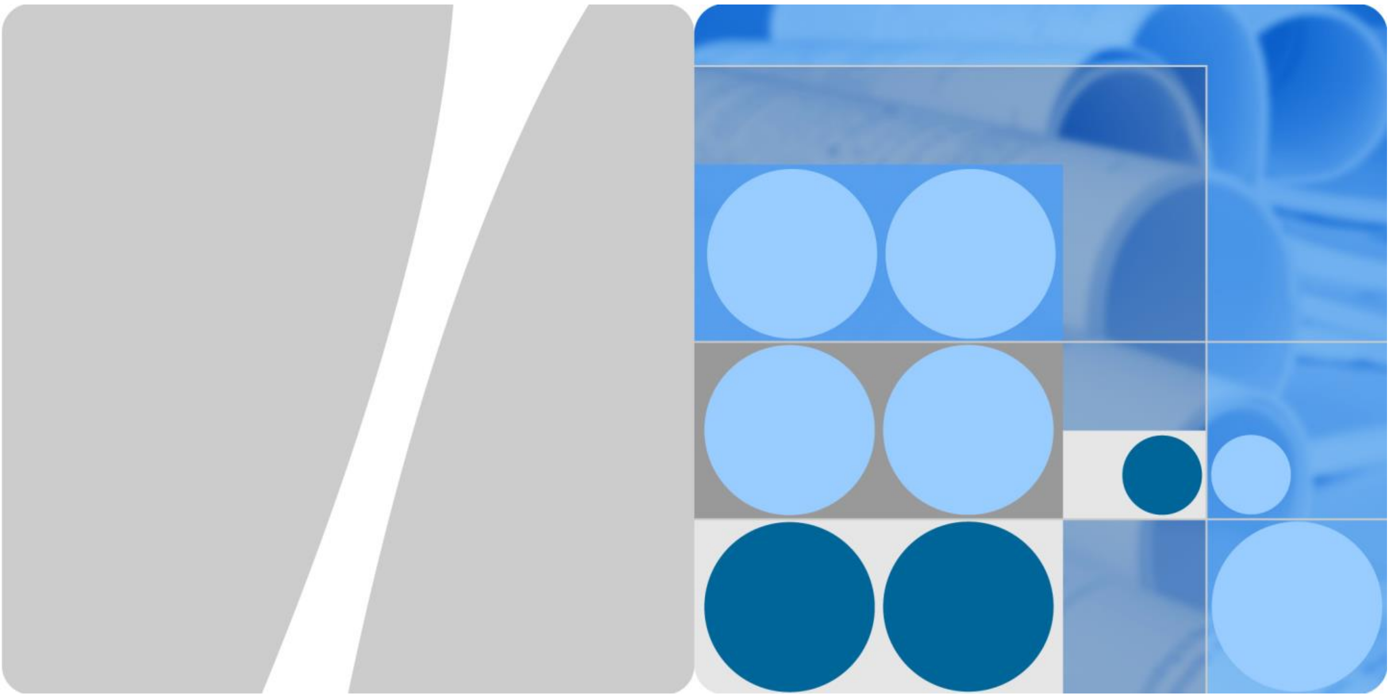

Edge OTN Technical White Paper

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1 Trends and Challenges of FMEC

1.1 Growing Requirements on High-Quality Services

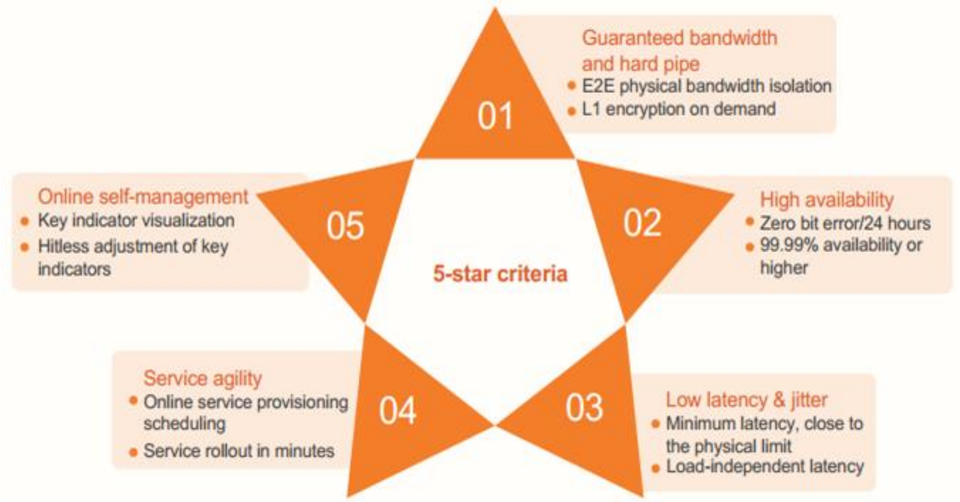
Broadband plays a vital part in our work and daily lives. Its importance has led to users prioritizing service experience and quality, and as a result, carriers are also shifting their focus to service quality in order to align with this trend.

Premium Private Line

Government and enterprise private lines yield much more than mobile services and home broadband services, making them a highly sought after value proposition for carriers. Such private lines do, however, place greater demands on infrastructure networks. One of the reasons for this is that different industries have specific quality requirements for private line services. For instance, the finance industry values latency, whereas the government values reliability, both of which differ significantly to large enterprises or Internet OTTs that prioritize self-service experience.

Carriers need to provide five-star private lines to cater to users from different industries. To measure this, the Next Generation Optical Transport Network Forum (NGOF) has researched and released the five-star private line indicator, which redefines network KPIs of enterprise private lines from five dimensions: high availability, assured bandwidth, low latency and jitter, service agility, and online self-management.

Figure 1-1 Five-star indicator for premium private lines

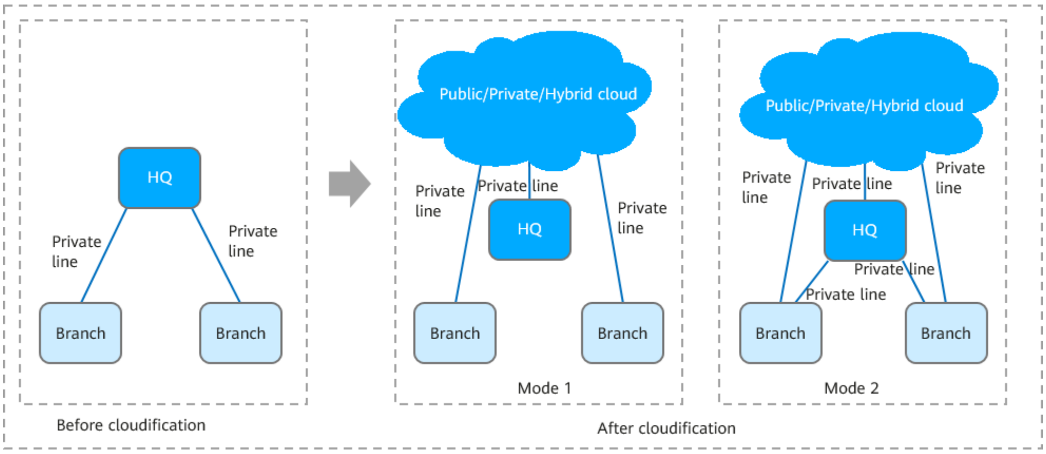


Quality to the Cloud

The trend of industry digitization coupled with the COVID-19 outbreak have caused businesses to migrate their services to the cloud to facilitate working and learning from home. The cloud computing market is expected to reach US$350 billion by 2023, according to Gartner.

