Intelligent E-OTN 2.0 Solution White Paper

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Abstract: ZTE intelligent E-OTN 2.0 solution, as the connection ties between DCs, access and core networks, builds a DC-centric all-optical network for unified transport of fixed broadband, wireless broadband and enterprise private line services. The network features large bandwidth, low latency, flexible scheduling and intelligent operation and maintenance. Its core highlights including **“New Algorithm”** for extreme speed and distance, **“New Platform”** for flexible and efficient service transport and scheduling, and **"New intelligence"** for accelerated service deployment fully meet the high-quality connection requirements of various vertical industries in the 5G era.

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1 Trends and Challenges

1.1 ICT and Vertical Industries Get More Integrated in 5G Era

In May 2020, the concept of "New Infrastructure" was first incorporated into the Government Work Report of the State Council in China, which attracted the attention of all walks of life. "New Infrastructure" relates to the transformation and upgrade of China's economy, and will provide a powerful impetus for the new round of economic growth and will continuously induce new investment hotspots. At the top of the "new infrastructure," 5G can provide important basic networks for big data centers, artificial intelligence, and industrial Internet, and so it is the basic guarantee for the comprehensive development of China's digital economy.

The new 5G infrastructure will have a profound impact on all aspects of society. Compared with 4G, 5G can not only provide high-quality services for consumer market, but also enter vertical industries. Forecasts from IHS, a famous consultancy, suggest that by 2035 5G will exceed US $12 trillion in global economic output. Driven by 5G, traditional industries are deeply integrated with the ICT industries, and industry application scenarios such as smart grid, smart manufacturing, telemedicine, and remote education have been flourishing.

At present, among the three 5G application scenarios defined by the International Standards Organization 3GPP, the eMBB scenario has been applied first, such as live sports, AR/VR and remote education. Especially under the influence of the COVID-19 pandemic in 2020, telecommuting and online education have become the normal situation, and APPs for online education and teleconferencing have been widely used all over the world. The key requirement of the eMBB scenario for transport network is ultra-high bandwidth, which is the basis for ensuring stable service transmission and improving user experience.

Following the steps of the eMBB scenario, the uRLLC and mMTC scenarios have also gradually become visible. Typical representatives of the uRLLC scenario include telemedicine and V2X. This scenarios has extremely strict requirements for latency and reliability. The one-way transmission latency should be as low as 1 ms, and the reliability should be 99.999%. The mMTC scenario is mainly for massive IoT services, such as smart transportation, smart

agriculture and environment monitoring, and other application scenarios aiming at data collection. In such scenarios, there are a large number of terminals which are widely distributed, so the transport network is required to support massive connections.

In general, ultra-high bandwidth, low latency, high reliability, and massive connections are the key requirements of 5G network construction. In addition, the 5G network needs to promote the innovation of vertical industries through end-to-end network slicing and AI-based intelligent management and control platform to achieve the vision of "one network for all industries."

1.2 Popularity of UHD Video Brings Traffic Surge

As video plays an important role in people's life and work as the core carrier of information manufacturing and transmission in the ICT industry. According to the analysis report of the consulting company Omida, it is estimated that the video is the primary source of global network traffic and contributes more than 80% of the traffic.

As a bandwidth killer, video also has important commercial values, and is the key point for operators to consolidate and open up the consumer market. So far, tier one operators have positioned video as a strategic service. High definition and real-time performance of videos have always been the core demands of user experience. By continuously improving video definition and reducing service transmission latency, operators can provide users with excellent visual experience and increase user loyalty and retention rates.

The development of video has gone through standard definition, high definition and ultra-high definition. The ultra HD video represented by 4K, 8K and VR/AR poses higher requirements for bandwidth and latency. For example, 4K video requires the bandwidth of 45Mbps and RTT latency of less than 20ms, while VR video requires the bandwidth of 1Gbps or above, and the RTT latency of less than 12ms. Therefore, operators urgently need transport networks to provide larger bandwidth and lower latency, so as to avoid jamming and lagging in video playing, and guarantee high-quality user experience and improve market shares.

1.3 Digital Transformation of Enterprises Gives New Impetus to Operators' Revenue Growth

With the further intensification of digital transformation, the enterprise private line has become a new engine of revenue for operators. The enterprise private line services are diversified, which have different transport network requirements.

For financial customers, the service granularity is usually small and it requires high reliability and low latency of the network. In the past, SDH equipment was used to carry services and small-granularity rigid pipes with VC cross-connect to transmit services. However, with the increase in both the service numbers and rates, the SDH equipment cannot meet the development requirements as its bandwidth utilization has been almost saturated. In addition, SDH equipment has been operating in the network for a long time, and operators are facing increasing O&M risks. In view of this, operators in China have gradually started to withdraw the SDH networks, and seek the OTN solution integrated with VC cross-connect function and large-capacity cross-connect feature as an alternative solution.

For large-scale enterprises such as OTT and health care customers, the service granularities are relatively large. In particular, these customers pay special attention to the feature of large bandwidth and reliability and latency indicators at the same time. These services often need to be transmitted with ODUk-level rigid pipes. However, for some small and medium-sized enterprises, they usually attach importance to high price performance, such as the high bandwidth utilization and network flexibility. These services are generally transported by using soft pipes.

In conclusion, the requirements of enterprise private lines mainly concentrate on high bandwidth, high reliability, low latency, and flexible networking. Meanwhile the requirements for different private lines are also different. This requires operators provide differentiated services to meet the personalized requirements of different customers.

1.4 DCI is Leading New Investment Boom

Cloud and big data are driving a new round of ICT reforms, and data centers have become new investment hotspots. The forecast from Omdia indicates that by 2025, the global DCI

market of optical network is expected to reach US $5.9 billion, accounting for more than 30% of the overall optical network market, and will become the most important component of the ON market revenue.

With the acceleration of cloud-based networks and data centers, the scale of global data centers is rapidly expanding, and they are gradually moved down to network edge nodes with wide coverage. Between different levels of data centers, DCI networks need to provide high-speed and non-blocking transmission channels to meet the bandwidth requirements of massive services.

