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ZTE TECHNOLOGIES

VIP Voice

Airtel SVP on Industry Challenges, Wireless Strategy, and Customer Experience

Expert View

Innovation Leads 5G Vertical Applications to Go From Supporting System to Core Operation

Special Topic

5G-Advanced

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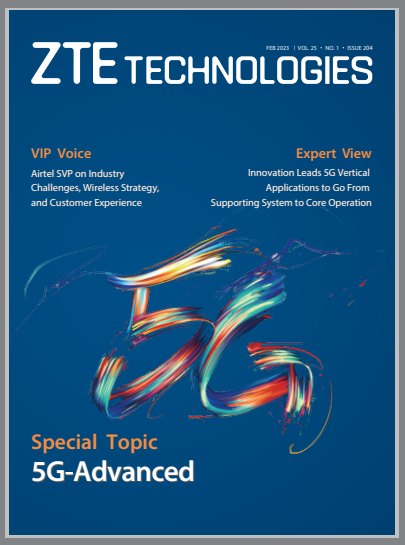

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Airtel SVP on Industry Challenges, Wireless Strategy, and Customer Experience

Reporter: Liu Tao

Sawan Gupta, SVP of Wireless Strategy & Head of 5G Experience at Bharti Airtel

While the wireless communications industry has been growing rapidly in recent years, fueled by the growing demand for data, multi-faceted challenges may slow down the industry's growth. Sawan Gupta, SVP of Wireless Strategy & Head of 5G Experience at Bharti Airtel, talks about the major challenges of the wireless sector and key elements in building the wireless strategy catered to its distributed user base. He also highlights Airtel's efforts in maximizing network capacity and coverage for an enhanced customer experience.

What are the biggest challenges facing the wireless sector today?

While the rampage of new technologies in the telecom realm has been creating ample growth opportunities, there are certain challenges that we observe daily, making this quite a dynamic sector to be part of.

Economic Challenges: The average revenue curtailed from the end user remains relatively low concerning global measures owing to the tariff wars. Adding huge expense with respect to spectrum costs and technological investment to this creates a dicey imbalance. While government policies help to reduce the margin, the wide disparage remains that potentially hampers the industry's growth.

Energy Consumption: With the advent of new technologies and a multifold increase in end-user devices, there shall be more power requirements due to the substantial computational needs for intelligent processing. Subsequently, enormous energy consumption is expected by the various connected nodes in the wireless networks. Demand for wireless information and power transfer (WIPT) integration that would enable proactive energy replenishment of wireless devices is also rising to combat the same.

A multitude of End Users Devices: How to design a network architecture to tackle dynamic cooperation among terminals to meet users' requirements, support seamless and ubiquitous communications during the movement, and enhance spectrum efficiency and user experience. Characterizing the environment dynamics to ensure that the system takes full advantage of this new topology will be crucial in the next generation of wireless networks. Moreover, due to the dynamic behavior of devices joining and leaving wireless systems, maintaining privacy and anonymity will be challenging in future wireless networks. Here, to a large extent, dynamic network slicing shall be a key management driver to resolve the network and resource management.

Development of compatible ecosystem: Availability of a proper and well-matured ecosystem to make new technologies accessible to the masses. Currently, 5G is the revolution introduced in India. While the end-user device support to cater to this technology is present, there is still a long way to go before the ecosystem matures. 5G NSA device support is strong, but major OEMs are yet to introduce key functionalities that will further improve the 5G experience. And 5G SA is still relatively nascent in terms of supported devices available in the market. Also, device capabilities should mirror technological

advancements. While the devices may help the new technologies, battery consumption during usage is also a matter of concern which degrades the performance of the technology.

As per your role, what has been your consideration in making a wireless strategy? With a presence in a number of countries, what has been Airtel's overall wireless strategy to stand out from the competition?

Three significant aspects are juggled to carve out a unique tradeoff that consequently builds our strategy to cater to the users across our distributed base. Customer demand and grievances, spectrum availability, and un-tapped but potent market are accessed at cluster and circle levels to understand the scope. Network design is then subsequently pursued, keeping in mind the bandwidth and spectrum availability, population and region to be catered to, and the cost-effective product selection to deploy on-ground. Using the higher bands to serve capacity demands and the lower bands for range and coverage increases the efficacy of our network alongside several techniques to improve spectral efficiency. Also, considering the ecosystem support for the technologies to be implemented in the network is important to ensure accessibility to all.

Airtel focuses on winning customers for life through an exceptional experience. What are the keys to keeping up with the increasingly high demands for network coverage and connectivity performance, and what have been your efforts?

Indeed, customer experience is at the forefront of Airtel's driving pillar for success. We continually work toward catering to the end user's demands and satiating their expectations. Anticipating the increasing request and proactive planning for the same is a crucial aspect of our focus that allows us to develop the required capacity well in time. Further, projects to improve spectral efficiency, network harmonization, and densification of the existing sites with innovative high-power small cells and various IBS

solutions, along with targeted customer complaint resolution, cumulatively assist in maintaining the ubiquitous network while catering to both coverage and capacity-based demands' exponential rise each day.

Looking at the advancement of 5G, and as a part of that, how do you feel about the essential role of CPE within that process, and what do you expect to see for CPEs in India?

The concept of FWA—Fixed Wireless Access has been around for quite a while, but the existing technologies were insufficient to cater to the demands and guarantee service ubiquitously. But with the plethora of exciting features of 5G technology that supports 10x lower latencies and higher bandwidths, the realization of this concept into a reality is inevitable.

Customer Premise Equipment (CPEs) are portable, small, user-friendly end devices that shall power the last mile connectivity by connecting to a live 5G network. This technology finds its applications as an alternative to wired fiber-based Broadband and DSL connections. 5G network can be leveraged to connect the end user at a much faster pace and provide a fiber-like experience.

The untapped market potential is enormous in India, where almost 64% of the population lives in rural areas. 5G can power the rural regions and those areas where a fiber connection is quite impossible and consequently prove to be an excellent alternative service.

In parallel, the urban world would also benefit from this for building capacity-heavy connections in shopping malls, intelligent factories, and even for temporary entertainment venues like stadiums, private campuses, and concerts.

Where do you see the telecom industry going within the next few years?

Telecom has constantly been evolving to bring the next big revolution in the sector. The pandemic has brought new avenues for the operators as the focus shifts toward digital realms through a multifold increase in online content consumption. Telcos now have to look beyond mere connectivity and lead digitization from the forefront to support the onslaught of demand.

In the coming few years, the cellular networks in India shall be capable of supporting emerging technologies such as AI—Artificial Intelligence, Augmented & Virtual Realities, Edge Computing, IoT-fulfilled smart cities, smart villages, and much more. Hence, in the coming years, the primary ambition for the industry shall be to change from a simple bandwidth supplier to a business ecosystem of partners providing a platform, security, and analytics in this era of Digital India. ZTE TECHNOLOGIES

Innovation Leads 5G Vertical Applications to Go From Supporting System to Core Operation

Bai Gang
ZTE VP, Deputy General Manager of RAN Products

Since the commercial launch of 5G, the application of 5G in vertical industries has developed rapidly, and multiple application cases with commercial feasibility have been incubated. According to China's Ministry of Industry and Information Technology, more than 7900 5G 2B private networks had been built in China by September 2022, and the effect of 5G empowerment has gradually appeared in many industries such as manufacturing, ports, mines and power grid. The value of 5G networks will be better reflected as 5G vertical applications gradually shift from supporting system to core operation and enable use cases that are crucial for industrial core production process. During this transformation, the 5G private network will also face some new challenges:

- **Split of cloud, network and applications:** Traditionally, enterprises need to purchase cloud, network and applications from different suppliers when launching new services. This leads to high costs, time-consuming and laborious on-site integration, and unclear fault location responsibilities.
- **Difficult performance guarantee:** The traditional public network adopts best-effort policy, because services on this network have a great tolerance to delay and jitter. However, the private network for core operation is sensitive to delay and jitter, and there is a big gap for deterministic capability between network supply and service demand.
- **Complex O&M:** The private network in the early stage adopted the same O&M procedure as the public network. For customers in vertical industries such as steel, manufacturing and ports, operating such a network is technically challenging. From the product perspective, a private network can be divided into RAN, core, and transmission network. From the operation perspective, a private network roll-out needs planning, construction, maintenance, and optimization. At each stage, expertise is required for each product category, and industrial customers usually do not have such resources.

If not addressed, these problems will hinder the in-depth development of 5G vertical applications. Through the practice of several projects, ZTE has proposed three core capabilities that 5G private network must have when entering the core operation:

integration of cloud, network and applications, deterministic assurance, and simplified O&M (Fig. 1).

- **Integration of cloud, network and applications:** End customers need a one-stop solution that can solve real problems for the core operation and improve the efficiency. There is an overwhelming trend to integrate cloud, network and applications.
- **Deterministic assurance:** The private network for the core operation needs to provide deterministic service assurance, including ultra low delay/jitter and zero packet loss.
- **Simplified O&M:** A simplified O&M solution is needed to lower the barriers of 5G private network operation, which minimizes network management workload of on-site staff, including all-in-one management, lightweight deployment and service oriented O&M.

Integration of Cloud, Network and Applications: Providing One-Stop Solution

Applications are key to digital transformation of verticals. Cloudification is the current trend to achieve flexible, convenient, and low-cost deployment of various industrial applications. Cloud, network and applications are all required for 5G vertical empowerment. To this end, ZTE has customized a series of products that integrate cloud, network and applications, providing one-stop solution for industrial customers.

On the terminal side, ZTE has launched its 5G SmartEdge gateway and 5G multi-service emulator (MSE) tester. The SmartEdge gateway is equipped with abundant industrial interfaces that can be connected to various industrial devices on the operational environment, and also has built-in computing power that provides a basic computing platform for various applications such as video coding and programmable logic controller (PLC). The 5G MSE tester can simulate signals from various field applications, and is very helpful for service verification during network commissioning.

On the network edge side, ZTE has released NodeEngine, the industry's first base station-based computing engine. By inserting computing boards into the BBU cabinet, a regular base station can be quickly upgraded to NodeEngine that enables local traffic offloading and industrial application deployment. The NodeEngine solution integrates the functionalities of network and computing and provides a platform for deployment of various applications. ZTE has also launched customized product solutions for special industry scenarios, such as nomadic base station solutions for

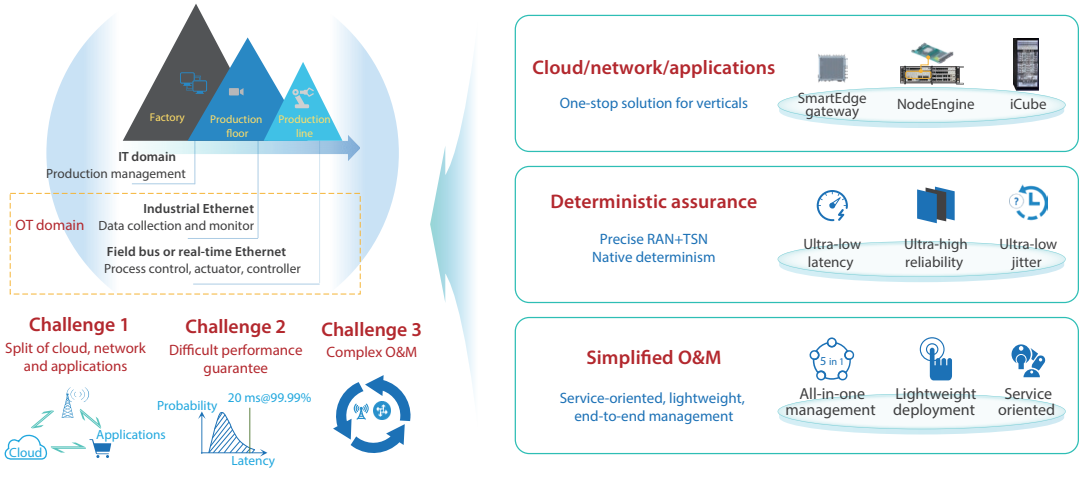

Fig. 1. Challenges and solutions for 5G for core operation.

