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ZTE TECHNOLOGIES

VIP Voices

VEON: Our Ambition Is to Engage with Our Customers for the Entire 1,440 Minutes that Make up Each Day

Expert View

Perspective of Autonomous Optical Transport Network

Special Topic

Intelligent E-OTN

Cover Figure | *VEON Group CEO Kaan Terzioğlu*

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VEON: Our Ambition Is to Engage with Our Customers for the Entire 1,440 Minutes that Make up Each Day

Reporter: Fu Yu

VEON Group CEO Kaan Terzioğlu

"Our ambition as a leading global digital operator is to be relevant and to engage with our customers for the entire 1,440 minutes that make up each day," says VEON Group CEO Kaan Terzioğlu in an interview with ZTE Technologies that focuses on the company's digital operator strategy and endeavors to tackle the challenges in operating diverse markets. He emphasizes "4G-for-all" and shares with us how ZTE helps VEON to achieve this objective. VEON, headquartered in Amsterdam, is a global digital operator that provides converged connectivity and online services to over 200 million customers. Operating across seven countries that are home to more than 8% of the world's population, VEON is transforming people's lives, creating opportunities for greater digital inclusion and driving economic growth across the markets the company operates in. Headquartered in Amsterdam, VEON is listed on NASDAQ and Euronext.

As a CEO for VEON and a GSMA Board member, how do you see the growth of Telecom industry? What's your strategy to transform VEON from a Telecom operator to a digital operator and how the next-generation technologies such as MobileID, 5G, AI, big data can help this transformation?

Telecoms is an industry that is constantly evolving. We have been driving a Group-wide strategy of transition from being a telecoms provider to a leading digital operator for the past few years. Our digital operator strategy continues to demonstrate solid results across our markets. This strategy rests on the goal of providing VEON's growing number of 4G customers with the data-enabled digital services that they may need during any of the 1,440 minutes in a day. This drives both data usage and engagement, supported by the digital offerings of VEON's Operating Companies.

For example, in Pakistan, the digital financial services platform JazzCash recorded an increase in monthly active users of 17.6% YoY for 8M 2022, bringing the total up to 16.1 million MAUs.

The recent round A investment by VEON Ventures in the SME lending platform Dastgyr in Pakistan is delivering synergistic results for JazzCash, with over 250,000 new merchants in the process of being added using the JazzCash wallet and 120,000 new merchants able to access the Dastgyr e-commerce solution. We believe that this kind of strategic partnership benefits both our own operating performance and the value of our venture investments.

In Ukraine, Kyivstar has acquired a majority stake in Helsi, a leading e-health platform. The app is connected to more than 1,600 public and private healthcare institutions throughout Ukraine and more than 30 million people have registered with the system within the first 8 months of the year.

We have also continued to expand digital services via new initiatives. In Bangladesh, the digital entertainment service Toffee has launched a new program that enables content creators to monetize their work. Toffee users will also be able watch the FIFA World Cup in Qatar, which will undoubtedly attract more users to the platform. Last month, Banglalink reached the milestone of 5 million MAUs of its self-care application (78% YoY growth), and VEON OpCos now bring relevant, transformational self-care service to 35 million customers across our footprint.

VEON's goal is to provide its customers with data-enabled digital services that they may need during any of the 1,440 minutes in a day.

Beeline in Russia has introduced Beeline Cloud, which delivers virtual server capacity, data storage systems, resources for high load and powerful computing, and remote employee workstations. In August 2022, the service saw 5x year-on-year revenue growth. Beeline Cloud also provides an environment for developing digital products for its B2B customers.

Finally, in Kazakhstan, our music and audio streaming service IZI continues to expand. We have now made IZI accessible to all people in Kazakhstan and we continue to add content, including three new radio stations showcasing music by local artists.

We also believe that communications for citizens is as vital as food, water and shelter, and is a basic humanitarian need. The telecom industry must look to have a major impact on the whole of society. That may be through digital education, digital healthcare, banking the unbanked or providing fundamental humanitarian support. The telecommunications industry has a responsibility to grow responsibly, sustainably, and mindfully.

Next-generation technologies can certainly help accelerate the global transition to a fully digital society. For example, I am proud to say VEON has played a leading role in the MobileID (Mobile Connect) initiative alongside with other partners, helping safeguard consumers and online companies to the threat of cybercrime and ensure efficient personal data management. Incorporating 5G, AI and Big Data based products certainly assists this transition, however, to establish an all-encompassing transition in the industry, we must ensure it is firstly available to all.

What are the major challenges for VEON, and how are you tackling them, like operating in diverse markets, how do you leverage the synergies within the group?

The humanitarian efforts is a critical way in which we are facing up to various challenges across our operating countries.

For example, In Ukraine, Kyivstar continues its exceptional work to protect its network from both physical and cyber threats. Thanks to the team's diligent efforts, 93% of the network remains operational. Kyivstar has become a pivotal leader in Ukraine's cybersecurity efforts. The company is cooperating with local authorities as well as international partners to implement best practices and become a hub to help other companies secure their connectivity and operations.

Elsewhere, VEON has been supporting people in Pakistan who have been impacted by the recent floods. Via Jazz,

JazzCash and Mobilink Microfinance Bank, we have provided free connectivity in flood-affected areas, in addition to the ongoing distribution of emergency supplies, as part of our PKR 1 billion (USD 4.5 million) pledge to humanitarian relief efforts.

We have furthered our commitment to boost connectivity in other markets, such as Uzbekistan and Bangladesh. We just announced new initiatives aimed at bridging the IT talent gap in Uzbekistan and supporting the country's plan to become a major IT hub in Central Asia. Beeline Uzbekistan will be opening a regional hub for AdTech services, bringing in leading digital advertising expertise, in addition to expanding its big data analytics and cybersecurity labs in the country.

As is the case with multinationals operating in varying markets across the globe, ensuring everyone shares common vision, culture and goals is vital, and enables us to deliver a fantastic service to our customers, employees and stakeholders.

Our approach is to let our operating companies define what is best for the countries they operate in. While we still promote best practices across the Group, we avoid dictating solutions that might work well in one country but be inappropriate in others.

What about your experience with ZTE and how can ZTE help you reach your company's targets?

We are actively engaged with ZTE across our entire footprint.

In Bangladesh, ZTE's working in tandem with Banglalink, was able to deliver to its customers 2.3 GHz TDD technology, achieving continuous improvements in network speed and coverage across the country, working towards better mobile connectivity for users across Bangladesh.

Together we were able to achieve a remarkable speed of service roll-out at certain instances reaching the roll-out of more than 500 base stations per month. In September, Banglalink announced the commercial launch of Bangladesh's first next generation 4G TDD-LTE Service with ZTE. Banglalink is set to double internet speeds with its next generation 4G network, increasing productivity and boosting economic growth among the country's 92.8% of internet users that rely on 4G for access to digital services. We are able to keep the leading position of the network speed in Bangladesh by achieving 190% increase in 4G throughput, 100% capacity improvement.

Through our joint work with the roll-out of Virtual Core, RAN, and Transportation networks, ZTE has proved to be a great strategic partner for VEON. We share common targets in aiming to offer a better digital experience to our customers and through the continuation of our partnership we will be able to bring transformative initiatives to our clientele.

What are your expectations and suggestions for ZTE in the future?

ZTE is an important and strategic partner for VEON, and we have worked closely with ZTE on network infrastructure in several countries including Bangladesh, Pakistan, Ukraine, Uzbekistan, Kyrgyzstan, Kazakhstan, and Russia. This has been particularly important in building out the 4G service, enabling our customers to engage with our digital services through their mobile devices. Our belief is that "4G-for-all" is more important that 5G for a few, and ZTE is helping us to make that happen.

We also feel that ZTE shares our belief that connectivity and communications transform lives of our subscribers. Where people lack entertainment services, we can provide these. Where people do not have access to bank accounts or new education opportunities, we can make these happen. ZTE TECHNOLOGIES

AIS: Accelerating Digital Transformation in Thailand

Reporter: Zhao Xi

Tanapong Ittisakulchai, Chief Enterprise Business Officer at AIS

Asia Pacific is the home to some of the world's fastest-growing economies, with spending on digitalization in the region set to reach $1.2 trillion by 2023. With the target of becoming the digital innovation hub in Southeast Asia, Thailand has also accelerated its pace of digital transformation. In the panel discussion of the Mobile 360 APAC event in August, Tanapong Ittisakulchai, Chief Enterprise Business Officer at AIS, and David An, director of CTO group at ZTE, talked about how AIS is accelerating digital transformation in Thailand and how ZTE is helping the operator move faster.

How is AIS accelerating digital transformation in Thailand?

Tanapong Ittisakulchai: AIS is the largest telecom operator in Thailand that provides the country's digital infrastructure as well. Over the last two years we have embarked on a 5G journey, and our vision is to drive a digital transformation for the customers and help them accelerate the transformation. We are working together with all the technology partners who have been endorsing more collaboration and also more capabilities to support the customers in the future.

Our core 5G strategy is firstly pretty much focused on building the intelligent network, and we've been engaged in the development of cognitive technology or capability to give greater customer support.

Second, the most important thing is leading the 5G eco-structure and eco-partners. We strongly believe that there is a side of thing we can't make by ourselves. Therefore, to build a 5G ecosystem is very crucial for us to bring more technologies and partners as well.

Third, we will develop a digital platform for the customers. In June we announced the collaboration with Singtel. We have a Paragon platform in Thailand. We try to create an intelligent platform for customers so we can speed up how customers deploy their 5G applications.

The fourth thing will be the data-driven business. I think everyone couldn't agree more how a telecom operator can be a key player in this area. A lot of data has come to us. The data will be a natural asset for the customers in terms of the digital marking, OT, operation for the customers and so on. We can bring not only more information but also more insights, and the best action is to collaborate with the customers to find the use case to help them accelerate their business transformation.

The last but not least challenge is on the capability side. The talent will be a key challenge for telcos like us. We grow, we succeed in our own way but in a new world where we still need to learn how to manage a world with a new generation of people and make them work together with us and also drive a digital journey together.

As one of the major enablers of the digital transformations of industries, how is ZTE specifically supporting AIS's transformation goal?

David An: AIS is the No. 1 digital service provider in Thailand. We signed a comprehensive cooperation agreement with AIS in June. Based on the agreement,

ZTE is AIS' comprehensive strategic partner to upgrade key technologies such as 5G to enhance network quality and deliver excellent user experiences to AIS customers, while developing innovations with AIS to put Thailand at the forefront of the digital economy (Thailand 4.0).

First, on technology leadership, AIS and ZTE have built Thailand's first "A-Z Center" (5G Innovation Center) as a hub to explore, verify and deploy the latest technology. In March, AIS, Qualcomm and ZTE announced world's first 5G new radio dual connectivity (NR-DC) showcase with 2.6 GHz and 26 GHz in Thailand, achieving 8.5 Gbps peak downlink speed and 2.17 Gbps peak uplink speed with a single mobile device. It will unlock the full potential of 5G and bring the full benefits of 5G mmWave to both the consumers and enterprise customers of AIS.

Second, ZTE is working with AIS on business enabler solutions. In order to boost the application of 5G in vertical industries, we need to tailor offerings to enable enterprise on-demand self-service. ZTE Private 5G Network as a Service can help AIS explore new B2B market. We have already started with smart factory, and are moving to the more general smart campus solution.

The third one is about the network. We talk about optical and especially 5G connectivity, which is the foundation for AIS's digital transformation. We are committed to building the best 5G network in Thailand for AIS, and will upgrade AIS's 5G network to an autonomous network capable of precise autonomous network management.

In summary, we are supporting AIS's digital transformation in terms of technology, business and network.

Thailand has a 4.0 strategy. Now we are always talking about digital advancements such as 5G+AIoT, Metaverse, Cloud and Blockchain in

empowering the transformation and innovation in industries such as finance, healthcare, automobile, manufacturing, education, entertainment and public sectors. Can you give us examples of some industries or particular customers where your work is helping them with their digital transformation?

Tanapong Ittisakulchai: Basically it is not just to provide 5G as a technology to the customers. In the past when we moved to the next G, it is about the speed, which is mainly applied to the consumer market. But 5G brings a different way of disrupting the market. It supports low latency and also a massive scale of IoT devices, which brings much more value to the enterprise customers. Key segments that we are focused on include manufacturing, retail, transportation and property. We bring and select several technologies, and we truly believe in building and leading the partner framework. We try to be the one who pulls all the best technologies from the networking, cloud, cyber security, IoT and blockchain.