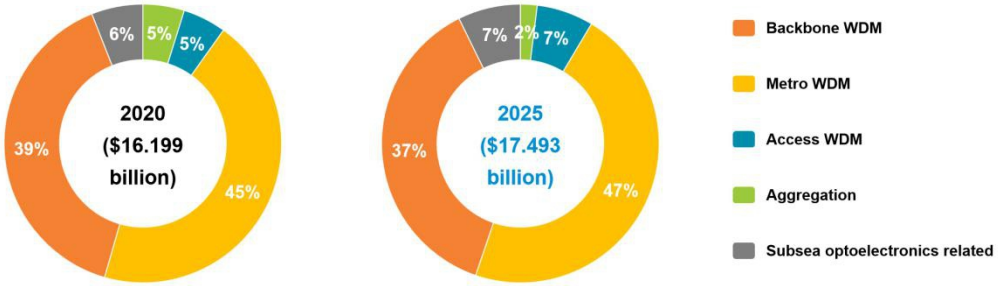
Due to the limited land, water, electricity, and other resources of large cities, with the good user experience of data obtainment into consideration, the construction of a distributed and cloud-based data center has become a mainstream choice in the industry. With the increase of data center sites, the requirements for resource sharing, disaster recovery and backup, and rapid traffic migration between data centers also increase. Therefore, the data center traffic is not limited to south-north traffic, but the east-west traffic is also increasing rapidly. Fast deployment and flexible scheduling of DCI have also become important indicators.

In general, the core requirement of DCI scenarios is to build optical transport networks with high rate, low latency, flexible deployment, and easy maintenance to address the increasing traffic requirement and achieve efficient and low-cost service interconnection.

1.5 Summary of ON Trend and Requirement

With the boom of 5G, 4K, VR and vertical industries, optical networks, as the "cornerstone" of communications networks, are growing steadily. The global COVID-19 pandemic highlights the importance of infrastructure. According to the ON forecast report of Omdia in 2020, the revenue of global optical network market will exceed US $17.4 billion by 2025. In terms of the network levels, Access WDM and Metro WDM are developing at the highest speed due to the growing bandwidth requirements bought by the downward shift of cloud-based DCs and the construction of MECs, which makes optical network connection as the future development trend.

Figure 1- 1 Optical Network Forecast, Omdia 2020



While the optical network market is expanding, there is also an urgent need for reforms and innovations on service transport, scheduling and O&M. It can be seen that through the analysis of 5G, fixed network, enterprise private line and DCI scenarios, the requirements of optical networks can be summarized as follows.

1) Ultra-large capacity and high-performance transmission: Ultra-long-haul transmission must be guaranteed while increasing the line rates to meet the bandwidth demand.

2) Ultra-low latency: This feature matches latency-sensitive services and can provide ultimate user experience.

3) Agile service scheduling: It is adaptable to ubiquitous connections of cloud networks to implement fast service provisioning.

4) Flexible service access: It can provide efficient service access at any rate of 2Mbps~400Gbps.

5) Intelligent O&M: To meet the diverse service requirements in various vertical industries, it is necessary to implement precise network management and control.

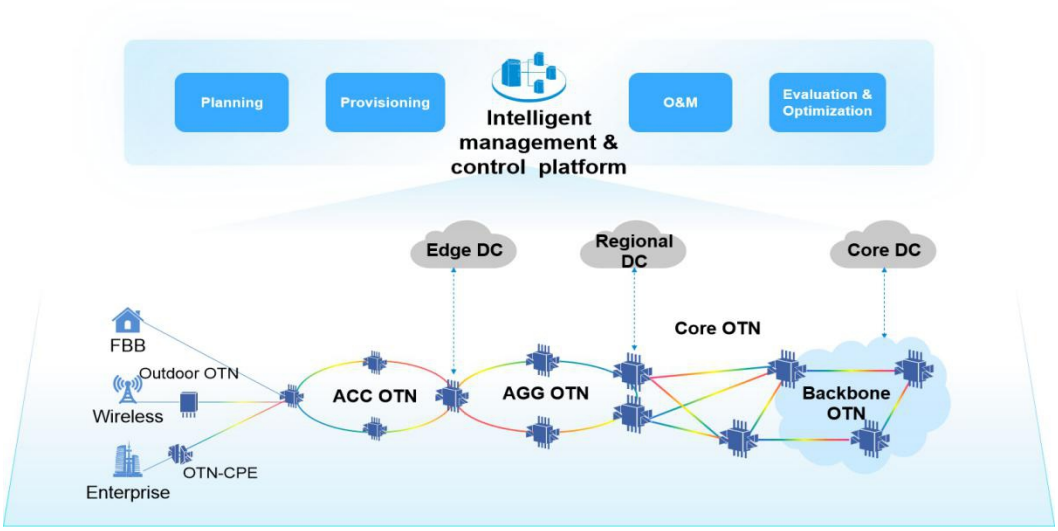
6) Ultra-high reliability: It can provide 99.999% high reliability, and significantly improves the network robustness.

2 Architecture of Intelligent E-OTN 2.0 Solution

To facilitate the development of 5G infrastructure, implement interactive communication based on broadband HD video, meet diversified scenario requirements of vertical industries,

and promote DCI network development, ZTE has launched the intelligent E-OTN 2.0 solution. Relying on advanced chips and technologies, ZTE has built an ultra-wide, flexible and efficient optical transmission platform for operators. The AI-based intelligent management and control system can also implement intelligent service interconnection and intelligent network operation.

Figure 2- 1 Intelligent E-OTN 2.0 solution architecture overview



The intelligent E-OTN 2.0 solution is aimed to build broadband and intelligent full connection for the ICT field in the 5G era. Based on cloud DCs, the E-OTN 2.0 solution establishes large-capacity interconnection pipes between DCs and between DCs and services, to implement unified transport of fixed/wireless networks and vertical industries.

In terms of capacity, the E-OTN 2.0 solution introduces C++ band with 6THz, and increases the single-fiber capacity to maximally 48T, providing sufficient bandwidth resources for all service access.

In terms of transmission performance, based on the original Flex Shaping algorithm, the E-OTN 2.0 solution significantly improves the transmission capability while increasing the service speed. Combined with the SDO technology, it enables the line rate to be continuously adjustable from 100Gbps to 800Gbps, so that achieves the best balance between the transmission distance and system capacity.

