Construction of High-speed and High-reliability Optical Networks for Social Infrastructure

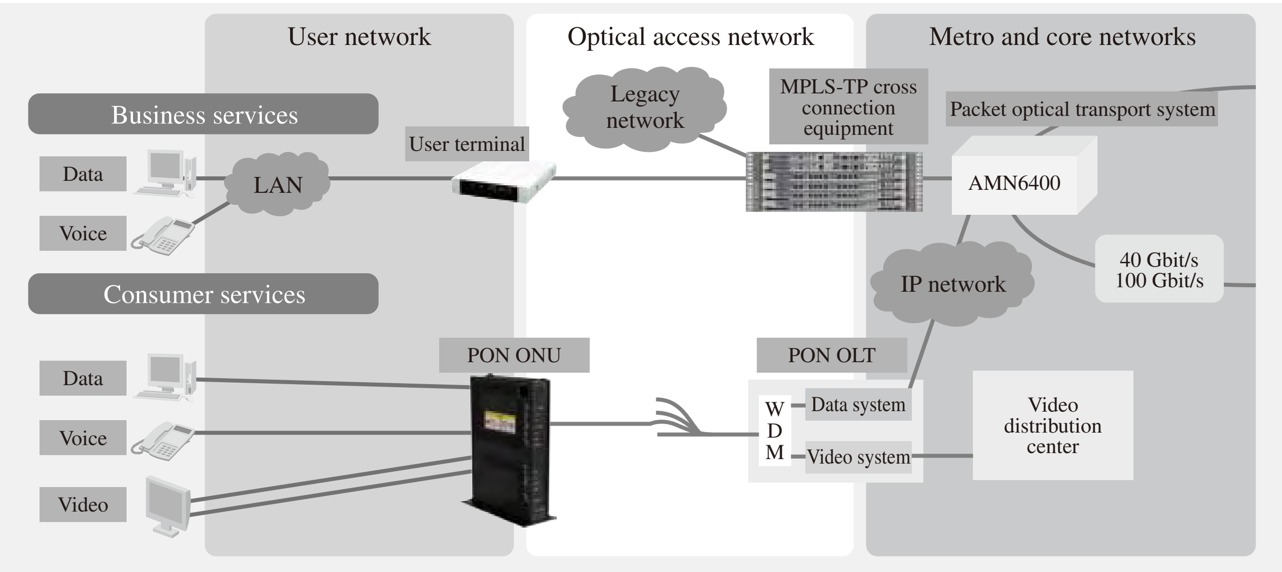
Ryosuke Nishino
Hideaki Tsushima, Dr. Eng.
Eisuke Sato
Shinsuke Tanaka

OVERVIEW: The number of optical broadband users in Japan reached 15 million at the end of March 2009(1), indicating that optical access networks are becoming an increasingly important part of the social infrastructure. In addition to requiring even higher levels of reliability, metro and core networks also need to deal with current problems such as the aging of equipment used to provide leased line and other existing services. For the construction of high-speed and high-reliability optical networks, Hitachi supplies optical access equipment and the packet transport equipment for metro and core networks. Hitachi is also involved in the standardization of 10G-EPON and is working toward its commercialization with a view to higher speed in future access networks.

INTRODUCTION

OPTICAL network systems include optical access networks that connect from homes and businesses to the telephone company exchanges, and metro and core networks that provide long-distance connections between city exchanges and between regional exchanges[2]. Although the speed, interface, and other requirements of these networks may differ in their details, all share a common need for higher speeds and higher reliability to cope with the increasing numbers of optical broadband users.

The demand for higher speed can be met by increasing the actual number of lines, increasing the interface speed, or adopting wavelength-division multiplexing to create additional capacity, but this needs to be achieved using equipment that is no bigger than the existing equipment. In the case of higher reliability, this can be achieved through the application of alarm transmission, monitoring, and other functions that use OAM (operation, administration, and maintenance) in the packet network and through integrated resource management for the packet network.



