



Towards an Intelligent World White Paper 2023

# All-Optical Network

Intelligent OptiX Network,  
Empowering Industries with AI



---

## Trend 1 | Home Broadband Accelerates All-Optical Gigabit Coverage and Gives Rise to 10G

---

1.1. Multi-Service Homes, More Terminals and Apps, and HD/Interactive Experience .....	01
1.2. Fiber-in Copper-out and Gigabit Broadband Driven by Lower Costs and Preferential Policies .....	02
1.3. Commercial Use of 50G PON in 2024 to Boost 10G Applications .....	03
1.4. Suggestion: Accelerating Fiber Construction for 10G PON Ready Networks and Piloting 10G Services .....	03

---

## Trend 2 | All-Optical Home Network Development Picks Up Speed Driven by New Services and Premium Experience

---

2.1. Current Networks No Longer Meet the Requirements of Smart Home Experience .....	04
2.2. Home Networking as a Major Operator Service Drives FTTR Into a Full Bloom .....	05
2.3. FTTR Bringing Additional Smart Home Revenues .....	06
2.4. New Services and High Experience Requirements Call for Premium Broadband Services .....	06
2.5. Suggestion: Continuously Improving FTTR Standards and Capabilities for Extensive Deployment and Long-Term Benefits .....	07

---

## Trend 3 | Campus are Going All-Optical, Realizing "Zero-Wait, Zero-Frame-Freezing, and Zero-Fault"

---

3.1. FTTO Meets the Requirements of Campus Cloudification and Sustainable Development .....	08
3.2. FTTO Enables Hard Isolation of Office, Security, and Other Services over One Network, Reducing over 70% .....	09
3.3. FTTO Becomes the Best Partner for Campus Wi-Fi 7 to Evolve from GPON/XGS-PON to 50G PON .....	10
3.4. Suggestion: Continuously Building Consensus on FTTO Standards and Capabilities .....	10

---

## Trend 4 | Industry Communication Networks Are Upgraded and Developed Towards Digitalization and More Reliable Connections

---

4.1 Industries Such as Energy and Transportation Are Upgrading Towards Intelligence, Green and Low-Carbon Development, and Networked Control .....	11
4.2 Multiple Networks Are Converged to Meet Production Networks' Requirements for Physical Isolation, High Bandwidth, Wide Connection, and Low Latency .....	12
4.3 Time for SDH Network Upgrade, with the Latest fgOTN Standard Being the Best Solution .....	13
4.4 Suggestion: Helping Enterprises Upgrade Digitally and Build a High-Quality Industry Communication Network That Features Multi-Network Convergence .....	13



---

## **Trend 5 | Network DCI, East-West Traffic Surge, Transmission Capacity Upgrade, and Large-Scale Application of High Baud Rate Technologies**

---

5.1 Rapid Growth of Global Data Centers Places Higher Demands on DCI .....	14
5.2 High-Baud-Rate Technologies Are Mature, and 400G/800G Ultra-Long-Haul Transmission Capability Has Been Verified .....	15
5.3 Computing Power/DC User Experience Upgrade, Promoting Network Upgrade in Transmission Capacity Quality and O&M .....	16
5.4 Suggestion: Building All-Optical Premium Transmission Capacity Networks, with Single-Fiber Capacity Evolved to 100T to Match Traffic Surge .....	17

---

## **Trend 6 | Traffic and Experience Drive Metro All-Optical Bearing and Grooming, Accelerating the Deployment of Optical Networks**

---

6.1 New Cloud-Based Services Require Differentiated Network Experience, and Explosive Traffic Growth Is Driven by FMC Acceleration and 10G Home Broadband .....	18
6.2 More Optical Networks Are Deployed for Flexible Scheduling of Networks and Improved Automation Capabilities to Efficiently Construct Networks .....	19
6.3 Suggestion: Building Wide-Coverage Metro Optical Networks to Enable Ultimate Service Experiences and Facilitate All-Service Development .....	20

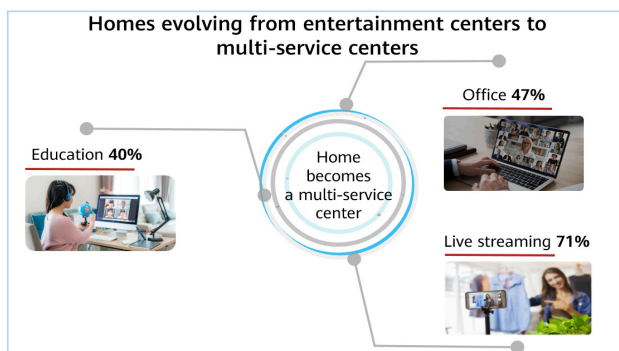
# Trend 1

## Home Broadband Accelerates All-Optical Gigabit Coverage and Gives Rise to 10G

### 1.1 Multi-Service Homes, More Terminals and Apps, and HD/Interactive Experience

#### » Home Transforming to a Multi-Service Center

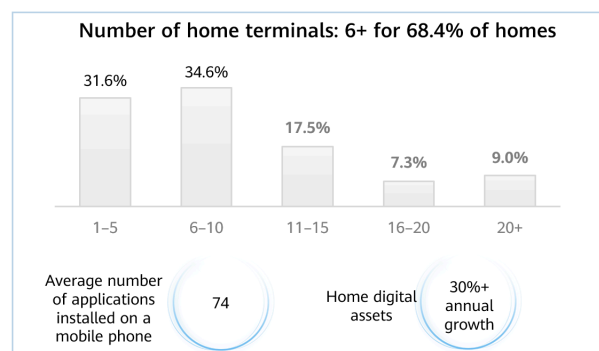
As networks and digital services become widespread, homes have become versatile, undertaking services such as online working, e-learning, and live streaming & e-commerce. These three services have penetrate rates of 47%, 40%, and 71% respectively among broadband users, indicating that network applications have expanded from entertainment to work, study, and other facets of life.



Source: Statistical Report on Internet Development in China, Huawei MI

#### » More Terminals and Apps

Intelligent terminals and apps are developing rapidly as well. Data shows that 68.4% of households in China use more than 6 terminals. An average of 74 apps are installed on each mobile phone. Digital assets such as files, images, and videos have increased by more than 30%, demonstrating that user requirements for networks keep growing.









Data source: 1. Report on Digital Home Index; 2. Mobile

» Rise of UHD and Interactive Applications

The application experience is also evolving towards 8K, interaction, and 3D. Television and OTT providers have introduced 8K channels and content sections. On OTT platforms, the number of anchors has exceeded 10 million and 8K games are launched in 2023.

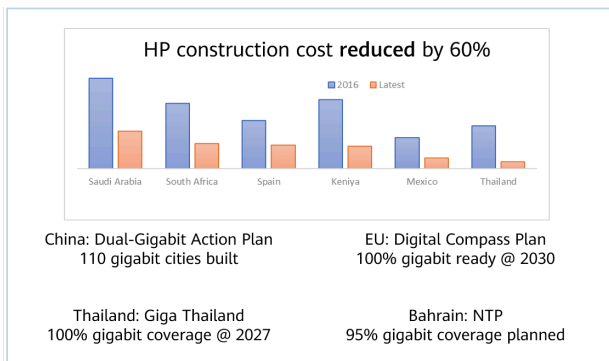
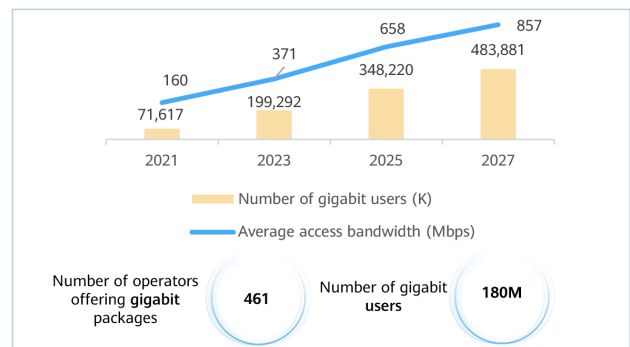
3D display is also advancing rapidly with diverse products, including 3D tablets that are already in commercial use and XR goggles with over 10 million shipments. Looking ahead, interactive applications integrating 8K and 3D display will be the next trend.

<b>Resolution</b> HD → 8K	 China's New Year Eve Gala 8K live @ 2021
	 OTT 8K content section
<b>Interaction</b> One-way → Two-way	 More than 10 million anchors @ 2023
	 <i>The Grass of Genesis</i> 8K gaming @ 2023
<b>Dimensions</b> 2D → 3D	 More than 10 million XR users @ 2023
	 Naked-eye 3D tablet @ 2023

1.2 Fiber-in Copper-out and Gigabit Broadband Driven by Lower Costs and Preferential Policies

» Fast Decrease of HP Cost

Statistics shows that the fiber home pass (HP) cost in major countries have decreased substantially as the network scales out and new solutions become mature. Compared to years ago, the cost has been slashed by 60%. Also, fiber is becoming the infrastructure for global economies and societies, and governments around the world are setting policies to boost the development of fiber-based gigabit networks.