In terms of service grooming, the industry-leading OXC and OTN switching technologies are

used to build an ultra-large capacity, flexible and efficient platform. At the optical layer, E-OTN 2.0 supports 32-degree OXC with optical switching capacity exceeding 1000T, and supports upgrade to 40-degree OXC in the future. For wavelength-level services, it can significantly reduce the transmission latency with one-hop to transmission. At the electrical layer, the E-OTN 2.0 products have the biggest switching capacities in the industry in terms of single subrack and cluster. The maximum switching capacity of a single subrack is up to 128T. The maximum switching capacity of a cluster is up to 192T, which can be smoothly upgraded to 384T in the future. In addition, the E-OTN 2.0 solution supports unified cross-connection of ODUk/PKT/VC, and can implement flexible access of 2Mbps~400Gbps. ZTE has also been actively promoting the progress of OSU technical standards, and has launched the Pixel OTN solution oriented to vertical industries, expecting to build a more simplified, efficient and accurate service access platform in the near future.

In terms of O&M, the new intelligent management and control system based on “SDN, AI and Big Data” greatly improves the capabilities during the whole lifecycle, including service deployment, provisioning, O&M and optimization. It can help operators accelerate service innovation, improve user experience, reduce the complexity and OPEX of network O&M, and guarantee network reliability.

The core highlights of the intelligent E-OTN 2.0 solution can be summarized into three aspects: “New Algorithm” to construct ultra-fast pipes while guaranteeing the ultra-long transmission distance, “New platform” to realizes flexible and efficient service transport and scheduling, and “New Intelligence” to accelerate the digital transformation of vertical industries. In a word, the intelligent E-OTN 2.0 solution can fully meet the high-quality connection requirements of various industries in the 5G era.

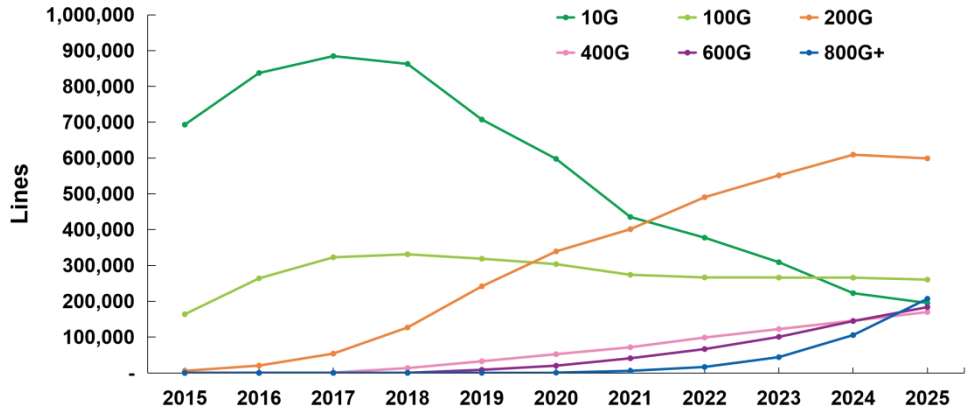
3 Highlights and Values of E-OTN 2.0 Solution

3.1 New Algorithm: Original Flex Shaping Significantly Improves Transmission Performance

It is urgent to accelerate the rates of optical networks with the acceleration of 5G network construction and growing bandwidth requirements of fixed broadband network, digital vertical

industries, and DCI. According to the forecast report of Omdia, the shipment of 400Gbps ports and above will continue to increase sharply in the coming years. It is estimated that by 2025, the shipment of 400Gbps+ ports will account for about 35%, and the bandwidth will account for about 70%. As the operators proactively deploy 200Gbps OTN networks to replace the existing 100Gbps OTN networks, the shipments of 200Gbps ports will continue to increase. It is predicted that shipments of 200Gbps ports will reach the peak in 2024, with the proportion exceeding 40%. It is foreseeable that beyond 100Gbps ports will become standard configurations of both backbone and metro core networks in the optical network market.

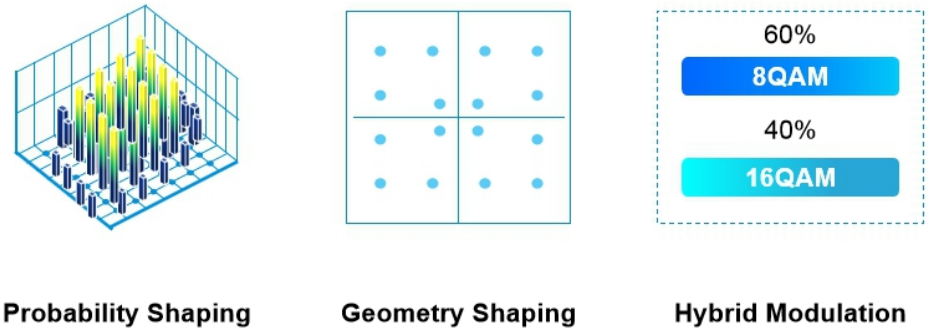
Figure 3- 1 Optical line-port shipment forecast (Source: Optical networks forecast, Omdia)



So far, ZTE has launched the coherent 800Gbps solution. Based on the SDO technology, the solution enables the line rate to be continuously adjusted from 100Gbps to 800Gbps, so as to rapidly respond to the traffic changes.

The transmission distance and performance can be significantly improved in addition to the transmission rate based on ZTE's original Flex Shaping algorithm. Unlike the traditional electrical domain shaping technology in the industry, the Flex Shaping technology adopts the collaborative design combining electrical domain shaping and optical domain shaping. The constellation diagram is optimized through electrical domain shaping to achieve longer-distance transmission at equivalent bandwidth or maximum bandwidth at the same distance. Optical domain shaping is used to shape the signal spectrum passing through ROADM sites, thus reducing the filtering penalty and enables the services to pass through more ROADM sites in Metro scenarios.

Figure 3- 2 Electrical domain shaping in Flex Shaping



The electrical domain shaping consists of probability shaping, geometric shaping and hybrid modulation.

1) Probability shaping: By changing the appearance probability of the constellation, it increases the probability of low-energy point and reduces the probability of high-energy point. In this way, it can reduce the transmit power and non-linear effect and greatly improve the transmission performance.