All in all, we need to have more collaboration with the customers. They have the business issue, but they aren't pretty much keen on the technologies. We have a lot of technology bullets in our pocket but we don't know where to shoot. We need to bring these together. We do a lot of collaboration, workshops, co-create things and learn to fail. We learn from several projects where we try and fail, and now you can see more and more use cases where you can integrate several technologies together because as an operator we have the data center, we have connectivity, IoT, MBIoT, 5G, 4G, clouds, and cyber security. Once we bring these together on board, we can help our customers move faster in the digital transformation.

One of the areas that we work with ZTE is in the Suranaree university. We bring the technology for them to drive several use case solutions like 5G robotics, 5G machine vision, AR and VR. This is still just the horizontal solution. But more value will be added to the vertical solution, and now we are also working a lot in several areas. That needs more collaboration with our customers, partners, and players in the market, especially those on the OT side which the telco and IT are also not familiar with. My background also came from an OT player. That will be the area that we can create the collaboration on the customer side—IT technology and OT technology will drive the 5G business so that we can help our customers drive the transformation. ZTE TECHNOLOGIES

Perspective of Autonomous Optical Transport Network

Bo Kaitao
Chief Expert of System Architecture, ZTE

Wang Xiaoyi
Director of Transmission Department, Network Management Center of China Mobile Zhejiang Branch

Digital economy is becoming the key force in reorganizing global resources, reshaping economic structure, and transforming global competitive landscape. Driven by a direct investment worth $6.8 trillion in digital transformation in 2020–2023, 65% of global GDP is expected to come from the digital economy, where products, services and experiences are digitally enhanced. Telecom operators, as the pioneers, accelerate their digital transformation through autonomous networks and share the benefits from the digital economy. On the one hand, autonomous networks can give rise to new service models and ideas, bringing new revenue opportunities to operators; on the other hand, digital O&M can help operators cut costs and increase efficiency.

Development of Autonomous Network

Driving Force

Major operators have been engaged in digital transformation in recent years, and the acceleration of digitization has increased significantly since 2021. As the digitization grows, the industry increasingly relies on these all-digital operations to add business value. An important part of digital transformation is that automated O&M can meet the needs of the environment at a growing rate. Lack of automation can cause bottlenecks in provisioning/operations and increase the possibility of human errors, which may lead to system downtime and affect normal operation. This may eventually delay the delivery of services to the line of business (LOB) and reduce the availability of services. Meanwhile, the network needs to be more responsive, and automation tools are needed to ensure that the network meets high standards, including reducing errors and support costs, increasing uptime and enhancing agility.

History of Development

To address these challenges, Deutsche Telekom took the lead in launching the

NSM workshop in Bonn as early as December 2016, with the theme "Network and Service Management of Future Networks: ZERO TOUCH", which started the process of network automation. Then automation and SD-WAN, two topics in the SDN Congress held in the Netherlands in 2017, marked that autonomous networks officially entered the pre-research phase. ETSI established the Zero touch network & Service Management (ZSM) group in 2018, which started the process of network intelligence. Subsequently, there are all kinds of research on network intelligence. For example, GSMA released the *AI & Automation: An Overview* research report, followed by the *AI in Network Use Cases in China* white paper at the end of 2019. ETSI published the *Autonomous Networks, Supporting Tomorrow's ICT Business* white paper, 3GPP SA5 published the *Study on Concept, Requirements and Solutions for Levels of Autonomous Network*, ITU-T released the Y.3173: *Framework for Evaluating Intelligence Levels of Future Networks Including IMT-2020*, and TM Forum set up the Autonomous Networks Program.

The 2022 Gartner® Hype Cycle™ for CSP Networks Infrastructure shows that the network AI and automation is in the "trough of disillusionment" and is expected to reach plateau of productivity within two years. In recent years, Vodafone, MTN, China Mobile, China Telecom, China Unicom, AIS and Indosat have come up with their 2025 autonomous network strategies, indicating that autonomous networks are about to enter a new stage of large-scale trials and systematic deployments for operators.

Standard Definition

At present, the industry generally agrees with TMF's definition of autonomous network. The TMF Autonomous Networks Program defines self-serving, self-fulfilling, and self-assuring (Self-X) capabilities from a network perspective, and zero wait, zero touch and zero trouble (Zero-X) experiences from the perspective of vertical industries and users. This makes it possible to "leave complexity to vendors and give simplicity to customers". The program also specifies core concepts and grading standards of single-domain autonomy, hierarchical closed-loop, and intent-driven to achieve and measure customer experience and

Autonomous Levels	L0: Manual Operation & Maintenance	L1: Assisted Operation & Maintenance	L2: Partial Autonomous Networks	L3: Conditional Autonomous Networks	L4: High Autonomous Networks	L5: Full Autonomous Networks
Execution	P	P/S	S	S	S	S
Awareness	P	P/S	P/S	S	S	S
Analysis	P	P	P/S	P/S	S	S
Decision	P	P	P	P/S	S	S
Intent/Experience	P	P	P	P	P/S	S
Applicability	N/A	Select scenarios				All scenarios
P People (manual)			S System (autonomous)			

Fig. 1. Rating model of autonomous network.

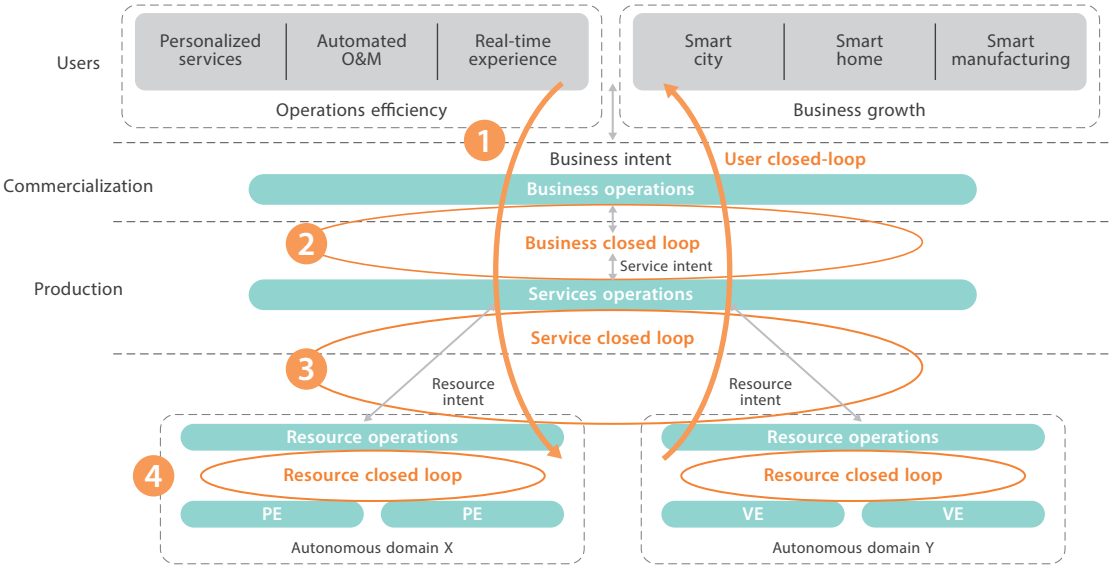


Fig. 2. Autonomous network architecture.

SLAs, guide the automation and intelligence of networks and services, evaluate the value and advantages of autonomous network services, and guide operators and vendors to carry out intelligent upgrade. L5 is the ultimate goal of telecom network evolution, where the system supports full-scenario closed-loop intelligence for multi-service, multi-domain and full life cycle (Fig. 1).

Network Architecture and Key Technology Analysis

Network Architecture

The autonomous optical network uses the autonomous network framework set up by the TM Forum, which is divided into three layers: resource operations layer, service operations layer and business operations layer, and four closed-loops: user closed-loop, business closed-loop, service closed-loop and resource closed-loop (Fig. 2).

Based on the basic principle of closed-loop correlation and interaction at different layers shown in Fig. 2, the autonomous network architecture can be summarized as follows: based on the autonomous domain, the user closed-loop serves as the main line of connecting business, service and resource closed loops; driven by the business, the business, service and resource closed loop collaboration mechanism is used to solve the interaction problems between the adjacent layers, and finally digital closed-loop automatic intelligent business, service and resource operations can be realized, thus providing the best user experience, maximum resource utilization and full lifecycle automatic and intelligent operations.

Key Technologies

In the full lifecycle of network planning, construction, maintenance and optimization, an autonomous network is made intelligent through network awareness, automation, intent-driven, pre-event simulation and post-event verification. To obtain these intelligent capabilities, four key technologies are needed, including capability exposure,

digital twin, intent based network (IBN) and AI.

Capability Exposure

The three-layer four-loop autonomous optical network requires the capability to be exposed from the bottom up for agile collaboration between NE and business layers. Capability exposure at the resource layer is the basis of all capability exposure and also a key factor for improving the OTN closed-loop autonomous level. Based on Self-X, the OTN capability exposure at the resource layer are divided into provisioning, awareness, maintenance and optimization.

- **Provisioning:** Service provisioning is the primary requirement of automation. Provisioning should be intelligent, simple and agile while addressing the original needs of users qualitatively and quantitatively.
- **Awareness:** Network awareness is the most fundamental and important capability. Awareness of OTN resources and usage, transport and service performance quality, and potential risks can support effective resource allocation, visual service quality, and risk warning, thereby increasing operating revenue and ROI.
- **Maintenance:** Network maintenance is the most technically differentiated capability, including inspection, diagnosis, testing, and repair. By encapsulating technology differences in a single domain, the capability is exposed to the upper layer for cross-domain coordination, so as to achieve end-to-end maintenance automation with low cost and scalability.
- **Optimization:** Network optimization is always a single-domain function. End-to-end optimization is an advanced embodiment of autonomous capability. On the basis of awareness and maintenance capabilities, the optimization capability can be exposed to optimize resources and quality from the perspective of the whole network.

Capability exposure is the cornerstone of autonomous network. Capability exposure at the resource layer helps to evolve OTN to a higher closed-loop autonomous level.

Digital Twin

Professor Michael Grieves first put forward the concept of digital twin (DT) at the University of Michigan in 2003, NASA first applied the DT concept in 2012, and China Mobile released the *Digital Twin Network (DTN) White Paper* in 2021, introducing DT into telecom networks. DT is an important means to achieve network intelligence and automation. It helps the autonomous network obtain topology perspective and traffic holography, trace faults back to the past, simulate and verify network configuration and optimization in digital twins, so it is the core of autonomous network L4. In the autonomous OTN field, DT cases have three types of models (Fig. 3):

- **Basic structure model:** Based on physical object features such as structure (ROADM optical cross-connect matrix), status (optical fiber health) and performance (optical power and OSNR) , a twin abstract mathematical model is built as the modeling basis for DT network awareness and cognition.
- **Awareness model:** The data is sampled based on the features of OTN physical objects obtained from the basic structure model to train and generate a DT awareness model to complete awareness functions such as optical

performance prediction, optical health analysis and fiber break fault diagnosis.

- **Cognition model:** According to changed features such as OTN performance, status and fault root causes obtained from the awareness model, a DT cognition model is trained and generated to complete cognitive functions such as optical resource planning simulation, optical performance optimization design, and fault recovery decision-making.

DT can be used to trace history, know the present and predict the future. It provides a digital presentation and decision-making basis for the autonomous network, thus promoting the optical network to reach autonomous network L4.

Intent Based Network

ONF released the *Intent: Don`t Tell Me What to Do! Tell Me What You Want* in 2015, which came up with the intent concept. The most important technologies of intent are intent translation and assurance. The former translates user intents into network configuration and monitoring configuration, while the latter monitors and assures user intents. Each layer of the autonomous network architecture can be driven by an intent. For example, the service operation layer uses resource intents to send requirements and constraints on network resources and performance to the resource operation layer.

Take service provisioning of an enterprise OTN private line for example. Based on the basic information (such as source and destination nodes), user SLAs, application scenarios, and user preference of the OTN private line to be provisioned, the intent is parsed with natural language processing (NLP) into the optical/electrical network resource configuration solution required by the private line and deployed in the network.

After service provisioning, the system monitors the SLA of the intent according to the requirements and corrects the deviation manually or automatically to ensure that network management resources meet the intent requirements. The intent-based network can not only simplify O&M, but also improve high availability of services to achieve the high-level goal of an autonomous network.

