is a new network forwarding technology based on enhanced periodic queuing and forwarding technology in the IP network. Deterministic IP network can guarantee the upper limits of network packet transmission delay, delay variation and packet loss rate. It is not only suitable for small and medium-sized networks but also for solving such problems as end-to-end deterministic transmission in large-scale and long-distance IP networks. DIP technology is added with periodic queuing and forwarding technology in the native packet forwarding mechanism and realizes the deterministic forwarding capability of large network through

resource reservation, periodic mapping, path binding, aggregation scheduling and other means. Through the combination of deterministic technology and computing power, it can provide accurately guaranteed service experience and meet the demands of computing power variation and sensitive services.

(3) App-aware networking technology

Based on the App-aware networking (APN) technology, the IPv6 extension header is used to transfer the application information and its requirements to the network. According to the information, the network ensures the SLA requirements of the application through service deployment and resource adjustment. Especially when the site is deployed at the edge of the network (i.e. edge computing), APN technology will effectively connect the network and applications so as to meet the demands of edge services, lead the traffic to the network path that can meet its requirements and fully release the advantages of edge computing.

(4) Service chain technology

Service chain makes different computing power service links become a reality, which can quickly provide new services. Service chain is an ordered set of service functions and can make the service flow pass through the specified value-added service equipment in a specified order so that the service flow can obtain one or more value-added services.

The nature of service chain in the compute first networking is to offer the computing power service, that is, to realize the connection of different computing power services according to the customer’s requirements. Combined with SRv6 SID as a service, we can build a computing power trading platform. All kinds of computing power sellers register their services to the network in the form of SRv6 SID. Buyers use computing

power by purchasing services, while the network links computing power services through the service chain so as to provide services to buyers seamlessly.

(5) Flow detection technology

Visualization of computing power paths and measurable performance become the key capabilities in the integration of computing and network. Flow detection technology can realize packet-by-packet flow detection, accurately detect delay, packet loss, variation and other performance information of each service and present the SLA of real service flow in real time through Telemetry second-level data sampling. It adopts a hop-by-hop deployment mode to realize millisecond-level fault recovery and ensure lossless transmission of computing power.

(V) Customized services with defined performance

In the next 5-10 years, the development of cloud games, AR/VR and other large videos and interactive public network services will impose higher bandwidth and delay performance requirements for the network. It is difficult for the best effort network to provide high-performance consistent experience because of strong burst and scattered distribution of these services. Moreover, the application scenarios of vertical industries are diversified. Telemedicine and industrial control impose more accurate requirements for network delay, reliability, time service accuracy and data security isolation. To provide differentiated, more definite and stable service quality assurance for vertical industries customers has become the most urgent demand for 5G to expand its industry applications.

Based on the architecture of CUBE-NET 3.0, China Unicom has proposed the concept of fully realizing the customized network oriented to

deterministic services. With the goal of being standardized, replicable and customizable, it constructs an end-to-end network technology system to provide deterministic services, promote the integration of technical innovation, create differentiated network products and achieve the goal of network as a service (NaaS). Therefore, we will gradually create the customized network capability of providing deterministic services from the following three aspects.

(1) Unified deterministic SLA parameter system

We classify the key requirements of different vertical industries applications so as to realize the normalization and standardization from application scenario requirements to network indicators and form a unified deterministic SLA parameter system for the whole industry, including the deterministic indicators of delay and variation, bandwidth, reliability, positioning and clock accuracy. From the perspective of industry solution design, we have proposed the exclusive definition to meet different industry specifications. It provides a visual, operable and friendly interactive interface for customers to monitor the SLA services in real time and accurately sense the service indicators.

(2) Accurate match between service requirements and technical means

From the perspective of network top-level design, it accurately decomposes the end-to-end deterministic network capability and indicators, selects the best technical scheme and designs the network for each sub-domain of the network and ensures the closed-loop management and rapid response of the network. This is a systematic project, involving the cooperation among access network, core network, transmission network and even service application side. From the technical level, the air interface needs to adopt

AI-based real-time resource prediction, scheduling, cross-layer optimization and other technical means to achieve more fine-gritted wireless access performance customization. Data forwarding needs to consider wide area certainty, new IP technology, efficient hardware forwarding technology, etc. At the core network and service application level, we need to further consider network architecture optimization, accurate cloud network collaboration, efficient multi-cloud collaboration, slice enhancement, etc. In the specific implementation process, the sub-domains of the network need to coordinate with each other efficiently. For example, the air interface is vulnerable to external environment interference, and there may be large variation in the SLA guarantee. It is necessary to form a pre-designed coordination mechanism with the core network and transmission network from the management and control level for joint variation compensation. From demand mapping, technical realization, product R&D, standard formulation to the final overall scheme realization, it will be a spiral process of gradual exploration and continuous optimization.

