10G-EPON System Broadens Possibilities of Optical Access

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Fiber to the home (FTTH) service encourages the growth of high-speed broadband services. Today, 26 million people are subscribed to such service in Japan. Further, the optical access network is expanding its coverage, leveraged as a backhaul or offload for mobile network services, to compensate for ever-increasing traffic due to an increasing number of services that distribute high-definition image data and enhanced data communication speed. The emerging popularity of machine-to-machine (M2M) communications, the smart grid being an example, also relies on the optical network, making this indispensable social infrastructure. Fujitsu currently offers an FTTH-compatible product range based on the Gigabit Ethernet-Passive Optical Network (GE-PON). Meanwhile, a 10G-EPON system is under development, designed to realize easy migration to a 10G-based system. The 10G-EPON system will improve FTTH service quality as it reduces equipment and maintenance footprint, and minimizes the impact of system failures if they happen, as well as the recovery time. This paper describes the outlines of the 10G-EPON system, specific features, and future prospects.

1. Introduction

According to statistical data of the Ministry of Internal Affairs and Communications, the number of broadband service contracts in Japan exceeded 124 million as of the end of March 2015.[1)] This number included 26.61 million fiber to the home (FTTH) contracts (up 5.1% year on year), accounting for 21.4% of the total. Furthermore, recent years have been characterized by explosive growth in the number of contracts for broadband wireless access (BWA) such as WiMAX, which rose to 19.47 million (up 160.9% year on year), and the number of LTE mobile phones, which rose to 67.78 million (up 46.09% year on year). As a result, never ending traffic growth is an urgent issue that cannot be ignored.

FTTH services are usually offered using passive optical network (PON) technology. PON technology can reduce the cost of laying fiber by splitting optical fiber between an optical line terminal (OLT) and optical network unit (ONU) with optical couplers installed on utility poles or the like. Traditionally, FTTH has been principally a service for general households living in detached homes and housing complexes. On the other hand, owing to its advantages in terms of high-speed and high-capacity communications through the effective use of optical fiber, application of this technology is currently being deployed beyond FTTH services, as an important social infrastructure for traffic offload and backhaul for wireless access services, and for machine-to-machine (M2M) communications such as smart grids.

At present, the Gigabit Ethernet-PON (GE-PON) system is being deployed domestically in Japan as an FTTH service network. Since 2005, Fujitsu has been developing equipment to realize optical access, including FTTH services, offering PON equipment such as the FUJITSU Network FA2232 GE-PON OLT and FA2132 GE-PON ONU. This paper describes the development background of the 10G-EPON system currently being developed as the successor of the GE-PON system, and gives an overview of the system and its benefits.

2. Development background

1) FTTH environment

According to the road map of 4K/8K TV broadcasting announced by the Ministry of Internal Affairs and Communications, the launch of high picture quality 4K broadcasting in 2015 will be followed by the spread of even higher picture quality 8K Super Hi-Vision broadcasting in 2020.[2] 4K and 8K ultra high definition picture technology is expected to spread to a wide range of fields besides the broadcasting field, such as Internet Protocol Television (IPTV), including industrial applications such as medical care, design, and accommodating ever higher volume traffic, including for FTTH services, is a must.

In households that use FTTH services, one finds now widespread smartphones and tablets, but also a variety of consumer electronics products connected to home networks via Wi-Fi. Wi-Fi, which is one of the wireless LAN standards, is a standard defined by the IEEE. In recent years, the number of terminals supporting this standard has been increasing, and the IEEE 802.11ac standard covers communication speeds from 433 Mbps to 1 Gbps and higher. In addition, for wireless LAN, the IEEE 802.11ad standard, also known as Wireless Gigabit (WiGig), which realizes communication speed of up to approximately 7 Gbps, has already been established.

On the other hand, the communication speed of the FTTH services offered for the GE-PON system is generally a maximum of 1 Gbps. Based on the above, this communication speed will likely become a bottleneck in the future.

2) Expectations of FTTH service providers

Anticipating the coming wave of high-capacity communications both inside and outside homes, FTTH service providers are starting to investigate the provision of 10 Gbps-class services.