Enterprise private line services have gradually evolved from the conventional HQ-branch structure to HQ-cloud-branch, widening the carrier market for small and medium-sized enterprises. High-end industry customers value the reliability, security isolation, low latency, convenience, and flexibility of cloud services.

Figure 1-2 Private line cloudification requirements



Premium Home Broadband

Video services are a basic service on home broadband networks, and the demand for them will only increase as 4K, 8K, VR, AR and ultra HD become more widespread. According to Omdia's latest forecast, videos will account for 82% of all Internet traffic by 2022, and 100 million minutes of videos will be transmitted through networks every second.

HD videos display rich images that are very immersive, but they also cause high traffic. These demands on the bearer network are reflected in the bandwidth, latency, and packet loss rate, which in turn must use an architecture with a lower convergence ratio to achieve one-hop service transmission that is stable and provides low latency to ensure smooth video playback.

Table 1-1 HD video quality requirements

Indicator	Fair-Experience Phase (4K)			Comfort-Experience Phase (8K)		Ideal-Experience Phase (12K)	
Type	4K live streaming	Weak-interaction VR	Strong-interaction VR	Weak-interaction VR	Strong-interaction VR	Weak-interaction VR	Strong-interaction VR
Bandwidth	54 Mbit/s	≥ 60 Mbit/s	≥ 80 Mbit/s	≥ 120 Mbit/s	≥ 130 Mbit/s	≥ 420 Mbit/s	≥ 540 Mbit/s
Latency	20 ms	≤ 20 ms	≤ 20 ms	≤ 20 ms	≤ 20 ms	≤ 15 ms	≤ 8 ms
Packet Loss Rate	1E-6	≤ 1E-5	≤ 1E-6	≤ 1E-5	≤ 1E-6	≤ 1E-6	≤ 1E-7

1.2 The Convergent Services Trend

As our demands break the traditional boundaries of mobile and fixed communication, and enterprises continue to integrate communication, IT, and cloud, a growing number of carriers are launching the FMEC service to expand their service boundaries and attract high-value customers. Convergent services include services that bind mobile communications, fixed communications, and entertainment for individuals and families, and services that bind communications, IT, and cloud services for enterprises to help build a fully connected world.

- Individual users generally pursue ubiquitous connection, breaking the traditional boundary of mobile communication and fixed communication requirements. A single service cannot generate enough user loyalty to prevent users from switching services, but a package that incorporates MBB traffic, home broadband, and video services is nevertheless attractive.
- With the cloud-based transformation of enterprise users and gradual convergence of communications, IT, and cloud service requirements, communication connections grow in importance once service systems are migrated to the cloud. Mobile and remote office, and cloud-based operations become new working habits. High-value users require unified ICT services.

Carriers that provide only single services are inferior in the market. Under this global trend, convergent services have become a prevailing trend. By 2025, over 90% of top carrier networks will be constructed with FMEC, and almost all of these carriers will develop FMEC services.

Figure 1-3 Proportion of FMEC network construction for 241 top carriers

Source: Huawei survey and forecast on 241 top carriers

Convergent services will bring the following advantages to carriers:

- **Expand business boundaries and increase revenue**: Seek new business opportunities in a saturated market. Mobile carriers vigorously develop broadband services, and fixed network carriers vigorously develop private line services to become comprehensive carriers, boost revenue growth, and strengthen the risk resilience of enterprises.
- **Enhance customer experience and boost customer loyalty**: The one-stop package integrates all services to efficiently enhance customer loyalty and boost customer experience.
- **Improve operation efficiency and cut operation costs**: Reuse existing infrastructure for multiple purposes on the same network to maximize the value of carriers' networks, improve network resource utilization, and cut network operation costs.

1.3 Challenges of FMEC Network Construction

Carriers have a long-standing tendency to use the separated network construction mode when single services are developed into FMEC services. This means that mobile services, enterprise private line services, and home broadband services are developed separately and form independent networks.

Figure 1-4 Conventional separated network construction mode

As the network scales up and service development reaches a certain stage, the conventional separated network construction mode faces the following challenges:

- High network construction costs

  The consumption of optical fibers and equipment room resources is high. If the optical fibers and equipment room resources are insufficient, the network cannot be fully covered. The costs for deploying or leasing optical fibers and equipment rooms are high, while networking multiple sets of equipment also increases power consumption.

- Complex network maintenance

  Separated network construction results in disjointed resource management, difficult resource sharing, and slow O&M response. On top of this, maintaining multiple networks is demanding and costly.

- Difficult coordination between bearing and coverage

  Due to uncertain service development, high-value areas cannot be accurately identified, and the network coverage of these areas is insufficient. For example, in hotspot areas, services develop rapidly, network traffic is heavy, and devices are frequently upgraded and expanded. As a result, auxiliary facilities such as equipment rooms, optical fibers, and power supplies cannot be supplied in time, affecting long-term service development and user experience.

If the separated network construction mode is still used for the large-scale development of fixed broadband (FBB), mobile broadband (MBB), and private line services, considerable investment will be wasted, and the flexibility and scalability of network construction and service access will be severely restricted. As a result, users cannot enjoy the services they need.

1.4 Summary

Carrier infrastructure networks face a number of new challenges along with the high requirements of services on bandwidth, latency, jitter, reliability, and security, as well the development of convergent services for carriers. On top of this, costs, a limited budget, and operation restrictions make it almost impossible to provide a basic bearer network for each service type. Carriers need to build a high-quality and scalable bearer network for FMEC to quickly develop integrated services and provide high-quality experience to remain competitive in a fully-connected world.

2 Edge OTN: Optimal Choice for FMEC Network Construction

2.1 Edge OTN Architecture

Networking Architecture

Edge OTN consists of aggregation sites, access sites, and the corresponding management and control system. It supports multi-service bearing and one-hop connection from an access site to an aggregation site to build a flexible bearer network.

- **Networking Architecture Requirements**

  Edge OTN needs to use the one-hop connection network architecture from an access site to an aggregation site. Such architecture has the following advantages:

  - On-demand precise bandwidth expansion

    For hotspot sites that suffer from poor bandwidth during service development, you only need to expand the capacity of hotspot sites without changing intermediate nodes. In this way, you can quickly expand the network capacity and protect investment.