(3) Focusing on breaking through technical bottlenecks

Wireless air interface variation, wide area certainty and the ability to integrate with industry technology become the key points with an urgent need for technical breakthrough.

3GPP proposes the technology of URLLC to solve the problems of low delay and high reliability of air interface and introduces the mechanism of multi-service coexistence. On the one hand, the feasibility and performance of these technologies have yet to be verified. On the other hand, it is necessary to continuously enhance the capability of air interface. We can remove the mutual influence caused by the coexistence of a large number of complex services through AI real-time control and other technical

means and make up for the impact of highly burst services on the air interface performance.

At present, deterministic technologies are highly localized, but for the applications of IoV and remote control, there are still great challenges in the cross-regional and large-scale wide area deterministic services. Meanwhile, the introduction of wide area certainty has high requirements for network device and requires a lot of network upgrading, so the cost will become the key factor to achieve wide area certainty.

At present, the 5G system is integrated with the TSN system in the form of black box so as to meet the demand of delay sensitive services. How to support the TSN function and realize the deep integration with industry network is the key technical problem to be solved in the 5G customized network.

(VI) AI-empowered cloud and network brain

The deployment of communication network across layers, domains and manufacturers lasts for a long time, and the customer experience is affected. CUBE-NET 3.0 will combine advanced IT/DT/AI and other technologies to build a safe and reliable end-to-end rapid opening, fault diagnosis integration, resource visualization, automatic load balancing, service SLA monitoring and predictable collaboration capabilities across cloud networks, disciplines and manufacturers. It will horizontally pull through end-to-end and vertically pull through service acceptance to network configuration and realize flexible, intelligent selection, agile and safe service distribution. Therefore, we need to carry out the following research and development work to build the CUBE-NET 3.0 cloud and network brain.

(1) End-to-end choreography and control of cloud network

Resource abstraction: Based on the universal data model, the cloud or network of different scenarios and technologies are abstracted as the standardized basic resource models. The unified acquisition, conversion, storage and management capabilities are provided to offer a data basis for choreography across services and technologies.

Choreography engine: It develops automatic choreography engine unrelated to services, decouples design and realization and supports dynamic resource injection and service model. It supports the automatic analysis of service intention, receives the control strategy and configuration items under the B/O automatic conversion through the scenario-based interface, realizes intelligent control of the network by combining AI reasoning and senses and responds to the state changes of the network in real time. It supports the highly reliable distributed transaction mechanism and has the ability of failure breakpoint retrial, automatic/manual time snapshot rollback. Through the choreographer, it can realize the hierarchical visualization of resources, complete the analysis and association of services and make OSS lightweight.

Scenario-based interface: Through standard interface protocol and public model, it builds a cluster sharing, flexible, scalable, hierarchical and unified API interface to realize the fast connection between service choreographer, BSS/OSS and equipment management and control systems.

Multi-manufacturer adapter: It builds an open programmable framework with plug-in capability which is not affected by networking and technology. Through dynamic modeling, it supports the choreographer to quickly connect to the standard scenario API interface provided by the controller of manufacturer and flexibly access to the controller of manufacturer.

(2) Network digital twin

Adopting information technologies such as perception, computing and modeling, CUBE-NET 3.0 is committed to building a digital twin network management capability with “traceability” status, “predictability” goal and “easily adjusted” changes, providing virtual support for network diagnosis, prediction, decision-making and sharing.

Construction of hierarchical dynamic modeling architecture: Based on the characteristics of CT network and service layering, the industry standard modeling technology (e.g.: YANG) is adopted to abstract and define the attributes and context relationship of each service and network such as node, link and topology and ensure the consistency of data in the whole life cycle of the product.

Interaction mechanism between real-time logic and physical objects: The precise mapping between logic and physical network is realized through real-time perception and dynamic modeling technology. Taking software as a carrier and integrating artificial intelligence technology, it can realize virtual and real interaction, assistant decision-making and continuous optimization of physical network and logic management. It can dynamically monitor, emulate and simulate real state, behavior and rules of physical network and support dynamic design and programming, fault emulation, cutover emulation and other scenarios.

