ZTE TECHNOLOGIES

AUG 2018 | VOL. 20 • NO. 4 • ISSUE 177

VIP Voice

ZTE: Getting Ready for 5G

Special Topic: Pan 5G

ZTE Pioneering 5G Through Extensive Field Tests

Scan for mobile reading

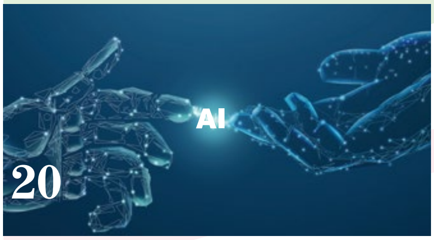
CONTENTS

ZTE TECHNOLOGIES AUG 2018

VIP Voice

Expert View

Special Topic: Pan 5G



Success Story

Solution

ZTE TECHNOLOGIES

Advisory Committee

Director: Wang Xiang
Deputy Directors: Yu Yifang, Zhang Wanchun, Zhu Yongxing
Advisers: Chen Jian, Cui Li, Fang Jianliang, Yang Jiaxiao

Editorial Board

Director: Wang Xiang
Deputy Director: Huang Xinming
Members: Bo Gang, Cui Liangjun, Han Gang, Heng Yunjun, Huang Xinming, Liu Shouwen, Sun Jiruo, Wang Xiang, Ye Ce, Zhang Zhenchao

Sponsor: ZTE Corporation

Edited By Shenzhen Editorial Office, Corporate Development Department
Editor-in-Chief: Wang Xiang
Deputy Editor-in-Chief: Huang Xinming
Editorial Director: Liu Yang
Executive Editor-in-Chief: Yue Lihua
Circulation Manager: Wang Pingping

Editorial Office

Address: NO. 55, Hi-tech Road South, Shenzhen, P.R.China
Postcode: 518075
Tel: +86-755-26775211
Fax: +86-755-26775217
Website: wwwen.zte.com.cn/en/about/publications
Email: yue.lihua@zte.com.cn

Statement: The magazine is a free publication for you. If you do not want to receive it in the future, you can send the "TD unsubscribe" mail to magazine@zte.com.cn. We will not send you this magazine again after receiving your email. Thank you for your support.

Bai Yanmin, Vice President and General Manager of TDD&5G Products at ZTE

ZTE: Getting Ready for 5G

Reporter: Xiong Manqing

The early deployments of commercial 5G have kept increasing around the world after the first version of 5G standards was completed in June 2018. Operators and vendors are busy preparing for pre-commercial 5G deployments because faster deployment means a much bigger market share in the next 10 years. ZTE sticks with 5G as its core strategy and outperforms rivals in terms of 5G standard specification, technology innovation, product verification, and commercial deployment. Has ZTE been well prepared for 5G competition? Bearing this question in mind, the reporter Xiong Manqing interviewed Bai Yanmin, Vice President and General Manager of TDD&5G Products at ZTE.

In the first half year of 2018, ZTE and China Mobile made the 5G first call, which indicated that commercial 5G deployment began to speed up. Would you like to introduce the 5G first call in detail?

At the end of March 2018, we collaborated with China Mobile to make the 5G first call in Guangzhou in compliance with the latest 3GPP R15 standard and formally built up the field site for an end-to-end 5G commercial system. The first 5G call was a key milestone in the commercial 5G progress and will boost 5G development.

Guangzhou is a pilot city of China Mobile for 5G field tests and also an important base for ZTE to push commercial 5G use. Early in June 2017, ZTE constructed the world's first pre-commercial 5G base station in Guangzhou and finished key tests in collaboration with China Mobile, verifying KPIs and technical solutions of 5G NR at 3.5 GHz including the coverage, speed, capacity, and latency. ZTE outperformed the competitors in completeness, time, and quality of test cases and gained extensive experience for commercial 5G deployment. As planned, China Mobile will build more than 100 5G gNBs in Guangzhou this year. As a core partner of China Mobile, ZTE will go hand in hand with China Mobile to build 5G trials and develop the 5G industry.

Independent innovation has been the main source of 5G competitiveness within Chinese enterprises. What advantages and highlights does ZTE have for independent innovation in terms of key 5G technologies?

Independent innovation is indeed the primary driver. Our unique and innovative gene will put ZTE in an invincible position in the competition. We lead 5G innovation in three aspects.

First, ZTE is the pioneer and leader of Massive MIMO, the key technology in 5G. Based on the precise and mature channel estimate algorithm and proprietary MU-MIMO mechanism, Massive MIMO enhances the spectrum efficiency by six- to eight-fold and thus increases cell capacity significantly. In June 2014, ZTE was the world's first to propose innovative Pre5G concept that could apply Massive MIMO in 4G and bring 5G-like experience to users on their 4G terminals. With extensive verification and commercial experience, ZTE won top awards in the telecom industry: the Best Mobile Technology Breakthrough and Outstanding Overall Mobile Technology—The CTO's Choice 2016 at the Mobile World Congress 2016. So far, ZTE has put Pre5G Massive MIMO into commercial use for four years and has been working with China Mobile, SoftBank, H3G, O2, and Telefonica. ZTE has gained rich experience in the commercial use and operation of Pre5G. This has laid a solid foundation for mature commercial use of Massive MIMO in 5G.

Second, ZTE is the main force to promote non-orthogonal multiple access (NOMA) for 5G. As the first drafter of NOMA, ZTE took the lead in initiating the NOMA research project in 3GPP. NOMA can

be implemented in several ways, among which is multi-user shared access (MUSA) proposed by ZTE. The MUSA supports both grant-free and high-burst transmission, allowing the system to access much more users with the same time and frequency resources in all eMbb, uRLLC and mMTC scenarios. We believe that MUSA will be an international standard. Moreover, ZTE is a member of international mainstream standard organizations such as ITU, 3GPP, IEEE, and NGMN. ZTE has submitted more than 4700 international proposals in total on 3GPP 5GNR/NGC and has become the editor in three 5G key specifications and the vice chair in RAN3.

Third, We have invested a lot in 5G chip technologies and achieved a good result. Based on outstanding capability in 7nm chip design and development, we have launched self-developed multi-mode 5G baseband chips and digital intermediate-frequency chips that have a superior architecture and powerful functions.

ZTE has also proposed other key 5G technologies such as beam management, high-frequency channel modeling, and low-density parity check code. We stick to independent innovation, and we are convinced that independent innovation is a primary driver of 5G.

OVUM predicts that 5G will be put into commercial use in 2019 and will be commercially deployed on a large scale around the world in 2020. There are less than two years left, so what has ZTE done towards 5G commercialization?

The horn of initial 5G commercial deployment has sounded, and ZTE has been ready.

In terms of 5G products, ZTE is one of the few vendors that can supply 5G end-to-end equipment. We have rolled out a full range of 5G commercial products for all application scenarios, including 5G low-frequency base stations, high-frequency base stations, fast-deployed base stations, and indoor distributed base stations. We are quick to deliver 5G commercial services.

In terms of 5G tests and verifications, ZTE has begun collaboration and tests with more than 20 well-known operators around the world such as China Mobile, China Telecom, China Unicom, Telefonica, Orange, Italy's Wind Tre and OpenFiber, Belgium's Telenet, and Umobile. We are ready to provide services and products for first-round commercial 5G deployment all over the world. ZTE signed agreements with Wind Tre, the biggest Italian mobile operator in Italy, and OpenFiber, a leading fixed operator in Italy in October 2017, aiming to build the first pre-commercial 5G network in Europe.

Promoting the industrial cooperation is also a key for 5G commercialization. ZTE has established extensive cooperation relationships with partners in whole telecom industry chain. In 2017, ZTE collaborated with China Mobile and chip vendors to conduct the world's first 3GPP-compliant low-frequency interoperability development test (IoDT), which became a milestone in the 5G industry.

In short, with the large-scale commercial 5G deployment approaching, we will continue to invest greatly in 5G R&D and maintain our leading position to build the best 5G network and help operators move toward new business growth and achieve win-win results.

As the big tide of commercial 5G deployment is coming, what do you suggest for the future network deployment of operators?

In my opinion, the first thing for operators to consider is 5G network architecture. An operator may face two options of deployment: standalone (SA) and non-standalone (NSA). In general, the two network architectures have their own advantages and disadvantages. NSA focuses on enhancing the bandwidth in hotspot areas. It has no independent signaling plane but relies on 4G base stations and 4G core network. However, SA is independent of any network and provides both the control plane and user plane to achieve all new 5G features and practise all 5G capabilities.

After long-term comparison and field-testing, we conclude that SA is a better choice than NSA in terms of network performance, networking complexity, and construction cost. As for network coverage, which bothers operators the most, SA performs as good as the 4G network. As 3.5 GHz (3.3 to 3.8 GHz) is the primary frequency band in the initial 5G deployment, the coverage capability that 3.5 GHz NR provides has great impact on an operator's option of deployment. After many link estimations, system simulations, and 5G field tests in Guangzhou, Shenzhen, and Xiongan, we found that 5G NR at 3.5 GHz could provide network coverage equivalent to or even better than that of the 4G network. This means that 5G NR at 3.5 GHz has the exact independent networking ability.

So we recommend that operators select SA for their 5G network deployment. The SA option can not only protect their existing 4G investment but also ensure customers have a brand new and excellent 5G experience. The network deployment can begin with low-frequency technologies to achieve fundamental coverage. When traffic grows to certain extent, high-frequency technologies can be used to increase network capacity.

China is devoted to building the country into a cyber power, so it has been actively involved in the 5G field. What do you think of China's position and role in the global 5G arena?

China has indeed been actively involved in the 5G field. It is now agreed in the industry that China has become a leader in the 5G era.

From the standards perspective, Chinese telecom enterprises have contributed approximately 40% of total 5G proposals in 3GPP, and Chinese experts have taken a big proportion in each 5G working group.

From the policy perspective, Chinese government plans to build the world's largest commercial 5G network. Also, China is the first country to release 5G frequency bands. These are positive signals for 5G deployment in China.

From the market perspective, a well-known consulting firm Ovum released in its independent research report that there had been about 7.79 million 4G base stations in the world and about 4.34 million 4G base stations in China by the end of 2017. The number of 4G base stations in China accounted for 55.68% of the global total. ZTE has secured one third of China's 4G market share. A country's voice in 5G depends on its market scale. The scale effect brought about by China's enormous market will greatly boost the 5G industry. Industry partners around the world including system, terminal and chip vendors are all willing to move around China's 5G market, know clearly its 5G commercial requirements, and to create 5G end-to-end industrial chains in China. Meanwhile, the cost advantages brought by the economies of scale of China's 5G networks can be shared globally. So we believe that 5G will have a promising prospect in China. ZTE TECHNOLOGIES

Li Miao

Director of 5G Architecture Planning, ZTE

Meeting the Business Challenges of Future with Flexible 5G RAN Architecture

By Li Miao

Compared with the evolution of previous radio technologies, 5G is a comprehensive technological innovation. 5G has three critical application scenarios: eMBB, uRLLC, and mMTC, which are designed for IoT business with heavy traffic, low latency and high reliability, and low power consumption respectively. 5G covers various fields like UHD video, AR/VR, smart grid, smart transportation, industrial automation, and automated driving.

It can be seen that when compared with 4G that focuses on mobile broadband services only, 5G has a broader vision and its target markets also evolve from the pure CT market to various vertical industry markets. However, under the new situations, the traditional NE-based access network architecture with software functions closely coupled to hardware goes no further. New access network architecture that is more flexible, universal, and self-adaptive is needed to adapt to massive market features and service requirements. New RAN split architecture is therefore used in the 5G network.

On the one hand, it is necessary to introduce centralized units in the 5G era, while on the other hand, distributed units must also be retained. To achieve the two objectives, ZTE uses a separable, flexible RAN architecture to provide more agility in a variety of scenarios.

