DEC 2024 | VOL. 26 • NO.6 • ISSUE 215

ZTE TECHNOLOGIES

VIP Voice

CCT: Delivering Ubiquitous Connectivity in the British Virgin Islands

Expert View

Discussion on Development of Wi-Fi Multi-AP Home Network Technology

Special Topic: FTTR+X

Scan for mobile reading

ZTE TECHNOLOGIES

DEC 2024 | VOL. 26 • NO. 6 • ISSUE 215

Sponsor: ZTE Corporation

Edited By Shenzhen Editorial Office
General Editor: Lin Xiaodong
Deputy General Editor: Lu Dan
Editor-in-Chief: Liu Yang
Executive Editor-in-Chief: Yue Lihua
Circulation Manager: Wang Pingping

Editorial Office

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

CONTENTS

Customer Insights

Success Stories

CCT: Delivering Ubiquitous Connectivity in the British Virgin Islands

ZTE Reporter

Averad Penn
CEO of Caribbean Cellular Telephone (CCT)

CCT CEO Averad Penn provides an in-depth look at the vibrant telecom market of the British Virgin Islands (BVI) and how Caribbean Cellular Telephone (CCT) meets the growing demand for data and connectivity at the ZTE Broadband User Congress held in late October. CCT is the leading wireless telecommunications provider in the BVI offering various innovative services for business and residential clients.

Can you describe the characteristics and development trends of the BVI's telecom market?

The British Virgin Islands' telecom market is really dynamic. It's a small country with only about 30,000 people. However, our proximity to the US market—we are very close to the US Virgin Islands—places us within the American ecosystem in terms of the media market and so on. Therefore, my customers really expect to have whatever the latest and greatest technology available in America is as soon as it comes out. So, even though we are a small country, we have a dynamic market. Other things special about the British Virgin Islands is that we are a very developed economy for the Caribbean. We have the second highest GDP per capita in the entire Caribbean. So we probably have some of the most tech savvy customers compared to other Caribbean countries. They want all of the latest technology, and that drives the market.

Consumer demand for connectivity and digital services is rising rapidly. How have you managed to keep up this demand while maintaining high network quality? What key initiatives are being implemented?

The key for us is to realize that consumer demands are exponential. Every year, I talk to people about how much data they are using on their phone, and I know they're going to use more next year. So we have been continually upgrading our network to try to keep up with this demand. When I took over the company 11 years ago, it was facing a tough time due to a change in ownership. The real lesson learned there was to continue reinvesting in the product. What we do is that we try to set a target in terms of what percentage of our revenue we'll put back into the network every year to drive it forward. In a sense, we're not waiting for the demand; we are assuming it's coming and trying to continually reinvest in the latest and greatest technology in telecommunications.

From your observation, what are the most popular services and applications that suit local people's lives?

The most popular thing is Internet. Our company's name is Caribbean Telephone Cellphone. I remembered one of the first things I said when I took over is that telephone service would become just an app. I didn't realize how correct I would be moving forward, but everything is about data. We are a data company, and we want to make sure that you have ubiquitous data wherever you go out. We face one of the greatest challenges in the world: connecting everyone in the world, all the time, everywhere, no matter what they are doing. This is a great challenge, but we try to step up to that challenge each and every day.

CCT and ZTE have collaborated in various fields, including fixed-line and mobile. How do you view ZTE as a partner, and what are your expectations for vendors like ZTE?

One of the reasons I am here today is that ZTE is not just a vendor to me; they are truly

CCT CEO Averad Penn at the ZTE Broadband User Congress 2024 held in Mexico City, Mexico

a partner. They have walked this journey alongside us—when they develop, we develop. It's not a simple buyer-seller relationship; it's about what you see coming around the corner and what you see happening in other markets. They are working in more markets than we are, so they know what's best in class in this area and that area. Thus, it's becoming a collaborative relationship: we bring local expertise, while they bring a wealth of technology experience being a global provider to our small corner of the world.

How do you envisage the digital lifestyle of the BVI in the next three years and what will be your priorities?

I think we are in a never-ending trend. The COVID pandemic has really pushed the market forward by about 10 years in terms of digitalization and connectivity. We don't see any return to the old world. Everything is connected right now. We have to face that challenge—whether being connected wired or wirelessly. Therefore, we are trying to converge these two worlds—the world of wireless connectivity and that of wired connectivity—to give you ubiquitous connectivity. That's where we see the future going and the future we want to be a part of.

I've been to a lot of conferences and people say you are never more than 6 feet away from your cellphone, and I think that's a true statement. The first thing most people do after waking up in the morning is check their phone, and the last thing they do before sleeping is check their messages, their emails and what's going on in this website or that. This is part of people's lives, and we want to be an integral part of this revolution and the full digitalization of society.

Discussion on Development of Wi-Fi Multi-AP Home Network Technology

Zhang Zhigang

FM Product Planning Director, ZTE

Yang Huan

CPE Product Planning Manager, ZTE

Broadband networks are strategic public infrastructure for social-economic development. Globally, they have driven a new wave of informatization development, with countries prioritizing broadband development as a key strategic action area. Fixed broadband is evolving towards F5G such as PON, Wi-Fi, and 400G, accelerating the interconnection of everything with fiber, from fiber-to-the-building (FTTB) to fiber-to-the-home (FTTH), fiber-to-the-room (FTTR), and even to the future fiber-to-the-machine (FTTM). Home broadband services have shifted from early one fiber scenario to an integrated one home solution that combines fiber and Wi-Fi networking.

However, the significant increase in bandwidth has not resulted in a corresponding growth in average revenue per user (ARPU). From 2017 to 2022, China's broadband speeds surged by 3000%, yet ARPU decreased by 25%. User experience has not improved with the increase in bandwidth speeds. Expectations for broadband services have shifted from merely increasing internet speed to enhancing the quality of experience (QoE). Operators need to improve the Wi-Fi experience to reverse the downward trend in bandwidth pricing. Factors affecting QoE include not only bandwidth but also latency, reliability, coverage, and fault troubleshooting.

To enhance Wi-Fi QoE, a deeper overall management of Wi-Fi is necessary to ensure that ultra-gigabit capabilities cover every room in the home. For this purpose, organizations in the standards and applications domain such as IEEE, ITU, CCSA, and the China Academy of Information and Communications Technology (CAICT) have designed and discussed various solutions based on the FTTR+Wi-Fi Multi-AP home network architecture. The home Wi-Fi network is gradually evolving into a more manageable system.

FTTR+Wi-Fi All-Optical Multi-AP Networking

The all-optical multi-AP home networking is inherently suited for centralized multi-AP control and distributed AP collaborative management, aimed at optimizing Wi-Fi networking.

The "FTTR White Paper 2022" by CAICT states that the all-optical centralized/cloud wireless-optical access network (C-WAN) architecture primarily addresses the ineffective coordination among home networking technologies, disordered competition in the air interface, and challenges in meeting user demands for emerging business experiences. The overall design approach involves the main device collecting information and making decisions, centrally controlling both optical and Wi-Fi transmissions as a unified network, and achieving unified and coordinated configuration of optical and air interface link resources. The main device provides real-time control of subordinate devices to ensure orderly collaboration of air interface Wi-Fi within the FTTR network (managing the air interface Wi-Fi from CSMA to C-WAN), dynamic AI-based link management, and roaming control through seamless handoff technology. This maximizes air interface performance and enhances user QoE.

The C-WAN architecture defined by ITU FTTR (G.fin), as shown in Fig. 1, aims to optimize latency-sensitive services, enhance real-time communication tuning, and enable seamless roaming. It ensures low-latency transmission of channel information by establishing prioritized information channels. In scenarios with stringent air interface collaboration requirements, the round-trip signaling delay should be less than 120 μs.

In the CCSA FTTR DLL draft, the Wi-Fi management and control channel (WMCC) and the Wi-Fi management and control interface (WMCI) are defined for multi-AP Wi-Fi management. WMCC carries messages of the WMCI protocol, providing an interface for Wi-Fi management functions, primarily handling multi-AP air interface scheduling (in time, frequency, and space), roaming control, and energy-saving measures.

The main purpose of C-WAN is to centrally manage, configure, and control Wi-Fi network resources distributed across various devices (air interface time, channel/width, and spatial SR BSS color/transmit power). This control includes QoS mapping, air interface scheduling, STA roaming, and energy saving, all aiming at enhancing user QoE.

IEEE Wi-Fi 8 Multi-AP Solution

The IEEE agenda has included extensive discussions on optimizing multi-AP scenarios for home environments. The exploration of multi-AP collaborative solutions began in the originally planned Release 2 of the Wi-Fi 7 802.11be standard. However, due to the complexity of the solutions, the progress of the standard, and the development and commercialization of chips, the multi-AP functionalities have been postponed to the Wi-Fi 8 802.11bn UHR specification. Potential solutions for multi-AP may include C-OFDMA, C-beamforming, C-spatial reuse (CSR), joint transmission, and seamless roaming (Fig. 2).

- **C-OFDMA:** When multi-APs synchronize their

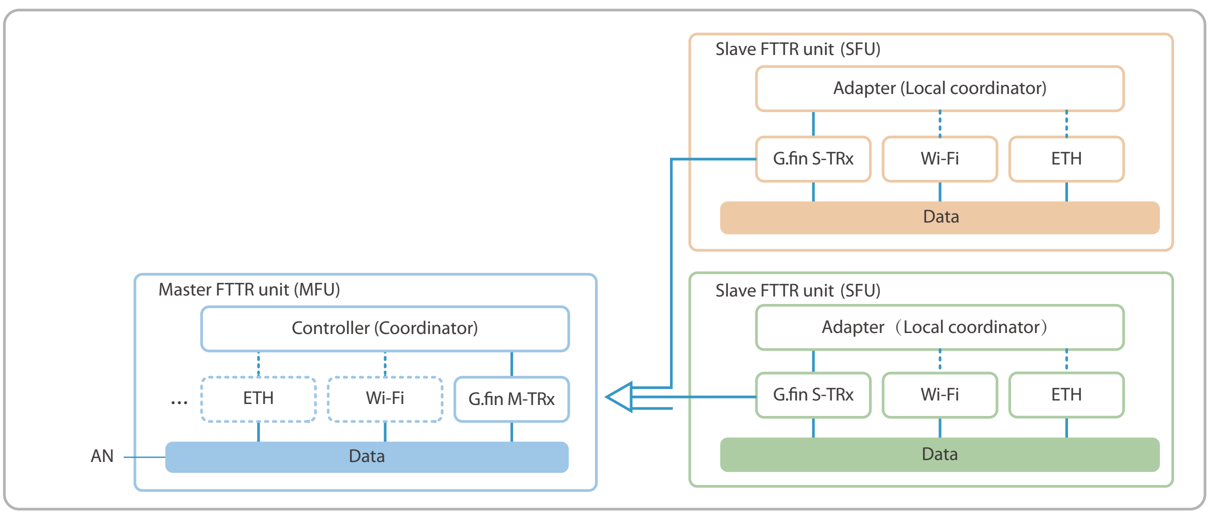


Fig. 1. ITU FTTR C-WAN architecture.

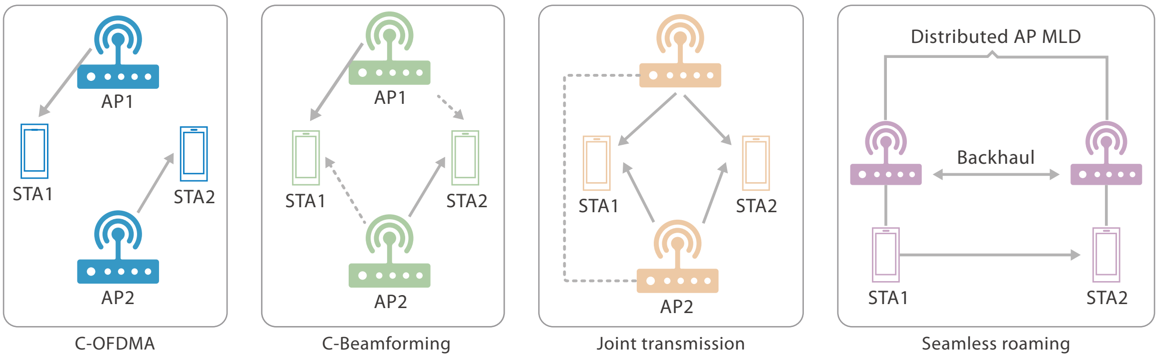


Fig. 2. Wi-Fi 8 multi-AP methods.

respective resource status, different APs can simultaneously transmit data to their associated STAs using the same or different resource units (RUs). Simulations indicate that this feature significantly enhances overall system capacity in medium to large networks.

- **C-beamforming:** When an AP uses beamforming for directional transmission to its associated STA, it also minimizes interference for specific adjacent STAs, avoiding mutual interference between neighboring APs. However, implementing this solution requires the APs to obtain channel state information (CSI) for STAs associated with neighboring APs, which poses a challenge.
- **C-spatial reuse:** CSR is the simplest coordination mechanism for multiple APs and can be used when interference among BSSs is weak, but the channel state is perceived as busy. To ensure all STAs have sufficient signal-to-noise ratios, APs collaboratively control transmission power to reduce interference. CSR can be achieved with minimal inter-AP collaboration information.
- **Joint transmission:** By creating a dynamic distributed MU-MIMO system, joint transmission allows multiple APs to serve the same STA. The system operates jointly across multiple APs. Experiments have shown that the benefits of joint transmission and reception are greatest in the downlink.
- **Seamless roaming:** The aim is to exchange frames between a STA and a group of cooperative APs without adding negotiation overhead. To achieve this, the authentication and association process should be completed with all centralized APs.

The required level of synchronization among the multi-AP methods varies: CSR can operate with coarse frame-level synchronization, CBF and Co-OFDMA require symbol-level synchronization, while JTR needs tight time and phase synchronization. This implies a need for highly reliable, low-latency backhaul links, such as fiber-based FTTR, which presents the greatest implementation challenges.

For the seamless roaming technology in multi-AP architecture, two main architectural schemes are currently under discussion in the Wi-Fi 8 specification process: the non-co-located UHR AP MLD architecture and the UHR AP MLD architecture with Virtual-MLD.

