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Special Topic

5G-Advanced Core Network

Cover Figure | ***Nugroho, Director of Network at Telkomsel***

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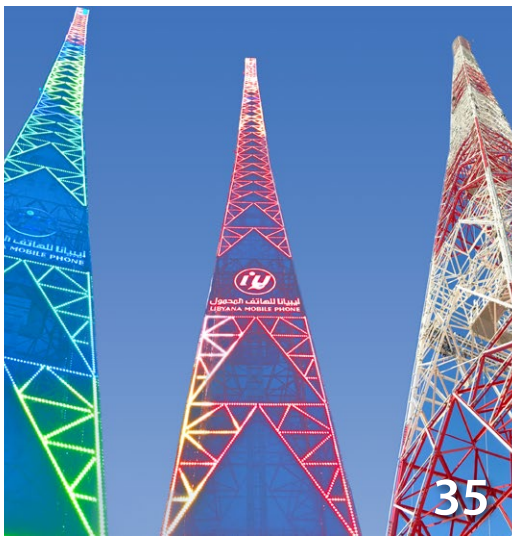


Telkomsel:

To Unlock Opportunities of 5G in B2C and B2B Markets

Reporter: Shena Agusta

Nugroho, Director of Network at Telkomsel

As the first 5G operator in Indonesia, Telkomsel is committed to providing access to leading digital connectivity, which will encourage the opening of new opportunities and experiences. Nugroho, Director of Network at Telkomsel, talks about how Telkomsel is going to maximize the use of 5G through tapping both the B2C and B2B markets. Richard Liang, President Director of ZTE Indonesia, also shares his views on how ZTE can help Telkomsel in building a better 5G network. ZTE is a strategic partner of Telkomsel for 5G rollout.

In the coming years, how do you see 5G will grow, and how is Telkomsel's positioning contributing to the advancement of digital society in Indonesia?

Nugroho: Before answering that question, let me share some backgrounds about what's happened in the mobile communication market in Indonesia. The competition is getting fiercer and fiercer, but we believe that we will win the competition. Why? Simply because we are committed to becoming the leading technology player who provides the best consumer experience, and therefore we have managed to become the No. 1 5G operator in Indonesia.

Telkomsel 5G is already available in 9 cities in Indonesia and we are committed to expanding it further in the coming years. So, the first question is how we think it will grow. I believe as it happened elsewhere globally, it will also grow significantly in Indonesia be it in the B2C or B2B markets. In the B2C market, mostly it will be on the fixed wireless access or the enhanced mobile broadband market segments, while for B2B it will focus more on the industry revolution 4.0 solution, which will cover the industries such as mining, health industry, government, education, etc.

As mentioned before, we are going to have an aggressive expansion in both the B2C and B2B markets. For B2C we have a good plan to penetrate more into residential areas with our fixed wireless access, and we also have a unique value proposition in the market because we can deliver the best customer experience, for example, the throughput that we can achieve is up to 1 Gbps today. For B2B, it needs a better ecosystem. We cannot walk alone, we need to collaborate with all stakeholders. The ecosystem comprises of some components like educational institution, government or the industrial partners as well as our potential customers. As an example, we have some discussion with an educational institution to have their research report—what is the next priority that Indonesia needs, what the customers in this country need, so that we will collaborate using their knowledge and probably their available solution that we can integrate with our 5G technology. We also have some pilots in the manufacturing, mining industries and soon will have 5G implementation in the health industry. Another effort that we have spent is the collaboration with the government on how to make sure that all the devices related with 5G will be compatible with our networks because sometimes network technology is ready earlier than the market itself, and this needs a better alignment in the future. So, for example, if 5G is available today, it is supposed to be supported by the ecosystem like the devices the next day rather than one or two years later.

As the first 5G operator in Indonesia, what is Telkomsel's strategy on 5G network implementation, considering the current spectrum asset and upcoming spectrum allocation plan by the government?

The spectrum that we have today is simply enough, especially in the early stage of the 5G adoption in the country. Our first goal is to socialize this 5G technology—its benefits as well as the kind of problems that our customers can solve with this solution. There is no doubt that the 5G network that we have today is enough for that purpose, and we are going to have staged expansion based on customer needs. So, the first stage was for the socialization purpose, and in the second stage we would like to monetize. Looking into the trend of 5G in

ZTE participates at the Telkomsel 5G launch in Jakarta.

the fixed-mobile convergence market, we need to have a better proposition, and for that we will need more spectrum. With additional spectrum, we would like to have a better throughput, higher capacity and wider coverage of 5G with a cost effective investment on the per site basis.

We know 5G is a great technology to enable new service innovation. What kind of market segments do you think present the greatest potential opportunity to develop in Indonesia?

In general, market segments are always two, B2C or B2B, both of which have a great opportunity for Telkomsel to penetrate. For the B2C as I explained before, the focus will still be on the fixed wireless access as well as the enhanced mobile broadband. Let me give you some examples on the enhanced mobile broadband use case, when there is a gathering, big event, let's say, in the stadium, we used to have multiple BTSs to serve thousands or tens of thousands of customers in the same spot. With 5G, if it is already heavily adopted by the customers, we don't need that much and we can still deliver a good customer experience, because 5G can simply deliver high throughput and high capacity in a very high density area. Even for journalists they can just simply do the live streaming using 5G in the middle of a big crowd, not like today.

For the B2B market, the focus will be on the industry revolution 4.0, which is about automation, about the zero-touch or humanless approach. And there are many examples from the mining, health and media industries, and what has been proven in the market today is similarly on the smart mining or health. Some mining companies have been adopting driverless truck operation. And we are now also doing the same pilot with one of the major mining companies in Indonesia. This will be our priority today, and later on we also would like to have a better collaboration to penetrate the health industry. The challenge in Indonesia is that while the population is spread all over the country, hospital is not available in some of the areas or villages, and to help that, automation and digitalization in the health industry is becoming more urgent. Therefore, soon we will have a trial for the remote surgery or remote inspection. For the remote observation, a very low latency is required, which can be solved by using 5G. Noted that the architecture in our solution has to adopt a standalone architecture instead of non-standalone architecture.

What is ZTE's plan to help Telkomsel build a cost-effective and profitable 5G network?

Richard Liang: Over the past few years, ZTE has established excellent cooperation and partnership with Telkomsel to prepare for 5G deployment. ZTE has products and solutions tailored to meet Telkomsel's 5G requirements and scenarios. We also provide Telkomsel with innovative and latest technologies, including compact, high-performance, and high-capacity products that support 2G/3G/4G/5G powered by the latest 7 nm chip, which deliver four times computing power and 30% less power consumption. In terms of the 5G business opportunity, ZTE always gives full support to Telkomsel in exploring 5G applications in vertical industries and moving towards digital transformation to achieve better technology performance and more significant business improvements. ZTE TECHNOLOGIES

Living on AI, Present and Future

Wang Xinhui, General Manager of Wireless Standardization and Industrial Relations, ZTE

At the AI for Good Global Summit webinar held in September, Wang Xinhui, General Manager of Wireless Standardization and Industrial Relations, ZTE, talks about how AI+ is shaping today's society and four evolution trends in AI.

Artificial intelligence (AI) is a new technological science that studies and develops theories, methods, technologies, and application systems used to simulate, extend, and expand human intelligence. With the further development of artificial intelligence science and the deepening of the simulation of human consciousness and thinking information process, artificial intelligence has received more and more attention in various fields, and is gradually applied to industries such as robotics, medical treatment, manufacturing, environmental protection, and network construction. It's so charming and disruptive that it has become a hot spot pursued by global technology companies. Furthermore, with the development of science and technology, artificial intelligence will sparkle in more and more aspects of human life.

Nowadays, a wave of digital transformation has swept over all walks of life around the world. Realizing business optimization, industrial upgrading, and value creation by embracing emerging information technology has become the common vision of enterprises. In this process, the potential of artificial intelligence, as a key enabling technology, is being uncovered in terms of computing power, algorithms, or data. Now, what are the successful landing cases? In the future, what new possibilities will it bring?

Capturing Present

Artificial intelligence has penetrated all aspects of today's society, and "AI+" is unknowingly subverting traditional industries and changing people's lifestyles.

Artificial Intelligence + Medical

The outbreak of COVID-19 has attracted widespread attention in the medical industry. It is worth mentioning that the increasingly mature artificial intelligence has played a great role in the fight against the epidemic. Telemedicine, intelligent imaging, medical robots, and pathology-assisted diagnosis have all shined in this epidemic. In the prevention

and control stage of COVID-19, an organization has also proposed a set of machine learning algorithms that can identify the "asymptomatic infections" and "super spreaders" of the population who are most likely to be COVID-19 patients, for the prevention and control of the epidemic.

Artificial Intelligence + Manufacturing

More and more data shows that the future market prospect of artificial intelligence is very impressive, and it also creates more new opportunities for the development of intelligent manufacturing. ZTE's Nanjing Binjiang 5G Intelligent Manufacturing Base focuses on the needs of smart factory digital production lines, automated testing and real-time data interaction, and implements the concept of "manufacturing 5G with 5G".

Artificial Intelligence + Environmental Protection

For low-efficiency, high-cost, and high-risk environmental protection work, artificial intelligence can replace manual operations. In addition, artificial intelligence technology and products can assist people in the prevention of environmental pollution and destruction.

Artificial Intelligence + 5G

With the commercialization of 5G, communication network operations are facing huge challenges. Traditional operation and maintenance management methods are difficult to adapt to the unprecedented huge network scale, complex network structure, and surge of network traffic of 5G. The use of artificial intelligence can enable the network to achieve high efficiency of operation and maintenance, predictability of traffic, and precision of marketing.

Trends of Artificial Intelligence

Following the two climaxes of artificial intelligence development in the 20th century, deep learning has set off the third wave of artificial intelligence with its outstanding performance in automatic feature extraction. Since the beginning of 2006, deep learning has made great breakthroughs in voice and vision recognition capabilities from its budding to maturity. A new technological breakthrough with a cycle of about 20 years has been gestating.

Four trends are becoming more and more obvious, according to the development process of artificial intelligence technology.

- **Accelerated integration of artificial intelligence and industry:** The application of artificial intelligence in industry is generally in its infancy, and there are still some difficulties that hinder the implementation of application scenarios. Therefore, artificial intelligence must be closely integrated with the industry, not only to promote the implementation of artificial intelligence application scenarios, but also to push forward the breakthrough innovations in basic data and platform technology, and to build a bridge that effectively connects with the traditional

> Artificial intelligence has penetrated all aspects of today's society, and "AI+" is unknowingly subverting traditional industries and changing people's lifestyles.
>
> Wang Xinhui

industry ecology.

- **AI technology research: in-depth details:** At present, the new generation of artificial intelligence has gradually shifted from the initial algorithm drive to the compound drive of data, algorithm and computing power. Among them, the driving role of data-based applications has become increasingly prominent.
- **A closed loop without human intervention:** Today's artificial intelligence is not an automatic and complete closed-loop system. After outputting wrong results, it cannot self-correct and immediately achieve better output. Instead, scientists need to retrain on better training datasets to achieve better results. The closed loop without human intervention will be an important goal for the development of artificial intelligence technology.
- **Trusted AI:** In order to prevent artificial intelligence from being misused and abused, on the one hand, it is necessary to address the symptoms from different levels such as laws and regulations, ethical norms, and industry consensus, but also to address the root cause from the level of technological innovation. Therefore, it will be more and more important to embed ethics and governance in the entire life cycle of artificial intelligence product design, research, development, deployment, and use.

Imaging Future

It is foreseeable that artificial intelligence will continue to learn and advance with the times. What will happen in the future? There is no doubt that all aspects of our travel, medical care, and production will be further upgraded due to artificial intelligence.

Perhaps dealing with robots will become our daily routine, perhaps brain-computer interfaces will come true, helping people with disabilities to restore their lives and communication skills, perhaps artificial intelligence will make them more creative, free humans from complicated tasks, and even replace humans in most jobs. The technological development of artificial intelligence will go hand in hand with the digitization and intelligent upgrading of the industry, building a future with unlimited possibilities. ZTE TECHNOLOGIES

Wang Weibin
Chief Scientist of ZTE
Product Planning

Guo Xuefeng
Chief Product Engineer
of ZTE CCN

Core Network Evolution in 5G

Introduction of 5G-Advanced

While 5G construction has entered the fast lane, the research on 6G network is also in full swing. The communications industry is tremendously impacting the development of various industries and fields, and has become a pioneer of social and economic growth.

However, the development of the communications industry cannot be achieved overnight. Especially with the integration of multi-industries and multi-disciplines, the communication industry needs to develop collaboratively with more fields. 5G is undoubtedly a big leap of technology. Whether Massive MIMO, C-RAN, ultra-dense networking, millimeter wave, and in-band full duplex on the wireless side, or NFV/SDN, service-based architecture (SBA), network slicing and edge computing on the network side, are of revolutionary significance. Therefore, 5G R&D, deployment and application will face greater challenges. There is still a long way to go to the 5G vision. Some technologies also face new problems and limitations, and integration with industry partners needs to be deepened.

It can be said that there is still a long way from 5G to 6G. Mobile communication is a process of iterative development. 5G needs further development and maturity, and 6G pre-research and reserve are also needed.