RAN Split

ZTE's 5G architecture provides functional split at the higher layer of radio protocol stack in compliance with 3GPP standards. This means that the BBU function in 5G is reconfigured and divided into two functional entities: centralized unit (CU) and distributed unit (DU). The two functional entities process different data based on whether the processing procedure meets the real-time requirements. CU provides the functions of non-real-time high-layer radio protocol stack, and also supports localization and deployment in the network edge of some CN functions and applications. DU provides the physical layer function and real-time layer-2 function.

Cloud and Non-Cloud Based Deployment

After the two functional entities (CU/DU) are split, the CU bearing non-real-time functions can be deployed on general-purpose hardware, with high-layer functions of the access network operating on virtual machines, while the DU still uses dedicated hardware. This architecture, where CU is deployed in a centralized manner, is called cloud CU. Comparatively

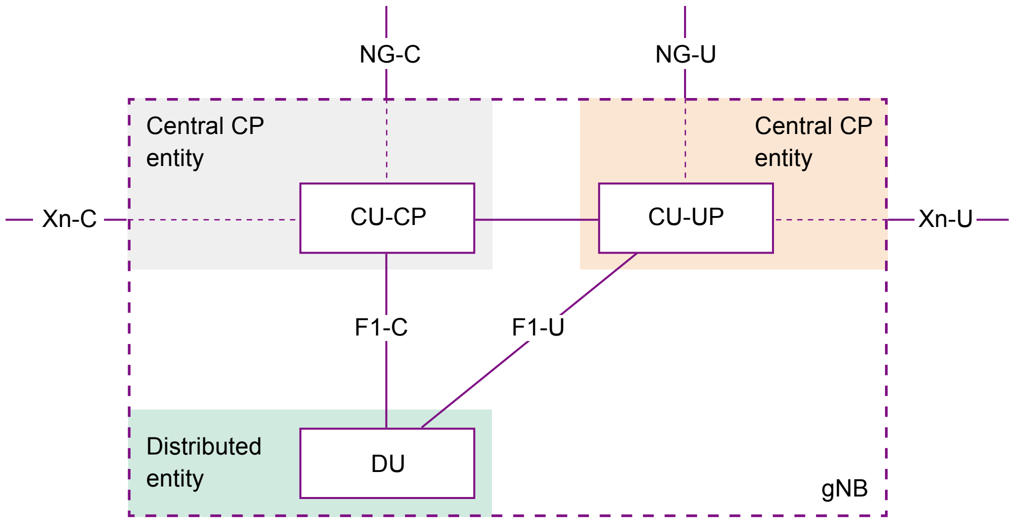


Fig. 1. CP/UP split architecture.

speaking, there are two types of non-cloud deployment architecture of the traditional access network without introducing virtualization technologies. One is D-RAN, where multiple BBUs are completely independent and are not co-located. The other is C-RAN, where multiple BBUs are co-located, so that the baseband resources of the BBUs may be shared or isolated from one another.

ZTE's 5G RAN supports all above-mentioned deployment architectures. This is not only for forward and backward compatibility, but also more primarily for adapting to complicated and diverse service scenarios.

CP/UP Convergence Optimization

ZTE's 5G RAN can also optimize using the converged control planes (CPs) and user planes (UPs) on the CU unit. For CPs, the convergence of CPs corresponding to multiple cells or sites allows unified resource coordination, interference control, and load balancing. Both the efficiency and the effect are better than those of the distributed interface-based inter-sites/cells RRM procedure. For UPs, the convergence of multiple UPs is beneficial to cross-cell or even cross-site packet processing. For packets that previously needed to be delivered through an interface, only context reusing on the centralized unit is required now, and the bearer between RAN and CN that previously needed to be migrated in the mobility procedure can now be reused.

Further CP/UP Split

Based on the CU/DU split, to adapt to different service requests, CP and UP can be further split at the CU side of the access network. After the split, CP and UP are decoupled from each other. They interact through the standard E1 interface and can be deployed on different physical nodes.

Fig. 1 shows the interfaces after CP and UP are split, but does not fully illustrate how CP and UP are deployed. In fact, after CP and UP are further split, their deployment locations can be selected as required. For example, after split, CPs can be further integrated to better implement CP coordination, and UPs can be deployed at network edge or higher-layer nodes based on service latency requirements.

As described above, after the introduction of the CU/DU split, multiple architectures appear in the 5G RAN, including D-RAN, C-RAN, and cloud-RAN, and the further CP/UP split makes architecture change diversely. However, the architectures are not mutually exclusive. Operators and users can flexibly deploy their networks based on their own needs.

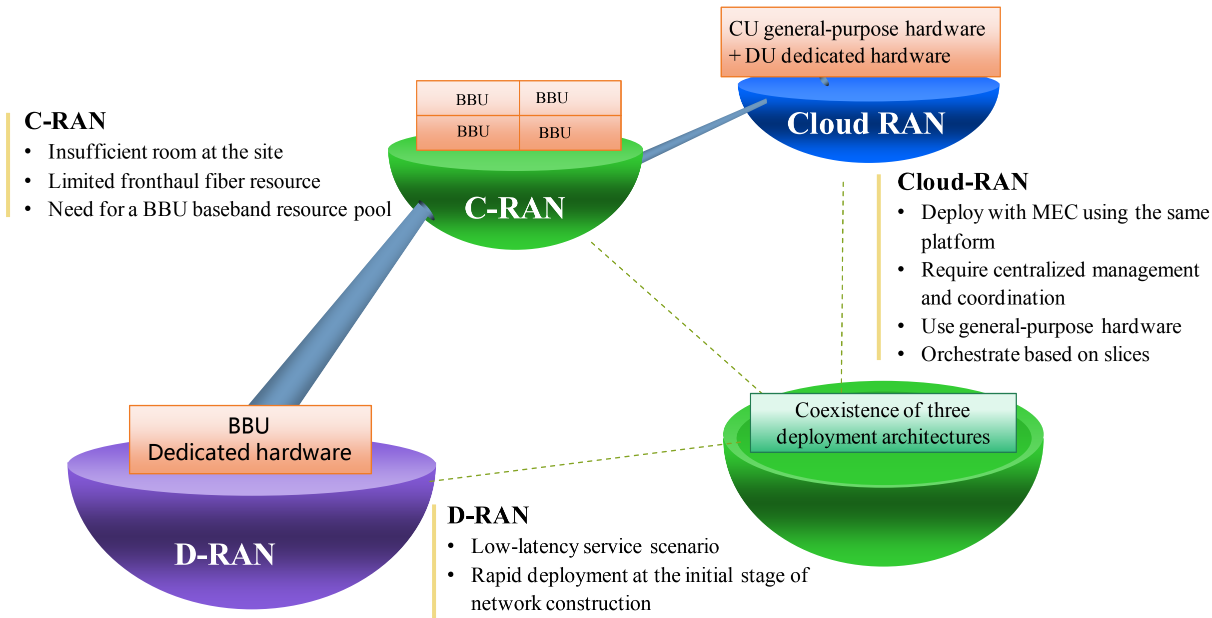


Fig. 2. Co-existence of hybrid architectures.

Fig. 2 lists some rules for using the three deployment architectures. The evolution from traditional 4G networks to 5G networks can start from the D-RAN deployment architecture and then gradually introduce more architectures. After the mature commercial deployment of 5G, the three architectures can still co-exist in the same network based on areas and service needs. ZTE's 5G RAN has flexible topology architectures that can be compatible with ideal fronthaul and non-ideal fronthaul transport environments. It not only supports various deployment architectures, but also can use its self-adaption feature to adjust the architecture based on different application scenarios.

Two typical 5G application scenarios are listed below, which describe how the flexible 5G RAN architecture adapts to the scenarios to deliver best user experience:

- Convergence of 4G and 5G networks: In this scenario, LTE and 5G dual-connectivity mode is used. CP signaling passes LTE base stations to ensure continuous coverage. UP data passes 5G DU for heavy-traffic wireless access. High-layer CP and UP protocols all converge at the CU. When a terminal moves, the CP and UP anchors do not change. This ensures seamless mobility.
- Internet of vehicles (IoV): DUs are deployed by roadsides to assist in distribution of vehicle-side V2V/V2X radio resources. CUs can be deployed on upper-level nodes. The application server can be deployed at the CU side to provide fast feedback interaction over the application layer.

In summary, functional split at the RAN side makes it possible to reconstruct the service-driven access network. Such reconstruction includes not only function layer split, but also processing convergence, applications localization, and CN functions integration. More importantly, the network can automatically enable its required architecture. ZTE's 5G RAN architecture is versatile and flexible enough to meet the commercial needs of 5G IoT and the future development trend of mobile communications.

ZTE Pioneering 5G Through Extensive Field Tests

By Yan Guoqing

Providing high-speed, low-latency, and high-reliability services, the 5G network plays an important role in the transformation from “Made in China” to “Created in China”. The Chinese Ministry of Industry and Information Technology started 5G-related tests in 2016 with the aim to promote the commercialization of 5G. Taking advantage of this opportunity, China’s 5G industry has been advancing rapidly. Together with China Mobile, China Telecom, and China Unicom, ZTE has carried out 5G field tests in various places, providing an integrated end-to-end solution including 5G CN, base station, and test UEs. This solution is developed and verified based on system prototypes developed under the 3GPP SI framework, which promotes the finalization of the product architecture and completion of pre-commercial product specifications.

ZTE establishes its industry-leading position in 5G by creating numerous records. In June 2017, ZTE and China Mobile established the world’s first pre-commercial 5G base station in Guangzhou. In the following November, China Mobile, ZTE, and Qualcomm completed the world’s first end-to-end 5G NR interoperable system based on 3GPP standard at China Mobile’s 5G Joint Innovation Lab. On November 8, 2017, the first 5G field call for China Telecom was successfully made in Xiong’an and Suzhou. In January 2018, ZTE was the first to complete China Mobile’s 5G field test with excellent results. In March 2018, ZTE, together with China Telecom and Baidu, completed China’s first autonomous driving road test based on a 5G network environment in Xiong’an, advancing the research on 5G application scenarios.

Yan Guoqing
TDD&5G Domestic Marketing Planning Manager, ZTE

Major test base stations in a 5G field test carried out in Guangzhou, 2017

Comparison Tests to Verify 4G/5G Co-Site and SA Feasibility

China's three major operators pay close attention to the coverage capability of 3.5 GHz NR. Whether 5G base stations can be co-located with 4G base stations determines the network architecture of 5G. Consequently, the three operators carried out comparison tests between 3.5 GHz NR and different LTE frequency bands.

3.5 GHz NR vs. 2.6 GHz TD-LTE Comparison Tests to Verify Featured Enhancement Technologies

During the field test in Guangzhou, ZTE and China Mobile jointly completed tests on complicated items within the shortest time. They obtained the ultimate performance data and verified a single 5G NR base station's performance and multi-site networking capability.

In the Lab Building of Guangdong University of Technology in 2017, comprehensive indoor and outdoor tests were carried out, covering various types of scenarios. Multiple groups of data were obtained from the best to the worst points. Generally speaking, the 5G coverage at 3.5 GHz was better than the LTE coverage at 2.6 GHz. While penetration was weak in the field, there were significantly higher gains in a mid-field or far-field position. 5G Massive-MIMO and outdoor NLOS conditions can fully verify the networking capability of 3.5 GHz NR equipment. The connection dropping point of the 64TR 3.5 GHz NR was further than that of the 2.6 GHz LTE. For an isolated site with the LOS range extended by 3 km, the downlink rate could still reach 300 Mbps and the uplink rate 0.4 Mbps. The coverage of a single 3.5 GHz cell and the remote deployment results for an isolated site were both satisfactory.

At the Nantingcun site in Guangzhou, coverage of broadcast synchronization channels were enhanced. A 5G base station was deployed on a 45-meter sightseeing tower. With an extended coverage radius of 1.2 km, it served ±30° segment of the horizon. The wide beam configuration and narrow beam configuration were used in the tests that included multiple points. The results showed that the four-beam configuration had an average gain of 3 dB, in comparison with the single-beam configuration, and was good for vertical beam configuration. The PDCCH beamforming coverage enhancement technology and the PUCCH coverage enhancement technology have been proven to be capable of overcoming the weaknesses of 4G and giving full play to the advantages of 5G Massive-MIMO.