Compared to the 802.11be MLD architecture, the non-co-located UHR AP MLD architecture adds a UHR UMAC entity to provide services related to UHR MAC-level functionality. While this architecture addresses some roaming and technical issues, it also introduces complexity. In certain scenarios, the non-co-located UHR AP MLD architecture may result in additional latency and increased complexity in infrastructure and chipsets.

The UHR AP MLD architecture with virtual-MLD makes minimal changes to the existing EHT AP MLD architecture. However, due to the lack of a unified management entity similar to the UHR AP MLD UMAC, it may require significant inter-AP communication to transmit the context needed for roaming and multi-AP cooperation.

In the era of ultra-gigabit whole-home networks, home networking is centered on enhancing user experience. The deep integration of FTTR all-optical foundation with Wi-Fi coverage has made speed, latency, concurrency, and reliability key areas of development for Wi-Fi technology. New technologies such as FTTR+Wi-Fi, Wi-Fi 8, and AI will further evolve home networks into manageable, controllable, and operable intelligent systems for operators. ZTE TECHNOLOGIES

FTTR+X: Driving High-Quality Development of Home Broadband

Wang Yadong

Integrated Solution Manager of FM Products, ZTE

Zhao Jing

FTTR Solution Manager of FM Products, ZTE

In recent years, fiber to the room (FTTR) has emerged as a key driver for operators to enhance the value of gigabit. Its primary value lies in improving user experience and increasing ARPU. According to market research data from China's three major operators, the satisfaction of FTTR users is 3.8% higher than that of ordinary gigabit users. In terms of ARPU improvement, for new gigabit users, the ARPU from those subscribing to FTTR integrated packages is 30% higher than from those choosing non-FTTR integrated packages. For existing subscribers, upgrading to the FTTR package boosts the ARPU value by RMB 16–53.

FTTR also plays an important role in retaining existing subscribers and acquiring new ones. Research shows that among medium- and high-end users with an APRU value of RMB 120 or above, the retention rate of FTTR integrated package users is 2.2% higher than that of ordinary broadband users. The new user acquisition rate for FTTR exceeds 35%, with particularly prominent growth among high-value user groups subscribing to packages priced at RMB 199 or above.

It can be seen that FTTR not only provides users with a high-speed and stable gigabit experience, but also creates new business value and innovation opportunities for operators. It has become an industry consensus to vigorously develop FTTR. By June 2024, the number of FTTR users in China had exceeded 20 million. Dell'Oro Group predicts that this number will rise to over 80 million by 2026. At present, FTTR is in the market incubation period in global markets. In 2023, more than 20 operators released FTTR packages to promote its adoption. Outside China, over 350,000 FTTR users is expected to be developed by 2026.

In the future, the FTTR market will continue to gain momentum, increasing the value of connections and promoting high-quality development of home broadband. In response to the more specific scenarios in the smart home field and the trend of digital intelligence technologies such as AI, ZTE has taken the lead in proposing the innovative concept of "FTTR+X" for all-optical operations (Fig. 1). Built on an all-optical foundation, ZTE is actively exploring three aspects: connecting experience, scenario ecosystemization, and cloud-network intelligence, to deepen and expand the scope of home broadband services, enhance the sustainable operation of FTTR, and facilitate the high-quality development of home broadband.

Connecting Experience: Higher Rates, Stronger Connections, and a Unified Home Network

In the era of managing existing home broadband

users, user experience has become a key factor in the competitive landscape of the industry. With FTTR, home networks achieve ultra-gigabit speeds. By working in tandem with Wi-Fi and networking technologies, FTTR bridges the last 10 meters of the gigabit network to terminals, creating an ultra-fast intelligent home network that delivers a seamless and instantaneous connection experience.

In the Wi-Fi technology field, Wi-Fi 7 began commercial use in 2024. ZTE has been deeply involved in the development and implementation of Wi-Fi 7 standards, and worked with industry partners to drive continuous exploration and innovation. In June 2023, ZTE released the industry's first Wi-Fi 7 FTTR product. This product introduces 4096-QAM technology, which enhances the throughput performance by 20%, meeting the demands of high-bandwidth services such as UHD video, high-speed downloads, and home data storage. In addition, the integration of multi-link operation (MLO) and multi-RU (MRU) technology enables terminal devices to connect to multiple Wi-Fi hotspots simultaneously. This capability allows user devices to get faster access speed and lower latency, ensuring the reliability and stability of latency-sensitive services such as online conferences and gaming. With ZTE's in-house developed scenario-based AI algorithm, the product provides home users with faster, smarter, and more comprehensive home networks, enhancing their broadband experience.

To address issues such as insufficient coordination between home networking technologies and disorderly competition of air interfaces, ZTE has introduced D-WLAN technology. The main ONT collects information, makes decisions, and implements centralized control over both optical and Wi-Fi transmission within a single network to achieve unified and coordinated resource configuration of optical links and air interface links. Through real-time control of the room ONTs by the main ONT, the solution ensures orderly coordination of Wi-Fi air interfaces in an FTTR network, dynamic link management, and roaming control, thus maximizing air interface performance and enhancing customer QoE.

Scenario Ecosystemization: Multi-Service Integration to Improve Home Network Value

With the growing demand for personalized and scenario-based smart homes, FTTR has integrated with multi-scenario services based on its characteristics of large bandwidth, low latency, and high concurrency. It not only brings ultimate experience to end users but also helps operators expand their operation strategies.

In the video field, improvements in home network speed and quality lay a solid foundation for the development of UHD video and virtual reality (VR) services in the home environment. ZTE's multi-service integrated video cloud platform, built on a microservice architecture, improves existing service functions while incubating new services. By delving into technologies such as ultra-low latency, low-bitrate high definition, video super resolution, and edge-cloud collaboration, the platform enriches home video experience, meeting users' increasingly diversified demands and continuously improving user experience.

In terms of terminals, ZTE has launched the smart medium screen series. This smart medium screen integrates audio-visual entertainment, smart control, security, home care, health care, elderly care and edutainment functions, creating an all-round smart home center. These products have been applied in several provinces, and ZTE has been collaborating with operators, communities, and institutions to build a full-scenario elderly care platform. Additionally, the smart mini-projector offers home users a cinematographic experience with its 120-inch large screen and high-definition image quality, and extensive content resources that allow for high-quality entertainment and audio enjoyment.

The smart security scenario is another key area of user interest. ZTE provides an intelligent security solution based on edge-cloud collaboration. The AI console, based on cloud computing, features full-process automation capabilities, from data labeling to model deployment. This solution is widely used in home, community, and rural scenarios, offering home health monitoring and security functions together with AI-enabled home care cameras, visual doorbells, smart displays, and smart locks.

Currently, Wi-Fi networks are widely accessible, serving as important communication infrastructure. Beyond communication, Wi-Fi can also be utilized to perceive and measure the activity status of specific objectives in an environment. Wi-Fi sensing technology expands the use of Wi-Fi network devices, enabling them to monitor the health status of family members while ensuring privacy protection, and it can achieve integration with scenarios such as elderly care, unattended monitoring, and anomaly alarming, expanding the value of home networks.

Additionally, based on edge-cloud collaboration technology, FTTR can empower cloud applications in multiple scenarios, such as scenario acceleration and green Internet access, further enriching home network services and improving the user experience.

To address the demands of diverse smart home scenarios, ZTE's new-generation FTTR gateway, launched in September (Fig. 2), features a screen and supports various broadband and narrowband protocols such as low-power Wi-Fi, Zigbee, and BLE, establishing an IoT foundation for smart homes. It integrates the home control center, security center and network management center, enabling users to

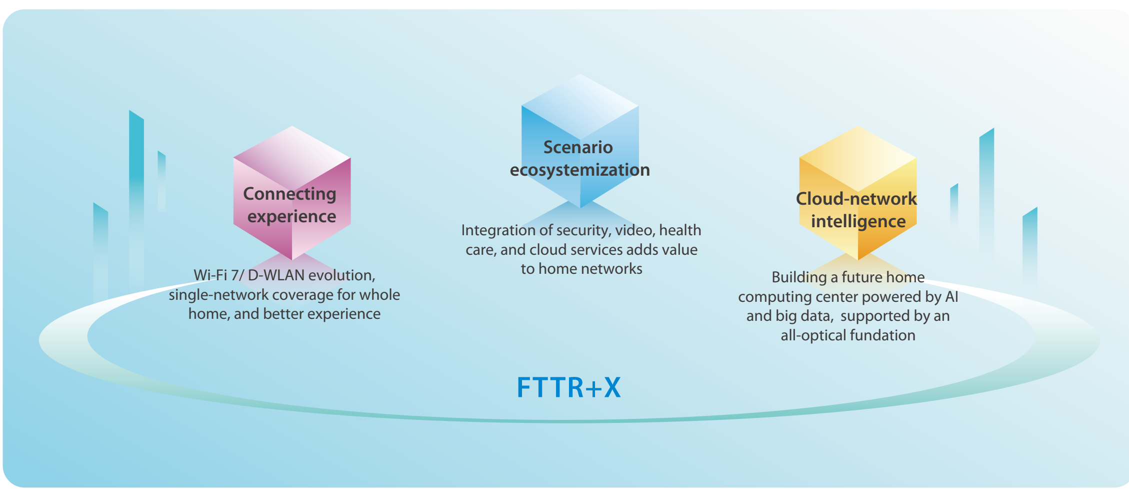


Fig. 1. The innovative concepts of FTTR+X.

Fig. 2. The new-generation FTTR gateway serves as the hub of a smart home.

enjoy smart life across multiple scenarios. This marks the transition from a traditional network pipeline to a smart home ecological control center, positioning ZTE at the forefront of of FTTR industry development.

Cloud-Network Intelligence: Building Future Home Computing Centers

With the development of smart home and new technologies, home users' demands for intelligence are growing. Users expect better solutions for data storage, processing, and privacy protection, along with higher demands for the smoothness and response speed of video and gaming experiences. Besides, they have increasingly higher requirements for the intelligence of smart home devices. These factors promote the integration of video rendering, private storage, and AI large model technologies into the home environment.

Looking ahead, homes will become important nodes in computing power networks. Each home needs a computing center to meet the demands of diverse application scenarios. These centers will act as extensions of computing power networks, and will continuously expand their capabilities to adapt to new service scenarios. Overtime, they will gradually transition from providing a single service to providing more comprehensive, scenario-based services, bringing users a richer, more convenient, and more secure smart life experience.

Home computing centers play a key role in the entire computing power network. To address the rapid iteration of algorithms and applications, system design must fully consider the coordination and cooperation among cloud computing, edge computing, and local computing. In addition, it is essential to strike a balance between home users' acceptance of device prices and their recognition of long-term service value, and the layout of edge-side and cloud-side computing power must be planned reasonably to achieve an optimal configuration of terminal devices and cloud computing resources.

As the foundation of home connections, FTTR has the potential to serve as a home computing center. The new-generation FTTR gateway integrates multi-scenario intelligent computing functions such as built-in NAS, AI, Wi-Fi sensing and IoT scenario identification. ZTE is committed to developing new intelligent computing business packages together with operators.

Early in 2020, ZTE carried out the first pilot verification of the all-optical home network, and collaborated with operators to gradually promote the commercial implementation of FTTR in both the home and industrial markets. From 2020 to 2024, ZTE has launched five generations of products over five years and implemented the "FTTR+X" strategy, consistently leading the development of the industry.

Looking ahead, ZTE will continue to strengthen the foundation of the FTTR industry, working with operators and industry chain partners to drive the adoption of FTTR technology in both home and industry applications, while assisting operators in achieving new breakthroughs in home broadband and industrial value operations. ZTE TECHNOLOGIES

Device-Network Collaboration for High-Quality Home Video Experience

Chen Wei

CPE Product Planning Manager, ZTE

Wang Hecong

SCP International Marketing Representative, ZTE

Home video services have become an integral part of daily life, encompassing low-latency live streaming, entertaining short videos, and immersive VR experiences. As home users increasingly demand higher video quality, home networks must collaboratively optimize video services to provide users with a superior viewing experience (Fig. 1). This article explores how to achieve a high-quality home video experience through device-network collaboration across three aspects within the home: the access layer, transmission layer, and content layer.

Access Layer: DNS and Tunneling Technologies for Interfacing with Upstream CDNs to Enhance Performance

The access layer serves as the connection point between home networks and external networks, and its performance directly affects the quality of video service transmission. To achieve high-quality video transmission, home networks can employ the domain name system (DNS) and tunneling technologies to interface with upstream content delivery networks (CDNs).

DNS, as the core of the domain name system, is responsible for resolving user requests for domain names into their corresponding IP addresses. In the home network, optimizing the DNS resolution process is crucial for enhancing the response speed of video services. By utilizing built-in DNS services and caching techniques, the home network can reduce query time, accelerating video content loading.

Additionally, the use of VPN, MPLS, and other tunneling technologies can establish secure and reliable connections between the home networks and upstream CDNs. These technologies ensure the security and stability of video data during transmission, preventing data loss or tampering. They also enable low-latency connections, ensuring real-time and fast transmission of video data to user devices.

Transmission Layer: Building Optimal Video Channels with Wi-Fi and SCP

The transmission layer is a crucial component of home networks, and its performance directly affects the quality of video transmission. The smart cloud platform (SCP) is the first integrated home network management platform in the industry that optimizes Wi-Fi performance, identifies services, optimizes the network, and ensures video quality of service (QoS) to create the best home video transmission channel.

Wi-Fi quality is the foundation of wireless network transmission, with its stability directly affecting video quality. As the number of wireless devices increases, channel congestion becomes a significant issue. The SCP platform can intelligently select and manage Wi-Fi channels. Utilizing the AI technology, it monitors the load of each channel in real-time, predicts future traffic changes, and automatically selects the optimal channel for video transmission, ensuring stable data transmission.

Service identification is key to network optimization. In complex network environments, different services have varying requirements and priorities for network resources. The SCP platform can accurately identify critical services such as video streams, online meetings, and live broadcasts through big data analysis, optimizing the network based on their characteristics and needs. This includes adjusting resource allocation and configuring QoS to ensure smooth and clear video transmission.