LAN: local area network   MPLS-TP: multi-protocol label switching - transport profile   PON: passive optical network   ONU: optical network unit
OLT: optical line terminal   WDM: wavelength-division multiplexing   IP: Internet protocol

Fig. 1—Structure of Optical Network System.
Optical network systems consist of optical access networks and core networks.

This article describes the various equipment used to build optical access networks and metro and core networks that are representative of Hitachi's involvement in the construction of high-speed and high-reliability optical networks that support the social infrastructure (see Fig. 1).

OPTICAL ACCESS NETWORKS

For last several years, high-speed Internet data access and IP (Internet protocol) telephony have been the key services that are driving the rapid and wide deployment of optical access networks, specifically, FTTH (fiber to the home), in Japan. In 2009, FTTH achieved more than 15 million subscribers. Today, video service integration over FTTH is being paid attention to as another driver for further FTTH deployment.

There are two different methods to providing video service using FTTH. One method is the RF (radio frequency) method in which wavelength-division multiplexing of the RF signal is used to send video and communications data via different wavelengths. The RF method is suitable for high-resolution video and multi-channel distribution and does not require an IP-STB (IP set-top box) at the subscriber premises. The other method is the IP method where digitized video data is sent as IP packets. The IP method is not subject to degradation of the transmission path since the video is treated as a digital signal. The IP method is known to be suitable for interactive service such as VOD (video on demand).

For video distribution, Hitachi has released a range of V-ONU (video optical network unit) products that use an FM (frequency modulation) conversion technique[3] that is tolerant of degradation of the transmission path. Hitachi is also working on technical development aimed at commercializing 10G-EPON (10 gigabit Ethernet* passive optical network) technology that can support distribution of a large number of high-resolution video channels using the IP method.

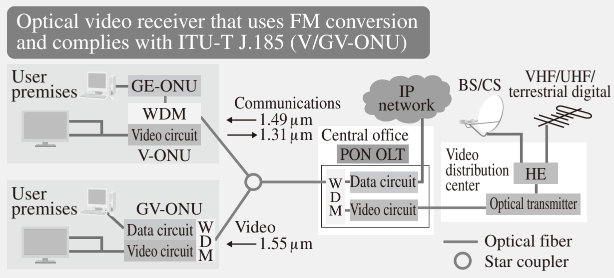
V-ONU Product Range and Characteristics

In addition to two previously released V-ONU[4] models for indoor and outdoor use, Hitachi's product lineup also includes GV-ONUs based on Nippon Telegraph and Telephone Corporation (NTT)'s specifications that combine a V-ONU with a GE-ONU (gigabit Ethernet ONU) function for data communications (see Fig. 2 and Table 1). This device can provide both IP-based data and voice service, and also provides a video service that uses the RF method over a single optical fiber.

These four ONU types can bring more convenience and values to end users and allows optimum installation according to their premise environment and requirement.

The GV-ONU achieved reduced size and space saving features by using triplex optical module incorporating an optical transceiver and a WDM (wavelength-division multiplexing) optical filter that multiplexes video and data, and also by implementing all the ONU functions on a single circuit board. Other

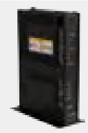
* Ethernet is a registered trademark of Xerox Corporation.



ITU-T: International Telecommunication Union–Telecommunication Standardization Sector GE-ONU: gigabit Ethernet ONU
V-ONU: video ONU HE: head end FM: frequency modulation
BS: broadcasting satellite CS: communication satellite
VHF: very high frequency UHF: ultra high frequency

Fig. 2—Structure of Video Distribution System Using FM Conversion.
The video output signal from each ONU can be received by the terrestrial digital/BS digital/110° CS tuner in the television.

TABLE 1. V-ONU Product Range and Main Features
The product range includes video-only models (indoor and outdoor models) and combined video and data models (type 1 and type 2), and can provide both data and video services from a single optical fiber.