In terms of the PON technology for achieving this, the IEEE has completed the 802.3av standard (10G-EPON: 10 Gbps in the downstream direction, 10 Gbps or 1 Gbps in the upstream direction). 10G-EPON being compatible with GE-PON, the ONU at the homes of FTTH subscribers (hereafter, end users) can continue to be used as is without need of replacement, allowing 1 Gbps service continuity.

On the other hand, the ITU-T, the International Telecommunication Union - Telecommunication Standardisation Sector, has completed its G.987 series of recommendations (XG-PON (10 Gigabit Capable-PON): 10 Gbps in the downstream direction, 2.5 Gbps in the upstream direction). However, XG-PON is not compatible with GE-PON, and therefore cannot accommodate existing ONUs as is. For this reason, large-scale investments will be newly required for laying fiber and replacing existing ONUs.

Based on the above, providers with a significant amount of GE-PON equipment have high expectations for 10G-EPON, which will allow effective use of existing broadband facilities and efficient capital investment as the next-phase system.

3) Fujitsu initiatives

Until now, Fujitsu has developed a prototype of the 10G-EPON system that complies with the 802.3av standards, demonstrating the feasibility of commercializing 10 Gbps-class products.[3] At present, to meet FTTH service changes and the expectations of providers, we are developing a new 10G-EPON system that will allow the provision of 10 Gbps FTTH services, and allow efficient capital investment while promoting the effective utilization of existing assets.

3. Development of 10G-EPON system

Figure 1 shows a system configuration example of the 10G-EPON system under development. **Table 1** lists the main specifications of 10G-EPON OLT, and **Table 2** the main specifications of 10G-EPON ONU.

The main features of the system under development are listed below.

1) The 10 Gbps signal of the PON interface complies with the IEEE 802.3av PR30 standard specifications.
2) Based on the IEEE 802.3ah PX20 standard specifications, the transmission and reception level of the 1 Gbps signal at the PON interface is enhanced to the existing GE-PON level through proprietary Fujitsu technology.
3) Mixed installation of GE-PON ONU and 10G-EPON ONU is possible.
4) Support of 64 branches of fiber on PON segment
5) As bridge functions, 10 G-EPON OLT provides a Media Access Control (MAC) address learning function, Virtual LAN (VLAN) function, Dynamic Bandwidth Allocation (DBA) function, and priority control function.
6) 10G-EPON ONU provides two User Network Interface (UNI) ports.

7) Encryption and decryption, authentication, and maintenance and control functions are also provided.