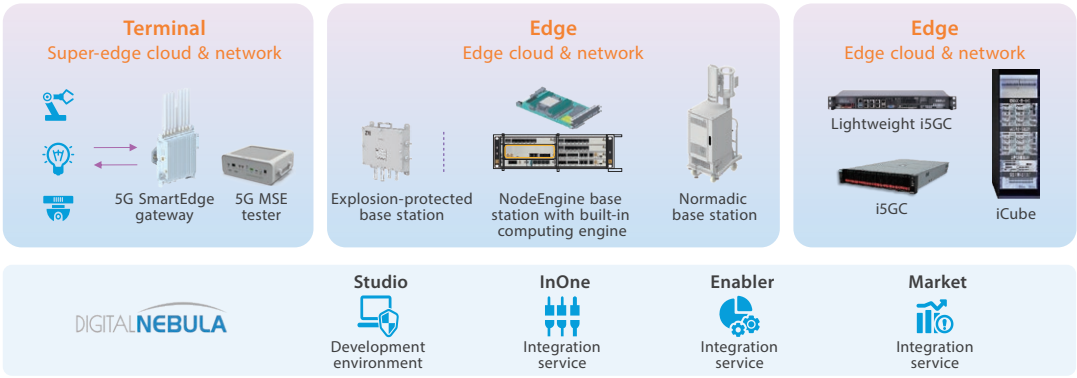

Fig. 2. Industry-oriented integration of cloud, network and applications.

temporary coverage and explosion-protected base station solution for explosive hazardous environment.

On the data center, ZTE has rolled out iCube and a variety of lightweight i5GC solutions. iCube integrates the functionalities of cloud, network, applications and maintenance to meet customer needs for 4G/5G connection and edge computing, and has become an ideal private network solution for enterprise campuses.

Based on its products and solutions that combine cloud and network, ZTE has created a ubiquitous computing environment for industrial customers to flexibly support on-demand deployment of various applications, such as PLC, data collection, video transcoding and distribution, and machine vision. To better serve the digital transformation of enterprises, ZTE has also launched the "Digital Nebula" one-stop solution (Fig. 2). Based on the cloud-network integration infrastructure, Digital Nebula provides an overall digital solution for enterprises with unified architecture and standardized capabilities via building-block components. Through the digital base platform, Digital Nebula achieves standard southbound connections and personalized northbound services, eliminating the pain points of traditional industrial digitization. Moreover, the one-stop development tool can provide an integrated environment for both development and maintenance, which helps enterprises improve development efficiency, reduce difficulties and facilitate agile innovation.

5G Precise RAN Solution: Providing Deterministic Assurance for Core Operational Applications

To provide deterministic assurance for core operational applications, ZTE has launched 5G precise RAN solution that enhances network performance in latency, jitter, reliability, and network-application coordination.

- **Ultra-low latency:** A lot of use cases for the core operation require ultra-low latency. For example, coordination between two automated guided vehicles (AGVs) needs to know each other's status information accurately with minimum latency. To guarantee low latency for target scenarios, eMBB or URLLC technologies such as intelligent pre-scheduling, DS frame structure and mini-slot need to be implemented to enhance network capabilities. In addition, based on network edge intelligence, services are dynamically identified and scheduled to meet different QoS requirements.
- **Ultra-low jitter:** Deterministic latency is needed to support the accuracy of cloud PLC. TSN-related technologies such as TSN traffic shaping and gating control at the edge of the network can be introduced to achieve microsecond-level jitter.
- **Ultra-high reliability:** The remote control of iron and steel metallurgy requires a reliability of up to 99.999%. However,

wireless links are naturally uncertain due to signal fluctuation and interference. To improve the reliability of data transmission, frame replication and elimination for reliability (FRER) can be adopted, with one wireless link operating in band A and the other in band B.

- **Network-application coordination:** Video surveillance in ports or steel factories often encounters the scenario where cameras are densely deployed in limited space. The concurrent I-frames of multiple cameras can cause traffic peak that exceeds network capacity. Considering commercial feasibility, a network should not be planned according to its peak traffic. ZTE has developed I-frame collision avoidance solution that can adjust the I-frame time sequence of cameras to reduce burst peak traffic, thus guaranteeing the quality of video services.

Simplified O&M: Lowering Barriers of Applying 5G Private Network

To lower the barriers of applying 5G private network in vertical sectors, ZTE has also developed a series of features that enable extremely simplified operation and maintenance, including all-in-one management, lightweight deployment, and service oriented O&M.

- **All-in-one management:** The O&M system for private network supports RAN, core, cloud, fixed network and transport network simultaneously, providing end-to-end professional management for all network elements (NEs), including unified topology, alarm, performance, resource, and log management. This increases operational efficiency and helps with quick troubleshooting.
- **Lightweight deployment:** A lightweight, low-cost, plug-and-play approach is preferred for private network. All devices, NEs, and O&M products can be put into service with just one click on site, thus helping enterprise customers quickly complete 5G network provisioning with minimal expertise.
- **Service-oriented O&M:** Network O&M is targeted for enterprise customers. All configuration and management tasks are service oriented and have user-friendly interfaces. The end-to-end service status can be presented in a visual manner, and any service abnormality can be automatically identified.

The procedure for 5G applications to enter the core operation is still in its infancy. ZTE, together with CSPs and industry partners, has made successful explorations in various vertical sectors, such as mining, steel, manufacturing and ports. ZTE has worked with China Mobile to help Zhejiang Hotel Star Co., Ltd. (Hotel Star for short) build the first fully intelligent carton manufacturing factory in China, verifying seven 5G use cases including cloud AGVs, data collection, intelligent storage, electronic fence, transport vehicles, and production billboards. These use cases of 5G private network adopt ZTE's unique NodeEngine solution that provides not only 5G services but also a common platform for selected applications, offering Hotel Star an one-stop solution for high-quality connections, rich capabilities and characteristic services. ZTE has partnered with China Telecom to implement cloud PLC at ZTE's Nanjing Binjiang manufacturing base. Cloud PLC applications can be flexibly deployed on NodeEngine or SmartEdge gateways to achieve integration of 5G and industrial control networks. ZTE has also cooperated with China Unicom to build a 5G network in Baosteel that enables remote control of a robotic arm to finish the painting work. ZTE will work with industry partners to explore more use cases of 5G private network for the core operation, promote mature use cases, and maximize the value to the industry. ZTE TECHNOLOGIES

"1+2+3" Framework for 5G-Advanced Evolution

Bai Yanmin

General Manager of ZTE RAN Products

Since 5G-Advanced has become a consensus, it is necessary for the industry to define its key features, deployment strategies, key R&D directions, and application practices based on the requirements of operators, vertical industries, and society.

As a key player in the 5G industry, ZTE has invested a lot of resources in exploring 5G-Advanced. In 2021, we proposed the "1+2+3" framework for 5G-Advanced evolution. "1" represents the foundation, namely chipset technology, algorithm, and architecture, "2" represents the double-chain genes, namely intelligence and security, and "3" represents three directions, namely, performance enhancement, efficiency improvement, and boundary extension. With this new framework, we can release the unlimited potential of 5G and continuously empower new business types, new scenes and new fields.

Integrate AI into 5G

The future 5G network will be a system with intrinsic AI capabilities. AI will be integrated into the whole system design in the standard formulation phase, and intelligence will be injected into the core network, access network, and physical layer. Intelligence and computing power are inseparable. The combination of intelligence and computing power has become an important engine for the current network development, and also an important capability base for 5G-Advanced and 6G networks in the future.

ZTE has explored a wireless intelligent framework. First, wireless intelligence is built on the intelligent computing base, including the three elements of data, algorithm and computing power. Second, the base capabilities can be flexibly orchestrated to incubate diversified intelligent applications. Finally, the digital

twins of wireless networks are built in parallel to existing physical networks to achieve real-time interactions between virtual and physical worlds and closed-loop systems for efficient self-optimization of various intelligent applications.

In terms of intelligent orchestration, ZTE launched the industry's first network resources orchestration solution Radio Composer powered by the native AI at base stations in 2021. It improves user experience by enabling the shift from network-centric to user-centric. In 2022, Radio Composer evolved to the 2.0 stage. With the integration of intent-driven technology, Radio Composer 2.0 allows the network to achieve "what you expect is what you get".

ZTE's computing power orchestration breaks the computing power limitation of a single site through cross-site computing power sharing. In June 2022, China Mobile Group Research Institute, China Mobile Zhejiang Branch and ZTE jointly completed the first cross-base station computing power orchestration in Jiaxing. In the scenario of unbalanced network load, the computing power can be orchestrated among base station clusters, increasing the computing power of base stations in busy hours by 14%.

As for digital twins, ZTE has built an end-to-end high-fidelity digital twin system for wireless networks in the lab. Through servers and ultra-computing platforms, ZTE has built twins of UEs, channels, wireless networks, transmission networks, and core networks. Based on this system, we simulated typical service flows of commercial terminals, and built a video service experience evaluation model with the difference between the evaluation value and the actual value being only 0.1.

Cool 5G Technologies

Performance Enhancement

5G-Advanced aims to bring a 10-fold increase in both the network capacity and the number of connections. This requires wider spectrum, more coordinated networking and more efficient air interface.

To improve the throughput, ZTE has launched some new solutions and one of them is the sub-band full-duplex (SBFD). ZTE has completed the industry's first prototype and function verification of SBFD. The SBFD technology divides uplink sub-bands and downlink sub-bands in the TDD single-carrier frequency domain to implement full-duplex on the base station side and enable simultaneous signal transmission and reception with a single-carrier bandwidth of 100 MHz. This is a breakthrough innovation of the TDD spectrum on the air interface. The SBFD technology may further support flexible cross-sub-band scheduling as required, so as to implement large uplink and low-latency services at the same time. For conventional terminals, based on the configuration of a flexible frame structure, it can be compatible with SBFD while still operating in the TDD half-duplex mode. In August 2022, ZTE's sub-band full-duplex prototype achieved a large uplink rate of 1.4 Gbps and an ultra-low end-to-end latency of less than 4 ms over a single 100 MHz carrier in the laboratory environment, which will better support applications that require both high bandwidth uplink and low latency in 2B scenarios.

To increase the number of connections, ZTE has conducted deep research into the reconfigurable intelligent surface (RIS) technology, which is believed to be one of the key technologies for 5G-Advanced and future wireless network evolution. In the third quarter of 2022, ZTE and China Mobile Research Institute completed the industry's first prototype trial of dynamic RIS technology. In addition, ZTE has also studied non-terrestrial network (NTN), a supplement of terrestrial network (TN). At the end of August 2022, ZTE, together with China Mobile and other industrial partners, showcased the world's first 5G NTN field trial at the 5G-Advanced Industry Development Summit held in Beijing. The trial implemented end-to-end link interconnection among terminals, satellites, terrestrial gateways, base stations, core networks and servers.

Efficiency Improvement

The autonomous network (AN) is considered as a key capability to improve O&M efficiency. ZTE has launched an intelligent network solution uSmart-RNIA to reduce O&M cost and improve efficiency for operators. At present, it can support operators' network autonomy capability to evolve from Level 3 to Level 4. At the same time, we are exploring the evolution to L5, covering the intent-driven technology and digital twins as mentioned before.

Energy Efficiency

ZTE proposes to pursue the "perfect Bit/Watt curve". This includes the AAU hibernation mode, a new shutdown mechanism that can help AAU reach less than 5W power consumption when there is no traffic. Meanwhile, ZTE continues to evolve its PowerPilot pro solution, which adds the base station

> The value of 5G evolution does not lie in the technology itself but in its external empowerment and value presentation.

intelligence on the basis of the platform intelligence to break the non-real-time bottleneck of current energy-saving strategies. Base stations can process massive user measurement data in real time and provide real-time insights into user conditions in the network, and based on the accurate prediction of user behavior and network load, the intelligent base stations can formulate a near-real-time energy-saving policy to maximize the shutdown and minimize the wake-up, thus building a green network.

Value of 5G Evolution

The value of 5G evolution does not lie in the technology itself but in its external empowerment and value presentation.

One of the more important missions of 5G is to change the industry. Currently, the 5G+ industry has achieved a "zero to one" breakthrough, and some industries have seen their application solutions replicated at scale. However, these are just a tip of the 5G iceberg. To drive 5G industry applications, we have developed a series of products covering the cloud, edge, and device. In ZTE's Binjiang factory, the PLC controller is cloudified and flexibly deployed on the distributed computing system of 5G computing power base stations and edge gateways as required to integrate the 5G network and industrial control network. In the future, we will continue to study and deepen our efforts in the operation technology (OT) domain to realize the industrial value of 5G.