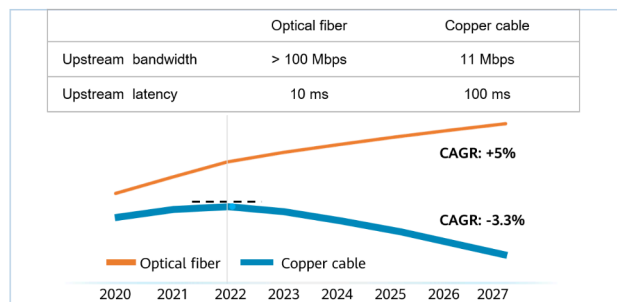


» Fiber in and Copper out

Traditional copper cables provide only 11 Mbps for upstream transmission with latency up to 100 ms, which can no longer meet the requirements of high-quality interactive services. In contrast, fibers not only provide higher upstream bandwidth, but also support smooth evolution with an extended lifespan. Due to these benefits, many operators start migrating to fiber-based networks. Statistics show that the number of copper cable users peaked in 2022 and started to decline in 2023, and it will continue to decrease annually by 3.3% for the next five years.

» Gigabit Broadband Becoming the Mainstream

Fiber HP enables operators to provide users with higher bandwidth. It is estimated that the average access bandwidth around the world will increase from 160 Mbps in 2021 to 857 Mbps in 2027. So far, 461 operators have launched gigabit packages, attracting 180 million users and expecting to serve 500 million users by 2027.



## 1.3 Commercial Use of 50G PON in 2024 to Boost 10G Applications

### » More 10G Application Scenarios

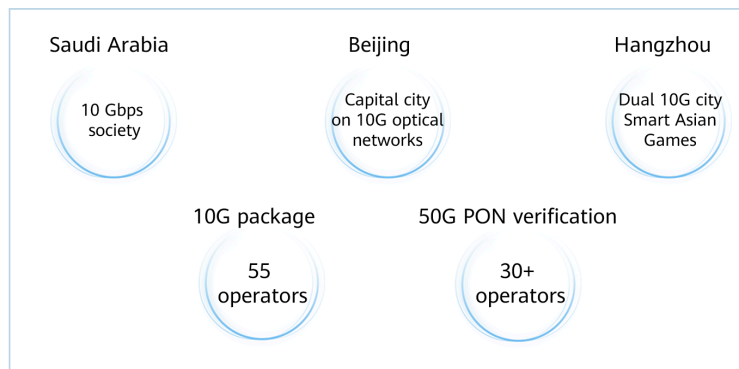
As the next milestone on the F5G-A roadmap, the application scope of 10G have been expanded to smart campus, digital production, daily life, and city governance



### » Operators Launch 10G Packages, Striding Towards the 10G Era

Some regional operators already took a step towards 10G. For example, Saudi Arabia has set the target of "10 Gbps Society". In China, Beijing has unfolded the "Capital City on 10G Optical Networks" initiative, and Hangzhou aims

to build a "Dual 10G City". Moreover, more than 55 operators around the world have launched 10G packages, and Huawei and more than 30 operators have completed 50G PON technology and service verifications. Thanks to these efforts, 50G PON will be put into commercial use since 2024.



## 1.4 Suggestion: Accelerating Fiber Construction for 10G PON Ready Networks and Piloting 10G Services

"To quickly meet user demands on premium fiber access, promote 10G services with improved experience, and continuously benefit from fiber infrastructure, the following measures are recommended for developing fiber networks."

### » Fiber Construction: Governments Making Preferential Policies for Infrastructure Construction and Operators Using Flexible Network Solutions to Expand Coverage

To encourage fiber construction, it is recommended that regulators make related resources available, including pipes and poles, and set preferential policies such as tax reduction. In parallel, operators should adopt flexible site selection, implement thick coverage and short access, and build digitalize ODNs to reduce the TCO for rapid expansion.

### » 10G PON Ready: Introducing 10G PON During Network Planning and Deployment as the Base for Gigabit Services

Operators should consider 10G PON at the beginning of fiber constructions to get ready for quick service provisioning and gigabit upgrade in the future. A 10G PON ready network is compatible with both GPON and 10G PON, which helps save the TCO for future evolution.

### » 10G Service Pilot: Actively Piloting 10G Services to Maintain Competitiveness and Unleash the Potential of Fibers

With 10G on the horizon, regulators should formulate new policies to provide guidance, and operators and industry partners should utilize innovative technologies and architectures to promote new 10G services.



## Trend 2

### All-Optical Home Network Development Picks Up Speed Driven by New Services and Premium Experiences

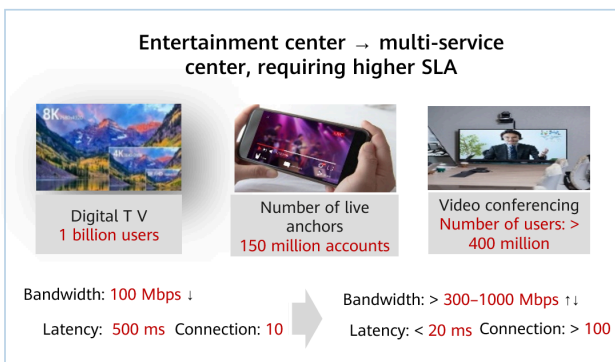
#### 2.1 Current Networks No Longer Meet the Requirements of Smart Home Experience

##### » Homes Evolving from Entertainment Centers to Multi-Service Centers

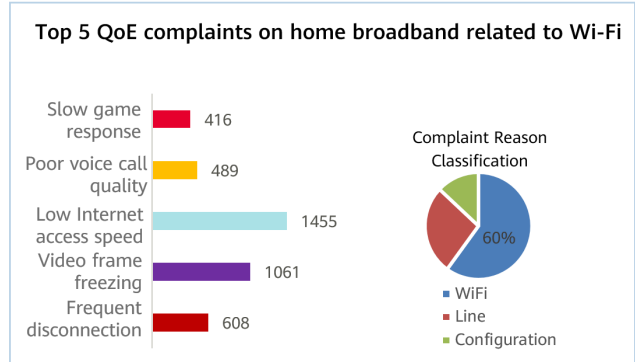
As homes become more digital and intelligent, services such as remote office, e-Learning, and e-commerce live streaming become popular in homes, in addition to entertainment. These services place greater demands on home network SLAs, requiring 10-fold connection capacity, 300-100 Mbps bidirectional bandwidths, and a deterministic latency below 20 ms.

##### » Poor Wi-Fi Experience Causing the Most User Complaints

As intelligent services emerge and flourish, the network requirements of home broadband users keep increasing. Among all broadband complaints, Wi-Fi related ones account for more than 60%, which results in a higher OPEX and churn rate, and hinders the development of home broadband.



Data source: White Paper for Hierarchical Home Broadband, CACIT

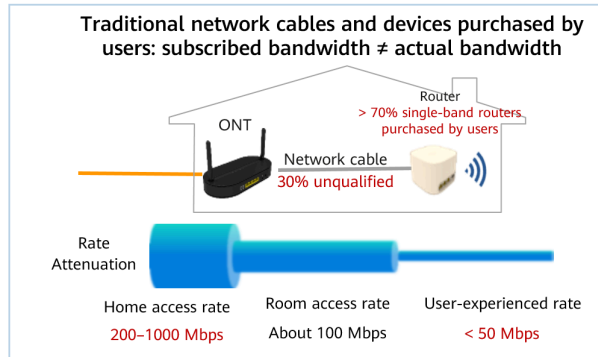


Data source: Poor QoE analysis of an operator in Zhejiang

» Subscribed Bandwidth ≠ Actual Bandwidth

Users have gigabit to homes but can hardly enjoy megabit in rooms. Statistics show that 76% residential users obtain bandwidths below their subscriptions, and Wi-Fi bandwidths inside rooms can be as low as dozens

of megabytes. This is largely due to aging network cables, outdated ONTs, 2.4 GHz single-band routers, and cumbersome networking with various devices from different vendors.

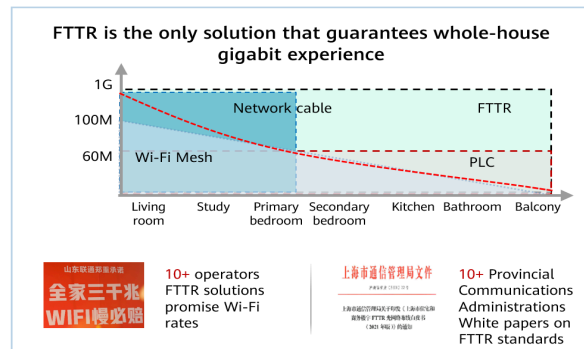


Data source: Statistics of 1.98 million residential users in XX province, China

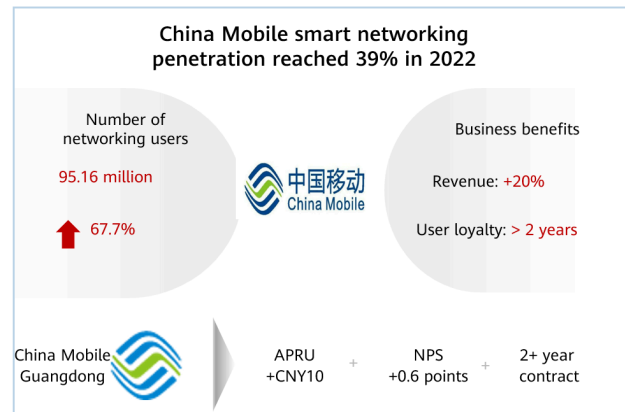
» 2.2 Home Networking as a Major Operator Service Drives FTTR Into a Full Bloom

» From FTTH to FTTR, home networking has become a majorservice of operators.