3GPP officially named the 5G evolution as 5G-Advanced (5GA) starting with R18 at the 46th Project Coordination Group (PCG) meeting in April 2021. 5G-Advanced oriented to 2025 defines new objectives and capabilities, and enables 5G to produce greater social and economic value through 5G evolution and enhancement.

Core network, the management center of mobile network, plays a vital role in network access, security, connection, switching and routing. With the large-scale deployment of 5G networks, it is necessary to explore the development direction and evolution target of 5G-Advanced core network from two dimensions, i.e. 5G achievements and limitations, as well as 6G vision and key technologies, expand 5G achievements and application scenarios, and lay the foundation for 6G startup and long-term vision.

Insight into 5G-Advanced Core Network from 5G Status Quo

There are still many limitations and disadvantages in a 5G network.

- The network architecture still needs to evolve to achieve a user-centric on-demand network. For example, the service-based architecture (SBA) is still limited to the control plane; there is a long way to dynamic elastic network; and the decentralized architecture needs to be studied in the data plane to reduce the risk.

- Network capabilities still need to be enhanced to meet various needs of future industrial Internet. Network bandwidth and latency cannot meet the requirements of XR immersive experience and holographic communications. The limitations of uplink bandwidth and deterministic functions still restrict the development of industrial Internet applications, and mobility management cannot meet the need of high-speed service continuity.
- Network intelligence has a long way to go. Network data analytics function (NWDAF) and management data analytics function (MDAF) are still limited to data collection and analysis. The closed-loop artificial intelligence (AI) technology based on data perception, collection, analysis and decision-making needs to be further studied to achieve automatic and intelligent network operation and maintenance.
- The edge, pipe, cloud and terminal products need to be deeply integrated and collaboratively developed. In the future, ubiquitous network connections and service-based computing will become a reality. For users and applications, it is necessary to study the deep integration and collaborative development of computing and networks to maximize resource efficiency and optimize service experience.
- Security problems are becoming increasingly serious. The security of users and data has been paid more attention than ever before, and the trust and security of products and solutions have become basic requirements. With the applications of industrial Internet and the interconnection of more devices and heterogeneous networks, the security issues are more severe.

The in-depth study of 5G-Advanced involves expanding application scenarios, optimizing existing 5G technologies, and enhancing new technologies and capabilities, as shown in Fig. 1.

Expanding Application Scenarios

5G-Advanced puts the expansion and integration of application scenarios in the first place. 5G is oriented to three major scenarios: eMBB, mMTC and URLLC. After more than two years of deployment in China, 5G eMBB applications have matured in the ToC market, but they are not satisfactory in the ToB market. When the originally promising industries such as the Internet of vehicles, industrial Internet, XR, smart city, and telemedicine are implemented, they are still faced the problems of protocol, networking, standard compatibility between private network, IoT terminals and communication network, data and network security, and network operation and maintenance. There are still challenges in network encapsulation, customization, manageability and controllability, as well as environmental adaptability, and the deep integration in more scenarios is far from enough. Under 5G-Advanced, more effort should be made to integrate with the industries, study and expand application scenarios, and truly achieve 5G enabling thousands of businesses.

Optimizing Existing 5G Technologies

5G-Advanced should be based on existing 5G technologies and promote their development and maturity for large-scale commercial use. Network slicing, non-public network (NPN), and 5G LAN are

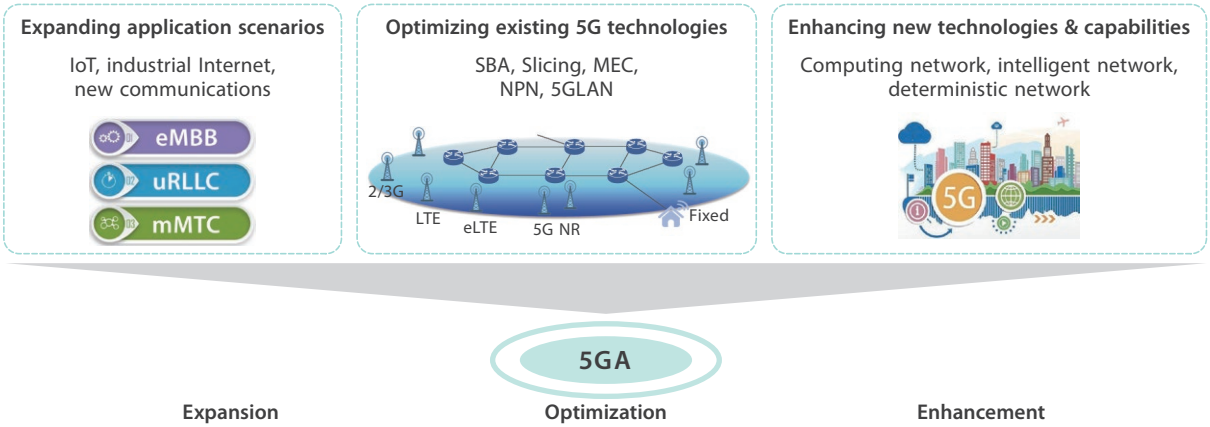


Fig. 1. 5G-Advanced is the evolution of 5G.

three powerful tools for the network enabling industry to provide private and customized networks, but they are not mature enough to be applied on a large scale. For example, network slicing is mainly implemented on the core network side, which is defined from the isolation policies of the control plane and user plane. With the development of cloud, software and programmable technology on the wireless access side, slicing can be extended to the wireless side to implement 5G end-to-end slicing. Moreover, there is still a lot of room for improvement in automated and intelligent slice operations. It is necessary to promote the standardization of CSMF, NSMF, NSSMF interfaces, improve NSSF, AMF, and TA-based RAN slice availability flows, and optimize slice SLA management. A large number of current 3GPP R18 proposals are also enhanced researches on existing 5G technologies, including the service-based UPF and N2 interface, SM/MM separation, and dual registration improvement in terms of network architecture, and NPN, 5G LAN, eNS and MEC capability enhancement in terms of industry enabling capability. New XR communications, multi-access coordination, and intelligence are also included.

Enhancing New Technologies and Capabilities

5G-Advanced should analyze its own capability weaknesses, and carry out research on new capabilities, new technologies and even new architectures. The high-reliability low-latency deterministic network is not only the basic requirement of industrial Internet, but also one of the necessary capabilities for 5G to enter the field of intelligent manufacturing. 5G needs to make breakthroughs in high-precision clock synchronization, deterministic gating control, latency, and TSN policy capability. With the development of computing networks, their combination with the core network needs to be studied to achieve integrated computing and network and efficient data forwarding and computing in mobile network. In addition, with the online operation of hierarchical network decoupling, service-based function, and network slicing, network intelligence is imperative. At present, TMF has defined the autopilot network and given the grading standard of network intelligence. 5GA also needs to continuously explore the application and implementation of intelligence in planning, construction, maintenance and optimization.

Insight into 5G-Advanced Core Network from 6G Vision

IMT-2030 released the white paper on "6G Vision and Candidate Technologies" in 2021, proposing intelligent Internet of everything and digital twin as 6G vision. According to the white paper, the 6G network should have four major features: native AI, native security, multi-domain convergence, and deterministic network, including 12 candidate technologies in terms of architecture and capability. Among them, architecture technologies include distributed, integrated terrestrial and non-terrestrial network, native AI, native security, digital twin, and computing network. Capability technologies contain programmable network, integrated communications and sensing, deterministic network, data services, immersive sensing, and semantic communication. It can be seen that most of the technologies are not new, and have been applied in 5G. They should be enhanced in 5G-Advanced to lay a foundation for 6G (Fig. 2). There are also some technologies that have not been applied or are still in the early stage of research. A prospective research on 5G-Advanced should be made based on the combination of application scenarios and related technologies.

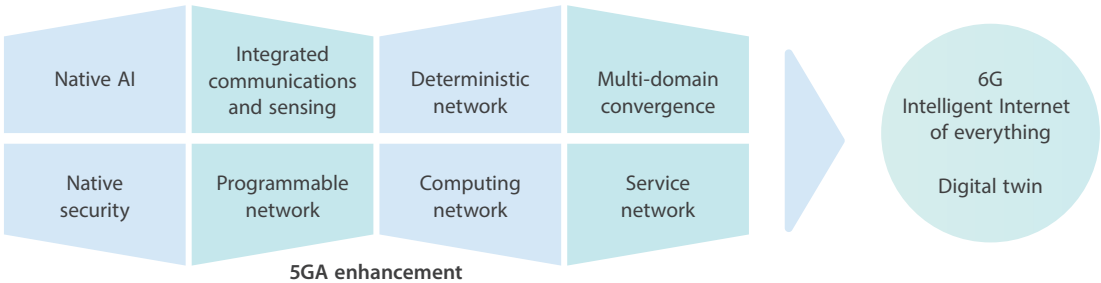


Fig. 2. Prospective research on 5G-Advanced for 6G.

Integrated Communications and Sensing

Sensing is not a new concept in the telecom field, but its technology, scope, and application scenarios will continue to expand. Integrated communications and sensing must be a phased development. The ultimate vision of digital twin also depends on the sensing technology, i.e. the sensing and digitalization of the physical world. The core network and applications sense and cooperate with each other to provide efficient data transmission. The core network senses computing needs and resources to maximize resource efficiency. It cooperates with RAN to achieve high-precision terminal location and expand applications, and collaborates with AI to deliver intelligent network services such as gesture sensing, facial expression sensing, and environment sensing. It senses network topology, congestion and traffic in real time to monitor the network and predict traffic and fault. With the continuous integration and development of communications and sensing, digital twin virtual networks of NEs, subnets, and even the whole network can be achieved step by step.

Customized Network

The network customization capability is the basis of serving thousands of industries. However, the current customization capability based on network slicing cannot meet the industry requirements. In addition to the requirements for network indicators such as bandwidth, delay and jitter, industry applications also require customized protocols, terminal compatibility, service continuity, customized session type, network management and capability exposure. The customization capability of 5G-Advanced will be enhanced with the continuous development of the support layer, function layer and orchestration layer, flexibly providing differentiated network customization capability for industry applications. The capability includes the research on programmable chips and SRv6 and other programmable protocols in function and protocol customization, the further development of virtualization, cloud and software to provide basic capabilities for programmable networks, the evolution of service-based function, and the esearch on service/function chain orchestration and cloud network integration orchestration to promote sustainable development of programmability at the network level.

Native AI and Security

AI and security technologies that have been introduced for a long time will complement and promote each other with telecom network technologies in 5G, 5G-Advanced or even in the future. The focus here is native, that is, the inherent, self-learning and self-growing capabilities corresponding to the external mode. Taking AI as an example, with the continuous growth of network data, only native and self-enhancement capabilities can meet the increasing challenges of data collection, analysis and security. In the implementation of specific native solutions, both native AI and native security are still in the preliminary research stage, and there is a long way to go.

Conclusion

5G-Advanced is a cold reflection on actual 5G development. 5G still faces many difficulties and limitations, and its maturity, scenarios and value still have great room for improvement. 5G-Advanced is also a forward-looking research on 6G, conforming to the long-term evolution of 6G and cooperating with various industries to provide a technical reserve for 6G.

As one of the two major fields of mobile communication, 5G-Advanced should be based on the expansion and core requirements of industry application scenarios, and make comprehensive efforts in standard research and evolution, technical capability improvement, actual deployment and implementation, so as to achieve the goal of enabling all industries, serving the society and promoting economic development.

ZTE has widely deployed its core network in 2G/3G/4G/5G networks. With its profound technology accumulation and R&D resources, ZTE has independently developed all 5G product families and is willing to explore the progress of 5G-Advanced with industry partners. ZTE TECHNOLOGIES

5G-Advanced Core Network Integrating OT, DT, IT and CT

Zhou Jianfeng

Chief Engineer of ZTE CCN Planning

5G network introduces NFV, SDN, and SBA to enable three major scenarios: eMBB, mMTC and uRLLC. After R15, R16 and R17 enhance the support for vertical industry applications and network intelligence. The development of network and that of service are mutually reinforcing. The development of 5G network opens new horizons for industry applications. Applications like HD cloud gaming and industrial vision require 5G network to meet the requirements of low latency, deterministic performance, high edge computing power as well as high bandwidth. Therefore, 5G needs to continue its evolution. The next step in 5G evolution is 5G-Advanced (5GA) starting from R18, and the 5G core network will also continue its evolution.

Looking back, the wireless core network has been continuously integrating technologies from multiple fields. In 2G/3G network, CT is rapidly developing in wireless communications. Customized CT equipment supports the development of the voice service and value-added service in core network. With the development of IT technology, 4G core network introduces a full IP interface to support the IP broadband service and ICT integration. When entering the 5G era, the introduction of technologies such as VM, container and SBA further promotes the integration of ICT. With the development of big data and intelligence, network data analytics function (NWDAF) that provides network intelligence enters the CT field, marking the integration of DICT, which comprises of data technology (DT) and ICT. From R18 onwards, the 5G core network will further enhance operational technology (OT) as well as DT, IT and CT. The integration of OT, DT, IT and CT (ODICT) is based on the current 2G/3G/4G/5G integrated core network. Meanwhile, security is the cornerstone of the core network. ZTE puts forward the 5G-Advanced core network vision ODICT 4+1 (Fig. 1).