For consumer businesses, the combination of 5G and XR is expected to open the door to the Metaverse. In the future, XR services will become more and more popular among individual users, and also be leveraged for manufacturing, medical care and flight training. ZTE has also made great efforts in the research and deployment of XR services.

In the future, we will also explore more new technologies and new fields to maximize the potential of 5G. For example, the integrated sensing, computation, control and communication system is promising. The base stations are equipped with extra sensing capability besides the basic communication capability, and these capabilities, when combined with the computing power and control, allow the incubation of various new applications and have great potential in the fields like low-altitude security and vehicle-road collaboration.

In the follow-up 5G and 5G-Advanced evolution, ZTE will promote the continuous expansion of business boundaries and unlock infinite possibilities of digital intelligent society through enabling new consumer experiences and new industrial upgrades. ZTE TECHNOLOGIES

Radio Composer 2.0: Intent-Driven Network Adaptation

Zheng Lingxia

Director of Wireless Product Planning, ZTE

5G is more than a new generation of technologies; it marks a new era in which connectivity will become increasingly fluid and flexible. By 2025, 5G networks are likely to cover one-third of the world's population. To provide optimal experience and high performance, 5G networks shall adapt to applications and performance tailored precisely to user needs. Therefore, integrating AI into radio network has become a consensus in the industry.

Radio Composer is the industry's first native-AI based solution that has AI built inside 5G base station for fine-grained management of radio resources to offer better user experience with higher network efficiency and less carbon footprint.

Radio Composer 1.0: Industry's First Network Resources Orchestration

User experience is a key driving force of 5G development. However, 5G still uses some radio resource management technologies that are not really competent for the task, and uses an inflexible radio resource management policy to deal with all 5G users, which can not perceive and adapt to diverse user needs. It is of great importance for operators to deliver a user-centric experience for consumers and industry applications, which is exactly what Radio Composer can achieve.

Radio Composer enables multi-dimensional perception and machine learning of service characteristics, network characteristics and UE capabilities to achieve optimal match between user needs, network resource allocation and UE capabilities. This helps to yield the best user experience and the highest network efficiency, thus increasing 5G user base and promoting the development of 5G industry and ecosystem. Radio Composer offers a real-time and always-smooth user experience anytime and anywhere. AI training and inference are both implemented at the base station, and the AI training is carried out under the low load of CPU to minimize the impact on legacy user experience.

ZTE has deployed Radio Composer in more than 10,000 sites in China, increasing 5G network capacity by more than 30% and user speeds by 300%. In-depth and comprehensive trials of this solution are also being carried out in Thailand, Spain and Italy, which will help to build higher-quality 5G networks.

Radio Composer 2.0: Industry's First Intent-Driven Network

The real value of AI, however, is not limited to the applications connected to the network, but will eventually be realized in the network itself, thus facilitating advanced network intelligence. That is why the intent-driven technology is introduced as an evolution of Radio

Composer (Radio Composer 2.0).

Radio Composer 2.0 deeply integrates the intent-driven technology into the most common daily scenarios, such as Tiktok live streaming, Tencent video streaming and WeChat online conferencing to implement automatic strategy optimization in B2B and B2C scenarios. Simply by using natural language as the input to describe the business outcomes customers wish to accomplish, the network can convert these objectives into the configuration necessary to achieve them without having to manually code and execute individual tasks. The network implements a software-enabled automation process that uses high levels of intelligence, analytics, and orchestration to improve network operations.

Taking the intent-driven user experience guarantee as an example. For an intent to "have a smooth TikTok experience around 10:00 tomorrow morning", the system will automatically translate the intent and handle the service guarantee flow, including automatic millisecond scheduling policy generation, minute-level performance feedback, and automatic service experience optimization. With historical learning of packet size, sending frequency and intervals, transmission protocols used, intervals between uplink sending and downlink receiving and data throughput, an offline model is trained with convolutional neural networks (CNN) and random forest and put in BBU. This is the implementation of BBU-based traffic pattern analysis. When data flow is input, it can be identified in real time, with an accuracy of up to 90%. An application can be identified as multiple services. For example, Wechat can be divided into at least 5 service types, including Wechat voice calls, video calls, payments, moments and videos. As a result, more than 7000 service types can be identified, covering 95% of mainstream services.

The intent-driven network deployed in China Mobile's Fujian Branch shows that the specific service experience has been improved by more than 100%, and the efficiency of operation and maintenance has increased by 500%. More integrated intents will be implemented in the future, such as the combination of user experience and network energy efficiency.

It is also challenging to integrate AI into RAN networks. Taking data and algorithms for an example. Traditional data is discrete, coarse-grained and unidentified, while the data used for AI needs to be structured and identified, so it is necessary to automatically collect, clean, correlate, identify and store data based on a unified data model. Algorithms need to be abstracted for independent evolution, just as experience prediction algorithm will be scheduled by multiple AI-based applications and evolve with the development of applications. The middle platform will flexibly orchestrate data and algorithms to empower diverse AI-based applications, thereby improving user experience.

As 5G develops rapidly, intent-driven networks will be widely deployed. Therefore, a large amount of computing power is needed, which is quite challenging, and the computing power sharing scheme between different base stations is a perfect solution to this problem. The computing power orchestration breaks the limit of computing power of a single site and realizes cross-site computing power sharing. It increases the available computing power of busy sites by 14% and empowers more intelligence-based applications such as energy saving.

As the key infrastructure of digital society, 5G network not only provides consumers with more and more diverse and demanding applications, but also supports digital transformation for a variety of vertical industries. Radio Composer helps to unlock the potential of 5G networks and promote advanced network intelligence. ZTE TECHNOLOGIES

PowerPilot Pro: Creating Green 5G for Sustainable Digital Future

Fan Yingying

Director of RAN Product Planning (RAN Energy Saving), ZTE

Guo Cheng

Director of RAN Product Planning (RAN Energy Saving), ZTE

It is now widely agreed that moving toward carbon neutrality will help to ensure the survival and development of all human beings in facing the impact of global climate change. Major countries are committed to fulfilling their national carbon neutrality goals by the middle of this century at the latest. China has been committed to reaching net-zero emissions by 2060, which is a significant shift. Telecom is a leader in various corporate sectors in its efforts to cut carbon emissions.

5G is the most significant advance in mobile technology today. It will not only revolutionize the way we use our networks, but also change the way we live, work and play. With the mobile network, everyone will have a seamless connection. Looking forward to 2030 and beyond, human society will enter an era of intelligence, the physical and digital worlds will integrate seamlessly, social services will be comprehensive and rich, social governance will be precise and scientific, and social development will be environmental friendly and energy-efficient. The continuous iterative upgrade of mobile communications from 5G to 6G will support the expansion of ubiquitous interconnection, inclusive intelligence, multi-dimensional perception, full-domain coverage, green and low-carbon, security and trustworthiness.

The energy efficiency of 6G promotes technical progress towards "zero-load zero-carbon". To promote the environment-friendly and sustainable development of the network, it is essential to incorporate the concept of energy saving and emission reduction into system design, technology innovation, product design, and network O&M. However, the energy usage of the current network equipment grows incrementally and quickly. Even in the case of zero demand, there is still a significant energy waste. The network cannot maintain a high level of energy efficiency. The linear growth of load demand and energy consumption is called a "perfect curve", which means the two are fully aligned.

AAU Hibernation: Tapping the Potential of Zero-Load Zero-Carbon

Both vendors and operators are exploring green methods to lower the power consumption of base stations. Downlink power optimization, symbol shutdown, channel shutdown, 4G/5G collaborative base station shutdown, and deep sleep all significantly reduce the power consumption in static and low-load conditions, but there is still a long way to go. Currently, the industry

maintains deep sleep energy consumption at a hector-watt level. Although the system with external smart circuit breakers can reduce energy usage to less than 10 watts in a no-load condition, the issues such as equipment condensation, decreased reliability, increased repair costs, and abrupt changes in user perception cannot be adequately addressed. The first step towards "zero-load zero-carbon" should be the equipment itself.

ZTE has initiated a new shutdown mechanism called AAU hibernation when there is no traffic (Fig. 1). This is a deeper shutdown with a power consumption of less than 5W, which is a big advancement. The AAU hibernation technology blends hardware and software in a collaborative manner. A multi-mode hybrid modeling backed by in-depth multi-dimensional study is used to coordinate the adaptive energy-saving technology. Commercial trials have validated the almost carbon-free emission. The one-site, one-plan, dynamic AI energy-saving policy allows for flexible network deployment and precise energy saving. The AAU hibernation technology can work with deep sleep, symbol shutdown, and channel shutdown technologies in the existing network. Technological innovation, however, still faces big obstacles from the wear and tear of machines starting and stopping repeatedly. To support the development of auto start and stop technologies, it is necessary to carry out continuous research on system on chip (SoC), hardware shutdown and software protection.

Native AI-Driven base station: Improving Performance Through Edge Decision Making

Cloud AI-driven energy saving is nothing new, through which network history data can be automatically retrieved. Using big data analysis, operators can identify energy-saving scenarios, predict traffic patterns, deliver energy-saving policies and implement them at the network level. This method is more efficient than the manual approach, but it also has some disadvantages. Although AI models and algorithms are installed on the cloud, the system is far from real time and cannot detect traffic fluctuations due to barriers caused by distance and transmission costs.

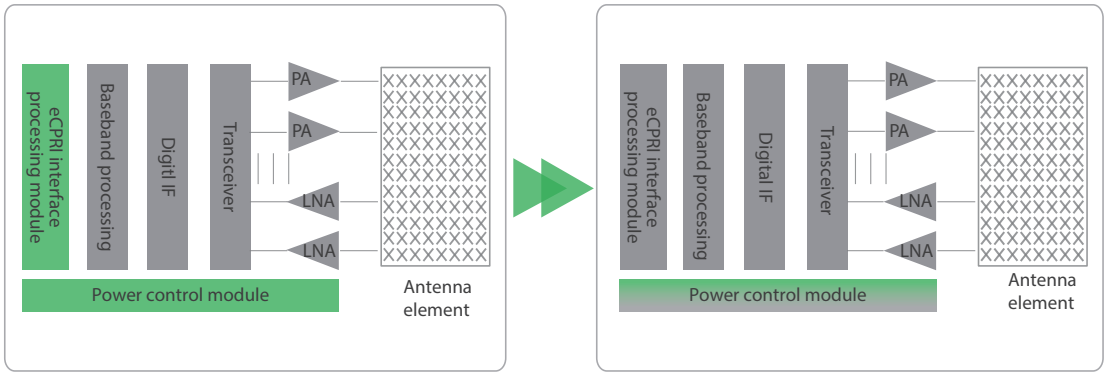

Fig. 1. From deep sleep to hibernation.

User data is transmitted from terminals to the Internet via the air interface, base station, transmission network and core network. Base stations are widely deployed and serve as the core of a mobile network. They have access to more real-time information that can be utilized to balance network needs and energy usage for they are closest to users.

The computing power of base station makes additional sensing capabilities possible, such as user requirements, real-time location, network traffic/load, and network energy consumption. This is an inevitable trend in the growth of native intelligence of base station, helping to create near-real time energy-saving strategies and ensure real-time user experience and network performance.

According to the terminal measurement report, a base station can determine network coverage on different frequency layers and allow the use of energy-saving technologies like carrier shutdown, deep sleep, and hibernation. To accurately steer users and redistribute network traffic while ensuring user experience, the base station analyzes user locations and requirements according to the grids, builds a knowledge base, and forecasts near real-time load. Intelligent multi-layer network carrier shutdown and on-demand wakeup are also adopted to deliver superior services with optimal capacity and consume less network energy.

Long short-term memory (LSTM) time series prediction and K-Means clustering algorithm commonly used in the IT industry can be integrated with communication technologies like real-time positioning and TTI-level resource scheduling to implement site-level high real-time and complex energy-saving policy, user experience, and closed-loop network performance. The system can adapt to traffic bursts in real time and execute quick decision-making at the edge to improve network performance by accurate matching at the second granularity.