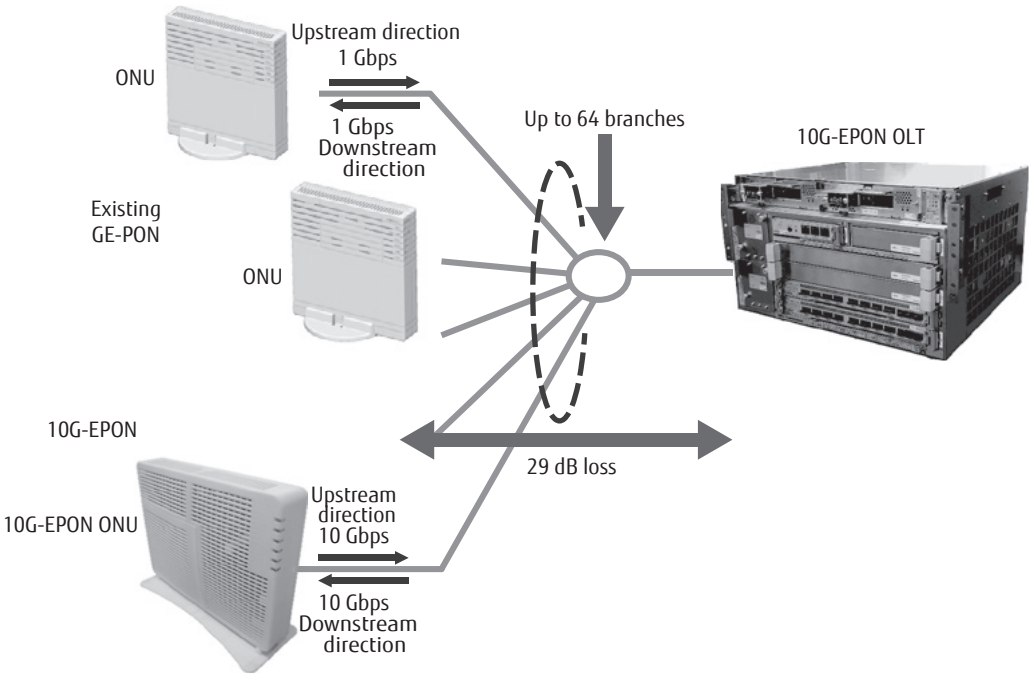

Figure 1
10G-EPON system configuration example.

Table 1
Main specifications of 10G-EPON OLT.

Equipment	Number of ports	32 PON ports/system 8 EPON ports/PON card 2 Ether ports/PON card
Interfaces	PON interface block	10GBASE-PR30 IEEE 802.3av compliant (Optical loss budget: 29 dB) * For 1 Gbps, IEEE 802.3ah compliant 10G/1G optical module and 1G dedicated optical module selectable for each port
		Number of ONU connections: 64 branches per PON port
		Mixed connection of 1G/10G-EPON ONUs
	CNI interface block	10GBASE-R/1000BASE-X×2/PON card (SFP+/SFP selection)
Functional specifications	Encryption and decryption functions	IEEE 802.1AE compliant
	Authentication function	Provided
	Bridge functions	MAC learning function
		VLAN function
		DBA (dynamic bandwidth allocation) function
		Priority control function
	Maintenance and control functions	Storm control function Loop detection function ONU false light emission detection function Various alarm processing, monitoring and control functions

Table 2
Main specifications of 10G-EPON ONU.

Equipment	Number of ports	1 EPON port/ONU 2 Ether ports/ONU
Interfaces	PON interface block	10GBASE-PR30 IEEE 802.3av compliant (Optical loss budget: 29 dB)
	UNI interface block	10GBASE-T/1000BASE-T/100BASE-TX×1 1000BASE-T/100BASE-TX/10BASE-T×1
Functional specifications	Encryption and decryption functions	IEEE 802.1AE compliant
	Authentication function	Provided
	Bridge functions	MAC learning function
		VLAN function
		Priority control function
	Maintenance and control functions	ONU false light emission detection function Various alarm processing, monitoring and control functions

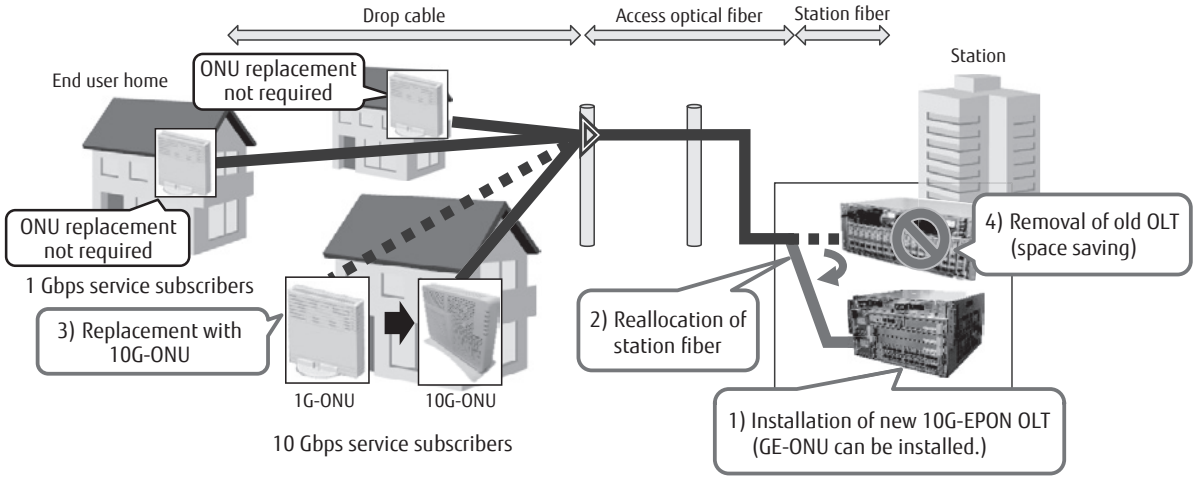

Figure 2
Migration to 10G-EPON system.

