Standardization of G-PON (Gigabit Passive Optical Network) in ITU-T

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Abstract

While the main factor driving the increase in access line speeds in Japan is the popularity of ADSL (asymmetric digital subscriber line), the number of customers using FTTH (fiber to the home) services, such as our B-FLET'S service, is also increasing by leaps and bounds. NTT has been contributing to standardization activities to promote FTTH. In this article, we explain the latest FTTH standardization activities in ITU-T. The standard is called G-PON (Gigabit passive optical network).

1. Introduction

Over the last few years, access line speeds have continued to advance due to the growth of the ADSL (asymmetric digital subscriber line) service. However, since ADSL suffers from limited transmission speed and distance because it uses conventional metallic cables, optical access is expected to become the default broadband access system in the future. For this reason, ITU-T (International Telecommunication Union—Telecommunication Standardization Sector) has been discussing a standard for optical access systems called G-PON (Gigabit passive optical network), which is an optical access system with gigabit-per-second-class transmission capability; it is suitable as the next-generation optical access system.

2. Previous optical access system standards

ITU-T has created several standards for optical access systems. One of the most important is the B-PON (Broadband PON) standard. PON is a network topology that shares a single optical fiber among two or more customers. Figure 1 shows its basic structure. The main feature is that network equipment, called OLT (optical line termination) placed in a central office, is connected to the optical network terminal equipment, called ONU (optical network unit) installed in a customer's premises, via an optical splitter*1. Since the optical fiber and OLT are shared by several customers, PON can offer economical services by reducing subscriber (or customer) cost. For these reasons, a PON system is considered to be eminently suitable for the future optical access system.

B-PON was developed as a PON system that uses ATM cells for transmission and has a maximum access speed of 155 Mbit/s upstream and 622 Mbit/s downstream. By using ATM cells, B-PON can accommodate various services, such as Ethernet or TDM (time division multiplexing) services. Stan-

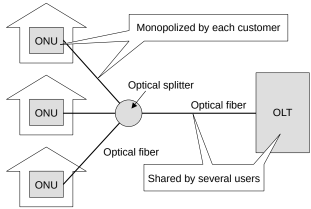

Fig. 1. Basic composition of PON.

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*1 Optical splitter: a passive element that can split a single optical signal, without converting the optical signal into an electrical one. It can also merge multiple optical signals into one optical signal.

dardization of B-PON has been carried out in SG15 (Study Group 15, which is discussing standards for optical transmission technology and the physical medium network) in ITU-T as G.983 series (Table 1).

3. Need for a new access system

In the latest B-PON standard, the transmission capacity has been expanded to 622 Mbit/s upstream and 1.2 Gbit/s downstream. However, it is thought that the technical hurdle of achieving synchronization at speeds higher than 622 Mbit/s (upstream) is quite high given the physical layer specification of B-PON. Therefore, discussion of a new PON specification for gigabit-per-second-class transmission began in April 2001. For this new PON, a new frame format was also discussed to transmit variable-length packets efficiently, from comparatively long data such as Ethernet to short data such as 53-byte ATM cells.

4. Standardization of G-PON

Since the new optical access system had the capability of gigabit-per-second transmission, it was named G-PON (Gigabit-PON). The standardization work was divided into three topics, as shown in Fig. 2, so that specifications could be released as soon as they become available, making it easier to reflect them in other recommendations, such as IEEE802.3ah.

① G-PON Service Requirements (GSR): Service providers' requirements for G-PON equipment, such as the accommodated services, transmission speed, and optical distribution network requirements.

② G-PON Physical Medium Dependent Layer (GPM): Specifications related to the physical medium layer such as those for G-PON optical transmitters and receivers.

③ G-PON Transmission Convergence Layer (GTC): The layer 2 specifications of G-PON, such as transmission frame structure of the

Table 1. Standardization of B-PON in G.983 series.

Number	Outline	Date recognized
G.983.1	OLT-ONT physical interface specification (upstream 155 Mbit/s, downstream 155, 622 Mbit/s) Addition of 622 Mbit/s upstream Addition of 1.2 Gbit/s downstream	10/1998 12/2001 Amd1 10/2003 Amd2
G.983.2	OLT-ONT management&control interface (OMCI) specification Revision on some additions and compensations Revision of editorial errors	4/2000 7/2002 Revision 3/2003 Amd1
G.983.3	The specification on wavelength arrangement of the various signals in B-PON wavelength division multiplexing A part of change in specification accompanying the addition of 622 Mbit/s on upstream	4/2001 7/2002 Amd1
G.983.4	Dynamic Bandwidth Allocation (DBA) specification on an upstream signal	12/2001
G.983.5	Specification on survivability (SUR) between the OLT and ONT	1/2002
G.983.6	Extension of OMCI for adding the SUR function to an upstream signal	7/2002
G.983.7	Extension of OMCI for adding the DBA function to an upstream signal	12/2001
G.983.8	Extension of OMCI for adding the services of IP, VLAN, video, etc.	3/2003