As 5G network construction is shifting to enhance indoor and hotspot coverage, energy saving solutions need to be more collaborative between indoor and outdoor, macro and micro, public and private networks, and even between ground and air. Energy saving is no longer a standalone solution that has to be addressed. Instead, it needs to be organically combined with many factors, including network planning, user distribution and behavior, and industrial needs. With the urgent demand of global operators for low-carbon emission reduction in the future, it is believed that all mobile infrastructure will be intelligent.

In addition, 5G capabilities allow for deep integration into all areas of society and business, promoting the digital transformation of the whole society. Through close industrial collaboration, the entire production and operation processes will be digitized to achieve process optimization, accurate control and efficient operation. According to GSMA in “The Enablement Effect” report, the mobile sector will save 10 kWh of electricity for every 1 kWh used by 2025. The world is expected to be greener and sustainable by making full use of the 1:10 lever of information technology, leveraging carbon emission reduction in thousands of industries and creating sustainable consumption and production patterns through 5G. ZTE TECHNOLOGIES

Integrated Sensing, Computation, Control and Communication Solution: Creating New Blue Ocean for 5G Applications

Hai Zhenkun

Director of Wireless Product Planning, ZTE

Overview

In the 5G-Advanced stage, in addition to improving communication performance, how to leverage 5G advantages and bring more profit growth is an issue that the entire telecom industry needs to consider. The integrated sensing and communication is one of the promising approaches for the telecom industry to empower thousands of industries. In July 2021, the IMT2020 Promotion Group established the Communication and Sensing Convergence Task Force to carry out research into 5G-Advanced scenarios, technologies, experiments and standards. ZTE has actively participated in promoting the evolution of 5G-Advanced and proposed an integrated sensing, computation, control and communication solution that can provide innovative ideas for the expansion of commercial 5G networks in vertical industries.

There are requirements for sensing services in thousands of industries, and the sensing services that meet these requirements need dedicated spectrum resources and networks. The widely deployed 5G network has unique networking advantages, wide coverage and large-scale antenna arrays. It can be upgraded through software and hardware to have native sensing capability while meeting the communication requirements. With the advantages of wide coverage, multiple sensing nodes can be converged to form a sensing network.

With higher requirements for communication capabilities, 5G-Advanced will expand deeper into vertical industries and explore more intelligent fields from supporting Internet of everything to enabling intelligent Internet of everything. The integrated sensing and communication means to use the same equipment and network to deliver two types of services: communication and sensing. It can sense the direction, distance and speed of a target, and detect, capture, track, and image the target. In this way, tasks in the communication network can be extended and sensing services can be universally implemented, and a low-cost, high-precision, and seamless ubiquitous communication and sensing integrated network can be built up to meet the industry need for one network with multiple capabilities.

Solution

ZTE has innovatively proposed its integrated sensing, computation, control and communication solution to promote digitalization and empower the industry (Fig. 1). The solution implements integrated design of communication, sensing, computation, and control functions through hardware sharing and spectrum sharing.

Integrated Sensing and Communication

ZTE is the first in the industry to use a single AAU to transmit and receive communication and sensing signals. The single-site sensing has more flexible and convenient networking over multi-site sensing. Based on LFM/OFDM waveforms, ZTE transmits sensing and communication signals in time division multiplexing. In network architecture, a single integrated AAU is used for high-frequency integrated sensing and communication, while a collaborative sensing network is used for low-frequency integrated sensing and communication. Moreover, the sensing distance of the integrated sensing, computation, control and communication prototype can be improved by increasing the transmit power and antenna gain, and its sensing precision can be enhanced by using the 100M bandwidth and increasing antenna isolation.

Integrated Computation and Control

ZTE deploys the sensing computing function on its unique NodeEngine to implement the computation and and control of the entire system, including sensing computing, target identification, track prediction, monitoring control, and video processing. The functionalities are exposed to industrial applications to form a closed-loop system that deeply integrates with the industry.

Application Scenarios

Based on the ubiquitous sensing capability provided by 5G base stations, the integrated sensing, computation, control and communication system has wide application scenarios.

- **Smart low altitude:** The integrated sensing, computation, control and communication system can sense drones and implement low-altitude security in airports, government buildings, and scientific research institutions. In addition, path planning and route management of the logistics drone can also be implemented.
- **Smart transportation:** In the Internet of vehicles scenario, the integrated sensing, computation, control and communication system can identify and sense the road itself and the road environment, identify the position, speed, and movement direction of the vehicle, and implement communication between vehicles and between the vehicle and infrastructure.
- **Smart life:** Smart health care can be provided by monitoring the heartbeat and breathing of the human body. Gesture recognition and motion

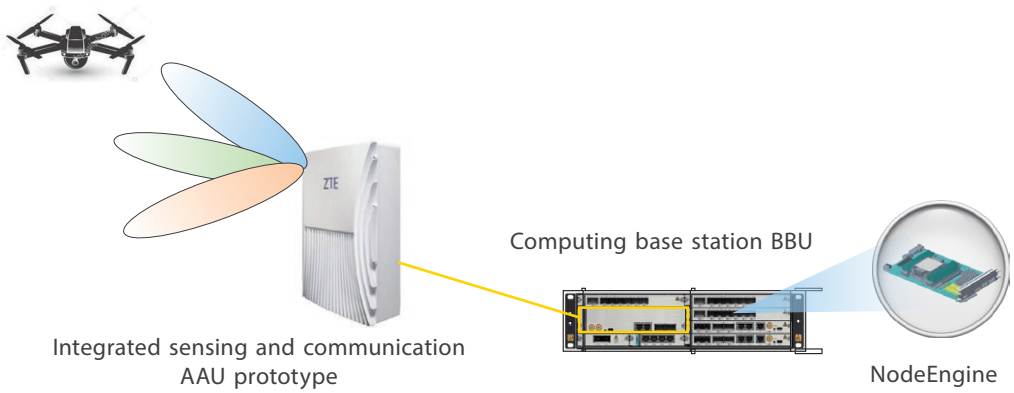

Fig. 1. ZTE's integrated sensing, computation, control and communication solution.

recognition can also be performed to control the smart home.

- **Smart industry:** In the future, intelligent robots and AGV vehicles need to provide high-precision sensing capabilities. Through the sensing information, intelligent production and control of a smart factory can be implemented.

Prototype Verification

ZTE has accomplished the prototype verification of its integrated sensing, computation, control and communication. The verification shows ZTE's technical strength and successful applications in this field.

- **Trial in low-altitude security of parks:** ZTE accomplished industry's first trial of integrated sensing, computation, control and communication with a single AAU in July 2022. The trial witnessed ZTE's successful application of the integrated sensing, computation, control, and communication system in the low-altitude security of parks. It can integrate the security facilities of the parks and provide the five-in-one low-altitude security solution that covers detection, positioning, identification, tracking and countermeasures. In this trial, the system achieves a sub-meter sensing accuracy and a sensing distance of more than 1 km by using a single AAU.
- **Sensing of smart transportation scenarios:** ZTE tested and verified the sensing of vehicles and pedestrians in smart transportation scenarios based on real traffic conditions and enterprise campus scenarios in November 2022. In traffic scenarios, the integrated sensing, computation, control and communication system detects the sensing distance of over 800 meters and reaches a decimeter sensing precision. The system can track and identify the lane change of a single vehicle, which verifies the feasibility of vehicle and pedestrian tracking and detection based on the integrated sensing and communication. In addition, the detection system can also provide the capability exposure of the sensing platform, and implement security control collaboration of pedestrian invasion based on sensing data, which is helpful to implement security management in smart parks.
- **Test of low-frequency integrated sensing and communication:** ZTE completed the sensing test and verification of outdoor drones, vehicles, and pedestrians, and breathing sensing in indoor scenarios by using 4.9 GHz low-frequency 5G commercial base stations in November 2022. The verification results show that outdoor low-altitude drones can sense the maximum distance of more than 1400 meters in a certain environment, and can also sense multi-target movement trail of drones, vehicles and pedestrians. In indoor scenarios, line-of-sight and non-line-of-sight breathing sensing tests are carried out. In line-of-sight scenarios, the breathing monitoring capability is equivalent to that of commercial breathing monitoring instruments, with an accuracy rate of more than 95%.

With massive and ubiquitous deployment of 5G base stations, the integrated sensing, computation, control and communication system will have many advantages such as large-scale continuous coverage, low costs and easy deployment. It will be a bridge between the physical world and the digital world, and also be a powerful means for the telecom industry to empower thousands of industries. Operators can deploy the system to enable traditional base stations to provide radar sensing capabilities while delivering mobile communication capabilities, and the relevant data can be provided to different industry users to create more value. ZTE TECHNOLOGIES

Enhancing Spectrum Flexibility with Subband Full Duplex

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Delivering enhanced mobile broadband experiences to consumers and extending 5G's reach into new use cases are continuously urging breakthroughs in 5G for higher flexibility and efficiency on limited radio spectrum.

FDD and TDD Have Their Own Advantages and Limitations

Frequency division duplex (FDD) and time division duplex (TDD) are widely used in 2G, 3G and 4G networks. In FDD mode, the frequency domain resource is divided for downlink and uplink. With continuous time domain resources, FDD is characterized by lower latency, lower throughput and scattered spectrum bands. In TDD mode, the time domain resource is split between downlink and uplink, which leads to higher latency. The fixed allocation of time/frequency resources of TDD/FDD has both advantages and limitations.

As a promising enhancement to the limitations of conventional duplex operation, full duplex (FD) is introduced to improve spectrum efficiency and flexibility. It is also known as single-frequency full-duplex by allowing both downlink and uplink to exist on the same spectrum frequency, which can theoretically double the spectrum efficiency.

5G-Advanced Lists SBFD as a Key Enabler of Full Duplex

Though FD is a new technology to improve spectrum efficiency, simultaneous transmission on downlink and uplink will bring severe interference that may lead to design complexity of gNBs and UEs and increase the cost. Therefore, in the early stage of 5G-Advacned, the focus will be on subband full duplex (SBFD), and then gradually extended to FD networks applicable to gNBs and UEs.

Subband full duplex or subband non-overlapping full duplex is considered as a promising enhancement to the conventional limitations for it allows gNBs to transmit and receive on non-overlapping subbands at the same time. Half duplex operation is implemented at UEs, so gNBs can allocate resources for different UEs to meet different service requirements and enhance the flexibility in spectrum utilization.

Full duplex operation is a significantly different duplex mode from FDD or TDD. Subband full duplex enhancement is a fundamental change in the way the NR air interface operates. It can provide 5G services for different users on demand to meet the medium- and long-term deployment needs of operators.

ZTE Keeps Exploring Full Duplex Techniques to Achieve Breakthroughs in SBFD

ZTE and China Mobile have joined hands to explore full-duplex techniques. They made a breakthrough in SBFD and completed the IOT test in Xi'an Joint Innovation Laboratory.

Industry's First SBFD RRU with Excellent Self-Interference Mitigation Performance

Because gNB can transmit and receive simultaneously on the same carrier, the

signals transmitted by gNB may leak directly to its receiver, resulting in blocking the radio unit. This is called self-interference. Therefore, one of the biggest challenges of full duplex operation is to mitigate self-interference.

ZTE has launched the industry's first SBFD RRU with enhanced transceiver architecture that integrates spatial isolation, subband analog filter, and digital interference cancellation techniques. The self-interference signal up to 130 dB can be mitigated, which enables the uplink signal to be optimally received at the gNB receiver.

Flexible Frame Structure Compatible with 5G Legacy UEs for 5G-A Applications

ZTE has designed the flexible frame structure for SBFD in order to be compatible with 5G legacy UEs. The period of 2.5 ms includes five time slots. The first time slot is kept as "Downlink slot" to ensure the broadcast of system information, the last time slot is fixed as "Uplink slot" to ensure normal access of UEs, and the remaining three time slots are set as "Flexible slot" to serve different UEs with flexible UL and DL transmission (Fig. 1). In the initial stage, subband for uplink adopts the UL-dominated time-frequency resource partitioning manner to enhance uplink throughput.

The interoperability test with Qualcomm shows that commercial UEs powered by Qualcomm's Snapdragon® X65 5G Modem can operate normally in SBFD cells, which includes identifying the flexible frame structure, accessing the system properly, and implementing large uplink services and low-latency services.