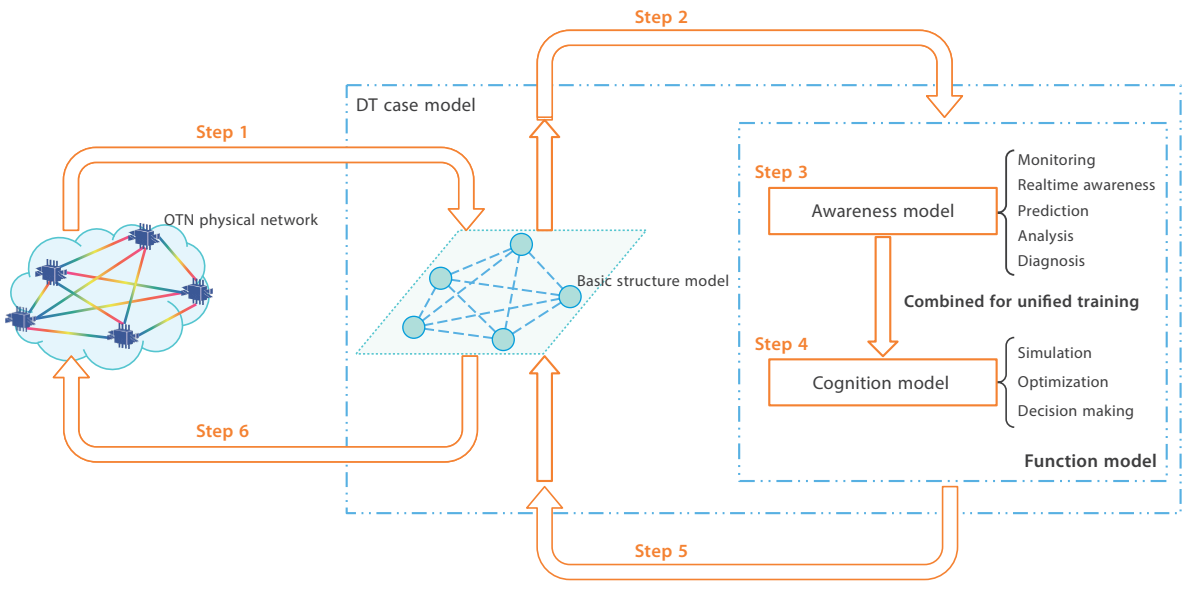


Fig. 3. OTN DT modeling.

In the future, autonomous OTN will evolve towards digital, intelligent, full-lifecycle Self-X O&M, building an efficient and reliable all-optical basic network, and enabling Zero-X experience.

AI

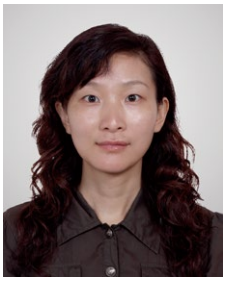
The network makes its own decisions based on analysis. Due to the complexity of OTN networks and services, there is a lack of logical methods for the analysis of network faults and performance quality, especially for hidden troubles of the system physical features, so it is necessary to introduce AI to define and determine. As a major enabling technology for an autonomous telecom network, AI lays a solid foundation for setting up an autonomous OTN ecological industry chain. Typical applications of AI in AN OTN are as follows:

- **OTN health status awareness:** Time series with deep learning, and GAN algorithms are used to perceive the health status of an OMS link through performance time series such as OSNR and optical power attenuation, and improve the agility, precision and generalization of awareness.
- **OTN service recovery cognition:** The OTN link performance awareness algorithm model can be combined with the private line service optimization algorithm model. Based on the awareness of OTN link performance degradation, the private line services carried over the OTN link are learned based on the objectives like latency, cost, and bandwidth utilization to generate an optimization solution and form the cognition of service recovery.
- **Cross-domain optical performance analysis:** Take the prediction of OTN NE performance (OSNR, optical power) for example. The horizontal federated machine learning (HFML) can be used to build a cross-domain OTN NE performance prediction model involving multiple vendors to avoid model overfitting caused by partial training of a single vendor, improve the generalization of the model, and solve the problem of sample data privacy leakage in centralized training.

Conclusion

In the future, autonomous OTN will evolve towards digital, intelligent, full-lifecycle Self-X O&M, building an efficient and reliable all-optical basic network, and enabling Zero-X experience. It will rely on capability exposure, intent-based network, DT, and AI technologies, and will be combined new application scenarios of future networks to improve OTN autonomous levels. In terms of industrial operation, it vertically connects business-operation (B-O) domains and drives service operators to schedule and enable OTN resources of equipment vendors at the OTN resource layer, so as to gradually create a win-win situation for service operators and equipment vendors. It is generally agreed in the industry that the autonomous OTN will evolve in three phases and is expected to reach autonomous network L4 by 2025. ZTE TECHNOLOGIES

Intelligent E-OTN 2.0: Building Smart Highways in Digital and Computing Era

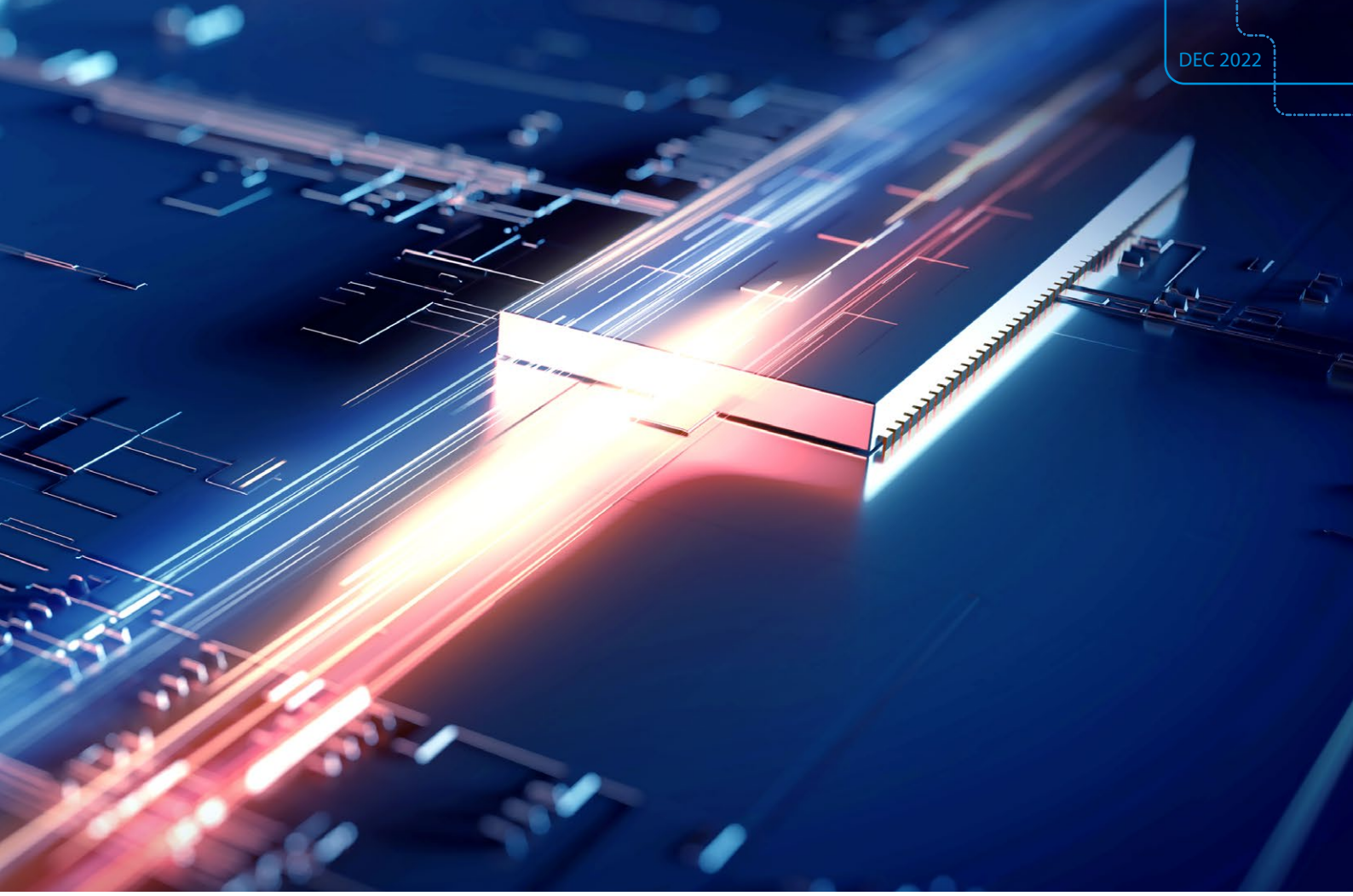


Liu Junjuan

Chief Engineer of OTN Product Planning, ZTE

Digital economy has become the key word in national competition and government reports, and is also an important assessment of a country's comprehensive strength. According to a report by CAICT, the trillion-dollar infrastructure investment bill signed by US president Biden actively promoted network coverage in remote rural areas and improved digital divide. The bill has become the largest investment of the United States in decades. The Korean government has proposed to develop the 5G ecosystem, and plans to increase the number of new 5G firms by nearly 20 times in the next five years, from 94 at present to 1,800. It has also formulated a "6G R&D Initiative" to develop core 6G technologies, with the goal of putting 6G into commercialization in 2028–2030, providing a network 50 times faster than the current one, and expanding the coverage to 10 km above the ground. The European Commission has put forward a Digital Decade Guide that by 2030 all European users will enjoy gigabit broadband connections and 5G networks will cover the whole of Europe. China has made the digital transformation an important measure of the strategy of cyber power, digital China, and smart society, and successively put forward major policy guidelines such as "new infrastructure", "vigorously boosting the development of industrial digitization", and "east-data-west-computing" projects at important meetings to promote the digital transformation and digital economy growth.

It is necessary to build a new type of digital infrastructure with the integration of "computing power + ICT network" in the digital era. Computing is the core productivity of the digital economy and also a core driving force after heat and electric power, while ICT network infrastructure is closely related to computing. The countries with high computing power often take the lead in their network infrastructure. As the cornerstone of ICT network, optical

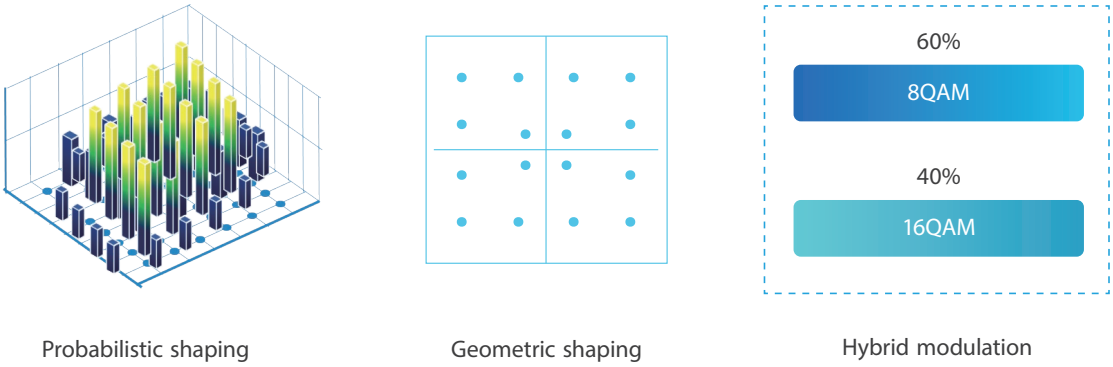


network needs to be upgraded and evolved to provide powerful computing. Therefore, ZTE has launched a new intelligent Ethernet over OTN (E-OTN) 2.0 solution that uses DC as the center, has the ability to transport fixed, wireless, cloud/computing and enterprise network services, and features large bandwidth, low latency, flexible scheduling, and intelligent and simple O&M. Its core value is to build extremely high-speed, ultra-broadband transport pipes based on new algorithms, implement agile transport upon the new platform to meet various service-level agreement (SLA) requirements, and adopt new intelligence to create a convenient, intelligent digital all-optical network that ensures high computing power in the digital and computing era.

New Flex Shaping Algorithm: Building Extremely High-Speed, Ultra-Broadband Transport Pipes

According to the latest ICP data center network optical components forecast by Omdia, 400G client interfaces account for 15% of the total in 2022 and are expected to hit about 56% in 2026. As the shipment of high-rate interfaces continues to grow, single-wavelength 400G is bound to be a necessity for backbone and metro optical networks. At the same time, the future traffic will continue to increase, and optical networks urgently need to find other ways to expand capacity if the spectral efficiency remains unchanged.