3.5 GHz NR vs. 1.8 GHz LTE FDD Comparison Tests in Different Near-Commercial Scenarios

In the 5G field test carried out by ZTE and China Unicom in Xili, Shenzhen, a coverage capability comparison between 3.5 GHz NR and 1.8 GHz FDD could truly reflect their performance in real-world coverage environments.

In a scenario where indoor coverage was provided by outdoor base stations, 17 test points were selected on two floors of a test building. RSRP showed that good, medium, and bad points were included in the 17 test points. The comparison results demonstrated that at each point the uplink rate at 3.5 GHz NR was better than that at 1.8 GHz FDD LTE, and at 16 points the uplink rates at 3.5 GHz NR had over 100 percent gains over those at 1.8 GHz FDD LTE.

In a remote base station deployment scenario, ZTE carried out common drive tests and ultimate drive tests separately. In a common drive test, at 99.7 percent of the test points, the 3.5 GHz uplink throughput was higher than the FDD 1.8 GHz uplink throughput. Most test points had over 100 percent gains. The preliminary 5G field tests showed that the uplink coverage of 3.5 GHz NR was better than that of 1.8 GHz FDD LTE. The 3.5 GHz NR sites can be planned based on the locations of the 1.8 GHz FDD LTE sites to achieve continuous coverage.

3.5 GHz NR vs. 1.8 GHz LTE FDD Comparison Tests in More Scenarios to Verify Co-Location Capabilities of 3.5 GHz NR

China Telecom and ZTE carried out tests in Suzhou and Xiong'an to compare 3.5 GHz NR and 1.8 GHz LTE in terms of uplink and downlink coverage. Test results showed that the coverage distance, the uplink and downlink performance of 5G were obviously better than those of 4G.

Coverage comparison tests completed by multiple operators in multiple areas and multiple scenarios showed that 5G outperformed 4G in both uplink and downlink rates, and its edge rates had nearly 100 percent or even higher gains, proving the feasibility of standalone 3.5 GHz NR network architecture.

Complicated Items Tested with Great Results

In addition to coverage tests, ZTE has also carried out a series of field performance verification tests. In a scenario where the downlink resource usage ratio was 70 percent, the low-frequency SU-MIMO single-UE peak throughput exceeded 2 Gbps, and the single-cell peak throughput exceeded 6 Gbps, providing strong support for future eMBB scenarios. The assessment of the real capacity in typical densely-populated urban areas showed that user experience improved 10–100 times in comparison with 4G. The assessment of bidirectional latency

Driverless vehicle field test in Xiong'an

in real multi-site networking environments showed that the latency of 5G was 1/3–1/5 times lower than that of 4G, making it ready for new service development. ZTE took the lead in carrying out assessments of 5G network architecture and mobility, accumulating valuable experience for future large-scale tests. In labs and field environments, ZTE conducted 26 GHz high frequency tests in various scenarios, exploring future 5G high-frequency commercial environments. ZTE completed three-party OTA verification for the first time, laying a foundation for verification of specifications for automated high-performance products. ZTE was the first to verify the dynamic scalability of cloud-based CUs, accumulating experience in defining their hardware specifications and exploring their network architecture. The first MEC service commissioning and hardware power consumption tests promoted the industry to think deeply into practical field deployment issues.

Leading-Edge 5G Service Experience

The 5G experience car unveiled during the China Mobile Global Partners Conference 2017 in Guangzhou allowed users to enjoy HD VR videos and view maps, dynamically changing tracks, speeds per hour, and real-time and historical uplink/downlink data. The IoDT test based on the 3GPP 5G NR standard was broadcast live to the conference. Moreover, cloud games based on the MEC architecture, 5G autonomous submarine, and ultra-high bandwidth video transmission by 5G UVA were also showcased, allowing people to experience 5G services before entering the 5G era.

In March 2018, together with China Telecom and Baidu, ZTE completed China's first autonomous driving road test based on a 5G network environment in Xiong'an. This event is expected to kick off 5G's application in autonomous driving and push forward commercialization of 5G. In this test, the three parties focused on verifying the 5G air interface transmission solution for dynamic incremental data of 3D high-precision map, including dynamic incremental updates to 3D maps from vehicle to cloud (V2C) and vehicle to vehicle (V2V) transmission.

Summary

ZTE's 5G field test sites in various areas have been gradually expanded and the number of verification scenarios have also been increased. It is believed that ZTE will achieve more breakthroughs in 5G technology and provide high-quality 5G network services for operators around the world.

Leading the 5G Era

Through Technology, Commercialization and Scale Benefit

By Ding Yi

5G will bring a qualitative change in the history of telecom development. Thanks to its high performance, massive connections, and flexible network architecture, 5G will greatly improve human information infrastructure and speed up industry upgrade. Many countries such as China, United State, Japan, and South Korea have taken 5G as their national strategies and have introduced policies to promote 5G industry development.

China's 5G blooms in Shenzhen. Focusing on 5G end-to-end solutions is exactly the 5G strategy made by ZTE. With an all-out effort in 5G standard development, product R&D, and commercial verification, ZTE aims to lead the 5G era through technology, commercialization and scale benefit.

Technology Leadership: Continuing 5G Innovation, Establishing a Benchmark Image

Investment in R&D is crucial to 5G innovation. ZTE invests annually 10% of its revenue into R&D and more than 3 billion RMB into 5G wireless sector. The company has set up a 5G expert team of over 4500 professionals, focusing on 5G key technologies to facilitate 5G commercial use around the world.

ZTE was the first to recognize the value of Massive MIMO early in 2009 when 5G had yet to take shape and many 5G candidate technologies emerged. Based on the global R&D think tank of ZTE, and after arduous

Ding Yi
Market Planning Manager of TDD & 5G Products, ZTE

exploration and attempts, ZTE has proposed that Massive MIMO would be the key technology to greatly improve spectral efficiency, capacity, and coverage in the 5G era. Moreover, ZTE became the first in the industry to overcome technical difficulties, develop a precise and mature channel estimate algorithm and a patented multi-user MIMO (MU-MIMO) scheduling mechanism, and succeed in applying them to 4G networks. 5G-like networks bring a 8-fold increase in spectral efficiency. This not only benefits operators and users, but also accelerates the industrialization and continuous innovation of Massive MIMO. More importantly, this contributes to many technical proposals containing measured data for 5G standards.

To meet the massive access need of 5G networks, small-packet data will increase exponentially. ZTE put forward the MUSA candidate solution and non-orthogonal multiple access (NOMA) that allowed a three- to six-fold increase in the number of users the system could access under the same time-frequency resources. This achieved free scheduling and reduced terminal power consumption significantly. ZTE, as the first drafter, led in 3GPP RAN1 and passed NOMA research project, advancing the industry standard.

ZTE boasts strong capabilities in chip design and development, aiming to develop by itself core chips for its main system equipment. ZTE's NG BBU uses its self-developed high-performance vector processing baseband chip that provides the largest capacity and highest efficiency in the industry. With this chip, the NG BBU is destined to be another star product following the BBU 8000 series that was rated as a leading product (the highest level) by GlobalData, a well-known consulting firm. Based on its highly integrated digital intermediate-frequency chip, ZTE has also launched the industry's lightest and smallest

5G AAU.

Commercialization Leadership: Making a Global 5G Deployment Plan, Breaking through High-End Markets

ZTE has found favor with many high-end operators for its innovative 5G technologies and solutions. It has helped China Mobile deploy the first 5G pre-commercial base station and has built the first 5G pre-commercial network in Europe. To date, ZTE has established 5G partnerships more than 20 top operators around the globe.

Those 5G operators hoping to first commercialize their 5G networks have cooperated with ZTE on 5G strategies and tests. Telefonica and ZTE jointly completed 5G network architecture and transport tests, and will further verify 5G end-to-end solutions. Orange plans to work with ZTE to conduct tests for 5G multi-site standalone network architecture in Europe in 2018. China Mobile cooperated with ZTE to run a 5G trial closest to the real 5G environment in Guangzhou and to verify 5G continuous networking. They also plan to expand the trial network to cover most areas in Guangzhou in 2018. China Telecom joined hands with ZTE to conduct the first 5G pre-commercial tests in Xiong'an and Suzhou, exploring innovative applications in vertical industries and helping China become a leader in 5G applications. China Unicom worked with ZTE to set up the first 5G NR field test site, complete relevant service verification, and implement a single-UE peak rate of up to 2 Gbps.

In November 2017, ZTE partnered with Qualcomm and China Mobile to complete the world's first interoperability data test (IoDT) based on the 3GPP R15 standard. This is a big step for 5G to move from trial to commercial products and also a powerful force to drive 5G commercialization in the industry.

Scale Benefit Leadership: Building a Most Competitive Commercial 5G Network

The governments, operators and vendors in many countries plan to commercialize 5G on a large scale in 2020. The Chinese government has planned to build the world's largest 5G commercial network in 2020. The large-scale deployment of 5G networks in China will bring huge economic benefits. ZTE will develop more mature 5G system products and significantly improve its scale advantages to offer the most competitive 5G commercial networks to global operators and to lead in economies of scale.

By virtue of its profound TDD technical strength, ZTE boasts a full range of 5G solutions to meet flexible deployment needs in multiple scenarios. With rich experience in scale product development and network operation, the company has shipped its TDD products around the world, accounting for one third of global TDD shipments for several consecutive years. ZTE will fully leverage its advantages in the 4G era to lay a leading foundation for mature 5G commercial use and cost control.

As of the end of 2017, there was about 7.79 million 4G base stations around the world, and China had about 4.34 million 4G base stations, accounting for 55.68% of the global total according to Ovum's report. China will surely have the biggest 5G commercial network in the world, which will bring substantial scale benefits as well as experience and cost benefits for operators and vendors.

At present, ZTE has a series of 5G solutions that support flexible, cost-effective deployment in different scenarios. Thanks to its leadership in six major 5G product lines including Massive MIMO, 5G NR, 5G transport, fronthaul and backhaul, 5G core network, and 5G terminals, ZTE is highly praised by Ovum. The latest report released by Ovum shows that ZTE is one of the two vendors that can provide complete 5G end-to-end solutions and have a more comprehensive understanding of 5G network requirements.

By relying on the leadership in 5G technology, commercialization and scale benefit, ZTE will focus on innovation to secure its leading position in the 5G era and strongly push 5G commercial availability around the globe. ZTE TECHNOLOGIES

End-to-End Network Slicing Technology and Its Applications

By Bian Yingyin, Meng Xiaobin

Bian Yingyin
System Solution Architect, ZTE

Meng Xiaobin
Chief Engineer for System Solution, ZTE

As the key infrastructure of the digital society, 5G could not only serve individuals but also accelerate the digital transformation in all walks of life. 5G networks will be ubiquitous to meet diverse demands for man-to-man, man-to-machine, and machine-to-machine communications.

Network Slicing: To Meet Diverse Service Demands of 5G

While 4G has only to meet the traffic demands of individual users, 5G has diverse application scenarios, which pose different demands on the network. For example, in an industrial control scenario where a service interruption may cause property loss, the network needs to provide a low latency of 1 ms, high availability, and effective isolation between different services. For internet-connected self-driving cars, its anti-collision systems concerns human safety and the network needs to provide an ultra-low latency and 99.999% network reliability. For VR/AR applications, the network needs to provide more than 1 Gbps bandwidth. For the IoT data collection service, there are low requirements for network bandwidth and latency, but the network needs to provide up to 1 million connections per square kilometer. Other scenarios such as smart factory, telemedicine, and smart grid have all posed strict requirements on 5G networks. Building a new network for each type of service will lead to great network construction costs and hamper business development; however, carrying all the services over a single network could not simultaneously fulfill the requirements for ultra-high bandwidth, ultra-low latency, and ultra-high reliability, and also has potential risks in service isolation.