Thanks to the mass adoption of FTTH, 84% of operators around the world are developing their home networking services. By the end of 2022, the smart networking service of China Mobile has seen a penetration rate of 39%. In addition to ARPU increase, home networking also improves user loyalty with long-term package contracts (2-3 years), and lowers the churn rate.



Data source: CAICT at 2022 China Optical Network Seminar



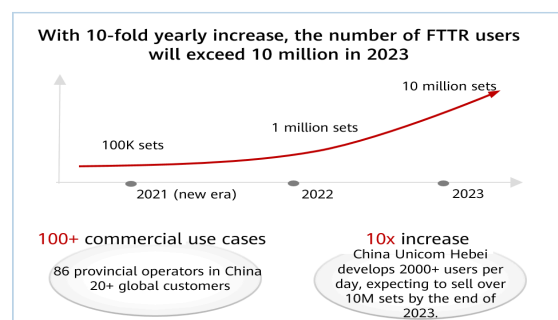
Data source: China Mobile Operations Report 2022

» FTTR Becoming Industry Consensus and Starting to Soar

As gigabit becomes popular, the industry has reached consensus on FTTR + 10G PON to realize true gigabit experience. This consensus is shared by more than 20 operators in the world, including AIS Thailand and CTM Macao in Asia Pacific, STC Saudi Arabia and ET UAE in the Middle East, TDE Spain and VDF Portugal in Europe, as well as Oi Brazil and Entel Chile in Latin America. Tens of millions of residential users around the world have subscribed to FTTR. Leading operators in China such as China Unicom Hebei can develop more than 2000 FTTR users per day.

» FTTR is the only solution that guarantees whole-house gigabit experience.

With more digital home services available, user requirements for Wi-Fi coverage are also growing. Compared to Wi-Fi mesh, PLC networking, and copper cable networking, FTTR provides stable whole-house gigabit coverage without blind spots and supports seamless roaming, laying an all-optical base for digital home applications.



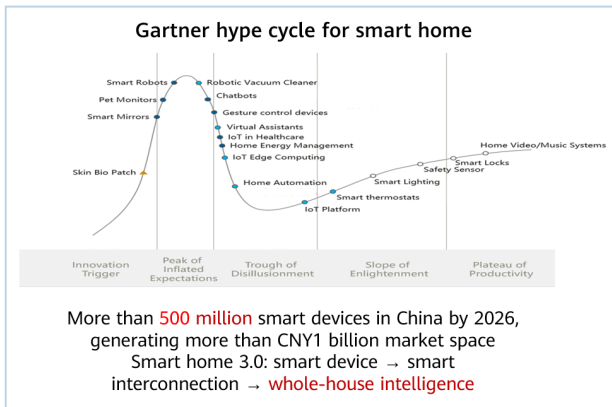
Data source: Huawei MI



## 2.3 FTTR Bringing Additional Smart Home Revenues

### » Smart Home Tides over the Trough and Increases Again with 20%+ CAGR for the Next 5 Years

Shown by the Garner hype cycle, smart home has overcome the trough of disillusionment and entered the phase of steady growth. According to a 2022 Omdia report, the number of smart homes will exceed 200 million globally in the next 5 years and generate market space of more than \$200 billion. At the same time, smart homes will evolve from individual smart devices to whole-house intelligence.



Data source: China Smart Home White Paper

### » Operators Viewing Smart Homes as the Next Growth Engine

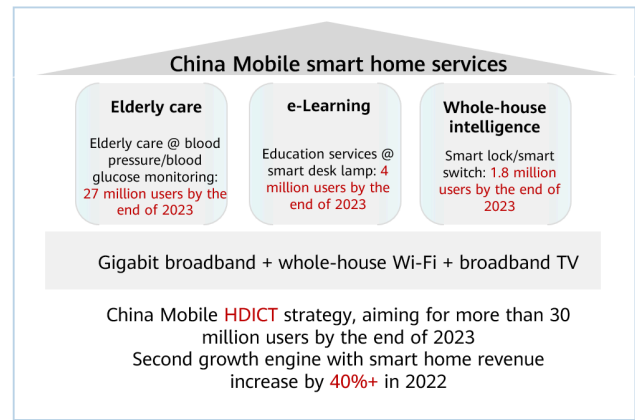
Leading operators such as LGU+, DT, and three major Chinese operators are actively leveraging smart homes to kick into a new gear. China Mobile implements the "HDICT 1+6" strategy, which stands for value-added services including mobile home security, smart home, elderly care, and in-home education, with revenues increasing by 40% in 2022.

## 2.4 New Services and High Experience Requirements Call for Premium Broadband Services

With the rapid expansion of UHD, interactive, and immersive broadband services, users care more about home broadband experience and are willing to pay for it. To address these requirements, operators turn to premium broadband operations in three aspects:

### » Digital Measurement of User Experience

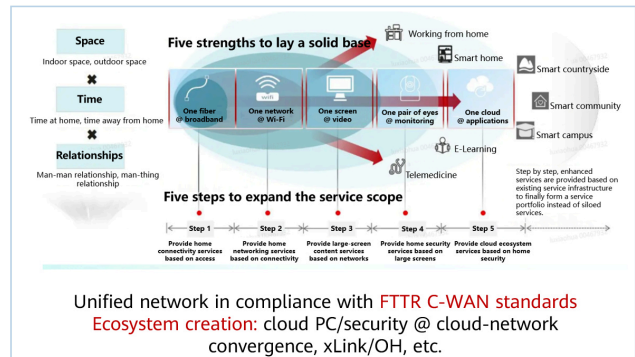
The focus of network evaluation has transitioned from network quality to user experience, and operators need to accurately measure home broadband service performance. Some operators in Latin America use Wi-Fi management systems to measure home Wi-Fi experience. In China, China Mobile is the first operator to pilot the home broadband experience evaluation system, taking a



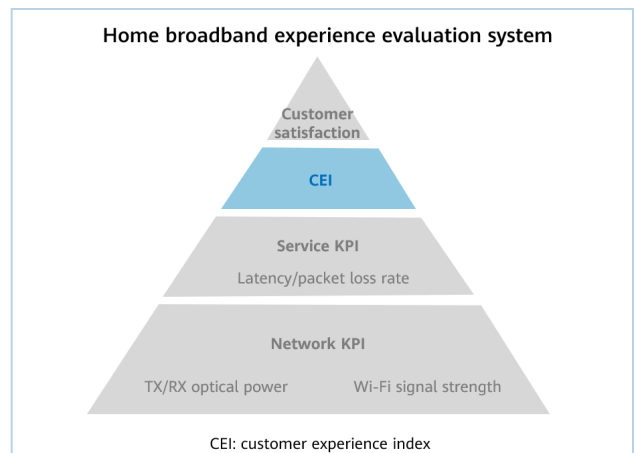
Data source: China Mobile Operations Report 2022

### » FTTH → FTTR → Smart Home

FTTR provides an all-optical base for digital home services with additional revenues. Using the C-WAN architecture to create a unified network, operators can extend FTTR connectivity to whole-house intelligence + cloud broadband + computer sensing, so as to leverage cloud-network synergy to provide new intelligent services.

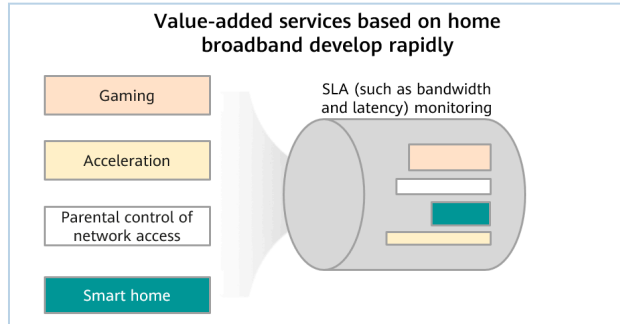


step towards evaluation standardization.



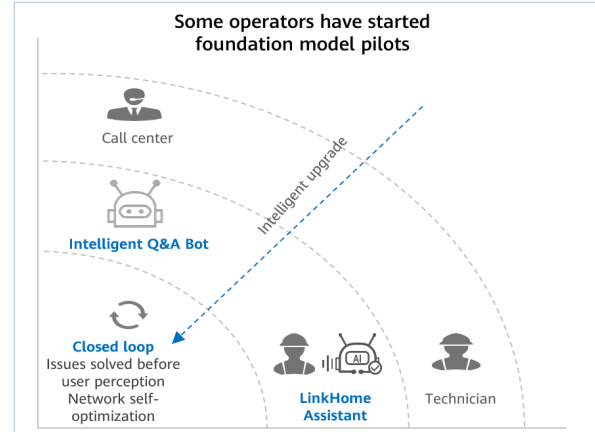
### » Hierarchical Experience Monetization

Operators are developing scenario-specific services based on all-optical networks to increase revenues. In Europe, operators are promoting smart home services such as home security, data storage, video streaming, and healthcare. In the Middle East and Asia Pacific, operators have introduced acceleration services for gaming, e-Learning, and global network access.