An ultra-broadband optical network is built in two ways. The first one is to increase single-wavelength rate and transmission distance, that is, maximize spectral efficiency while guaranteeing performance. Therefore, chip and



Probabilistic shaping Geometric shaping Hybrid modulation

Fig. 1. Electrical domain shaping in Flex Shaping.

algorithm are quite crucial. At present, ZTE's OTN system supports single-wavelength 800G and can be upgraded to 1.2T for 400G backbone long-haul (LH) transmission and 1.2T for data center interconnect (DCI). The new Flex Shaping algorithm uses the joint design of electrical domain shaping (Fig. 1) and ZTE's patented optical domain shaping (Fig. 2) to transmit data longer and pass through more ROADM sites, thus reducing the number of regenerators and Capex.

ZTE has repeatedly set records for beyond-100G optical network transport. It unveiled world's first 1.2T system prototype in 2021, and worked with China Mobile to completed the industry's first single-wavelength 400G QPSK LH transmission prototype test based on the existing network scenario in July 2022. This test employed G.652 fibers and RAMAN amplifiers for several spans to achieve 49-span 3,038-km transmission without electrical regenerator. This proves the advantage of 400G QPSK in long-distance transmission over the optical backbone network. With the patented optical domain balancing technology, ZTE helped Thailand deploy the world's first LH Flexgrid 200G backbone WDM network, which increased transport capacity while reducing regenerator boards and Capex.

The second way is to expand spectrum width in the optical fiber. C++ band has

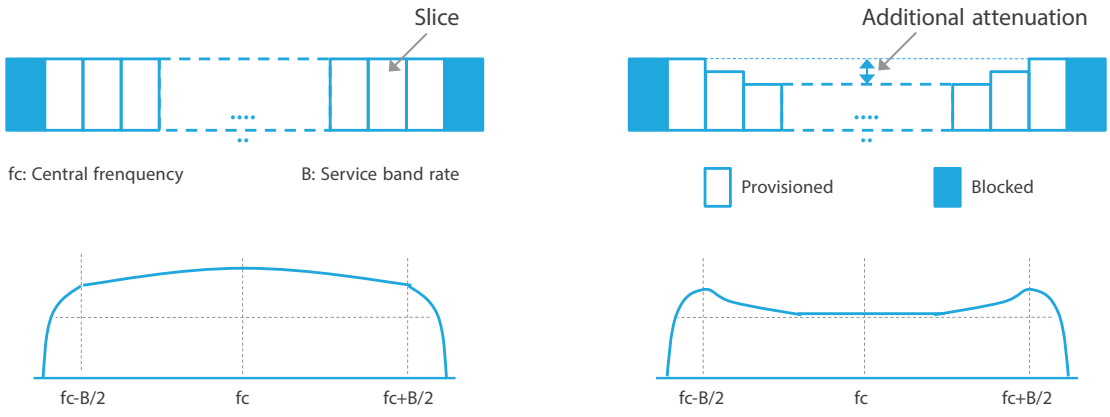


Fig. 2. Optical domain shaping in Flex Shaping.

been widely used and will be extended to L band to double the capacity. Spectrum extension involves many system components. In addition to the new series of traffic boards, new optical amplifiers (OAs) and reconfigurable optical add-drop multiplexer/optical cross-connect (ROADM/OXC) are also required. At present, the C+L band 11 THz spectrum solution has become mature, and the 12 THz spectrum solution still needs to further optimize OA performance. ZTE has trialed the innovation in this field. It exclusively completed the innovation test of China Mobile's C+L 11 THz band 400G network in the fourth quarter of 2021, and worked with Turkcell to deploy the world's first commercial 12 THz ready WDM system in Bursa, the fourth largest city in Turkey in 2022. The evolution to ultra-wide optical network ensures a strong demand for transmission in the digital and computing era.

New Optical-Electrical Synergy Platform: Implementing Agile Transport

The transformation of industrial digitalization has led to a variety of new SLA needs. 4K and XR videos need large bandwidth and low latency, remote industrial control needs millisecond-level latency and ultra-high reliability, and smart home and smart grid need mass connections and low-frequency small-data transport. Everything to cloud needs full-mesh, fast connection and diverse SLAs. All-optical cross-connect platforms, ultra-large-capacity OTN electrical cross-connect platforms, and ubiquitous access capabilities are therefore necessary for full-service optical networks to transport mass data everywhere.

ZTE's backplane-based OXC system supports 32-degree optical grooming that can evolve to 40+ degrees in the future, allows for multidimensional, cloud-based, full-mesh connection, optical one-hop connection, and guarantees latency-sensitive services. Without the need to manually connect internal fibers, the all-optical backplane effectively avoids misconnection and cuts the deployment time from week to hour. Compared with traditional ROADM boards, OXC boards integrate OA, monitoring and protection functions, save the footprint by 80% at most and lower the power consumption by 70%. Up to now, ZTE's OXC solution has served more than 50 optical networks, satisfying the needs of flexible and fast grooming of massive services.

In terms of new ultra-large-capacity electrical switching platform, ZTE is the first to commercialize the single 64T subrack that will evolve to 100T+ in the future. The 64T subrack also supports hitless bandwidth adjustment from 2 Mbps to 100 Gbps and diverse SLAs on demand to better ensure non-blocking add/drop of large DC services. The new platform is backed by core in-house chips such as framer, switching, network processor (NP), and silicon photonic components (SiPh). Relying on ZTE's in-house third-generation framer integrated fabric interface chip (FIC), the platform reduces overall power consumption by over 50% compared with industry separation mode. The cost-effective Omni-OTN solution supports "5-in-1" unified access to 4G, 5G, home broadband, enterprise network and cloud services, achieving omni-scenario cost-effective transport, omni-area large-capacity coverage and omni-service high-quality access. According to the latest data released by Omdia in August 2022, ZTE ranked No.2 in global OTN switching market.

> The optical network has experienced a long evolution from full manual mode, semi-automation, full automation to intelligence.

New Intelligent Operation: Creating a Convenient, Intelligent Digital All-Optical Network

A variety of new digital scenarios are emerging with different requirements. The optical network continues to extend and covers more widely, which makes O&M more complex and evolve to intelligence. The optical network has experienced a long evolution from full manual mode, semi-automation, full automation to intelligence.

Optical network intelligence is reflected in three aspects. The first is network digitalization and intelligence for itself, including rich data collection points based on photoelectric tags, on-demand adjustment of the rate and power of optical and electrical layers based on flexible and agile architecture design, and accurate fault location and risks/demand prediction based on hardware and AI algorithms. The second is intelligence of user experience. Quality services are guaranteed by adjustable, visible and optional capabilities such as diverse SLA services, latency, software/hardware bandwidth and reliability. The third is intelligence of the management and control system. Terminals, edges, networks and clouds can be operated and maintained uniformly via standard and open interfaces. Optical-cloud integration is not achieved overnight, but a gradual evolution from optical network integration, and IP and optical synergy, to optical-cloud integration.

So far, ZTE's intelligent management and control solution has served more than 100 networks worldwide, including the full deployment of China intelligent management and control systems in 27 provinces, the world's largest 100G/200G backbone SDON system in China, and the largest 200G intelligent SDON in South America. The solution has greatly enhanced the convenience and intelligence of network O&M.

ZTE has deployed over 600 100G/Beyond-100G OTN networks worldwide in cooperation with global mainstream operators such as China Mobile, China Telecom, China Unicom, Telefonica, VEON, MTN, Thailand's True, Vietnam's Viettel and India's Vi. It will continue to invest in the research and development of optical network technology and work closely with global operators and industry partners to build new intelligent optical networks characterized by ultra broadband, high-quality transport and intelligent operations, so as to meet the need of digitization and computing and create a bright future for human society. ZTE TECHNOLOGIES

Ultra-High-Speed Optical Devices for Building High-Performance Optical Infrastructure

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According to Omdia forecast in 2020, global network traffic in 2024 will be 3.4 times that in 2019, with a compound annual growth rate (CAGR) of 28%. Optical communications is the infrastructure that supports Internet traffic growth, and the coherent optical communications technology is the key to implement an optical communications system. The next-generation high-performance optical infrastructure includes optical transceiver, optical amplifier, and optical switch. The ultra-high-speed coherent optical devices in the coherent optical module are the key units for building high-performance optical infrastructure.

Trend

It can be seen from Fig. 1 that one generation of coherent optical modules are developed every three years based on the timeline of advanced digital signal processor (DSP) technologies and the rule of baud rate evolution. The coherent 96 GBd technology began to enter the market in 2020. It uses PM-32QAM modulation signals and ultra-strong forward error correction codes to achieve coherent 800G transmission. The coherent 128 GBd technology is expected to enter the market in 2023.

The trends of ultra-high-speed coherent optical module technologies include selection of 128 GBd, band extension to maintain 80-wavelength capacity, and small form-factor pluggable module. According to the OIF 800ZR project, coherent 800G short-distance transmission uses 120 GBd PM-16QAM modulation. Both 96 GBd PS-16QAM and 128 GBd PM-QPSK can implement coherent 400G transmission. The transmission performance of 96 GBd PS-16QAM is not as good as that of 128 GBd PM-QPSK. Without the help of a

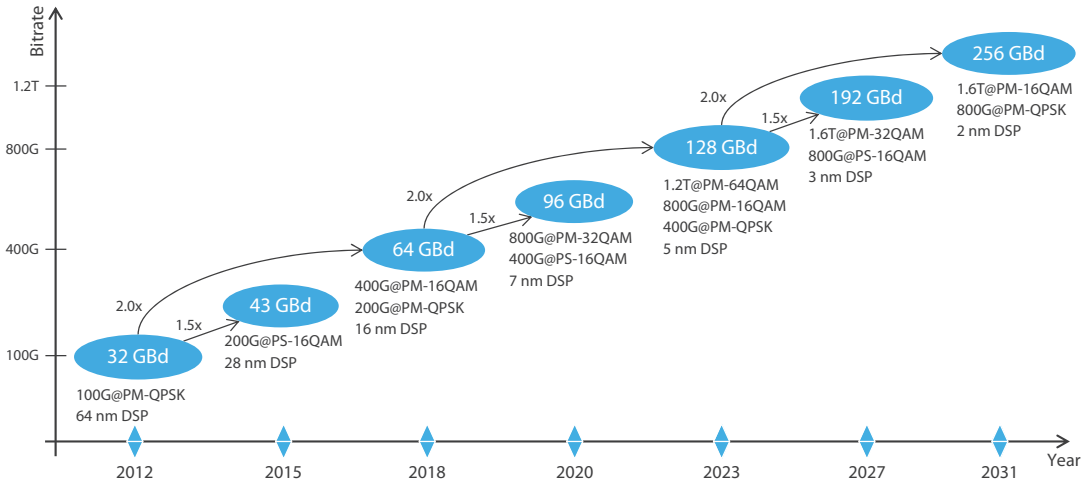

Fig. 1. Coherent optical communications evolution map.

distributed Raman amplifier (DRA) or G.654.E fibers, 96 GBd PS-16QAM can not meet the transmission requirements of backbone networks over 1000 km. Therefore, the 128 GBd technology will be the mainstream rate of next-generation coherent optical communication after 64 GBd. 75 GHz channel spacing is used for 64 GBd coherent optical transmission, while 150 GHz channel spacing for 128 GBd coherent optical transmission. To maintain the 80-wavelength channel design, the working band of 128 GBd coherent optical transmission needs to be extended to the L band. The second generation of C form-factor pluggable transceiver (CFP2) modules are used as coherent optical modules for metro and long-distance transmission. Smaller quad small form-factor pluggable-double density (QSFP-DD) and octal small form-factor pluggable (OSFP) modules are used as coherent optical modules for data center interconnect (DCI) short-distance transmission. Metro and DCI coherent optical modules tend to be integrated. The 800G coherent optical module standard includes the OIF-800ZR project, which is under development. The standardization work of OpenROADM and OpenZR+ for long-distance coherent 800G transmission has not been publicly reported.

Ultra-High-Speed Optical Devices

Key units of a coherent optical module include integrated coherent receiver (ICR), coherent driver modulator (CDM), integrated tunable laser assembly (iTLA) and DSP chips (Fig. 2). Optical devices involve separate and integrated solutions. The separated solution contains independent optical devices such as iTLA, CDM, and ICR. The integrated solution combines the units mentioned above into integrated devices including transmit-receive optical sub-assembly (TROSA) that can be an integration of iTLA+CDM+ICR or CDM+ICR, and multi-chip module (MCM) that can be an integration of CDM+ICR+DSP. Different material technologies are applicable to different packaging forms. MCM has high integration and high performance, but it requires optical chips to support non-hermetic packaging.