OT for Precise Network

The development of OT in 5G is mainly reflected in network determinism. A deterministic network provides bounded latency and jitter for end-to-end packet

transmission, end-to-end ultra-reliable network transmission by using technologies such as multi-path transmission, and guaranteed deterministic transmission for deterministic flows in a mixed traffic network.

In the initial stage of 5G, technologies such as slicing, uRLLC and 5G LAN can be integrated to provide deterministic communications. R16/17 clearly enhances support for 5G-TSN integration, and defines a system architecture where the 5G system is perceived as a TSN bridge, which puts 5G into use for the industrial IoT. In the stage of 5G-Advanced, the 5G TSN technology will be further developed and enhanced in terms of reliability. 5G TSN supports the LAN-level deterministic communication with bounded latency. 5G-Advanced proposes the cross-domain deterministic communication where the core network will further connect with the transport network so that deterministic scenarios of end-to-end remote man-machine collaboration can be supported.

DT for Intelligent Network

DT is mainly reflected in the aspect of network intelligence. Network intelligence is the key development direction of 5G-Advanced and 6G.

In 5G-Advanced, network intelligence will play an important role in user experience optimization, efficient O&M and security guarantee. It can be used to assist in service QoS parameter adjustment, slice access control, user plane path selection and RAT/Frequency selection. It can also be used for intelligent analysis of network operations, which provides health score, anomaly detection and prediction and fault root cause analysis, and the corresponding capacity optimization, configuration optimization and resource scale-in/out. Intent-driven network is introduced to facilitate network planning, design and deployment, thus reducing the requirements for O&M personnel. The intelligent engine can intelligently analyze the mobility and

interactive behaviors of the user terminals, identify user terminals with potential threats to protect network security.

NWDAF is a known intelligent network development direction. New technologies such as federated learning, intent-driven network and digital twin will also be applied in network intelligence.

IT for Computing Power Network

With the use of SDN, NFV, VM, container, and SBA architecture, IT has been deeply integrated with CT in current 5G core networks. In addition to the efficiency and agility of IT technology, the high performance, security, and reliability of CT are still guaranteed, which are the benefits of ICT integration.

Computing power network represents the further development of IT technologies in 5G network. In May 2021, China released the guiding opinions on accelerating the construction of a national collaborative innovation system for the integrated big data center, which first proposed promoting the use of computing resources as a service. The purpose of introducing computing power network technologies into 5G is to support national industrial upgrade, achieve digital transformation of the whole society, and achieve efficient and reasonable utilization of network and computing power resources through the use of intelligent technologies. At present, the three major operators in China have been intensively exploring computing power network to bring the value of network into full play. Many key technologies and solutions require in-depth analysis and evolution. The core network UPF is the first network hop. Technologies such as computing power routing, measurement and scheduling need to be integrated by the core network. Technologies such as network slicing, unified computing and network resource orchestration and intelligent O&M also need to evolve with the core network to maximize the utilization of network and computing power resources in the 5G-Advanced network.

CT for Ultra-Simple Network

The deployment of the 2G/3G/4G/5G core network is complicated because interconnection tests are required between different NEs and network functions. The 5G SBA architecture simplifies the communicating mode between network functions, but the interactions between network functions are not reduced. 5G-Advanced core network, on the premise of supporting the current deployment mode, needs to simplify deployment, simplify the design, and reduce signaling interactions between NEs. A unified architecture is used to support the coexistence of multiple access networks and interconnection among heterogeneous networks, to enable simplified access based on unified access protocols such as SRv6 and unified authentication mode. On the basis of current centralized management, the core network needs to be flatter (further integrated with the access network), more distributed, and adds autonomous domains (autonomous management within a certain region) to implement simplified core network

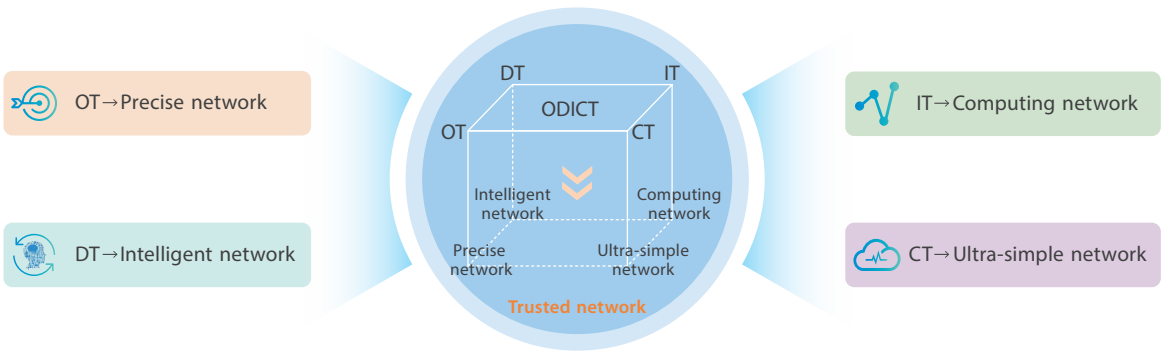


Fig. 1. ODICT 4+1 core network.

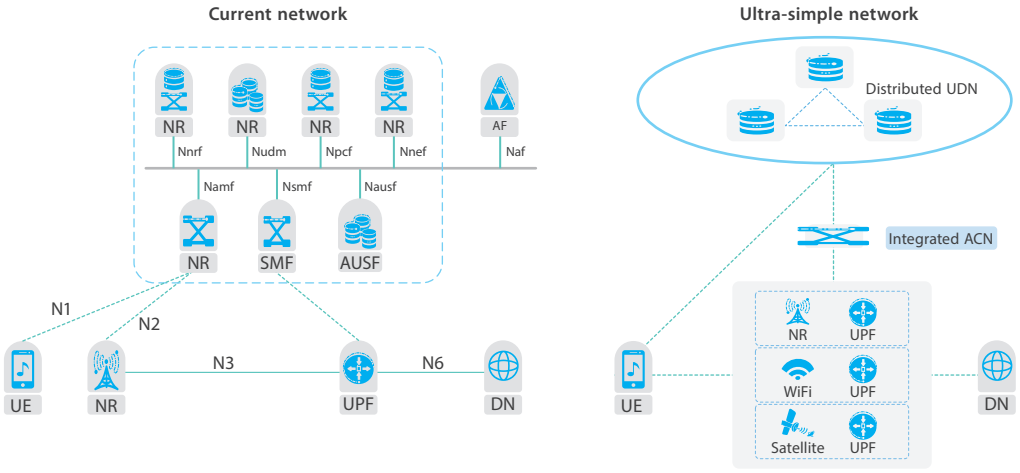


Fig. 2. 5G-Advanced ultra-simple core network.

deployment. At the same time, the SDK interfaces can be made available to third parties so that core network can be defined, which, when combined with the intelligent technology, enables simplified management. The ultra-simple core network is shown in Fig. 2.

The goal of 5G-Advanced core network evolution is a network architecture with "centralized + distributed autonomous domains". A centralized network is similar to the network architecture where the current control plane is centrally deployed and access management is provided for private network through slicing. This scenario is applicable when the private industrial network does not need independent O&M. A distributed autonomous network refers to an independent and complete network where network O&M, terminal access management, and security management of user data are implemented in the autonomous domain. By building autonomous domains, the network can be further flattened, and can be managed and maintained automatically, meeting the personalized requirements of various industries.

Trusted Network with Endogenous Security

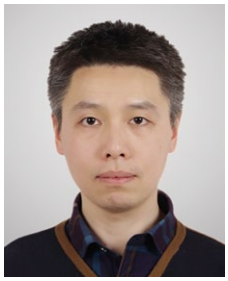
The security of 5G-Advanced core network is equally important. Security and trustworthiness are the cornerstone of a network. A secure telecom network needs to provide trusted access, data and operation.

In 5G-Advanced core network, the identity authentication and trust management of network access equipment will be more complicated. The diversity of equipment IDs makes it difficult to adapt to the current authentication and authorization mode. It is necessary to study the feasibility of separating the equipment ID from the routing ID and the two-way authorization and authentication scheme based on the new ID system, so as to make the equipment ID unique, complete and tamper-proof, and to make the network access authentication trustworthy and secure.

To enable trust management for network operation, the security monitoring process for the 5G-Advanced network should be visualized, and the network faults predictable, preventable and recoverable. The behaviors of network participants and network equipment operators have complete security elements with transparency and traceability, and can be predicted and controlled.

As for trust management for network data, when network data grows explosively with the rapid increase of data traffic, it is important to carry out data management, network operation indicator detection, and introduce network data security technologies like blockchain and federated learning on the premise of ensuring the data security of users and enterprises. ZTE TECHNOLOGIES

Deterministic Network: Enabling Precise New Connections in Industrial Internet



Zheng Xingming

CCN Integrated Solution Architect of ZTE

The Need for Deterministic Network

With the development of mobile technologies, mobile network provides not only high-speed Internet services but also communication services for various industries, realizing on-demand services through one network. In the vertical industry, the traditional "best effort" mechanism can no longer meet the demand. In some specific fields such as industrial control, the network needs to support bounded delay and jitter, extremely low packet loss rate, and ultra-high reliability.

In the early industrial network, dedicated lines were used to meet the transmission requirements of specific service streams. However, with the accelerated development of global science and technology revolution and industrial transformation, industrial Internet has become a key technology of intelligent and information-based industrial manufacturing in the future. In the industrial Internet, IT and OT networks are integrated in one network to meet the large bandwidth required by Internet and information data, as well as the real-time and deterministic requirements of industrial control data.

In the best-effort network, different data traffic is forwarded in accordance with the QoS scheduling mechanism such as first-in first-out (FIFO) and priority preemption. Under this mechanism, network conflicts cannot be avoided, and it is difficult to provide stable and reliable transmission. Once there is a packet conflict, the packet needs to be waited or retransmitted, which may lead to a long forwarding delay and uncontrollable jitter. This cannot be tolerated in high-precision industrial control, because it may cause errors or even crashes in production systems. To enable mobile networks to provide services for latency-sensitive industries, it is necessary to introduce strict and precise deterministic service guarantee.

Key Features

Deterministic network provides deterministic service guarantee for services carried in a network domain, including bounded delay, jitter and packet loss rate. By coordinating the scheduling and forwarding resources of each forwarding node for key traffic streams in the network, it ensures smooth operation and achieves ultra-low delay and anti-jitter forwarding capabilities. In addition, ultra-low packet loss rate and high-reliability transmission can also be achieved through traffic stream replication and multi-link redundancy transmission. The deterministic network of 5G-Advanced will have the following key features (Fig. 1).

Precise Time Synchronization

Nanosecond-level high-precision time synchronization helps each network node obtain consistent time, which not only provides high-precision time consistency checking capability for each service node, but also provides the basis for the scheduling mechanism based on time gating.

Bounded Delay and Jitter

The enhanced scheduling and forwarding mechanism ensures accurate uplink and downlink bandwidth guarantee, ultra-low latency, and ultra-low jitter forwarding capabilities. For example, it provides end-to-end accurate-time-based resource reservation and scheduling to ensure that every link in the network runs smoothly. It also enhances the priority preemption mechanism, interrupts the forwarding of other packets with low priority at any time, and reduces the waiting delay of packet transmission.

High-Reliability Transmission

Deterministic network requires uninterrupted services and transmission guarantee with no packet loss. Therefore, the 5G-Advanced network needs to provide all-service, all-state, and all-data real-time hot-backup capability to implement seamless abnormal switching and uninterrupted network services. In addition, the end-to-end dual-path redundancy transmission mechanism also needs to be provided to prevent network service interruption and data loss caused by network faults and packet loss.

