Fiber-To-The-Room (FTTR): Standards and Deployments

Xuming Wu[(1)], Yan Zeng[(2)], Xiaoshu Si[(1)], Xiang Wang[(2)], and Xiang Liu[(3)]
[(1)]Huawei Technologies Co., Ltd. No. 207, Jiufeng Third Road, Wuhan, China
[(2)]Huawei Technologies Co., Ltd. Songshan Lake, Dongguan, China
[(3)]Huawei Hong Kong Research Center, Hong Kong, China
wuxuming@huawei.com

Abstract: We review recent advances in the field deployment of fiber-to-the-room (FTTR) systems for Gigabit/s home networking and in the global standardization of the FTTR solution. A novel centralized Wi-Fi access network (C-WAN) architecture is described. © 2023 The Author(s)

1. Introduction

With the evolution of network technology, various broadband applications in home are increasingly popular and diversified. High-quality broadband network service experience such as real-time interactive HD videos, online games, and online education becomes more and more important. Future-oriented service experience such as augmented reality (AR), ultimate HD VR and holographic interaction is becoming more and more desirable, which brings new challenges to home networks. For example, from 4K to 8K, the data rate requirement is increased from less than 50 Mbit/s to more than 120 Mbit/s. VR services require the end-to-end delay and delay jitter to be less than 20 ms and 15 ms, respectively [1]. The in-home Wi-Fi experience is an essential part of the broadband service as user's terminal devices are connected to network via home networking. Due to the launch power limitation and signal attenuation by obstacles, single Wi-Fi access point (AP) is not enough to cover a house or apartment with multiple rooms. To solve the problem, different multi-AP networking solutions are provided, e.g., by Ethernet cables, wireless cascading and power line cables. Fiber has been widely used in communication system because its advantages such as large capacity, immunity to electromagnetic interference, low insertion loss, small size and light weight. Since 2020, fiber-based home networking solution, Fiber-to-the-Room (FTTR), is proposed as an extension of Fiber-to-the-Home (FTTH) by the fifth-generation fixed network (F5G) industry specification group (ISG) of the European Telecommunications Standards Institute (ETSI) [2]. Meanwhile, the use cases and requirements, system architecture, physical layer and data link layer of FTTR are studied by standards developing organizations (SDOs) such as ITU-T Q18/SG15 and CCSA TC6 WG2. In this paper, we review recent advances in the global standardization and deployment of FTTR, as well as some new features of the FTTR solution.

2. Deployment of FTTR

With the increase of FTTH coverage to 95% and the upgrade of 10G-PON in China, operators can provide more and more users with more than 1 Gigabit/s access bandwidth. By 2020, 70% of broadband services are more than 200 Mbit/s, but the average download bandwidth is only 41 Mbit/s [2]. According to the analysis of a large number of home network complaints, the causes of poor user experience are insufficient bandwidth of the home network cables, insufficient capability of home Wi-Fi devices, and insufficient Wi-Fi access points allocated in each home. The traditional business mode of operator is to provide network access services for subscribers, whereas the home networking of subscribers is usually performed by subscribers themselves.

With the popularization of Gigabit/s bandwidth, the bottleneck of home networking becomes more obvious. Therefore, the operators released the FTTR commercial service for the first time at the end of 2020, and provided users with Gigabit/s access bandwidth and Gigabit/s home networking services based on FTTR. After two years, there are more than one million FTTR users, and the current user growth rate is increasing. FTTR can be favored by users due to several factors. Firstly, with the impact of the epidemic, end users have higher requirements on home networks and need to support online classes and remote working. Secondly, operators have professional operation and management teams to provide reliable quality-assured services, and FTTR helps deliver such reliable services with reduced operating expenses. Thirdly, based on the intelligent network management platform, operators can quickly diagnose and solve user network problems. Correspondingly, operators have also been rewarded by the emerging FTTR deployment. FTTR enables operators to shift from network bandwidth operation to network experience operation, and provide value-added home networking services and consumer devices to the end users. As FTTR can provide stable network experience which can enhance the communication experience of the end users. In addition, based on FTTR, service operators can also provide more smart home internet-of-things (IoT) services to the end users. In addition to home networking, service operators also released FTTR networking for small and medium-sized enterprises (SMEs) in 2021, which further broadens the application space of FTTR.