Data privacy and security: Digital twin builds a new digital space outside the relatively closed physical resources, which will be open and shared and thus inevitably lead to more security and privacy problems in the future. Blockchain is decentralized, difficult to be tampered and non-repudiation, which is very suitable for protecting data privacy and security. CUBE-NET 3.0 will develop a trusted computing service system based on blockchain

and build a more efficient and reliable “twin intelligence” system by combining the AI capabilities.

(3) Intelligence of cloud network

AI is the technological basis of network self-operation and self-decision-making. The network architecture of CUBE-NET 3.0 achieves the result of effective AI model applied throughout the whole network through the efficient collaboration of “cloud” and “ground” and solves the industry problem of difficulty in replicating the network AI application.

The “Cloud” has a powerful computing power and is applicable to all network AI application scenarios. Because of the large distance from the users in the network, AI reasoning capability focuses on the scenarios where the real-time response is not too needed (in seconds or longer) and requires global collaboration across fields and manufacturers, such as long-term prediction of service quality based on performance indicators, IP + optical collaboration and wireless + carrying collaboration. The Cloud is more conducive to the collection and accumulation of expert experience and product knowledge. It can build a strong AI training platform, use knowledge mapping and other technologies to form “a network knowledge base”, continuously feed back to the “ground” through the training model and continuously improve the intelligent operation and maintenance capability of the network.

The “ground” includes network device layer and management and control layer, which is characterized by wide area, distribution and so on. Meanwhile, it needs strong timeliness but its computing power is limited, and it focuses on AI reasoning ability which requires high timeliness. When the “ground” cannot meet the accuracy requirements of the model due to the small number

of samples, the “cloud” retraining can be used to publish the “cloud” training results to the “ground” reasoning framework. Through periodic model updating and model selection evaluation mechanism, the aging problem of the “ground” model can be solved.

(VII) Data-driven intelligent operation

The intelligent operation system of CUBE-NET 3.0 advocates a concept that data are products and services. Based on the cloud and network brain and data twin network and taking big data and AI technology as the engine, it develops the intelligent service capability of “overall network control, service object tracking, intelligent demand matching and customer experience improvement”. It also establishes the intelligent interconnected service system of cloud network, data and application to achieve agile service scheduling management, optimization and the intelligent matching of dynamic supply and demand.

In terms of network intelligent operation ecosystem, it connects the customers and the suppliers through the digital operation platform and realizes the interconnection with the cooperative enterprise and supplier platform in the ecosystem. It realizes the second integration of self-owned products and partners’ products and the supply for all customers. The operation model is changed from traditional operation model to ecological operation model. It gathers customers, product R&D teams and partners and gradually constructs the cooperative and open ecology of “products-platform-services” for the purpose of serving customers.

Data-driven network intelligent operation mainly includes data integration and capability opening, data intelligence and driving layer building, data innovation application and ecosystem building.

(1) Data integration and capability opening

Based on CUBE-Net 2.0, CUBE-NET 3.0 emphasizes more on global data integration, hierarchical closed-loop, security management and control.

Global integration: Through data standardization and ID, the data source can be identified and managed, the establishment of data analysis chain can be supported, and the ability of data source tracking can be achieved. A scenario-based data integration relationship + public data model is established to realize scenario-based application, standardization and automation of data interface and conversion from data to information.

Hierarchical closed-loop: By providing intention-based interface to the outside, it simplifies the capability requirements of the upper layer for professional network knowledge. Meanwhile, it simplifies the upper layer's acquisition of network data through the unified API and data so as to build the corresponding hierarchical data management architecture and support data collection, transmission and analysis with different processing time, processing scale and processing precision.

Data management and control: Through the construction of the security management and control framework throughout the whole life cycle of data, it focuses on the data flow link involving the most serious risk. It sorts out data assets and formulates security management strategy by understanding data risk to quickly support the customized data security requirements of customers in ToB, ToH and other service scenarios.

(2) Data intelligence and building driving layer

Build a common algorithm model, data emulation and network operation knowledge base, build a data-driven middle layer and support the upper

application development.

Universal algorithm model: It builds the knowledge base of network AI model to promote the knowledge accumulation for services. The hierarchical architecture of the AI model for cloud network collaboration is constructed, and combine with federated learning, migration learning and AutoML technologies to achieve cross-layer, cross-domain and cross-LAN cooperation of the AI model and self-adjustment of long cycle model degradation.