Hybrid Multiplexing

Mobile network is a network with mixed coexistence of multi-service

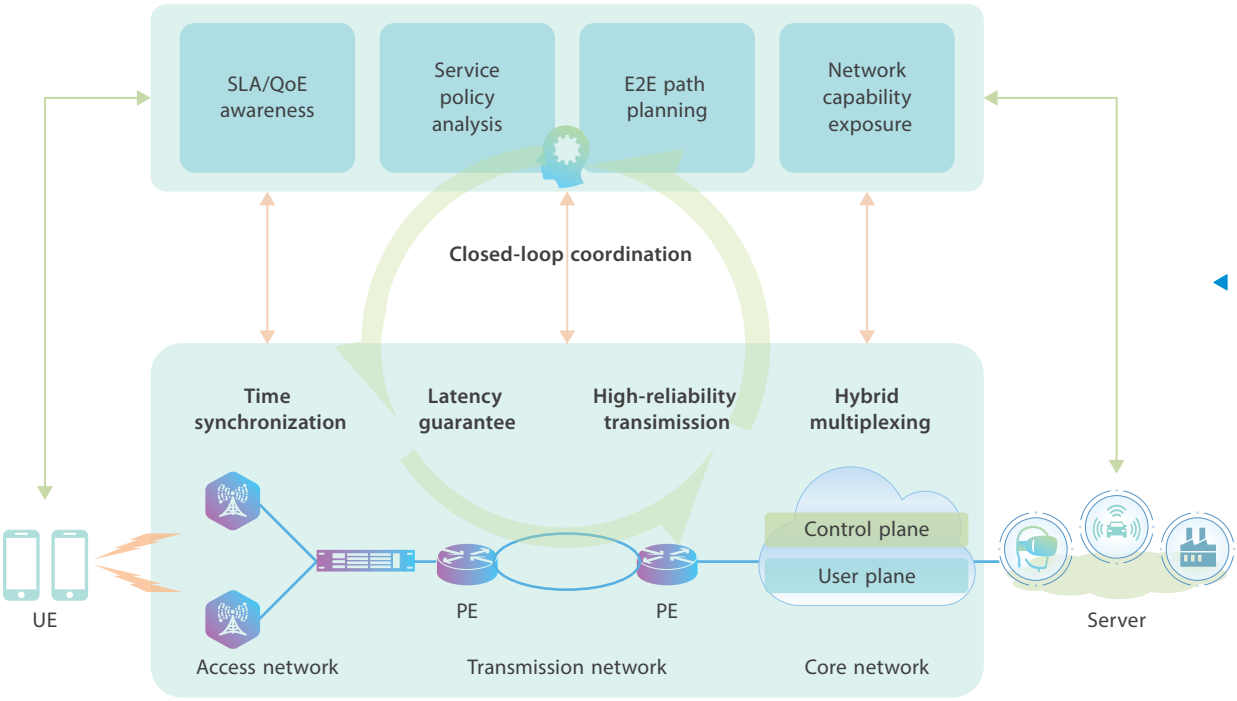


Fig. 1. Key features of deterministic network.

flows, which needs to provide deterministic guarantee for specific traffic flows in multi-service multiplexed networks. For example, there are IT and OT traffic in the industrial Internet, and OT traffic needs to ensure ultra-low delay, jitter, and packet loss rate. The hybrid multiplexing technology of deterministic network greatly reduces the cost of private network deployment and simplifies the complexity of networking.

End-to-End Closed-Loop Coordination

Deterministic network guarantee cannot be separated from optimized management and coordination of network resources. A comprehensive monitoring mechanism from terminal to network and to service will be further built in a 5G-Advanced network. It will

- provide end-to-end slice management to guarantee SLA.
- implement on-demand network customization through end-to-end coordination among terminals, networks and services.
- perceive network status, service experience and scheduling effect data, adjust service scheduling policies in real time, and construct an end-to-end closed-loop control of "perception-decision-optimization".

Standards and Evolution

The standards for deterministic network include IEEE 802.1 TSN, IETF DetNet and 3GPP TSC.

Time sensitive network (TSN) is a L2 Ethernet-based deterministic network standard defined by IEEE. More than 10 specifications related to 802.1 TSN such as 802.1AS, 802.1Qbv, 802.1CB and 802.1Qcc have been released, and they have been relatively mature. The industry has also launched a variety of TSN switches, as well as chips and industrial terminals that support TSN, which are gradually put into commercial use.

Deterministic networking (DetNet) was set up by IETF in 2015. The standard is still being formulated. Currently, more than 10 RFC specifications, such as Use Case and Data Plane Framework, have been released. Unlike TSN that only supports the L2 Ethernet network, DetNet extends the deterministic network technology to the L3 network of IP/MPLS to achieve deterministic transmission and interconnection with the TSN network, providing a technical basis for deterministic transmission over a wide area.

Time sensitive communication (TSC) was introduced by 3GPP in the R16 standard released in July 2020. In the R16 standard, the whole 5G system serves as a TSN logical bridge to implement interconnection with the TSN network. In the R17 standard being developed, the 5G system will introduce native determinacy to achieve UE-UE deterministic transmission without interconnection with the TSN network. It is expected that 3GPP will also implement interconnection with the DetNet network in the R18 standard.

Conclusion

Driven by the digital transformation of industrial networks to the convergence of IT and OT, 5G-Advanced networks will bring advantages such as ultra-low latency and jitter, ultra-high reliability deterministic transmission mechanism, no cabling, flexible deployment and mobility. These advantages will be widely used in smart factories, smart grids, smart ports and other industries. ZTE TECHNOLOGIES

Integration of Computing and Networking to Release New Network Value

Mao Lei

Director of ZTE CCN Product Planning

Research Background

As Internet technologies develop rapidly, computing carriers are more lightweight and dynamic, applications are decoupled into microservices, and network functions are cloudified, resulting in increasingly blurred boundary of computing and networking. With the business development of the intelligent society, massive raw data generated by various sensing terminals needs to be processed, and the demand of L4/L5 automated driving for computing will grow rapidly, which will promote the growth of computing infrastructure. Facing the future, ubiquitous computing resources, services, and networks need to be integrated efficiently so that the demand side can use computing resources in the same way as electricity.

China issued the "Guidance on Accelerating the Construction of Collaborative Innovation System of National Integrated Big Data Centers" in May 2021, which put forward "promoting service-based computing resources" for the first time, including building the integrated computing service system and optimizing the computing resource requirement structure. The concept of "East Data & West Computing" is proposed at the national level. To support national industry upgrade and digital transformation of the whole society, there is an urgent need to solve the problems of competition, coordination and win-win among computing, networking and applications, as well as maximizing resource efficiency.

Global standards organizations including ITU-T, IETF, BBF, ETSI and CCSA have made some technical proposals for application scenarios, requirements and reference architecture of computing force network, but they still need to be clearly converged.

Research Focus

At present, computing and networking belong to two independent technical and operational domains. The networking serves as the center to schedule computing, storage, and network resources in a unified manner. Through the enhancement of the network layer, network devices participate in sensing and orchestrating computing resources, and the network can perceive computing

power, thus providing new integrated computing services.

The research focus of computing force network includes computing operation, computing-aware network, and computing power measurement, with the aim to achieve an end-to-end closed loop of computing from generation to scheduling, and finally to external transaction (Fig. 1).

Computing Operation

Computing operation means to integrate and transact computing resources, and manage and schedule ubiquitous computing devices and multi-level computing at the end, cloud and edge in a unified manner to form a distributed cloud and complete computing transactions for end users through the operation platform. To achieve intelligent scheduling of computing and networking, the operator's computing nodes in its data center, MEC and CO, as well as the third-party's computing nodes at the end, edge and cloud, are registered to the computing and networking orchestration management system through a trusted mechanism.

The blockchain technology is introduced and applied to computing access authentication and transaction to implement de-centralization computing sharing through the consortium blockchain. Ubiquitous computing nodes, through the permission, enter the link, shield illegal nodes and traffic, and protect data security. A trusted transaction is achieved through a smart contract. During a computing transaction, the operation transaction platform accounts out through the smart contract, and the data is input into blocks and recorded on the chain.

Computing-Aware Network

Network equipment that participates in computing resource awareness and orchestration, is highly related to routing protocols. The network equipment needs to be reconstructed fundamentally. With the help of computing service routing and address-based routing, a native computing-aware network can be implemented. The computing-aware network can perceive global computing resources by dynamically releasing the resources of computing nodes such as edge DCs, regional DCs

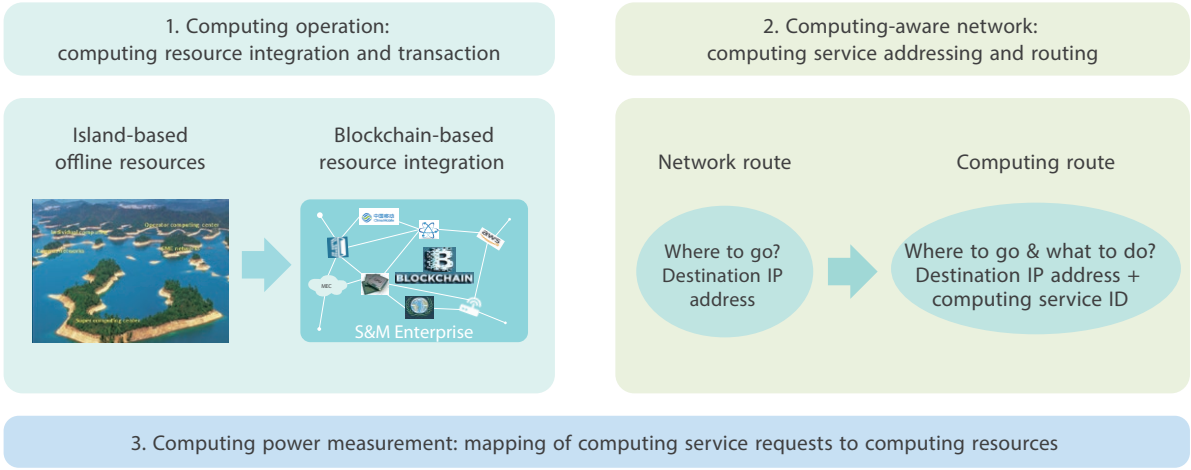


Fig. 1. Research focus of computing force network.

and central DCs to the network and coordinating with each other. The computing service awareness decision point, namely the computing service gateway, is introduced to resolve user service requests to computing resources and forward computing services based on the double constraints of computing and networking SLA. Network forwarding plane technologies such as SFC, ICN and SRv6 are also used to provide precise differentiated computing services through certain expansion.

- **Computing route:** The head node of the network needs to map computing service requirements of the application and encapsulate computing routes, and the routing layer needs to perceive the computing application and its requirements.
- **Control plane awareness:** Access control process such as IPoE/PPPoE is extended. Currently, only user access authentication is provided, which can be extended to perceive important user applications. BGP/IGP protocols are extended. The computing applications can be registered and authenticated in PE or access GW, and notified and synchronized through BGP/IGP.
- **Forwarding plane awareness:** The packet header encapsulates the application information and performs the corresponding forwarding according to the delivered policy.

Computing Power Measurement

Computing measurement and identification is the basis for supporting computing transaction and operation, and there is no consensus or standard in the current industry. With the development of cloud computing, computing carriers are becoming more lightweight, and applications are lighter. In the age of computing and networking integration, the orchestratable computing granularity at the network layer should also be fine-grained and hierarchical. By quantifying the computing power, a mapping model from service to computing is established to meet the user's request to initiate computing service. The network resolves the computing service, calculates the mapping from computing service to specific computing resource, and thus implements efficient scheduling of ubiquitous computing resources.

- **Computing grading:** Computing power is graded in fine-grained mode. The serviceable computing granularity includes service granularity (AI training, and video processing), function granularity (coding compression, and encryption) and atomic granularity (CPU, GPU, FPGA, and ASIC).
- **Computing conversion:** The conversion between computing should be provided at the level of functional granularity. Especially in the MEC scenario, when the computing resources of the same type are scarce and the services need to be expanded, the network gives priority to the conversion of computing within the MEC, such as the conversion from FPGA to CPU.

Conclusion

Network connections will be ubiquitous in the future, and there will be massive ubiquitous computing access networks. The ubiquity of computing is becoming true. The future network will be oriented to users and applications, and computing and networking need deep integration and collaborative development to maximize resource efficiency and optimize service experience. Through the computing force network, a new green, low-carbon and multi-level computing and networking infrastructure can be built. ZTE TECHNOLOGIES

Enhanced Mobility Management for Differentiated Service Continuity Requirements

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Chief Engineer of CCN Products, ZTE

While 3G and 4G use centralized mobility management to provide consistent service continuity for all users, 5G defines three types of service and session continuity modes to meet differentiated continuity requirements of different services. Under 5G-Advanced, the network and application scenarios will be greatly changed, posing new challenges to the mobility management technology.

Mobility Management Requirement Analysis

From the perspective of mobility and handover scenarios, mobile subjects are becoming more ubiquitous, horizontal handover more frequent and vertical handover more common. With cloud-network synergy and computing-network integration, network connections evolve from physical entity connections to virtual connections with intangible contents, services, and computing power, resulting in increasing ubiquity of mobile scenarios and entities (including terminals, servers, and networks). The flattening network and high-density networking at the wireless side make horizontal handover more frequent.

On the other hand, cross-network vertical handover becomes normal since coordinated heterogeneous networks provide full-scenario coverage and IPv6 and multi-host terminals get wide adoption. When it comes to service continuity requirements, different applications have different requirements for service continuity. ToC services like web browsing and video services are not sensitive to connection interruption caused by mobile handover. ToB applications such as the Internet of Vehicles, UAV and industrial Internet require seamless handover management and deterministic network performance guarantee.

It can be seen that in the 5G-Advanced network, the mobility management technology needs to solve at least the following problems:

- Provide differentiated service continuity services for different scenarios.
- Provide zero-interruption and zero-packet-loss network connections to meet seamless handover requirements.
- Guarantee consistent network performance before and after a handover to achieve fast handover

with deterministic network QoS.

Key Technologies of Enhanced Mobility Management

In line with ubiquitous mobile scenarios and differentiated service continuity requirements, mobility management also needs to evolve. This can be started from multi-connection management, bidirectional perception of application and network, AI enablement, and service-based architecture design (Fig. 1).

Multi-Connection Management in Heterogeneous Networks

Centralized mobility management using fixed anchors introduces an increase of transmission delay and reduced network performance. In distributed mobility management scheme, when the data plane mobility anchors are relocated to complete a handover, network interruption occurs.

