Standardization Trends for Next-Generation Passive Optical Network Stage 2 (NG-PON2)

Kota Asaka and Jun-ichi Kani

Abstract

The FSAN (Full Service Access Network) Group and ITU-T (International Telecommunication Union-Telecommunication Standardization Sector) are actively working to develop new standards in order to achieve high capacity transmission, multiple service capability, and flexible network operation in future optical access network systems. This article reports on the standardization trends of NG-PON2 (Next-Generation Passive Optical Network Stage 2) systems that are being developed under a framework of the ITU-T G.989 series.

Keywords: ITU, optical access, NG-PON2

1. Introduction

To meet the large demand for high capacity transmission in optical access systems, a 10-Gigabit-capable PON (passive optical network) has already been standardized by IEEE (Institute of Electrical and Electronics Engineers) and ITU-T (International Telecommunication Union-Telecommunication Standardization Sector). To enable cutting-edge standardization of future optical access systems, the FSAN (Full Service Access Network) Group and ITU-T SG15/Q2 (Study Group15/Question 2) are currently discussing the specifications of a 40-Gigabit-capable PON, which employs wavelength-division multiplexing (WDM) technology, for the purpose of enabling cost-effective 40-Gigabit-capable transmission capacity and multiple service capability. The FSAN Group is a forum for discussing future optical fiber access networks, and FSAN member companies offer their contributions to ITU-T SG15/Q2 in order to promote the development of international standards for PON systems.

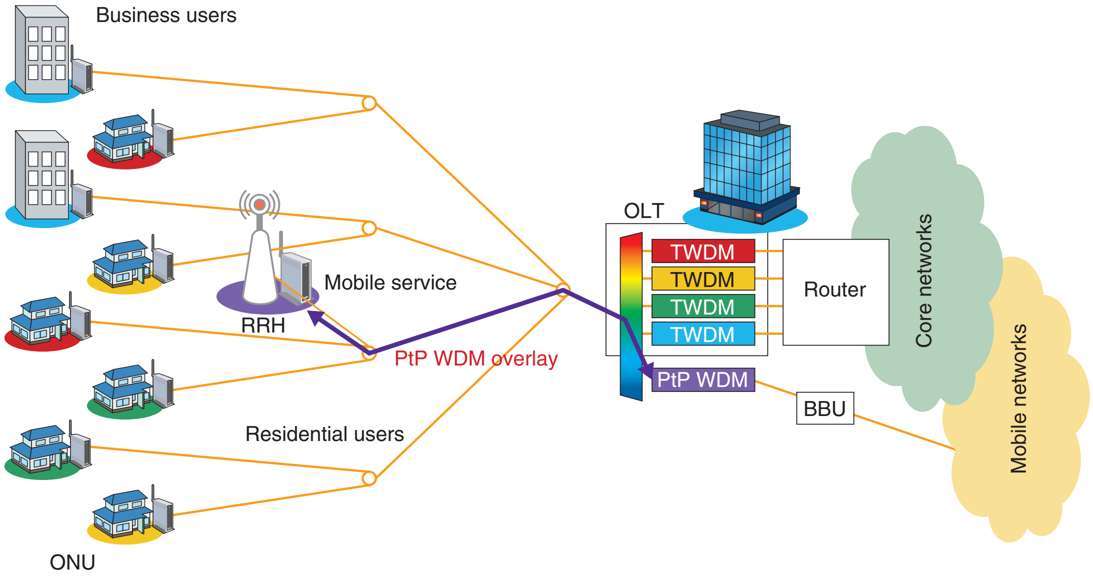
2. NG-PON2

In 2010, FSAN initiated discussions on a 40-Gigabit-capable PON known as NG-PON2 (Next-Generation Passive Optical Network Stage 2), which is going to be standardized in the ITU-T Recommendation G.989 series. **Table 1** lists the framework and standardization status of the G.989 series recommendations.