Network optimization is essential for enhancing video service quality. The SCP can predict the possibility and location of network congestion by analyzing historical data and real-time traffic, identify potential issues, and issue warnings to ensure network stability and reliability. Additionally, the SCP intelligently determines solutions for existing problems and performs automatic repairs to enhance the video experience.

Content Layer: Expanding Storage Capacity, Preheating Content and Offering Proximity Services with FTTR

The content layer is crucial for the storage and distribution of video content within home networks, and its performance directly affects the loading speed of video services. To achieve high-quality video loading speed, home networks can adopt strategies such as fiber to the room (FTTR) to expand storage capacity, preheat content, and offer proximity services at the content layer.

First, FTTR technology provides users with higher bandwidth access capabilities. By expanding storage capacity with FTTR, home networks can cache more video content, reducing reliance on upstream CDNs and minimizing transmission delays. Additionally, FTTR also enables high-speed transmission within the home network, ensuring that video data can be quickly transferred from storage devices to user devices.

Second, content preheating is a strategy for pre-loading and caching video content before viewing. By preheating content, users can start watching videos faster and reduce waiting time. The home network can intelligently predict and preheat related video content based on user viewing history and preferences. This improves user experience and reduces bandwidth pressure on upstream CDNs.

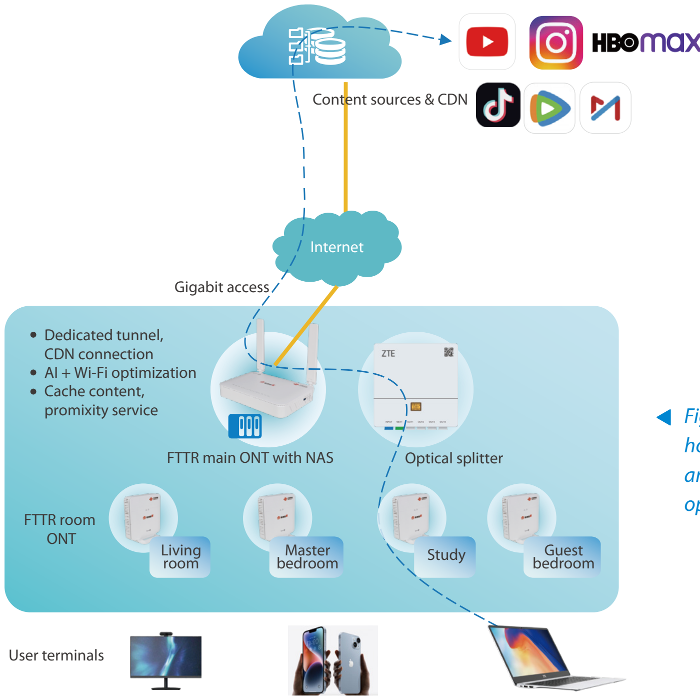


Fig. 1. All-optical home networking and video service optimization.

Lastly, proximity service refers to storing video content closer to users, such as on home NAS devices or routers, to enable fast loading and viewing. It reduces the transmission distance and time of video data, lowers transmission delays, and improves the viewing experience. Home networks can use FTTR technology to store video content on home devices and transfer it quickly to user devices through high-speed transmission.

In the future, continuous technological advancements will make device-network collaboration the core of home video experiences. By integrating terminal devices with network optimization, users will enjoy an unprecedented high-quality video experience. Home video will no longer be limited by network bandwidth or device performance, enabling seamless, high-definition, and smooth transmission and playback. With SCP empowering home networks, service identification will become more accurate, and network optimization more intelligent, further enhancing the quality and efficiency of video services. Device-network collaboration will enrich the home video experience, meeting users' growing needs and ushering in a new era of home entertainment. ZTE TECHNOLOGIES

Scenario-Based AI Solution Facilitates Value Growth in Security and Care Service

Chen Qiuji

FM Product Planning Manager, ZTE

As the penetration rate of home networks rises, families, enterprises, and communities are evolving toward greater intelligence. According to the 2023 Omdia consulting report, global smart home service market revenue—excluding China and the United States—is expected to reach USD 63.69 billion in 2024 and USD 142.11 billion in 2027. Over 585 million smart home devices are estimated to be delivered in 2024, rising to 1.18 billion in 2027. As network services expand, the key to the next phase of digital service growth lies in building personalized, intelligent, scenario-based services.

In the security field, advancements in AI technology make it possible for security surveillance products to evolve from being merely "visible" to "clear" and "understandable". Machine vision now performs cognitive tasks across vision, hearing, and emotion, delivering a simpler, more intelligent user experience. Leveraging its resources, ZTE has launched a scenario-based AI solution for end-cloud collaboration, focusing on home and enterprise scenarios to drive large-scale expansion and enhance care services.

Application in Home Safety Guardian Scenario

The service utilizes indoor or outdoor cameras along with advanced image processing technologies, such as human shape recognition, voice recognition, motion detection, and area analysis, to detect suspicious individuals entering specific areas or abnormal behaviors. When detecting abnormal behavior, the platform immediately sends an alert. This scenario-based service application effectively improves the safety of elderly individuals, children, pets, and property at home.

Application in Child Safety Guardian Scenario

This service involves the installation of video surveillance equipment in locations such as schools and parks, utilizing advanced image processing technologies like area analysis and motion detection to identify whether suspicious individuals enter specific areas. When abnormal behavior or unauthorized individuals are detected, the video network platform immediately notifies relevant management personnel and parents, providing details such as time, location, and potential risks. This scenario-based service not only enhances the personal safety of children but also offers parents peace of mind, ensuring their children can grow up in a well-protected environment.

Application in Community Vehicle Illegal Parking Detection Scenario

To address the issue of illegal parking in the community and improve the quality of life for residents, ZTE has launched a scenario-based illegal parking detection service utilizing license plate recognition and illegal parking detection technologies. This service deploys surveillance

cameras at community entrances and key areas, such as garages and internal roads, to capture real-time license plate information of passing vehicles. Once the license plate information is automatically recognized, the system compares it against the community's registered vehicle database, marking non-community vehicles as visitor vehicles.

Simultaneously, if a vehicle is detected parking in a non-designated area, the video network platform will automatically mark and record the time and location of the violation. The information about illegal parking is uploaded to a cloud server for easy access and data analysis, allowing management personnel and residents to query and verify parking violations. By implementing this illegal parking detection service, the community has reduced the incidence of illegal parking, enhanced governance, and improved residents' quality of life.

Application in the Ultra-Simplified All-Optical Campus Solution

To meet the digital transformation expectations of small and medium-sized enterprises, ZTE has launched a fiber optic networking and monitoring solution to create an ultra-simplified all-optical campus. The network portion of this solution adopts the business FTTR (FTTR-B) model, utilizing fiber optic transmission technology to establish a high-speed enterprise network.

For the monitoring aspect, the FTTR-B devices provide seamless, high-speed Wi-Fi, enabling video surveillance across the entire campus network. By covering the campus network with a single fiber optic line, this solution not only addresses the pain points of traditional approaches but also accommodates various spatial needs, delivering efficient, cost-effective, and reliable one-stop services to government and enterprise users.

Additionally, ZTE has introduced the home AI guardianship and time miniature features, giving close care to family members. For street-facing retail scenarios, ZTE has launched an intelligent guest reception feature that counts foot traffic during the day and conducts area intrusion detection at night, helping shops operate efficiently.

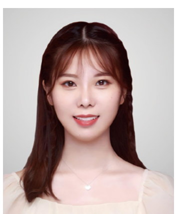
Through ZTE's intelligent security solutions, operators have transformed from mere network providers to comprehensive solution providers, enhancing user engagement and achieving sustained revenue growth through value-added services. This solution was awarded the GLOMO 'Best Connected Consumer Device Award' at the Mobile World Congress held in Barcelona in 2022.

As an industry leader in fixed-line terminal products, ZTE is committed to strengthening its foundational capabilities and continuously enhancing technological innovation to provide high-quality products and services to customers worldwide. In the future, ZTE will continue to increase investments, enhance the exploration of scenario-based video applications, and solidify AI capabilities, accelerating the development of smart life services to create a better digital life. ZTE TECHNOLOGIES

10G-to-the-Home and 10G-to-the-Enterprise: Prospects for 50G PON Applications

Chen Wei

CPE Planning Manager, ZTE



Zhang Feifei

FM Product Planning Supervisor, ZTE

With the rapid development of information technologies, network bandwidth requirements are growing explosively. To meet this demand, the 50G PON standard has emerged, marking a new stage in the evolution of optical networks. Offering high bandwidth, low latency, and wide coverage, 50G PON is becoming the preferred technology for the construction of future home, campus, and government & enterprise networks. In light of the release of the 50G PON standard and the gradual improvement of the industry chain, we'll delve into the potential of 50G PON in these applications.

50G PON Standard and Industrial Progress

The evolution of PON standards is shown in Fig. 1. In 2018, ITU/FSAN initiated the formulation of the single-wavelength 50G PON standard, also known as G.HSP or Higher Speed PON. In 2019, the ITU-T G.9804.1 standard (general requirements) was approved, defining the single-wavelength TDM PON architecture and the combination of uplink and downlink rates. It also specifies the coexistence of 50G PON with existing GPON, 10G PON, and the current optical distribution network (ODN) infrastructure.

In 2021, the ITU-T officially released a series of standards for 50G PON: G.9804.1 Amd1, which includes additional requirements for higher speed PON; G.9804.2, which specifies the common transmission convergence (ComTC) layer of HSP systems; and G.9804.3, which delineates the physical media dependent (PMD) layer specification. This indicates that 50G PON has completed the standardization of basic functions, laying a foundation for further product R&D and solution implementation and verification. The PON industry is moving towards convergence based on the ITU-T 50G PON standard.

50G PON adheres to the traditional TDM-PON point-to-multipoint architecture, and it employs advanced modulation and coding technologies and optical components to enhance the bandwidth and transmission efficiency of the optical fiber access network, increasing the single-wavelength rate to 50 Gbps. Additionally, 50G PON boasts robust transmission capabilities, and supports multiple ONU rates, including 50/12.5 Gbps, 50/25 Gbps, and 50/50 Gbps. This versatility ensures it meets diverse access requirements across a wide range of scenarios. Compared with traditional 1 Gbps and 10 Gbps PON technologies, 50G PON significantly improves bandwidth, latency, and coverage. These key technologies enable 50G PON to meet growing network bandwidth demands, providing users with faster and more stable network experiences, and addressing the rapidly increasing bandwidth requirements of

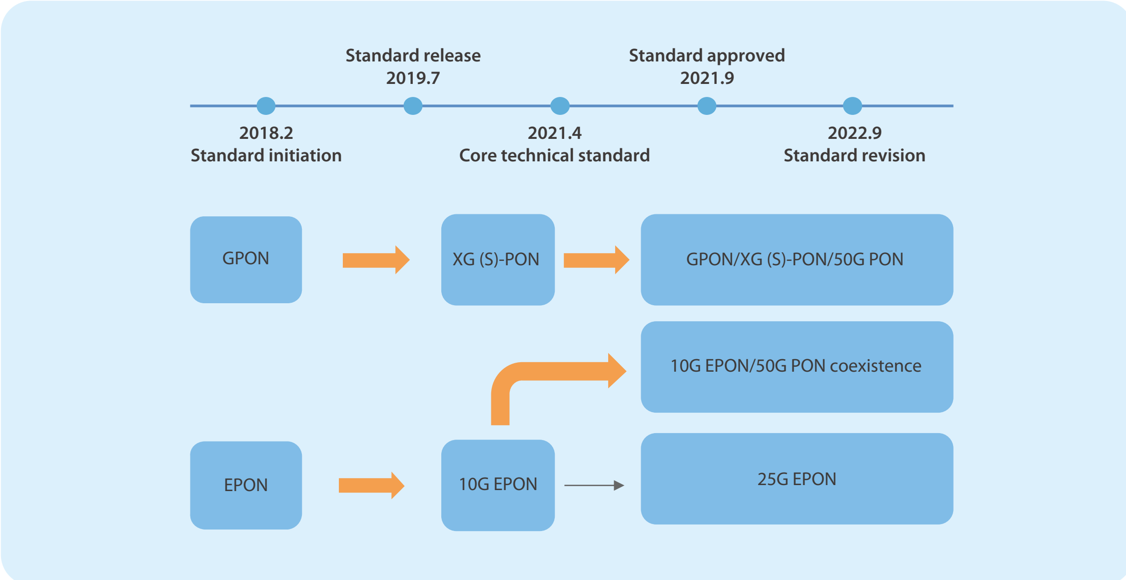


Fig. 1. PON standard evolution roadmap.

home, campus, and government & enterprise networks in the future.

The 50G PON industry chain is gradually maturing, covering multiple segments, from equipment vendors and optical component suppliers to network operators. Major equipment vendors have launched high-performance 50G PON devices and solutions. These devices provide higher bandwidth, better compatibility and better scalability, providing operators with more choices. As 50G PON technology commercialization accelerates, optical component suppliers have significantly improved the performance and reliability of their products. The performance of key components, such as optical modules and optical chips, is continually improving, ensuring the efficient and stable operation of 50G PON networks.

50G PON is evolving towards higher rates and lower latency. With the increase of the 50G PON line rate, receiver sensitivity decreases, necessitating improvements in the performance of transceivers to reuse the already extensively deployed ODN networks. To reduce the performance requirements of high-speed optical components, 50G PON introduces low-density parity-check (LDPC) coding for FEC. Low latency in 50G PON is achieved mainly through dedicated activation wavelength (DAW), cooperative dynamic bandwidth allocation (CoDBA), and reduced allocation periods. The DAW technology avoids opening the quiet window on the 50G PON uplink wavelength, canceling the delay caused by the quiet window. In CoDBA, the OLT learns about the uplink service transmission requirements of the ONU through the upper-layer device, and allocates bandwidth to the ONU in advance, minimizing service data buffering time within the ONU. Regarding reduced allocation periods, each T-CONT can be configured with multiple burst frames within a 125 μs period to reduce the time interval for the ONU to obtain bandwidth allocation, thus reducing the service data buffering time in the ONU.