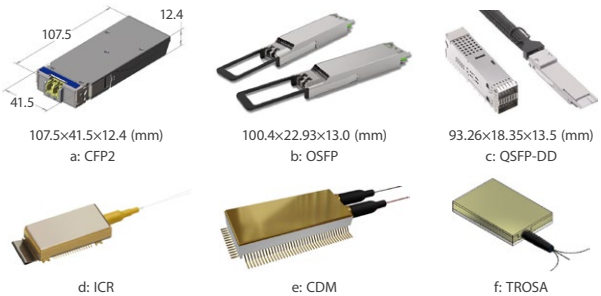

Fig. 2. Form factors for coherent transceivers and devices.

Key Technologies

Key technologies of ultra-high-speed optical devices include material technology, wide spectrum band technology, large bandwidth modulation technology and advanced packaging technology. The material technology includes indium phosphide (InP), silicon photonics (SiPh) and thin film lithium niobate (TFLN), as shown in Table 1. InP and SiPh are mature material technologies, while the new material technology TFLN has a promising application prospect due to its outstanding low loss and large bandwidth.

Ultra-high-speed optical devices require the wide spectrum band technology to upgrade optical transmission capacity. The 64 GBd modulation signal corresponds to 75 GHz channel width, while the 128 GBd modulation signal 150 GHz channel width. The working wavelength of the 64 GBd system is C120 (120 channels with 50 GHz spacing in the C band), and the working wavelength of the 128 GBd system is C120+L120. If a multi-mode interferometer is used in the optical chip for optical splitting and combining functions, there is a risk of deterioration in edge wavelength performance, which is a great challenge to the InP solution. The SiPh solution can use a broadband coupler for multi-band operation. The germanium detector in the SiPh solution needs to consider whether the responsivity near the 1626 nm decreases or not. SOA and InP modulators are difficult to implement C120+L120 in a single chip.

The large bandwidth modulation technology

Items	InP	SiPh	TFLN
Baud rate supported (estimated)	200−250 GBd	130−150 GBd	>300 GBd
Technology readiness	Mature	Mature	To be seen
Business model	IDM (mostly)	Fabless	IDM
Tx and Rx integration	Both	Both	Only Tx
Chip integration	Polarization management is realized by package	All functions are integrated in a single chip	Hybrid integration is not mature; MPD is added by package
Working wavelength	Tx: Support C120 or L120; Rx: Possibly support C120+L120	Support C120+L120	Possibly support C120+L120
Bandwidth	Median	Small	Large
Insertion loss of Tx modulator	Median	Large	Small
Temperature sensitivity	Sensitive	Insensitive	Insensitive
Hermeticity	Hermetic package is required	Support non-hermetic package	Support non-hermetic package
Package friendliness	PIC and EIC are separated in the package	Support PIC and EIC 3D-stacked package	Support PIC and EIC 3D-stacked package
TEC required?	Yes	No	No
MCM package supported?	No	Yes	Yes
EDFA required?	No, SOA can be integrated	Yes	Yes
Cost	High	Low	Median

Table 1. Comparison of material technology for optical devices.

is related to optical chip, electrical chip and packaging solution. Using electrical chips to compensate for the bandwidth shortage of optical chips is an effective means to achieve large bandwidth in the photoelectric synergy of ultra-high-speed optical devices. InP and SiPh modulators are limited, so both need to make use of the bandwidth peaking effect of electrical chips of the driver to increase bandwidth. The chip of a TFLN modulator can support a bandwidth of above 100 GHz according to an experiment report.

Advanced packaging technology is related to the optical chip material technology. Shortening the distance of high-speed electrical signal transmission lines and reducing impedance discontinuity have become the trend of packaging for ultra-high-speed optical devices. The MCM packaging with DSP has become a hot topic in R&D. Traditional InP chips need hermetic gold box packaging, such as separate devices ICR and CDM, and the integrated device TROSA. SiPh chips support non-hermetic ball grid array (BGA) packaging. Due to the limited bandwidth of optical chips, MCM is preferred to TROSA. MCM has fewer impedance discontinuity points. In particular, it does not go through BGA solder ball twice, so it has better bandwidth performance and higher integration. The TFLN chip supports both advanced BGA packaging and traditional CDM packaging. If the optical chip does not support the through silicon via (TSV) process, the wire bonding is used, in which high-speed signals need double-wire bonding, and the substrate implements short-distance wire bonding by means of cavity.

Conclusion

The 96 GBd and 128 GBd ultra-high-speed optical devices are key components for building high-performance optical infrastructure. Considering 800ZR standardization and the difference of transmission performance, 128 GBd optical devices are expected to be more widely used.

When the baud rate of the signal increases, it is necessary to expand the working wavelength band to upgrade the capacity of fiber optic transmission. At present, the industry has started to study the technical feasibility of implementing S+C+L+U bands. As the further increase of the signal baud rate poses more and more challenges to optoelectronic chips, multi-channel highly integrated optical devices will also become a trend. ZTE TECHNOLOGIES

Omni-OTN Accelerates Growth of All-Optical MAN

Sun Jianfeng

Chief Engineer of Wireline Product Planning, ZTE

Higher Expectations for OTN Access Nodes

All-optical network is the inevitable trend of network development and evolution and is also generally agreed in the industry. It can offer ultra-large bandwidth, ultra-low latency, ultra-high reliability, massive connections, and intelligent service allocation and grooming. As a major part of the all-optical network, OTN is moving down to the edge to transport growing complex services. OTN access nodes support intelligent, ubiquitous, ultra-broadband, full-scenario access. Any service can access OTN via the access node as needed. This lays the foundation for OTN to serve as the all-optical base for integrated service transport, and makes it possible to access the increasingly booming computing networks and obtain computing resources on demand.

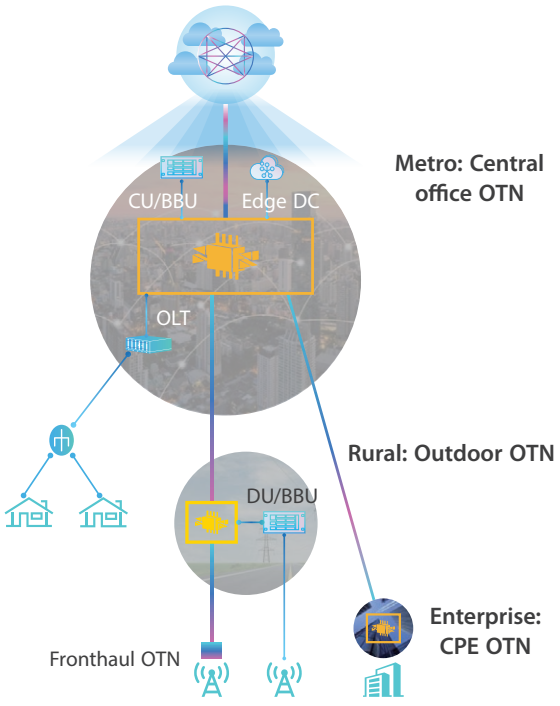

Fig. 1. Omni-OTN redefines OTN access nodes.

Definition of Access Nodes in All-Optical MAN

ZTE's Omni-OTN redefines OTN access nodes in three aspects: full scenario, full service and full coverage (Fig. 1).

- **Full scenario:** Omni-OTN devices move down to MAN edges for full-scenario deployment including 4G, 5G, OLT, enterprise network and edge cloud. They can replace SDH devices and switches, saving equipment room by 30% and consuming about 35% less power. With large capacity, small size, low power consumption and industry-leading advantages, Omni-OTN can be deployed on an access node. With simplified network architecture and its own device advantages, Omni-OTN offers a

better choice to operators, that is a new type of device that covers all scenarios to decrease the difficulty of network design, evolution and O&M and considerably reduce TCO of the whole network.

- **Full service:** Full scenario supports at least 5-in-1, that is 4G/5G/OLT/enterprise network/edge cloud at an OTN access node. With the growth of service types and scenarios, more and more services and scenarios will emerge in the OTN network via Omni-OTN. The full-service access as well as flexible adaptation and grooming of access services enable Omni-OTN to have the "all-in-1" capability. Omni-OTN incorporates other transport technologies, integrates multiple logical planes into a single OTN subrack/platform, and shares some hardware devices such as subrack, boards and cross-connect chips. The integration involves SDH plane (VC cross-connection) and packet plane (PKT cross-connection), along with its own OTN plane (ODUk cross-connection) and OTN-derived OSU plane (OSU cross-connection). With four planes on one platform, Omni-OTN can transmit a variety of services from 2M to 100G and meet diverse service needs such as four hybrid cross-connections, large and fine granularities, rigid/flexible transport, and on-demand selection.
- **Full coverage:** The demand for better transport quality, large bandwidth, low latency and high reliability drives OTN to move down from the MAN core and aggregation layers to integrated service access areas and villages to access more users. Omni-OTN can move to the lowest point of integrated OTN transport to complete "full service" access and grooming and "full scenario" transport. The deployment at the access layer has complex environment, poor conditions and strict requirements on devices. Omni-OTN devices can be installed indoor or outdoor in a cabinet or mounted on a wall to meet the needs of various deployment environments. Omni-OTN's natural long-haul transmission attribute effectively makes up for the shortcomings of poor quality and large loss of optical cables at the access layer. Its system capacity rises to 80×200G from 40×10G of the traditional OTN access-layer, and can evolve to a higher capacity to address the bandwidth pressure of "full service". With strong adaptability for deployment, Omni-OTN expands the OTN coverage, increases network capacity, enriches "full scenario" applications, and makes the "full service" more accessible. Its deep coverage also makes OTN-based one-hop connection and ultra-low latency possible.

Conclusion

Omni-OTN is deployed at the end of an all-optical network. Its development determines the control range and transport capacity of the whole all-optical network. As the ingress of OTN, Omni-OTN characterized by "full scenario", "full service" and "full coverage" constantly expands the OTN coverage and enhances flexible network grooming for high-quality OTN extension. ZTE TECHNOLOGIES

OTDR+GIS-Based Intelligent Fiber Fault Location System

Wei Dengpan

Planning Manger of OTN Products at ZTE

Problems

Fibers are the core carrier of optical transport network (OTN). Since OTN networks carry a huge number of services, fiber cuts have a considerable impact on the services, and the repair efficiency directly affects user experience.

Some of the reasons for fiber cuts include engineering construction, rainstorms, and road deformation due to truck weight. When a fiber cut occurs, the OTN system reports the alarm to the maintenance personnel. After determining it is a fiber cut, the maintenance personnel will go to the equipment room at either end of the broken fiber, use the OTDR to measure the distance to the fault, locate the fault based on the analysis of the measurement results and the fiber inventory information, and go to find the break point and repair it.

This traditional mode has serious disadvantages in both timeliness and efficiency. The untimely fault location and insufficient location accuracy make it difficult for the maintenance personnel to repair the fiber.

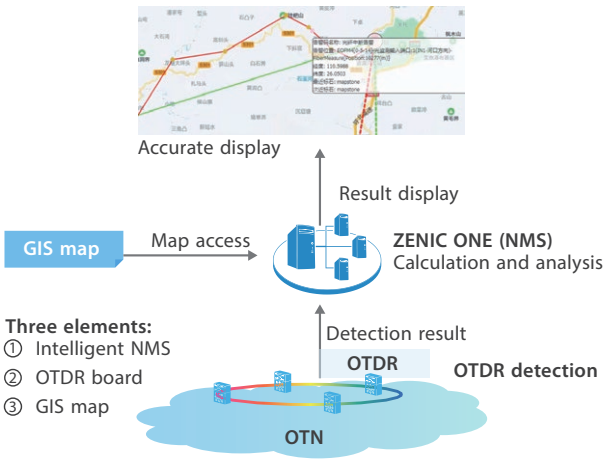

Fig. 1. ZTE's OTDR+ GIS-based intelligent fiber fault location system.

Solution

To automatically locate fiber fault and increase the repair efficiency, we have developed the OTDR+GIS-based intelligent fiber fault location system. The system includes three major elements: intelligent network management system (NMS), OTDR board, and GIS map (Fig. 1). The OTDR detects the distance to the fault point. The intelligent NMS as the core and brain of the whole solution calculates and analyzes alarms and data and gives a visual representation of the fault location on a map.

When a fiber fault occurs, the system operation procedure is as follows:

- **Alarm detection and analysis:** Fiber cuts will cause the loss of OTN line signals. The intelligent NMS can detect the alarms in real time. A fiber fault will cause faults with all service layers and services that pass these layers. In this case, a large number of alarms will be reported, and the system does not know whether it is a fiber fault, laser fault, or board fault at the beginning. The intelligent NMS prompts the maintenance personnel through audio and visual alarms. Based on AI and the library of rules, it analyzes the correlation between different alarms to determine the root cause (fiber cut).