To resolve the conflicts between differentiated SLAs and network

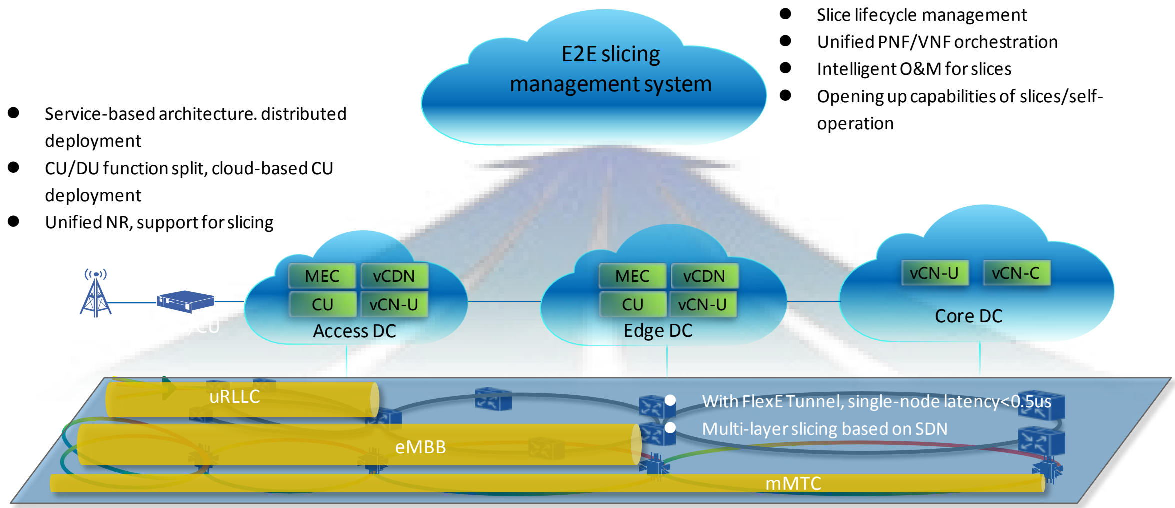


Fig. 1. Overall architecture of E2E 5G network slices.

construction costs, network slicing becomes an inevitable choice. Network slicing enables flexible slicing of 5G network resources into multiple virtual networks to meet specific customers' requirements. In addition, network resources can be fully shared, dynamically balancing on-demand services and network construction costs. Network slicing by offering flexibility and openness will have a direct influence on operators' capabilities for service innovations and capturing business opportunities, and thus has become a basic 5G network requirement.

ZTE's End-to-End Network Slicing Solution

An end-to-end 5G network slice is composed of RAN, core network, and bearer sub-slices, and supports the lifecycle management of network slices through its upper-layer E2E management system (Fig. 1). Focusing on 5G E2E solutions, ZTE takes the lead in releasing an E2E slicing solution, facilitating operators to build sliced networks.

Service-Oriented Core Builds On-Demand Slices

Traditional core networks based on dedicated hardware are rigid and closed, and cannot meet diverse 5G requirements. The 5G core networks based on NFV further introduce a service-based architecture, which decouples network functions from hardware, implements components-based functions, and adopts a stateless design, and lightweight, open interfaces, and are thus more agile, easily scalable, flexible, and open. The service-oriented virtualized core networks for 5G can realize on-demand orchestration and rapid deployment of network functions and slices while meeting the elasticity and high availability requirements, laying a solid foundation for network slicing.

RAN Slicing, Unified NR to Support Diverse Scenarios

5G RAN supports slicing and flexible deployment of AAUs, CUs, and DUs, meeting networking requirements in different scenarios. The cloud-based deployment of CUs facilitates centralized management of radio resources, while the co-location of DUs and CUs and the deployment of service anchors close to users can reduce latency in transmission.

5G NR with a flexible frame structure design can meet the service requirements in different scenarios. In addition, differentiated key 5G technologies can fulfill the SLA requirements in different scenarios, for example, Massive MIMO technology doubles data rates for users, the MUSA technology developed by ZTE increases the number of connected terminals, and the mini-slot greatly reduces the latency in communications. With flexible parameter configurations, RAN can support different frame structures and key technologies to adapt to various scenarios, meeting different network slices' requirements based on a unified NR.

Multi-Layer Slicing for SDN-Based Bearer Network Flexibly Creates Slices

Bearer network slices are created by physical network virtualization, and the SDN architecture with unified management and control can achieve IP and optical layer synergy. This allows a physical network to become open and programmable and support innovation in network architecture and service in the future. The degree of intra-slice isolation depends on the slicing technology used, for example, FlexE and FlexO technologies can be used to build rigid pipes, ensure strict isolation between slices while implementing rapid forwarding at the underlying layer. The technologies can be selected flexibly to address different service requirements on bearer networks.

Compared with constructing multiple physical planes, implementing virtual bearer network slices greatly reduces network construction costs, and flexibly schedules resource on demand, meeting rapidly changing 5G service requirements.

E2E Slicing Orchestration & Management Enables Creation of Intent-Driven Slices

The application of new technologies brings about flexible network slicing as well as complicated management, and there are various types and a great number of network slices, which necessitates unified E2E slicing orchestration and management.

ZTE network slicing, based on the carrier-grade DevOps platform, supports the life-cycle management of E2E network slices, achieves "closed-loop" automated design, automated development, automated deployment and automated operations and maintenance (O&M), and also provides wizard-based Dev design to implement E2E orchestration and minute-level deployment (Fig. 2). Based on AI-driven O&M, it can also achieve network self-healing, elasticity, and self-optimization. Driven by model-based workflows, the E2E slicing orchestration and management system flexibly matches network resources with service requirements, enabling rapid customization and deployment of slices based on specific customer requirements.

Building an Ecosystem for Slicing

Network slicing brings about new business models. 5G network slicing based on SDN/NFV technologies matches resources to applications and supports rapid customization for industry-specific customers. Network slices that are customizable, deliverable, measurable, and chargeable can be sold by operators as a product to industry customers. In addition, slicing-related capabilities can be opened to enable network slice as a service (NSaaS) model to better meet the needs of different industrial services. With open interfaces, industry customers can combine network slices with their own applications, and flexibly use and manage a network slice as with

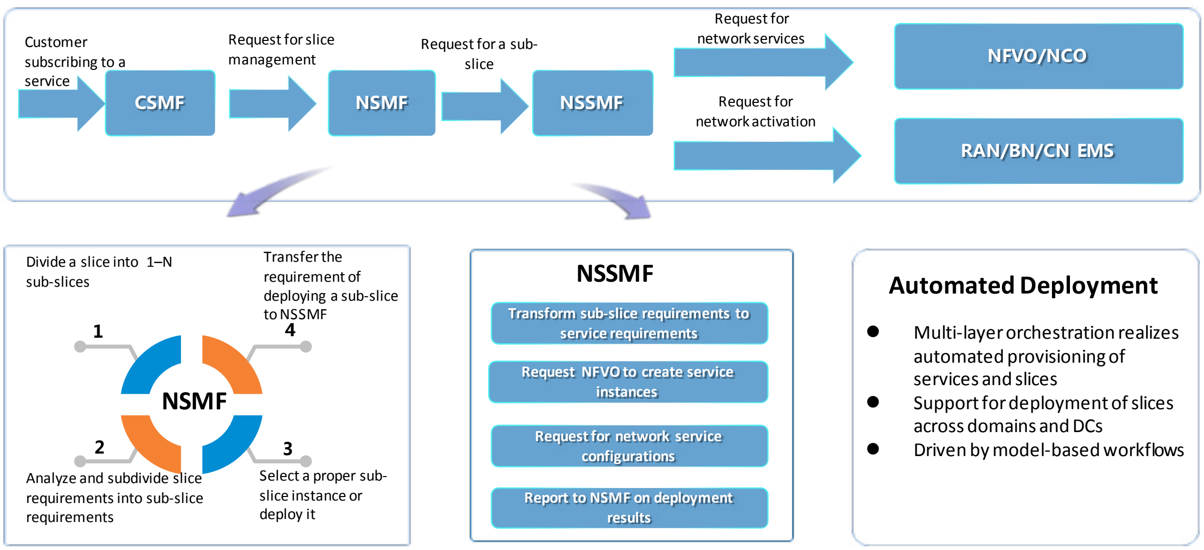


Fig. 2. Flow of automated slice deployment.

a self-built dedicated network, thereby providing convenient services.

For vertical industry customers, they can cooperate with operators to gain access to 5G networks, which helps them save initial network construction costs and rapidly achieve digital transformation. For example, the internet of vehicles (IoV) slices can provide high-availability and low-latency services with the security of IoV platforms guaranteed through slice isolation. Open interfaces can be used to meet the requirements for vehicle positioning, and edge computing nodes to guarantee better user experience. Take a future smart factory for another example. Massive sensors need to be deployed to monitor the production environment, with each sensor requiring a low bandwidth. Low latency and 99.9999% high availability are needed for efficient collaboration between smart robots. HD video surveillance used for workshop area inspections, and VR/AR technologies used for image processing in industrial design require ultra-high access bandwidth. These network requirements can be met by using the slicing technology to slice a single 5G network into three virtual network slices. In addition, physical network resources can be fully shared to facilitate enterprises to achieve digitalization of manufacturing at the lowest network construction costs.

5G has extensive application prospects in the fields such as internet of things, smart city, automatic pilot, smart manufacturing and remote control. These scenarios have different requirements for networks, which represents great opportunities for network slicing. With the close integration of slices and industrial applications and the development of an ecosystem, it is believed that network slicing will give full play to the leading role of 5G in the construction of a digital community, promote application innovation and achieve a win-win future for verticals and operators. ZTE TECHNOLOGIES

Applications of Artificial Intelligence in 5G

By Sun Yifei, Liu Changpeng

Sun Yifei
System Solution Architect, ZTE

Liu Changpeng
System Solution Architect, ZTE

As 5G standards mature more quickly and its pre-commercial tests are carried out around the globe, the pace of 5G deployment is speeding up and more innovative applications are made possible through 5G networks. In the era of 5G, telecom carriers are also faced with the challenges of network complexity, diverse services and personalized user experience.

Network complexity refers to complex site planning due to densely distributed 5G networks, complex configuration of large-scale antenna arrays, and complex global scheduling brought by SDN/NFV and cloud networks. Diverse services range from original mobile internet services such as voice and data to known and unknown services developed in IoT, industrial internet, and remote medical care. Personalized user experience means to offer differentiated and personal services to users and build user experience model in terms of full-life cycle, full-business process, and full-business scenario that are associated with service experience and marketing activities for smart operations. These challenges require networks to be maintained and operated in a smarter and more agile manner.

Typical Application Scenarios of AI in 5G

Artificial intelligence (AI) represented by machine learning and deep learning has done a remarkable job in the industries of internet and security protection. ZTE believes that AI can also greatly help telecom carriers optimize their investment, reduce costs and improve O&M efficiency, involving precision 5G network planning, capacity expansion forecast, coverage auto-optimization, smart MIMO, dynamic cloud network resource scheduling, and 5G smart slicing (Fig. 1).