Item	Description			
Type	Video-only ONU		Video and data ONU	
Models (installation location and operating temperature)	Indoor V-ONU (indoor, 0 to 50°C)	Outdoor V-ONU (outdoor, -20 to 50°C)	GV-ONU type 1 (indoor, 0 to 40°C)	GV-ONU type 2 (can incorporate home gateway) (indoor, 0 to 40°C)
Video transmission	FM conversion that complies with ITU-T J.185			
Data transmission	–	–	Ethernet	
Appearance				
Volume	Approximately 700 cm^3	Approximately 1,300 cm^3	Approximately 700 cm^3	Approximately 1,700 cm^3

notable features are; (1) remote monitoring of the video reception unit and (2) video service shutdown control though use of the OAM function implemented in the GE-ONU.

The remote monitoring function confirms an alarm when a video signal is not delivered, or when the signal level is below the required level, or when there is a fault in the video receiver circuit. The remote monitoring functions also allow the operator at the central office to check the status of the fault remotely. The video service shutdown function is intended to minimize power consumption and maintenance work by remote shutdown of video service when the video service is not subscribed.

10G-EPON

Work has been underway on standardizing 10G-EPON (transmission speed: 10 Gbit/s) under the IEEE802.3av standard and approved in September 2009[5]. 10G-EPON provides ten times the bandwidth of the GE-PON (transmission speed: 1 Gbit/s) standard that is currently in general use.

Fig. 3 shows the basic system structure of 10G-EPON.

To allow the same optical fiber to be shared with the existing GE-PON, use of wavelength-division multiplexing with allocation of a dedicated wavelength for 10 Gbit/s transmission has been stipulated as the standard specification.

Use of 10G-EPON will allow, for example, up to 500 channels of high-resolution video with a bandwidth of 20 Mbit/s per channel and this can be used to provide a video distribution service to all subscribers.

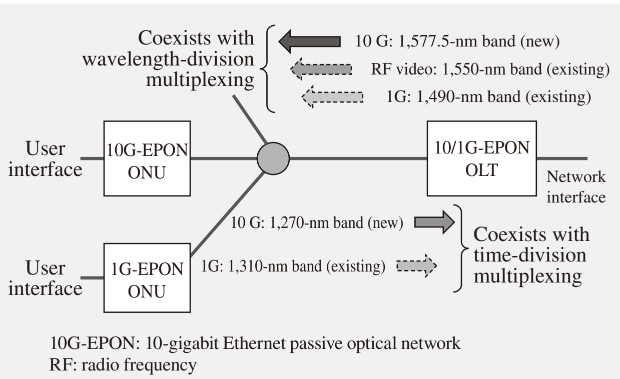


Fig. 3—Basic System Structure of 10G-EPON.
To allow the same optical fiber to be shared with the existing GE-PON, allocation of 1,577.5-nm for the 10 Gbit/s downstream transmission and the 1,270-nm band wavelengths for upstream transmission is stipulated as the standard specification.

Hitachi has been involved in the standardization of 10G-EPON from an early stage and has undertaken technical development aimed at commercializing the technology. In March 2009, a Hitachi system with a communication distance of 20 km that connected to 32 home transceivers achieved a level of communication quality that satisfied the high-reliability specifications with a bit error rate of 10^{-12} and was able to handle bi-directional transmission of high-resolution video[6]. Part of Hitachi's development of 10G-EPON is being supported by the National Institute of Information and Communications Technology in Japan.

METRO AND CORE NETWORKS

MPLS-TP

The following lists four key issues for transmission networks.

(1) Network complexity resulting from separate networks for each service
(2) Difficulty of identifying fault points due to networks becoming flatter and more autonomous through the use of router/L2SW (layer 2 switch) networks
(3) Aging of existing equipment
(4) Larger capacity requirements and more diverse network quality requirements that result from supporting different IP services

MPLS-TP (multi-protocol label switching–transport profile) has attracted attention as a way of resolving these issues. As this technique makes it possible to control and manage the entire network in a way that can guarantee end-to-end quality, unlike existing routers and L2SWs, it has an architecture that separates the packet transfer function from the route control function that handles path maintenance management on a packet network, and is in the process of being standardized by the IETF/ITU-T (The Internet Engineering Task Force/International Telecommunication Union–Telecommunication Standardization Sector). Integrating management of resources such as routes and bandwidth across the entire network allows for quality guarantees and the identification of fault points.