As the table indicates, the G.989 series consists of recommendations G.989, G.989.1, G.989.2, and G.989.3. The G.989 recommendation specifies NG-PON2 definitions, abbreviations, and acronyms and will be consented in July 2015. The G.989.1 recommendation, which covers the general requirements for NG-PON2, was approved in March 2013. The G.989.2 recommendation, which specifies the physical media dependent (PMD) layer including the wavelength plan and power budget of NG-PON2, was consented in December 2013 and approved in December 2014. The G.989.3 recommendation specifies particulars for the transmission convergence (TC) layer of NG-PON2 such as the wavelength protocol and bandwidth allocation, and is targeted for consent in July 2015. These achievements so far suggest that the standardization of the G.989 series will

Table 1. Framework and status of ITU-T G.989 series recommendations.

Recommendation	Title	Status
G.989	40-Gigabit-capable passive optical networks (NG-PON2): Definitions, abbreviations, and acronyms	To be consented (Jul. 2015)
G.989.1	40-Gigabit-capable passive optical networks (NG-PON2): General requirements	Consented (Jul. 2012) Approved (Mar. 2013)
G.989.2	40-Gigabit-capable passive optical networks (NG-PON2): Physical media dependent (PMD) layer specifications	Consented (Dec. 2013) Approved (Dec. 2014)
G.989.3	40-Gigabit-capable passive optical networks (NG-PON2): Transmission convergence (TC) layer specifications	To be consented (Jul. 2015)



BBU: baseband unit
OLT: optical line terminal
RRH: remote radio head

Fig.1. Example architecture of NG-PON2 system.

be completed in 2015 or 2016.

2.1 System architecture

An example of NG-PON2 system architecture is shown in **Fig. 1**. Although the previous PON systems offer broadband service only for residential users, NG-PON2 systems are expected to accommodate business users and mobile users in addition to residential users. The primary NG-PON2 solution is called TWDM (time and wavelength-division multiplexing)-PON, which is a hybrid of conventional TDM (time-division multiplexing) and WDM technologies. Optionally, NG-PON2 also supports Point-to-Point (PtP) WDM overlay, which is expected to be suitable for mobile services that require low latency. In NG-PON2, colorless optical network units (ONUs) are mandatory for reducing system operating expenses because they can eliminate the complicated inventory management of ONUs.

2.2 General requirements

Table 2 lists the general requirements for NG-PON2 that are specified in G.989.1 [1]. In TWDM-PON there are four (optionally eight) multiplexed wavelengths for upstream and downstream, respectively. In an NG-PON2 network there are three types of line rates (per wavelength) of 10-Gbit/s symmetry, 2.5 Gbit/s and 10 Gbit/s for upstream (US) and downstream (DS), respectively, and 2.5-Gbit/s symmetry. Therefore, the transmission capacities for each line

Table 2. General requirements for NG-PON2.

System	TWDM-PON (primary) PtP WDM overlay (option)
Capacity[*1]	DS[*2] 40G (10G × 4λ), US[*3] 40G (10G × 4λ) DS 40G (10G × 4λ), US 10G (2.5G × 4λ) DS 10G (2.5G × 4λ), US 10G (2.5G × 4λ)
Logical split ratio	1:256
Distance[*4]	40 km (without repeater)
Co-existence	All legacy PONs (RF video included)
Service	Residential and business users, mobile backhaul, and other applications

*1 For 4 wavelengths (λ)
*2 Downstream
*3 Upstream
*4 The maximum split ratio at this distance will depend on the budget class.