Precision Network Planning Enables

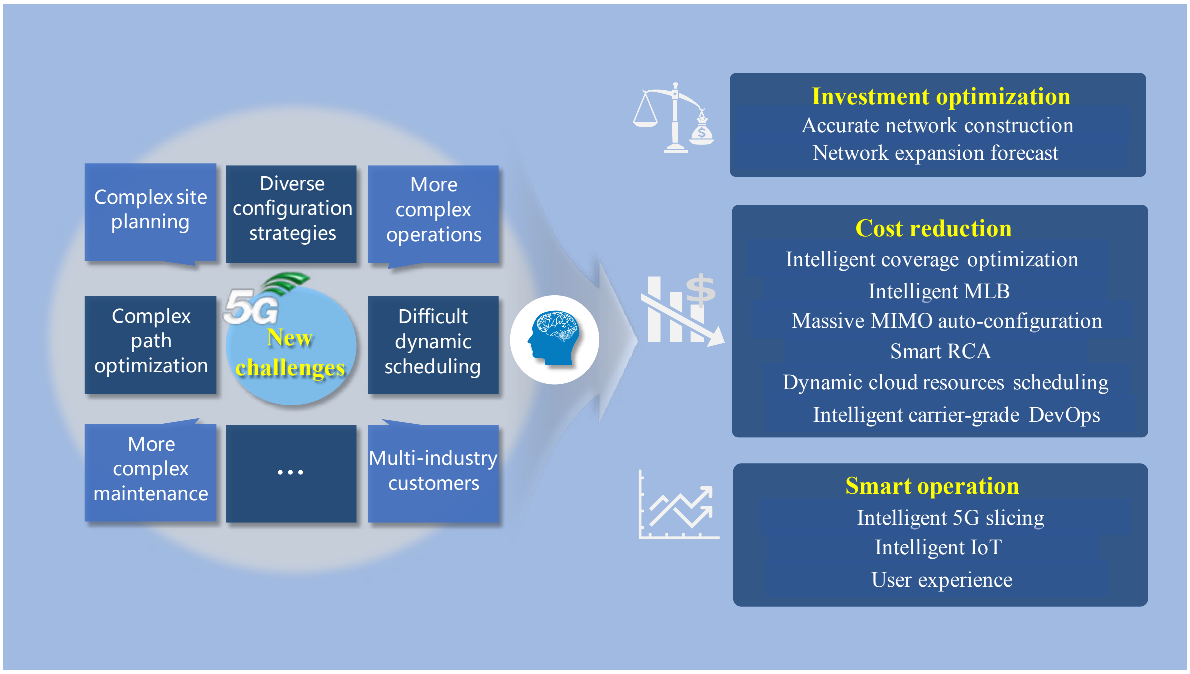


Fig. 1. Typical application scenarios of AI in 5G.

Smart Network Construction

How to distribute cell sites is a major challenge carriers will face in 5G deployment. Traditional site layout relies on network simulation, drive tests and complaint trigger mechanism. This depends on expert experience and also requires substantial manpower. However, as 5G is introduced, the existing deployment mode will face greater restrictions and challenges especially for hybrid scenarios that comprise multiple systems, multiple frequency bands, and multiple cells.

In smart network planning and construction, machine learning and AI algorithms can be used to analyze multidimensional data, especially the cross-domain data. For example, the 0-domain data, B-domain data, geographical information, engineering parameters, history KPI, and history complaints in a region, if analyzed by using AI algorithms, can help make reasonable forecast on business growth, peak traffic, and resource utilization in this region. Also multi-mode coverage and interference can be measured for optimization and parameter configuration can then be recommended to guide coordinated network planning, capacity expansion, and blind spot coverage in 4G/5G networks. In this way, operators make their regional network planning close to theoretical optimum and can significantly reduce labor cost in network planning and deployment.

Smart Massive MIMO Enables Higher Efficiency and Better User Experience

Massive MIMO is a key 5G technology. To leverage the advantages of massive MIMO sites (hereinafter shorted as MM sites), meet the coverage needs, and to provide optimal user experience, the beamforming for massive MIMO channels needs to match cell user distribution and minimize the interference from broadcast channels of neighboring cells.

The weight setting for an MM site is a critical factor that affects the beamforming effect. As for the needs of different coverage areas or different scenarios in the same coverage area, the weight setting and adjustment of the MM site plays a decisive role in improving coverage quality and efficiency. The O&M system can trigger the adjustment based on actual needs and expert experience. But the efficiency in this mode is quite low, and many adjustments have to be made to get close to the optimal value.

AI technology can be used to identify the law of change in user distribution and forecast the distribution by analyzing and digging up historical user data. In addition, by learning the historical data, the correspondence between radio quality and optimal weights can be worked out. Based on the AI technology, when the scenario or user distribution changes or migrates, the system can automatically guide the MM site to optimize its weights. To achieve optimal combination and best coverage in a multi-cell scenario, interference among multiple MM sites should also be considered besides the intra-cell optimization. For example, when a stadium is used in different scenarios such as a sports event and a concert, its user distribution is quite different. In this case, MM sites in the stadium can automatically identify a different scenario and make adaptive optimization of the weights for the scenario so as to obtain best user coverage.

Data Cube and AI Brain Serve for Smart Life-Cycle Operation of Slices

In future 5G networks, slices will be commodities and NSaaS will become a normalized business. Network slicing provides special industrial tenants with a complete end-to-end virtual network. The key to successful network slicing is to ensure a good quality of experience (QoE) for industrial users in a virtual network.

To improve experience of slice users, it is primarily necessary to construct a panoramic data map of the slicing. Information about slice users, subscription, QoS, performance, events and logs can be collected in real time for multidimensional analysis and then sliced into data cube. Based on the data cube, AI brain can be used to analyze, forecast and guarantee a healthy slicing. Experience of different industrial users can be evaluated, analyzed and

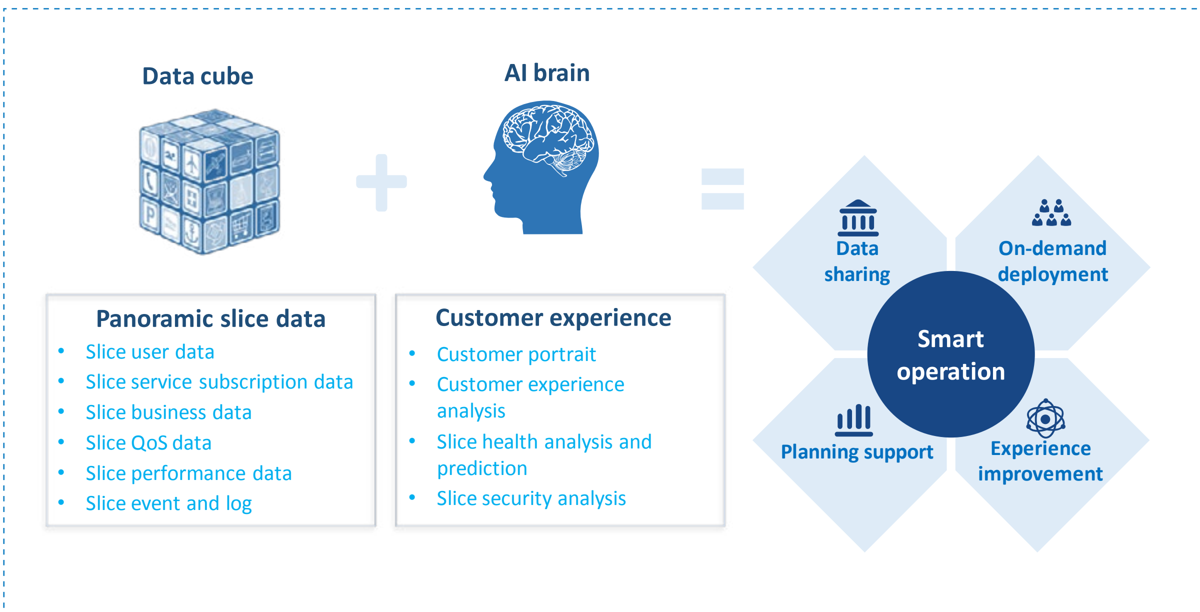
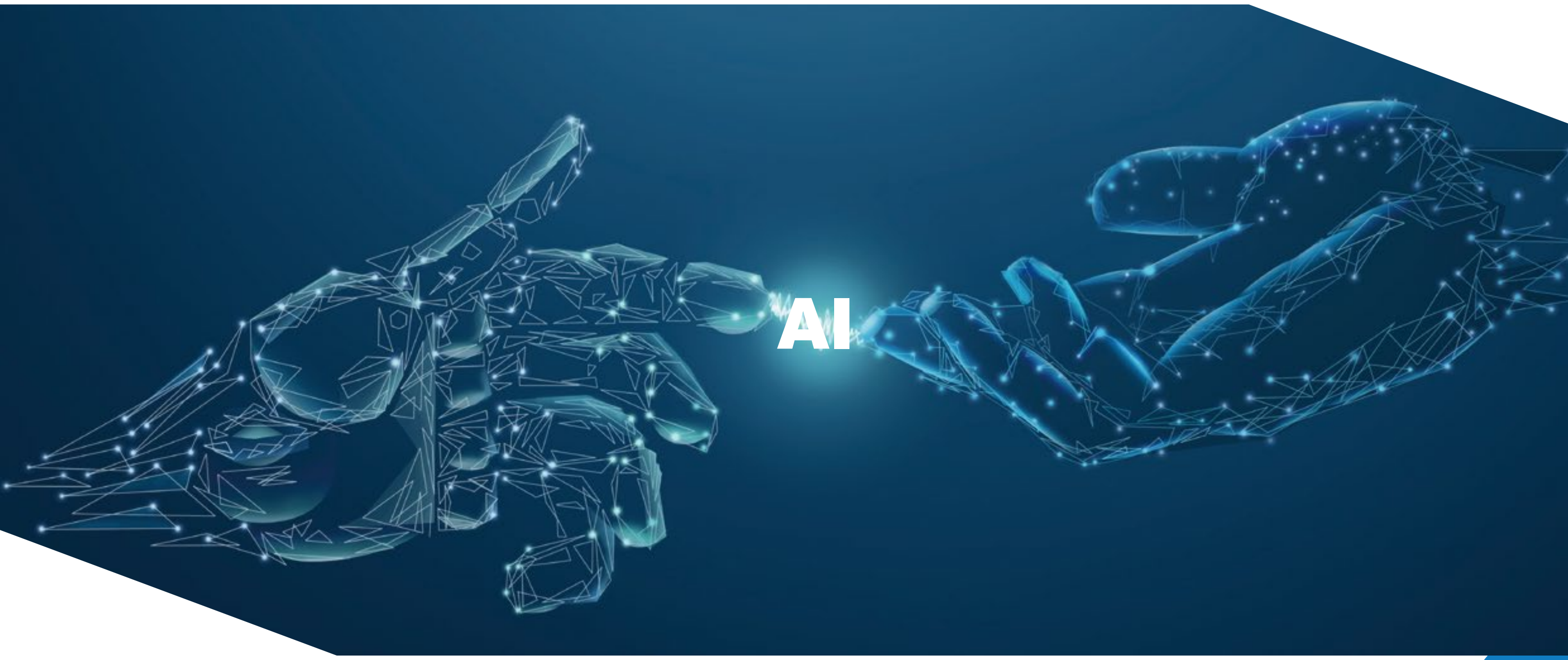


Fig. 2. Data cube and AI brain serve for smart life-cycle operation of slices.



optimized for building user portraits and guaranteeing a healthy, safe, and efficient operation of slices.

In addition, the data cube and and AI brain can serve for every process throughout the full-life cycle of slices, forming a closed loop. AI can also help to generate the slicing strategy and resolve slice faults in a smart way, and optimize the performance automatically, so as to achieve smart scheduling of slice resources and give optimal configuration. The combination of data cube and AI brain will give effective guidance for smart life-cycle operation of future slices (Fig. 2).

Suggestions for Carriers to Deploy AI

When deploying AI in 5G networks, carriers need to take into account their business growth, technology, and cost. At the present stage (from 2018 to 2019), AI algorithm models can be embedded into certain network elements, maintenance tools or big data platforms that have been deployed, to perform offline training and model-based reasoning. This deployment mode requires relatively low computational capability and is suitable for local quick application, but needs a long period for upgrade and has limited strategic coordination of the entire network. At the second stage (from 2019 to 2020), an AI platform can be built in the operations orchestration system for centralized deployment and online training. This mode has the advantages of covering cross-domain and large-scale data, using special AI hardware for faster speed, and offering online training and fast iteration, but the reasoning in this model cannot be performed in real time. At the third stage (after 2020), considering large-scale deployment of 5G networks, lightweight AI engines can be used at the MEC/CU, so that the training and reasoning can be done close to the edges. This mode is suitable for low-latency IoT services and can cover all ubiquitous smart scenarios.

The application of AI in the telecom field is still in the early stage. The coming 5–10 years will be a critical period for smart transformation of carriers' networks. With its gradual maturity, AI will be introduced in various telecom scenarios to help carriers transit from the current human management model to the self-driven automatic management mode and truly achieve smart transformation in network operation and maintenance.