### » Proactive User Experience Assurance

Intelligent big data analysis and foundation models can close the loop of experience assurance. The three major Chinese operators and leading operators outside China have all launched their foundation models together with trial applications.



## 2.5 Suggestion: Continuously Improving FTTR Standards and Capabilities for Extensive Deployment and Long-Term Benefits

Telecom operators and related industries should focus on experience monetization instead of bandwidth monetization, keep improving smart home experience of home broadband users, and ensure that true gigabit is available to them. The following measures are recommended for advancing the FTTR construction.

### » Standards First: Creating and Improving the FTTR Standard Ecosystem

To improve FTTR deployment efficiency in residential and commercial buildings, government departments should come together to formulate FTTR standards related to cabling, construction, and acceptance. They should also work with global organizations such as ITU, CCSA, and ETSI to push forward the FTTR standardization, including the measurement standard to evaluate service experience and C-WAN architecture standard.

### » Extensive Deployment: All Out for FTTR

FTTR should be vigorously promoted from all facets,

including operators' commercial package design, construction and acceptance standard setting, engineering team enablement, and preferential policies. Furthermore, the delivery of premium FTTR products and services depends on proper planning, construction, acceptance, maintenance, and operations. By offering FTTR-based packages, operators can provide users with true gigabit experience.

### » Sustainable Development: Incubating Value-Added Smart Home Services Based on FTTR

To gain differentiated advantages, operators can adopt new capabilities such as Nearlink and HarmonyOS to create an all-optical base and service ecosystem for whole-house intelligence. In this way, operators can create a connectivity, control, compute, and storage center for smart communities and smart homes, enhance home broadband quality, and improve user experience.

## Trend 3

### Campus are Going All-Optical, Realizing "Zero-Wait, Zero-Frame-Freezing, and Zero-Fault"

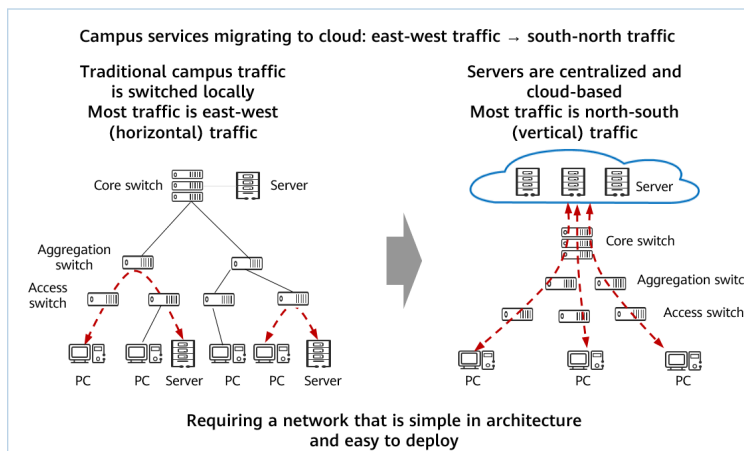
#### 3.1 FTTO Meets the Requirements of Campus Cloudification and Sustainable Development

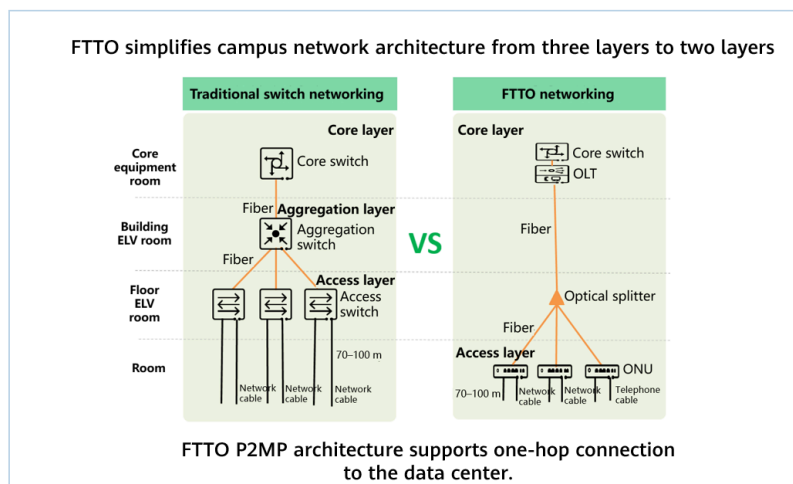
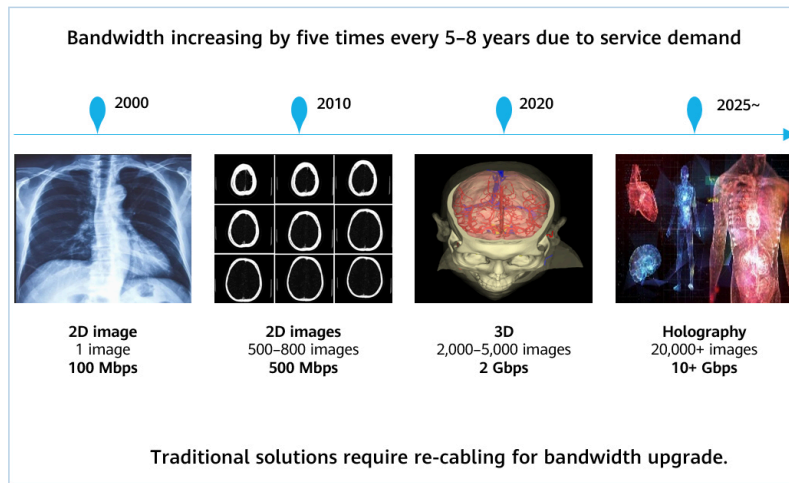
» More enterprises are migrating services to the cloud. It is predicted that 80% of enterprises will have 85% of their services run on cloud and application servers centrally deployed in data centers or on public/private clouds. The traffic model of campus networks has also changed from east-west (horizontal) traffic to north-south (vertical) traffic.

» Bandwidth increases by five times every 5–8 years due to service demand. In traditional solutions, re-cabling is

required each time the bandwidth needs an upgrade.

» Moreover, as campus requirements outgrow the traditional switched Ethernet architecture, enterprises are in urgent need for a network that supports north-south traffic and fast bandwidth increase with a simplified architecture. The Huawei FTTO solution can meet these requirements with P2MP architecture, high energy efficiency, renewable resources, and smooth bandwidth evolution.



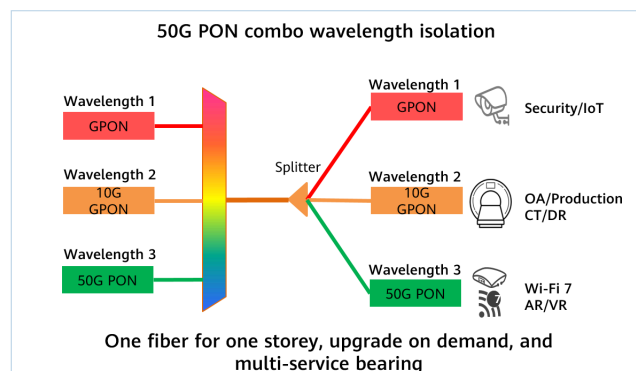
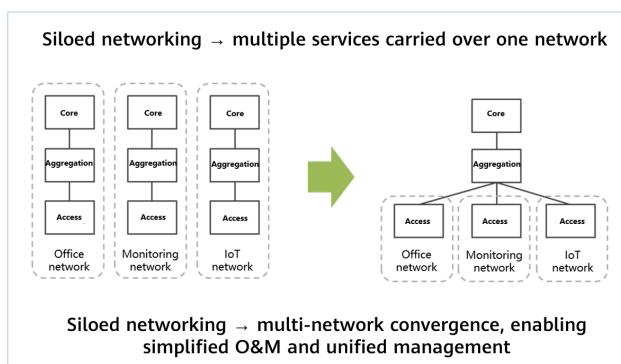


### 3.2 FTTO Enables Hard Isolation of Office, Security, and Other Services over One Network, Reducing over 70%

- » There are many services running in a campus, including office, security, production, and IoT. It is difficult to isolate these services and guarantee service security on traditional networks, which lead to high equipment footprint, large-scale cabling, high investments, and difficult O&M.
- » To achieve lower cost and higher efficiency in network O&M, customers are seeking multi-network convergence and multi-service transport while ensuring service

isolation and security.

- » FTTO provides multiple isolation solutions, including D-NET private network isolation, OSU over PON private line isolation, and 50G PON combo wavelength isolation. With the solutions, all services including office, security, IoT, and production can be carried over one network, reducing 70% cable usage. Therefore, FTTO is applicable to education, healthcare, retail, large business, and many other industry scenarios.