Data emulation function: According to service model and historical operation data, it can realize data emulation function based on business scenario. Combining small sample learning and data self-annotation technology, the problems of little abnormal network data and high cost of data annotation are solved.

Network operation knowledge base: It builds network operation knowledge base, forms network real-time and dynamic operation views, faces 5G and IoT, builds collaborative matching knowledge set of cloud network, services and users, forms general and extensible services modeling methods and data mining algorithm components and forms intelligent decision-making system and capability.

(3) Data innovation application and ecological operation

It collects, stores and analyzes the data which features huge amount, scattered sources and various formats and discovers new knowledge, creates new values and enhances new capabilities.

Data innovation and application: Guided by intelligent services and based on the integration of data and open capability, network AI algorithm

and network operation knowledge base, a series of data intelligent applications such as network dynamic monitoring and prediction, network intelligent distribution, network intelligent maintenance and network intelligent excellence are created to realize the real-time tracking and perception control of service objects. Aiming at the diversified customer demands, the resources are adjusted dynamically and intelligently to enhance customer experience, promote service process change and realize automation and intelligence of network operation.

Ecological operation: With the gradual transformation of service objects from ToC to ToB, the individuation of service demands will be higher. Operators need to fully discover the market opportunities, establish symbiotic partnership with the upstream and downstream of each industrial chain, provide integrated service products to customers through close cooperation, carry out ecological operation and achieve the win-win results in the industry.

(VIII) Network security based on endogenous immunity

At the beginning of communication network design, connectivity and transmission efficiency are mainly considered. There are many inherent defects in identity authentication, access control, network communication and data transmission. Especially with the continuous evolution of network cloud and IT as well as the further expansion of network scale and service scenarios, the requirements of network and services for security and reliability are greatly improved, the security exposure is constantly expanding, the open-source universal software and hardware security vulnerabilities are frequently seen, the security boundary is increasingly blurred, and the attack means are constantly upgrading. The traditional “patching” passive defense mode cannot meet the security requirements of

new network and services. The network is required to have a certain native security gene so as to provide a more flexible and suitable security capability for the upper services.

As an endogenous technology based on architecture, the endogenous security of CUBE-NET 3.0 unifies the design and implementation of security and function requirements of new information infrastructures, takes network as the center, trust as the anchor and intelligence and software definition as a means to build a network endogenous security capability system with path following, embedding, self-perception and self-healing, obtain the enhanced network of intelligent security situation perception, collaborative response of security events and open output of security capability and provide a safe and stable digital base for the development of all walks of life.

The main feature of network endogenous security is the co-existence of network capability and security capability. In view of this, the following research work will be carried out.

(1) Trusted identity technology embedded along the path

Through the transformation and optimization of communication protocol and network device, the trusted identification and password certificate are embedded in the header of the packet. The network device can confirm the authenticity and legitimacy of the request based on the verification of the identification, prevent forgery and counterfeiting and build a fine-gritted access verification and traceability capability.

(2) Network element endogenous security technology based on trusted start and abnormal behavior detection

The chip-level trusted computing technology is introduced in the network element so as to build a trusted and safe software and hardware running environment based on the underlying infrastructure of the network element, realize the level-by-level verification from the hardware platform, the operation system to the application and ensure the confidentiality and integrity of the whole system.

(3) Dynamic programming of security policy based on artificial intelligence

Due to the growth of user service scale and complexity, the number and complexity of security policies increase exponentially. Traditional security policy planning based on manual method is difficultly adapted. Network needs to create the capabilities of self-learning and modeling of traffic and service characteristics, the ability of risk prediction and security policy arrangement based on characteristic model and the ability of security policy conflict detection and automatic adjustment and optimization.

(4) Intensive security capability configuration based on software definition

In the future, the network should build the integrated service architecture of “cloud network security”, conduct pooling and micro servitization of security functions and realize intensive configuration and capability availability. In this way, users can define security policies flexibly, utilize security resources on demand and realize agile deployment and online launching of security capability. Matched with the capability of intelligent strategy planning, security is always with the cloud and the network.

(5) Security management of basic network digital resources based on blockchain technology

The trusted system of basic network digital resources (such as IP address,

domain name and AS number) is built with blockchain technology. Through distributed accounting and consensus mechanism, the authenticity of resource ownership and mapping relationship can be guaranteed, and security problems such as IP tampering, routing detours, domain name counterfeiting can be prevented.