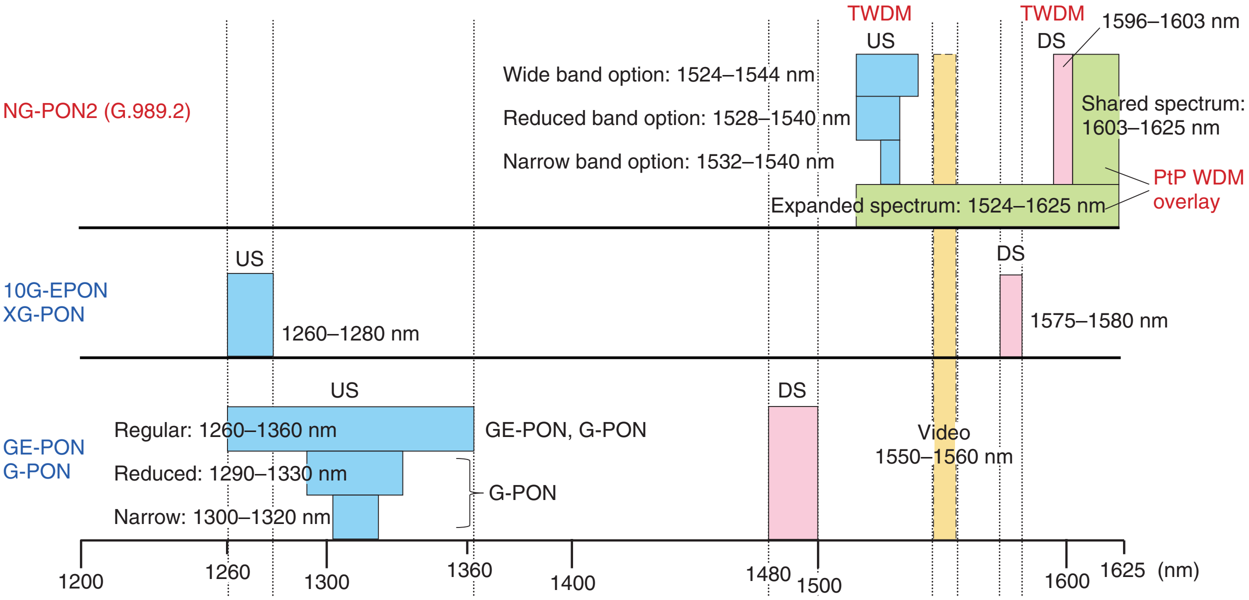


Fig. 2. Wavelength plan for NG-PON2.

rate are 40-Gbit/s symmetry, 10 Gbit/s (US) and 40 Gbit/s (DS), and 10-Gbit/s symmetry. The 40-Gbit/s symmetric capacity is expected to be applicable to business users, and the 10/40-Gbit/s asymmetric capacity to residential users. In G.989.1, the logical split ratio and the transmission distance are specified as 1:256 and 40 km, respectively. However, the optimum capacity, split ratio, and distance may depend on the NG-PON2 system services or applications. Therefore, G.989.1 shows combinations of these to be supported, for example, a 40-Gbit/s optimum capacity (DS), 20-km distance, and 1:64 split ratio.

2.3 Wavelength plans

The NG-PON2 wavelength plan specified in G.989.2 [2] is shown in **Fig. 2**, along with other system plans for comparison. To support co-existence with legacy PON systems that include an RF (radio frequency) video system, G.989.2 specifies 1524–1544 nm (wide band option) and 1596–1603 nm for US and DS, respectively. Two other options are also specified for the US plan: a reduced band option (1528–1540 nm) and a narrow band option (1532–1540 nm). These three options are specified by taking

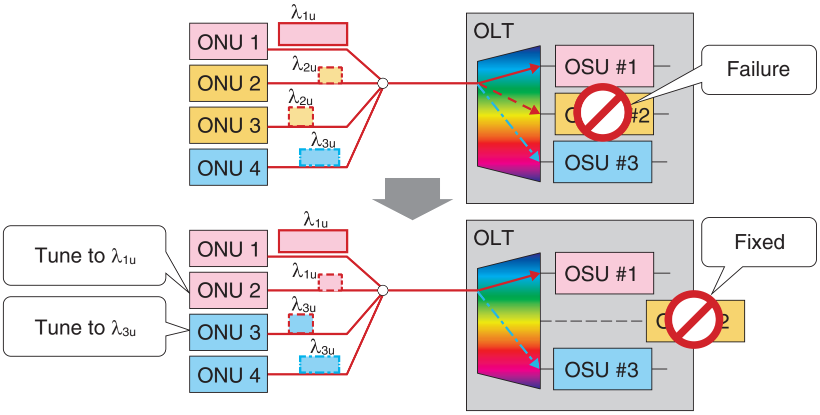


Fig. 3. Example of OLT protection technology using wavelength tuning in ONUs.

into account the wavelength channel spacings (min. 50 GHz, max. 200 GHz) and the tunable components implemented in ONUs. Since the C band is to be used for US in NG-PON2, a dispersion compensation technique would be necessary for a line rate (per wavelength) of 10 Gbit/s. For the wavelength plan for PtP WDM overlay, shared spectrum (1603–1625 nm) usage is specified for co-existence with legacy PONs. Expanded spectrum (1524–1625 nm) usage is also specified for greenfield applications. As mentioned above, G.989.2 specifies the wavelength band for PtP WDM overlay, but it does not specify the number of wavelengths or the wavelength allocation for US and DS.