Cross-Subband and UE-Level Scheduling for Higher UL Throughput and Lower End-to-End Latency

Based on the flexible frame structure, gNB can flexibly schedule the DL/UL resources as required. For high-bandwidth UL services, the radio resources in Flexible slot and Uplink slot can all be scheduled. For low-latency services, with DL/UL resources available in every slot, the DL or UL latency can be lowered to about 1 ms. In addition, gNB can also meet the needs of both large UL capacity and low latency through the cross-subband scheduling.

ZTE SBFD system has achieved an uplink throughput of over 1.4 Gbps for a single carrier while reducing the end-to-end latency to 4 ms, reaching the best level in the industry.

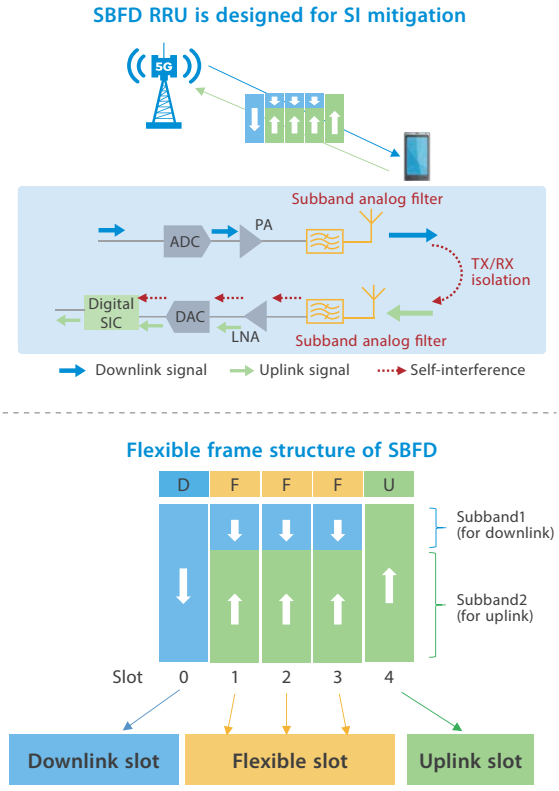


Fig. 1. Design and flexible frame structure of SBFD RRU.

SBFD Evolves to Bring New Value in 5G Commercialization

SBFD is a key enabler of full duplex air interfaces. In 3GPP Rel-18, SBFD is listed as the main research direction to further enhance 5G mobile broadband and expand use cases. As the evolution to 5G-Advanced accelerates, ZTE will continue to promote innovation and create new growth opportunities in the consumer and enterprise markets. ZTE TECHNOLOGIES

RIS Helps Sustainable and Efficient Evolution of 5G-Advanced and Beyond

Ren Tao

RAN Product Solution Manager, ZTE

5G supports a wide range of high-speed and large-bandwidth applications, which not only enrich people's daily lives, but also stimulate the demand for network capacity. It is expected that in the next decade, the capacity of communication networks will increase by a thousandfold, and ubiquitous wireless connectivity will become a reality. However, highly complex networks, high-cost hardware, and increasing energy consumption have become the key issues. It is urgent to explore new technologies and new materials to provide low-cost, low-energy, high-performance wireless network evolution solutions. Among the candidate new technologies, reconfigurable intelligent surface (RIS) stands out for its unique configurability, low cost, low energy consumption, and easy deployment features.

The static metasurface in the early stage after being designed and manufactured had solidified electromagnetic wave responses and functions, which cannot be adjusted. We call it the RIS 1.0 phase. Because it does not support on-demand dynamic adjustment, its application scenarios are very limited, and it is only suitable for technical verification, and unsuitable for commercial deployments. ZTE is the first vendor to enter the stage of RIS 2.0. ZTE not only developed the dynamic RIS hardware but also launched the industry's first 5G base station and dynamic RIS collaborative beamforming algorithm to realize millimeter-wave dynamic beam steering. This greatly improves the coverage of RIS and ensures seamless connectivity of users even in mobile scenarios.

Multi-Band and Multi-Form Portfolio Adapts to Different Scenarios

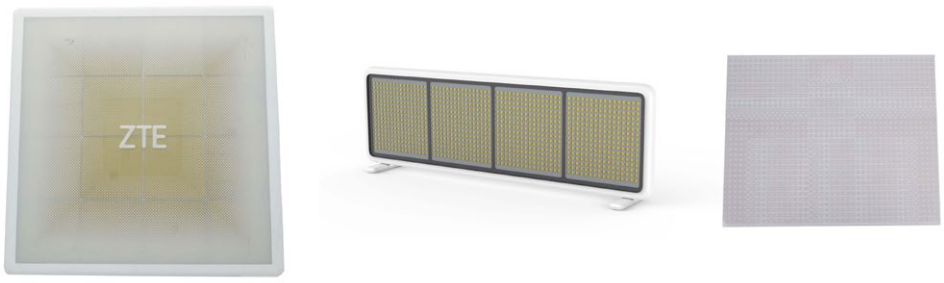
In order to realize the dynamic adjustment of RIS, it is necessary to integrate active devices (such as PIN diodes, varactors, etc.) or phase-shift materials (such as liquid crystals) on the metasurfaces. By changing the external excitation, the metasurfaces with fixed physical structures can present dynamically tunable or reconfigurable electromagnetic properties. Based on the characteristics of different materials, ZTE has developed various forms of RIS

to adapt to different application scenarios (Fig. 1).

For the millimeter-wave dynamic RIS, the control system adopts PIN diodes, and the state (size) of the electromagnetic unit is controlled by applying different bias voltages to the PIN diodes, thereby realizing the phase shift of the incident electromagnetic wave. Accurate beamforming is achieved through the independent control of different electromagnetic units combined with the effects of phase shift of all units. At present, ZTE's millimeter-wave dynamic RIS contains more than 16,000 electromagnetic units (antenna elements), which can form ultra-narrow reflected beams, and the single-point RSRP gain exceeds 30 dB. In addition, in terms of control accuracy, ZTE has achieved an industry-leading 2-bit dual-polarization control. Compared with the 1-bit solution commonly used in the industry, the coverage gain can be increased by 3 dB. The PIN diode has the advantages of high device maturity, low insertion loss, and fast switching speed (ns level), but it also has the drawbacks of high cost and power consumption. To this end, ZTE is also actively exploring other control materials, such as liquid crystals. Liquid crystal materials have the advantages of continuous phase shift (higher control accuracy), lower cost, and lower power consumption, but due to the high environmental requirements, they are currently considered suitable for indoor use. In addition, in the penetrated scenario, ZTE has also developed a transparent penetrated RIS. By superimposing a copper mesh on a transparent substrate such as glass or PC, it can realize the focused transmission of electromagnetic waves, and at the same time, it can achieve a high light transmittance, which is very suitable for being attached to building glass surfaces and high-speed rail window surfaces.

Collaborative Algorithm Realizes Flexible Coverage Reconfiguration

On the basis of hardware, the true realization of intelligent control of electromagnetic waves by RIS also depends on well-designed



mmWave dynamic RIS

Liquid crystal RIS

Transparent RIS

Fig. 1. ZTE serialized RIS prototypes.

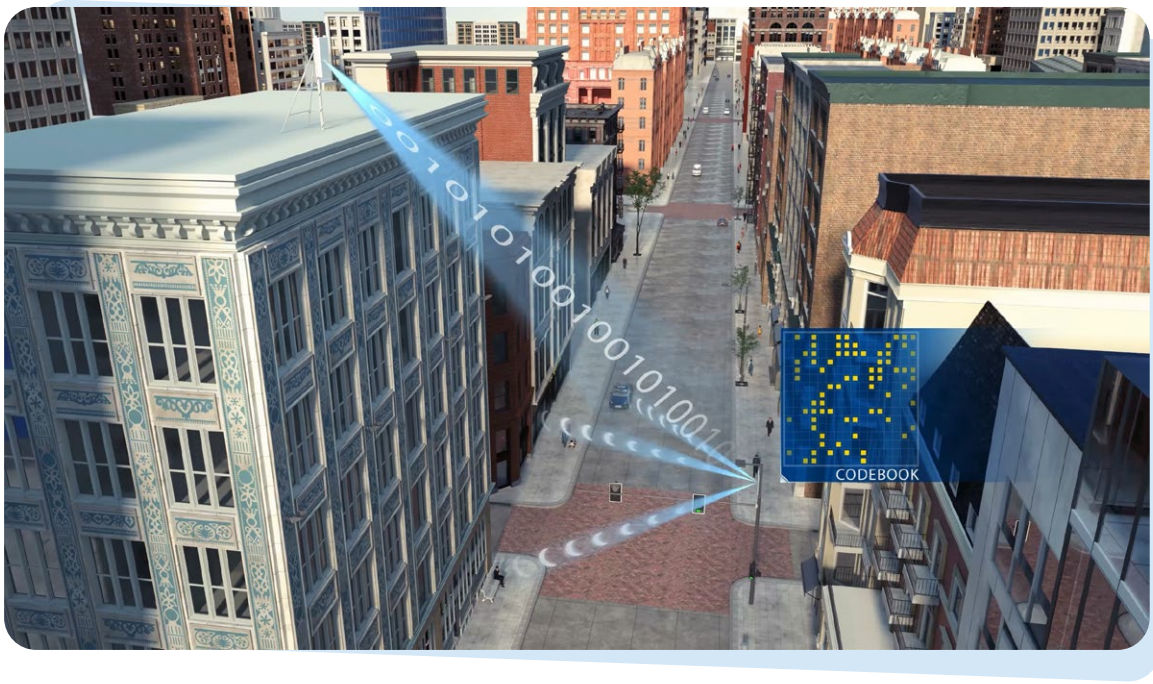


Fig. 2. 5G base station and dynamic RIS collaborative beamforming technology.

beamforming algorithms. A necessary condition for RIS to achieve energy convergence is the high gains produced by the narrow beam. But the problem with the narrow beam is that the coverage is very small, and when the UE moves, it is easy to leave the coverage of the RIS. This requires RIS to support beam scanning to achieve dynamic tracking of the UE and coverage of a larger area. However, due to the fact that RIS is a passive device, it does not have the ability of channel estimation and measurement, which requires the base station to help RIS realize joint channel estimation. ZTE has innovatively proposed the base station and RIS collaborative beamforming algorithm (Fig. 2). The algorithm uses the base station to instruct the RIS to realize time division-based beam scanning/ switching, which expands the coverage of the RIS and achieves the effect of UE beam tracking. In addition, the algorithm is based on the 5G air interface protocol framework and supports 5G commercial terminals, laying a solid technical foundation for the early commercial use of RIS, a 6G technology in the 5G stage.

Typical RIS Application Scenarios

Due to its flexible control of electromagnetic waves, RIS will have a wide range of application scenarios in the 5G-A and 6G stages. In the 5G-A stage, RIS can be applied to enhance outdoor blind or weak coverage, enhance edge coverage, increase hotspot streams and

throughput, outdoor-to-indoor coverage, and enhance coverage in the carriages of vehicles. In addition, RIS helps millimeter waves achieve continuous coverage in dense urban areas, making millimeter wave services move from FWA only to mobile services, unleashing the mmWave spectrum's untapped potential. In the 6G stage, with the introduction of higher frequency bands such as terahertz, RIS can help to improve high-frequency coverage. In addition, relying on RIS's ability to establish virtual line-of-sight (LOS) links in non-LOS environments, and ultra-large-scale antenna arrays, higher positioning accuracy can be achieved, facilitating the introduction of integrated sensing and communication.

RIS is a wireless technology with huge potential. ZTE dynamic RIS innovates on RIS by empowering operators to use beam steering in real-time. ZTE believes that the real-time capabilities of dynamic RIS are necessary for the successful commercial use of RIS, as 5G networks are increasingly and inherently dynamic.

Comprehensive Collaboration and Trials to Drive Commercial Progress

Since 2021, ZTE and operator partners have conducted comprehensive prototype trials. By exploring the feasibility of RIS to improve coverage and user experiences in multiple frequency bands and multiple scenarios, the commercial process of RIS is actively promoted.

In August 2022, ZTE and China Mobile Research Institute completed the industry's first prototype verification of dynamic RIS technology. The trial results show that the 5G base station and dynamic RIS collaborative beamforming technology can not only greatly improve the coverage, but also support the seamless connectivity of users in mobile scenarios, laying an important technical foundation for the future commercial use of RIS.