For ultra-reliable communication, 3GPP has defined the redundant user plane transmission solution based on dual connections. Two redundant PDU sessions are used to transmit data, enabling a reliability of at least 99.9999%.

Combining the dual connectivity solution with distributed mobility management can effectively solve the connection interruption problem with the mobility anchors and ensure that the network performance is consistent before and after the handover. That is, the data plane uses a distributed deployment of mobility anchors, and mobile terminals use dual connectivity to maintain communication connections with the network. When a UE is on the move, the dual-connection handover mechanism allows the handover of only one connection at a time while the other connection is still available. During the moving process, the network is always available, thus avoiding connection interruption. Data-plane anchors closer to mobile terminals are selected. This, together with technologies such as explicit path, ensures consistent network performance before and after handover.

Bidirectional Perception of Application and Network

The future network is moving towards

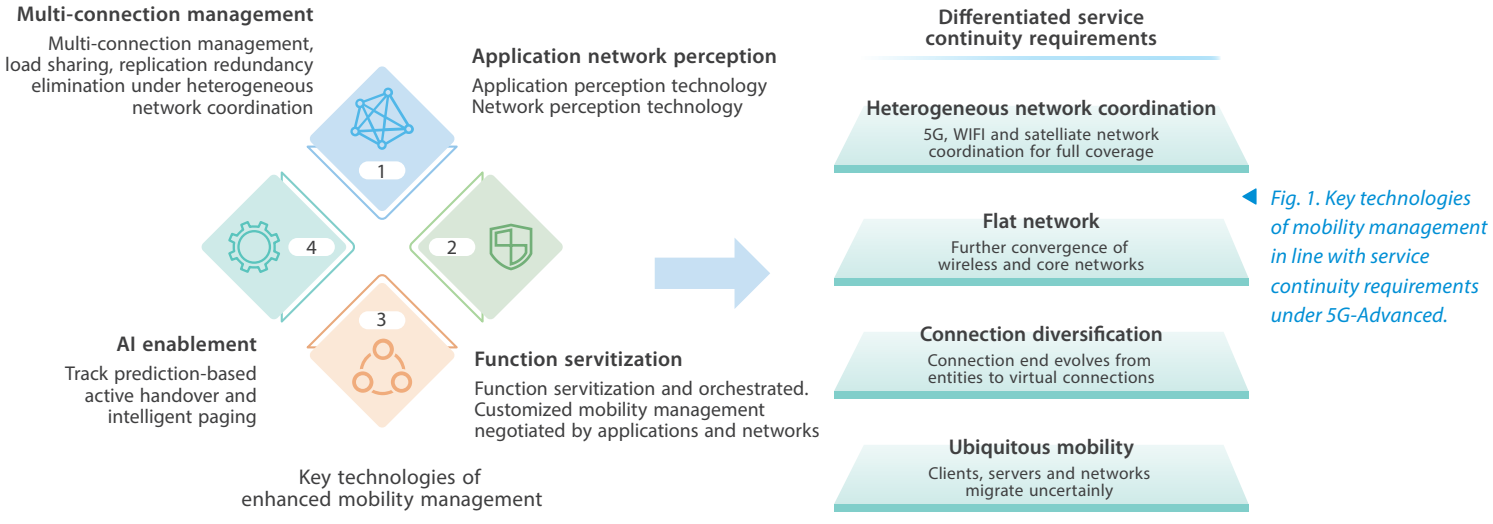

Fig. 1. Key technologies of mobility management in line with service continuity requirements under 5G-Advanced.

collaboration among the cloud, network, edge, terminal and application. By perceiving the applications' requirements, the network selects the corresponding mobility management policy for targeted network and path selection, handover triggering, and policy execution. On the other hand, applications can perceive information such as delay, bandwidth and congestion from the network in real time, and adjust data sending and receiving policies to enable a better experience.

The deep packet inspection (DPI) technology is used to detect information about applications and packet contents. In the application-aware IPv6 networking (APN6) scheme, an IPv6 packet carries the application-related information including their requirements via its extension headers, and the network layer schedules the network resources and provisions the service accordingly.

An application can subscribe to information from the network capability exposure function such as SCEF/NEF, or implement network quality detection through technologies like STAMP, TWAMP and in-band OAM to obtain network information.

AI-Enabled Mobility Management

AI, as a basic element, will be deeply integrated into networks to achieve all-round intelligence covering NEs, networks, services, O&M and operations, thus improving network efficiency and reducing O&M costs.

AI can also be used in mobility management. The research on AI-based mobility optimization is carried out in 3GPP R17 to predict and manage the location and track of the terminals and optimize the AMF paging process.

Powered by AI, the system collects and analyzes the information from terminals, networks, and applications and trains a model for the prediction of terminal tracks and handovers, thus achieving active mobility management, decreased handover delay, optimal transmission paths and customized mobility management processes.

Servitization of Mobility Management

To meet the service continuity requirements of multiple scenarios and differences, 5G-Advanced needs to provide a general mobility solution, and servitization is one of the feasible solutions.

First, the mobility management functions are abstracted and encapsulated. Service-based functions can include dual connectivity in heterogeneous networks, replication redundancy elimination, bidirectional perception of application and network, AI-based active handover, caching and forwarding based on inter-access gateway tunnel, and identity and location separation. Second, the functions can be orchestrated. For different scenarios, function chains are formed through flexible orchestration, and function chain identifiers are provided for upper-layer selection. Finally, the new functions can be smoothly introduced. The overall framework remains unchanged, while functional components are updated with the evolution of technologies and scenarios.

The research on mobility management for service continuity has been going through the entire development of wireless network, and is constantly facing new challenges. Integration with new technologies and protocols is one of the effective ways to continuously improve mobility management performance, and requires joint efforts of the industry. ZTE TECHNOLOGIES

Advantages of SRv6 and Its Applications in 5G-Advanced Core Network

Song Jie

Chief Planning Engineer of ZTE CN Products

Segment routing over IPv6 (SRv6) is a technology used to forward data packets in the IPv6 network based on the source routing concept. It combines the two most popular network technologies: segment routing and IPv6.

The native IPv6 attribute of SRv6 ensures the reachability to any network node while its powerful network programming capability can better meet the SLA requirements of network services, making it the most promising network technology in the IPv6 era.

Major Advantages of SRv6

Simplification of Network Protocols

SRv6 removes requirements for MPLS tunneling technologies such as LDP and RSVP-TE through an extension of IGP/BGP, simplifying the control plane. It uses an IPv6 address as the label for packet forwarding in place of an MPLS label on the data plane. On both the control plane and the data plane, unified transport is implemented, greatly simplifying network protocols, reducing the complexity of operation and maintenance, and allowing the cloud, network and terminals to implement an end-to-end manageable and controllable solution based on the same standard protocol. It also enables flexible front-line access to multiple clouds and agile service provisioning.

Native IPv6 Attribute

SRv6 uses an IPv6 extension header without changing the IPv6 encapsulation structure, assuring compatibility with the existing network. SRv6 relies on the IPv6 reachability to implement interworking between IPv6 nodes, making its cross-domain deployment simpler. In the packet forwarding process, the intermediate node only needs to support IPv6 forwarding and needs not to support a special forwarding logic so that SRv6 can break the boundary between the operator network and the data center network and be deployed in the data center network, which greatly enhances the extensibility and deployment flexibility of SRv6.

Network Programmability

SRv6 network programming requires an SRv6 header (SRH), which has three layers of programming space (Fig. 1):

- **Segment list:** SRH combines multiple segments in an orderly manner for path programming. It can intelligently select the best path according to the service purpose and network status and adjust it in real time.
- **SRv6 SID:** An SRv6 SID is a 128-bit IPv6 address expressed in the Locator:Function:Args format. It can be flexibly divided into multiple segments with variable length, which enables flexible programming capability. The Locator indicates information for routing to a specific SRv6 node, and Function and Args identify the specific functions and parameters to be performed on this node. Different SIDs are defined for different functions, thus offering good scalability. An SRv6 SID supports both the routing capability of IPv6 address and the behaviors of SRv6. It can represent not only the route, but also the interface, equipment, service and application. The flexible definition and application of SRv6 SIDs can realize device/application-level programmability.
- **Optional TLV:** Optional type-length-value (TLV) can be used to further define functions and support more extensive network programming. During packet transmission, some irregular information needs to be encapsulated on the forwarding plane, which can be enabled through a flexible combination of TLVs. This gives support to advanced features such as SFC, OAM, DetNet, VPN and APN6.

SRv6, based on the three-dimensional programming space of SRH, can support multiple types of encapsulation and meet the diversified requirements of new services and realize abundant network functions.

Applications of SRv6 in 5G-A Core Network

The above advantages of SRv6 make

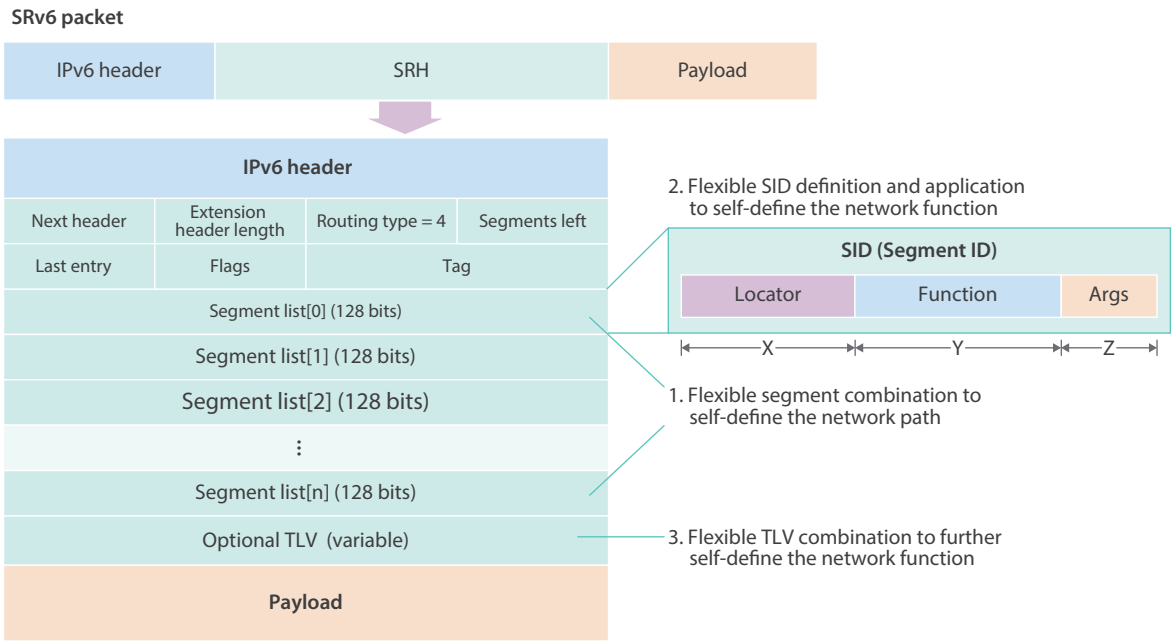

Fig. 1. SRv6 network programmablility.

the network more concise and intelligent, and make it the core technology and hotspot of IPv6+. It breaks the boundary between cloud and network and extends the network to user terminals so that an operator's network is not pipelined. It also helps operators rapidly develop intelligent cloud networks, realize application/user-level network SLA guarantee, and obtain more value.

The 5G/IoT/Cloud service requires the network to be highly scalable, maintainable, deterministic, stable and secure. A 5G-A core network only needs to expand UPF and SMF to support SRv6 and match these requirements:

Based on SRv6, a SID locator can be used as the unique identifier for a virtual network slice, identifying the network resources allocated to the slice. In data forwarding, the SRv6 SID identifies the virtual network that the packet belongs to, and indicates the topology and resources to be used for data forwarding. Based on the unified network infrastructure, differentiated forwarding paths and isolated network resources can be provided for different network slicing services, ensuring isolation between network slices both in terms of traffic and security policies and avoiding inter-slice interference.

SRv6-based SFC can be implemented by inserting SIDs related to SF into the SID list of the SRv6 header, and integrate the overlay, underlay and service chaining based on the SRv6 traffic engineering capability. The SRv6 technology has lower requirements for SF equipment (supporting IPv6 forwarding or L2 transparent transmission) and is more universal in delivering SFC. The SRv6-based service chain can support both SR-aware and SR-unaware services, and can be deployed on any network supporting IPv6 to connect high-performance, high-reliability dedicated hardware to the cloud network.

SRv6-based DetNet encapsulates data in the SRv6 header, and encodes explicit paths in the SRH to provide a stable forwarding service and to ensure that DetNet service is not affected when the network topology changes. Other functions/parameters for service protection (packet replication, elimination and ordering) and congestion control (packet queuing and forwarding) are defined in SRH, which gives supports to DetNet path redundancy and congestion protection. Thus, deterministic network services with bounded latency, low jitter and zero packet loss can be provided for high-value service flows.

APN6 uses SRv6 packets to convey application information into the network, allowing SLA requirements from applications to be perceived by the network in a native way. According to the application information carried in the packets, the network is able to apply the corresponding policy, dispatch the traffic, adjust the resources, and select the corresponding SRv6 path (such as low-latency path), providing SLA guarantee and appropriate network services to applications. APN6 achieves seamless combination of network capability and service requirements so that the network can sense the applications' requirements, provide high-quality differentiated services, and realize streamlined operation.