VIII. Implementation concept

As the top-level architecture of China Unicom's network transformation in the next 5-10 years, CUBE-NET 3.0 will follow the following six implementation concepts, especially actively build an open and cooperative industrial ecology, aggregate the upstream and downstream of the industrial chain with an open mind and open capability and jointly empower economic and social digital and intelligent transformation.

(I) Technical implementation concept

1. Open-source

We focus on open architecture, industrial ecology and open-source white-box technology. On the basis of CUBE-Net 2.0 open-source and white-box device achievements, we gather the upstream and downstream parties in the industrial chain to deeply implement the open-source concept and jointly build an open network system with multiple balances, safety and efficiency, accelerated innovation and full vitality.

2. Energy saving

We implement the concept of green development, actively introduce energy saving technology, promote energy saving and consumption reduction, constantly reduce network construction and operation cost, improve resource utilization efficiency, achieve a win-win pattern between

industrial development and ecological environment and serve the strategic goal of carbon peak and carbon neutralization.

3. Co-construction and sharing

Based on the successful experience of co-construction and sharing of telecommunications industry infrastructures (iron tower, base station, office, etc.), we promote the co-construction and sharing of computing and network facilities and industry applications in the whole society. We accelerate the construction of a new generation of digital infrastructures through co-construction and sharing, avoid repeated construction, save the overall cost of society and achieve a win-win pattern among multiple parties.

4. Independent and controllable

We persist in the core technologies which are independent and controllable. On the one hand, China Unicom will strengthen its independent R&D capability and grasp the initiative of network development. On the other hand, it will actively coordinate with industry chain partners, universities and scientific research institutions to jointly make technological breakthroughs, form a number of core technologies and products with independent intellectual property rights and enhance the technical competitiveness of the national information and communication industry.

5. Safe and trusted

We reinforce the security, reliability and robustness of the network, protect user privacy and data security and build a self-perception, self-immune and on-demand network endogenous security capabilities. In the whole life cycle of product R&D and network construction, the design concept of security and credibility is deeply integrated, and the end-to-end network security system is

built through the collaboration of processes, management, technologies and specifications.

6. Model innovation

Network transformation is inseparable from the innovation of management and operation models. R&D model, purchase model and operation and maintenance model must be changed simultaneously.

(1) Innovation of R&D model: Taking user demand as the guidance, application implementation as the goal, expansibility and rapid iteration as the requirements, R&D and experiment are promoted synchronously, and the popularization and application of technical achievements are accelerated. The platform based R&D model is adopted to carry out R&D cooperation with partners on the unified technology platform.

(2) Innovation of purchase model: We open up purchase channels for innovation and independent R&D technologies/products and accelerate the implementation and application of innovative technologies and products.

(3) Innovation of operation and maintenance model: We introduce automation and intelligent means to promote the transformation from network-centered operation and maintenance model to user-centered operation and maintenance model and enable vertical industries applications more effectively.

(II) Industrial partnership

CUBE-NET 3.0 hopes to gather industry technology partners to jointly build a new generation of digital infrastructures. We hope to work closely with the vertical industries to empower the digital transformation of the industry. We hope to cooperate with application developers and integrators

to provide users with high-quality integrated service products.

1. Service-oriented ecosystem with open capability

CUBE-NET 3.0 will build an open ecosystem which is opened and integrated on demand, create a unified network capability open platform, implement the network service platform strategy, provide standardized network capability API interface, open more network service elements through Apps and realize network as a service (NaaS). It will strengthen the cooperation with intelligent terminals and content providers, relying on the 5G superb experience network for individuals, F5G excellent experience network for families and the new generation of deterministic intelligent cloud network to work with partners to promote service application innovation.

2. Intelligent service ecology that empowers industries

CUBE-NET 3.0 will work closely with vertical industries, industry application developers and industry terminal providers to realize the integration of application, computing, network and terminal, provide intelligent integration services for vertical industries based on “connection + computing + intelligence” and empower industry digital transformation.

3. Independent and controllable open-source technology ecosystem

CUBE-NET 3.0 of China Unicom persists in open innovation, gives play to the advantages of application and resource integration, constantly expands the open-source ecological partner circle and works with the industries to build an open-source industry technology alliance. Focusing on the independence and control of basic hardware and software and core technologies, it strengthens the technical cooperation with leading

enterprises in domestic industries, the R&D cooperation with national laboratories, key universities and scientific research institutions, strive to be self-reliant in science and technology and gradually build a kind of full-stack, independent and controllable open-source technology ecosystem including chips, devices, networks, operation systems and security.