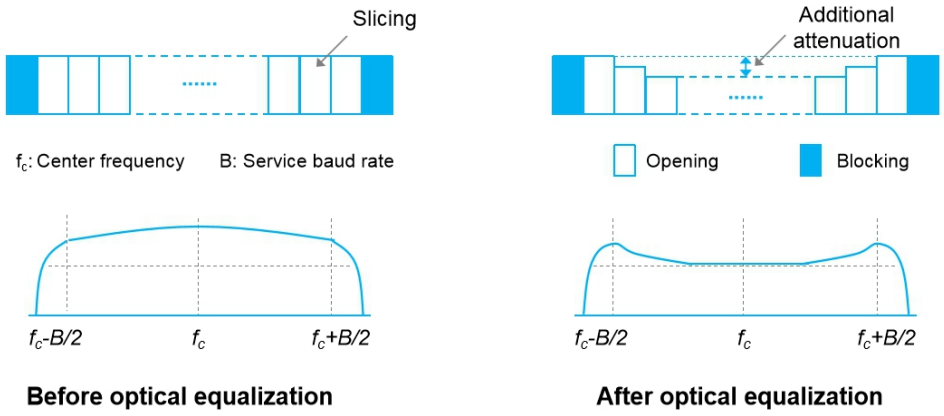
2) Geometric shaping: The positions of constellation points are shaped, and the spacing between different constellation points is adjusted to a non-uniform value to obtain a larger Euclidean distance, so that the system capability is closer to the Shannon limit.

3) Hybrid modulation:The single-carrier signal can be transmitted in multiple modulation modes. For example, the 200Gbps signal may not use the PM-16QAM or PM-8QAM modulation technology alone, but use the combination of the two. Through the analysis of actual link conditions, the proportion of different modulation modes can be flexibly adjusted to achieve the best balance between system capacity and transmission performance at any transmission distance.

With the combination of the three technologies, the performance of ZTE's beyond 100Gbps system is significantly improved, and the transmission distance is increased by more than 30%. You can select the transmission rates and modulation modes that best match the different application scenarios. And it is applicable to both backbone and metro networks. At present, ZTE is capable of deploying 600Gbps or 800Gbps for Metro or DCI scenarios. Compared with 200Gbps or 400Gbps with the same capacity, the proposed solution can significantly reduce the number of photoelectric components and CAPEX. In Backbone network, 200Gbps or 400Gbps are adopted to achieve ultra-long-haul transmission distance,

so as to reduce the regenerators and save the investment.

Figure 3- 3 Optical domain shaping in Flex Shaping



In terms of optical domain shaping, the patented optical equalization technology is used. By slicing the spectrum and using the spectrum shaping with WSS fragmentation attenuation adjustment, this technology reduces the filtering penalty when beyond 100Gbps signals pass through the ROADM site. This ensures that the signals can be received correctly after passing through multi-level WSS, and the number of pass-through WSS can be increased by more than 50%. In the scenarios where there are many ROADM sites, this feature can effectively extend the transmission distance and maximize customer's investment.

ZTE has created a number of optical transmission records with the original Flex Shaping technology.

In 2017, ZTE assisted True Thailand to deploy the world's first Flex Grid 200Gbps system for the backbone layer, with the single-fiber capacity reaching 21.2T. Based on ZTE's patented optical equalization technology, the number of cascading ROADMs exceeds the industry level by 50%. As no generators are needed for the whole system, the CAPEX is greatly reduced.

In 2019, in the field test of single-carrier 400Gbps of China Mobile, ZTE's single-carrier 400Gbps transmission distance exceeded 600km, which was the longest among all test vendors. The proposed solution also supports abundant modulation modes and can meet the requirements of metro, long-distance, and other application scenarios.

In July 2020, China Unicom and ZTE jointly completed the 800Gbps innovative test, and increased the single-fiber capacity form 8T to 48T, achieving sixfold bandwidth increase. The

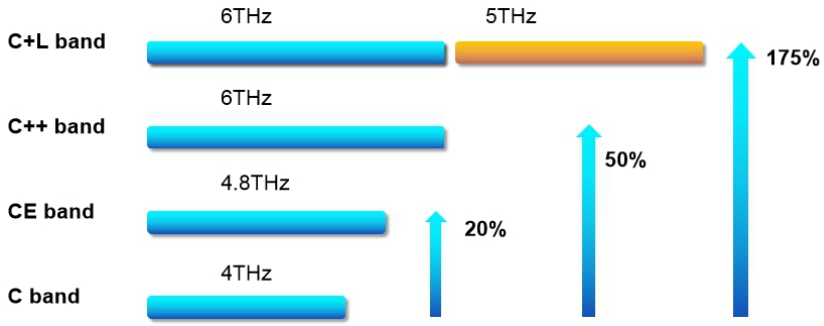
advanced 800Gbps solution can flexibly adapt to DCI and other short reach scenarios, and effectively support the new-generation cloud-network integration.

3.2 New Platform: Large-Capacity Electrical&Optical Platforms Enable Flexible and Efficient Service Scheduling

3.2.1 Spectrum at C++ Band Significantly Improves Single-fiber Capacity

To meet the bandwidth requirements, spectrum extension has become an important choice in addition to increasing the single-carrier rate and maximizing spectrum efficiency under Shannon's limit.

Figure 3-4 Spectrum resources evolution of ZTE OTN equipment



ZTE's intelligent E-OTN 2.0 solution has evolved from the traditional C band (4THz spectrum width) to the current C++ band (6THz spectrum width). This breakthrough has increased the spectrum width by 50%. So far, the single-fiber capacity has reached 48T (80x600Gbps or 60x 800Gbps), which can effectively reduce the Gbit cost.

To implement spectrum expansion, related system components need to be upgraded at the same time. In addition to the new series of service boards, a new series of amplifiers, Multiplexers/Demultiplexers and optical cross-connect systems (OXC) are also needed. In the future, the spectrum resources will be expanded to L band. Compared with C band, the spectrum width will be increased to 175% (C+L band has a total of 11THz), so as to provide sufficient bandwidth resources.