As a basic technology for future networks, SRv6 is developing at a high speed. In 2020, ZTE supported China Telecom to realize the world's largest commercial SRv6 network. With rapid development of 5G/IoT/Cloud services, SRv6 will certainly play a more important role. The IPv6+ innovation represented by SRv6 is leading the transformation of the future network from the interconnection of all things to the "intelligent" connection of all things. ZTE TECHNOLOGIES

Intelligent Evolution of 5G-Advanced Core Network

Niu Jiaohong

5G CN System Architect, ZTE

Mobile services will be immersive, intelligent, and global in the future. The present mode of operations such as manual awareness, analysis, decision and execution cannot meet the needs of fine-grained SLA guarantee and operations. Operators need new methods to simplify the deployment, operation and maintenance of mobile networks.

In recent years, artificial intelligence for IT operations (AIOps) has achieved high-level automated operations based on big data and AI, which has greatly reduced operating costs. Thousands of devices in mobile networks generate a large amount of data, which can play an important role in network planning, deployment, maintenance, optimization and operation.

Vision of Network Intelligence

New services and scenarios in the 5G-Advanced era, such as holographic interaction and integrated space-terrestrial network, impose higher requirements upon mobile communications. The continuous integration of AI and telecom technology will realize a new type of native intelligent network, providing enterprises and end users with zero wait, zero touch and zero trouble (Zero X) experience. In the future, network intelligence will play a huge role in user experience optimization, efficient operations, and security guarantee.

- **User experience optimization:** It involves assisted service QoS parameter adjustment, slice access control, user plane path selection and RAT/Frequency selection.
- **Efficient operations:** The intelligent analysis provides health check, anomaly detection and prediction, and fault root cause analysis, based on which the operations such as capacity optimization, configuration optimization, resource scale-in/out and fault location are performed to reduce repetitive work. The intent-based network is introduced to drive network planning, design and deployment through the intent, thus reducing the requirements for the O&M personnel.
- **Security guarantee:** The mobility and interaction behaviors of specific types of terminals are regular. User equipment may be maliciously hijacked, resulting in serious network security problems. The behaviors of user equipment can be monitored through big data analysis.

Intelligence Architecture and Key Technologies

To continuously enhance network intelligence and meet the distributed collaboration intelligence and secure and trustworthy intelligence required by IoT, it is necessary to achieve the self-optimizing, self-healing, and self-evolution capabilities with respect to the architecture design.

To achieve the goal of zero touch, zero wait and zero trouble in network operations, the following AI technologies can provide reference for intelligent development of 5G-Advanced network.

Machine Learning is the Basis of Network Intelligence

The traditional network operations mode relies on manual static rules, so it cannot adapt to dynamic scenarios. However, machine learning can make efficient and accurate decisions under complex dynamic changes. The machine learning technology can be introduced for the transition from “expert experience” to “machine learning”.

In a mobile network, data is scattered and may have privacy requirements. Federated learning can help multiple parties in data use and machine learning modeling while meeting the requirements of user privacy protection.

The applications of federated learning also face the challenges of communication efficiency, non-independent identically distribution data, security, and robustness.

Intent Driven Management Defines User Intent and Helps to Implement Zero-Touch Operation

Intent specifies expectations, including requirements, objectives, and constraints on specific services or network management work flow. The intent network aims at the user's intent or business objective, emphasizing the intent of network operations and architecture personnel (the entire network users).

The application scenarios include network planning and design (such as intent-driven capacity planning, coverage optimization, and site planning), network and service deployment, intent-driven service deployment (such as service deployment at the network edge) and intent-driven network and service maintenance, optimization, and guarantee.

The intent network has problems such as declarative API creation, intent breakdown and translation, and compatibility between components and devices.

Digital Twin Provides Better Simulation Verification Capability

The digital twin network constructs real-time mirroring of a physical network, which can enhance system simulation, optimization, verification and control ability that the physical network lacks.

Digital twin is applied to the network to create a virtual image of physical network facilities and build a digital twin network platform. Through the real-time interaction between physical network and twin network, low-cost trial and error, intelligent decision-making, and efficient innovation can be achieved.

The construction of digital twin network system is faced with compatibility problems, modeling difficulties, real-time challenges, and scale problems.

Application Scenarios

End-to-End Service Experience Assurance

When user experience is not satisfactory, operators need to adjust network resources in time. They need the service experience evaluation capability to measure user experience. The user experience can be affected by terminals (such as CPU/memory occupancy rate, air interface measurement), networks (such as user-plane bandwidth, user-plane latency, and user-plane congestion), and service servers (such as TCP sliding window at the transport layer, and cache at the application layer). Due to the privacy of user data and the isolated data islands, the data in various domains that affect service experience cannot be trained together. Therefore, federated learning is needed to train or reason the service experience model without losing the original data of terminals, networks and service servers.

Security Guarantee in the Verticals

In the verticals, data analysis can be used to identify terminal or network exceptions. First of all, the behavior baselines of NEs and signaling access are established based on the predefined and big data AI learning. Secondly, according to the abnormal user behavior characteristics, signaling logs and traffic logs, abnormal signaling and NE attack behaviors are accurately identified, such as abnormal user terminals, base stations and MECs. Finally, the corresponding handling methods, such as de-attachment, de-activation, rate limit, blacklist, and N6 blocking, can be implemented together with PCF/EMS.

Looking to the Future

ZTE has cooperated closely with operators in network intelligence in many provinces and cities in China. They have also made positive progress in a national key project, the data-centered DICT deep convergence, promoting the pre-research of network intelligence. ZTE TECHNOLOGIES

Building Native Security System in 5G Trusted Network

Yang Chunjian

Network Security Architect, ZTE

Security Issue

5G is the underlying core technology of digital economy and also the basic support for high-speed development of the information industry. The 5G network security becomes an important challenge for mobile communications in the future.

At present, the telecom network provides security protection through patch-based, passive, and external measures. The risk level of network security can only be evaluated statically, and its risk status can be roughly evaluated through factors such as network value, security vulnerabilities, and frequency of security incidents. However, the attacks on the network cannot be detected and protected in real time.

In the deployment of network security and protection, the maintenance cost is high, so it is difficult to adjust the dynamic policy and maintain automatically. This has been unable to meet the service needs and application scenarios of current complex telecom networks.

Native Security Solution

Facing future network evolution, ZTE has proposed to build an integrated trusted network security architecture (Fig. 1). The 5G/5G-Advanced network security should have four features: automation security, self-defense security, self-adaption security and self-evolution security.

Automation Security

The security and protection capabilities of various assets in 5G networks are automatically improved, including equipment nodes, infrastructure, network service, data, users, management nodes, operating systems, middleware, database, and software service. This helps to achieve complete and trusted protection, service, access, and data, dynamically measure and detect system status and security, and build native security at the NE level, thus promoting native security at the network level.

Security management is implemented for all assets of 5G network cloud through visualization, and unified security vulnerability management, configuration delivery, and upgrade can be realized. Intrusion detection is implemented for network traffic and data streams, ACL policies are set, and abnormal processes are managed and controlled.

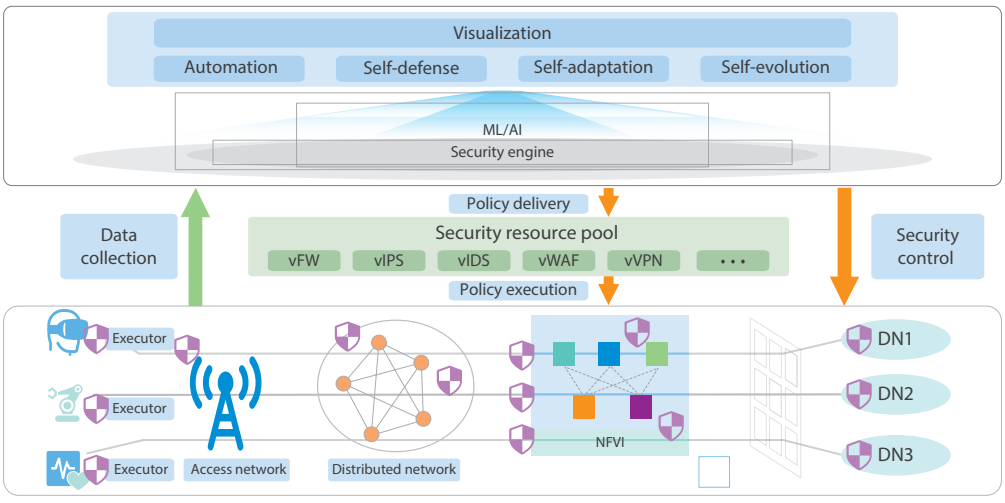

Fig. 1. Trusted network security architecture.

The security engine is used to implement unified security capability orchestration. The cloud and network are scheduled and orchestrated for automatic security resource allocation, automatic security service distribution, automatic security policy adaptation (network security coordination), and real-time protection responses to advanced network threats (security analysis linkage). Multiple NEs and layers coordinate to ensure network security, implement centralized security policy management and orchestration, and provide security services as required.

Self-Defense Security

5G network cloud based on cloud computing and SDN/NFV needs to learn from traditional experiences and lessons and introduce the blockchain technology to help the network build a secure and trusted communication environment and realize the tamper-proof and recovery of the system. Trusted computing can be used to implement trusted startup, trusted measurement, and remote trusted management of NEs, make network hardware and software functions run continuously in line with expectations, and provide active defense capability for network infrastructure.

Zero trust is also introduced to carry out fine visual management of the network. The corresponding security components are deployed to build an end-to-end 5G network cloud security system. All user behaviors and logs in the management system are managed in a centralized manner, and regular audit policies are set to perform security audit. The overall 5G network-cloud security can be audited and traceable.

Self-Adaptation Security

5G security service can monitor and perceive the security status of 5G network cloud at any time, and the asset security risks are visible. Security events can be quickly predicted and alerted at the first time, and can be detected, repaired or dealt with in time to ensure the availability of network service. When the network service or security system is upgraded, or the service process is rebuilt, the security capability can be improved dynamically.

When part of the network is invaded, the security engine intercepts threat traffic and starts a security hardening process to quickly avoid or eliminate the threats. In addition, the security service can share threat information to protect the entire network from similar threats.

Self-Evolution Security

Each layer of the network is embedded with AI capabilities and federated learning (distributed machine learning) capabilities to implement network self-adaptation, self-awareness, and self-operations. Through rapid learning and training, the AI and federated learning technologies can detect, backtrack, and analyze network traffic and behavior abnormalities more accurately, and establish a ubiquitous interaction and coordination mechanism among the end, edge, network, and cloud intelligence entities of the telecom network. These technologies accurately perceive the state of network security, predict potential risks, and then complete self-optimization and self-evolution through the intelligent consensus decision-making mechanism to achieve active in-depth security defense and automatic handling of security risks. They also provide practical security analysis and alarms to resist various APT attacks.

Summary

From the four dimensions of automation security, defense, prediction, detection and response, the native security system in a 5G trusted network emphazes that security and protection is a continuous and cyclical process, and can build a self-adaptive security model in major business scenarios. Based on the self-adaptive security architecture, the native security system generates and coordinates defense, detection, response and prediction capabilities to achieve self-discovery, self-repair, and self-balancing of security attacks. In this way, an independent security immunity can be built to provide an integrated network security service.

ZTE has been committed to building an end-to-end automatic, AI, resilient and trusted native security communication network to provide more secure and reliable products and services for customers around the world. ZTE TECHNOLOGIES

IP Network Evolution Based on Ubiquitous Service Awareness

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During the evolution from 5G to 5G-Advanced, the bearer network evolves synchronously with the core network on the network side. In particular, IP evolution requires core network and bearer network to evolve at the same pace to complete the end-to-end wireless network evolution.

TCP/IP has achieved great success in the past 50 years, but the existing IP technology has great limitations facing the needs of future industrial Internet and digital economy development era. In this context, ZTE, together with the China Academy of Information and Communications Technology (CAICT) and the research institutes of three major telecom operators in China, released the *Technical White Paper on IP Network Evolution*. The white paper analyzes the vision of IP network development and the needs and challenges it is facing, and proposes a new path based on IPv6 evolution on the basis of the traditional IP network.

Future IP Network Visions

The development of future IP network can be summarized as three capability vision goals including multidimensional interconnection, precise transmission, and enhanced service, as well as three mission vision goals (Fig. 1).

The three capability vision goals of future IP network refer to the continuous improvement and evolution of three basic network capabilities: interconnection, transmission and service. Multidimensional interconnection means to continually expand network interconnection boundaries, connecting heterogeneous networks such as integrated space-terrestrial network, intelligent optical bearer and access network, B5G/6G mobile Internet, IoT, and industrial Internet, as well as industries and digital economic and social systems. Precision transmission refers to providing more powerful and accurate transmission capabilities such as ultra-high bandwidth, ultra-low latency, ultra-low jitter, and ultra-high reliability based on the basic transmission capability provided by current networks. Enhanced service means that network expansion provides a variety of enhanced services such as deterministic transmission, native security, computing and mobility based on the best-effort service, and can dynamically perceive service types to provide accurate scheduling capabilities for cloud, network, edge, and end integration.