IX. Outlook

With the rapid rise of digital economy, digital industrialization and industrial digitization have become a new engine to promote economic growth, constantly making new industries emerge, new forms of business and new models and leading the high-quality development of economy and society. The emerging ICT technologies and applications represented by 5G, all-optical network, IPv6+, cloud native, edge computing, AI, blockchain, etc. are driving the transformation and upgrading of traditional industries in an all-round way throughout the industry chain, continuously improving total factor productivity and fully releasing the enhancing and synergistic effects of digital technology on the development of real economy.

“As chances are lost easily, one should grasp them quickly”. In the face of the “opportune time” when the industry transits from informatization to intellectualization and opens a trillion-yuan new market, operators have the “geographical advantage” of 5G-bandwidth commercial network and the “popular support” from government and enterprise customers who attach importance to network and data security and have more trust in the operators’ basic services. The operators need to find the precise value orientation and make more efforts to actively build a new generation of digital infrastructures to meet the requirements of digital transformation of the industry, provide seamless brilliant integration of new services, build

the new open ecosystem of value co-creation and achieve a win-win pattern for operators, partners and customers.

In response to the "the 14th Five-year Plan", China Unicom will accurately identify changes, scientifically react to changes and actively seek changes. It will upgrade CUBE-Net 2.0 to CUBE-NET 3.0. Based on 5G and taking a broad view on 6G, it is about to start a new round of network transformation. CUBE-NET 3.0 will continue to deepen the integration of CT with IT, OT and DT technologies driven by technology and business and create a new generation of ubiquitous, flexible, collaborative, intelligent, secure and customizable digital infrastructures. CUBE-NET 3.0 will continue to focus on making breakthroughs, achieve deep cloud and network integration through the integration of computing power and network as well as high-quality cloud and network integration through the integration of cloud and optical communication and empower industry digitization through end-to-end deterministic services, endogenous security and capacity availability. It will realize intelligent management and operation by relying on the independently developed cloud and network brain. CUBE-NET 3.0 will stay innovation-driven, increase independent R&D of core technologies and accelerate technology and service innovation by relying on open-source and ecosystem.

China Unicom hopes to join hands with industrial partners to create and build a new generation of CUBE-NET 3.0 digital infrastructures, realize high-quality development of communication network, create a new life of high-quality information, promote the deep integration of digital technology and real economy, and make new contributions to the development of cyberpower, digital China and smart society.

Glossary

Acronym	Definition
5GC	5G Core
ACTN	Abstraction and Control of Traffic Engineered Networks
AI	Artificial Intelligence
API	Application Programming Interface
AR	Augmented Reality
CAPEX	Capital Expenditure
CFN	Computing First Network
CT	Communication Technology
DC	Data Center
DLT	Distributed Ledger Technology
DT	Data Technology
EMS	Element Management System
FTTR	Fibre to the Room
FTTM	Fibre to the Machine
FTTD	Fibre to the Desktop
HQoS	Hierarchical Quality of Service
GDP	Gross Domestic Product
GPON	Gigabit-Capable Passive Optical Networks
IoT	Internet of Things
IP	Internet Protocol
IT	Information Technology
LTE	Long Term Evolution
MEC	Multi-access Edge Computing
NaaS	Network as a Service
NFV	Network Function Virtualization

NMS	Network Management System
ODU	Optical channel Data Unit
OLT	Optical Line Terminal
ONT	Optical Network Terminal
OPEX	Operating Expense
OSC	Optical Supervisory Channel
OSS	Operation Support Systems
OSU	Optical Service Unit
OT	Operational Technology
OTN	Optical Transport Network
OXC	Optical Cross-Connect
PaaS	Platform as a Service
PON	Passive Optical Network
QoE	Quality of Experience
ROADM	Reconfigurable Optical Add-Drop Multiplexer
SDN	Software Defined Networking
SLA	Service-Level Agreement
SRv6	Segment Routing over IPv6
TTM	Time To Market
TSN	Time Sensitive Network
uRLLC	Ultra Reliable Low Latency Communication
VxLAN	Virtual Extensible LAN
VLAN	Virtual Local Area Network
VR	Virtual Reality
WAN	Wide Area Network
WDM	Wavelength Division Multiplexing
WLAN	Wireless Local Area Network