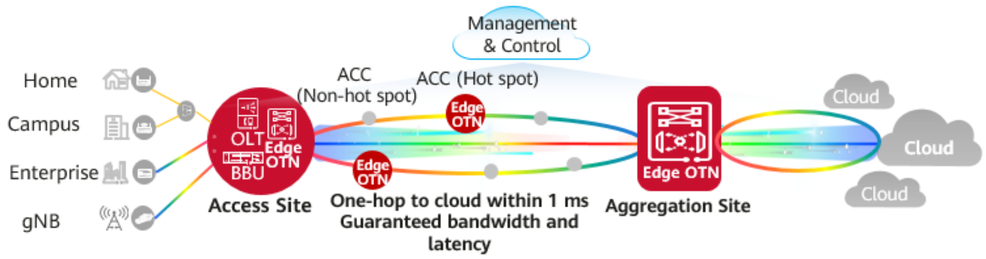
  - Path with optimal latency

    For latency-sensitive private line services in finance, securities, and active-active DCs, low latency is the core competitiveness. Latency is generated by optical fibers and device forwarding hops. The one-hop connection architecture can reduce the number of device forwarding hops to achieve optimal latency.

- **Bearer Technology Requirements**

  Edge OTN uses the OTN/Liquid OTN bearer technology to encapsulate multiple access services into an ODU/OSU pipe, simplify the network-side bearer technology and networking architecture, provide high-quality bearer channels of 2M to 100G+, and maximize the value of access sites and optical fibers.

Figure 2-1 Edge OTN architecture



Functions of an Access Site

- Deployment in any environment: The network location of an access site is low-lying, and therefore providing an equipment room is a challenge. To overcome this issue, the access site needs to support indoor and outdoor deployment.
- Highly integrated equipment: The equipment room space at an access site is insufficient, and as a result, optical and electrical subracks need to be integrated into one subrack to save space.
- Access of any service: Private line services have a wide range of bandwidth, most of which are small-granularity services, with 90% of them being lower than 100 Mbit/s. Some services, however, use traditional E1 interfaces (2 Mbit/s). In contrast, enterprise cloudification has resulted in increasing large-granularity GE/10GE private line services. On top of this, 100GE high-speed ports are used for inter-DC synchronization as data centers (DCs) move downwards. Therefore, Edge OTN must have an access capability of 2 Mbit/s to 100 Gbit/s to meet different service bandwidth requirements.
- Highly efficient and reliable bearer pipes: The bandwidth of some services (such as private line services) is lower than 100 Mbit/s. Meanwhile, the carrying efficiency of small-granularity services needs to be improved, and the physical isolation requirements of high-quality services must be met.
- Simplified O&M: Since there are a large number of access sites, intelligent and automatic O&M capabilities are required to reduce OPEX.

Functions of an Aggregation Site

- Strong environment adaptability: Supports outdoor deployment when there is no equipment room.
- Devices with large-capacity grooming capabilities: An aggregation site usually connects to several or even dozens of access rings based on the site location. On average, the bandwidth of an access ring reaches 50 Gbit/s to 100 Gbit/s through one-hop connection to an aggregation site. In some densely populated areas, the bandwidth even reaches 200 Gbit/s or 400 Gbit/s.
- 100G+ line in the upstream direction: Delivers high-bandwidth DC interconnection and long-term service development.
- Bandwidth aggregation: Services on multiple low-bandwidth ports of a ring can be aggregated to a high-bandwidth port for upstream transmission to decrease the port density of upper-layer devices.

2.2 Precise Network Deployment Based on High-Value Areas

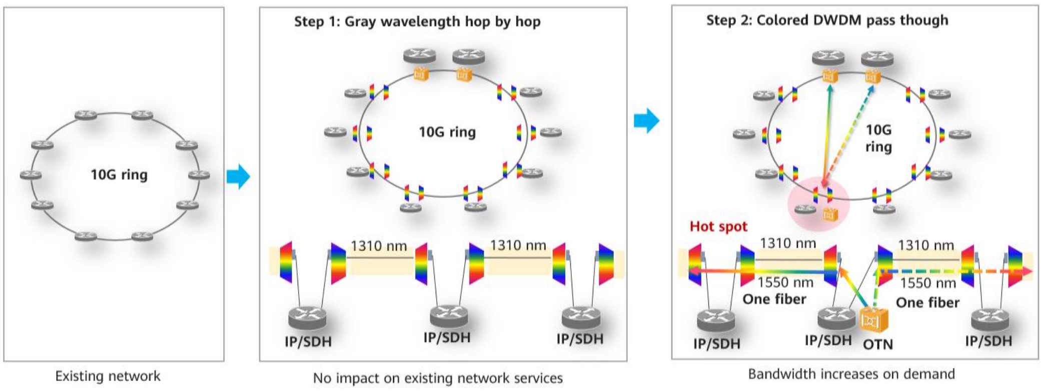
If OTN devices are simultaneously deployed at all sites, FBB, MBB, and private line access can be provided quickly, although it is costly. Therefore, Edge OTN provides a deployment policy of "optical first, electrical later, and network construction based on high-value areas". In this way, more than 40% of initial investment can be saved, relieving the burden on capital and improving ROI.

The goal of FMEC network construction is to flexibly adapt to all-service development requirements, but not to migrate all enterprise services on the live network to the new bearer network. Carriers require that the new network fully protect existing network investment. However, FMEC may face challenges in a new service field, but carriers hope that they can make better investment and flexibly cope with future service requirements.

When a conventional OTN network is being constructed, the optical layer and electrical layer need to be deployed at each site. However, for mobile carriers, home broadband and private line services are the main cause of traffic for bandwidth upgrade on an access ring, but these services are uneven on the access ring. On an access ring, and based on the distribution of people and business buildings, only sites in some areas have access points that need to be covered by home broadband or private line services. These sites, which are also known as integrated service access areas (sub-COs), account for approximately 20% to 30% on the access ring.

For this reason, Edge OTN should adopt a brand-new network construction mode called "optical first, electrical later". In the initial phase of network construction, only the optical layer is deployed to allow existing IP/SDH services to pass through. This protects investment by reusing existing devices. The electrical layer is superimposed on demand only at high-value hotspot sites that require new AirPON, and OTN private line services. Such a network construction mode is ideal for the service development trend of implementing step-by-step network investment, prolonging the investment period of carriers, achieving PAYG, greatly reducing the initial investment threshold, and improving investment efficiency.

Figure 2-2 Edge OTN construction strategy: optical first, electrical later



The Edge OTN solution lets carriers select different network construction modes based on network construction requirements and service planning in different phases.

Investment Focus	Concurrent Optical/Electrical	Optical First, Electrical Later

Investment Focus	Concurrent Optical/Electrical	Optical First, Electrical Later
Network construction cost	The initial investment (one-off investment) is high.	The initial investment is low and capacity can be expanded on demand.
Service capability	Integrated services can be developed at any site.	Integrated service access sites (hotspot sites) need to be planned.
Service development period	This mode is recommended for new network construction. If this mode is used to reconstruct an existing network, existing services need to be changed.	This mode can be used for both new network construction and existing network reconstruction. This will not affect live-network services.

2.3 Summary

From a network architecture perspective, Edge OTN is based on the one-hop connection architecture, and supports deployment in any environment and access of any service. It also provides optimal latency and on-demand smooth capacity expansion capabilities to cope with 10-fold or even 100-fold bandwidth growth, making it future proof for the next decade. From a network construction mode perspective, Edge OTN effectively reduces initial investment through the "optical first, electrical later, and network construction based on high-value areas" principle. It is the optimal choice for FMEC network construction as its flexible network architecture can handle any potential issues regarding service development.