The three mission vision goals of future IP network include industrial empowerment, ubiquitous service, and cloud-network integration. Future IP network takes industrial empowerment as the main scenario mission to serve the needs of digital industrialization and industrial digitalization such as industrial Internet, Internet of vehicles, smart city, and smart healthcare. It has the service mission to use resources anytime, anywhere and at will by users. The deployment of resources and services will gradually change from a centralized model (central cloud) to a distributed model (cloud-edge-end), allowing the network to provide nearby users with fast response, low latency, and high reliability services. As higher requirements are posed on supporting ubiquitous and differentiated services, a third mission that future IP network needs to complete is to better combine computing

resources and precise transmission capabilities to achieve computing power distribution and coordination at the cloud, edge, and end levels. Future IP network based on the new infrastructure that integrates computing and networking will realize a close integration of application, network and service, and provide optimal service experience and the best network resource utilization for applications.

Two Principles for Improving Future IP Network Design

From the perspective of Internet history and evolution, the two core design principles, end-to-end and hierarchical decoupling, give IP strong scalability and flexibility, and are still applicable to development and evolution of future IP network. The evolution of the Internet should inherit the efficiency and stability of core functions and avoid revolutionary replacement. Based on the visions of future IP network, the following two principles are proposed for improving its design.

- **End-to-end to empower service-based network:** The IP network expands network functions to both ends. It realizes the interaction between applications and the network through intelligent plug-ins to ensure high reliability and high scalability of future network services. It also provides enhanced and common service capabilities, including deterministic transmission, native security, computing network capabilities and continuous mobile services, while maintaining the original best-effort service.
- **Narrow waist model supported by the intelligent control plane:** Based on the narrow waist model of the traditional IP network, the enhanced intelligent control plane is used with AI, intent network and mirror network to program atomic functions such as forwarding plane identification, routing, shaping and scheduling to meet the needs of complex applications.

IP Network Evolution Based on Ubiquitous Service Awareness

Based on the vision goals of future IP network and the two principles for improving its design, it is necessary to introduce two new functional paradigms to the IP network: ubiquitous service and network awareness.

Ubiquitous service means that the demand side of service is everywhere. The service demander does not need to know the identity and location of the service provider in advance, and the network selects the best service provider according to the needs of the service demander to achieve efficient service discovery and distribution.

Network awareness means that in the face of new ubiquitous service paradigms, IP network not only needs to perceive the service provision and needs of terminals and the cloud, but also can transfer the service status to the network layer efficiently and meet the service requirements more accurately by combining the capabilities of service demanders, service providers, and the network itself.

Focusing on new function paradigms of ubiquitous service and network awareness, ZTE has proposed a new path of IP evolution based on ubiquitous service awareness (Fig. 2).

Based on the above-mentioned two principles for improving future IP network design, the new path of IP evolution based on ubiquitous service awareness introduces home-independent protocol interfaces and the unified service naming system to effectively support the new paradigms of ubiquitous service

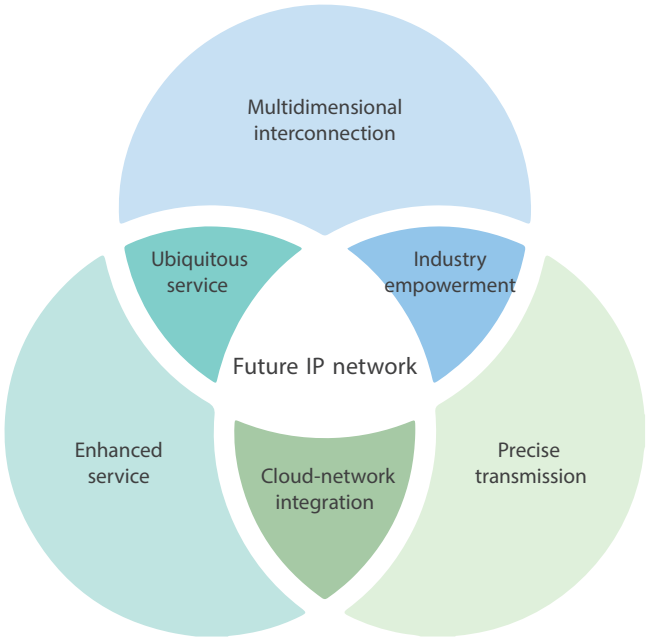

Fig. 1. Future IP network visions.

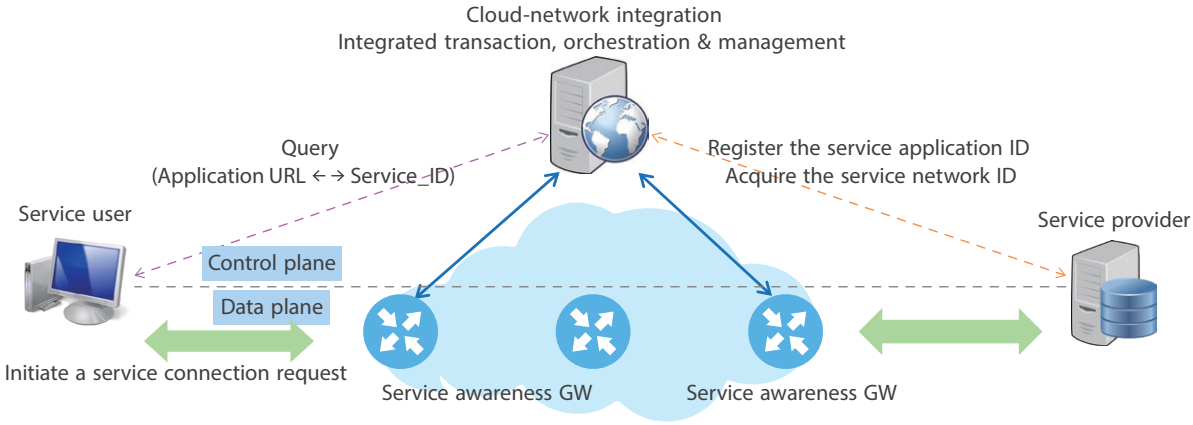

Fig. 2. A new path of IP evolution based on ubiquitous service awareness.

and network awareness, thus ensuring the fulfillment of future IP network vision goals.

The home-independent mechanism ensures that users can request and obtain services at any time, anywhere as they wish. The application does not need to care about the provider and location of the service, but only needs to focus on the needs and logic of the application itself. The home-independent protocol is responsible for requesting the network to establish a service connection, manage and maintain the service-based connection status, and provide enhanced transmission functions such as service-oriented congestion control, mobility, order preservation, multi-path/multi-homing, and native security. The application can directly call the home-independent protocol interface to request a service.

The unified service naming system is introduced to enable unified allocation and scheduling of applications and the network and provide optimal network scheduling and QoS. The service ID can serve as an open service network interface that provides home-independent ubiquitous service connection management and connects virtualized resources such as computing, storage, content and capabilities. It can also ensure the network-aware service, and uniformly register, manage and index the service.

On the control plane, the integrated cloud-network transaction, orchestration and management controller in the new path is responsible for service registration, release, and query, and dynamically associates the mapping of service IDs to network-layer addresses. Service IDs must be allocated by the network, unique in the network, and remain unchanged during the service connection to ensure mobile continuity. Service routing policies and tables are delivered to network-layer devices through the control channel.

On the data plane, the service user initiates a service connection request with a service ID, and the service provider listens to the service request based on the service ID. The network edge node selects the optimal service destination node according to the service ID, orchestrates network resources, and executes the corresponding SLA policy.

The new path of IP evolution based on ubiquitous service awareness decouples the application from the service, so that the application focuses on its own logic innovation, and the common home independent services are provided by the native network. Because the application is decoupled from the network, the inefficient search process of DNS is removed and service addressing is more efficient (the efficiency in MEC scenarios can be increased by at least 100%).

The IPv6-based IP technology based on ubiquitous service awareness enables the cloud-network integrated infrastructure to provide the best service experience for service demanders. It leverages a good IP ecological chain to make applications and the network evolve smoothly, facilitates the rapid deployment of digital economy, and protects the early investment in resource construction. The integrated supply of network and service promotes the transformation of network as a service and adds the network value from a pipeline to an empowerment platform. This accelerates the deployment of digital economy and multiplies the capabilities of IP network. ZTE TECHNOLOGIES

Lighting up "Eiffel Tower" in Libya

Libyana is the largest mobile operator in Libya, committed to increasing local mobile penetration, improving users' lives, and promoting national economic growth and intelligence transformation. Libyana provides network coverage in all key regions of the country, and has the best local LTE network, serving users in over 49 cities. In the future, Libyana will work with its partners and the capital government to launch the first local 5G network and promote the implementation of the 3SC plan, i.e. smart company, smart city and smart country.

Libyana proposed to build a new 100m tower at its headquarters in the capital Tripoli in 2017 to share the traffic of the existing 70m tower. The 70m tower is an important convergence site. After the 70m tower was put into use, a large number of antennas were installed on it, and the tower was in a state of overload operation. Because the headquarters is close to the seaside, the tower has been rusted in the harsh environment. The new 100m tower will not only meet the needs of future service development, but also show the brand image of Libyana.

Libyana has selected ZTE's lighting tower solution that integrates a lighting system on the communication tower. The new tower has become an outstanding landmark building in the area, while meeting the requirements for installation and operation of telecom equipment. It highlights the high-end image of Libyana and has few precedents in the industry. The tower structure is designed according to the American ANSI/TIA standard and with the highest safety index. More than 22000 brightening light sources and Libyana Logo are deployed on the tower, which are colorful and changeable after the lights are on.

ZTE has put forward a number of innovative technologies and developed the "1+4" solution that includes one super tower and four major systems such as equipment installation system, power

Liu Chengwen

Director of ZTE Wireless Product Planning

supply and distribution system, lighting control system, and wiring system. The solution has been certified by professional consulting institutes and highly recognized by Libyana.

One Super Tower

The tower is 100m high, the antenna load is up to 65 m², and its future expansion capacity is reserved. The tower body is designed with two slope changes to solve the contradiction between the small site area and the high anti-deformation requirement for the tower. High-strength steel and high-efficiency anti-corrosion technologies are used on the tower to ensure long-term reliable operation in coastal areas.

Tailor-Made Equipment Installation System

More than 22000 light sources have been deployed along the members of the tower to achieve the ultimate brightening effect. Libyana has chosen ZTE's tailor-made equipment installation system to address the installation issue.

- **Standard connectors:** The light source deployment solution used in traditional lighting projects is not applicable for the telecom tower due to its structural characteristics. ZTE has designed standard connectors that match the tower structure. The connectors build a bridge between the tower and light sources, providing a unified installation interface for them. This results in easy installation, stable construction quality, and reliable connection of light sources. After installation, the light sources are neat and beautiful.
- **Protruding antenna bracket:** As a core tower of Libyana's network, many antennas in different forms will be gradually installed on the tower during its service period. As both the antennas and light sources are installed on the tower, how to make the light sources not affect the installation of the antennas is a problem that must be solved. ZTE has creatively developed its protruding antenna bracket that makes the installation independent of light sources and suitable for all kinds of antennas, so that the antennas can be added to the tower at any time as needed.
- **Well-deployed equipment platform:** To ensure stable operation of 22000 light sources, reliable power supply and distribution equipment need to be deployed near the light sources. According to the tower structure and light source distribution, five layers of equipment platform are placed at a distance of 85m, 60m, 40m, 22.5m and 7.5m above the ground respectively. Each platform supports the installation of sufficient power supply and distribution equipment, laying a solid foundation for stable operation of the lighting system.

Power Supply and Distribution System

The power supply and distribution system is designed in accordance with power distribution requirements and on-site conditions, and matches the Libyan power grid system. It consists of a main inlet cabinet and multiple power distribution cabinets, which drive 230 switch mode power supplies (SMPS) on the tower and supply power to the light sources. The power supply and distribution system is self-designed by ZTE and matches the tower lighting scene perfectly. The lighting system can be automatically turned on and off at a set time. In the design, each string of light sources and the corresponding SMPS are numbered, so that the on-site construction and follow-up maintenance can be accurately managed. Thorough leakage

protection and grounding devices are also provided to ensure power safety.

Lighting Control System

The lighting control system consists of two main controllers and several sub-controllers. Using the DMX512 signal control standard, it can control each light source accurately and independently, make it change in 256 colors, and provide the tower with a colorful, gorgeous and ever-changing appearance.

Light sources are controlled flexibly through a memory card or remotely controlled by a computer. Through the professional playback control software, managers can debug the lighting system, edit playback files, and control the playback process. The operation of the lighting control system is very simple and can be mastered with a small amount of training.

Wiring System

The cables involved in the tower include power lines, grid lines, feeders, grounding wires and other types, each of which has different specifications. The number and variety of the cables far exceed that of conventional communication towers. ZTE's well-designed wiring system effectively connects all the components, makes them work together, and realizes communication and lighting functions. The customized wiring/climbing integrated facilities have good stability and strong carrying capacity, and can meet the need of a large number of cables for vertical routing. Strong and weak electricity cables are deployed separately and conveniently with neat appearance. Horizontal wiring channels are deployed around the equipment platform, which can match the layout of the cabinets, so that the cables can be easily connected to the cabinets.