50G PON optical components are the key factors influencing the development of the 50G PON industry chain. These include optical transmitter and receiver components, laser diode drivers (LDDs), burst-mode TIAs, CDR chips. The OLT can use the electro-absorption modulated laser (EML) or integrated semiconductor optical amplifier (SOA)-EML components as the transmitter, and the avalanche photodiode (APD) or integrated SOA-PIN components as the receiver. The ONU driver requires burst-mode support, and its receiver does not necessitate burst-mode clock data recovery (BCDR), whereas the OLT receiver does. Degradation of high-speed optical signal transmission needs to be compensated and restored through a dedicated DSP. The 50G PON industry chain is gradually maturing, with cutting-edge technologies continually emerging. As technologies advance and the market expands, 50G PON will be widely deployed in home, campus, and government and enterprise broadband networks, playing an increasingly important role in the future information and communication field.

50G PON Applications

Home Application Scenario: 10 Gbps Residential Communities

- **High-speed broadband experience**

The introduction of 50G PON technology enables home users to enjoy Internet access speeds of up to 10 Gbps. This advancement ensures that users won't be limited by network bandwidth when streaming HD videos, playing online games, or downloading large files, resulting in a smoother and more stable network experience.

- **Smart home upgrade**

With the rise of IoT technologies, smart home devices are increasingly popular. The introduction of 50G PON technology will provide stable and high-speed network connections for these devices, enabling home security systems, smart lighting, and smart home appliances to respond to user instructions in real time and with greater accuracy, thereby enhancing the intelligence and convenience of everyday life at home.

High-Speed Campus Network

- **Enterprise network upgrade**

For enterprises within the campus, 50G PON technology offers a comprehensive upgrade to their networks. High-speed bandwidth will provide enterprises with more efficient and stable support for video conferencing, data transmission, and cloud computing, enhancing their operational efficiency and market competitiveness.

- **Smart campus construction**

50G PON holds immense potential for the development of smart campuses. With the increasing demand for high-speed and

> **50G PON technology is poised to revolutionize home, campus, and government & enterprise applications, thanks to its unparalleled advantages, including high bandwidth, low latency, and wide coverage.**

high-capacity networks in smart campuses, 50G PON has emerged as a crucial technology driving this development, offering high bandwidth of 50 Gbps, low latency, and high reliability.

By leveraging 50G PON technology, smart campuses can achieve more efficient data transmission, faster information processing, and more stable network connections. This enhances the campus's intelligence while optimizing its management and service models, ultimately improving its overall competitiveness.

Additionally, 50G PON can meet the requirements of smart campuses for high-definition videos, big data, cloud computing, and other applications, providing strong support for their innovation and development. It is foreseeable that 50G PON will play an increasingly important role in the construction of smart campuses, driving their development to new heights.

Government & Enterprise Application Scenario: Low-Latency Smart Factory

With the development of industrial Internet, enterprises are placing increasingly stringent demands on network bandwidth and low latency. 50G PON technology will provide enterprises with high-speed and low-latency network connections, enabling them to obtain production data in real time, perform remote control and scheduling operations, and improve production efficiency and product quality.

Smart factories are a key manifestation of Industry 4.0, and 50G PON technology will offer essential network support for the construction of smart factories. By building a high-speed and low-latency network within the factory, devices can interconnect and share data, ensuring the development of smart factories. In addition, 50G PON technology supports multiple industrial protocols and interfaces, meeting the requirements of smart factories for network flexibility and scalability.

Conclusions

50G PON technology is poised to revolutionize home, campus, and government & enterprise applications, thanks to its unparalleled advantages, including high bandwidth, low latency, and wide coverage. As the industrial ecosystem matures and market adoption increases, 50G PON technology will deliver a consistently stable and ultra-high-speed network experience to users, boosting the advancement of smart home, campus, and factory applications. Looking ahead, there is every reason to anticipate that 50G PON will play an even more pivotal role within the broader ICT landscape, shaping the future of connectivity and driving innovation forward. ZTE TECHNOLOGIES

Large Models Driving Evolution of Smart Homes

Li Yuan

FM Product Planning Manager, ZTE

Zhao Jiawei

FM Product Planning Manager, ZTE

With the increasingly widespread application of artificial intelligence (AI) and big data technologies, these advancements are driving a profound evolution in the field of smart homes. Large models, equipped with powerful data processing capabilities and precise predictive analytics, provide robust technical support for the intelligence, personalization, and efficiency of smart homes. Coupled with the evolution of technologies such as fiber to the room (FTTR), next-generation Wi-Fi, video imagery, voice recognition, these innovations collectively propel the development of smart homes.

Application Architecture of Large Models in Smart Home Scenarios

Large models typically refer to deep learning models with massive parameters and complex network structures, such as the GPT series and BERT. In smart homes, the core components of these models include voice recognition, natural language processing, and image recognition. These components enable smart home systems to better understand user needs and deliver more intelligent services.

As the implementation of large models deepens, edge-cloud collaboration has emerged as a key development trend in smart home applications (Fig. 1).

Edge-side applications refer to the direct use of computing power from smart home edge-side chips by large models to generate results. However, the immense computing power, storage, and energy consumption required by large models with hundreds of billions of parameters pose high demands on edge-side chips. Moreover, edge-side users have specific requirements for high performance, low latency, and data privacy. Therefore, deploying large models in the cloud combined with edge-side applications is the optimal choice for balancing performance, cost, power consumption, privacy, and speed.

Edge-side large models are more user-aware and can understand user intentions through edge-side learning, enabling them to provide personalized services. The foundational large models in the cloud, with larger parameter counts and broader capabilities, can address more complex issues. When the smart home perception layer detects a user request or household event, the edge-side model can accurately interpret the intent and provide timely, personalized responses. If users need more information, they will be directed to the foundational large model in the cloud for a more in-depth and comprehensive answer. The complementary capabilities of edge-side and cloud-side models create an excellent experience for smart home users.

ZTE's smart home solution positions the home gateway/router as the network control hub, with various terminal devices such as smart speakers, cameras, and smart locks serving as perception control nodes. This setup makes it an appropriate choice for edge-side AI applications. Additionally, ZTE's FTTR+Wi-Fi 7 all-optical networking solution, combined with AI computing power, storage capabilities, and smart home IoT applications, provides a solid network foundation for implementing large models in smart homes.

FTTR and Wi-Fi 7 Provide High-Quality Connection Foundation

As next-generation network communication technologies, FTTR and Wi-Fi 7 will offer smart homes users ultra-high bandwidth and ultra-low latency connection capabilities, ensuring reliable connectivity for the efficient application of large model technology.

FTTR technology lays fiber directly into each room, providing comprehensive high-speed network coverage throughout the home. Compared to traditional broadband access methods, FTTR offers higher bandwidth, lower latency, and more stable network performance. It ensures real-time communication and data transmission among smart home devices, delivering a smoother and more efficient experience to users.

As a next-generation wireless networking technology, Wi-Fi 7 boasts higher transmission speeds, lower latency, and improved anti-interference capabilities. It ensures more stable and reliable wireless communication among smart home devices and supports a greater number of devices accessing the network simultaneously, meeting the growing demands of smart home connectivity.

Large Models Empower Smart Home Applications

Large models, by deeply learning from massive user data, can accurately predict user behavior and preferences, enabling smarter and more personalized services for smart home devices.

- **User behavior prediction:** By collecting and analyzing users' daily behavior data, large models can predict user needs and actions, allowing smart home devices to adjust proactively. For instance, based on the user's wake-up time, the smart lighting system can automatically modify brightness and color temperature to create a comfortable wake-up environment.
- **Personalized services:** Large models can provide tailored services based on users' preferences and habits. For instance, the smart music system can automatically play the user's favorite songs according to their tastes, while the smart appliance system can adjust operational modes to save energy and improve comfort based on the user's lifestyle.

Smart Locks Empower Home Security Entrance

As an essential component of smart homes, the security of smart locks is directly related to personal and property safety. Large models can achieve more intelligent and secure lock management through deep learning and the analysis of user behavior and environmental data.

- **Intelligent recognition and verification:** Large models can perform deep learning and recognition of users' biometric features such as fingerprints and facial characteristics, enabling more intelligent and accurate identity verification.

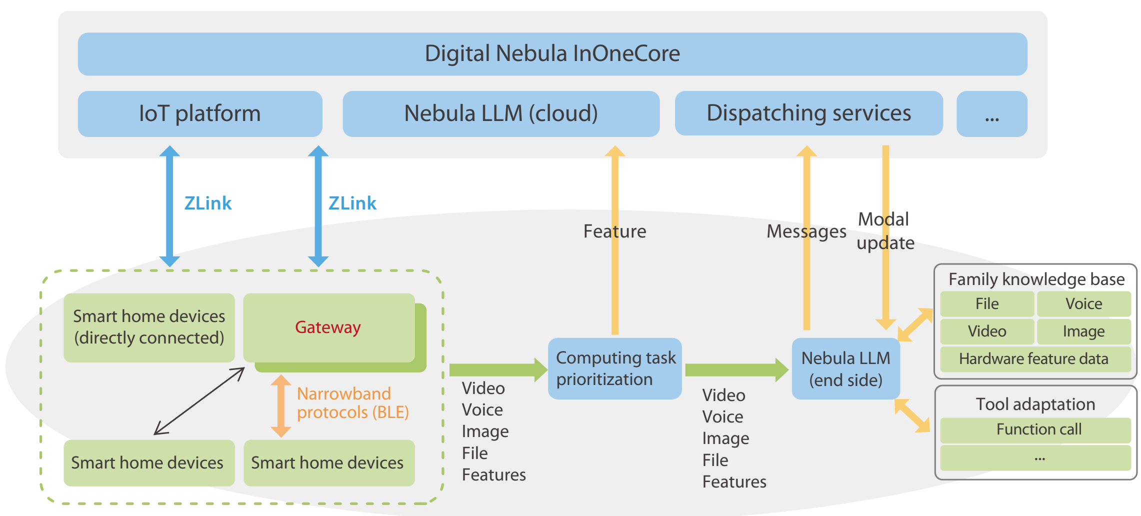


Fig. 1. Integrated edge-cloud architecture for large models and smart home collaboration.

Additionally, these models can also integrate users' behavior patterns with environmental data to verify users' identities from multiple dimensions, ensuring the lock's security.

- **Detection and early warning of abnormal behavior:** Large models can also perform deep learning and analyze lock usage data to detect abnormal behavior and issue early warnings. For instance, when detecting that the lock is frequently opened or closed within a short time frame, the large model can identify this as abnormal behavior and send alerts, reminding users to pay attention to safety or take appropriate measures.
- **Smart control and home interconnection:** Large models enable smart locks to interact with other smart devices in the home. Users can control lighting, temperature, security systems, and more through the smart lock, facilitating one-touch home automation. Also, the smart lock can automatically adjust device settings based on user behavior and environmental changes.

Smart Cameras Empower Home Security Monitoring

Using large model technology, smart cameras can provide more comprehensive and efficient monitoring solutions to ensure home security and privacy.

- **Intelligent recognition and monitoring:** Large models can analyze images captured by the camera using deep learning technology to intelligently recognize family members and visitors. By learning user's facial features and behavioral patterns, the system can offer more personalized monitoring services.
- **Environmental perception and analysis:** When combined with smart cameras, large models can not only recognize faces but also perceive and analyze the environment.
- **Behavior pattern learning and prediction:** By continuously learning and analyzing users' daily behaviors, large models can understand family members' habits and predict potential security issues.
- **Detection and early warning of abnormal behavior:** Large models can analyze the behavior captured by smart cameras in real-time, promptly identifying abnormal activities such as intrusions by strangers or the movement of objects.

Smart Speakers Empower Home Intelligent Interaction

As the interaction center of a smart home system, the intelligence of smart speakers directly affects the user experience. The application of large models in smart speakers enables more personalized and intelligent voice interaction services through deep learning and analysis of users' speech habits, preferences, and environmental data.

- **Intelligent voice recognition and interaction:** Large models can deeply learn from user speech, achieving high-precision voice recognition. By analyzing users' pronunciation, tone, and speech speed, smart speakers can better understand instructions and needs. Additionally, the large model can provide personalized voice feedback based on users' preference settings.
- **Environmental perception and intelligent response:** Large models empower smart speakers to integrate environmental data for intelligent responses. For instance, by analyzing indoor light intensity, a smart speaker can automatically play soft music when the user wakes up or adjust the lighting when the user returns home.
- **Smart control and home interconnection:** Large models enable smart speakers to control other smart devices in the home. Users can issue voice commands to control lighting, temperature, security systems, and more, achieving seamless home automation.

Large models, as an advanced AI technology, can enhance the interaction capabilities and intelligence of smart home devices, resulting in a revolutionary upgrade in human-machine interaction experiences. With advancements in hardware computing power, the optimization and innovation of AI algorithms, and improvements in multi-modal data quality, smart home systems empowered by large models will achieve true intelligence and personalization. ZTE TECHNOLOGIES

SCP Precise Marketing System: Assisting Operators in Premium Gigabit Operation

Wang Hecong

SCP International Marketing Representative, ZTE

With the rapid advancement of bandwidth technologies, home networks are evolving from mere bandwidth increases to a more holistic focus on both bandwidth and user experience enhancement. This transformation signifies a shift from traditional common home networks that relied on a single cable to a more sophisticated and unified network system. As a result, mesh and FTTR networking are gradually becoming mainstream demands, reflecting the growing need for seamless connectivity. Operators possess access to vast amounts of valuable data regarding home networks, yet they face three significant challenges when attempting to leverage this data for improved user experience: invisible experiences that are hard to quantify, difficulties in analyzing low quality of experience (QoE) metrics, and challenges in accurately identifying user demands. Consequently, precise network operation has become a core concern for operators striving to deliver enhanced services and customer satisfaction.