In addition, in 2021, ZTE completed the industry's first field verification of RIS in the 5G high-band with China Telecom, cooperated with China Unicom to complete the industry's first field verification of RIS in the 5G mid-band, jointly released the industry's first RIS cascade prototype verification results based on the 2.6 GHz commercial network with China Mobile Beijing Branch.

RIS Technical Challenges and Trends

Although RIS has made great progress in technical research, engineering application, and prototype verification, as a cutting-edge technology, RIS still faces many technical challenges such as research on new materials with lower cost and power consumption, on simple deployment solutions, on interference between RIS of different operators, and on RIS management, operation, and maintenance. ZTE will continue to carry out research in the above-mentioned aspects and jointly promote the technological development and commercialization of RIS in cooperation with industry-university-research institutes. ZTE TECHNOLOGIES

5G NTN Helps to Build Satellite-Ground Converged Network

Wang Yue

Senior Engineer of RAN Product Marketing Solutions, ZTE

Hao Ruijing

Senior System Architect of ZTE RAN Products

NTN Leads the Trend of Satellite-Ground Converged Network

Non-terrestrial network (NTN) is a terminal-satellite direct communication technology based on the new radio (NR) interface technology developed by 3GPP in R17, and also an important supplement to the terrestrial cellular communication technology. With the integration of the satellite communication network and the ground 5G network, NTN can provide ubiquitous coverage without being restricted by terrain and landform, and connect the sky, earth, sea and other spaces to form an integrated ubiquitous access network that enables on-demand access in all scenarios.

NTN is an important function of 3GPP R17. It continues to evolve in 5G-Advanced stage and has become an important part of the 3GPP R18 work plan. NTN includes two workgroups: IoT NTN and NR NTN. IoT NTN focuses on satellite IoT services that support low-complexity eMTC and NB-IoT terminals, such as global asset tracking (sea containers or other terminals beyond the coverage of cellular networks). NR NTN uses the 5G NR framework to enable direct-connection between satellites and smartphones to provide voice and data services.

NTN consists of the user equipment (UE), satellite, satellite gateway, base station (gNB), core network (CN) and server. Its architecture will evolve from more feasible transparent payload (Fig. 1) to renewable payload (Fig. 2). At present, the 3GPP Rel-17 specification focuses on transparent payload structure.

To solve the problems caused by long distance, fast movement, and wide coverage of satellite communication scenarios, such as large Doppler frequency deviation, large signal attenuation, and large propagation delay, NTN has designed the air interface enhancement protocol, introduced advanced technologies such as scheduling time sequence management, HARQ function orchestration, delay compensation, frequency compensation, and fast air-to-ground handover mobility management enhancement, and provided basic

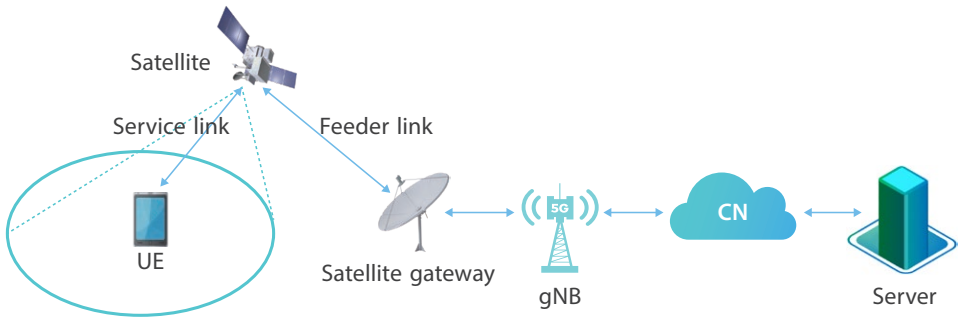


Fig. 1. NTN architecture with transparent payload.

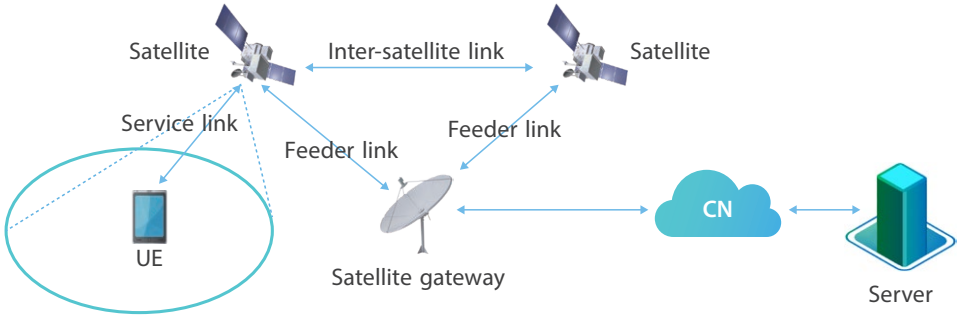


Fig. 2. NTN architecture with renewable payload.

capabilities for direct communication between the satellite and UEs.

Highlights of the NTN Solution

Recently, the topics on satellite-ground convergent communications and direct terminal connection to satellite oriented to 5G-Advanced and 6G evolution are very hot in the industry. Industry-leading companies have made many explorations on satellite communications. For example, SpaceX Starlink and T-Mobile announced that they would use Starlink V2.0 satellites to provide connection services for existing terminals on 1.9 GHz frequency band. Globalstar also announced that they would cooperate with Apple to launch the "satellite communications" function on the new iPhone 14 series with Qualcomm chips inside. However, they all have certain restrictions in the areas they use and the contents and objects they send.

Compared with the similar solutions of StarLink, and Apple iphone 14, the 5G NTN solution in full compliance with the 3GPP standard has distinct advantages in terminal penetration, industrial integration and service variety, and will lead the trend of satellite-ground converged network.

IoT-NTN short messages and IoT services take the lead in current 5G NTN. In the future, mobile phones that support NR-NTN voice and data broadband services will be directly connected to satellites. Therefore, 5G NTN is very suitable for constructing all-area ToB and ToC emergency communication networks, and the business model has obvious competitive advantages.

The renewable network architecture supports base station embedded in low earth orbit (LEO) satellites, and allows existing terminals to directly connect to satellites without modification. The existing terminals bring significant economies of scale of satellite links, rapidly reducing satellite connection cost.

Rich Application Scenarios and Huge Value Spaces for 5G NTN

From the perspective of global network coverage, more than 80% of land areas and 95% of sea areas are not covered by ground cellular networks. With 5G NTN, smart phones and IoT terminals can be directly connected to satellites, and can be integrated with terrestrial cellular networks. In this way, a converged network with ubiquitous connections, abundant scenarios, highly integrated industry chains, and lower O&M costs can be built and maintained. 5G NTN can be widely used in emergency communications, minerals, oil and gas, power grids, maritime affairs, logistics, animal protection and agriculture.

For operators, 5G NTN integrates the satellite and ground cellular networks to greatly reduce invalid construction of base stations in remote areas, lower network construction and O&M costs, and expand new markets for emergency communications and wide-area IoT applications. For end users, 5G NTN provides low-cost ubiquitous connections and ToB+ToC services in various scenarios. For the industry, 5G NTN will promote in-depth integration of the satellite and cellular industries, forming a commercial scale effect.

5G NTN will be widely used in the future. In terms of supporting China's national strategies such as strong ocean country, strong transportation country, rural revitalization, and national unified large market, 5G NTN will work together with terrestrial cellular mobile networks to bring huge social values into full play.

ZTE Continues to Forge Ahead in 5G NTN

After the R17 NTN standard was frozen in June 2022, ZTE, together with China Mobile and other industrial partners, released the results of the world's first operator 5G NTN field test in August 2022. Based on 3GPP R17 NTN protocol, this verification broke through two major challenges: ultra-long-distance of 36000 km high-orbit synchronous satellite and direct connection of common UEs, forming two innovative solutions: dynamic ultra-long-distance delay compensation and RF data conversion between satellites and base stations on the ground. It achieves end-to-end full-link 5G NTN interconnection, and verifies the feasibility of direct connection of UEs to satellites under the prerequisite that the 3GPP protocol is met.

Based on the market requirements of satellite IoT and the value of NB-IoT NTN scenarios, ZTE has worked with China Mobile to conduct the pilot test based on the geosynchronous earth orbit (GEO) satellite. The test consists of user terminals, satellites, satellite gateway stations, base stations, core network and server. The L-band satellite and ground gateway station are located between NTN terminals and base stations to transmit air-interface messages. The ground gateway stations are interconnected with 5G NTN base stations. Terminals are connected to the ground core network and service platforms through satellites, gateway stations, and NTN base stations to implement end-to-end service interconnection with satellite-ground integration.

The world's first operator 5G NTN field test shows that the actual performance meets expectations. This field test supports SMS and short voice intercom services, and fully verifies the implementation capability of UE direct-connection with satellite in terms of architecture, protocols, and devices. According to test results, the adjacent channel leakage ratio (ACLR) of the base station RF was better than that of the gateway base station required, link quality met the expectation, delay of ping 64-byte was about 4s, SMS functions were normal, and short voice intercom was clear and smooth. The test performance met the expectation. This pilot project verified the feasibility of NTN networking with high-orbit satellite transparent forwarding architecture, verified the feasibility of NTN in solving problems such as long delay and wide coverage in terms of protocols, and verified the capability of direct connection between satellite and mobile phones in terms of communication equipment. This is a breakthrough of the NTN technology from zero to one, and has laid a solid theoretical and technical foundation for direct connection of mobile phones with satellites.

ZTE is working with another operator in China to complete the end-to-end interconnection verification of 5G NTN, and will continue to promote and accelerate the commercialization of NTN in the future. ZTE TECHNOLOGIES

ZTE X-Edge Solution: Diversifying XR Commercial Scenarios

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The extended reality (XR) industry is one of the seven key industries in the development of digital economy. As XR equipment can provide immersive experience, it is regarded as the entrance into the metaverse in the future. 2016 was once called the first year of Chinese VR, but poor mobility and low resolution of terminals became hindrances to industry development. With the large-scale commercial use of 5G, XR services have ushered in a good momentum of progress.

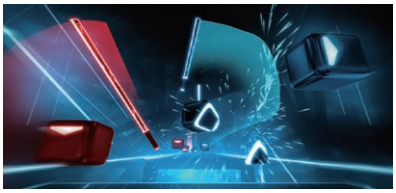
Opportunities and Challenges Coexist

According to statics, the global XR market size is about US $27.96 billion in 2021 and is expected to reach US $252.16 billion in 2028, at a CAGR of about 31.64%. The Asia-Pacific market is growing most rapidly. With the enrichment of content and the upgrade of device experience, the shipments of VR/AR head-mounted displays are growing steadily.

Compared with video services, XR requires higher resolution for immersive experience. Most smart phones support a resolution of 1080p, while XR is a near-eye display service that requires a resolution of 8K to completely eliminate the sense of image granularity, which increases the demand for network traffic more than ten times. This is both an opportunity and a challenge for 5G networks.

The XR service can be divided into the following four levels according to different bandwidth and latency requirements (Fig. 1):

- **High fidelity and strong interaction:** bandwidth > 100 Mbps, latency < 20 ms
- **High fidelity and weak interaction:** bandwidth > 100 Mbps, latency > 150 ms



High fidelity and strong interaction: Gaming

High fidelity and weak interaction: XR videos

Low fidelity and strong interaction: XR conferences

Low fidelity and weak interaction: On-line shopping

Fig. 1. Four levels of the XR service.

- **Low fidelity and strong interaction:** bandwidth < 100 Mbps, latency < 100 ms
- **Low fidelity and weak interaction:** bandwidth < 10 Mbps, latency > 150 ms

It is a huge challenge to commercial scenarios with data rates of over 100 Mbps and 20 ms latency. As more and more users use XR applications, ensuring the best experience for each user is an urgent issue to be addressed.

ZTE X-Edge Solution Enables Deterministic User Experience

ZTE has put forward the X-Edge solution to guarantee XR services. With 5G RAN intelligent sensing and scheduling, differentiated services are precisely guaranteed to enable ultimate user experience. First, identify XR service features, such as frame size and period; second, schedule it with the best suitable scheme. What's more, introducing multicast and broadcast services (MBS) for XR will enable greater user density in a single cell, which is a major issue in commercial networks. In addition, the network status can be transferred to XR applications for cross-layer coordination. This helps the applications adjust their transmission strategies to improve the success rate.