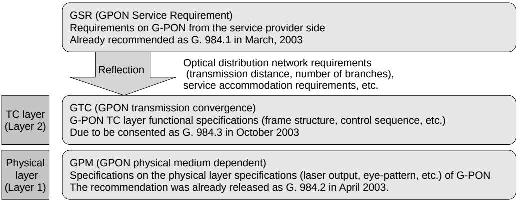

Fig. 2. Framework and schedule of GPON standardization.

PON section and the control sequence between OLT and ONU.

4.1 G-PON service requirements (GSR)

GSR summarizes the service requirements that service providers expect of the G-PON system. By referring to these requirements, one can discuss GPM and GTC. GSR has been discussed and determined by communication carriers in the U.S., Europe, and Japan. It specifies what kinds of services to accommodate, what level of access speed is necessary, how long transmission should take, and so on (Table 2). Basically, G-PON is expected to replace B-PON, so the requirements are set to be consistent with B-PON.

G-PON must accommodate "full services", meaning that it must accommodate all services on a single optical fiber. IP data transmission traffic has continued to expand explosively in recent years, and most data terminals such as users' personal computers now offer the Ethernet interface. However, the legacy analog telephone (POTS) and T1/E1[*2] lines are still important services for communication carriers. Therefore, G-PON accommodates IP data, analog telephony, and leased line service on a single fiber.

The access speed has been set at 1.2 or 2.4 Gbit/s downstream (OLT→ONU) and 155 Mbit/s, 622 Mbit/s, 1.2 Gbit/s, or 2.4 Gbit/s upstream (ONU→OLT). Since IP data service is mainly used for Internet access, such as net-surfing, the downstream traffic volume is much larger than the upstream one. Increasing the upstream speed would require improving the performance of the optical transceiver, which increases its cost. Therefore, GSR specifies asymmetrical transmission and a service provider can select a slower upstream speed with a faster downstream speed.

GSR was released in March 2003 as ITU-T G.984.1: "General Characteristics for Gigabit-capable Passive Optical Networks" [1].

*2 T1/E1 dedicated line: T1 is the standard of the digital dedicated line, mainly used in North America, with transmission speed of 1.5 Mbit/s. E1 is the standard of the digital dedicated line with transmission speed of 2 Mbit/s, common in Europe.

4.2 G-PON physical medium dependent layer (GPM)

GPM provides the specifications of the G-PON physical medium dependent layer, which is equivalent to the 1st layer of the OSI reference model. The physical medium layer includes optical/electrical converters and CDR (clock data recovery). It passes data from the physical medium to layer 2 and vice versa.

GPM mainly specifies the optical transmitter and receiver at each transmission speed. G-PON has adopted Class A/B/C of ITU-T G.982 as the optical level gap between OLT and ONU, which is called the power budget, and transmission power and reception sensitivity values are specified in each class. Since the technical verification of the 2.4 Gbit/s upstream service has not been discussed adequately, it remains a future issue. To keep optical transceiver costs low, forward error correction (FEC) can be used as an option. Table 3 gives an outline of GPM which was released as ITU-T G.984.2 in April 2003 [2].

4.3 G-PON transmission convergence layer (GTC)

The transmission convergence layer is the data transmission layer equivalent to the 2nd layer in the OSI reference model. GTC specifies the data frame structure, the control sequence between OLT and ONU, and the encryption function to prevent eavesdropping or masquerading. Since G-PON is expected to accommodate all services efficiently, a new transmission method called GEM (GPON Encapsulation Method) was adopted to encapsulate data services and TDM services. GEM provides a variable-length

Table 2. Outline of GSR specification targets.

Service	Full service (10/100 Base-T, sound, and dedicated line, etc.)	
Bit rate	Downstream: 1.2, 2.4 Gbit/s Upstream: 155 Mbit/s, 622 Mbit/s, 1.2 Gbit/s, 2.4 Gbit/s	
Physical distance	Maximum 20 km or maximum 10 km	
Logical distance	Maximum 60 km	
Number of branches	64 is the maximum at the physical layer 128 is the maximum at the TC layer	
Wavelength arrangement	Downstream: 1480-1500 nm. Upstream: 1260-1360 nm	Capable of multiplexing downstream wavelength for video distribution (1550-1560 nm)
ODN (optical distribution network) class classification	Classes A, B, and C (the same requirements as B-PON are applied.)	