3 Key Edge OTN Technologies

3.1 Environment Adaptability Enhancement Technology

The condition of an equipment room at an access site is poor and lacks basic air quality control such as air conditioners. To cope with these environments, Edge OTN devices need to be more adaptable to such environments to prevent possible device corrosion caused by temperature, wet dust, or sulfidation.

To enhance the anti-corrosion capability of devices, the corrosion failure mechanism of electronic components and printed circuit boards (PCB) needs to be thoroughly researched. Protection measures need to be taken at multiple layers, including cabinets, subracks, boards, and components, to isolate key corrosion factors and block corrosion occurrence conditions.

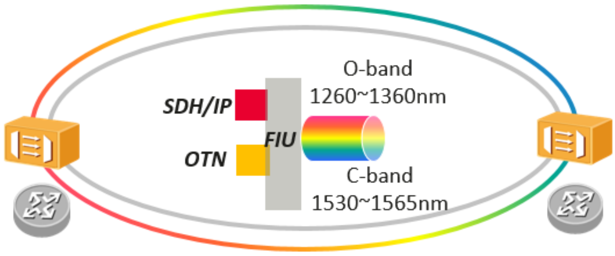
- Intelligent heat dissipation: The fuzzy proportional–integral–derivative (PID) intelligent speed adjustment algorithm is used to decrease the fan speed and blow away corrosive materials such as dust and salt mist on boards.
- Anti-corrosion: Sensitive components such as the backplane, connector, fan, and power supply, are coated to prevent corrosion.
- Precise temperature control: The temperature of devices and boards is accurately controlled to reduce humidity in the component microenvironment and prevent corrosion.

3.2 Hybrid Transmission of Gray and Colored Light

To smoothen FMEC network investment and efficiently reuse existing network resources, Edge OTN must support gray light pass-through on the live network. The wavelengths of an FIU board are specifically designed so that gray light (O-band) and colored light (C-band) can be transmitted in the same pair of fibers.

Services can pass through existing IP/SDH gray rings on the live network using O band. This process requires no reconstruction on the network, protecting existing device investment. On top of this, no modification or migration is required for existing services, cutting service interruption time by 90%, and slashing service migration risks and costs. In this way, smooth network evolution is achieved.

Figure 3-1 Hybrid transmission of gray and colored light

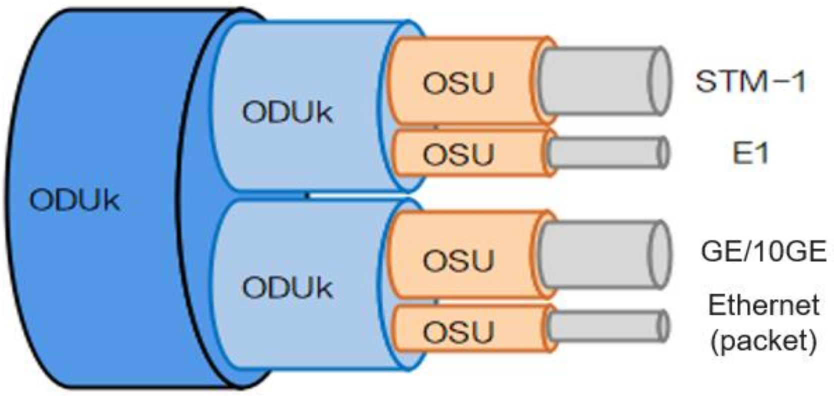


3.3 Liquid OTN Technology

Conventional OTN has large pipe granularities and multiple multiplexing layers. Edge OTN needs to support the Liquid OTN technology to provide high-quality bearer pipes, delivering flexible bandwidth and unified transmission, as required by FMEC.

An optical service unit (OSU) container is added to Liquid OTN. The OSU container divides an ODU into smaller bandwidth granularities to implement flexible OSUflex pipes with adjustable bandwidths ranging from 2 Mbit/s to 100 Gbit/s and support hybrid transmission of multiple services.

Figure 3-2 ODU/OSU-based bearer technology



As a next-generation optical transmission technology, Liquid OTN can bring the following key benefits:

- **Simplified architecture**: Liquid OTN evolves multi-service and multi-plane bearing to multi-service access and unified bearing, implements physical isolation based on ODUk/OSUflex hard pipes, and defines different bearing quality requirements for pipe slices.

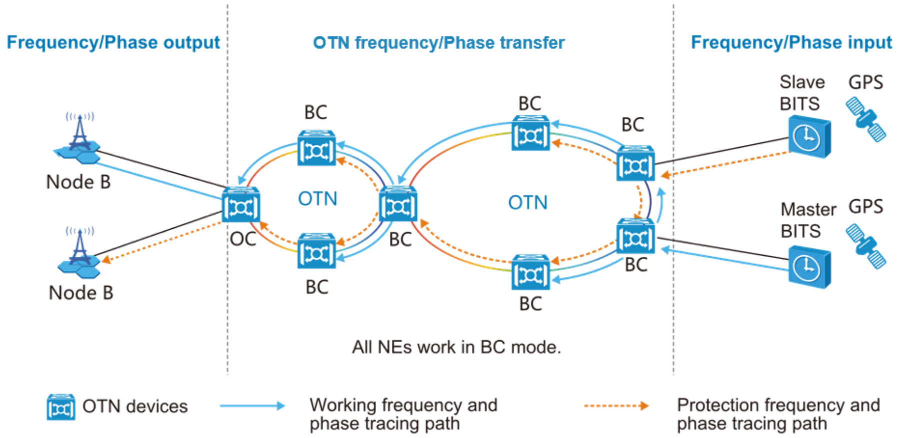
- **Efficient bearing**: The flexible OSUflex pipe minimizes the granularity of network hard slices from 1.25 Gbit/s (ODU0) to 2 Mbit/s (OSU), improving flexibility by 500 times. The number of supported basic pipes is increased from 80 x ODU0 to 1000 x OSUflex and bandwidth utilization reaches nearly 100%.
- **Ultra-low latency**: Liquid OTN simplifies the mapping mechanism, reduces processing layers, provides differentiated latency levels, and reduces per-site latency by 70%. This enables carriers to provide more latency packages based on different service requirements to support the sales and business monetization of network latency resources.
- **Hitless bandwidth adjustment**: Liquid OTN supports seamless and hitless bandwidth adjustment, ensuring 100% bandwidth utilization, meeting temporary and unplanned bandwidth requirements, implementing refined bandwidth resource management and control, and providing on-demand bandwidth consumption services.

3.4 High-Precision Time Synchronization

The TDD mode, which divides the same communication frequency band into different timeslots for upstream and downstream transmission. In principle, time synchronization is required for alignment between different timeslots. If the base station time is not synchronized, inter-base station interference occurs, and this can cut off network access for a large number of users or lead to deteriorating service quality. TDD base stations require a time synchronization precision of ±1.5 μs. However, future-oriented coordination services, such as separated multiple point (SMP), require an end-to-end synchronization precision of ±350 ns.