5G Industrial Applications and Practices

By Huang Ming

Huang Ming
System Solution Architect, ZTE

5G Industrial Applications

Featuring high bandwidth, high reliability, low latency, and massive connections, 5G extends its applications to various industries and fields far beyond traditional telecom and mobile internet. Typical 5G application scenarios include self-driving, remote control, VR/AR, smart manufacturing, and smart grid. Those applications that are unavailable for use or provide poor experience because of limited network capacity will be developed rapidly and be deployed on a large scale in the 5G era.

Self-Driving

Self-driving is regarded as one of the most typical 5G applications that raise high requirements for network bandwidth, reliability, and latency. Self-driving also needs high-precision maps to implement centimeter-level positioning. Because the maps contain a substantial amount of vector information such as road marks and traffic signs as well as land-cover information abstracted from laser-point clouds and videos, downloading real-time high-precision navigation maps requires a network with high bandwidth and low latency. Meanwhile, since the self-driving vehicle uploads sensor-collected data to the cloud in real time for map update and coordination among vehicles, certain requirements are placed on uplink bandwidth.

Self-driving uses V2X communication to implement coordination between multiple vehicles and cloud-based decision-making such as advance notice of traffic light signals and game of two self-driving vehicles at the intersection. V2V communication used for collision

avoidance to ensure vehicle safety has high requirements for latency and reliability.

Remote Control

Remote control refers to remote operations to remote devices through a 5G network, including remote engineering machinery control, remote medical treatment, and connected drones.

Remote control applications need to transmit two types of signals. In the uplink, a remote controlled device uploads videos and device status data to the cloud. In the downlink, the cloud server delivers the control and operation instructions to the remote device. The latency of the control feedback and loopback needs to be reduced as much as possible so that remote operators can have field operation experience. In most cases, the latency must be less than 100 ms. There are also high requirements for transmission reliability of control signals.

VR/AR

VR applications include VR videos and VR games. To provide immersive panoramic video experience, VR videos require 60 PPD pixel density and 120 Hz screen refreshing rate. The transmission bandwidth of compressed videos requires nearly 2 Gbps, and even optimized display transmission solutions such as FOV transmission require a bandwidth of over 100 Mbps. This poses a big challenge to network bandwidth and capacity.

VR games tend to be cloud VR. Animation and render that involve a large amount of computation are made at the cloud, and the HMD at the client only displays video images produced at the cloud and implements game instructions. To prevent dizziness from VR games, the motion-to-photons (MTP) latency must be less than 20 ms. In the cloud VR scenario, the latency of network transmission must be less than 10 ms.

AR can be widely applied to industrial design, surgery, and equipment assembly and repair on the production line. AR glasses can superpose virtual objects on the real environment through modeling of the real 3D space, and can also allow people to easily view the anatomical figure of the objects. The transmission of AR videos requires high-bandwidth and low-latency features provided in 5G networks.

Smart Manufacturing

Smart manufacturing uses ubiquitous connection, full perception, real-time control, and smart data analysis to enable flexible and smart production processes, increase production efficiency, and make production closer to end users. 5G is used for smart manufacturing in the following scenarios:

- Real-time control: Future robots will be cloud-based with centralized control at the cloud. This raises high requirements for communication latency and reliability (a latency of 1 to 50 ms delay and a reliability of 99.999 %).
- Video application: The applications include wearable devices and industrial image processing. The bandwidth ranges from 100 Mbps to 1 Gbps, and the latency is less than 100 ms.
- Industrial IoT: The applications involve collecting and reporting data of industrial meters and sensors, which require massive access capabilities and extremely low power consumption for terminals.
- Scheduling of mobile devices: The applications include real-time scheduling of AGVs and mobile robots, which transmit control signals with a latency of 50 to 1000 ms.

Smart Grid

Smart grid covers electric power generation, transmission and transformation, distribution, usage, and other links for power production and consumption. Each link has different requirements for communication. The protection and control functions of power transmission and transformation as well as smart power distribution require highly reliable and real-time communications, video surveillance of communication links raises high requirements for bandwidth, and remote metering and data collection at the user side require large-scale coverage and massive connections.

5G network slicing can satisfy special communication requirements for different smart grid applications through the same physical network that contains the power control slice for managing power distribution control data and commands, the power monitoring slice for collecting and uploading massive meter data, and the power communication slice for secure voice calls.

ZTE's 5G Industrial Application Practices

Thoughts on 5G Industrial Applications

5G applications in vertical industries are being experimented and explored. The current work involves analyzing 5G needs, discussing its application scenarios, and demonstrating 5G commercial prototypes. ZTE believes that 5G will be gradually applied and expanded to the vertical industries as its commercial deployment is accelerated.

In the initial stage of 5G commercialization, dominant applications will still cover high-speed mobile data services for individual end users as well as fixed and mobile broadband services for business users. Major services will be based on eMBB applications. As 5G commercialization steps up, bandwidth-consuming applications such as AR/VR and HD/UHD videos will develop explosively and become killer applications.

In the development stage, 5G applications for vertical industries will gradually mature. 5G will

Fig. 1. ZTE's 5G industrial application partners.

be widely applied in the industries covering the manufacturing, transportation, electric power, medical care and education, and also speed up their digital transformation. In the mature stage of 5G commercialization, the need for massive IoT connections will gradually explode as 5G industrial applications prevail and the IoE trend emerges.

Application Practices

ZTE has invested heavily in 5G and kept its leading position in the industry. It has also actively explored 5G industrial applications and established extensive and in-depth cooperation with operators and industrial partners worldwide, preparing for the upcoming 5G era. ZTE has established partnerships with leading enterprises in various industries ranging from self-driving/internet of vehicles (IoV), AR/VR, smart manufacturing, to electric power and healthcare (Fig. 1). The company has built up a 5G ecosystem alliance for various industrial applications.

In terms of self-driving, ZTE and Baidu jointly applied for a major national technological project and conducted the industry's first field test of 5G-based self-driving cars in Xiong'an New Area in March 2018. ZTE has also cooperated with Audi China in the IoV field. In the manufacturing industry, ZTE has worked with Xinsong, China's leading robotic company, to explore 5G applications in the smart manufacturing field. In the electric power industry, ZTE has partnered with the State Grid Corporation of China to validate the applications of uRLLC and network slicing in the smart grid. In the healthcare industry, ZTE has worked with BGI to trial 5G-based remote ultrasonic diagnosis.

As 5G speeds up its commercialization, ZTE will further expand its cooperation with industrial partners worldwide to embrace a bright 5G era. ZTE TECHNOLOGIES

Internet of Things
and Data Pipes

By Zhang Xunniu, Wang Shaofei

Zhang Xunniu
System Architect of IoT Project, ZTE

Wang Shaofei
Project Manager of IoT R&D, ZTE

We live in an era of highly developed information technologies. Various new technologies emerge one after another, constantly affecting our work and life. As the infrastructure of this era, the internet and mobile internet continuously integrate all sorts of emerging technologies, and are developing towards the internet of things (IoT), which undoubtedly excite us the most. IoT itself is not a new concept. It was first proposed in the 1990s, but developed slowly. However, its great goal of interconnecting everything has always been the development direction of various technologies. The IoT-based smart life, smart city, and smart earth are gradually becoming a reality. Nowadays, IoT has been recognized as the third wave of the development of the world's information industry after the waves of computer and internet. IoT has become a competitive technological highland that technology giants want to occupy.

It can be seen that IoT has two core features: connections and data. Centered around connections and data, IoT widely integrates a large number of existing technologies, involving telecom, big data, artificial intelligence, data mining, cloud computing, automation, electronics, and materials. In terms of connections, IoT extends the functions and scope of traditional telecom networks to a wider physical world. In terms of data, IoT allows the access of a considerable variety of massive devices, greatly expanding the source channels of network information data. According to statistics, 20% of the world's total amount of recently created, obtained, and copied data is from IoT, and is growing at the fastest pace. With gradually ubiquitous connections and richer data being converged, IoT is becoming a new driving force for the advancement of various technologies.

IoT is a complex giant system that can be divided into different parts in different dimensions. In the dimension of hierarchical network architecture and based on the data processing procedure, IoT is divided into three layers: the information perception layer for comprehensive information perception, the data transmission layer for reliable data transmission, and the data application layer for big data storage and intelligent processing.

Generation of IoT Data

The information perception layer or the nerve terminal of IoT, is key to IoT information data sources. This layer is connected to a large number of application devices that integrate a variety of information sensing and data collection components, including RFID readers, temperature sensors, humidity sensors, acoustic and photoelectric sensors, and cameras. These components allow this layer to have a certain level of intelligence for dynamically sensing context information of the devices themselves and their surroundings. This layer is the main producer of IoT data. The rich data generated by this layer is the foundation for IoT applications and also a prerequisite for continuous development of IoT and growing popularity of IoT applications.

Although the information perception layer is the main producer of IoT data, it does not have sufficient data storage and processing capability, but can process data locally and pretty simply. The data generated by this layer needs to first be transmitted to the data processing center through the network, then collected, stored, and analyzed, and finally exchanged and shared. Only through this procedure can the IoT data have its value.

> Centered around connections and data, IoT widely integrates a large number of existing technologies, involving telecom, big data, artificial intelligence, data mining, cloud computing, automation, electronics, and materials.

Transmission of IoT Data

IoT is an extension and expansion of traditional telecom networks, and also an integration of traditional network technologies. Meanwhile, the inherent characteristics of IoT also facilitate the emergence of many new telecom technologies.

In terms of data transmission, the biggest challenge lies in the device access network. The devices at the information perception layer of IoT are of many kinds and large difference. Some are very big, some are very small, some are located on both sides of a road with convenient transportation, some are deployed in a remote wasteland, some seldom send messages and their message transmission speeds are very slow, some frequently interact with others and send messages as fast as hares run when going into action, some consume a large amount of energy, and some consume a small amount. These diverse characteristics make it highly complex for the devices to access IoT. There is no unified network access mode that can fully meet IoT requirements for device access.

In general, wireless is the primary access mode of IoT devices, and wireline is their auxiliary access mode. In the wireless access mode, there are short-range wireless communication technologies such as Wi-Fi, Zigbee, and Bluetooth, as well as long-range wireless communication technologies such as 2G, 3G, 4G, LoRa, 5G (NB-IoT). Short-range wireless access is generally applicable to indoor devices, while long-range wireless access is more suitable for outdoor devices. Long-range wireless access technologies support low power consumption, medium and low bandwidth, large capacity, and long distance, meeting the access requirements of most IoT devices. LoRa and NB-IoT, two major wireless access modes, can meet these requirements. LoRa is led by the enterprise alliance, while NB-IoT is mainly promoted by telecom operators. With the advent of 5G, the wide deployment of mobile communication base stations with NB-IoT functions makes the competition between LoRa and NB-IoT increasingly fierce.

In terms of backbone network data transmission, IoT brings a significant impact on data traffic. IoT requires higher data bandwidth to accommodate more data being transmitted, and more flexible data routing and forwarding rules to intelligently forward data. With new network design ideas represented by software-defined networking (SDN), the traditional data communication network architecture is being reconstructed. New data communication technologies including quantum communication also provide new options for data transmission in the IoT era.

In terms of data communication protocol stack, the underlying physical layer protocol is determined by each physical network. Different physical networks use different underlying physical layer protocols, each of which operates in its own way. The traditional TCP/IP protocol stack still dominates all network layer protocols. At the transmission and application layers, the HTTP protocol for the application-oriented northbound interface is still in a dominant position, but for the equipment-oriented southbound interface, MQTT, COAP and other protocols designed for IoT can meet device requirements for low power consumption and low bandwidth transmission.

In terms of data communication security, the data security requirements of IoT involve every aspect at each layer. At present, there is no standard integrated solution. In the near future, it will be a general practice to use traditional HTTPS, TLS, and DTLS technologies to meet the security requirements of their respective applications.