In 2023, ZTE, in partnership with a leading operator, launched the industry's first smart cloud platform (SCP) precise marketing system. This innovative solution aims to assist operators in enhancing their broadband service operations by providing valuable insights and targeted marketing strategies. By leveraging advanced data analytics and customer profiling, the SCP precise marketing system enables operators to better understand user needs, optimize service offerings, and ultimately improve customer satisfaction.

Framework of SCP Precise Marketing System

The SCP precise marketing system is designed to collect data across six dimensions: terminals, traffic, network quality, packages, preferences and other operator networks. It aims to deeply analyze user profiles, mine potential users of various services, and facilitate targeted marketing of multi-service packages (Fig. 1).

- Analyzes and identifies potential users who may migrate to other networks, providing early support to retain existing users.
- Analyzes and discovers inactive users, proactively addresses their issues, and provides early assistance to prevent them from becoming potential network-migrating users.
- Analyzes and identifies high-value users, categorizing them with specific labels to distinguish between heavy gamers, video users, readers, livestreamers, and SOHO users. It further tailors gigabit package services to meet the diverse needs of these high-value segments. For example, users with low Wi-Fi quality, numerous smart terminals, and strong spending power will be recommended to install mesh AP or FTTR. Users with high daily data usage and significant consumption of high-bitrate content will be advised to upgrade their packages. Additionally, users who spend over XX hours online daily, consume more than XX amount of data, and frequently watch both short and long videos will receive tailored video package recommendations.

Core Functions of SCP Precise Marketing System

Leveraging the collection and in-depth analysis of home network and user service data, the SCP precise marketing system provides six-dimensional profiles for home broadband users, enabling effective precise marketing.

Home Network Data Collection and Mining

By default, terminal devices (such as ONU, FTTR and mesh AP) report data to the SCP precise marketing system every 15 minutes, generating comprehensive network KPI reports that provide valuable insights into performance matrics. Operators can easily access detailed home network usage reports and tailored capacity expansion suggestions through the SCP webpage. Additionally, they receive automatically generated reports on a periodic basis, ensuring they are always informed about the latest network conditions and can make timely decisions to optimize service delivery.

Network KPI data includes various metrics, including CPU and memory utilization of terminal devices, online and offline time, as well as traffic, flow rate and bandwidth utilization of WAN and LAN interfaces. It also covers WAN connection traffic, Wi-Fi traffic, flow rate, idle time ratio and interference occupation ratio, and service bearer capability (including delay, jitter, packet loss, and reachable bandwidth) of user terminal links. The network KPI reports are designed as diverse statistical reports, focusing on home user terminals, enterprise user terminals, Wi-Fi coverage, bandwidth traffic, offline status, service bearer capability, and destination analysis. Additionally, user labels are created to extract market value.

User Service Data Collection and Mining

Integrated with deep packet inspection (DPI) plug-ins, terminal devices transmit user service flow information to the SCP precise marketing system via the message queuing telemetry transport (MQTT) event interface, generating detailed service usage analysis reports.

The service usage analysis data includes the MAC address, hostname, and IP address of the stations (STAs). Based on users' network usage and habits, service usage analysis reports are designed as statistical reports categorized by games, videos, shopping, social media, app stores, and operator applications. These reports are used to identify users engaged in games, videos, shopping, social interactions, app stores, and other operator networks, facilitating targeted promotions for acceleration packages, traffic packages, offline living equity, and

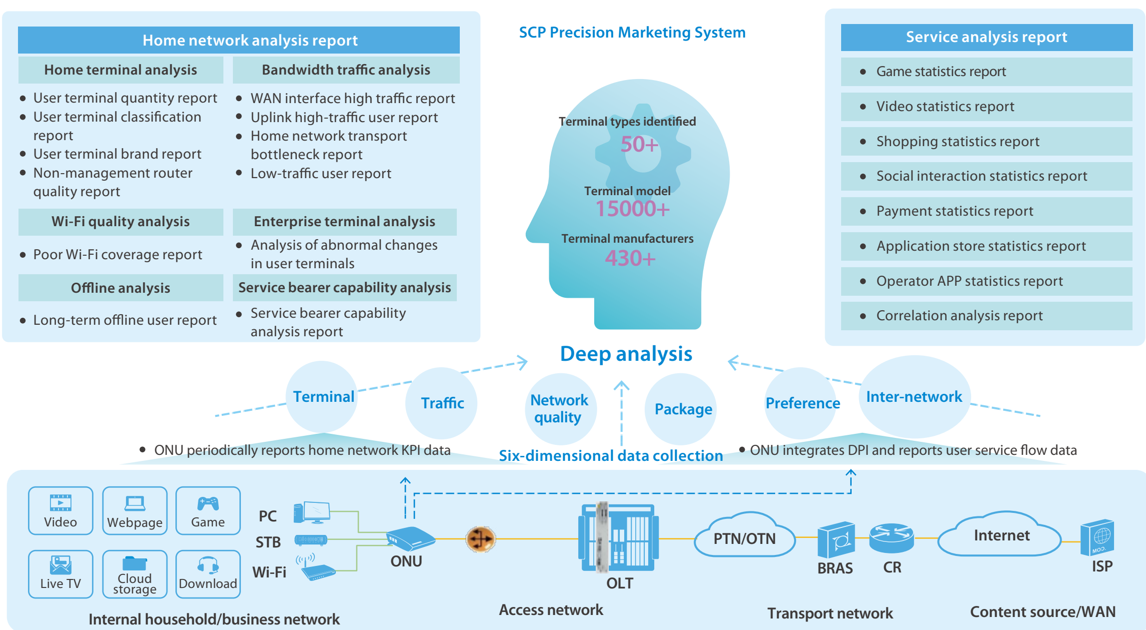


Fig. 1. SCP precise marketing system framework.

Precision marketing	User label	Description	Value	Marketing item of the operator
Game statistics report	XXX game APP, used traffic, duration, peak period	Network-wide game statistics by category	Identify game users and popular games	Directional acceleration
Video statistics report	XXX video APP, uplink and downlink traffic used, duration, peak period	Network-wide video APP statistics and details	Identifying video users	Directional acceleration, IPTV/OTT, traffic package, scenario bandwidth, Internet member
Shopping statistics report	XX shopping APP, traffic used, duration, peak period	Network-wide shopping APP statistics and details	Identifying shopping users	Offline living equity
Social interaction statistics report	XXX social interaction APP, uplink and downlink traffic used, duration, peak period	Network-wide social interaction APP statistics and details	Identifying social interaction users	Advertisement promotion
Payment statistics report	XXX payment APP, number of usage	Network-wide payment APP statistics and details	Identifying shopping users	Offline living equity
Application store statistics report	XXX application store APP, traffic used, duration, peak period	Network-wide application mall APP statistics and details	Application store ranking	XXX application store APP, traffic used, duration, peak period
Operator APP statistics report	Operator A, operator B, operator C	Operator APP usage statistics and details	Discovering other operator users	Handset marketing

Table 1. User service marketing items.

handset marketing, as shown in Table 1.

Four Highlights of SCP Precise Marketing System

The SCP precise marketing system has advantages in precision, cost, data, and revenue. It guides operators in delivering products and services tailored to the needs of specific customer groups, ultimately increasing sales revenue, enhancing customer satisfaction, and strengthening competitiveness.

- **Precise user profiles:** The SCP can associate a service flow with a specific user terminal to create accurate user profiles and can determine whether the service used by the user aligns with the link quality of their terminal.
- **Rapid deployment and low investment:** The SCP supports various deployment modes, including physical machine deployment and customer private cloud deployment. It features low costs and a short implementation period, enabling association analysis of user services and terminals. According to different precise marketing strategies, it can significantly increase ARPU value and reduce operators' OPEX.
- **Wide application and large data samples:** The SCP has been widely deployed by operators in China and abroad, managing over 10 million devices. A substantial volume of data samples is available for the SCP to collect and analyze in-depth, enabling it to provide precise marketing strategies for operators.
- **Diverse application scenarios and high returns:** Precise marketing is not only targeted at the marketing departments of operators but also assists installation and maintenance engineers by providing precise marketing suggestions through the mobile app associated with the SCP system. For example, for users who complain about slow network speeds or lagging, the app can display real-time network topology and terminal link connection quality, guiding users to install FTTR room ONTs or mesh APs to replace outdated routers and promoting specific service packages.

Currently, the home network KPI reports and service usage analysis reports from the SCP precise marketing system are being utilized at numerous sites for both domestic and international operators. These comprehensive reports play a crucial role in helping operators transition from simply increasing bandwidth to significantly enhancing user experience. By providing actionable insights, they enable operators to optimize their services and address user needs more effectively, ultimately improving the overall development efficiency of home broadband users. ZTE TECHNOLOGIES

Security Protection for Smart Home Networks

Xu Baohong

FM Terminal Product Security Manager, ZTE

Wang Lili

FM Product Planning Manager, ZTE

Smart home networks are transitioning into the FTTH Gigabit era, providing unprecedented bandwidth, reduced latency, and expanded coverage. This transformation offers operators opportunities to introduce emerging services such as home cloud security, cloud offices, cloud VR, and game acceleration. However, these services also introduce a wider range of potential cyber threats to home networks, making the protection of private data essential.

ZTE's smart home product portfolio utilizes the IPDRR security framework to establish a security system and architecture for smart home networks, with CPE products as its core. This model consists of five functional modules: risk identification (Identify), security protection (Protect), security detection (Detect), security response (Respond), and security recovery (Recovery).

Risk Identification

Risk identification for smart home networks includes determining asset priorities, identifying risks, and conducting impact assessments.

The internal devices in a smart home network include home gateways (HGWs), access points (APs), and various access terminals like PCs, set-top boxes (STBs), smart door locks, smart cameras, and smart phones. These devices, along with the software and data running on them, are assets that require robust protection.

The interior of a home network can be considered as a trusted area, while the exterior is an untrusted area. According to the STRIDE threat model analysis, the risks faced by home networks mainly stem from external attacks and internal data leaks concerning network privacy. The primary attacks include flooding attacks, buffer overflows, command injections, brute force attacks, and reverse engineering.

Security Protection

To ensure the continuity of home network services and mitigate risks and impacts from attacks, the security measures for smart home networks focus on the external protection of the all-optical main gateway at the boundary. This includes system security, network security, data security, and application security.

The system security function includes hardware protection, operating system protection, and security for open source components. No debugging interfaces (JTAG/serial ports) are left on the hardware, and the serial port pins are removed. The operating system's root file system must be a read-only and include address randomization to increase the difficulty of overflow attacks. The operating system disables support for unnecessary file types. By default, the system kernel does not load unnecessary file system drivers, reducing the attack surface. Open-source components are scanned regularly to eliminate any related vulnerabilities.

The network security function includes firewall, VPN tunnel protection, access control, and DoS attack prevention. The firewall can set access rules based on protocol type, MAC address, IP address, and packet port. VPN tunnel protection employs IPsec for encryption and authentication. Access control is implemented through blacklists and whitelists of URLs or IP addresses, and guest access devices are isolated within the Wi-Fi network. To prevent DoS attacks, the CPU load is reduced by limiting packet rates, thereby alleviating the risk of being attacked.

The data security function includes algorithm and key management, configuration file encryption, data transmission security, and personal data protection. The authentication algorithm's security strength requires that the DSA key length should be at least 2048 bits. Each device must have a unique, strong key password, and plaintext passwords are prohibited. Configuration files are encrypted during storage and transmission. Encrypted channels and access authentication are used for data transmission on the WAN side. User passwords and other personal data must not be displayed in plaintext, and sensitive data must be scrambled and encrypted.

The application security function includes authentication and authorization, input and output verification, third-party plug-in resource control, and access management. Authentication and authorization involve verifying identities when external media, such as Web/TR069, access the home network. The home network conducts legitimacy checks on external inputs to prevent injection attacks, cross-site scripting, and format string attacks. The system must control the permissions of third-party plug-ins, prohibiting them from running with root privileges and minimizing their process permissions. Web configuration via the HTTP GET method is forbidden, and the HTTP POST method should be used instead. Additionally, URL parameters must not contain sensitive data.

Security Detection

The home network security detection function monitors attacks in real time and tracks the normal operation of services and protection measures. It includes monitoring EMS user operations, overseeing home network system resources, controlling malicious software, and recording user logs.

- **Monitoring EMS user operations:** This involves monitoring the use of system accounts, ensuring that access is granted only with valid authorization, and auditing related operational records. It also includes detecting brute-force attacks on user accounts and implementing silent measures to mitigate these threats.
- **Overseeing home network system resources:** This involves monitoring the performance indicators of system software and hardware resources, such as CPU, RAM, FLASH, and processes during attacks. It includes recording logs and reporting alarms.
- **Controlling malicious software:** This involves using digital signatures and encrypted executable programs to restrict the installation and upgrade of malicious software. Downloading, installing, or executing third-party plug-ins from unknown sources is prohibited through certificate verification.
- **Recording user logs:** This involves recording user-related activities, exceptions, faults, and information security events, including but not limited to user ID, system activities, date, time, and details of key events. It also includes implementing privacy protection measures for sensitive data and personal identity information contained in the logs.

Security Response

The home network security response function involves responding to, processing, and managing security events.

Security event response processing includes detecting DoS attacks and other invasion events, as well as supporting the notification and reporting of security incidents. The system can be restored through rate limiting, traffic interruption, and filtering controls. The system automatically rolls back to the previous version when a malicious version upgrade is detected.

Security event management involves documenting the entire handling process of security events, which includes, but is not limited to, the detection process, response procedures, outcomes, and any related information.

Security Recovery

The home network security recovery function includes restoring the system to its normal state and implementing prevention and recovery measures. Users can manually or automatically execute an appropriate recovery plan based on the generated security events. The HGW facilitates offline configuration for access points, enabling a seamless plug-and-play experience along with automated deployment to ensure environmental recovery. Additionally, the HGW supports patch upgrades and security hardening through upgrade policies to minimize security risks.