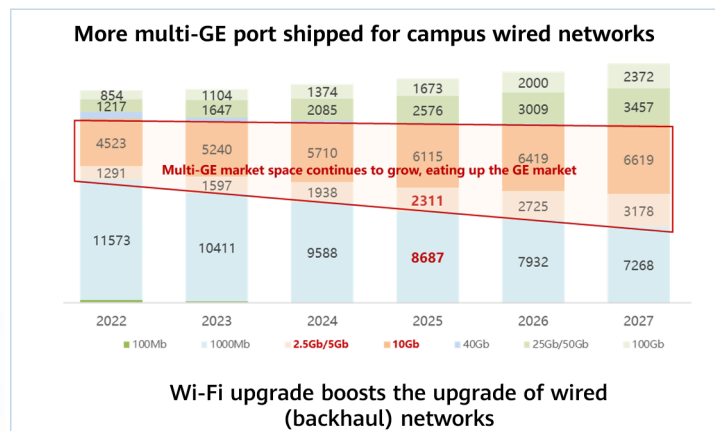
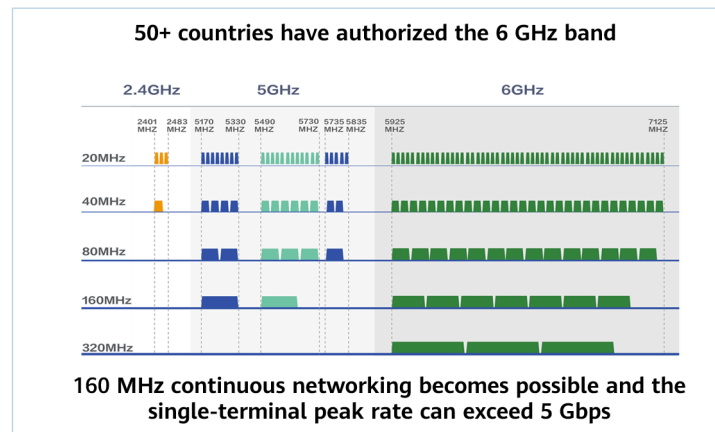


### 3.3 FTTO Becomes the Best Partner for Campus Wi-Fi 7 to Evolve from GPON/XGS-PON to 50G PON

- » Wi-Fi 7 has moved from standardization to commercial use. Since 2022, Wi-Fi 7 chips were launched by vendors such as Qualcomm, Broadcom, MTK, and Intel. More than 50 countries have authorized 6 GHz to Wi-Fi, making 160 MHz continuous networking possible and providing over 5 Gbps peak rate for a single terminal.
- » Wi-Fi upgrade boosts the upgrade of wired (Wi-Fi AP backhaul) networks, and 2.5 GE is the minimum

bandwidth for Wi-Fi 7 APs. The proportion of multi-GE (2.5/5/10 GE) port shipment for campus networks will continue to increase.

- » FTTO supports smooth evolution from GPON/XGS-PON to 50G PON, meeting the requirements of high-burst and high-density bandwidth in campus Wi-Fi. Therefore, it is an optimal choice for Wi-Fi 7 AP backhaul.



### 3.4 Suggestion: Continuously Building Consensus on FTTO Standards and Capabilities

FTTO features full-fiber connection (FFC), enhanced fixed broadband (eFFB), and guaranteed reliable experience (GRE). It is an optimal solution to replace the traditional Ethernet and game changer in improving competitiveness.

- » Enhancing Industry Consensus on FTTO by Expanding Application Scope

It is recommended that stakeholders throughout the all-optical industry — including design institutes, integrators, and typical customers and partners — work together to optimize the FTTO solutions, set engineering standards and specifications, promote demonstrative use cases, cultivate talents, tackle challenges with extensive

collaboration, and ultimately realize sustainable industry development.

- » Replacing Traditional Ethernet Networking with FTTO

Advanced technologies such as FTTO, 50G PON, and network slicing should be applied to campus networks with growing north-south traffic, bandwidth-hungry services, and multi-network convergence. Benefits of these technologies are substantial, including simplified network architecture, easy evolution and O&M, and high reliability. They can greatly reduce the complexity of campus network construction, reduce the TCO and carbon footprint, and improve O&M efficiency.

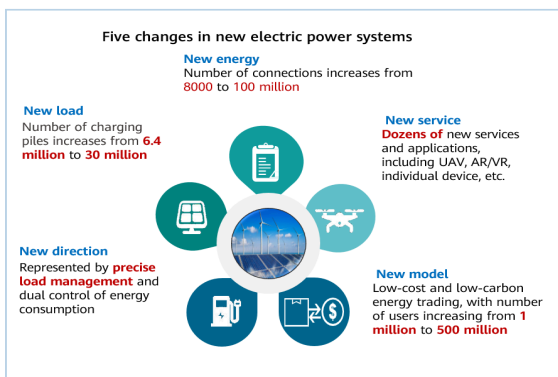
## Trend 4

### Industry Communication Networks Are Upgraded and Developed Towards Digitalization and More Reliable Connections

#### 4.1 Industries Such as Energy and Transportation Are Upgrading Towards Intelligence, Green and Low-Carbon Development, and Networked Control

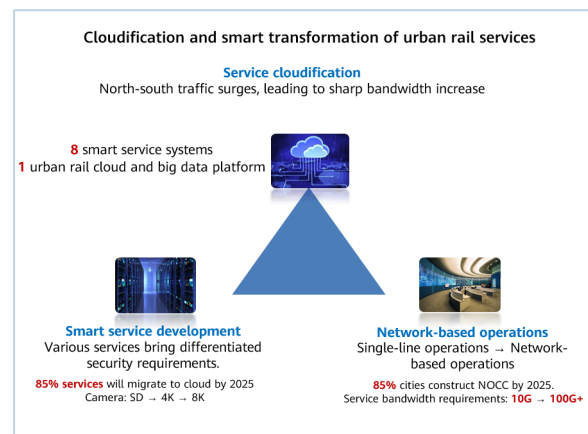
##### » Electric Power

Guided by carbon peak and carbon neutrality strategies, more small-inertia clean energy will be connected to grid. Against the backdrop, the proportion of new energy will reach 48% by 2030. In the future, new power system will undergo five major changes. First, the number of new energy connections will increase to 100 million. Second, the type of new digital applications will increase by several dozens during their deployment from substations to distribution networks. Third, the number of low-carbon energy transaction users will increase to 500 million. Fourth, new energy poses higher requirements on precise load control with low latency and high reliability. Fifth, the rapid development of new energy vehicles brings increase in the number and coverage rate of charging piles.



##### » Urban Rail

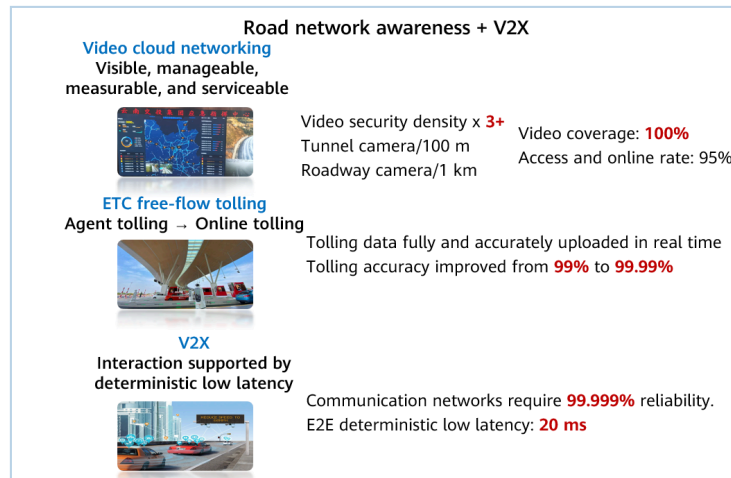
To implement the strategic goal of building national strength in transportation, the urban rail industry proposes to develop smart urban rail. In a development outline by Chinese government, the "1-8-1-1" layout structure (one blueprint, eight intelligent systems, one urban rail cloud and big data platform, and one technical standards system) has been proposed to promote service cloudification and smart transformation. Specific development goals are also provided in the outline. By 2025, 85% services will be migrated to the cloud, posing higher requirements on bandwidth and north-south traffic.



» Highway

Infrastructure has witnessed rapid digital upgrade. Road network awareness and online joint control will be realized by 2025. V2X through smart road + smart vehicles and L2+ autonomous driving capabilities will be supported by 2027. For video security and charging

services, specific quality improvement objectives have been proposed, including great improvements in video spot density, video online rate, and charging accuracy. To achieve smart highways in the future, infrastructure networks with lower latency and higher reliability are required.



4.2 Multiple Networks Are Converged to Meet Production Networks' Requirements for Physical Isolation, High Bandwidth, Wide Connection, and Low Latency

» Electric Power

1. Electric power has been digitally upgraded, with zone III/IV services deployed to distribution networks, calling for multi-network convergence, physical isolation, and unified bearing.
2. The grid connection of small-inertia clean energy and tens of millions of charging piles have posed higher requirements on precise network control, with the latency shortened from seconds to milliseconds.