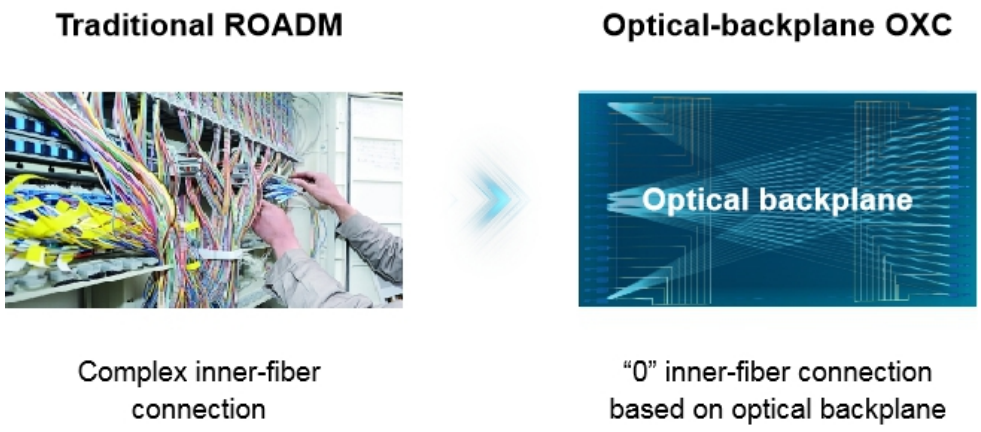
On March 31, 2020, ZTE won the western ring of the phase 13 project in China Mobile's national backbone network. ZTE proposed 200Gbps QPSK system in C++ band. Compared with the traditional 80x100Gbps system, the capacity of a single fiber is doubled, reaching up to 80x200Gbps. The network will cover 19 provinces, with a total link length of 53,828 km, covering more than 2/3 of China's territory. It will become the world's largest 100G/200Gbps OTN network after built, and meet the transmission requirements of massive cross-provincial services in 5G era.

3.2.2 Backplane-Based OXC Platform Enables Flexible Grooming of Optical-layer Services

The boom of big video services brings a traffic surge at core nodes, which increases the demand for bandwidth resources. In addition, as the services are more dynamic and unpredictable, to ensure user experience, the cloud-based mesh network architecture and downward shift become inevitable. This poses higher requirements for the flexibility of optical transport networks, and requires multi-degree service scheduling and control functions.

Currently, the Reconfigurable Optical Add/Drop Multiplexing (ROADM) technology is the mainstream choice. Based on the core component Wavelength Selective Switch (WSS), it can allocate any wavelength to any direction, thus implementing intelligent and fast provisioning of wavelength-level services. The WSS is combined with amplifiers, splitters, and couplers to build ROADM sites of different types and different degrees by way of building blocks for different scenarios. The ROADM technology can implement flexible service scheduling, but its disadvantages are obvious. With the increase of the site directions, the internal optical fiber connections will increase exponentially, bringing great challenges for operators. This affects the engineering commissioning efficiency, causes incorrect optical fiber connections, and greatly increases the OPEX.

Figure 3- 5 Comparison between traditional ROADM and OXC solution



To address the problems of the traditional ROADM technology, ZTE has launched a new OXC platform based on the optical backplane. With the optical cross-connect capacity exceeding 1000T, the system supports flexible service scheduling in 32 optical directions, and can implement full-mesh fast connection and one-hop transmission to meet the requirements of fast network deployment and lower latency.

The OXC system involves the following key technologies and highlights:

1) The fiber weaving technology is used to fix the internal fiber connections and form an all-optical backplane, so as to implement "zero" internal fiber connection. High-speed optical connectors and the automatic plugging/unplugging technology enables optical fiber connection once the board is inserted, greatly improving the usability of the equipment. The application of advanced technologies and components reduces the network deployment time from weeks to hours, significantly reducing the O&M pressure.

2) The OXC board is integrated with multiple modules such as the WSS, amplifier, optical line protection, OTDR, and OSC. A single OXC board can implement all optical layer functions in one line direction, thus greatly improving the level of integration. Compared with the traditional ROADM system, it can save 80% footprint and 70% power consumption. At the same time, the OXC platform can facilitate the expansion of the OXC network scale.

3) The optical labeling technology is used to identify the signals of each wavelength to implement end-to-end tracing and intelligent management of hundreds of wavelength, thus effectively preventing wavelength misconnection and improving optical system intelligence.

In general, ZTE's new OXC system can meet the requirements of fast service provisioning and flexible scheduling at core nodes in multiple degrees, and has the advantages of low power consumption, easy maintenance, and high intelligence. It greatly improves the efficiency of deployment, provisioning, and O&M, and reduces the TCO. With the development of network requirements and the application of OXC technology, the system will evolve to more than 40 degrees in the future to meet the requirements in more directions.

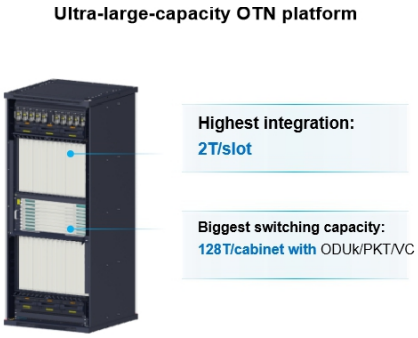
So far, the OXC platforms have served the core nodes of many networks. In China Mobile's Phase 13 Centralized Procurement Project in 2020, ZTE deployed a 32-degree OXC platform based on the C++ band for the first time for flexible service scheduling. According to the current solutions proposed in the industry, only two vendors have this capability. The OXC platform proposed by ZTE will be able to weave a larger and more flexible all-optical intelligent network for China Mobile.

3.2.3 Electrical Cross-connect Platform with Largest Single-cabinet Capacity Implements Accurate and Agile Scheduling of Massive Services

The optical cross-connect technology can provide wavelength-level services grooming, and has obvious advantages in power consumption, investment, and cross-connect capacity, but cannot flexibly dispatch small-granularity services. The electrical cross-connect technology can implement smaller-granularity service scheduling. However, as the capacity of the electrical cross-connect equipment increases, the pressure on the power consumption, power supply and heat dissipation becomes more and more obvious. Therefore, it has become a future trend to combine the two to build an ultra-large-capacity electrical-optical hybrid cross-connect system.

In terms of OTN electrical cross-connect platform, ZTE is the first vendor that has put 64T single subrack into commercial case. And ZTE has launched a new-generation electrical cross-connect platform with ultra-high integration, ultra-large capacity, and ultra-low power consumption. The key highlights are as follows:

Figure 3- 6 Largest OTN switching platform of 128T in the industry



1) The OTN platform supports 2T single-slot backplane bandwidth and 128T single-subrack capacity, leading in the industry.

2) The Framer chip integrates the FIC (Fabric interface chip) function. Compared with other vendors' Framer and FIC separated solution, it saves power by more than 50%.