Edge OTN must support high-precision time synchronization to provide ground time synchronization for networks. To provide precise synchronization, Edge OTN must work in all-BC clock mode to achieve a synchronization precision of 10 ns to 30 ns for each site. In the conventional two-fiber bidirectional synchronization technology, time deviation may occur due to different lengths of optical fibers in the transmit and receive directions. As a result, a large number of site-by-site time deviation tests and compensation settings are required. This means that Edge OTN must support OSC single-fiber bidirectional time synchronization to avoid compensating for asymmetric transmission over optical fibers in the transmit and receive directions and improve deployment and O&M efficiency of a time synchronization network.

Figure 3-3 Time synchronization scheme



4 Huawei Edge OTN Solution

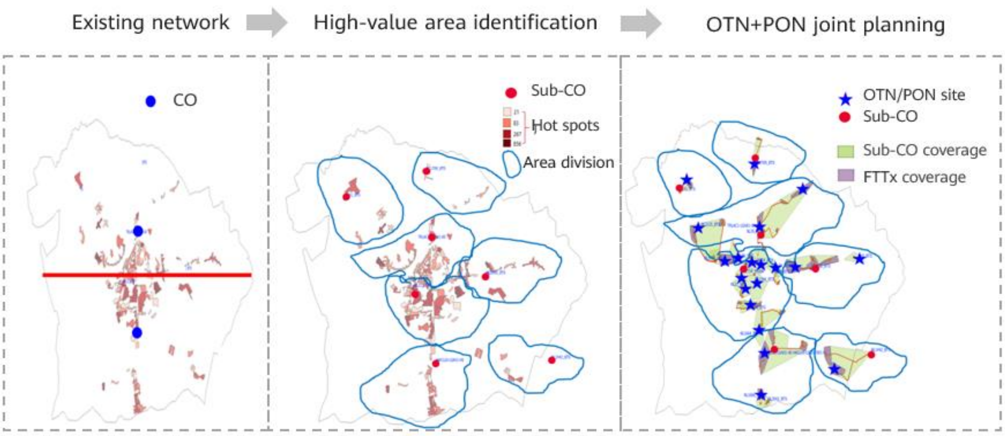
4.1 Accurate Planning Tool

Mobile carriers lack the rich FBB/private line operation experience that fixed network carriers have in FMEC network construction. Therefore, planning and design are critical.

Edge OTN provides uNetBuilder, an automatic planning tool, to help customers identify high-value areas (integrated service access areas), precisely construct networks, and support joint planning with home broadband AirPON and enterprise private line access points. In this way, the precise network construction policy of "optical first, electrical later" is followed. The optical and electrical layers are simultaneously deployed in hotspot areas (high-value areas), of which only the optical layer needs to be deployed in non-hotspot areas, maximizing ROI.

- Based on GIS big data, uNetBuilder uses models such as area value indexes to identify high-value users from multiple dimensions, including the number of households, building type, house rental rate, house price, construction period, and wireless traffic. By clustering high-value users, uNetBuilder can further identify high-value areas.
- uNetBuilder supports automatic and accurate route restoration and CTC algorithm. It automatically selects the most cost-effective option from massive sites to plan the integrated service access area.

Figure 4-1 Integrated service access area planning



4.2 All-Scenario Deployment

Edge OTN uses the highly integrated OSN 1800 series to adapt to all scenarios and reuses site infrastructure to provide customers with a fast and cost-effective network construction solution. The OSN 1800 II TP or OSN 1800 II Pro 2U subrack is used at an access site, whereas the OSN 1800 V Pro 5U subrack is used at an aggregation site, achieving "one fiber for one ring, one box for one site, and one board for one direction".

Outdoor Cabinet Solution

The outdoor cabinets of the Edge OTN solution are IP55 grade waterproof and dustproof. Outdoor cabinets also leverage the patented heat exchanger technology to improve heat dissipation by 30% and support stable operation in high-temperature environments. To strengthen device performance in challenging environments, two layers of two-plane protection and 23 rounds of spraying are added to the cabinet to achieve high anti-corrosion. And finally, the outdoor cabinet can operate for 20 years in areas within 500 meters of the coast.

Table 4-1 Outdoor cabinet specifications

Name	Appearance	Specifications

Name	Appearance	Specifications
M500 outdoor cabinet		• Dimensions (H x W x D): 1600 mm (1850 mm when an enhanced heat dissipation module is configured) x 650 mm x 480 mm • Scenario: aggregation site • Cabinet capability: A maximum of two 5 U subracks can be installed in a cabinet. An OTN device and an OLT can be installed in the same cabinet. The maximum heat dissipation capability is 2300 W.
M50 Pro outdoor cabinet		• Dimensions (H x W x D): 650 mm x 220 mm x 380 mm • Scenario: access site • Capability: A maximum of one 2 U subrack and one 1 U subrack can be installed in one cabinet. An OTN device and a mini OLT can be installed in the same cabinet. The maximum heat dissipation capability is 1000 W.

Aggregation Site Solution

OSN 1800 V Pro devices are deployed at an aggregation site. The optical layer supports one direction and two slots (1D2S) to add/drop 40 wavelengths, while the electrical layer supports 400G per slot. The optical-electrical integration platform supports flexible planning of subracks and slots.

Table 4-2 OSN 1800 V Pro specifications

Name	Appearance	Specifications
OSN 1800 V Pro		• 5 U chassis with 14 service slots • Up to 400G per slot at the electrical layer • Optical-layer 1D2S, adding/dropping of 40 wavelengths

The OSN 1800 V Pro can be installed indoors and outdoors.

- Indoor deployment: The OSN 1800 V Pro can be installed in a 21-inch or 19-inch cabinet. A maximum of six subracks can be installed in a cabinet to implement high-density aggregation, improving cabinet space utilization by 100%.

- Outdoor deployment: The M500 outdoor cabinet is used to meet the deployment requirements of an equipment room. The OSN 1800 V Pro can be installed with the OLT/BBU in the same cabinet.

Figure 4-2 Aggregation site solution

Access Site Solution

OSN 1800 II TP/OSN 1800 II Pro devices are deployed at an access site. The optical layer supports 1D1S to add/drop four wavelengths while the electrical layer supports 400G per slot. The optical-electrical integration platform supports smooth expansion.

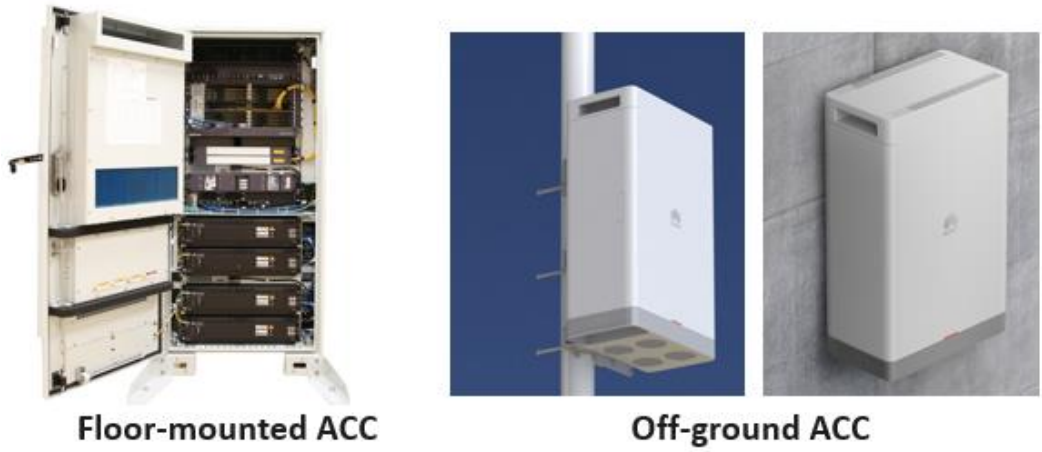
Table 4-3 OSN 1800 II TP/OSN 1800 II Pro specifications