- **OTDR detection:** After determining that it is a fiber fault, the NMS immediately triggers the OTDR to detect the faulty fiber link. The OTDR board measures the distance from the site where the OTDR board is located to the fault point through the use of scattered or back reflected light.
- **Intelligent analysis and result display:** The distance detected by the OTDR is not the longitude and latitude nor a specific location on the map, and cannot effectively guide the maintenance personnel. The intelligent NMS is needed here. With the AI-based intelligent analysis, the ZENIC ONE obtains the latitude and longitude of the fiber fault location based on the test results and OTN topology information as well as the information about the fiber cables, markstones, and length of compensating fiber. Finally, the NMS graphically displays the fiber fault location with the GIS map.
- **Fault repair:** The external maintenance personnel can clearly see the accurate location of the fault point, go there quickly and repair the fault.

It can be seen that the intelligent NMS allows the maintenance personnel to quickly learn about the specific location of the break point and go to repair it quickly, thus ensuring the stability of the OTN network.

Benefits

The intelligent fiber fault location system effectively solves the problems of O&M timeliness and efficiency, and improves the location efficiency by more than 90%. When a fiber fault occurs, the system can immediately find out the exact fault location (in longitude and latitude) and displays it on the GIS map visually. In this way, it leaves out the process of manual analysis, fault judgment and fiber information query, improving the location efficiency and saving the maintenance costs. Take a municipal branch of an operator as an example. Before the intelligent fiber fault location system is deployed, it takes the maintenance personnel at the network management center about 10 minutes to analyze and determine the fault. Then they notify the external maintenance personnel to go to the corresponding equipment room. It takes the external maintenance personnel an average of 40 minutes to arrive at the equipment room and about 10 minutes to complete the test and analyze the approximate location of the fiber fault, and about one hour is needed to complete the overall fault location process. After the intelligent fiber fault location system is deployed, the fault analysis can be completed within five minutes after a fault occurs. The system automatically analyzes the specific location of the break point and notifies the maintenance personnel. The whole location process is shortened by about 55 minutes and the location efficiency is improved by more than 90%. The external maintenance personnel can directly go to the fault point instead of the equipment room for testing, thereby shortening the repair time. At the same time, a large amount of O&M expenses such as vehicle use, test instrument maintenance and depreciation can be saved.

Conclusion

The OTDR board is similar to a common service board and can be installed in any common slot. With the addition of the network management software package and GIS map data, the network can implement the intelligent fiber fault location function without being directly modified. Therefore, this system function can be rapidly copied and deployed in other OTN networks. The wide application of this function can accelerate the recovery of line faults, improve network robustness, reduce O&M costs, and help operators provide better service experience for users. ZTE TECHNOLOGIES

Optical Cross-Connect Technology and Application

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ROADM can implement multi-degree large-capacity wavelength-level scheduling to meet the networking demands of backbone, metro and data center interconnection (DCI). However, as the degrees of a ROADM grow, the number of fiber connections inside the ROADM site increases dramatically, which makes the service provisioning and maintenance process time-consuming, prone to human errors and increases the footprint and power consumption. Optical cross-connect (OXC) addresses these problems by using the all-optical backplane in combination with the highly integrated optical line boards and optical add/drop boards. Since 2018, OXC has been widely used by Chinese operators.

Composition of OXC and Key Technologies

A 20-degree ROADM requires three cabinets, more than 100 boards, and 400 fibers inside the site. It occupies a large area and has high power consumption and complicated fiber connection, making service provisioning and maintenance difficult. As the number of degree increases to 32, the footprint, power consumption, and the number of fiber connections will increase dramatically, and it will be difficult to locate problems due to a large workload of service provisioning and maintenance. Compared with ROADM, OXC uses highly integrated boards and optical backplane to reduce the footprint and power consumption and simplify internal fiber connections (Fig. 1). A 20-degree OXC needs only one cabinet to reduce the footprint by 2/3 and about 30 boards to reduce the number of boards by 2/3 while also reducing the corresponding power consumption. The optical backplane connects all fibers inside the site to achieve automatic fiber connection, which improves the provisioning efficiency and reduces the maintenance costs.

An OXC is mainly composed of a optical backplane, optical line boards and optical add/drop boards, and involves key technologies like flexible optical backplane, high-density optical connector, 1×N wavelength selective switch (WSS) and M×N WSS. The optical backplane includes a flexible optical backplane and high-density connectors. The optical add/drop boards have two types: with colorless, directionless, flexgrid (CDF) capability or with colorless, directionless, contentionless and flexgrid (CDC-F) capability. The first type employs TWIN 1×N WSS and does not support contentionless functionality. It integrates the WSS and the optical amplifier, and occupies one slot. It can add/drop 32 wavelengths and schedule a service to any optical direction through the high-density connectors and fiber connections on the optical backplane. The latter type employs M×N WSS and occupies two slots. It supports contentionless add/drop of 48 wavelengths in 8/16 degrees. The optical line board highly integrates the OA, OP, OSC and OTDR function modules, and one slot corresponds to one direction. One optical line board occupies one slot and corresponds to one direction. The optical line board is connected with the optical backplane through

the high-density connectors and can schedule a group of wavelengths to any optical direction or any optical add/drop board for service add/drop.

- **Optical backplane:** The optical backplane technology is used to convert internal fibers between optical interfaces of the ROADM board into high-density interconnected fibers on the optical backplane. Internal fibers are divided into multiple groups, deployed through the fiber cabling machine and encapsulated into a flexible plate to form a flexible optical backplane that supports non-blocking fiber connections.
- **High-density connector:** The optical backplane is connected with the optical line board and optical add/drop board through the high-density connector. The optical connector must have high density to ensure full interconnection of all optical boards inside the OXC site and also support blind insertion with features like high interconnection precision and reliability of multiple plugging/unplugging.
- **WSS:** The core components of optical add/drop boards and optical line boards are 1×N WSS and M×N WSS. The related technologies mainly include micro-electro mechanical system (MEMS) and liquid crystal on silicon (LCoS).

OXC Application and Development

OXC products have the following advantages:

- **High integration to save equipment room space:** A ROADM site needs a large number of separate boards and so needs several cabinets. OXC optimizes it through high integration of board functions. One cabinet can implement 32-degree optical cross-connect scheduling, saving the footprint by 2/3.
- **Energy saving and convenient O&M with low OAM costs:** Compared with ROADM, the OXC equipment has a lower power consumption and requires a fewer number of power supply terminals. The optical backplane is used to solve the problems of a large number of fiber connections inside the ROADM, low provisioning efficiency, and difficult maintenance. OXC also supports optical-layer OAM to facilitate fault location and reduce the OAM cost.
- **Support for ultra-large-capacity optical cross-connect and low latency:** OXC

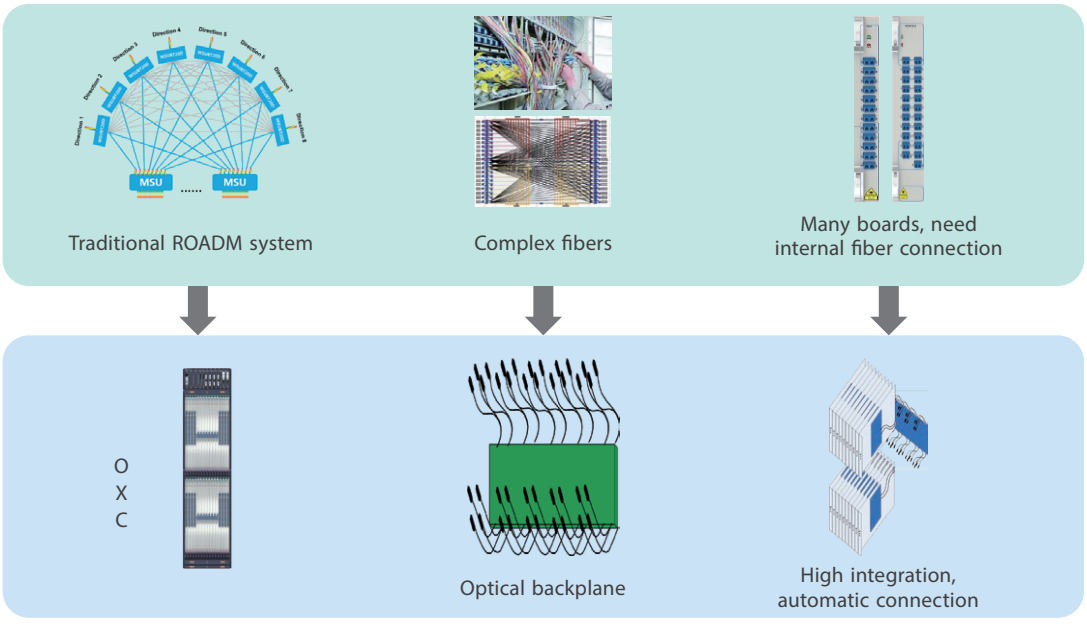


Fig. 1. Comparison between ROADM and OXC.

products support CE, C++ and L++ bands. One cabinet supports 32 degrees and 1024T optical cross-connect capacity to meet the requirements of backbone and metro networks. OXC nodes are only connected through fibers, so that the latency is almost zero.

- **Intelligent network:** As a physical-layer device, OXC supports the CDC feature, so it can solve wavelength conflicts, increase the flexibility of optical cross-connect scheduling, and improve the utilization of network resources. It supports flexgrid and can dynamically adjust the bandwidth of transmission pipes and intelligently schedule 100G and B100G wavelengths. It supports optical domain balancing and automatic optical power optimization to reduce inter-WSS crosstalk, improve the system transmission performance, increase available routes, and improve network survivability. The application of OXC in backbone and metro networks, especially in high-degree networks, provides guarantee for network intelligence.

Since 2018, manufacturers in China have gradually launched 16/20/32-degree OXCs to replace ROADM in the backbone and metro networks of China Mobile, China Telecom, and China Unicom. Backbone networks with a long transmission distance (from hundreds to thousands of kilometers) generally use a star typology and have a small number of physical links and low degrees. However, the node traffic is heavy, especially at the core node. Traffic add/drop occupies a large number of OXC degrees. The 16-degree, 20-degree and 32-degree OXCs have 16, 20 and 32 slots, respectively. One slot can be inserted with an optical line board to support one degree or an optical add/drop board for the add/drop of 32 wavelengths. The network design needs to consider the degrees and add/drop traffic capacity in the current stage while reserving slots for the expansion of line degrees and add/drop traffic capacity. When the OXC slots are insufficient, the local add/drop board that has two extension ports (a port for add/drop of 32 wavelengths) can work with the WSS board on the transmission subrack to add/drop 96 wavelengths on a single OXC slot.

Metro networks with a short transmission distance (generally hundreds of kilometers) use mesh networking and have a large number of physical links and line degrees. Core nodes have a large number of line degrees and heavy add/drop traffic. Non-core nodes have fewer line degrees and small expansion potential. Similarly, the OXC degrees need to be determined in accordance with the current and future requirements of line degrees and add/drop traffic capacity. Generally, 32-degree OXCs are used at core nodes and 16-degree OXCs are used at non-core nodes of metro networks in China.

With the network development, the number of optical layer scheduling degrees at core nodes is increasing, and the add/drop traffic at core nodes is also increasing. In the northwestern ring network of China Telecom, the Taiyuan hub site has grown to be 57 degrees. Currently, the commercially deployed 1×N WSS can maximally support 32 degrees, which cannot meet the high-degree requirements of core nodes in the existing network. With further network development, there will be increasing demands for high degrees. Therefore, 64-degree or 128-degree OXCs will become a development trend.

In high-degree scenarios, contentions could occur if services using the same wavelength from different degrees are added or dropped at the same add/drop structure, so the CDC capability has become an important requirement of OXC. Currently, the commercial M×N WSS has 8/16 degrees, and usually 24 add/drop ports, which cannot meet the requirements of high degrees and heavy add/drop traffic. In addition, M×N WSS does not support L++ band. Therefore, higher degrees, a higher port count and band extension are also development directions of OXC. ZTE TECHNOLOGIES

Thinking Smart Inside the Box

Set-top boxes are reclaiming their status as primary home entertainment access gateways

Source: The Register

By James Hayes

The latest generation of set top boxes (STBs) has reached a level of technological sophistication that's way beyond the single-function appliances that used to squat athwart chunky tubes in the early years of the satellite and cable TV revolution.

In doing so STBs have also outsmarted the PCs and smartphones that vied to fill the gateway gap when our TV viewing habits began to fragment back in the noughties.