4. Benefits of 10G-EPON system

This section introduces the benefits of introducing the 10G-EPON system.

1) Smooth transition to 10G-EPON system

Most of the providers who have introduced GE-PON introduced, prior to that, the Fast Ether-PON (FE-PON) system, which allows FTTH service up to 100 Mbps. When migrating service and equipment from FE-PON to GE-PON, given that GE-PON OLT does not allow the mixed installation of FE-PON ONU, capital investment from scratch is required, including not only OLT/ONU equipment, but also laying of access optical fiber, which was a major issue.

As shown in **Figure 2**, the 10G-EPON system under development uses only OLT equipment, and it allows continued provision of 1 Gbps services along with transition to the 10G-EPON system by just reallocating optical fibers within the stations. The end users who desire 10 Gbps service can upgrade by simply replacing the ONU to a 10G-EPON ONU. Moreover, following transition to the 10G-EPON system, GE-PON OLT can be removed. Often the stations that house optical access equipment are quite small, and removal of old equipment is thus beneficial considering the limited space available.

2) Capital investment in accordance with service policy

In the case of 10G-EPON OLT, mixed installation

of GE-PON ONU and 10G-EPON ONU is possible. PON optical modules for 10 Gbps have a wavelength band of 1,575–1,580 nm for 10 Gbps, and a wavelength band of 1,480–1,500 nm for 1 Gbps in the downstream direction from OLT to ONU, and both signals are multiplexed through wavelength division multiplexing (WDM) for optical transmission. In the upstream direction, the 10 Gbps signal and the 1 Gbps signal are optically received by time division multiple access (TDMA). While this technology has the merit of allowing mixed installation, optical modules for 10 Gbps are expensive compared with the cost of existing optical modules for 1 Gbps.

On the other hand, the policies for 1 Gbps services of providers differ depending on whether their main focus while exploring demand is 1 Gbps, or whether they aim for gradual deployment according to demand instead of full-scale introduction over all FTTH areas. In the case of 10G-EPON OLT, Fujitsu plans to offer not only optical modules for 10 Gbps for all optical interfaces but also dedicated optical modules for 1 Gbps as pluggable modules. This will allow providers to finely tailor their selection of equipment according to their own service policies.

3) Improvement of maintenance through all front access

As mentioned above, the stations that house optical access equipment are often small, thus the amount of space available for maintenance work is often limited. Moreover, in some cases no maintenance space is available at the rear of the racks. In the case of 10G-EPON OLT, all the equipment is designed to allow front access, whether to connect or disconnect electrical and optical cables, or to replace parts, thus reducing the required amount of maintenance space and contributing to improved maintainability.

4) Station equipment integration

As shown in **Figure 3**, in the existing configuration of the GE-PON system, the number of branches up to 32 using optical couplers from the PON interface is supported, and a single optical fiber is connected to each of the ONUs installed in end-user homes. Multiple PON interfaces can be housed in one OLT unit, but OLT realizes the PON function only and does not have uplink aggregation capabilities. Therefore, connection to a higher network requires the installation of a layer 2