Storage and Application of IoT Data

IoT-based applications are the driving force for sustainable IoT development. There are many simple and local IoT islanding applications, which involve simple data types and small amount of data, and can hardly be commercially used on a large scale and produce desired industrial effects. The influence is extremely limited.

The emergence of new data storage and processing technologies, such as big data storage, large data analysis, cloud computing, and artificial intelligence, meets IoT requirements for big data storage and intelligent processing and greatly accelerates the pace of IoT development.

In terms of big data storage, distributed cloud storage systems such as hadoop distributed file system (HDFS), distributed column-oriented storage system (HBase), Amazon S3 cloud storage, and Microsoft Azure storage can meet IoT requirements for large-scale data storage.

In terms of big data processing, big data processing frameworks such as MapReduce, Spark, and Storm can implement offline and real-time analysis of large-scale IoT data, explore more potential value in massive IoT data, and promote the launch of more IoT applications.

In terms of data exchange and sharing, related standardization organizations in the industry have been committed to specifying and standardizing IoT data models and service procedures to overcome

the pain points of IoT application fragmentation and islanding. Relevant architectures and standards include the LWM2M architecture proposed by the Open Mobile Alliance (OMA), the oneM2M architecture provided by oneM2M, an international IoT standardization organization co-founded by multiple standards development organizations, and the IoT device standards proposed by the Open Connectivity Foundation (OCF) that contains Microsoft, Intel, Samsung, Qualcomm and CISCO. Putting forward these architectures and standards gives powerful impetus to the development of IoT.

ZTE's ThingxCloud IoT Platform

ThingxCloud is a new-generation IoT platform rolled out by ZTE. By carrying upper-layer applications, connecting lower-layer devices, and generating data on its own, this platform empowers IoT, facilitates ecosystem growth, and creates a new IoT co-building, sharing, and win-win mode.

Based on the advanced ICT PaaS platform developed by ZTE, ThingxCloud allows IoT applications to be deployed as micro-services. The platform supports service orchestration, dynamic scaling, and horizontal expansion, greatly facilitating IoT service deployment and system self-adaptation in different application scenarios.

The ThingxCloud platform supports major global IoT standards and specifications such as LWM2M and OneM2M. For terminal devices, the platform supports multiple access protocols such as MQTT, COAP, and HTTP. Through SDK development packages, the ThingxCloud platform simplifies terminal access, so that any terminals can access the platform in any access mode. The platform opens data service API interfaces to application services, provides multiple external data services, and simplifies data interaction and its application development process.

In the future, the ThingxCloud platform will continuously integrate ZTE's advanced big data, artificial intelligence, and data mining platforms, to constantly increase its capabilities and push the development of innovative IoT applications. ZTE TECHNOLOGIES

5G Boosts VR Video Application

By Wang Jingfei

Wang Jingfei
Vertical Industry Director of 5G Products, ZTE

The ITU has set forth the vision for 5G in which 5G services will be delivered in three scenarios (eMMB, mMTC, and uRLLC). In the eMBB scenario, 5G will support a downlink speed of above 2 Gbps. In the mMTC scenario, 5G will support more than one million connections every square kilometer. In the uRLLC scenario, 5G will shorten latency at air interfaces to less than 1 ms and increase reliability to 99.999%. By integrating the three scenarios, 5G will boost the VR video industry.

Analysis on Mainstream VR Service Patterns

Users have experience in VR through terminals. There are three types of VR terminals in the market.

Wired VR Headset

A wired VR headset, acting as the display, needs to be connected to a host installed with a high-performance video card before providing users with VR experience. Strong image rendering enables wired VR headsets to run large VR games and provide the best VR experience. But high-performance hosts are not affordable for average users, which hinders VR popularization.

All-in-One VR Headset

An all-in-one VR headset integrates the data storage and receiving, image processing, and image displaying functions and provides VR experience after being connected to the network. However, the all-in-one VR headset is applicable to VR videos rather than VR games due to its poor image processing performance.

Smartphone VR Headset

A smartphone VR headset provides VR experience by using a VR box and a smartphone installed with VR-dedicated APPs. A user can use the smartphone VR headset to experience VR at the lowest cost. The smartphone VR headset hardly provides HD images or good VR experience because the experience depends on the smartphone screen.

Combination of VR and 5G

A common physical effect in VR experience is dizziness, which is due to the low resolution and insufficient frame rates. As generally believed in the VR industry, users will not feel dizziness when watching VR images at 4K or higher resolution. Higher resolution places higher requirements on network transmission (Table 1).

Table 1. Network requirements at different stages of VR development.

	2016	2018	2022
Head resolution	2K	4K	16K
Bandwidth (Mbps)	25	66	500+
Latency (ms)	20 ms	16 ms	5 ms
Computing location	Local	Local	Cloud
Network	4G	Pre5G	5G

As shown in Table 1, 5G provides high bandwidth required for VR services. The downlink speed for a single user in the 5G network can reach 2 Gbps, meaning that multiple users can experience VR through one access at one time.

Latency, another index of VR services, can be greatly shortened in the 5G network because of the MEC architecture. Video data is rendered and accelerated by the MEC without being transferred to the internet through the core network. This effectively shortens the data transmission path and thus shortens latency.

Innovative 5G Application Cases

After an in-depth research of 5G industrial applications, ZTE selected VR video as the first application to be deployed in the 5G network. Up to now, ZTE has achieved excellent VR demonstration effect, which can also have a tremendous social influence.

Live 360° Panoramic Broadcast

ZTE presented panoramic videos transmitted through the 5G network to the world at the 2017 World Internet Conference, which was the first of this kind in the world.

The 360° panoramic video uses standard 4K images and requires high bandwidth. This type of video was transferred only through the wired network, which restrained live broadcast because the camera had to be connected to a network cable. ZTE innovatively used the 5G network for panoramic video backhaul and enabled the camera to move freely.

The 5G live broadcast system comprises three parts: scenic area, 5G system, and demo area.

- Scenic area: In ZTE's live 5G broadcast system, panoramic cameras are installed on a sight-seeing boat in Xizha scenic area of Wuzhen. The 5G terminals in the boat transfer 4K panoramic video data to the 5G network in real time.
- 5G system: The 5G system includes 5G base stations (5G NRs) and 5G core (5GC). Video data sent by 5G terminals is converged in the 5GC and then transferred to the demo area.
- Demo area: The demo area is in the hall of WIC2017. A video host receives 4K panoramic data and then projects images onto a TV. Participants can enjoy the panoramic sight through VR as if they were on the sight-seeing boat.

Canals in Xizha are covered by 3.5 GHz 5G pre-commercial eNBs. HD cameras are installed on a sight-seeing boat. Images are uploaded through the 5G network in real time. With the sight-seeing boat navigating the water, a beautiful 4K scene of the water town is displayed to the audience in the conference.

Integrating images from multiple HD cameras raises high requirements on uplink transmission rates. The uplink transmission rate in the 5G NR network can reach hundreds of Mbps, enabling 4K HD images to be transferred to the big screen in the conference without any loss even though the field environment is continuously changing. So the audiences in the

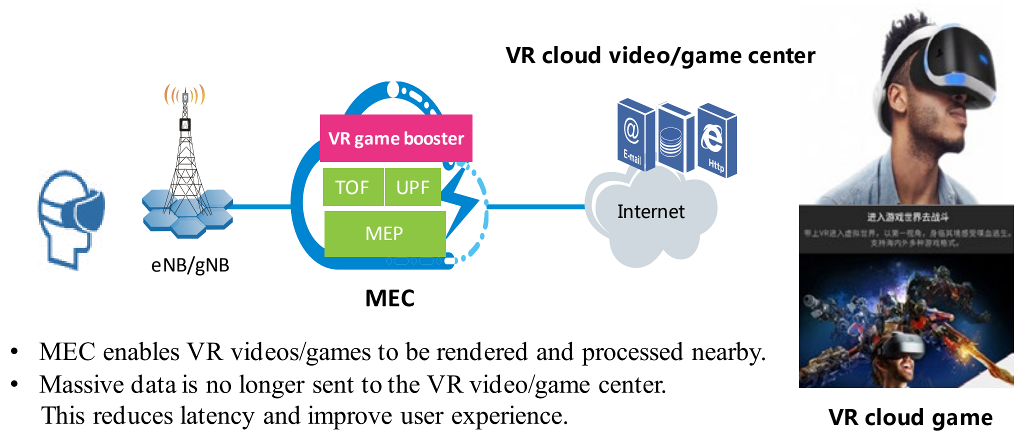


Fig. 1. Architecture of MEC-based cloud VR game.

conference can enjoy the sight o f the water town through HD panoramic video and experience the high bandwidth of the 5G network.

Low-Latency VR Game

ZTE demonstrated the industry's first cloud VR game based on the 5G network and MEC architecture in collaboration with China Mobile at the World Mobile Conference 2018 in Barcelona.

The cloud VR solution jointly proposed by ZTE and China Mobile can perfectly balance costs and performance of VR devices for users. In the solution, MEC is deployed in the 5G network to provide open capabilities, which allow GPU clusters to be deployed. Images of the VR game are rendered on the edge cloud. In this way, a user can use all-in-one VR headset at a lower price to experience VR games that could be available by HD hosts at a much higher price. It is estimated that the VR game industry will grow exponentially. Fig. 1 shows the architecture of MEC-based cloud VR game.

Live 360° panoramic broadcast site of WIC2017

Live Video Broadcast by Drones

In March 2018, ZTE, in collaboration with China Telecom and DJI, made a live drone video broadcast based on the 5G network in China's Xiong'an New Area.

Drones have been widely used in personal entertainment and industrial scenarios. However, videos captured by drones were hardly broadcast live because there were no high-speed video backhaul channels. The live broadcast drone of DJI can backhaul 1080p videos in real time. After being encoded and transferred through the 5G network, users can watch the video captured in real time by drones in the remote demo area.

Behind the rich application cases is the development of the next-generation telecom technologies. 5G is breaking through mobile communications and penetrating into every industry such as tourism, family entertainment, and manufacturing, to make human life more intelligent, more automated, and more connected on the internet. Its application in VR is only an epitome. ZTE TECHNOLOGIES

ROSTELECOM:

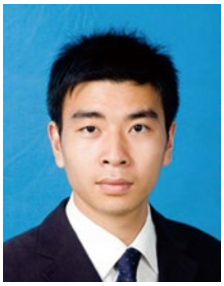
THE ROAD TO DIGITAL TRANSFORMATION IN ACCESS NETWORK

By Zhou Wei

Troubles for Rostelecom

Founded in 1993, Rostelecom is committed to providing a whole range of services, including mobile, fixed-line, internet, TV, and value-added services covering B2C, B2G, B2B and B2O. Rostelecom has operated national transport backbone networks and international gateways, with 12.4 million fixed-line broadband users, 9.3 million pay TV users and 21.2 million fixed-line telephone users. Since its founding, Rostelecom has acquired various small operators in each federal district and grown rapidly into the largest wireline operator in Russia, with subsidiaries in each federal district.

However, Rostelecom has its own troubles. With the rapid development of emerging internet services, IP-based internet telephony has gradually penetrated with low tariffs into traditional TDM business. The mobility and diverse service capabilities of mobile 2G and 3G networks have presented huge challenges to traditional fixed-line business. Traditional outdated TDM switches and multi-service access platforms have increased Opex. Moreover, it is difficult to deploy new services on the traditional TDM platform, and the platform cannot support smooth evolution to next-generation high-speed broadband technologies. In an open competition environment, as users have a fast-growing need for high-speed broadband internet access, more and more operators are competing for the broadband market.



Zhou Wei
Project Director of ZTE Russia Representative Office

Rostelecom inherited a large portion of the former Soviet Union's network legacy, and also inherited its problem of network development planning. Rostelecom's existing networks contain a large number of old PSTN devices that serve for over ten years and need high maintenance costs and Opex. Moreover, these old devices cannot provide higher bandwidth but occupy a large number of central offices (COs) that consume a large amount of high-value land. The issue of how to turn the large number of copper wires into things of value has also become a major concern of Rostelecom.