The contents of G.989.3 are currently being discussed in FSAN and ITU-T. Basically, G.989.3 may be specified on the basis of G.987.3, which is the TC layer specifications for a 10-Gigabit-capable PON, with supplementary contents related to the wavelength assignment protocol.

3. Expected network function by in-service wavelength tuning

In developing colorless ONUs for NG-PON2, it is essential for the ONU transmitter and receiver to have wavelength tunability. Therefore, it is expected that using the in-service wavelength tuning technique in ONUs will enable NG-PON2 systems to have advanced network functions. In addition, cost-effective tunable components are important for practical deployment. The term *in-service tuning* means that an ONU can tune its wavelength during service operation in addition to the ONU's initialization process. An example of an advanced network function called OLT (optical line terminal) protection is illustrated in **Fig. 3**. As shown at the top right, the OLT is composed of three OSUs (optical subscriber units), and different wavelengths are assigned to each one. In a normal state, OSU #1, OSU #2, and OSU #3 communicate with ONU 1 (λ_{1u}), ONU 2 and ONU 3 (λ_{2u}), and ONU 4 (λ_{3u}), respectively. Upon assuming a failure in OSU #2, ONU 2 and ONU 3 immediately tune their wavelengths to maintain communications with other OSUs. As shown at the bottom left, ONU 2 changes its wavelength from λ_{2u} to λ_{1u} in order to be connected to OSU #1, while ONU 3 changes its wavelength from λ_{2u} to λ_{3u} to be connected to OSU #3. One of the advantages of the OLT protection is that ONUs with the in-service tuning technique can easily provide a protection function without additional equipment, such as a backup OLT and an optical switch. Another example of in-service tuning is an OSU sleep function, which is also attractive as a means of reducing power consumption in the OLT. With this function, all ONUs are connected to one (or fewer) OSU(s), and the other OSUs can be forced to sleep. This function is also implemented by using wavelength tuning during service operation. For these advanced functions, a tunable component is required to have a short tuning time in order to avoid any signal frame loss even during a tuning process. On the other hand, such a fast tunable component is not needed if an operator requires wavelength tuning only for ONU initialization. In accordance with the aforementioned background, G.989.2 specifies tuning time classes, which are categorized into class 1 (<10 µs), class 2 (10 µs–25 ms), and class 3 (25 ms–

1 s). The categorization is specified by taking into account the requirements from expected network functions in NG-PON2 and the current technologies of tunable components.

4. Future prospects

This article reviewed NG-PON2 as the latest standardization trend for future optical access networks. In the near future, FSAN and ITU-T will focus on discussing PtP WDM overlay specifications as an amendment to the G.989 series. It is also expected that further evolution of optical access network technologies will be discussed in FSAN and ITU-T.

References

[1] ITU-T Recommendation G.989.1:40-Gigabit-capable passive optical networks (NG-PON2): General requirements.

[2] ITU-T Recommendation G.989.2:40-Gigabit-capable passive optical networks (NG-PON2): Physical media dependent (PMD) layer specifications.

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He received the B.E., M.E., and Ph.D. in applied physics from Waseda University, Tokyo, in 1994, 1996, and 2005, respectively. In 1996, he joined the NTT Optical Network Systems Laboratories, where he was engaged in research on optical multiplexing and transmission technologies. Since 2003, he has been with NTT Access Network Service Systems Laboratories, where he is involved in the research and development of optical communications systems for metro and access applications. He received the Leonard G. Abraham Prize from the IEEE Communications Society, the Best Paper Award from the 18th Optoelectronics and Communications Conference (OECC) in 2013, and 7 other academic/industry awards. He has been participating in ITU-T and working on the FSAN initiative since 2003. He has served as Associate Rapporteur of ITU-T Q2/15 (optical systems for fibre access networks) since 2009. He is a member of IEEE and IEICE.