By leveraging the industry-leading IPDRR security framework, the ZTE smart home CPE product solution offers a comprehensive and robust security solution for building secure home networks for users. ZTE TECHNOLOGIES

Application of FTTR-B All-Optical Solution in Campus Networks

Chen Daowei

Chief Planning Engineer of Wireline Products, ZTE

In a campus network, the FTTR to business (fiber to the room for business) all-optical solution is mainly used to provide wired and wireless access for user terminals. The FTTR-B main ONT integrates the functions of a mini OLT, AC, NAT gateway, DHCP server, and portal server, greatly simplifying the architecture of the campus network and cutting networking costs. As campus networks evolve, users seek better network experiences, leading to increased requirements for the FTTR-B all-optical solution, including redundancy protection and wireless roaming.

Redundancy Protection for FTTR-B Main ONT

The FTTR-B main ONT can connect to a maximum of 128 room ONTs, supporting access to over 1,000 users, which increases the need for better redundancy protection. FTTR-B redundancy protection focuses not only on the uplink PON interface but also on the downlink PON interface and the FTTR-B main ONT. Mature Type B and C solutions are available for the redundancy protection between the OLT and the FTTR-B main ONT. Given the redundancy protection requirements of FTTR-B, the dual FTTR-B main ONT redundancy protection solution is more suitable for the FTTR-B networking scenario.

As shown in Fig. 1, for redundancy protection between the OLT and the FTTR-B main ONT, a dual-active FTTR-B main ONT solution can be used to replace the common Type B and C protection solutions. This solution supports both single-OLT single-homing and dual-OLT dual-homing protection. Services are switched by the FTTR-B main ONT, and the switching process is quick, with low requirements for OLT and minimal impact.

For redundancy protection between the FTTR-B main ONT and room ONTs, a proper mode is usually selected based on the service scenario. For example, room ONTs used for wireless coverage, which provide service protection through multi-point overlapping coverage, generally adopt Type B dual-homing protection. Multi-port room ONTs used for camera access typically employ Type C dual-homing protection. When the dual FTTR-B main ONT services use L3 routing, direct network connectivity between the main ONTs is required to ensure that the WAN-side addresses remain unchanged and services are not interrupted during the switching of the devices connected to the left and right main ONTs. When the services use L2 bridging, direct network connectivity between the main ONTs is not necessary. In this case, when devices connected to the left and right main ONTs are switched, the MAC addresses can be actively refreshed to quickly restore the L2 paths.

- **Type B dual-homing protection of FTTR-B:** In the network architecture, a 2:N ODN is required. The left and right main ONTs are connected to the 2:N ODN, and the room ONTs are connected to the ODN properly. Communication should be established between the left and right main ONTs to negotiate the active/standby roles of the downlink PON interface, and synchronize the configuration information of the room ONT to ensure that the room ONT is not disconnected during the active/standby switching of the downlink PON interface. The room ONTs are unaware of the protection switching process.
- **Type C dual-homing protection of FTTR-B:** In the network architecture, two 1:N ODNs are required, and the left and right main ONTs are connected to

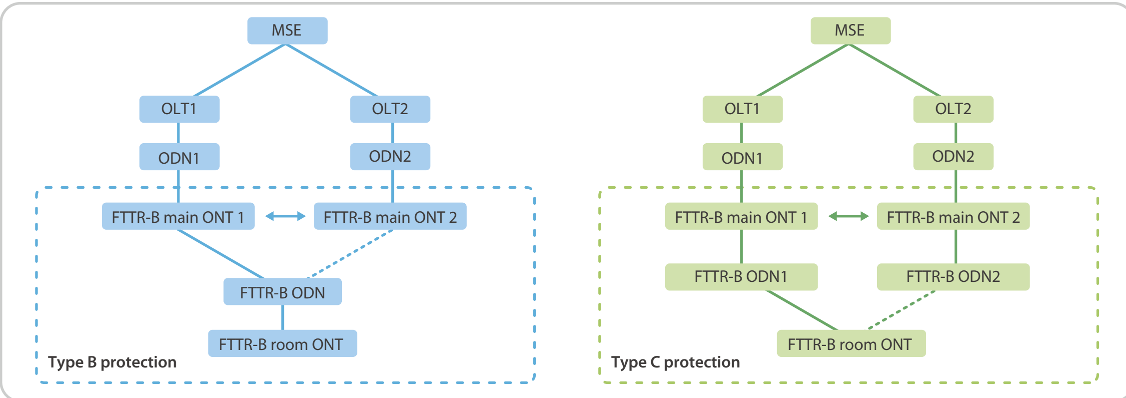


Fig. 1. Type B/C dual-homing protection in the FTTR-B network.

their respective ODN. The room ONT needs to connect to the left and right ODNs via dual uplink PON interfaces. Communication should be established between the left and right main ONTs to negotiate the active/standby roles of the downlink PON interface and synchronize the configuration information of the room ONT. This ensures that during active/standby switching of the downlink PON interface, the left and right uplink PON interfaces of the room ONT are notified to perform the same switching. The room ONT needs to allow services to be switched accordingly based on the active/standby status.

STA Roaming Across FTTR-B Main ONTs

For a large campus, multiple FTTR-B main ONTs usually have built-in mesh controllers to manage wireless roaming for their associated stations (STAs). A user STA may roam from FTTR-B main ONT 1 to ONT 2.

Mesh Controller Interworking Enables STA Roaming Across Main ONTs

The FTTR-B main ONT has a built-in mesh controller. The 802.11k standard allows a STA to scan for APs with a specific SSID over the air interface and continuously learn and update the neighbor AP list, which enables the STA to quickly measure signal strength and select a roaming target.

When the STA starts roaming to the AP of FTTR-B main ONT 2 based on the roaming policy, main ONT 1 queries the mesh controller of main ONT 2 according to the local neighbor AP list and notifies it that the STA will roam to the corresponding target AP. After the target mesh controller agrees, the roaming can proceed.

A STA Roams to an FTTR-B Main ONT Across L3 Routes

The FTTR-B main ONT operating in L3 mode performs NAT translation on service packets, causing the WAN-side addresses to vary from one main ONT to another. When a STA roams to a different FTTR-B main ONT across L3 routes, the network application link is disrupted due to the change in the WAN-side address. To solve this problem, the egress gateway for the STA should be fixed to the original FTTR-B main ONT.

An L2 “LAN connection” is added to the uplink PON interfaces of all FTTR-B main ONT to facilitate L2 interconnection between them. Each FTTR-B main ONT is enabled with a DHCP server, which assigns different network segments and gateway addresses (local main ONT addresses). When a STA roams to the AP of a new FTTR-B main ONT and attempts to renew its IP address via a DHCP request, the new main ONT enables the original FTTR-B main ONT to renew the STA’s original IP address and the original gateway IP address. As a result, the addresses on both the WAN and LAN sides remain unchanged, preventing any interruption to network application links.

The ZTE FTTR-B all-optical solution for campuses not only simplifies network deployment but also improves network reliability and user service experience. It allows operators to upgrade the campus network from "bandwidth connection" to "service experience", facilitating a strategic transformation in a new era. ZTE TECHNOLOGIES

Laser Sensing Technology and Its Applications

Zhu Songlin

Senior Expert on Technology Pre-Research, ZTE

Wang Zhongyi

Standards Pre-Research Engineer, ZTE

With the rapid advancement of artificial intelligence (AI) technology, the intelligent transformation of various industries is accelerating. Among the most extensive application scenarios in daily life, the development of smart homes has garnered significant attention. Smart homes encompass a wide range of intelligent devices, including smart appliances and security systems, and involve multiple technical fields such as Internet, automation, communication, and sensing technology.

Sensing technology is the core of smart homes. Existing smart home solutions typically require the deployment of multiple independent sensing devices, such as thermometers and cameras, which often lead to high interface costs, occupy valuable space, and create detection blind spots. However, laser sensing technology offers a feasible solution to these challenges. By integrating with the existing fiber infrastructure deployed in fiber access networks, laser sensing can enhance the capabilities of smart homes.

Future Trend: Integrating Laser Sensing with Fiber Optic Communication

The working principle of laser sensing technology involves laser detection signals reaching the test area via an optical transmission medium. When the measured parameters such as pressure, strain, acceleration, and sound waves interact with these laser signals, their optical properties—intensity, wavelength, frequency, phase, and polarization state—change, resulting in modulated optical signals. These signals are then transmitted to an optical signal detector through the optical medium, where they undergo optical-electrical signal conversion. After demodulation, the measured parameters can be obtained.

Laser sensing technology is categorized into fiber optic sensing and light detection and ranging (LiDAR) based on the optical transmission medium used. LiDAR uses free space as the transmission medium, while fiber optic sensing employs optical fibers as sensing materials to detect environmental changes around them. Existing mature fiber optic sensing systems include distributed acoustic sensing, distributed temperature sensing, and distributed strain sensing systems, all capable of monitoring vibration, temperature, and strain changes in the vicinity of the fibers. These systems can cover sensing ranges of tens of kilometers with meter-level resolutions. Most existing products are specialized systems that require the deployment of dedicated fiber optic lines.

The integration of fiber optic sensing and fiber optic communication represents a promising research direction. With large-scale fiber infrastructure already in place, fiber optic communication can leverage sensing technologies to unlock additional value. This integration enables the delivery of high-speed data services alongside sensing capabilities, ultimately offering customized solutions that provide greater value to users.

Research on the integration of fiber optic sensing and fiber optic communication is still in its early stages. Current fiber optic sensing technology can achieve a spatial resolution of less than one meter, meeting the internal sensing precision requirements for home applications. Exploring how to combine fiber optic sensing technology with the fiber to the room (FTTR) networks being deployed is an important development direction. ITU has begun

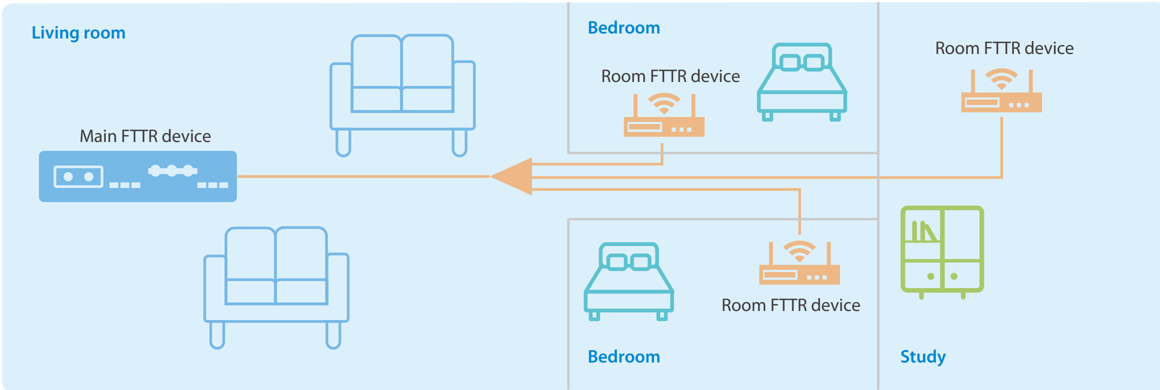


Fig. 1. FTTR networking in home scenario.

preliminary standardization efforts, sparking extensive discussions. It is anticipated that related standards will be preliminarily completed by 2026.

LiDAR, an acronym for light detection and ranging, utilizes laser sensing technology to analyze modulated optical signals. It obtains the distance between the laser transmitter and the target object to be measured, along with the intensity, frequency, and phase of the reflected light signal, to generate accurate three-dimensional structural information. This capability allows for detailed reconstruction of the target's movement and shape changes, enabling track detection and action recognition.

Typical Scenarios Integrating Laser Sensing and FTTR

In a smart home, FTTR technology provides high-speed data connections to individual rooms. Fig. 1 illustrates a typical FTTR networking configuration. Distributed fiber optic sensing technology leverages existing FTTR fiber resources to monitor various parameters in the room in real-time. Integrating high-speed data connections with real-time sensing services effectively meets the diverse needs of smart homes.

Fire safety is a crucial aspect of smart home security. A distributed fiber temperature sensing system provides real-time temperature monitoring within the home. By analyzing this temperature data, the system can detect abnormal environmental changes and offer early fire warnings to implement smart security. Additionally, FTTR's high-speed data connections enable remote alerts and fast alarms, ensuring the safety of both users and their property.

Intrusion detection is essential for smart homes. A distributed fiber optic vibration sensing system can identify potential intrusions by monitoring vibrations, triggering and activating other smart home devices. Additionally, data from these devices, such as video footage, can be transmitted remotely to the user via FTTR technology.

The distributed fiber optic vibration sensing system is well-suited for smart home applications. FTTR-based fiber optic sensing can analyze vibration data within the home to determine occupancy, enabling the use of smart switches. By monitoring vibrations across multiple rooms, the system can estimate occupants' locations, facilitating automated adjustments of home appliances. Moreover, temperature data from the sensing system can guide the autonomous adjustment of air conditioners and other electrical devices.

LiDAR technology has been widely used in autonomous driving and other application scenarios. As the industry chain matures, it is expected to find uses in smart homes. By integrating LiDAR and fiber optic sensing into the ONU device of FTTR systems, we can achieve coarse-granularity sensing for application scenarios like household security monitoring and tracking elderly individuals with Parkinson's disease. For fine-granularity sensing, potential application scenarios include motion analysis and respiratory monitoring. These advancements in sensing technology are poised to create new market opportunities.

FTTR technology enables gigabit all-optical access, delivering high-speed data connectivity. By leveraging fiber optic devices and high-speed data pipelines, laser sensing technology provides real-time perception services on a room-by-room basis. The deep integration of FTTR and laser sensing fully utilizes the capabilities of high-speed optical access networks, driving the advancement of intelligent technologies. ZTE TECHNOLOGIES

Application of G.654.E Fiber for High-Capacity Long-Distance Transmission Systems

Nguyen Duc Tho

Head of Fixed System Application Research Department, Viettel Network

Nguyen Thanh Hai

Fixed System Application Researcher, Viettel Network

Nguyen Ba Voc

Transmission Technical Support Specialist, Viettel Network

Introduction

As we enter the 5G era with applications like ultra reliable low latency communications (URLLC), massive machine type communications (mMTC), and especially enhanced mobile broadband (eMBB), we face extremely high requirements for transmission capacity—over 10 times that of 4G technology.