3) The ODUk/PKT/VC unified cross-connect platform is built for integration trend. As a unified transmission platform, it can flexibly access any rate of 2Mbps~400Gbps with high efficiency, and supports SLA on demand.

With continuous upgrade and development of ZTE's key OTN technologies, The capacity will be increased of 2~4 times and can build a larger-capacity electrical platform for massive service scheduling at core nodes.

In order to further improve the service transmission efficiency and flexibility, ZTE has been actively promoting the formulation of the OSU standard and has launched the Pixel OTN solution. Based on the new OSU mapping solution, the solution achieves accurate access of at least 2Mbps services, simplifies the service processing process, reduces board types, reduces space and power consumption, and effectively saves the customer's TCO. The Pixel OTN solution can also realize hitless bandwidth adjustment and make full use of bandwidth resources, to provide quality connections for vertical industries. ZTE intelligent E-OTN 2.0 solution supports smooth evolution of the OSU function and leads the optical network development direction.

Today, ZTE’s 64T OTN platforms have been deployed widely, so that a large number of services with different granularities can be dispatched flexibly and accurately. For example, at

the beginning of 2020, the Guangxi branch of China Mobile, together with ZTE, deployed the hybrid cross-connect OTN+OXC system. This system is deployed at the six core sites, and uses the 64T single-cabinet OTN platform and the flexible OXC platform, which significantly improves the efficiency of network deployment and O&M. In the future, the system can be smoothly upgraded and expanded in both the capacity and service granularity types, to meet the development requirements in a medium to long term.

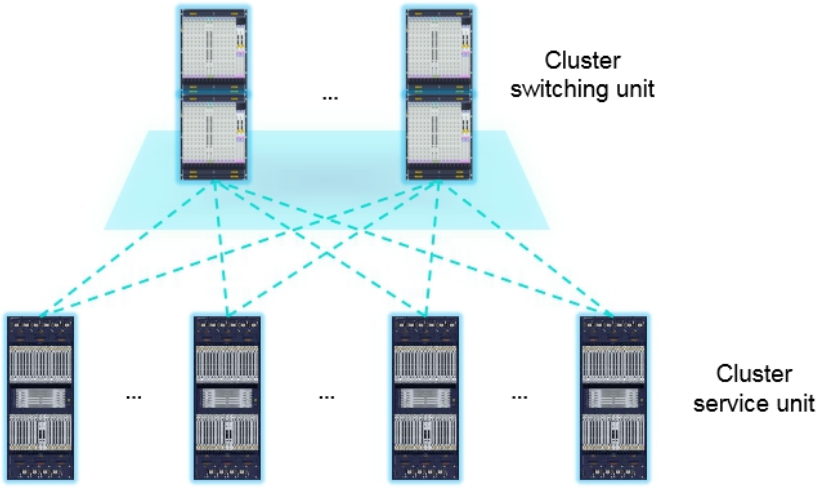
3.2.4 Strongest Non-Blocking OTN Cluster Meets Super-Large-Scale Service Scheduling Requirements of Core Sites

While improving the single-subrack cross-connect capacity of the OTN platform, ZTE has also launched the ultra-large-capacity OTN cluster solution. That is, multiple independent OTN devices in a site are interconnected as an OTN pool to meet the multi-degree large-capacity service scheduling requirements.

In fact, improving the single-subrack cross-connect capacity alone will face obvious technical bottlenecks. On the one hand, the number of slots on a single subrack is limited, and cannot meet the requirement for a large number of service ports. On the other hand, with the rapid increase of capacity, the power consumption density keeps increasing. Too high power consumption density will bring great pressure to the cooling system. The cluster-based solution not only provides more service slots, but also effectively shares power consumption and reduces power consumption density, solving the conflict between capacity growth and power consumption density of large-capacity electrical cross-connect OTN system.

For OTN cluster system, ZTE has the strongest OTN cross-connect capability with 192T in the industry, and will upgrade to 384T in the future. The proposed OTN cluster system adopts the fully non-blocking solution. Compared with other vendors' blocking solutions, it can more effectively meet the requirements for service burst, ensure the flexibility of service scheduling and facilitate service provisioning and maintenance.

Figure 3- 7 ZTE M+N OTN cluster architecture



The typical cluster system architecture of ZTE is shown above. It consists of M central cross-connect subracks and N service subracks, and supports a maximum of "3+12" system model. In the cluster system, the number of subracks can be increased and the cross-connect capacity can be upgraded. The OTN cluster solution has the following advantages:

1) Slots, boards, and ports are pooling, and can be flexibly deployed in accordance with the requirements in different directions. Each service subrack can only be installed with the boards in one direction. Service scheduling between different directions is implemented through the central cross-connect subrack, which reduces the difficulty in service planning and maintenance.

2) The high reliability of the cluster system improves the service survivability. The cluster system can provide the subrack-level protection. If proper service planning is available, the system can resist subrack-level faults to ensure that services are not affected. Meanwhile board-level faults can be easily handled by sharing redundant resources in the cluster pool.

3) Reduces power density and improves footprint efficiency. The OTN cluster adopts distributed architecture, and the power consumption is distributed on multiple subracks to reduce the power consumption of a single subrack. The power consumption of a single subrack is controlled within 7,000 watt, meeting the deployment requirement of no more than 10,000 watt per single subrack. In addition, the devices are placed continuously without spacing, and the space efficiency is close to 100%.

In summary, ZTE's OTN cluster solution uses the resource pooling design, and so the system

capacity is easily expanded and upgraded, and the utilization of slots, boards, and service ports are maximized. It can meet the electrical-layer scheduling requirements and the power supply requirements of equipment rooms.

Shenzhen city is actively promoting the interconnection and co-construction information infrastructure of Shenzhen, Hong Kong, and Macao, building a low-latency, highly reliable, and wide-coverage network in the Dawan region. In response to this call, China Telecom together with ZTE deployed the industry's first 400Gbps OTN Cluster in multiple metro core nodes. This solution supports 128 service slots at a single site and 64T cross-connect capacity, meeting the requirements for non-blocking scheduling of a large number of small-granularity services brought by SDH network withdrawal, and effectively guaranteeing high-speed and high-quality interconnection of 5G, broadband and enterprise private line services.