Table 3. GPM main specifications.

Access speed	Downstream :1.244, 2.488 Gbit/s, Upstream :155 Mbit/s, 622 Mbit/s, 1.244 Gbit/s, 2.488 Gbit/s.
Power budget	Class A (5-20 dB) Class B (10-25 dB) Class C (15-30 dB)
Burst overhead	Burst overhead is specified at each transmission speed. (De-regulated from B-PON)
FEC	FEC (forward error correction) is introduced to reduce an optical module cost, and aimed to ease transmitting power and receiving optical sensitivity of an optical module. (option)
Power leveling	The ONU optical output can be adjusted in two steps to relieve APD tolerance of OLT. (option)

APD: automatic power distribution

frame with a control header that is several bytes long. Details of this control header are still under discussion. ATM service is transmitted using the original ATM cells. Finally, the TC frame of GTC transfers both GEM frames and ATM cells (Fig. 3).

Since the downstream traffic is broadcast in a PON system, it is necessary to secure the data from theft. G-PON uses AES (advanced encryption standard), which has been selected as the next standard encryption system by NIST (National Institute of Standards and Technology, which manages technical standards for the U.S. Department of Commerce).

GTC is currently under discussion. It should be approved as an ITU-T standard in October 2003. Therefore, the details given here may change.

4.4 Other specifications for G-PON

Specifications for the interface for controlling and managing ONU, called OMCI (optical network termination management and control interface) are also under discussion. They will be equivalent to G.983.2 of B-PON.

4.5 Relationship to EPON

Ethernet PON (EPON) is being discussed in IEEE802.3 [3]. It has a transmission speed of 1 Gbit/s in both directions and transmits Ethernet frames without alteration. Thus, EPON is also called GE-PON (Gigabit Ethernet PON) sometimes. While G-PON aims to accommodate full services, EPON basically aims to transmit Ethernet frames. ITU-T aimed to have a common physical layer specification with EPON, as shown in Fig. 4, but the commonality of the specifications is imperfect because IEEE was basically considering only the use of existing Ethernet transceivers.

5. Future plans

Standardization of GSR and GPM has been completed, and ITU-T is now discussing the specifications of GTC and OMCI. ITU-T is planning to approve GTC and a basic part of OMCI in October 2003. The detailed discussion and editing work of the standard draft will be done in the organization called

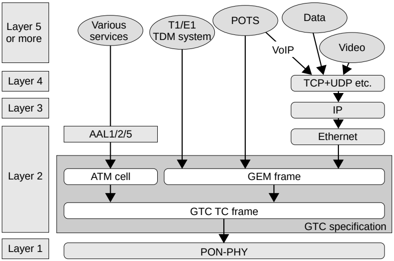

Fig. 3. Frame structure of G-PON.

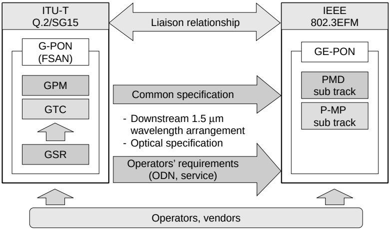

Fig. 4. Relationship between ITU-T and EFM.

FSAN (full service access network) [4]. The results of the discussion in FSAN will be submitted to ITU-T as a contribution, and a final standard will be released based on discussion in ITU-T. The advanced discussion in FSAN should ease the creation of the new standard in ITU-T.

NTT Access Network Service Systems Laboratories has made various contributions to these standardization activities. We will continue to contribute to the standardization of GTC and OMCI through FSAN and ITU-T.

References

[1] ITU-T Recommendation G.984.1: General characteristics for Gigabit-capable Passive Optical Networks.

[2] ITU-T Recommendation G.984.2: Gigabit-capable Passive Optical Networks: (GPON) Physical Media Dependent (PMD) Layer Specification.

[3] Y. Fujimoto, "IEEE802.3ah (EFM) standardization trend," NTT Technical Journal, Vol. 14, No. 10, pp. 66-68, 2002 (in Japanese).

[4] FSAN: Full Service Access Network, http://www.fsanweb.com/

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He received the B.E. degree in electronic engineering from the University of Electro-Communications, Tokyo in 1991 and joined NTT the same year. In 1996, he joined the Network Systems Development Department and developed the STM-PON system. Since then, he has been researching and developing optical access systems.

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