Name	Appearance	Specifications
OSN 1800 II TP		• 2 U chassis with 6 or 7 service slots • Up to 400G per slot on an electrical-layer board • Optical-layer 1D1S, adding/dropping of four wavelengths • Distributed electrical-layer cross-connection
OSN 1800 II Pro		• 2 U chassis with 6 service slots • Up to 400G per slot on an electrical-layer board • Optical-layer 1D1S, adding/dropping of four wavelengths • Centralized electrical-layer cross-connection

The OSN 1800 II TP/OSN 1800 II Pro can be installed in an M500 or M50 Pro outdoor cabinet.

- M500 outdoor cabinet deployment: The OSN 1800 II TP/OSN 1800 II Pro can be installed in the same cabinet with a BBU or an OLT to fully reuse existing resources and achieve fast capacity expansion.
- M50 Pro outdoor cabinet deployment: The M50 Pro supports pole-mounted and wall-mounted installation. The OSN 1800 II TP/OSN 1800 II Pro can be installed with a blade BBU or a blade OLT at the same site, leaving no footprint.

Figure 4-3 Access site solution



4.3 Innovative Optical-Layer and Electrical-Layer Solutions

4.3.1 Simplified Optical Layer

Huawei Edge OTN uses 5-in-1 highly integrated optical-layer boards and innovative hybrid transmission technology of gray and colored light to implement the simplified optical layer.

The conventional optical layer requires five boards to implement transmission in one optical direction. Edge OTN integrates all optical-layer modules, such as the OA, OTDR, FIU, multiplexer/demultiplexer, and OSC boards in one optical direction into one board.

- The access site uses the 1D1S board to support adding/dropping of four wavelengths.
- The aggregation site uses the 1D2S board to support adding/dropping of 40 wavelengths.

The space occupied by 5-in-1 optical-layer boards is reduced by 80%, while the number of fiber connections between optical-layer boards is reduced by 70%. One-click fiber connection verification is supported, shortening the commissioning time by more than 80% and reducing the single-site delivery cost by more than 20%.

Figure 4-4 Highly integrated optical layer

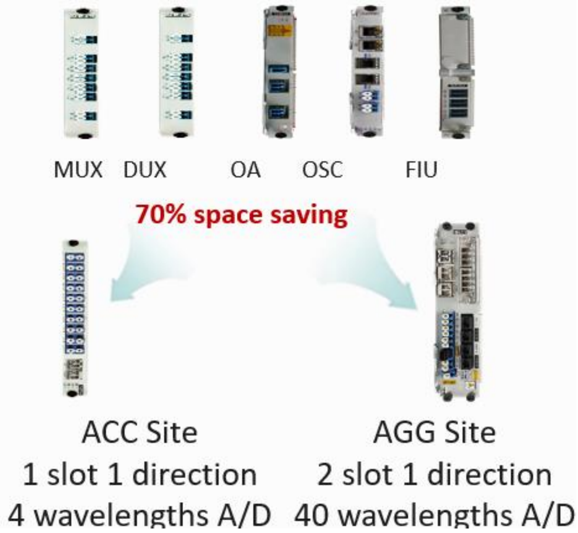


Table 4-4 Key optical-layer boards

Name	Appearance	Specifications
MD40AFS		• 1D2S optical-layer board, adding/dropping of 40 wavelengths • Integrated OSC/OTDR/OA/FIU/MUX-DEMUX board • Dual-slot
MR4AFS		• 1D1S optical-layer board, adding/dropping of four wavelengths • Integrated OSC/OTDR/OA/FIU/MUX-DEMUX board • Single-slot

4.3.2 X+Y Distributed Electrical Layer

Edge OTN utilizes innovative X-Mesh backplanes and Y-Ponder electrical-layer boards to support flexible grooming and capacity expansion of access sites.

- The Y-Ponder electrical-layer board uses the "tributary-line-backplane" Y-shaped architecture. It supports service access on both the client and backplane sides, improving line bandwidth utilization, and reducing electrical-layer costs and power consumption.
- The X-Mesh backplane can reduce the cost and power consumption of initial deployment. Meanwhile, through proper slot planning, the backplane can support service cross-connections between tributary boards and line ports without the need to deploy high-cost and high-power-consumption centralized cross-connect boards, which reserves resources for future electrical-layer capacity expansion.

The X+Y innovative distributed electrical layer supports multiple service models. The client side directly receives early FBB/MBB services from the Y-Ponder board and aggregates them to line ports for transmission. In future capacity expansion, only tributary boards need to be added to receive new services such as private line services. The services are then groomed to line ports through the X-Mesh backplane for transmission, resolving the issue of insufficient ports on the Ponder board, as well as allowing the remaining bandwidth on the line side to be fully utilized. This can result in improved line bandwidth utilization by 40% and reduced power consumption by approximately 15%.

Figure 4-5 X-backplane+Y-Ponder architecture

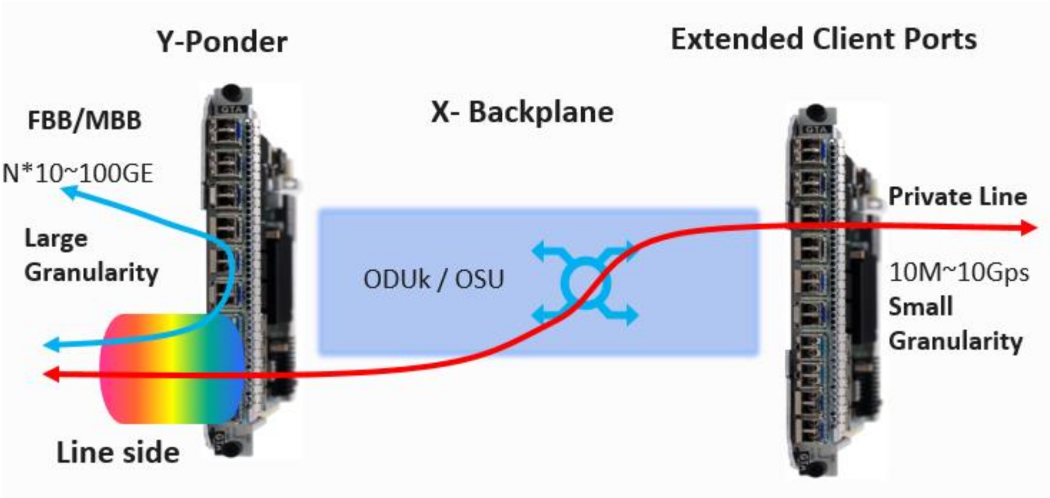


Table 4-5 Key electrical-layer boards

Name	Appearance	Specifications
MTA		• 4 x 25G Y-Ponder board • 4 x 10G/25G on the line side, 6 x 10GE on the client side • Single-slot
MDC		• 50G Y-Ponder board • 1 x 25G/50G on the line side, 1 x 40GE/50GE on the client side • Single-slot
MDCA		• 200G Y-Ponder board • 1 x 200G on the line side, 2 x 100GE + 10 x 10GE on the client side • Dual-slot
LDCD		• 2 x 200G Ponder board • 2 x 200G on the line side, 4 x 100GE on the tributary side • Single-slot

4.3.3 More Line Rates

Edge OTN supports multiple WDM-side rates, such as 10G, 25G, 50G, 100G, and 200G, to satisfy different bandwidth models.