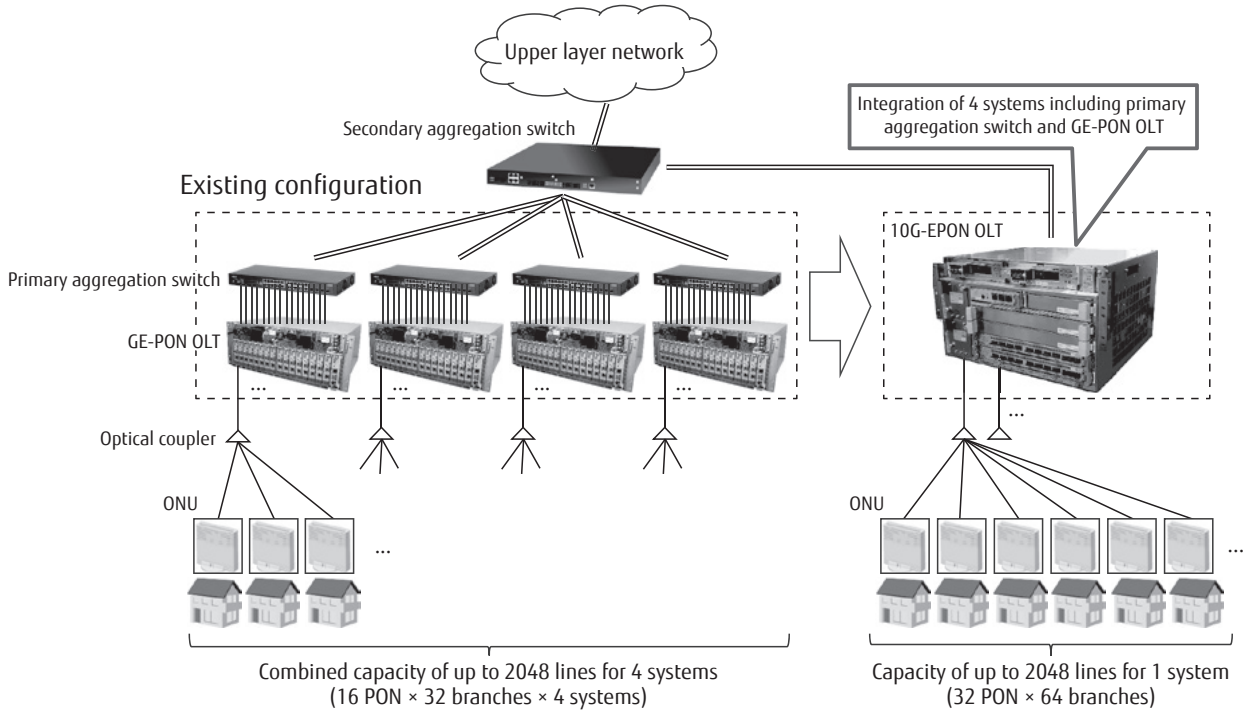

Figure 3
Equipment integration through 10G-EPON system.

switch (primary aggregation switch) to provide an uplink aggregation.

With the 10G-EPON OLT, the primary aggregation switch function has been integrated as required in the current network configuration. As a result, station equipment can be integrated, allowing space and wiring work reduction, as well as the integration of operations. Capital investment for unnecessary functions can be reduced and equipment size can be minimized without integration of the secondary aggregation switch function, which is installed if necessary in the upper layer. Further, 10G-EPON OLT can accommodate four times the number of end users of the existing GE-PON OLT system per equipment unit, and this effect can be further maximized through equipment integration.

5) Minimization of the impact of user loop faults

FTTH access lines typically consist of layer 2 networks. In the case of a layer 2 network, broadcast storms and multicast storms caused by improper connection of network equipment at end user homes may adversely affect services.

As a countermeasure against such adverse effects, Fujitsu has until now been offering primary aggregation switches that provide a storm control function to limit bandwidth on an individual port basis when real-time monitoring of the flow rate of broadcast packets and multicast packet detects that the set threshold has been exceeded.[4] Under limitation of the communication bandwidth in the primary aggregation switch, the storm impact may spread other end users on the same PON branch as the end user where the loop occurs.

Likewise, the 10G-EPON system will feature a storm control function, but as shown in **Figure 4**, by linking the DBA function, it is possible to subject only the end user where the loop occurs to communication bandwidth restrictions. Consequently, compared with the function realized by the conventional means of a primary aggregation switch, the impact range can be further minimized.