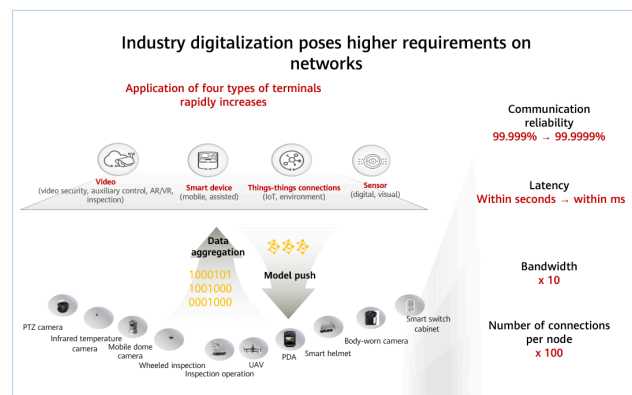
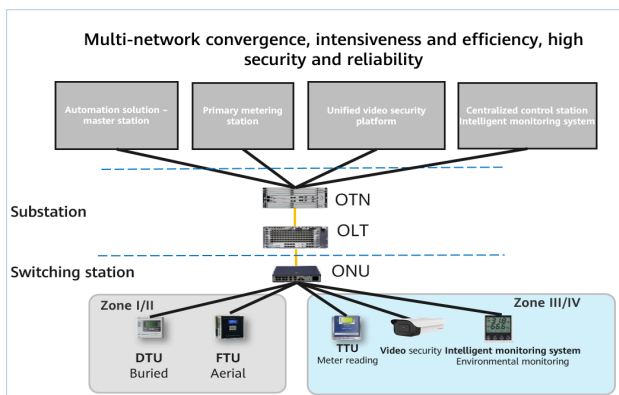
» Urban Rail

Video cloudification and centralized image analysis have brought surging north-south traffic. As such, 10-fold

guaranteed bandwidth and low latency are required to accelerate image analysis.

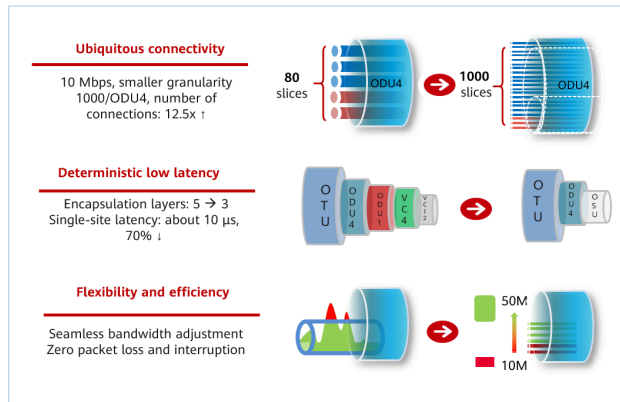
» Roadway

1. Roadside situational awareness of vehicle-road synergy, vehicle to everything (V2X), and intelligent driving have brought 50-fold traffic for one site, calling for high-speed, real-time, stable, and reliable service control networks.
2. In the construction of a modern comprehensive transportation system, more cameras will be deployed for the connection of video cloud, and the online rate requirement of cameras exceeds 99%.

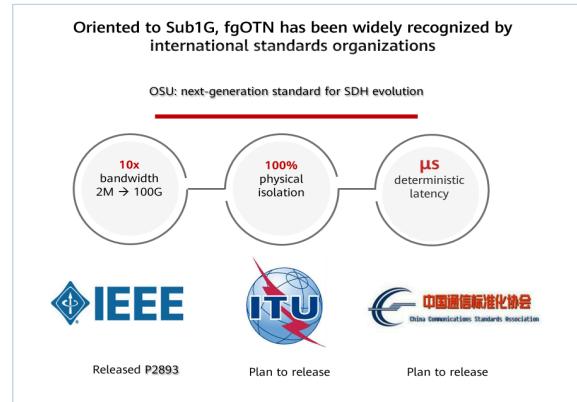


### 4.3 Time for SDH Network Upgrade, with the Latest fgOTN Standard Being the Best Solution

After more than 20 years of use, the industry's SDH production networks failed to ensure industry chain health and keep pace with the evolution of standards and new technologies. For ever-changing digital applications, various terminals, and AV/VR intelligent assistance, the 10G bandwidth upper limit has presented challenges for the industry's further development.



Incorporating SDH's small granularity and OTN's 100G+ high bandwidth, the latest fgOTN technology has become the best technical solution to replace SDH. fgOTN has been widely recognized in the communication industry and will be officially released at ITU-T/IEEE/CCSA by the end of 2023.



### 4.4 Suggestion: Helping Enterprises Upgrade Digitally and Build a High-Quality Industry Communication Network That Features Multi-Network Convergence

#### » Constructing High-Quality Networks Featuring Multi-network Convergence

Industry production networks pose higher requirements for latency and reliability, and industry office networks are increasingly demanding on network bandwidth upgrade. New types of services and applications continuously emerge. Against the backdrop, a high-quality communication base featuring multi-network convergence should be built to pave the way for the industry's digital upgrade.

#### » Upgrading Bandwidth and Fundamental Technologies

OSU technology and industry chain are mature, and related standards have been fully released. Global enterprises have witnessed rapid digital upgrade, leading

to surging bandwidth requirements. It is time for SDH network reconstruction and upgrade. The latest transmission and access technologies can be used for network upgrade to improve bandwidth and network KQIs.

#### » Performing E2E Visualized Management

Network digital twin has been widely recognized in the industry. Industry network requirements are gradually extended and expanded beyond transmission. In addition, the number of access terminals is increasing rapidly, adding complexity to network management. As such, a visible and manageable E2E network from transmission to access should be built to provide an overview for unified management and O&M.





# Trend 5

## Network DCI, East-West Traffic Surge, Transmission Capacity Upgrade, and Large-Scale Application of High Baud Rate Technologies

### 5.1 Rapid Growth of Global Data Centers Places Higher Demands on DCI

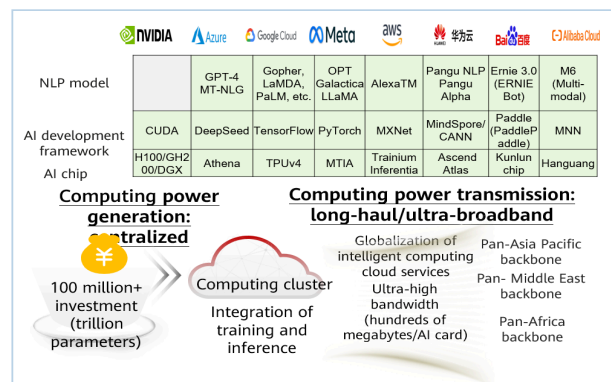
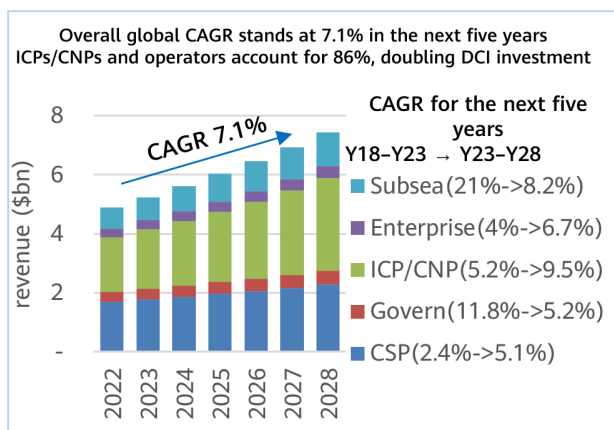
» Data Centers Flourish, Driving Data Center Interconnect (DCI) Demand Growth

The DCI investment scale is growing rapidly, with ICPs/CNPs and CSPs making up a large proportion of the investment: ICPs/CNPs makes up 50% of the investment, and CSPs 36%.

(ICP is short for Internet content provider, typically AAG; CNP is short for carrier-neutral provider, typically Equinix and Digital Realty; CSP is short for communications service provider.)

» OTT Giants Deploy AI Full Stack, and the Generative AI Industry Will Be Rapidly Developed in 2-5 Years

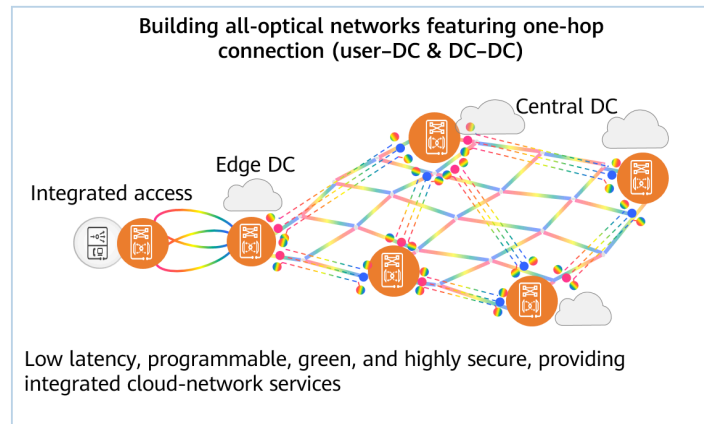
With the rapid development of generative AI, massive bandwidth requirements will be released during the development from text to video and machine awareness. Foundation models drive computing power to the cloud, and a new mode of intelligent computing cloud services has been created, including computing power generation and transmission. Computing service provisioning points tend to be centralized, and computing training requires continuous interaction of new data to enable smarter and real-time judgment. Massive data is efficiently transmitted for hundreds or even thousands of kilometers between DCs and between DCs and enterprises.