- **Intelligent identification:** The XR industry is maturing and developing on a large scale, and there is a strong demand for using XR everywhere. However, there are various types of XR services with diverse features, so it is difficult to unify the requirements for mobile networks. ZTE owns unique base station-level deep packet inspection (DPI) that can identify 16,000+ services (apps) and provide targeted guarantee for different XR services.
- **Intelligent scheduling:** After being identified, different XR flows need to be guaranteed. The intelligent scheduling policy can reduce the waiting delay of the XR service, and an XR video source coding algorithm presents a quasi-periodic rule. For example, a 120 frame-per-second (fps) video transmits one frame of data packet at an interval of 8.33 ms. The gNodeB automatically learns the packet period characteristics of different XR flows and matches them with efficient scheduling policies to reduce the XR delay and jitter.
- **Multi-user anti-congestion scheme:** Video data packets usually consist of I frames and P frames, in which an I frame involves all the information of the image and a P frame only contains part of the supplement information, so that the I frame is much larger than the P frame. In a large-capacity scenario, because I frames are irreplaceable, when multiple users request the XR service at the same time, I frames may arrive at the base station at the same time, causing I frame collision and instantaneous congestion. As a result, some XR services are delayed, and user experience is poor. Therefore, the multi-user anti-congestion policy is used in the X-Edge solution to stagger traffic periods and avoid congestion. The result shows that the collision probability decreases by 10 times, that is, the video stalling probability decreases by 10 times.

- **XR experience evaluation system:** An end-to-end XR evaluation system is established on the basis of differentiated guarantee for XR services. Digital twins are used to improve efficiency and accuracy of the evaluation and accelerate the development of the XR industry chain. The evaluation system is established in terms of media quality, interactive quality and display quality, which involves whether there are VR audios and videos, whether users feel dizzy, and whether blurred screens and stuttering occur when watching videos. In addition, a digital twin simulation platform is also built to collect and process data, analyze service features, and iteratively optimize evaluation algorithms to improve the accuracy of the evaluation system.
- **Cloud rendering @ computing base station:** At present, the processing capability of the terminal cannot meet the requirement for full immersive experience, and the existing network architecture cannot meet the latency need of strong interactive XR services. One highlight of the X-Edge solution is the industry's exclusive cloud rendering @ computing base station, which implements accurate identification of XR services and guarantees priority scheduling of XR services. Moreover, the rendering function is offloaded from the terminal side to the base station, reducing power consumption and terminal complexity.
- **Energy saving on XR terminals:** The terminal energy-saving function improves battery life of the terminal, alleviates its heating problem, and provides users with a comfortable wearing experience. For example, if the video frame rate is 60 fps, the XR service transmits one frame of data packets at an interval of 16.7 ms. In the traditional solution, the C-DRX period is an integer (such as 6/8/10/20/30), which cannot correspond to the XR service period. As the data volume increases, the deviation becomes larger and larger, resulting in jitter. In the X-Edge solution, the gNodeB can adaptively adjust the wake-up signals in accordance with the identified period characteristics, so that the C-DRX period can be dynamically matched with the XR service period. The simulation result shows that the solution saves power by 20%.

5G Helps XR Become a More Popular Application

In addition to the development of XR applications, 5G will bring mobility to drive XR from indoor to outdoor, from fixed places to broad areas, and expand more XR applications to anywhere. The growth of XR services will greatly increase the needs for 5G traffic, increase the investment in 5G network, and improve user experience. This will promote the development of more high-quality content, thereby attracting more XR users. 5G and XR can form the flywheel effect. ZTE is poised to work with industry partners to promote the development of new technologies with the aim of providing superior networks for large-scale commercial use of XR. ZTE TECHNOLOGIES

ZTE Deploys 5G CampSite to Guarantee Emergency Communications in Earthquake-Stricken Areas of Sichuan

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At 12: 52 local time on September 5, 2022, a magnitude-6.8 earthquake hit Luding County in Ganzi Prefecture, Sichuan province, causing damage to communication facilities in several areas of Shimian County, Ya'an City. Together with China Mobile Sichuan Branch, ZTE immediately delivered 5G CampSite to Shimian County, rapidly providing 4G/5G emergency network coverage for the command center and temporary shelters. The emergency communication system deployed in this project includes 5G CampSite, rescue mobile phones, flexible backhaul and edge computing engine, providing all-round emergency communications services. The 5G CampSite is a small 5G+ cloud base station together developed by ZTE and China Mobile. It features 7/24-hour plug-and-play, low latency, and wide coverage with support for the access of both public network users and private network services.

In the disaster-stricken areas in Xinmin Town of Shiman County, the situation was extremely complicated with concentrated residents and dense rescue teams. There was a need to implement on-site survey, rescue operations, and emergency communications, and also to provide phone and Internet services for the disaster-stricken people. However, most public network facilities had been out of service or even damaged, resulting in communication failures. Within only one hour after arriving at the area, the 5G CampSite started to run to guarantee emergency communications. Due to the powerful integrated RF antenna equipment, CampSite provides the affected people with 4G/5G multi-frequency multi-system capacity.

Meanwhile, the on-site technical engineers from ZTE interconnected the built-in edge computing engine of the 5G CampSite with the command center to build a wireless rescue private network. Through this convenient private network, rescue images, videos, and voice information can be shared between rescuers and the command center. Thanks to the local offloading function, the delay of video services can be reduced by 80% and the 10 Gbps processing capability is supported to greatly

improve the front-line rescue progress. Compared with the traditional UPF implementation, the 5G CampSite only needs to have one NodeEngine board inserted into the BBU to provide simple and fast local private network services. This board has low power consumption and does not occupy any further supporting resources. Comparatively, the traditional UPF+MEC solution needs at least three servers, two switches, and two firewalls, with its power consumption reaching more than 3 kW. Such equipment-intensive mode of UPF can be hardly used in the emergency rescue scenarios.

As rescue was moving forwards, it was necessary to move the command center from Xinmin Town to the front line, but large emergency communication vehicles can not reach there. On-site engineers immediately deployed a wireless multi-level cascading solution, which flexibly uses multiple 5G CampSites to extend the coverage of the private network and to guarantee the front-line rescue operations in a harsh environment.

5G CampSite consists of four parts: 5G RF module, backhaul unit, edge computing engine, and auxiliary equipment (Fig. 1). The RF module uses mature commercial lightweight RF units to provide 4G/5G signal coverage in multiple possible scenarios. The backhaul unit is responsible for the interconnection between CampSite and the core network. The edge computing engine, the core of CampSite, is embedded in the BBU to provide the local traffic offloading function at the BTS level, which saves transmission resources and significantly reduces the delay. The auxiliary equipment provides a convenient movable condition for the whole CampSite.

This is the first time that 5G CampSite has been put into the rescue operations. It provided reliable and timely communication services for the rescuers and the disaster-stricken people with the following advantages:

- **Quick deployment:** 5G CampSite can be deployed quickly and flexibly without site survey. The integrated mobile cart solves the problems of inconvenient movement of equipment and site selection difficulties. It only takes about 20 minutes from deployment to up and running. In addition, 5G CampSite also supports multiple backhaul modes such as dedicated line, wireless CPE relay, Internet, and satellite backhaul to support rapid deployment in many scenarios.
- **Three-dimensional coverage:** An AAU equipment that integrates an RF unit and an antenna unit can be adopted for 5G CampSite. The AAU is small in size, light in weight, and compact in structure. In addition, the AAU uses a universal hardware platform, supports 4G/5G dual-mode, and can flexibly configure 4G/5G cells through software, providing multi-frequency multi-mode coverage in disaster-stricken areas.
- **Powerful edge computing engine:** In addition to meeting public service requirements, the built-in edge computing engine of CampSite also supports local traffic offloading. After being filtered by CampSite, the upcoming private services were interconnected with the local command center via the edge computing engine to build a wireless rescue private network that enables the sharing of text, voice, pictures, and videos between on-site rescuers and command centers. CampSite can also support advanced functions such as high-altitude lighting, drone search and rescue, and infrared detection.

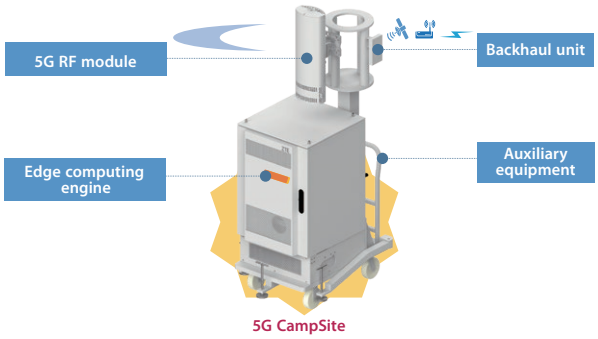

Fig. 1. Composition of a 5G CampSite.

In the face of the disaster, ZTE and China Mobile Sichuan Branch quickly coordinated the emergency, transmission, power, and satellite systems, and rapidly commissioned the 5G CampSite to solve the network coverage and capacity problems for the residential shelters while meeting the private network service needs of the rescuers, providing strong support for rescue work. ZTE TECHNOLOGIES

“Understanding” Users in Service Experience Assurance

China Mobile and ZTE Complete Commercial Verification of Intent-Driven Hierarchical Service Assurance

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Du Yongsheng

Wireless Intelligence Architect, ZTE

As intelligent technologies become prevalent in the 5G era, it is becoming increasingly urgent to evolve to intelligent, simple, and low-risk telecom networks. Intent-driven technology, a popular concept, applies a deep level of intelligence to the network that reads and aligns with a user’s intent. It simplifies the network operation and maintenance (O&M) , improves the experience of end users and enterprises, and holds great promise for application.

With the accelerated development of 5G networks, a variety of services have been generated and user expectations heightened. This means that network assurance is becoming more difficult and higher in cost. The traditional point-to-point assurance method, which relies on manual and expert experience, is no longer able to keep up with the rapid changes in service and traffic. Thus, network assurance becomes increasingly dependent on intelligence technology.

ZTE collaborated with China Mobile Fujian to provide an intent-driven hierarchical service assurance solution to realize “what you want is what you get” and ensure the optimal network efficiency and superior user experience. This solution has won the second prize in the 5G enhanced technology track of the 2022 "Bloom Cup" 5G Application Competition.

Advantages of Introducing Intent-Driven Technology

Since 2019, the autonomous network has gradually evolved from concept to reality, and new technologies have been continuously created and gradually applied to actual networks. In the standardization of the autonomous network, the intent-driven technology as an iconic technology for high-level networks is indispensable.

With the spotlight put on intent-driven

technology, the communications industry has been doing theoretical research on it vigorously. Based on a comprehensive assessment of the importance of various communications industry scenarios and network O&M challenges, ZTE and China Mobile Fujian agreed that the intent-driven technology has significant value for service experience assurance.

ZTE's intent-driven hierarchical service assurance solution incorporates key intent-driven technologies, including intent input, intent translation, conflict detection, intent execution, and intent guarding (Fig. 1). The system identifies the desired outcomes after the user inputs a request through natural language, matches different assurance levels according to intents, adopts the optimal assurance policy, monitors the business status in real time, and adjusts the policy accordingly. A user's intention is acquired and translated by introducing the bidirectional encoder representation from transformers (BERT) natural language processing model at the intent input and translation sides, while services features are identified and optimized based on intelligent deep packet inspection (DPI) at the intent execution side. By combining these high-level intelligent technologies, the system provides intent-driven hierarchical service assurance to ensure that the network operates as expected.

Using hierarchical and differential scheduling methods, the intent-driven hierarchical service assurance offers not only lifecycle service assurance but also many advantages over traditional assurance methods as shown below.