To handle this explosion in data traffic, dense wavelength division multiplexing (DWDM) optical transmission technologies have emerged, significantly increasing the transmission capacity per fiber—up to 8 times over the last 10 years (Fig. 1).

While DWDM transmission equipment has continued to develop rapidly, the optical fiber medium used for transmission hasn't seen much change. For the last 20 years, the most commonly used fibers have been G.652D and G.655 (Leaf) fibers.

With on-off keying (OOK) technology, the transmission quality in DWDM systems is heavily influenced by fiber characteristics, such as polarization mode dispersion (PMD) and chromatic dispersion (CD). To reduce the impact of CD, operators have switched to using G.655 fiber, which has a lower CD coefficient (≤ 6 ps/(nm.km)), instead of G.652 fiber, which has a higher coefficient (up to 18 ps/(nm.km)). This switch helps improve transmission quality but raises costs by about 7.5% per kilometer for 24 fiber optic cables (comprising 18 G.652 fibers and 6 G.655 fibers) compared to cables that use only G.652 fibers.

The introduction of coherent technology, used in DWDM systems with transmission capacities per wavelength of ≥100G, has completely eliminated the impact of CD on transmission quality. As a result, G.655 fiber is no longer needed. However, as transmission capacities increase, the system also requires better optical signal-to-noise ratios (OSNR) on the fiber. To accommodate these higher capacities, devices need more advanced chipsets that can handle higher modulation formats (up to 64QAM or 256QAM), higher baud rates (up to 96 Gbaud or more), and other advanced techniques like probabilistic constellation shaping (PCS) or Nyquist filtering (Fig. 2). On the physical side, reducing noise from fiber loss and nonlinear effects is essential.

By early 2022, many DWDM equipment manufacturers had released devices supporting transmission rates of up to 800G per wavelength over distances longer than 900 km. However, there remains a significant gap between the new technology and existing cable networks. At that time, Viettel, the largest telecom operator in Vietnam, tested high-capacity transmission of 800G per wavelength and found that the transmission distance was limited due to nonlinear effects and fiber loss, as shown in Table 1.

High-capacity transmission distances are primarily limited by high fiber attenuation (average 0.3 dB/km). To improve transmission distances with high capacities, we need to address the physical factors affecting the transmission medium.

To meet these needs, ITU-T introduced the G.654 standard for optical fibers. G.654 fibers have various

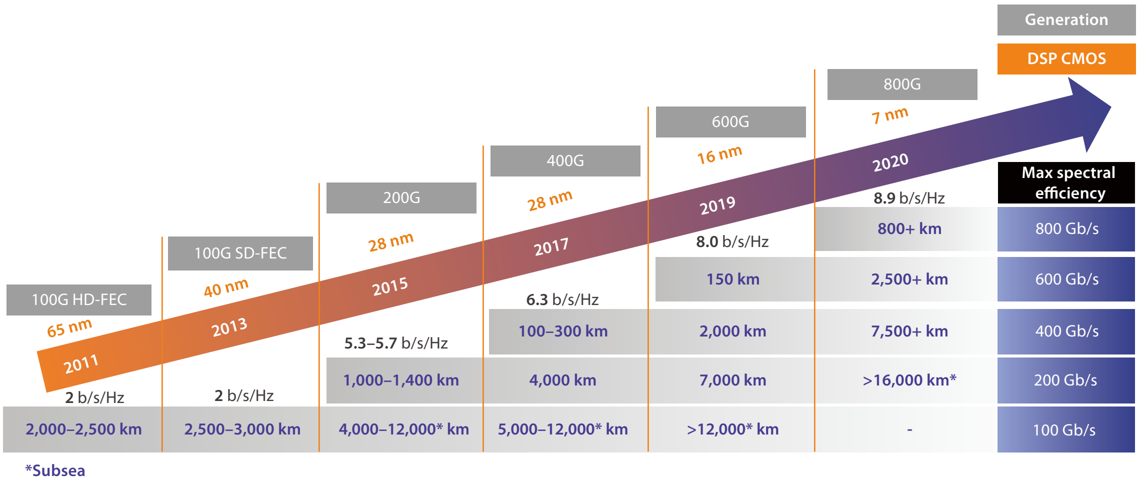


Fig. 1. The development of DWDM transmission equipment.

subclasses A/B/C/D/E to serve different purposes.

History of G.654 Fiber

G.654 fiber is a single-mode fiber with a pure silica core, designed to minimize loss at a wavelength of 1550 nm. It was developed in the mid-1980s for long-distance submarine optical fiber systems, as it offers about 10% less loss than G.652 fiber at this wavelength. In DWDM systems, optical fibers show nonlinear characteristics when transmitting high-capacity, long-distance signals. This reduces system performance when the input power exceeds a certain threshold due to the fiber's nonlinear effects.

The power density in the fiber core affects nonlinear effects. When the input power is constant, nonlinear effects can be reduced by increasing the fiber's effective area, thereby lowering the core's power density. As a result, G.654 fiber began to be mentioned in technical documents regarding improvements in the "effective area". Increasing the effective area also raises the cut-off wavelength, which needs to be carefully managed to ensure the fiber performs well in the C-band (1530–1565 nm). G.654 fibers have a cut-off wavelength of 1530 nm, but in 2000, the ITU revised this and introduced the term "cut-off wavelength shifted single-mode fiber". Low attenuation and a large effective area are the two main characteristics of G.654 fibers today.

Characteristics of G.654.E Fiber

In terrestrial transmission systems, G.652.D is

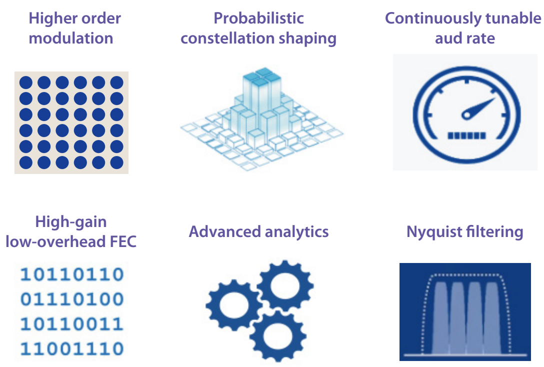


Fig. 2. Techniques for increasing transmission capacity.

the most commonly used optical fiber. The nonlinear effects of the fiber increasingly impact transmission performance as the transmission speed on a single wavelength of the DWDM system reaches 100G. At this point, G.654 fiber has drawn the attention of researchers and been adopted in long-distance backbone transmission systems. The macro bending loss criteria of G.654 fiber used on land are generally stricter than those used in underwater applications (macro bending loss in accordance with G.652D standards). In addition to having low attenuation, the effective area is also larger compared to the fiber used underwater. Due to this requirement, G.654E has become the industry standard. The differences in key transmission parameters for each subclass of G.654 fiber are shown in Table 2.

Advantages of G.654.E Fiber

OSNR is a critical factor in the performance of optical networks. G.654.E fiber has very low macro-bending loss and a large effective area, which

Table 1. Transmission capacity and actual distance evaluation.

Number of hops	Wavelength rate (Gbps)	Maximum actual distance (km)
01	800	50
02	700	80
03	600	170
04	500	180
08	400	420
10	200	720

Table 2. Characteristics of G.654.E fiber.

Parameters		G.654 A	G.654 B	G.654 C	G.654 D	G.654 E
Fiber attribute						
Mode field diameter	**Wavelengths**	**1550 nm**	**1550 nm**	**1550 nm**	**1550 nm**	**1550 nm**
	Core diamete	9.5 ~ 10.5 μm	9.5 ~ 13.0 μm	9.5 ~ 10.5 μm	11.5 ~ 15.0 μm	11.5 ~ 12.5 μm
	Tolerance	± 0.7 μm	± 0.7 μm	± 0.7 μm	± 0.7 μm	± 0.7 μm
Cladding diameter	Clad diameter	125 μm	125 μm	125 μm	125 μm	125 μm
	Tolerance	± 0.7 μm	± 1 μm	± 0.7 μm	± 0.7 μm	± 1 μm
Clad non-circularity	Max.	≤2.0 %	≤2.0 %	≤2.0 %	≤2.0 %	≤2.0 %
Clad concentricity error	Max.	≤ 0.8 μm	≤ 0.8 μm	≤ 0.8 μm	≤ 0.8 μm	≤ 0.8 μm
Cable cut-off wavelength	Max.	≤ 1530 nm	≤ 1530 nm	≤ 1530 nm	≤ 1530 nm	≤ 1530 nm
Macro bend Attenuation	Radius	30 mm	30 mm	30 mm	30 mm	30 mm
	Number of turns	100 turns	100 turns	100 turns	100 turns	100 turns
	Max. at 1652 nm	0.5 dB	0.5 dB	0.5 dB	0.5 dB	0.1 dB
Proof stress	Min.	0.69 Gpa	0.69 Gpa	0.69 Gpa	0.69 Gpa	0.69 Gpa
CD coefficient	D1550max	20 ps/(nm.km)	20 ps/(nm.km)	20 ps/(nm.km)	23 ps/(nm.km)	23 ps/(nm.km)
	S1550max	0.070 ps/(nm^2.km)	0.070 ps/(nm^2.km)	0.070 ps/(nm^2.km)	0.070 ps/(nm^2.km)	0.070 ps/(nm^2.km)
Cable attribute						
Attenuation coefficient	Max. at 1550 nm	0.22 dB/km	0.22 dB/km	0.22 dB/km	0.22 dB/km	0.23 dB/km
PMD coefficient	M	20 cables	20 cables	20 cables	20 cables	20 cables
	Q	0.01%	0.01%	0.01%	0.5dB	0.01%
	Max. PMDQ	0.5 ps/√km	0.5 ps/√km	0.5 ps/√km	0.5 ps/√km	0.2 ps/√km

improves OSNR by reducing transmission loss and allowing for higher launch power. A 1 dB improvement in OSNR can increase transmission distance by 25%, a 2 dB improvement by 60%, and a 3 dB improvement by up to 100%. Fig. 3 compares the performance of G.654.E fiber with other types.

G.654E fiber has two different effective areas: 110 μm^2 (A110) and 130 μm^2 (A130). The A110 and A130 fibers were used in China's backbone networks from 2015 to 2018. After 2018, only the A130 fiber was used for building backbone networks. The G.654E (A130) fiber has an effective area that is 47% larger than the G.652D (A80) fiber. With unchanged nonlinear effects, the optimal optical input power can be increased by about 1.7 dB. G.654E fiber has a typical attenuation coefficient that is approximately 0.02 dB/km lower than that of G.652D fiber. The optical loss of G.654E fiber is about 1.6 dB lower than that of G.652D fiber over an 80 km fiber span.

Because the locations of optical amplifier stations in the terrestrial backbone transmission system was fixed, increasing the optical input power and reducing fiber loss will not significantly decrease the number of optical amplification stations required. However, the OSNR value of G.654.E fiber can be improved by approximately 3 dB compared to G.652 fiber, assuming that the optical amplification/repeater stations remain unchanged.

In addition to low attenuation and a large effective area, G.654.E fiber also operates over a wide temperature range, from −65°C to 85°C, making it suitable for deployment in terrestrial transmission systems.

Disadvantages of G.654.E Fiber

Despite its advantages, G.654.E fiber has some notable drawbacks. For instance, its cut-off wavelength is limited to 1530 nm (Fig. 4), making it unsuitable for short-distance transmission (such as metro access networks). Moreover, G.654.E fiber is more expensive, costing 1.5 to 2 times more than G.652.D fiber, which limits its market share.

Real-World Applications of G.654.E Fiber

Recently, fiber and cable manufacturers have developed G.654.E fiber for use in terrestrial optical transmission systems. By 2017, two major telecom operators in China had commercially deployed G.654.E fiber for 400G DWDM transmission systems: China Unicom (about 472 km) and China Telecom (1,500 km). By the end of 2021, Chinese telecom operators had implemented G.654.E fiber in projects totaling approximately 41,000 km of cable, focusing on upgrading the East-West backbone links to support high-capacity DWDM systems.

- In 2021, China Telecom completed a backbone fiber link from Shanghai to Guangzhou, spanning 1,970 km.
- In 2022, China Telecom announced the 2022 backbone cable project, with the first phase covering 3,621 km, equivalent to about 610,000 km of fiber cores using G.654.E cable.
- In 2022, China Mobile initiated centralized procurement of G.654.E cable, totaling 2,134 km, equivalent to 332,400 km of fiber cores.
- In 2023, China Mobile's centralized procurement of G.654.E cable increased nearly fourfold, covering 8,463 km, equivalent to 1.2279 million km of fiber cores.

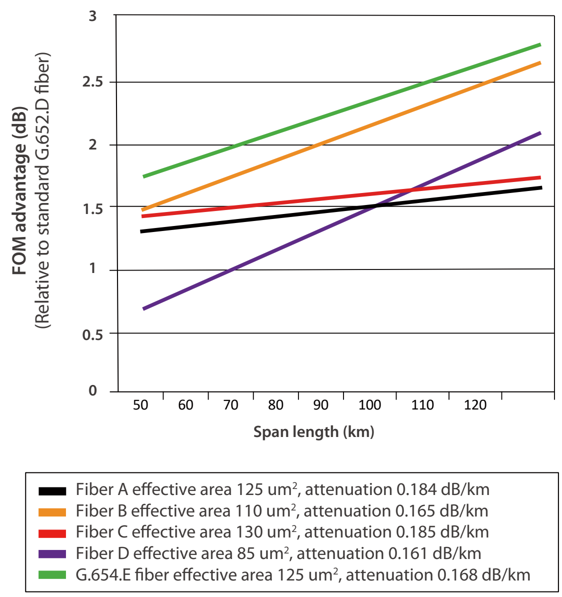


Fig. 3. Performance comparison of G.654.E fiber.