Transport System for Metro Networks

Hitachi is developing the AMN1710 MPLS-TP cross connection equipment as a transport system for metro networks (see Fig. 4).

The features of this equipment are as follows.

(1) Configuration of high-reliability networks: Highly reliable packet networks can be implemented using MPLS-TP and a comprehensive set of OAM

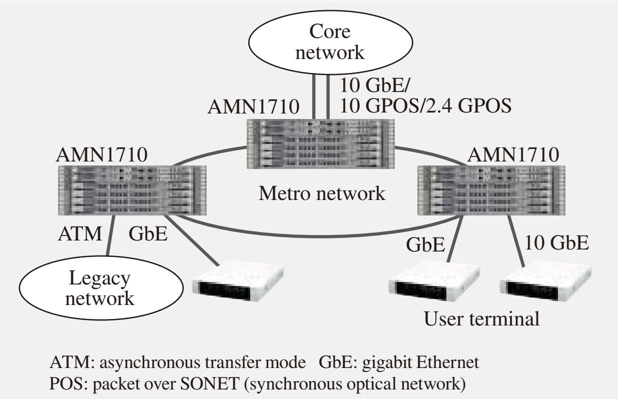


Fig. 4—AMN1710 Packet Transport System.
AMN1710 uses MPLS-TP to satisfy the various requirements of metro networks including high speed, high reliability, and legacy migration.

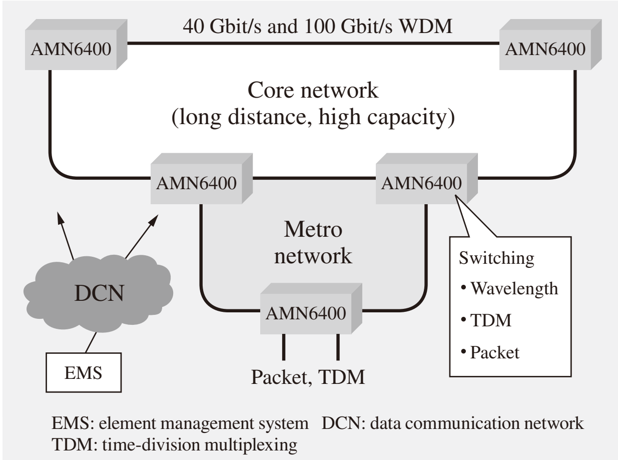


Fig. 5—AMN6400 Packet Optical Transport System.
The system is suitable for use in core and metro networks, can simultaneously support both packet and TDM traffic, and provides long-distance and high-capacity WDM transmission at 40 Gbit/s and 100 Gbit/s.

functions (path connectivity checking, high-speed switching, etc.).

(2) Interfaces to legacy networks: Interfaces to TDM (time-division multiplexing), ATM (asynchronous transfer mode), and other existing protocols allows for the migration of existing networks as the network ages.

(3) Small, high performance, and expandable: Small size, high performance, and low power consumption are realized through high-density mounting technology and high-speed signal wiring technology, and a shelf configuration capable of accommodating various different interface cards facilitates the addition of new interfaces (services).

Transport System for Core Networks

In addition to high capacity, the next generation of optical transport systems needs to provide switching functions that are optimum for the increasing volume of packet traffic along with the same high level of reliability as existing systems. To this end, Hitachi is developing the AMN6400 packet optical transport system that integrates an MPLS-TP function in a next-generation optical transport system (see Fig. 5).

The features of the AMN6400 include a large transmission capacity over long distances using WDM of optical signals at 40 Gbit/s and 100 Gbit/s for use in core networks, along with a capability for handling both packet and TDM traffic which is applicable in metro networks.

In addition to effective use of the bandwidth achieved by switching functions in the wavelength, TDM, and packet layers, OTN (optical transport network) for management of optical signals and MPLS-TP ensures higher reliability.

The AMN6400 consists of a shelf which can mount cards for supporting various services and an EMS (element management system) platform that monitors and controls these devices. A multi-shelf configuration is possible by using shelves and allows additional hardware to be added. The function of the EMS can be extended by software upgrades, therefore the system can be implemented with only as much investment as is required to meet the demand and this allows existing TDM services and new packet services to be provided in an economical way.