- **Excellent performance:** The system monitors the network environment in real time and matches it with appropriate assurance policies to achieve differentiated scheduling of system resources. Based on the priority, policy and algorithm, system resources are allocated to a particular application of the target user, assuring the optimal user experience, improving network performance and reducing network energy consumption.
- **Low cost:** The system is able to self-adjust and self-optimize based on the user's intention, which greatly improves productivity, reduces the network risks

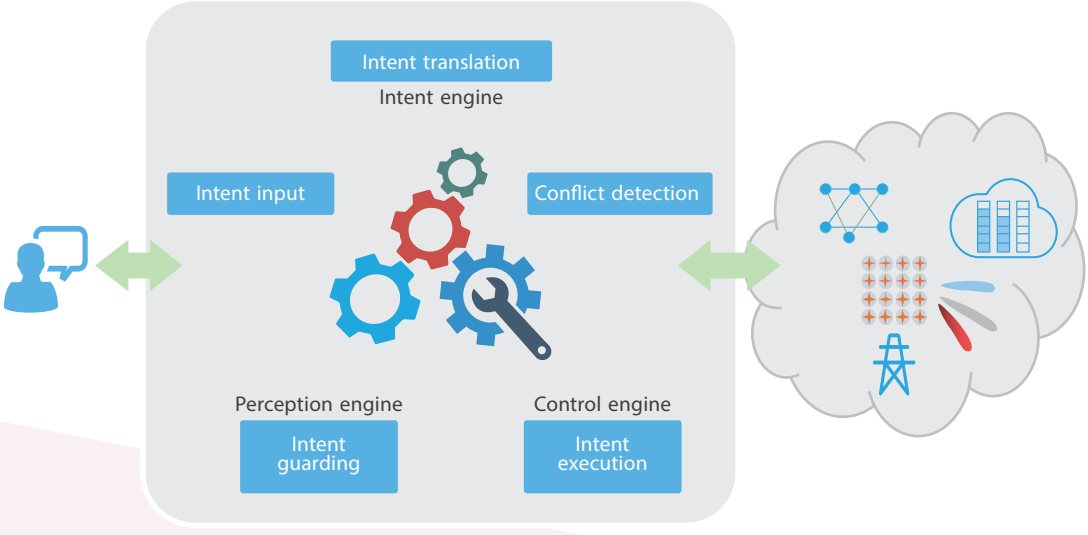

Fig. 1. Intent-driven hierarchical service assurance.

caused by human errors, and effectively reduces network O&M manpower and costs.

- **Easy to use:** Artificial intelligence is introduced to significantly reduce the user's threshold to work with the system. For common users, they only need to define their intent without paying attention to the procedures, which greatly reduces the complexity of network O&M and makes the O&M system easier to use.

Maximizing Network Benefits

China Mobile Fujian and ZTE applied the intent-driven technology to the traditional network O&M, making the shift from network-centric assurance to user-centric. In the verification of intent-driven hierarchy service assurance in Quanzhou, Fujian Province, it took the network approximately 30 minutes to complete service assurance operations for 10 sites using the traditional service assurance mode and about 5 minutes using the intent-driven technology. This was a noticeable improvement in assurance efficiency.

In order to verify the service assurance effect, the testing team chose four common application scenarios for detailed commercial verification, including Tencent video broadcast, Tiktok live streaming, Minzhengtong QR code scanning and WeChat video conference. Different assurance expectations are set at various assurance levels for these four services in the current network, including throughput increase targets of 100% (Level 1), 50% (Level 2) and 30% (Level 3), and latency reduction targets of 50% (Level 1), 30% (Level 2), and 20% (Level 3). Validations of the combinations of different services and assurance levels showed that, under the intent-driven hierarchy service assurance scenario, service throughput can be increased by up to 760.55% and latency can be reduced by up to 88.70%. Assurance expectations have been exceeded and user experience has been greatly improved.

The commercial verification of intent-driven hierarchical service assurance improves both service experience and O&M efficiency, providing a solid foundation for wider applications of intent-driven technology. In the future, the intent-driven hierarchical service assurance will focus on two major directions: first, expanding the application scale to reduce O&M costs; second, enriching the application scenarios to achieve endogenous interconnection between scenarios and create an intent assurance ecosystem.

Broad Application Prospects

China Mobile and ZTE will continue to cooperate on intent-driven technologies in the future, developing networks that can achieve high profits, high efficiency, simplicity and digital transformation and progressing to high levels of autonomy in the 5G era.

It can be expected that intent-driven technology will play a significant role in the entire telecom network and even in our daily life. With its gradual integration into the autonomous network, the intent driven technology will have large-scale applications with the continuous increase of the corresponding intent rules and enhanced productivity. Assisted by AI capabilities, it will change the progress of the communications industry and even the human society. ZTE TECHNOLOGIES

Towards Operational Excellence and Smart Site Management

Joaquín Ballestero-Herguedas

Global Technical Operations, Technical Area, Cellnex Telecom

Access management is a critical process for infrastructure operators such as Cellnex, dealing with several challenges. Based on the dimension of our portfolio, it surely is not a surprise to reveal that hundreds of thousands of accesses per year are registered in Cellnex sites (Fig. 1). The traditional approach has been to use some sort of mechanical access system (such as physical keys), but this has a series of disadvantages:

- The frequent loss of keys impacts in the efficiency of the whole process and results in unnecessary trips and interactions with customers, landlords and technicians.
- It is difficult (if not impossible) to individually do the end-to-end tracing and control of each one of the accesses to the premises.
- Potential unwanted accesses triggered by the loss and also uncontrolled copy of physical keys, at the end, could have a direct impact in the security of the sites and might also impact in the health and safety legal obligations.

On top of that, a very common problem that arises in the sector (and in Cellnex in particular) is the lack of uniformity in the whole access procedure due to different site scenarios coming from multiple portfolio acquisitions. In other words, the traditional system:

- Prevents from creating an industrialized and homogenous procedure.
- Is generally speaking quite inefficient.
- In some cases, puts even at risk the SLAs committed with customers.

The diagnosis was clear and it was decided that some action needed to be taken so it was opted to move a step forward and looked for a Smart Access solution. Based on Cellnex expertise and market prospection, it was decided that migrating to Smart meant to acquire a keyless solution which allowed us to

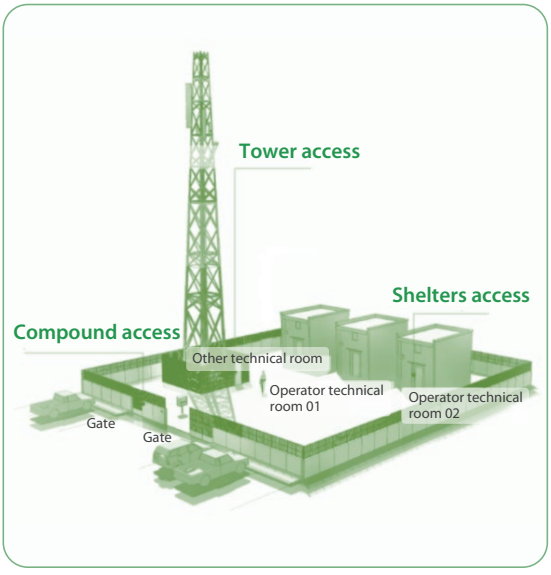

Fig. 1. Typical greenfield site structure.

completely digitize the events triggered by the accesses to the premises (Fig. 2). This way both the issue of the traceability and the problems associated with the loss of keys could be solved, and at the same time the window of opportunity to rethink and reengineer the whole access procedure could be opened, gaining efficiency and homogeneity and avoiding manual interactions as much as possible.

Keyless solution providers have been selected and the access involves in one way or another the usage of a smartphone (or equivalent portable device) with digital keys sent to the technician's mobile app running on the phone. The mobile keys contain access rights which are managed remotely and in real time. These rights can be updated and cancelled as needs change to ensure that only the right people have access to the right places at the right time. Administration of several sites is conveniently consolidated into cloud-based software platforms, which ensures a 24/7 monitoring capability.

One of the solutions doesn't even make use of batteries, as the power needed to open the mechanism inside the padlock is triggered by the NFC in the mobile device. This has the additional advantage to reduce maintenance costs even more, since incidents linked with battery failures are avoided.

Cellnex is now in the middle of the deployment phase, installing the necessary devices in the 12-countries portfolio. The Smart Access solution is feasible to install (at least in a first batch) in most of Cellnex sites; and from this initial set of sites, around 43% of them have already been migrated. The plan is to complete the deployment in 2-3 years.

In parallel Cellnex is deploying its own OSS system. One module inside this OSS tool manages the access requests. Customers create these site access requests (SAR) by filling in the necessary information (Fig. 3):

- Who wants to access,
- Where and when,
- What are they going to do.

Fig. 2. Examples of Smart Access solutions deployed in Cellnex.

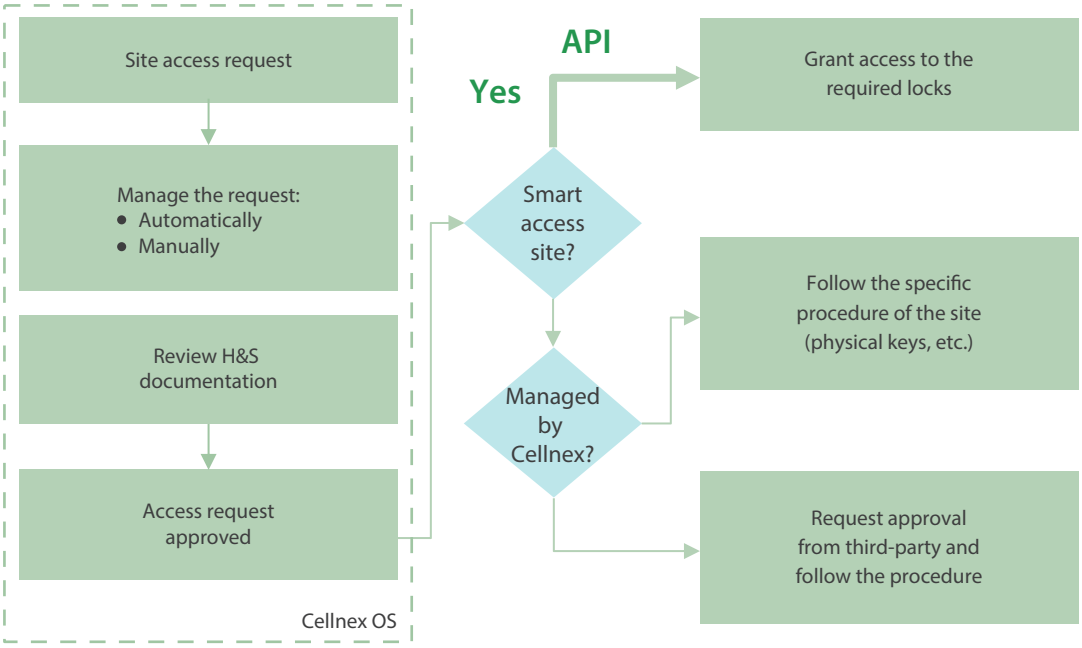

Fig. 3. Access procedure (Cellnex vision).

If the adequate conditions are met, the SAR is automatically approved; if not, some human interaction is needed to manually grant the access, having previously done a series of tasks.

By means of an API between our OSS and the Smart Access platform, basic information needed to grant the rights to the technicians to the selected locks (for a concrete timeframe) is sent. This way the whole process is, in some cases, completely automated, substantially reducing the response to customer petitions and therefore helping to achieve much more easily the contractual agreements (SLAs) and improving the overall service. Technical staff in operations is constantly supervising the whole process by means of dashboards and key indicators (KPIs) generated by capturing the access events so that abnormal behaviors, sites where the activity is above average or locks potentially left opened can be easily identified.

Cellnex is achieving with this Smart Access project an easier, faster and reliable way to manage access to sites. A mutual beneficial situation has been created, since Cellnex customers are taking advantage from the automation and quick response that this type of solution offers, and at the same time Cellnex, as infrastructure operator, has gained the ability to better control what is going on in their premises.

From business point of view, having an own model for managing access to infrastructure is critical to gain efficiency in operating the assets due to the fact that it is a very user intensive process. On the other hand, in this process of transformation to Smart it is key to be accompanied with strong and proper partners and to choose an innovative and state-of-the-art solution that helps to achieve the initial goal of automation and cost reduction.

During the last years, several companies around the world have started similar projects, expanding the concept of Smart Access in the industry. These are very good news also for Cellnex, as extended use of this kind of solutions is reinforcing the profit obtained from the solution and accelerating its adoption. ZTE TECHNOLOGIES

To enable connectivity and trust everywhere