» Operators Accelerate the Deployment of Computing Power Centers and Use the Network-Driven Computing Enhancement Strategy to Promote the Rapid Growth of DCI Requirements

Operators in China implement the east-to-west

computing resource transfer project to build high-speed DCI national backbone networks, and tier-1 operators in regions outside China build pan-regional backbone networks to improve single-fiber capacity.



5.2 High-Baud-Rate Technologies Are Mature, and 400G/800G Ultra-Long-Haul Transmission Capability Has Been Verified

Based on the development of the following technologies, the networking capability of 400G optical modules has reached the same level as that of 100G/200G optical modules, covering long-haul and ultra-long-haul backbone transmission scenarios.

1. Mature high-speed optical components: high-speed optoelectronic components with a baud rate of 130+ GBd have been mature in 2023, including modulators, ADCs, DACs, and ICRs, enabling QPSK high-performance encoding for 400G optical modules.
2. Packaging technique has broken the bandwidth limit: Optoelectronic packaging is used to package oDSP, modulator, driver, and receiver on the same substrate.

This helps eliminate the problem of key impedance discontinuity, greatly reduce reflection, and increase bandwidth.

3. High-performance optical algorithms compensate for system performance impairment and allow transmission performance to approach the Shannon limit: The indicator discretization and E2E impairment of optoelectronic components are the main factors that affect performance. DSP algorithm compensates issues including component consistency indicator defects, crosstalk, and nonlinearity using constellation shaping modulation, component impairment calibration, and nonlinearity suppression technologies.

**Technologies with a baud rate of 130+ GBd have been put into large-scale commercial use**

High-performance optical components with a baud rate of 130+ GBd have been mature in 2023. The availability of DSP has been supported by multiple vendors (Acacia/Cisco, Ciena, Infinera, NEL, Nokia, and Huawei)

<p>High-speed optical components <b>90 GB → 130 GB</b></p> <p>Modulator Drive Receiver TIA</p>	<p>Packaging technique breaks the bandwidth limit <b>Isolated → Co-substrate</b></p> <p>oDSP/modulator/ drive/receiver, etc.</p>	<p>High-performance DSP algorithm <b>Approaching the Shannon limit</b></p> <p>Shaping modulation Impairment calibration Nonlinearity compensation</p>
--	--	---

**400G QPSK Performance Test Covers 5000 km+, Meeting Backbone Deployment Requirements**

In June 2023, China Mobile and Huawei jointly completed the live network test and verification for **6028 km 400G** transmission from Ningbo, Zhejiang, to Gui'an, Guizhou. According to the results, the network fully satisfies the requirements of the east-to-west computing resource transfer project. In addition, Huawei uses Super C+L band technology to provide the industry's widest spectrum: 12 THz. <http://qiye.eastday.com/n34/u1ai1117410.html>



In March 2023, Nokia cooperated with GlobalConnect to conduct the first live network test of the sixth-generation super coherent photonic service engine: PSE-6s, which supports a baud rate of 130 GBd, and 1.2 Tbps metro transmission (118 km) and **800 Gbps** long-haul transmission (**2019 km**). [https://it.sohu.com/a/718554148\\_121118997](https://it.sohu.com/a/718554148_121118997)

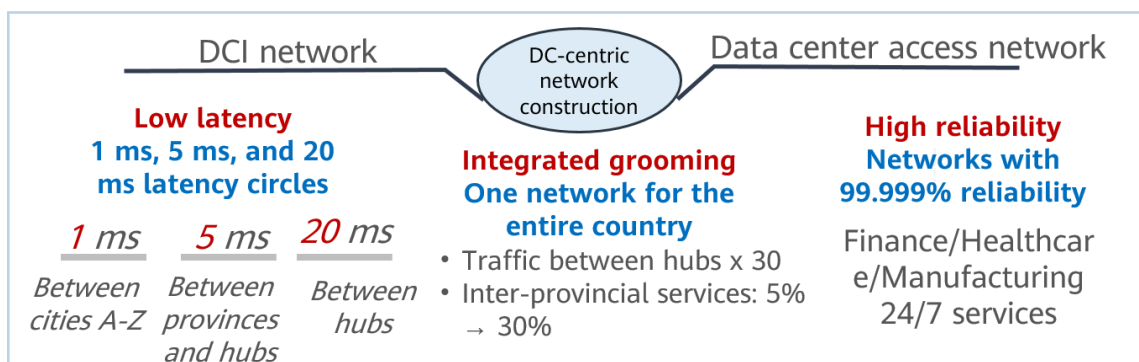


**5.3 Computing Power/DC User Experience Upgrade, Promoting Network Upgrade in Transmission Capacity Quality and O&M**

» **DC-Centric Network Construction Drives the Upgrade of Transmission Capacity Quality**

Amid accelerated digital transformation of enterprises and the rapid development of intelligent computing, supercomputing, and AIGC services, vendors such as operators and OTT providers have witnessed rapid increase in their DC scale and quantity. In addition, industries such as finance, smart transportation, smart manufacturing, healthcare, and video rendering require that massive data be quickly transmitted between the

cloud and the edge through highly-reliable and low-latency networks. Functioning as the link between users and computing centers, transmission capacity networks are accelerating the evolution towards certainty and high quality. Ubiquitous transmission capacity networks featuring low latency, high reliability, and integrated scheduling will be available on demand and help unleash computing service potential, bringing ultimate user experiences.

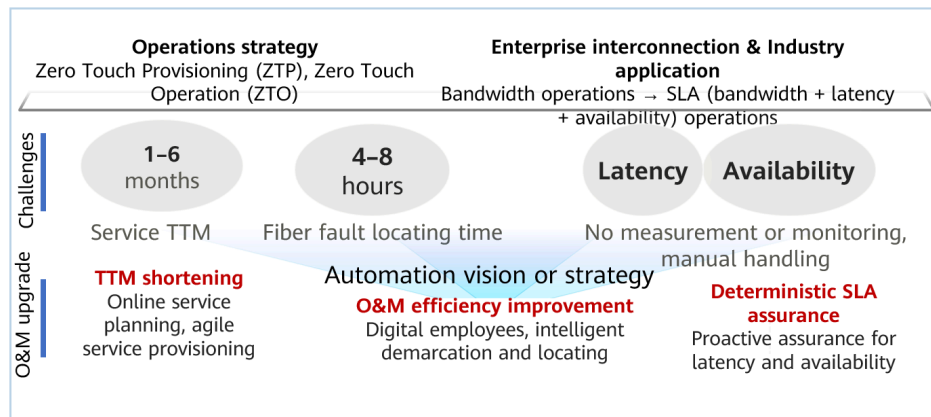


Source: China's Operator Market Insights

### » Automatic and Intelligent Optical Networks Accelerate O&M Upgrade

The scale of optical networks continues to grow. Traditional optical network O&M is user-centric, which cannot meet operators' requirements for OPEX reduction and high-quality operations of services. For example: In Europe, TTM of services can be several months. In Africa, fiber fault locating takes 4 to 8 hours. In Asia-Pacific, there are strong demands for agile provisioning of private line services, online bandwidth adjustment, and service SLAs. In Middle East and Latin America, much attention is paid to resource visibility and forecast. In China, we focus

on differentiated operations of deterministic service SLAs, and three tier-1 operators have released the goal of achieving L4 autonomous networks by 2025. Amid the development of converged sensing, data analysis, and intelligent technologies, the transmission capacity assurance of optical networks will gradually evolve to high-level automation. In this way, differentiated and deterministic transmission capacity assurance can be provided for various industries, helping operators reduce costs, improve efficiency and quality, and increase revenue.



## 5.4 Suggestion: Building All-Optical Premium Transmission Capacity Networks, with Single-Fiber Capacity Evolved to 100T to Match Traffic Surge

Matching the cloud-network strategy, build all-optical transmission capacity networks, upgrade the single-wavelength rate and optical spectrum simultaneously, and implement Moore's Law. (The capacity of a single fiber is doubled, with the backbone network upgraded from 16 Tbps to 32 Tbps, and the metro network upgraded from 32 Tbps to 64 Tbps or 96 Tbps.)