Increasingly, users now want to centralize their digital viewing and social interaction on a single high-specification HD display rather than juggle between connected devices, depending on whether they want to watch broadcast or on-demand TV, video sharing platforms, videoconference—or all four.

STB Market is Rolling

That trend was significantly boosted by shifts in viewer behavior wrought by the COVID pandemic, so much so that the STB market is now rolling, according to *Future Market Insights*. Broadly, this is due to new aggregations of content, technological innovation and increased subscriber demand, it concludes. The analyst expects the global STB market to be worth $33.4 billion by the end of 2022, growing to $57.7 billion by 2032, with a compound annual growth rate (CAGR) of 5.6 percent over the forecast period.

That revenue growth is being driven by a confluence of market forces, starting with developments in hardware and software which are key to STB product differentiation. Their ability to support advanced display technologies, for example, such as 4K UHD and 8K UHD resolution, plus voice-enabled remote control, are advanced features that users increasingly expect and are ready to pay for.

With software, a shift away from proprietary (and pricey) STB middleware toward more open system software options that are more user-customizable, able to seamlessly interface with diverse online media (like apps and social networks), and more cost-effective to deploy to market is also proving decisive.

The emergence of open platforms "cut out the software middleware from the STB ecosystem", notes Grand View Research. This creates an opportunity for STB vendors to reduce overall cost and integrate open software platforms like Android TV and RDK (Reference Design Kit) into their products to add value to their offerings.

Compelling technology of itself, however, will not guarantee growth for pay-TV players. The principle performance metrics across sector participants must also include the implementation of go-to-market strategies that are geared for agile partnerships with content suppliers, communications operators and other influential players.

Tech and Content Providers Form Alliances

Over-the-top (OTT) direct-to-consumer streamed media channels are also helping to orchestrate the STB renaissance, coinciding with steady value growth across subscription-based services like Amazon Prime Video, Disney+, HBO Max, Hulu, Netflix and others. Omdia's *Global: Pay TV & Online Video* report

calculates that global subscription numbers total went from 1.14 billion in 2020 to 1.34 billion in 2021, an increase of 17.7 percent year-on-year.

The analyst firm predicts those figures will swell by a further 10.5 percent in 2022 to reach 1.48 billion by the start of 2023. With market entrants and major incumbents still only part-way through their respective global expansion programs, this means the pay-TV and online video sector will continue to expand. Omdia forecasts the worldwide total will exceed 2 billion in 2027.

The OTT subscription TV market remains a turbulent and highly competitive global opportunity characterized by a constant battle to attract new subscribers and keep hold of existing ones. And commercial participants at all levels—from providers of the enabling hardware and software to content producers and aggregators—are betting on strategic partnerships to reinforce their own market presence in a bid to outperform their rivals. These also create routes for expansion where partners have established strengths in geographic regions.

Tactical alliances between technology providers and content providers in particular are proving critical to the consolidation of streamed content ecosystems.

The collaboration between ZTE and Netflix is a case in point. Since 2019, ZTE has been working with Netflix on multiple STB projects, including the Hailstorm Hybrid Program. This is Netflix's Android TV-based STB device scaling initiative, designed to give pay-TV operators and consumer electronics partners better ways to integrate Netflix on their devices.

"We are committed to being tightly involved in R&D with partners as the most effective way of ensuring complete integration between complementary solutions," says Wu Xin, VP of fixed & multimedia product at ZTE. "These commitments also complement plans to introduce our solutions into global markets where Android TV is already established."

'Super-Aggregators' Stepping up…

Providing a wide range of viewing options for pay-TV audiences is no longer enough to assure subscriber growth. Being able to deliver a diverse and constantly updated choice of films, boxsets, documentaries and other types of video content is table stakes for any player. But they also have to help their viewers navigate and make sense of the mass of choices they find on their screens. And this is where the 'super-aggregator' comes into play.

Pay-TV operators "need to be able to address (additional online activity) opportunities to continue to grow, argues Daniel Simmons, Research Director, Media Delivery at Omdia: "This means that pay-TV operators must become super-aggregators."

Super-aggregation defines the integration of streamed content, linear channels, and other digital media (social networks, say) into a holistic TV experience that's available ready-consolidated at its point of consumption. After content itself, the user experience is usually named as a pay-TV service's main differentiating quality: typically speaking the way in which content is accessed, surfaced, presented and interacted with. And it's here that STB software and hardware integration can make a real difference.

Providers that attempt this using software alone will be frustrated and limited by scalability, suggests Simmons. "Trying to achieve super-aggregation only as an app across the connected device ecosystem means that it just becomes an app among all the others in a TV screen's primary user experience," he says, "which is outside of operators' abilities to manage."

Put another way, a STB will be critical to the success of any super-aggregation strategy, "because it gives operators control over the primary user experience of the TV screen through which all apps are accessed and controlled, and can be used to add value," adds Rafael Cortes, Product Director of Multilaser Industrial.

"They can manage every element of this experience," Cortes explains, "from the available apps on the screen, right through to the buttons on the remote control."

Users Like App-Compatible STB Software

In its simplest form, super-aggregation is about providing consumers with "all their TV content in

one place" by aggregating multiple sources of online video into one platform adorned by value-added user interfacing features. It's a requirement which has led many STB manufacturers to move away from Linux, with Android TV emergent as the stronger challenger for next-generation STB operating systems.

"For us, Android TV has a strong market outlook," says Juan Carlos León Flores, Technological Development Manager at LatAm telco América Móvil. "One reason for this is it has an operators tier which allows them to customize the platform to suit their own needs, enabling them to attract more users and enhance consumer 'stickiness'. Plus, we can promote our own apps in the launcher and in search results."

ZTE is another STB leader that believes Android TV brings compelling advantages for super-aggregators looking to grow their subscriber base through value-added differentiation. The company first launched an Android TV STB in 2017, and has continued to develop enhanced offerings since.

ZTE's Digital Video Broadcasting (DVB) hybrid STB (ZXV10 B836CTSI-A20) for example is based on the Google Common Broadcast Stack (CBS) platform—announced in October 2020 and designed to accelerate the reach of Android TV—and was designed with the aim of accelerating the roll-out of new services for service providers.

The company has deployed Google Ad Manager—a compatible linear ad insertion (aka. addressable TV) platform—on its Android TV STBs for Telkom Indonesia. The service is expected to help generate more advertising revenue for the telco by allowing it to show customized ads to its payTV subscribers while they watch live TV, matching the contents more closely to their preferences and increasing the likelihood of stimulating a purchase.

More recently, ZTE launched a range of new STBs that support 4K and 8K ultra HD video output. Developed in partnership with semiconductor partner Amlogic, the ZTE 8K STB debuted in September 2022. When connected to a big screen, it can deliver immersive 4K UI and enhance ultra HD video quality, says the firm.

"The 8K STB, by virtue of a 12 nanometer chipset and a quad-core 64-bit processor, can support 8K video decoding and output, with resolution being four times that of its 4K predecessor," explains Wu Xin at ZTE. "It also supports innovative video services such as multichannel video decoding, 'naked eye' VR, and free-viewpoint video—all features indoor and outdoor ultra HD video services need."

ZTE and Amlogic also collaborated to simultaneously launch the 4K Wi-Fi 6 mesh home media terminal. "This is a converged STB, router and gateway built around our chipset that's based on the quad-core ARM Cortex-A55 architecture," says Ruiliang Yang, Amlogic's Senior Director of Business Development & Marketing. "By leveraging Android TV, it can provide access to a massive choice of apps and media resources."

With a gigabit-speed WAN uplink and five Wi-Fi antennas, the STB also brings network services for commercial use-cases such as hotels, retail, hospitals and other out-of-home requirements, Yang adds.

Smart Home Support Is Next Frontier

Smart home support is another market segment where next-generation STBs can add value, says ZTE's Wu Xin. Working with Amlogic again, ZTE recently launched an Android TV-based DVB-compliant STB with far-field voice which represents a type of cross between a smart speaker and an STB.

Xin says. "As a central voice control device, the STB achieves the entire home coverage of smart voice services, supports the control of a wide range of smart home devices, and enables visual installation." As such the STB is positioned to enable solutions developers to build a multi-ecosystem platform, using voice as a key interface for smart home management.

"This DVB STB adopts the far-field voice recognition technology and supports several of the most-spoken languages," ZTE's Xin continues. "Users can directly control the device by voice command instead of a remote control device. With a dual microphone array, its far-field voice pickup distance is 5-metres."

The pandemic has grown the stay-at-home economy to such an extent that it is unlikely that consumers will ever settle the one dimensional STBs of the past ever again. ZTE TECHNOLOGIES

ZTE Helps Turkcell Deploy World's First Commercial 12 THz WDM System

Xu Yongkang

Wireline Product Planning Director, ZTE

ZTE, in partnership with Turkcell, has deployed the industry's first commercial optical transport network (OTN) supporting 12 THz ultra-wide frequency spectrum in Bursa, the fourth largest city in Turkey. The network will bring greater bandwidth capacity to Turkey, allowing Turkcell's subscribers to enjoy high-speed internet access.

As 5G network requires bandwidth several times higher than 4G network to cope with the explosive growth of network traffic, Turkcell decided to build an advanced metro WDM network. In July 2021, Turkcell exclusively selected ZTE to build its metro WDM network in Bursa.

For the WDM network, ZTE has provided its powerful OTN platform based on 1T backplane bandwidth, which substantially increases the network transmission capacity. ZTE's ZXONE 9700 is a new universal switching OTN device oriented to 100G and beyond 100G transmission. It is applicable to the backbone core layer and metro networks and can fully meet operators' requirements for transparent transmission, flexible scheduling, aggregation processing, and service management and monitoring of large-granularity data services. It uses the G2K subrack, which has a total cross-connect capacity of up to 10T and a single-slot backplane bandwidth of 1T, and the advanced universal cell switching platform to implement non-blocking cross-connect scheduling of ODUk, PKT, and VC services. The ZXMP M721 CX66A (E) is also used in this project. The ZXMP M721 metro

WDM device is a compact OTN product applied to the aggregation and access layers of metro networks. With high integration and flexible service access, it can effectively save the equipment room space and power consumption, and significantly reduce the O&M costs.

Beyond 100G OTN is an inevitable choice to support the development of new services. In this project, ZTE employs the 200G PS-16QAM system to meet the customer's metro network transmission requirements. The system uses the electrical domain shaping technology to improve the transmission capability and implement ultra-long-haul transmission, and supports smooth evolution to 400G. The application of the new technology significantly improves the transmission capability of beyond 100G. At the same time, ZTE has preset a C+L-band coupler on the metro WDM network to help Turkcell implement quick and smooth upgrade to multi-band. The spectrum bandwidth of the traditional C band is about 4 THz, while the spectrum bandwidth of the C+L band can increase to 12 THz. Therefore, the C+L band can offer the future bandwidth capacity improvement by 200% compared with the original standard 80-channel C band, providing stronger transmission capability without increasing fiber resource investments and fully meeting the future data network bandwidth demands of Turkcell.

In terms of system reliability, ZTE offers multiple protection mechanisms, such as control board 1+1 protection, power board 1+1 protection, subnetwork connection protection (SNCP) and WDM automatic switch optical network (WASON), to substantially improve service reliability and network intelligence.

To achieve intelligent O&M, ZTE employs colorless, directionless, contentionless and flexgrid (CDC-F) ROADM solution, which greatly improves the wavelength flexibility, reduces the stress on equipment boards, and simplifies the O&M. ZTE also provides automatic power optimization to achieve power equalization at the channel layer and the multiplex section layer. Optical time domain reflectometer (OTDR) is used to locate fiber faults within minutes, so as to realize automatic fiber protection and recovery. Meanwhile, ZTE's ZENIC ONE system is adopted to manage the network. The system supports fast and automatic service provisioning and provides open southbound and northbound interfaces to improve the interoperability. It also supports intelligent fault prediction and analysis to reduce the fault location time, and enables automatic and proactive O&M to simplify O&M operations, thereby improving the efficiency and user experience.

It is worth mentioning that Netas, Turkey's leading information and communication technologies company with ZTE as its main shareholder, provides the project service for the WDM project. The successful commercial 12 THz WDM project will speed up the future 5G network development of Turkcell in Turkey.