As Rostelecom grew rapidly for many years through merger and acquisition, it faces the problem of properly coordinating its subsidiaries. Because the subsidiaries independently plan their own networks, it is difficult for the headquarters to plan the entire network in a unified way. Therefore, it is urgent to upgrade technologies to unify the network planning of the subsidiaries and to give a bigger say to headquarters. Under such circumstances, Rostelecom needs an integrated access platform that can carry traditional services and meet high-speed broadband service needs.

Initiating the Digital Transformation

Rostelecom has formulated new digital strategies that can revamp and upgrade its basic networks and enable outdated TDM to be IP-based to reduce network maintenance costs. Rostelecom has also improved the network speed to support new high-bandwidth high-value services such as 4K/8K video and potential AR/VR business.

After multiple tests and selections, Rostelecom finally chose ZTE's advanced MSAN access platform to implement digital broadband upgrade.

As an multi-service access platform for PSTN, NGN and IMS deployment, MASN supports IP voice, xDSL and xPON, and provides various broadband and narrowband access methods to meet Rostelecom's need of building the integrated broadband and narrowband. To solve the problems Rostelecom faces in its existing networks, ZTE provided a tailor-made solution for Rostelecom. The MSAN small outdoor deployment solution can narrow the service distance of copper wires, improve broadband quality, and convert the saved equipment room space into cash to achieve asset-light operation.

- MASN supports smooth evolution to next-generation VDSL: MASN supports smooth evolution to G. Vectoring and G.Fast. It fully uses the large amount of cooper wire resources in Rostelecom's existing networks, and uses the copper wire VDSL technology to dramatically increase network speeds and effectively reduce the overall Capex. With today's explosively growing need for broadband business, this solution can fully use the large amount of existing copper wire resources and make them an important source of income.
- MSAN supports smooth evolution to FTTx: MSAN supports smooth evolution to FTTx, enabling Rostelecom to successfully deploy MSAN on next-generation optical networks. This allows smooth interconnection with full optical networks and fully meets the need of smooth network evolution.
- Tailor-made outdoor cabinet can tolerate cold weather of Russia: Russia, the largest country in the world by area, is the closest to the Arctic. Most areas of Russia have a frigid climate with extremely low temperatures in the winter. This presents huge challenges for outdoor deployment of the MSAN platform, and thus Rostelecom sets strict test conditions. ZTE provides Rostelecom with anti-high-humidity, low temperature-tolerant, rain-proof, snow-

Participants from ZTE and Rostelecom that attend the MSAN training

proof, damp-proof, and dust-proof outdoor cabinets, which have proved to meet the requirements of Rostelecom after multiple tests and verifications. Therefore, the last obstacle of outdoor deployment of MSAN has been cleared for Rostelecom.

- Release equipment room resources to reduce Opex: As the outdoor solution matures, Rostelecom has carefully evaluated and formulated plans to release equipment room resources. Rostelecom will convert these fixed assets into proceeds through lease or sale to create bright spots on financial reports and to further reduce Opex.

Moving Faster on a New Journey

After the cooperation with ZTE, Rostelecom accelerated the deployment of MSAN over its subsidiaries. ZTE formed technical expert teams to closely work with the subsidiaries of Rostelecom to exchange ideas on network planning, deployment, and maintenance, and to jointly explore the future technological evolution. The expert teams also rapidly implemented network upgrading and helped Rostelecom test and share ideas on copper-wire-based bandwidth increase solutions and technologies.

As a traditional operator, Rostlecom has designed good strategies for its networks and shouldered due responsibility for Russia's digital development. It has also struck a balance between investments and network upgrade and used limited investments to achieve rapid business growth. As Rostelecom implemented its strategies, ZTE provided tailor-made solutions and products for Rostelecom to upgrade its networks.

Although Russia is a large country, it lags behind other countries of its size and even small European countries in terms of telecom network quality. Therefore, there are abundant opportunities for improving network building in Russia. As the largest national operator of Russia, Rostelecom assumes the responsibility of network planning and development of the entire nation. It is firmly believed that Rostelecom, which has successfully implemented network transformation, can help improve the overall network building capability of Russia and enjoy the enormous economic and political benefits brought about by the network transformation.

MEC+QCell: An Innovative Indoor Distribution and Positioning Solution

By Bai Wei, Zhao Qiongying

Bai Wei

International Marketing Planning Manager of TDD&5G Products, ZTE

Zhao Qiongying

TDD&5G Product Planning Manager, ZTE

The number of mobile phone users worldwide continues to increase rapidly. The number is expected to increase from 2.6 billion users in 2015 to 5.8 billion in 2020. Mobile broadband penetration will reach 71% in 2020 from 47% in 2015. Both the growth of user base and the emergence of new services have brought about explosive data growth. The amount of mobile data is expected to increase by 49% every year and will grow at least seven-fold in 2020. Macro cells carry not more than 30% of data, while indoor digital systems carry the other 70%. Therefore, increasing the quality and capacity of indoor coverage is a major concern of network development and deployment.

With the arrival of 5G and the spread of its concept, artificial intelligence (AI), IoT, and big data analysis have become the trends of technological evolution, and thus there are demands for diverse services. Value-added services such as indoor navigation, smart parking, and smart office are emerging. Indoor networks will become a new growth point of profits for carriers. In addition to the improvement in system capacity and coverage, carriers are in urgent need of new business models that can form end-to-end commercial applications and bring them more profits.

Featuring small size and quick deployment, ZTE's QCell+MEC indoor distribution and positioning system supports multiple systems, multi-carrier signal feeding, and multi-frequency signal access, with a capacity several times larger than that of the traditional DAS system. By shifting the content and applications to the edge, multi-access

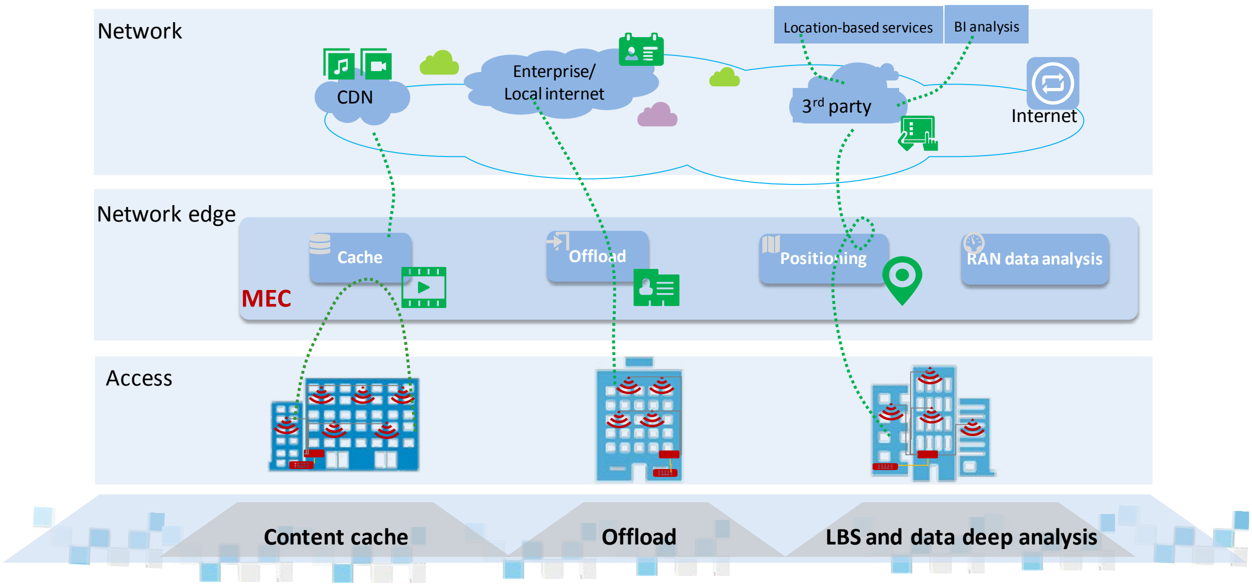


Fig. 1. QCell+MEC system architecture.

edge computing (MEC) can exploit service processing capability of the edge network, reduce latency and improve user experience. The algorithm based on field-intensity fingerprint database implements high-precision positioning. ZTE's QCell+MEC solution consists of several network elements such as PicoRRU, p-bridge (PB), multiple access unit (MAU), baseband unit (BBU), and MEC server. When combined with the big data analysis system, the QCell+MEC solution can meet the needs of both operators and central business districts (CBDs) for innovations in service and operation (Fig. 1).

End-to-End Indoor Digital Architecture

The traditional DAS system has many restrictions. Since analog components are used, the DAS system restricts further development to a more reliable indoor digital system. By contrast, ZTE's QCell+MEC solution uses end-to-end digital architecture supporting 4G technologies and has the following advantages over the DAS system:

- Capacity
- Macro/micro cell networking coordination
- QoE improvement
- Introduction of MEC to meet the high-rate and low-latency requirements
- Evolution

ZTE's QCell supports simultaneous feeding of TDD-LTE, FDD-LTE and GSM signals and also supports all indoor frequency bands including 900M, 1800M, E band, and D band, meeting the requirements of high capacity, multiple systems and concurrent services. The QCell indoor equipment is small, hidden, and easy to install. It features attractive appearance, quick deployment, and power over Ethernet (PoE). Its capacity is several times larger than that of a DAS system.

After introducing MEC, the QCell solution has greatly enhanced its capabilities in diverse service provision, fast deployment, and deep network analysis and optimization that involve precise fault location, prediction, synthetic analysis, and synergetic handling.

MEC-Enhanced Digital Service Capability

Innovative MEC covers indoor 4G signals rapidly and flexibly through QCell. Based on an open MEC platform, the QCell+MEC solution can provide local low-latency high-bandwidth services at the place closer to users. Open application programming interfaces (APIs) are also provided to allow various third-party applications and content to be transmit over network pipes. This meets the requirement of indoor users for diverse services and helps operators add value to their network pipes.

The QCell+MEC solution is capable of:

- Providing IT service environment and cloud computing at the places closer to mobile users
- Distributing or pushing the content to places near the user side (such as a base station)
- Deploying applications, service, and content in a highly distributed environment
- Meeting the requirements of low latency and high bandwidth in 5G networks.

The QCell+MEC solution has solved the problem of indoor positioning that was previously faced by the GPS+DAS system. Based on the algorithm of field-intensity fingerprint database, the solution implements high-precision indoor positioning and thus brings more profits to operators.

All-Digital O&M

After introducing MEC, the QCell solution has been greatly improved in terms of diverse service provision and fast deployment. The solution has also enhanced its capabilities in deep network analysis and optimization that involve precise fault location, prediction, synthetic analysis, and synergetic handling. These capabilities are by no means provided by the DAS system.

To meet the requirements of operators and networks at different phases, QCell provides dynamic capacity allocation through flexible NMS configuration and activates indoor positioning function in various networking scenarios such as super cells, cell split, and cell combination. The indoor positioning function is also supported in combination scenarios such as PicoRRU combination, PB cascade, and cell portion (CP) combination.

Success Cases

ZTE deployed its QCell+MEC solution and conducted indoor coverage and positioning tests in the Hualian supermarket, a shopping mall with a large visitor flow in Changping district, Beijing (China). The results showed that the positioning precision reached up to 5 m in full indoor coverage. By connecting to a third-party big data platform, the operator can attract more users through QoE improvement, precision

marketing, and consumption stimulation. Using big data to have precise user profile and analyze user behavior, the operator helped sellers adjust their operation strategies in time so as to attract more shoppers. Through shop attractiveness analysis, the operator helped sellers lock high-value brands, and also through the comprehensive analysis of brand association and conversion, the operator helped sellers improve their total value.

ZTE also deployed its ultra-dense network (UDN)+MEC solution in Hunan University City, Changsha (China) and completed the related verification tests. In the scenario of high user density and high-capacity requirement, user experience in download and VOD could be improved through the buffering of frequently accessed video resources on the MEC server. The operator improved QoE of college students and increased its profits by decreasing the load of network pipes. The two application cases are excellent demonstration to show the QCell+MEC solution have high commercial value and can be widely deployed.


Leading 5G
Innovations