6) Measures against false light emission by ONU

In a PON system, communication in the upstream direction is realized through TDMA, and each ONU is allowed to emit light and transmit data only at the timing indicated by the OLT. However, an ONU may emit light at the wrong time unintentionally due to a fault or the like, and this may cause erroneous light emission faults that affect the communication of other end users.

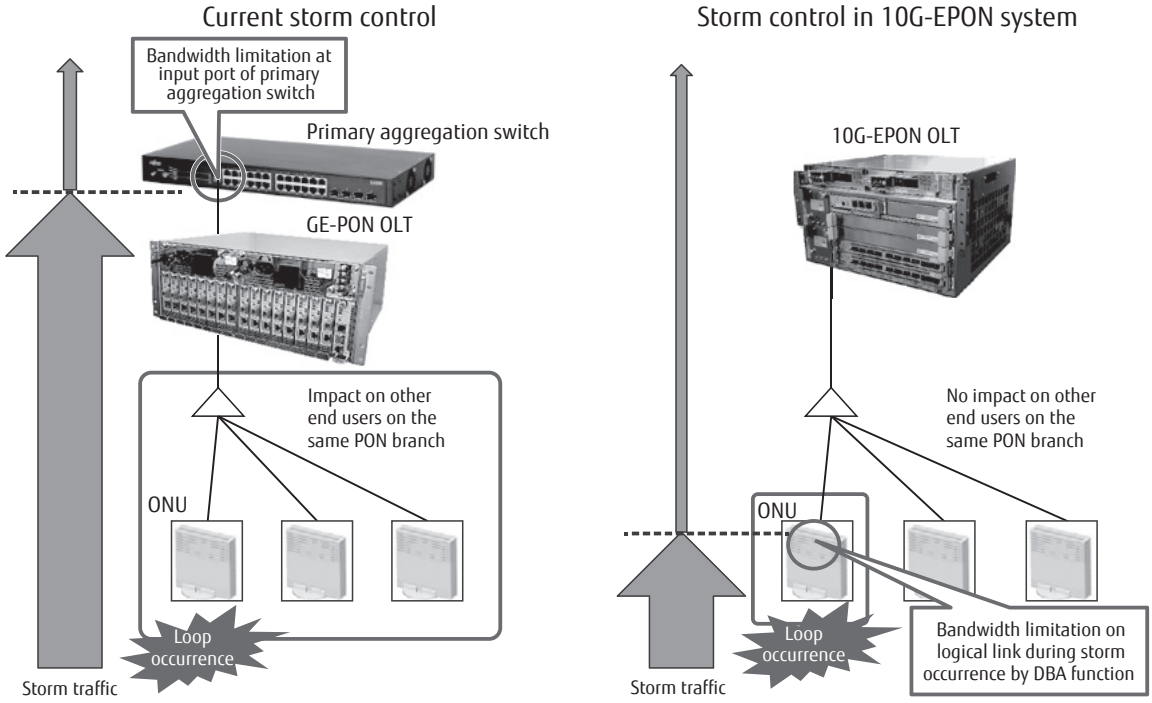

Figure 4
Storm control function.

The 10G-EPON system provides a function that detects the continuous light receiving state that occurs on the OLT side as the result of the erroneous light emission on the ONU side. A function that forcibly stops light output of individual ONUs through remote operation from the OLT is also provided, greatly reducing the time required until the ONU at fault is disconnected. Moreover, 10G-EPON ONUs have also a function that monitors their own light emitting state, and that forcibly stops their light output if they fall into a fault condition that causes continuous light emission. As a result, the time required to resolve erroneous light emission faults can be greatly reduced.

5. Conclusion

This paper describes the environment of FTTH services and various initiatives by Fujitsu to meet expectations of service providers. It also provides an overview of the 10G-EPON system currently being developed to realize 10 Gbps FTTH service, and introduces its benefits.

Going forward, Fujitsu plans to offer blade solutions with more flexible scale-out based on this platform. In the future, we will look into accommodating of a wider range of services and bring them about by, for example, discontinuing software functions and switching to a virtual environment, and expanding to other access technologies such as NG-PON2. Through these technologies, we aim to offer an optical access platform that contributes to the realization of an affluent society.

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