The older 10G access ring bandwidth can no longer meet modern service requirements, but the upfront cost of one-step expansion to a 100G network is also too high. This highlights the urgent need for FMEC networks to have proper medium-rate line ports that can facilitate smooth network construction.

OTU25 and OTU50 correspond to 25G and 50G, and were standardized and released in Recommendation ITU-T G.709.4 in March 2020. They have already become new options for access-layer networks, namely because 25G halves both the cost per bit and power consumption, compared with 10G.

Table 4-6 Optical modules

Optical Module Type	Appearance	Description
10G SFP+		Line-side colored light, non-coherent
25G SFP28		Line-side colored light, non-coherent
50G QSFP28		Line-side colored light, non-coherent
100G/200G CFP2		Line-side colored light, coherent

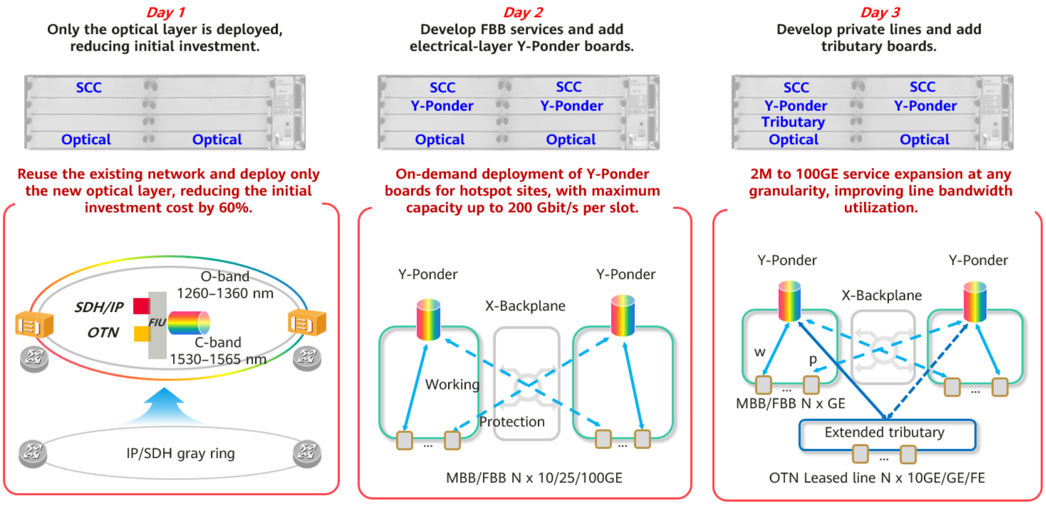
4.3.4 The Smooth Evolution Solution

Edge OTN is an innovative solution for the hybrid transmission of gray and colored light. By optimizing the design of multiplexer and demultiplexer modules, Edge OTN enables gray light (O-band) and colored light (C-band) to be transmitted in the same pair of fibers, bringing 800-fold improvement to overall fiber capacity and maximizing the value of existing networks.

- Services can pass through existing IP/SDH gray rings on the live network using O band with no requirement for reconstruction, protecting existing device investment. Moreover, no modification or migration is required for existing services, meaning services do not need to be migrated, thereby slashing service interruption time by 90%, and significantly reducing service migration risks and costs. This facilitates smooth network evolution.

- New support for colored light transmission achieves one-hop transmission and on-demand capacity expansion. An access ring supports evolution from 40λ x 10G to 40λ x 200G. With the innovative X+Y distributed electrical-layer technology, capacity can be expanded smoothly and PAYG can be achieved.

Figure 4-6 Continuous evolution, PAYG

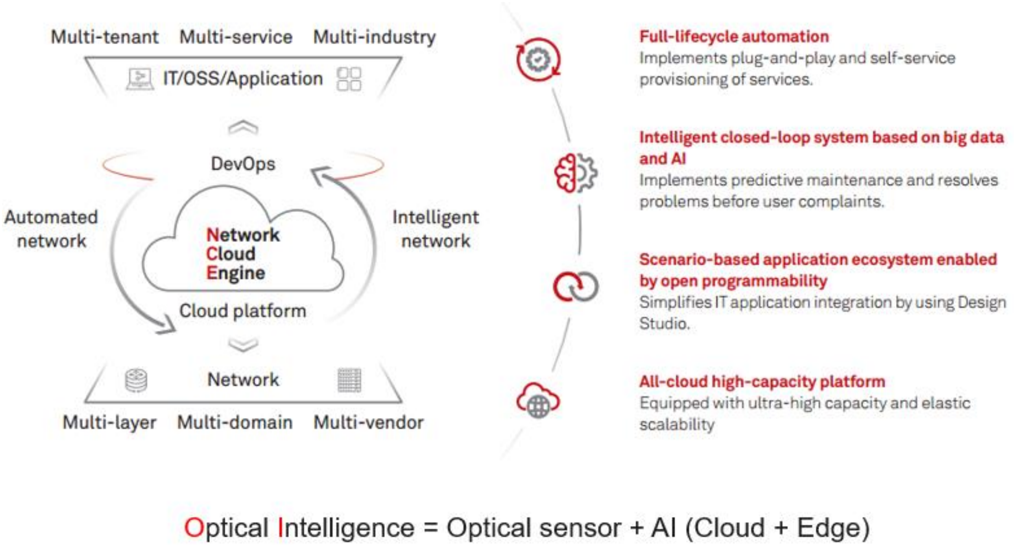


4.4 Intelligent O&M

4.4.1 Intelligent Management and Control via NCE

Huawei iMaster NCE is the industry's first network automation and intelligence platform that integrates management, control, and analytics functions. It bridges the gap between physical networks and business intents, and implements centralized management, control, and analytics for entire networks. It enables resource cloudification, full-lifecycle automation, and data analytics-driven intelligent closure according to business and service intents. On top of that, its open network APIs support rapid integration with IT systems. With key technologies, such as enhanced AI algorithms, big data, computing power, and automation, NCE helps build an intelligent all-optical network.