ZTE pays close attention to the development of networks as well as core demands of operators, and is committed to technological innovation and exploration in the telecom sector. Moving forward, ZTE will partner with Turkcell to make continuous innovations and drive the network digital transformation in Turkey. ZTE TECHNOLOGIES

ZTE Assists China Mobile in Building the World's Largest 100G/200G OTN Network

Li Xianfeng

Director of Wireline Product Planning for China Market, ZTE

As we are moving towards the intelligent era and generating a massive amount of data, the global optical network industry has fully entered the beyond-100G era. China Mobile is also continuously increasing its strategic investment in this field to secure its leadership position in the global market. In its phase 13 centralized procurement of the inter-provincial backbone transport network equipment, China Mobile worked with ZTE to construct the world's largest 100G/200G OTN covering 19 provinces, laying an ultra-broadband and ultra-fast transport base for the explosive growth of big data and the east-data-west-computing project.

With the large-scale deployments of 5G networks, home broadband and enterprise services have experienced fast growth. As a result, the inter-provincial traffic grows at a compound annual growth rate (CAGR) of over 40%, posing continuous challenges to the bandwidth efficiency of backbone transport networks. Meanwhile, as the network scale, the number of site degrees and the number of services are rapidly increasing, the traditional WDM network has been unable to satisfy the requirements on service scheduling and network O&M. Therefore, the optical networks also have to deal with the challenges of flexible scheduling and intelligent O&M.

To address these technical challenges brought by network development,

China Mobile adopted multiple key technologies including single-wavelength 200G, ultra-wide extended C band, optical cross-connect (OXC), SDN and high-density boards to enhance network performance in a comprehensive way, which has ushered in large-scale deployment of 200G optical transport, OXC, and SDN in China.

In terms of network capacity, the single-wavelength 200G achieves the best balance between capacity and distance with the application of multiple high-order modulation techniques. The western network employs 200G QPSK and 200G 16QAM modulation schemes according to link quality so that the enormous and complex provincial and municipal nodes distributed across the central and western regions can be connected to be the largest optical network. The 200G QPSK almost matches the 100G QPSK in transmission distance, but increases the capacity by 50%. The 200G 16QAM doubles the capacity with the spectral bandwidth of 4 THz remaining unchanged.

In terms of flexible scheduling, OXC makes it possible to schedule any service on the optical layer. ZTE's 32-degree OXC device can schedule wavelengths flexibly in 32 directions, and wavelength assignment can be performed with one click using the network management system, with no site visits required. One board can integrate the functions of up to eight boards, and high integration allows the equipment room footprint to be saved by up to 75%. All fibers between boards are interconnected via flexible optical backplanes, which reduce the complexity and errors of manual fiber connections as well as the difficulty of subsequent maintenance.

With respect to intelligent O&M, SDN enables end-to-end one-click service configuration and management to decrease a large amount of O&M manpower and material resources. The permission- and domain-based management models guarantee network security. Visualization of resource statistics and early warning provide a clear resource analysis for network maintenance, ensuring proper network capacity redundancy and sufficient bandwidth for burst service transport.

In line with the national low-carbon strategy, China Mobile takes high integration and low power consumption as major indexes of equipment assessment. Powered by the highly integrated Framer chip developed by ZTE, ZTE's OTN equipment cuts the power consumption by 50%, reaches 1T single-slot bandwidth and realizes 10×100G or 5×200G ultra-broadband transport in a single board.

Together with ZTE, China Mobile has applied multiple new technologies to the world's largest 100G/200G OTN to handle the soaring traffic volumes. The high-quality development of China's economy is associated with the construction of national infrastructure such as high-speed optical networks. The integration of optical networks with various industries and fields will facilitate full use of resources and efficient operation of the society, thus effectively boosting economic prosperity and growth. It is necessary for the Chinese ICT industry to move from building an "information superhighway" to cultivating an "information industry ecosystem", which is also an indispensable way to accelerate the development of the global ICT industry. ZTE TECHNOLOGIES

Chengdu Telecom: Establishing a Good Reputation for 5G Coverage Through Precise Planning and Macro/Micro Coordination

Wu Wei

Chief Engineer of Network Planning Technology, ZTE

Wang Yunzhong

Director of Network Planning Technology, ZTE

After multiple phases of construction, the 5G network of Chengdu Telecom has achieved continuous outdoor coverage in urban areas and counties. In order to improve the depth of the coverage, increase 5G network availability and offer a smooth 5G user experience, Chengdu Telecom and ZTE set up an integrated project team to explore the construction of a 5G network with a strong reputation by focusing on key scenarios.

The project team took eight scenarios for a trial, including universities, high-density residential areas, high-traffic business areas, high-speed rails, subways, large stadiums, traffic hubs, and hospitals (Fig. 1). Considering the characteristics of different scenarios and macro sites, as well as the advantages of micro sites, the project team implemented innovative solutions such as precise planning & construction, macro-micro site coordination, and vertical networking and achieved a steady increase of the coverage, capacity, and offloading ratio of the 5G network.

The integrated project team of Chengdu Telecom and ZTE put forward a five-step precise planning approach, i.e. requirement analysis, network evaluation, site survey, solution customization, and solution implementation.

- **Requirement analysis:** Analyze the network construction objectives, networking strategies, deployment scenarios, and site resources.
- **Network evaluation:** The 4G/5G multi-dimensional data is used to analyze the network structure, coverage and capacity. The network value is evaluated based on the number of MR reports, number of

terminal access times, traffic data, offloading ratio and scope of VIP areas.

- **Site survey:** Site survey is carried out in accordance with service requirements, product features, network structure, and feasibility.
- **Solution customization:** In the scenario-based design phase, precise simulation, AI-based capacity prediction, and customized antenna pattern planning are required.
- **Solution implementation:** In the final closed-loop verification phase, the accuracy of the solution is enhanced through continuous iteration of measured data and correction of key planning parameters.

Based on the "five-step precise planning" approach, eight solutions have been developed in accordance with characteristics of each specific scenario.

Universities: Macro/Micro Coordinated Networking

As a high-traffic scenario, universities are of great significance for operators to develop users and build brand. To simultaneously enhance the network coverage and capacity for spots such as dormitory buildings and canteens, the project team conducted high-precision three-dimensional simulation in combination with correction by actual tests to accurately predict planning indicators, calibrate macro & micro coverage capabilities and form guidelines.

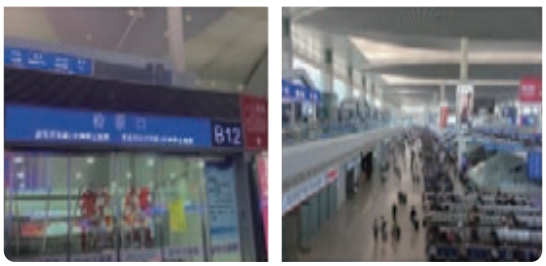
In the A university project, the coverage rate in simulation is 99.23%, highly consistent with the rate of 99.48% in actual test after site deployment. In addition, the project team collected historical data for machine learning analysis of user perception in the existing

Universities: macro-micro coordinated sites to cover student dormitory buildings

High-density residential areas: coverage by horizontally-installed micro sites + RRU+ spotlight antennas

Large stadium: QCells + beamforming antennas to cover the grandstand

Traffic hub: QCell + panel antenna to cover the waiting hall



◀ *Fig. 1. Typical 5G scenarios.*

network, and completed AI-based capacity prediction and capacity planning to improve user perception. For the communication guarantee during the fall opening in 2021, macro/micro sites were deployed at scale, and the drive test showed that the coverage rate was increased by 1.8%, the traffic by 133.09%, and the 5G traffic ratio by 8.5%.

Residential Areas: Horizontally-Installed Micro Sites and Spotlight Antennas for Macro Sites

Complaints about weak 5G coverage, ratio of MRs with weak coverage and backflow traffic are the most prominent problems in residential areas. To solve the difficulty of deploying macro sites in residential areas, the team innovatively deployed micro sites and medium- and high-frequency macro sites to cover high-rise buildings.

The iMacro is installed horizontally to cover one side of building B. It can cover 30-40 floors vertically and 35-40 meters horizontally. The RRU works with large-angle spotlight antennas to cover high-rise residential building C. The 2.1 GHz band is used to cover one side of the building and the corridor to provide basic coverage whereas 3.5 GHz one side of the building to enhance capacity of high-value buildings if needed.

Commercial Buildings: 1+X SSB Solution for Macro Sites

There are a large number of commercial buildings with complex architecture in Chengdu. In the case of limited indoor investment, the 1+X synchronization signal and PBCH block (SSB) solution for macro sites can be used to rapidly enhance the in-building coverage.
For the coverage of a 85.8-meter-tall, 22-story commercial building D, SSB 1+3 pattern is adopted. In the indoor corridor test, the coverage field strength is increased by 7.33 dB. In the indoor fixed-point test, the coverage field strength is increased by 6-8 dB, downlink traffic by 54%, and 5G traffic ratio by 6%.

By December 2021, in areas where the 5G network is constructed by ZTE, SSB 1+X solution had been applied to 50% outdoor cells, and the number of 5G subscribers in the whole network had been increased by 9.46%, the traffic by 9.98%, and the distribution ratio by 1.66% with the SSB 1+X function enabled.

High-Speed Railways and Subways: Shared Network with 4G-5G Coordination

The train body signal penetration loss in high-speed railway scenarios is high. During the network planning for high-speed railways, the optimal distance from the rail to a site (normally 150-200 m) should be considered. Frequent handovers can be avoided by combining cells. Passenger-dedicated railway E connects the Southern Sichuan cities, and 2.1 GHz 20 MHz NR + 20 MHz LTE solution is used to quickly achieve 4G/5G dual-layer network coverage at low cost. A total of 81 2.1 GHz NR sites with an average inter-site distance of 732 meters are planned based on standards of an uplink edge rate of 2 Mbps, a downlink edge rate of 50 Mbps and a -110 dBm field strength.

Subway scenarios, including station halls, platforms, office/equipment areas, and tunnels, are characterized by a complicated environment, high construction costs, intensive passenger flows, and heavy traffic requirements.

The existing DAS and POI solutions cannot support the construction of the 3.5 GHz network. The network planning should not only meet the 5G offloading requirements, but also release the suppressed 4G traffic, so as to improve the spectrum efficiency. Therefore, it is urgent to build a network co-constructed and shared by China Telecom and China Unicom. In this case, the carrier sharing solution of 1.8 GHz 40 MHz LTE + 2.1 GHz 40 MHz NR is adopted, saving the space in the BBU equipment room, as well as increasing the 4G resource utilization rate and traffic. With the deployment of 2.1 GHz 40 MHz NR, evolution to 5G NR is thus achieved and user perception improved, setting a leading 5G brand image for both the subway company and operator.

Traffic Hubs and Large Stadiums: QCells with External Antennas

Open space scenarios like the waiting hall of traffic hub and the grandstand at a stadium demand extremely high capacity. The interference can be reduced and the capacity be increased by deploying QCells connected with external directional antennas. In the case of the waiting hall of the Chengdu high-speed railway station F, the CL dual-mode equipment is replaced by the 4G/5G dual-mode QCell equipment, achieving both 5G network deployment and 4G network capacity expansion. The walk test shows that the average field strength reaches -81.33 dBm and the average downlink rate of 650.46 Mbps. For the large 18,000-seater capacity stadium G, the solution of QCells with beamforming antennas is adopted for the grandstand to precisely control the inter-cell interference. In this case, the average field strength reaches -76.8 dBm, and the average downlink rate of 625 Mbps.

Smart Healthcare: Intelligent 5G Indoor Distribution Solution

To cover hospitals with 5G, teaching buildings, outpatient buildings, and inpatient buildings are the focus. These scenarios feature heavy traffic all the year round, a wide variety of services, and great difficulty in access and later maintenance. Especially, the impatient buildings have a complicated environment and diversified new service applications, such as immersive visiting system, intelligent robot inspection and long-distance expert consultation. It is necessary to consider the dual-mode 4G/5G network for better coverage and capacity performance.

The 4G/5G dual-mode QCell equipment is used to replace dual-mode CL equipment to ensure that the 4G network quality remains unaffected. The 5G network is mainly dedicated to smart medical services. One pRRU covers three wards on one side, and the number of cells can be flexibly planned according to the user distribution and service characteristics. The average 5G field strength and average downlink rate of the impatient building are -71.63 dBm and 890.7 Mbps respectively. With the help of 5G network, Chengdu Hospital G takes the lead in implementing smart healthcare.

By December 2021, the 5G traffic offload ratio of the areas where the 5G network is constructed by ZTE had increased to 30.55%.

In the future, both parties will continue to strengthen cooperation in communication guarantee for the university games, 5G coverage portrait of buildings, refarming 2.1 GHz for 5G, prediction and improvement of 5G traffic offload ratio, so as to improve the networking performance and user experience for key scenarios. ZTE TECHNOLOGIES

To enable connectivity and trust everywhere