STANDARDIZATION TRENDS AND HITACHI'S INVOLVEMENT

The standards for technologies like PON and MPLS-TP are formulated by international standards organizations such as the ITU-T, The Institute of Electrical and Electronics Engineers, Inc. (IEEE), and IETF. In recent years, interconnection verification and conferences have had a growing role in the process of setting international standards. Against this background, the reality is that extracting standard specifications has become important for both carriers and vendors due to the increasing size of the specifications being standardized. In Europe and America in particular, interconnection verification is closely tied to conferences, trade shows, and similar and also has a role to play as a marketing tool or means of gaining greater presence.

Hitachi has participated in these standards organizations from an early stage and has provided staff, primarily specialists, who have participated in formulating the standards for the associated technologies. Utilizing the technologies, experience, and know-how accumulated through many years as a vendor of telecommunications systems, Hitachi is an active participant at the main trade shows and puts significant effort into interconnection verification and various conferences.

This comprehensive involvement in standardization is recognized by vendors from around the world who are themselves full participants. Hitachi's aim is to improve further its presence in the industry and establish itself as a global player through collaboration between the research, design and development, SE (system engineer), and other departments.

CONCLUSIONS

This article has described the various equipment used to build optical access networks and metro and core networks and that are representative of Hitachi's involvement in the construction of high-speed and high-reliability optical networks that support the social infrastructure.

High-speed networks are essential for coping with the growth in the number of users, volume of information, and other load factors and achieving high reliability is also seen as being of increasing importance.

Hitachi intends to continue observing the requirements of global market and trends in international standardization so that it can continue to offer networks that contribute to society in the future.

REFERENCES

(1) Ministry of Internal Affairs and Communications, "Number of Contracts and Related Matters for Broadband Services at the End of March 2009," http://www.soumu.go.jp/menu_news/s-news/14885.html in Japanese.

(2) Y. Nakano et al., "Optical Network Systems for Next-generation Network," Hitachi Review **58**, pp. 31–35 (Feb. 2009).

(3) S. Ikeda et al., "Wideband Video Distribution Using Integrated FM Conversion Technology," NTT Technical Review **19**, No.5, pp. 44–47 (May 2007) in Japanese.

(4) "Optical Video Receiver Unit Using Batch FM Conversion," Hitachi Hyoron **90**, p. 534 (June 2008) in Japanese.

(5) IEEE802.3av Draft 3.4 (July 2009).

(6) Hitachi, Ltd. News Release, http://www.hitachi.co.jp/New/cnews/month/2009/03/0317.pdf in Japanese.

ABOUT THE AUTHORS

Ryosuke Nishino

Joined Hitachi, Ltd. in 1996, and now works at the 2nd Group of Packet Transport Project, Network System Operation, Telecommunications & Network Systems Division, Information & Telecommunication Group, Information & Telecommunication Systems Company. He is currently engaged in the development of the optical packet transport system. Mr. Nishino is a member of The Institute of Electronics, Information and Communication Engineers (IEICE).

Hideaki Tsushima, Dr. Eng.

Joined Hitachi, Ltd. in 1984, and now works at the 3rd Group of Packet Transport Project, Network System Operation, Telecommunications & Network Systems Division, Information & Telecommunication Group, Information & Telecommunication Systems Company. He is currently engaged in the development of the packet optical transport system. Dr. Tsushima is a member of IEICE.

Eisuke Sato

Joined Hitachi, Ltd. in 1978, and now works at the Access System Department, Network System Operation, Telecommunications & Network Systems Division, Information & Telecommunication Group, Information & Telecommunication Systems Company. He is currently engaged in the development of the optical access system. Mr. Sato is a member of IEICE.

Shinsuke Tanaka

Joined Hitachi, Ltd. in 2000, and now works at the Global Business Development Department, Business Development Operation, Telecommunications & Network Systems Division, Information & Telecommunication Group, Information & Telecommunication Systems Company. He is currently engaged in the global marketing of network systems.