Figure 4-7 Intelligent O&M



4.4.2 Automatic Optical-layer Commissioning

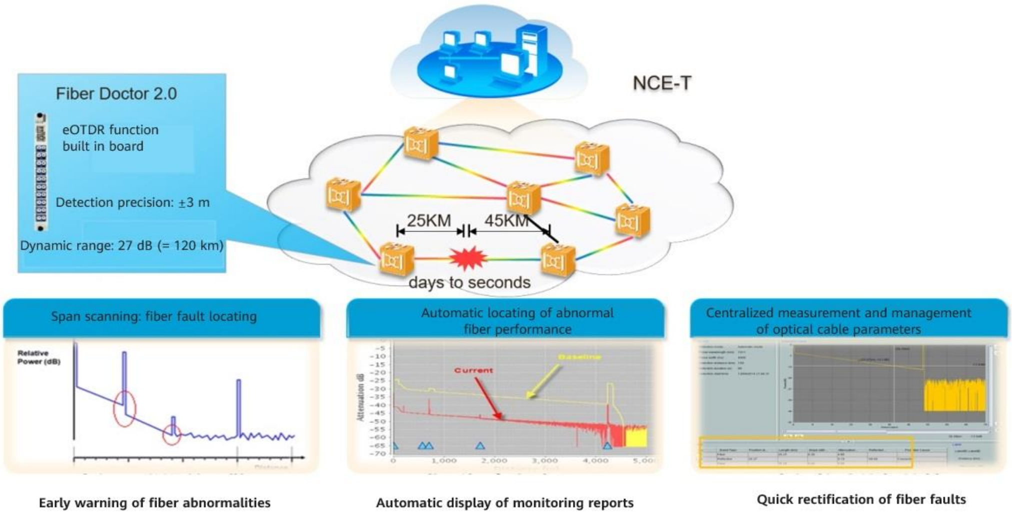
Edge OTN optical-layer boards have built-in optical sensors and support automatic optical-layer commissioning, streamlining the site deployment process.

- Automatic fiber connection detection: During site deployment, after engineers complete device installation and power-on the devices, the software automatically detects whether the physical fiber connections between boards are correct, and if so, generates logical fiber connection configurations, and configures wavelengths for OTU boards by one click. In this way, one-click automatic deployment is implemented, minimizing manual operations and avoiding a second site visit.
- Automatic optical power commissioning: With built-in optical sensors and variable optical attenuators (VOAs), the automatic commissioning tool can automatically adjust the optical power of added/dropped wavelengths and pass-through wavelengths based on the network topology. This relieves the burden on operators and shortens the network commissioning time from days to minutes.

4.4.3 Intelligent Fiber Management

Edge OTN supports the Fiber Doctor (FD) system to monitor and manage line fibers on a network. The FD system modulates OTDR detection signals into OSC signals, detects the fiber loss variation and position based on the Rayleigh scattering and Fresnel reflection principles, and reports the detection data to the NMS. In this way, the line health status and fiber connection status can be accurately detected and monitored online (without affecting services). This helps O&M engineers analyze the quality of fiber connectors and splicing points, quickly locate fiber quality problems, reduce onsite fiber maintenance costs, and facilitate engineering implementation.

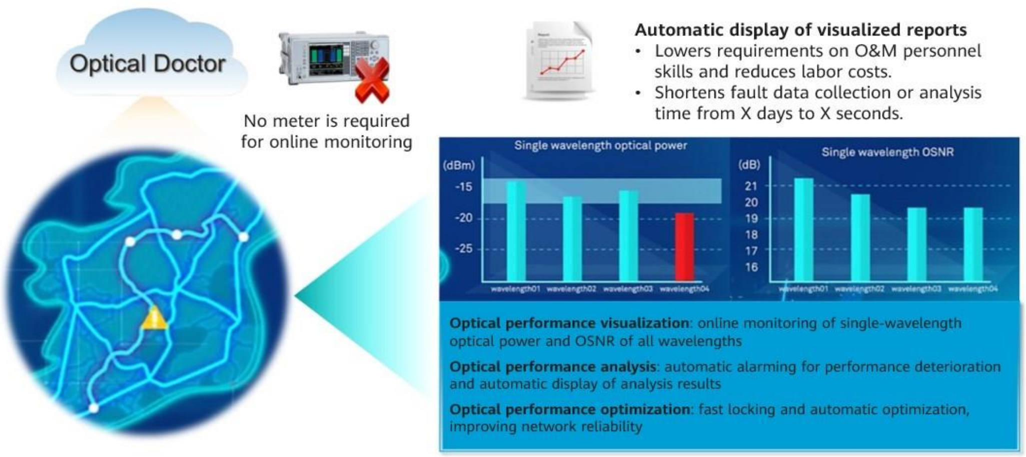
Figure 4-8 FD system



4.4.4 Intelligent Optical Performance Management

Edge OTN supports the Optical Doctor (OD) system to implement end-to-end, refined, and digital management of the optical layer on a WDM network. By using the OD system, Edge OTN can centrally configure optical-layer parameters, and monitor and graphically display OSNRs at various wavelengths and rates. It can also automatically monitor, analyze, commission, and optimize network performance, making OSNR detection more convenient. This consequently simplifies routine optical-layer maintenance and reduces OPEX.

Figure 4-9 OD system



5 Summary

With the trend of rapidly developing high-quality services and the need for carriers to develop FMEC services, the conventional separated network construction mode shifts to the FMEC network construction mode to reduce O&M costs.

Edge OTN combines all-scenario site capabilities, simplified optical-layer technologies, ODU/OSU electrical-layer grooming capabilities, and automatic O&M technologies to provide a groundbreaking FMEC network construction solution. With the one-hop connection architecture and on-demand deployment policy, OTN devices can be quickly deployed at COs or sub-COs such as high-value AirPON sites, cutting network construction costs and accelerating service provisioning.

A Acronyms and Abbreviations

Number	
1D1S	One Direction One Slot
1D2S	One Direction Two Slots
A	
ACC	Access
AGG	Aggregation
AI	Artificial Intelligence
API	Application Programming Interface
AR	Augmented Reality
B	
BBU	Baseband Unit
BC	Boundary Clock
C	
CFP	Centum Form-factor Pluggable
CO	Central Office
CTC	Center & Tree Cover
D	
DC	Data Center

F	
FBB	Fixed Broadband
FD	Fiber Doctor
FIU	Fiber Interface Unit
FMEC	Fixed, Mobile, and Enterprise Convergence
G	
GIS	Geographic Information System
I	
ICT	Information and Communications Technology
ITU	International Telecommunication Union
K	
KPI	Key Performance Indicator
M	
MBB	Mobile Broadband
MUX-DEMUX	Multiplexer/Demultiplexer module
N	
NCE	Network Cloud Engine
NGOF	Next Generation Optical Transport Network Forum
NR	New Radio
O	
OA	Optical Amplifier
OD	Optical Doctor
ODU	Optical channel Data Unit
ODU0	
ODUk	
OLT	Optical Line Terminal

OPEX	Operating Expense
OSC	Optical Supervisory Channel
OSN	Optical Switch Node
OSNR	Optical Signal-to-Noise Ratio
OSU	Optical Service Unit
OTDR	Optical Time Domain Reflectometer
OTN	Optical Transport Network
OTT	Over The Top
OTU	Optical Transponder Unit
P	
PAYG	Pay As You Grow
PCB	Printed Circuit Board
PID	Proportional-Integral-Derivative
PON	Passive Optical Network
Q	
QSFP	Quad Small Form-factor Pluggable
S	
SDH	Synchronous Digital Hierarchy
SFP	Small Form-factor Pluggable
SMP	Separated Multiple Point
T	
TDD	Time Division Duplex
V	
VR	Virtual Reality