### » 400G/800G Are Deployed at the Electrical Layer, Reducing Per-bit Costs

1. Ultra-long-haul backbone network: 200G QPSK → 400G QPSK
2. Metro medium- and short-haul: 400G 16QAM → 800G 16QAM/1.2T 64QAM

### » Optical Layer Is Upgraded to C120+L120 to Release Fiber Spectrum

1. Wavelength spectrum upgrade: C120 → C120+L120
2. Optical-layer grooming upgrade: FOADM/ROADM → C+L integrated OXC

### » Towards All-Optical Transmission Autonomous Networks, Enabling Premium Operations

1. O&M upgrade: offline service planning, manual fault locating → online planning, automatic optical-layer deployment, and intelligent fault locating
2. Service quality upgrade: bandwidth assurance → differentiated SLA agile scheduling, availability assurance, and latency assurance



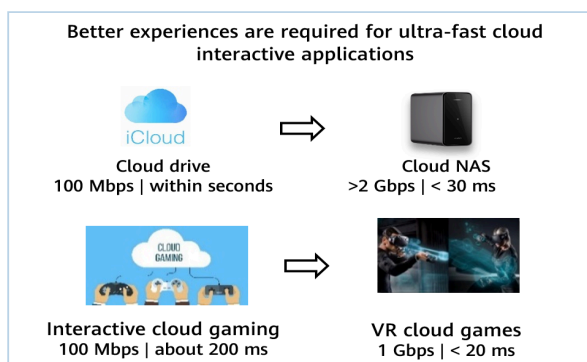
## Trend 6

### Traffic and Experience Drive Metro All-Optical Bearing and Grooming, Accelerating the Deployment of Optical Networks

#### 6.1 New Cloud-Based Services Require Differentiated Network Experience, and Explosive Traffic Growth Is Driven by FMC Acceleration and 10G Home Broadband

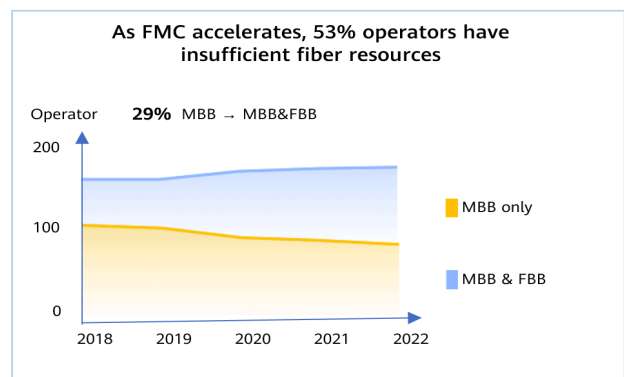
##### » New Cloud-based Services Require Differentiated SLA Network Experiences

With the rapid development of digitalization and intelligence, ultra-fast cloud interaction services, such as naked-eye 3D, cloud NAS, VR cloud gaming, and cloud office are developing rapidly. Network bandwidth and latency must be improved by 10 times to ensure user experience. For example, the interactive cloud gaming service requires higher than 1 Gbps bandwidth and lower than 20 ms latency, and cloud NAS services require up to 2 Gbps bandwidth.



##### » The FMC Trend Accelerates, and Optical Fibers Become Network Bottlenecks

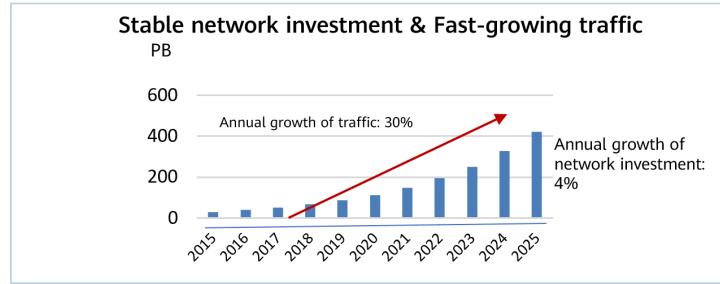
In the past four years, 29% global mobile operators have developed fixed network services, transformed into integrated operators, and released full-service packages to enhance their competitive edge. Most of operators have insufficient fiber coverage, and 53% operators need to lease more fibers. In this case, fiber efficiency needs to be maximized to reduce fiber leasing costs.



» Average Annual Growth of Network Traffic: 30%

With the development of 5G, gigabit home broadband, and enterprise services, the average annual growth rate of network traffic exceeds 30%. Per-bit cost of networks

needs to be continuously reduced, and network resource utilization needs to be improved to meet service development requirements.



Source: Omdia

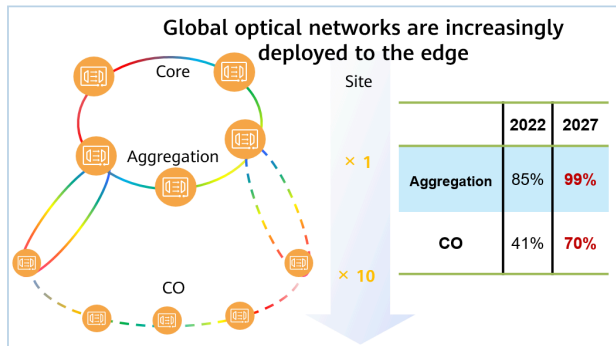
## 6.2 More Optical Networks Are Deployed for Flexible Scheduling of Networks and Improved Automation Capabilities to Efficiently Construct Networks

» Operators Accelerate Constructing Metro Optical Networks

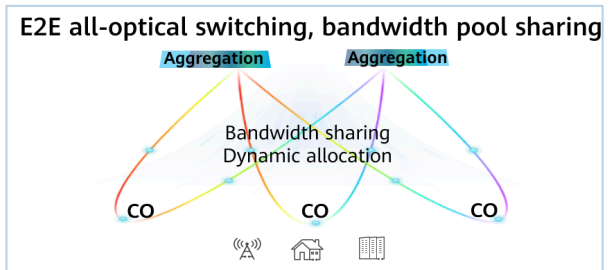
In the past five years, the proportion of global optical transmission networks deployed at metro aggregation sites has increased from 20% to 85%, and the proportion of global optical transmission networks deployed at metro CO sites has increased to 41%. The main reason is that the site scale increases tenfold for each network layer. In the future, all-optical networks will be further extended to cover 70% of CO sites, and all-optical integrated bearer networks will be built to implement operators' all-service development strategy.

latency.

This solution takes network costs and efficiency into account and supports smooth evolution. It has been deployed on more than 30 networks around the world and has become one of the mainstream solutions for metro network construction.



Source: Huawei M&I

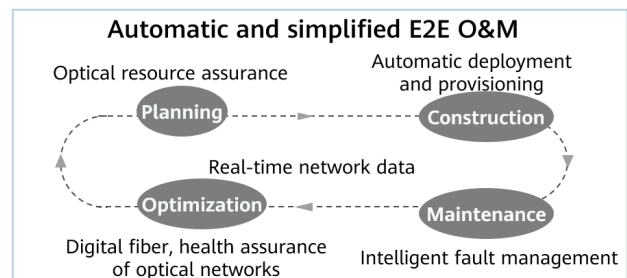


» Efficient Network Construction Using the Pooling Architecture

Traditional metro networks mainly use FOADM, which has inflexible scheduling and low resource utilization. Metro networks with optimal TCO can be built by innovating the pooling architecture solution, building bandwidth resource pool to efficiently share wavelength resources at aggregation sites, and by leveraging 100G to site, E2E all-optical switching, one-hop service connection, and lower network

» E2E Network Automation

Amid the large-scale construction of metro networks and increasing network nodes, traditional manual O&M cannot satisfy network development requirements. Network automation needs to be provided in the planning, construction, maintenance, and optimization phases to improve network O&M efficiency and reduce network OPEX.



## 6.3 Suggestion: Building Wide-Coverage Metro Optical Networks to Enable Ultimate Service Experiences and Facilitate All-Service Development

### » Constructing Metro Optical Networks with All-Service Bearing

New types of services and applications continue to develop. Metro optical networks that carry all services need to be constructed, with improvements on bandwidth, latency, and availability. This can help promote operators' all-service development strategy, meet service requirements in the next 10 years, and provide premium experiences.

### » Efficient Network Construction Using Metro Pooling Architecture

The resource-sharing pooling architecture enables 100G services to be delivered to sites, flexible E2E all-optical grooming, and one-hop connection to the core network to

build efficient and flexible metro networks. By doing so, energy-saving services, ultra-low latency, and cloud-network synergy can be enabled to promote network evolution in the next 10 years.

### » Network Automation, Simplifying O&M

Network digital twin has been widely recognized in the industry. The number of network nodes increases rapidly, adding complexity to network management. Transmission networks are evolving towards automation. Digitalization at the optical layer and AI technologies are introduced to improve network O&M and self-optimization capabilities, thereby lowering skill requirements for O&M personnel and simplifying O&M.

**Disclaimer**

This document may contain forecast information, including, but not limited to, information about future financials, operations, product lines, new technologies, etc. Due to the many uncertainties in practice, the actual results may be greatly different from the forecast information. Therefore, the information in this document is for reference only and does not constitute any offer or commitment. Huawei is not liable for any actions you make based on this document. Huawei may modify the above information without prior notice.

**Copyright © Huawei Technologies Co., Ltd. 2023. All Rights Reserved.**

Without the written consent of Huawei Technologies Co., Ltd., no unit or individual shall excerpt or copy part or all of the contents of this manual, and shall not disseminate it in any form.