3.3 New Intelligence: AI+SDN Builds Open and Intelligent Optical Networks

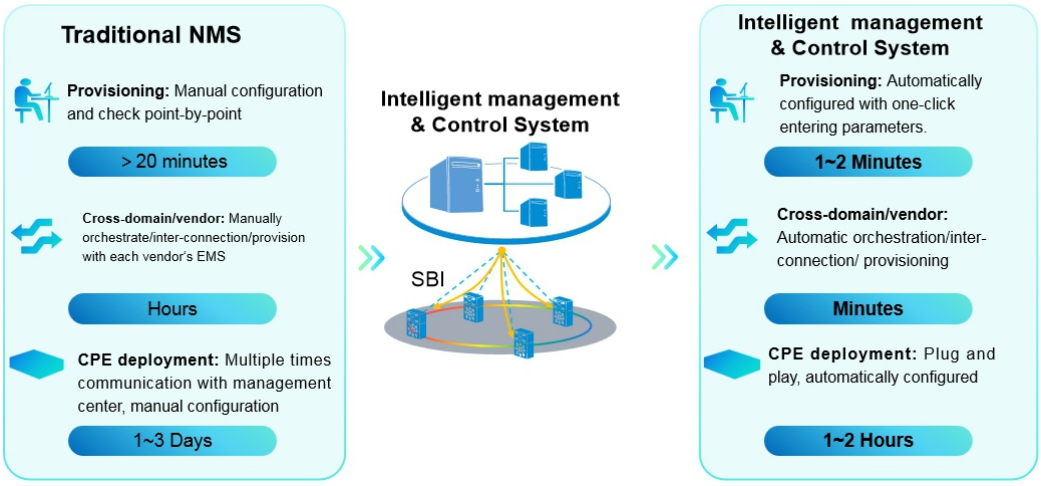
Today, the communication networks are moving from serving people to serving the whole digital society. With 5G network construction, new application scenarios are emerging in vertical industries, and service requirements are diverse. How to efficiently meet the requirements of new services and ensure the fast TTM is directly related to the operators' competitiveness. At the same time, the randomness, burst, and variability of new services make management more complicated. In addition, the evolution of optical networks from ring to mesh architecture increases the network complexity, and also leads to the continuously increasing OPEX. In short, the traditional human-centered O&M mode is increasingly difficult to meet the requirements of network development, such as real-time service deployment, complicated network O&M and accurate management and control. The O&M evolution towards intelligence has become an inevitable trend.

Facing the demands of network intelligence and diversified services, ZTE has launched the industry-leading intelligent management and control system based on "SDN+AI+big data analysis." As an important part of the intelligent E-OTN 2.0 solution, this system can help operators build intelligent, flexible, open and reliable optical transmission networks. The intelligent management and control system has a super management capability with 300,000

equivalent NEs as maximum. This system adopts the B/S micro-service architecture, supports centralized cloud deployment, and can be expanded flexibly on demand, thus saving operators' initial investment and maintenance cost.

The intelligent management and control system has standardized southbound and northbound interfaces, and is easily interconnected with upper-layer applications. Based on the cloud-native SDN platform, the whole lifecycle of network planning, service deployment, O&M guarantee, evaluation and optimization is fully optimized and improved, which reduces the maintenance complexity and cost, and provides high-quality user experience.

Figure 3-8 Fast service deployment with intelligent management and control system



In terms of service deployment, the intelligent management and control system adopts various measures to improve provisioning efficiency and enhance the operator's competitiveness, including:

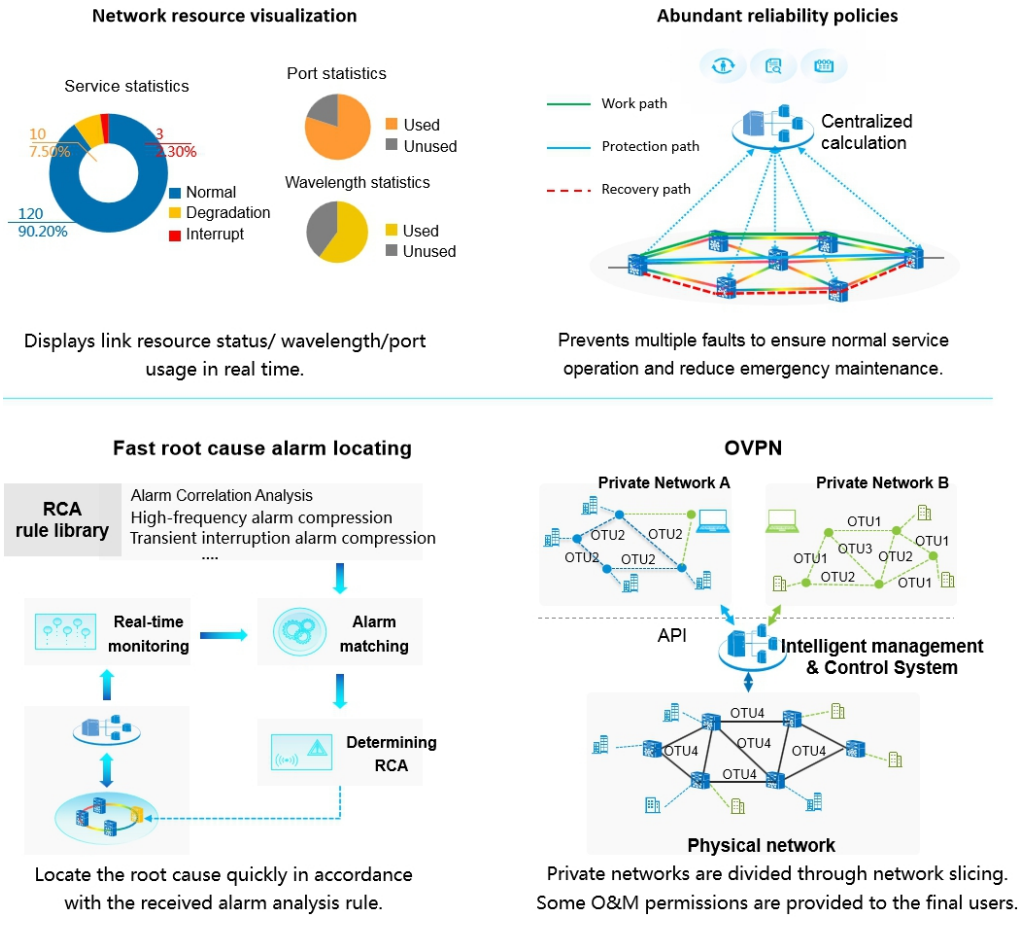
1) Service configuration and delivery: For traditional management system, the configuration must be performed point by point and checked manually, which is time-consuming and error-prone. The intelligent management and control system can automatically complete service configuration by simply inputting service parameters. The service delivery time is shortened to minutes, which significantly improves service provisioning efficiency and avoids configuration errors caused by human factors.