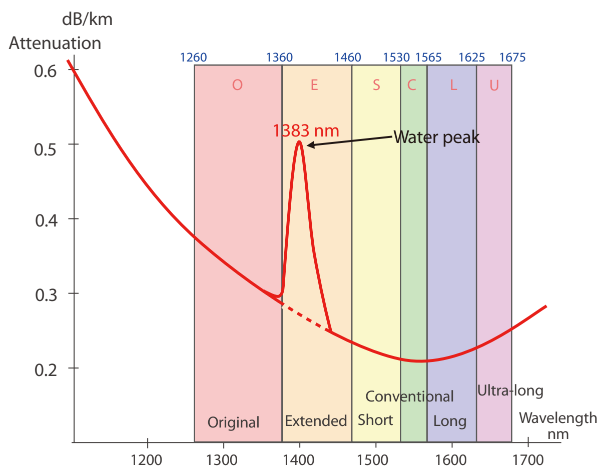


Fig. 4. Cut-off wavelength characteristics of G.654.E fiber.

At the beginning of 2023, Viettel, in collaboration with ZTE, tested a 1 Tb/s DWDM system using G.654.E and G.652.D fibers. The results showed that the 1 Tbps wavelength was transmitted over a distance of 1,040 km using G.654.E fiber, which is 1.5 times the distance achievable with G.652.D fiber. ZTE TECHNOLOGIES

China Unicom Hebei: Accelerating FTTO Commercialization to Lead Livestreaming Industry

Wu Chaowei

FM Product Planning Manager, ZTE

In recent years, the livestreaming e-commerce industry has grown rapidly. By 2022, China boasted 660 million online livestreaming users and 1.704 million livestreaming-related enterprises. Over the past four years, the average annual registration growth rate for these enterprises has exceeded 90%. In the first five months of 2024 alone, 347,000 new enterprises were registered.

Many of these enterprises are in urgent need of digitalization, but traditional ad-hoc networks lack scientific design, effective deployment, and reliable operation and maintenance (O&M). This leads to three main challenges: poor Wi-Fi experience (characterized by high latency, prone to stuttering, and dropped calls), an insufficient number of devices, and difficulties in network O&M. These issues raise operational costs and create barriers to digital and intelligent transformation for these enterprises.

During the final of the 2024 "Guanghua Cup" Gigabit Optical Network Application Innovation Competition, the China Academy of Information and Communications Technology (CAICT) and the three major Chinese operators jointly launched the "All-Optical Network Development for Small and Medium-Sized Enterprises" initiative at the "Digital Transformation Forum for Small and Medium-Sized Enterprises". This initiative aims to drive innovation and progress in fiber-to-the-office (FTTO) technologies and integrated applications, facilitating the digital transformation of these enterprises.

The livestreaming e-commerce business is booming in Hebei province. To meet the high demand for basic network infrastructure, one-stop networking solution and one-off network deployment have become priorities for China Unicom Hebei. At the FTTO press conference themed "Empowering livestreaming E-commerce to Enhance Economy", the operator is committed to leading the way in gigabit optical network construction. They aim to identify pain points in the transformation of livestreaming enterprises in the province, focus on operational services, leverage their integration advantages, and launch FTTO all-optical intelligent enterprise networking products.

To build an enterprise network with larger bandwidth, more connections, and lower latency, the FTTO all-optical intelligent enterprise solution offers stable and reliable livestreaming optical network services tailored to the development characteristics of local livestreaming enterprises. This "one-stop" solution empowers all enterprises to achieve digital transformation through a digital and intelligent optical network, injecting new momentum into the rapid growth of the digital economy in the province.

China Unicom Hebei worked with ZTE to

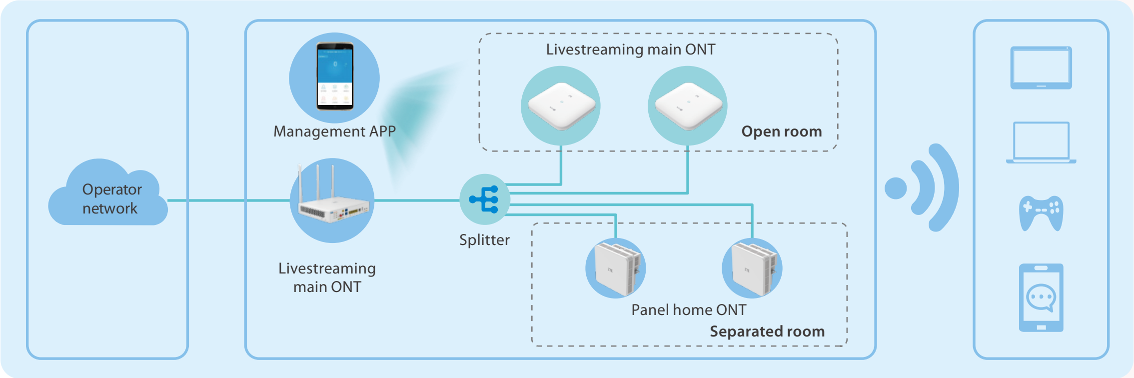


Fig. 1. Network topology in FTTO livestreaming room.

accelerate the commercial use of FTTO. In the initial phase, both parties addressed all key value areas with 10G PON ports, establishing a strong foundation for FTTO deployment at the system side. The operator also supplied an integrated package suitable for livestreaming scenarios, supporting ultra-gigabit Wi-Fi and enabling 300 concurrent connections for multi-person livestreaming in enterprise networks.

The ZTE FTTO all-optical livestreaming solution multiplexes the operator's PON resources, extending fibers to every corner of an enterprise based on a simplified all-optical network architecture. It incorporates new Wi-Fi 6 technologies to provide full coverage of the enterprise intranet, delivering an end-to-end all-optical network. This solution enables high concurrency, smooth and seamless roaming, and enhanced network visibility, manageability, testability, and optimization. With advantages such as fast deployment, high quality, and easy O&M, it ensures an ultra-gigabit wireless office experience for livestreaming enterprises.

- **Fast deployment:** The FTTO solution uses an all-fiber network, with photoelectric composite cables that support both data transport and device power supply. Wi-Fi devices can be configured as needed, allowing for quicker fiber routing. The FTTR main ONT consolidates five functions—ONT, router, AC controller, IAD, and switch—resulting in a 75% reduction in device size compared to traditional solutions, which simplifies and accelerates the networking process.
- **High quality:** Utilizing fibers and 160 MHz Wi-Fi 6 technology, the FTTO solution supports an ultra-gigabit Wi-Fi experience. It delivers dedicated acceleration channels for office applications such as conferences and livestreaming, prioritizing bandwidth usage for VIP applications to ensure a smooth office network without lag. By adopting the C system architecture of China Unicom's innovative smart home products, it deeply integrates optical and Wi-Fi technologies for intelligent scheduling of Wi-Fi air interface resources. This integration ensures that up to 300 terminals can access the Internet simultaneously and stably. By combining smart antennas, the solution provides full coverage in the office area and seamless network switching during movement, securing network stability for typical livestreaming scenarios with multi-device concurrency, such as walking, standing, and seated livestreaming.
- **Easy O&M:** The FTTO solution incorporates broadband private lines, network design, installation, deployment, and O&M services, offering professional O&M support and user applications. It enables IT personnel from enterprises and operators to efficiently manage network status with one-click viewing and management tools. Additionally, it provides a portable network management app for livestreaming enterprises, allowing for convenient self-management (Fig. 1).

The FTTO solution can establish a production network with ultra-high bandwidth, high security, reliability, deterministic performance, and minimalist architecture. Building on this foundation, it integrates network, security, cloud, accounting, and video services, significantly enhancing production efficiency, boosting enterprise vitality, reducing costs, and unlocking new business opportunities. ZTE TECHNOLOGIES

Building a Network Bridge Over the Digital Divide in Liberia

Source: LightReading

Sprinting to the Highest Hilltop: What Life in Remote Rural Liberia Means

When we first met Lina, she was sprinting towards the highest hilltop deep in the forest. The village where Lina's family lives lacks network coverage, so in emergencies such as severe illness among family members, locals have no choice but to run to the mountaintops. Only by placing their phones on a wooden stake at the summit can they barely receive a signal. As you pass by hill after hill and see people gesturing frantically and looking anxiously at the bare wooden stake, it's not an unusual sight in the area.

"Living here feels like being cut off from the world. There seems to be no sign of development, and many of my friends have gone to the city to earn money." Lina told us.

In fact, in remote rural areas of Liberia, we encountered many children facing the same predicament as Lina. Their schools are barely more than a brick wall, with no electricity supply. During the long, dark rainy season, the thunderous rain can even drown out the teacher's voice. Dropping out at a young age to seek their livelihood elsewhere is a choice many local families make for their children.

Liberia has a total population of 5.34 million, 34.8% of whom are classified as extremely poor according to the World Bank. The country's mobile communication infrastructure is severely lacking, with network coverage concentrated in the capital and a few major towns. Data from the International

Telecommunication Union (ITU) shows that as of 2023, approximately 75%-80% of Liberians are "offline," unable to benefit from the digital economy and with limited access to higher quality education, healthcare, and financial resources.

However, traditional network solutions have a low return on investment, hindering the establishment of a virtuous cycle. To enhance network coverage for local residents through affordable mobile voice and data communication, in 2024, the "Enhance Rural Area" network project, jointly carried out by Orange Liberia and ZTE, was officially launched. This initiative gave over 580,000 users in previously underserved areas the opportunity to enjoy 2G and 4G network service, contributing to digital, financial and energy inclusion.

Building a Network Bridge: Three Months, 1100 Kilometers, and 128 Sites Covering 128 Rural Villages

Liberia contends with the complexities of national infrastructure, influenced by its unique geographic and climatic conditions. The extended rainy season, lasting over seven months, adds significant challenges to material transportation and construction.

In March 2024, engineers ventured deep into the local forest. Thanks to the perfect supply chain support and the enthusiastic help of local residents, the distribution of tower installation materials and site equipment was completed as scheduled, reducing the impact of the rainy season on project delivery. Additionally, they adopted an innovative Lego-type modular tower construction plan, equipped with minimalist devices, achieving rapid and flexible deployment, and reducing the construction period by 60%. Ultimately, engineers overcame numerous unforeseen obstacles and completed the deployment of 128 rural network sites spanning over 1,100 kilometers in just three months.

To adapt to network transmission in remote areas and eliminate the dependency on electricity, ZTE customized a solution for rural Liberia in two dimensions: system product

Local villagers spontaneously built fences to protect the sites innovation and energy support.

The ZTE Rural EcoSite solution uses low-power, wide-coverage wireless base station equipment supporting 700 MHz, 800 MHz, and 900 MHz, compatible with 2G/3G/4G/5G systems. This meets the network needs of different countries and leaves room for flexible upgrades at various stages. Additionally, to address the challenge of scarce transmission resources in remote areas, the solution supports various methods such as microwave, satellite, and relay technology, ensuring high-quality network services. The solution also adopts a pure solar power supply, coupled with smart lithium batteries for flexible power storage, ensuring continuous power at night or during cloudy days. The solar power supply can even help meet some of the local residents' daily electricity needs, allowing them to charge household equipment.

Bridging the Digital Divide: What Network Construction Brings to 580,000 Residents in Remote Areas

The 128 sites have connected 128 remote villages in Liberia, meaning that 580,000 "offline" people living there, like Lina's family, now have the opportunity to access abundant information, knowledge, and resources. This will allow them to pursue a better quality of life and embrace a broader range of future possibilities.

As the profound gap between individuals and the digital world is reduced by this network "bridge," locals no longer have to "sprint to the distant hilltops." The network now allows them to consult medical experts on demand, obtain timely treatment services, carry out mobile financial transactions and converse with distant friends at any time. "With the network, I can chat with my mom and dad, learn foreign languages, send and receive money, pay local merchants using Orange Money, recharge my Orange Energies and know what the outside world is like," Lina once described her vision of a happy life to one of the network engineers.

Since its launch, the network has carried 510 gigabytes of data and 5700 Erlang voice traffic daily. We have witnessed the changes in the lives of Liberians, seeing more residents using data services, with data traffic growing at an annual rate of 50%.

Before the arrival of the rural network project, local agriculture faced challenges such as lack of technology and low productivity. The network enables farmers in remote areas of Liberia to access the latest agricultural information and learn planting techniques, thus increasing crop yields and income. In the future, rural areas are also expected to deploy IoT devices, enhancing agricultural sustainability with smart functions like precision irrigation and pest and disease monitoring.

Equally important, the network also provides new opportunities for education and women's development. These 128 sites cover more than 100 schools, mainly in primary and junior high schools. With the network, students can access online courses and learning platforms, enjoying higher-quality digital educational resources that help bridge the urban-rural education gap. A primary school teacher from Brown Town, Rofus, expressed delight, believing that the activation of the sites would provide new learning pathways for children, reducing issues such as juvenile. Moreover, the network offers hundreds of thousands of rural the opportunity to gain knowledge and skills in crop cultivation and handicrafts, improving their employment prospects. The network opens doors for them to participate in social and economic activities, promoting gender equality and women's empowerment.

In the future, ZTE plans to leverage its R&D strength to balance affordability and technological advancement, launching a range of smartphones and MiFi terminals for residents in remote rural areas of Liberia, priced within their reach. Orange Liberia will also offer

Engineer in commissioning operation

preferential policies and low-priced devices to further reduce barriers to access, accelerating digital inclusion in rural areas.

Towards a More Inclusive Future: Lighting up Digital Africa, Supporting the Digital World

Undoubtedly, the "offline" predicament of Liberia's 580,000 population is not an isolated case; it is a common challenge faced by rural regions across Africa and the world. The ITU "Facts and Figures 2023" report highlights that only 37% of Africa's population has Internet access, with cost being the main barrier to connection. For instance, in Ethiopia, the monthly rent for a 12M broadband line could consume over half a worker's monthly salary.

Since entering the African telecommunications market in 1997, ZTE has partnered with mainstream operators in Africa, building networks for over 50 countries and accelerating communication networks to 3G, 4G, and even 5G. This has significantly improved network connectivity and coverage in the region, positioning ZTE as a pioneer stimulating local economic vitality.

From Liberia to Cameroon to Ethiopia, ZTE will continue to bring network coverage and technological warmth to marginalized communities, working alongside partners like Orange to pursue a digital future for Africa and the world, as symbolized by Lina and others. ZTE TECHNOLOGIES

ZTE

To enable connectivity and trust everywhere