The core tower of Libyana's headquarters is also the first lighting tower in Libya, known as the country's "Eiffel Tower". It is the most important benchmarking project of Libyana and is highly valued by Libyana and ZTE. ZTE set up a special team to service the project. During the production period, ZTE organized professionals from all parties to test the tower and lighting system, and passed strict on-site factory inspections by Libyana and professional institutions. After the materials were delivered to the site, ZTE braved the influence of Covid-19, arranged for experts to provide on-site and remote support, and successfully completed the installation of the tower and lighting system.

These lights were first lit on the Libyan Revolution Day in 2021, making the holiday night even more beautiful. Senior Libyan government officials and senior Libyana management attended the ceremony and toasted with ZTE representatives. This news was widely reported on local TV stations and various social media, attracting great attention and enhancing the brand image of Libyana. ZTE will take this project as a model, keep optimizing the tower lighting solution, and promote it in other regions to create value for more customers. ZTE TECHNOLOGIES

5G Industrial Case Analysis and Best Practices

Egor Manyukov

Integrated Comprehensive Solution Manager, ZTE Russia

At the GSMA Mobile 360 Eurasia, Egor Manyukov, integrated comprehensive solution manager, ZTE Russia, shares ZTE's explorations in industrial applications of 5G.

What are the various industries from the point of view of the digital economy? We can see that digitalization gives impetus to the emergence of completely new directions in the industry, including the development of the Internet, technologies and services. All this is based on the basic principles of communication (standards) and is implemented on the basis of the latest developments in the electronics industry (i.e. chips). On the other hand, we see classical industries (industrial production, mining, energy, medicine, education, and so on) that currently require digitalization to increase efficiency at all stages of planning, production, management and operation. At the heart here is the data that needs to be processed quickly with the help of appropriate tools. And 5G in this case acts as a bridge between the latest innovative industries and applied digitalization tasks in classical industries.

What does digital transformation with 5G look like in vertical industries? The main technologies that are already available and are used to solve applied problems (such as big data, artificial intelligence, slicing, edge computing), with the help of 5G are transformed into appropriate services (augmented reality, remote control, video surveillance from cameras and drones), and then implemented in specific vertical industries to solve applied problems. Let's look at the most significant scenarios that we have managed to implement for various industries in different parts of the globe.

Let's start with a well-known saying: If you want to change the world for the better, start with yourself. ZTE has implemented digital solutions based on 5G at its leading factory in Nanjing for the production of telecom equipment (such as BBU—Baseband Module, AAU—active antennas). Digital transformation is

applied at all stages of the smart factory operation, includes checking the components that have arrived for defects using machine vision, remote control of conveyor robots, patrol robots, automatic means of transportation in workshops and in the finished product warehouse, the use of digital counterparts of finished equipment for quality control. Because of this, it was possible to reduce the cost of maintenance of the production line by 47%, as well as improve the detection of problem areas by 80% compared to the manual procedure. How was this system implemented?

A high-precision cloud network was implemented that covers the factory itself and the campus located around it. The solution is deployed in the data center in the Binjiang district, where the factory is located. There is also an IoT platform on which various applications are deployed. Already directly in the factory premises, closer to the workshops, there is mobile edge computing (MEC) equipment that performs boundary calculations that reduce latency and achieve real-time operation of machines and mechanisms when receiving remote commands. We use active antennas for external coverage and the Qcell solution for internal coverage when we get a precise cloud network, when cloud services are close to us and meet our needs.

The next important and very interesting case is the port. In the Port of Antwerp in Belgium, we managed to implement a collaboration between us, the ZTE vendor, the Orange operator, the state represented by the largest shareholder of the port and the largest companies that constantly use the port infrastructure for their business, such as Covestro, Borealis, Basf. The first interesting case is related to the direct activities of the port itself. The fact is that the territory of the facility is located in the depths of the continent far enough from the open sea, and therefore the place for maneuvering ships is strictly limited. Two small tugboats are used to guide the vessel—one from the bow, the other from the aft side of the ship. Previously, the captains of the ships did not see each other and used only voice communication for negotiations. With the introduction of 5G, thanks to high-definition video cameras, tugboat captains and dispatchers see images of ships from any angle, which allows for a fast and safe process of mooring the vessel and increasing the safety, efficiency and throughput of the port. The Mission Critical Push-to-Talk system was implemented for Basf, and this is not an ordinary closed-circuit negotiation system, but is fully integrated into the enterprise's platform for managing all processes and transmitting, if necessary, video images, location and other necessary data. A system for collecting technical parameters from chemical production and storage equipment located in the port was implemented for Colvestro using wireless 5G sensors. And for Borealis, a system for automatic detection of various fractions in the supplied material was implemented using machine vision. Different slices with different priorities were used for different services on a single system.

The use of 5G in medicine has become especially relevant in the current epidemiological situation. In many hospitals in China, robots were used instead to minimize human visits to red zones. They allow you to analyze the patient's condition and transfer data to medical staff, deliver food and medicines to the patient. Another important aspect is that, thanks to online medicine with the transmission of video images and data on the condition of patients diagnosed by a robot, the availability of highly qualified medical care for residents of remote rural areas has increased many times.

Smart learning scenarios allow students to visit various points of the globe and time epochs using high-definition video and a holographic presence effect. Also, data analysis using artificial intelligence allows you to automatically monitor the attendance of lessons, as well as, for example, the delivery of standards in physical education lessons. But most importantly, practical classes with virtual and augmented reality will allow us to better unlock the potential of a new generation of students and attract the best talents for the benefit of humanity.

And this is only a small part of the successful experience that ZTE has in implementing 5G projects. To summarize briefly, we have developed over 100 5G application scenarios for 15 industries, and to date have implemented more than 60 demonstration projects in China and around the world and this will be continued with more and more partners. ZTE TECHNOLOGIES

5G+ Deterministic Smart Grid Application

Zhang Qiang

Director of ZTE CN IPR

China Southern Power Grid, together with China Mobile and ZTE, has deployed the industry's first slicing-enabled electric power private network for commercial use in Guangzhou, covering the whole Nansha New Zone with over 100 sites, and has successfully verified over 50 categories of power communication services. The 5G slicing-enabled private network not only provides high-security resource isolation for services in the power grid production area but also deterministic, low latency and low jitter communication.

The grid operator's services involve five links: power generation, transmission, transformation, distribution, and consumption. Different services have different network requirements covering security isolation, bandwidth, latency, jitter, and timing accuracy. According to their functions and SLA requirements, grid services are divided into two types: production area and management area. Different types of smart grid services impose different 5G network performance requirements. For services in the production area (e.g. differential protection, PMU and power distribution automation), high reliability, low latency, and high-precision time synchronization are required. For services in the management area (e.g. substation services and integrated services), high bandwidth is required.

In the production area, services with low latency and low jitter requirements use advanced 5G technologies such as PRB resource reservation, FlexE high-speed forwarding channel, UPF deployed on edge for offloads, and mobile station-to-mobile station (MS2MS) point-to-point direct communication, and will gradually introduce 5G LAN, URLLC and TSN to provide deterministic communications, and in the management area, services with relatively low requirements on latency and deterministic performance use QoS-based scheduling. The slicing-enabled private power network is shown in Fig. 1.

Point-to-Point Communication

Traditional differential protection uses direct optical fiber connection to unicast or multicast L2 packets. In the Nansha Project, the 5G network is used to replace optical fibers to interconnect differential protection terminals. In the 5G communication technology, 5G LAN can provide L2 UE-to-UE communication. However, at this stage, the 5GLAN industry chain is not mature, and the terminals do not support the establishment of L2 session. Therefore, ZTE adopts the MS2MS function to provide point-to-point and point-to-multipoint

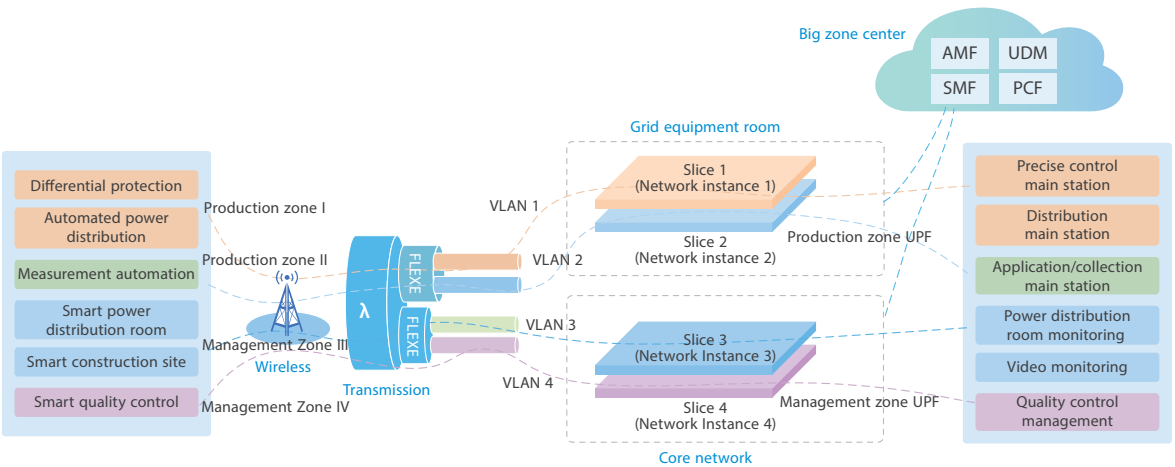

Fig. 1. Slicing-enabled private power network in Nansha, Guangzhou.

communication, and upgrade and reconstruct the DTU to provide L3 communication. A DTU accesses the 5G network through CPE, and the differential protection messages are directly switched back on UPF. In this way, UE-to-UE communication can be achieved and smoothly evolved to 5G LAN.

Preservation of PRB Resources

The 5G radio air interface resources can be divided into different resource blocks from such dimensions as time, frequency and air interface. The frequency domain can be partitioned into physical resource blocks (PRBs) with each PRB covering 12 subcarriers. To meet the high security and low latency requirements of services in the production area, the wireless side of the grid uses PRB reservation to guarantee fast forwarding, that is, a proper PRB resource reservation proportion is set for services based on their bandwidth and latency requirements,.

The reserved PRB resources can be dedicated to a slice group, which is used for all the services within the slice group. The data radio bearers (DRBs) for different slices are mapped to different PRBs to achieve physical security isolation. Resources can be obtained without competition, and high reliability can be guaranteed through reservation. Compared with QoS-based slicing with shared PRB resources, PRB reservation-based slicing provide hard isolation similar to dedicated radio spectrum resources while supporting the flexible policies of assigning PRB resources in a dedicated or shared manner. By reserving a certain proportion of PRB resources, ZTE's solution guarantees the bandwidth resources of the private power network and provides isolation and deterministic guarantee.

QoS Priority-Based Scheduling

The QoS priority-based scheduling is used for services with low requirements for isolation in the management area. For services with high isolation requirements in the production area, differentiated QoS guarantee may be required. For example, in the slice of the production control zone I, second-level latency is required for remote monitoring, control and measurement in distribution automation, and 50 ms latency required for PMU application. These services can be classified, allocated with different 5QIs, and matched with different radio policy parameters based on a specific S-NSSAI. In this way, different power services in the same slice have differentiated QoS guarantees.

Dedicated UPF

To meet the high isolation and low latency needs of grid services, UPF is directly deployed in the grid equipment rooms to provide local service access and ensure the security of grid service with no data leaving the zone. Thus, low latency and deterministic communication can be enabled.

In accordance with the security characteristics of grid services, ZTE also proposes the multi-network instance and multi-slice isolation technology for UPF sharing to solve the resource isolation problem when the services in the production or management areas share UPF. A physically-independent dedicated UPF is deployed in the production control area with high security requirements. On this basis, multiple logically independent slices can be created, providing isolation between the services in the security zone I and security zone II and SLA guarantee.

- **Multi-instance:** To meet the resource isolation and SLA requirements of services in different areas, different network instances are configured in the UPF, and different resources and VPN isolation strategies are configured in each network instance.
- **Multi-slice:** Multiple network instances can be mapped to power grid slices, and resource isolation, network plane isolation (VLAN) and bandwidth isolation between power grid slices are implemented through the utilization of network instances.

TSN Technology

URLLC + TSN is the best solution for the grid in the future as it can solve low latency, high reliability and low jitter problems at the same time. At present, URLLC or TSN is not mature in terms of industry chain. In line with the progress of the industry chain, both URLLC and TSN can be gradually introduced into grid communications.

In the demonstration project between ZTE and China Southern Power Grid, ZTE provides wireless, bearer, and core networks, and deploys end-to-end 5G deterministic-network slicing with low latency and jitter to provide differentiated SLA guarantees for power grid services in different security areas. At the same time, ZTE is committed to providing a variety of key technologies, such as 5G LAN, TSN, URLLC, precise timing, and small-granularity FlexE, to facilitate the rapid development and deployment of new 5G+ smart grid services. ZTE TECHNOLOGIES

To enable connectivity and trust everywhere