2) Cross-domain/vendor service scheduling: In a traditional network management system, the operator needs to check the interconnection ports of different vendors, and manually perform services provisioning for each vendor segment by segment. The intelligent management and

control system can implement automatic orchestration and interconnection with different vendors, thus reducing the cross-domain/vendor service scheduling time from hours to minutes.

3) CPE OTN deployment for enterprise services: The traditional mode requires that the debugging person communicate with the management center repeatedly and complete service configuration manually . The device commissioning usually takes several days. The CPE OTN with intelligent management and control system supports plug-and-play. After the debugging person completes hardware installation and equipment power-on at a time, the service can be automatically commissioned through a software protocol, which consumes only 1~2 hours. This not only saves the OPEX, but also significantly improves the service provisioning time.

Figure 3- 9 Efficient and reliable O&M performance with intelligent E-OTN 2.0 management and control system



In terms of network operation and maintenance, the intelligent management and control system implements automatic and active operation and maintenance, which helps operators avoid risks in the network in advance, improves service reliability, maintenance efficiency and reduces OPEX. The typical intelligent functions include:

1) Network resource visualization: The system displays the link resource status and wavelength/port utilization in real time. It can also display the utilization of related resources in accordance with the objects selected by the customer, for example, links or sites. Based on the collected resource information, the system can predict and analyze resource bottlenecks of key nodes, providing accurate guidance for future network expansion.

2) Diversified service protection and recovery modes: Integrated with centralized algorithm units and abundant routing policies, the system implements unified service scheduling protection at both optical and electrical layers, and provides different levels of security services. Based on intelligent management and control plane and mesh network, it can implement automatic resource discovery and automatic service rerouting functions, to prevent multiple faults and ensure up to 99.999% service reliability.

3) Intelligent alarm root cause analysis: Based on AI and big data analysis, fault alarm compression is implemented to help the maintenance personnel quickly find the root cause, thus eliminating the manual analysis and troubleshooting process and reducing the fault location time by 85%. Meanwhile, by continuously enriching the fault diagnosis rule library and accumulating fault diagnosis experience, it can save the costs of O&M training.

4) Optical Virtual Private Network (OVPN): The network resources can be virtualized. The operator can slice the virtual resources according to the requirements to implement network hard isolation. Users can also perform self-services based on virtual networks to implement bandwidth adjustment and self-maintenance. In addition to improving user experience, it can also increase operators' revenues.

ZTE intelligent management and control system, oriented to customers and services, fully improves user experience, enriches industry applications and increases operators' profit models. In the future, the intelligent management and control system will further integrate AI and big data technology, and implement functions like optical network risk prediction and accurate optical path design through AI algorithm. In this way, it can build more intelligent, convenient, efficient and reliable optical transmission networks, bringing more friendly user

experience.

In 2019, ZTE helped China Unicom build an open, intelligent management and control platform for the Ningxia branch, promoted service innovation, and built quality OTN networks. ZTE's intelligent management and control system can implement unified management on provincial backbone and local networks, so that the service provisioning time can be shortened from several hours to minutes. Through fault analysis and alarm analysis, it can greatly improve the operation and maintenance capability. Together with periodical preventive maintenance and network prediction, it can reduce the potential network risks. At the Mobile World Congress Shanghai 2019, the SDON solution jointly developed by China Unicom Ningxia and ZTE won the “Best 5G Network Solution Award”.

In 2020, ZTE was the first to complete the CPE HUB OTN field test organized by China Mobile, successfully implementing multi-vendor end-to-end service provisioning and control disaggregation in the service convergence scenario. It meets the flexible and open networking requirements of China Mobile, improves the deployment efficiency, and provides positive guidance for the follow-up CPE OTN deployment of different vendors.

4 Global Practice and Prospects

ZTE has been exploring for more than 20 years in the WDM/OTN field, and has accumulated rich technical experience and technical innovation capability. ZTE Intelligent E-OTN 2.0 solution can fully meet the requirements of various application scenarios in the 5G era. ZTE has been committed to building ultra-broadband, flexible, intelligent and convenient all-optical transmission networks for operators, maximizing network values and providing high-quality user experience.

Thanks for the advantages of technologies and solutions, ZTE has deeply cooperated with mainstream operators, and its optical network products have been deployed worldwide. So far, ZTE has more than 600 100G and beyond 100G OTN networks, including China Mobile, China Telecom, China Unicom, Telefonica, VEON, MTN, LG U+ in South Korea, True in Thailand, Viettel in Vietnam and Vi in India.

According to Omdia's latest report, ZTE ranked top 3 in the optical network market and top 2 in the OTN Switching and Access OTN markets. In the latest GlobalData product rating report, ZTE ZXONE 9700 remains the "Leader" position in "Core Packet Optical Transport" and the

"Metro Packet Optical Transport", meanwhile the ZXMP M721 remains the "Very Strong" position in "Access Packet Optical Transport", all of which are in the leading positions in the industry.

In the future, ZTE will continuously strengthen the R&D investment in the WDM/OTN field, and promote the innovation of optical network technologies. ZTE will actively embrace the wave of the 5G era, and establish closer partnership with global operators to jointly build “ultra-broadband" "efficient transport" and " intelligent management" optical networks, creating a bright future for human societies.

5 Abbreviations

Abbreviation	Full name
ICT	Information and communications technology
eMBB	Enhanced mobile broadband
uRLLC	Ultra reliable & low latency communication
mMTC	Massive machine type of communication
DCI	Data center interconnect
MEC	Mobile edge computing
SDO	Software-defined optical
OXC	Optical cross-connect
SDN	Software defined network
ROADM	Reconfigurable optical add / drop multiplexer
WSS	Wavelength selective switch
OTDR	Optical time-domain reflectometer
OSC	Optical supervisory channel
FIC	Fabric interface chip
SBI	Standardized southbound / northbound interface
CPE	Customer premise equipment
RCA	Root cause analysis
OVPN	Optical virtual private network
API	Application programming interface