3. Standardization of FTTR

In 2020, ETSI F5G ISG published the F5G use case group report [2], which is the first time to define FTTR for residential networks. The following updated group report extends the FTTR for SME applications. The network target of FTTR is to provide in-premises Gigabit/s connection everywhere.

ITU-T SG15 Q3 started the study of FTTR technology from 2020 and worked on a series of technical reports, supplements, recommendations to fully specify FTTR technology and its applications. A technical report [3] and supplement [4] have been published for introducing the FTTR use cases and detailed network requirements for home and SME application scenarios. The system architecture document (G.fin-SA) is currently under development, in which centralized coordination of optical link & Wi-Fi, P2MP fiber topology, new optical transmission requirements, and data rates (symmetric 2.5G & 10G) have been accepted [5]. Other recommendations like physical layer (G.fin-PHY), data link layer (G.fin-DLL), and management are left for further study.

In China, CCSA completed a study report on FTTR in 2020 and identified that the fiber based network is the most promising infrastructure for in-premises communication due to low transmission loss, high bandwidth, low power consumption, and long lifetime of fiber etc. Further technical specification of FTTR is under development and synchronized with the related ITU-T standards.

Table 1 shows the use case summary of FTTR for home and SME application scenarios. As can be seen, high data throughput (up to 10Gbps), latency bounded transmission, centralized control mode, large number of connections, and network slicing are the common requirements for the service bearing.

Table 1. The use case and network requirements studied by ITU-T SG15 Q3.

	Use Case	Network requirement
For home [2]	1. High Quality Wi-Fi Backhualing	High data throughput (e.g.10Gbps), support >8 AP connection
	2. Seamless roaming	Fast transmission of control message, coordination with Wi-Fi
	3. IoT support of smart home	Centralized low power mode, remote power feed
	4. Low latency service in home networks	Latency guarantee, coordinated MAC mechanism to avoid contention
	5. Network slicing	QoS guarantee, dynamic network slicing
	6. East-west data transmission	Support east to west streaming
	7. Support of a multi-service transmission	Support multiple data transmission profile
For SME [3]	1. Live applications	Guaranteed up-link latency, Stable data rate, uplink high broadband
	2. Small office	Guaranteed latency, high data throughput (2.5-10Gbps), remote power feeding, 32-128 connections
	3. Smart service hall	Network slicing, isolated wireless service
	4. School	Multiple authentication modes, multicast traffic, link access control, flexible network configuration
	5. Business building	Guaranteed QoS, Fast roaming, isolated wireless service, Automatic Wi-Fi channel planning and optimization
	6. Indoor leisure and entertainment	Low latency, simultaneous dense connection of user terminals
	7. Advertising design and virtual effect processing	Robust uplinks with Stable high throughput, high data throughput (1-10Gbps)
	8. Workshop	Unbalanced power splitting, general operation and management through multiple O&M functions
	9. Smart community	Low latency and stable connection, wire and wireless connection, high data throughput

To guarantee customer experience, the FTTR network should solve the technical problems from the traditional Wi-Fi network with contention transmission mode. This indicates a new architecture is needed. ETSI F5G has studied the centralized optical link and Wi-Fi coordination mechanism (see Figure 1) and it is also adopted by ITU-T and CCSA in the technical specification up to now.

To facilitate the centralized control procedure, a general mechanism is introduced. Primary and edge ONUs collect the Wi-Fi status, such as data buffer level and air interface status, from the Wi-Fi entity. The controller collects the Wi-Fi status mentioned above through the network and forwards the coordination strategy to the Wi-Fi module directly. The FTTR interface between the main FTTR unit (MFU) and the sub FTTR unit (SFU) enables latency bounded transmission in both data and control planes.

4. Technical evolution of FTTR

For current FTTR solutions, the backhauling link works independently with Wi-Fi air interface. The backhauling technologies have their own completed PHY and MAC, like a cascaded network topology. To offer optimal solutions for different application scenarios, different functional split options for integrating Wi-Fi into the C-WAN architecture need to be considered. Figure 2 shows the summary of some possible functional split options.

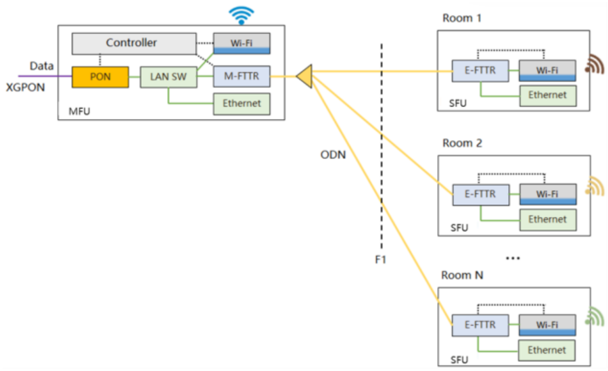

Fig. 1. The centralized Wi-Fi access network (C-WAN) architecture through centralized control in FTTR.

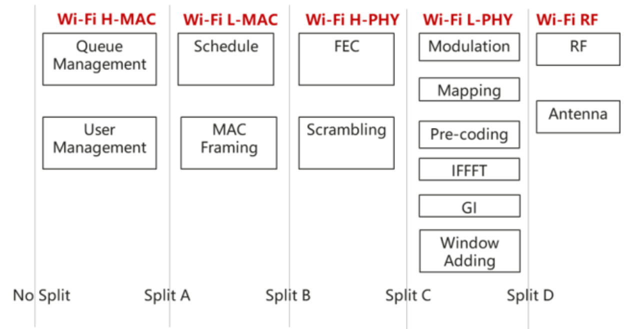

Fig. 2. Functional split options for integrating Wi-Fi into the C-WAN architecture to optimally support different applications.

Case 1: No split between backhauling network and Wi-Fi network. The case reflects the cascaded network scenario discussed above. Two independent networks work together for a local home network. The drawback is that there is no direct coordination between two networks and independent network management.

Case 2: Split A, where the Wi-Fi H-MAC of SFU is integrated within MFU. Wi-Fi queue management and user management functions of SFUs are reserved in MFU. This brings a common queue and user management between backhauling technology and Wi-Fi technology. The mapping queue priority is naturally supported. Therefore, centralized user management helps improve network roaming performance.

Case 3: Split B, where the Wi-Fi L-MAC of SFUs is integrated within MFU. Wi-Fi scheduling and MAC framing are reserved in MFU. This means a centralized control mode for whole home network that the scheduling of all packets can be done in MFU. Centralized scheduling helps coordinate resources on the entire network for optimal scheduling, reducing network latency and improving network efficiency. Besides, MAC framing is reused and adaptive to Wi-Fi technology. This converging brings less complexity of system. The backhaul network transmits Wi-Fi MAC frames instead of traditional Ethernet frames, which further reduces the forwarding delay of SFUs.

Case 4: Split C, where the Wi-Fi H-PHY of SFU is integrated within MFU. MFU reserves some Wi-Fi PHY functional blocks (like FEC and Scrambling) furtherly. This can reduce the complexity of SFU and make good use of the resource in MFU.

Case 5: Split D, where the Wi-Fi L-PHY of SFU is integrated with MFU. MFU reserves the whole Wi-Fi PHY functional blocks. All wireless processing is in MFU and the backhauling link only conveys Wi-Fi baseband signal before up-shifting to RF band. All network coordination is conducted in MFU, so no Wi-Fi air interface conflicting will happen among different SFUs.

The more the split point is to the right, the stronger the coordination capability of the entire network, and the better the E2E latency and roaming experience of the network will be. However, higher backhaul bandwidth is required. On the other hand, the more the split point is to the left, the lower the backhaul bandwidth requirement, but the performance of the entire network deteriorates. An optimal trade-off between the complexity and the performance can be selected for a given application scenario.

5. Conclusion

FTTR matches the development trend of Gigabit/s access to the home and ensures high-quality network experience in each room. The number of FTTR users is growing rapidly since the service was released. The C-WAN architecture of FTTR is under active development in multiple SDOs. For future evolution, the Wi-Fi network and optical access network can be further merged, and different functional splits can be applied to optimally support different application scenarios.

6. References

[1] Broadband Development Alliance, "Gigabit high quality Service Experience and Network Optimization White Paper."
[2] ETSI GR F5G 002 V1.1.1 "Fifth Generation Fixed Network (F5G); F5G Use Cases".
[3] ITU-T, Technical Paper, GSTP-FTTR "Use cases and requirements of fibre-to-the-room (FTTR)".
[4] ITU-T, G.SUP-FTTR-4B, "Supplement on uses cases for FTTR 4B".
[5] ITU-T, G.FIN.SA, "High speed fibre-based in-premises transceivers - system architecture".