Optical Network Systems for Next-generation Networks

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OVERVIEW: With the advent of full fledged NGNs where data, voice, and video are all IP based, it is necessary for the provision of stable services to provide metro access systems and optical transport systems that allow paths to be operated and maintained over packet networks. In order to achieve such highly managed IP networks, the end-to-end QoS is guaranteed by managing IP network resources using Transport-MPLS in a centralized manner and by allocating fixed routes and resources for the packet transfer function. The optical transport systems use ROADMs to set up wavelength paths between IP nodes flexibly to achieve path quality management and high path reliability.

INTRODUCTION

OPTICAL network systems include metro and access transmission networks in metropolitan areas and between homes or businesses and central offices, and optical transport networks for long-distance transmission between major central offices. Traditionally, optical network systems provide logical paths with a fixed bandwidth to the higher service layers such as telephony, and path operation and maintenance was performed by transferring any alarms that occurred in these logical paths to related devices and by switching failed paths over to standby paths.

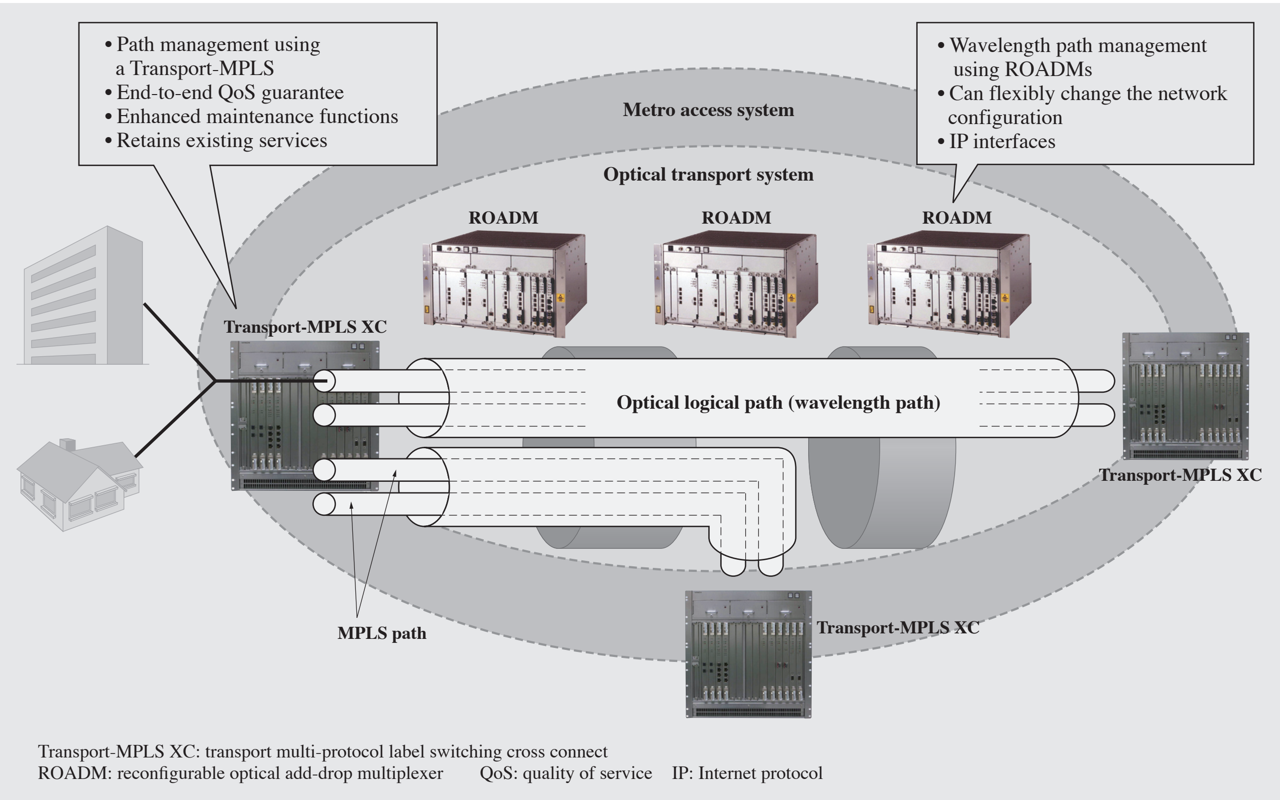

Fig.1—Managed Optical Network for Next-generation Networks.
Optical networks for the NGN (next-generation network) will be entirely packet-based and require enhanced management functionality. ROADMs have the flexibility to set up paths separately for each wavelength while transport-MPLS XCs can set up and manage end-to-end MPLS paths.

The era of fully fledged NGNs (next-generation networks) where data, voice and video all use the IP (Internet protocol), however, requires a packet-based optical network system suitable for packet services rather than a conventional system that provides fixed bandwidths. Metro access networks in NGNs need highly managed IP networks in order to provide stable services. On the other hand, in addition to the higher capacity provided by conventional wavelength division multiplexing, optical transport networks also need to be able to provide higher layers with paths flexibly.

This article discusses technological aspects of optical network systems. These include the requirements and system configurations for metro access networks, optical transport systems and the status of the international standards that play an important role in their implementation, as well as what the Hitachi Group is doing in these fields (see Fig. 1).

METRO ACCESS NETWORKS

Requirements for Metro Access Networks

(1) Managed IP networks

An IP network contains packet transfer equipment called router/switches. A feature of IP networks is that the router/switches have a routing control function that autonomously generates routing information by exchanging network configuration information between adjacent devices. This allows the construction of networks that can flexibly cope with network configuration changes and failures. The problems that have been identified with this approach, however, are that: (a) it is difficult to ensure an end-to-end QoS (quality of service) because this requires routing management and management of resources such as bandwidth across the entire network, and (b) failures in the routing control function of some router/switches can affect the entire network.

NGNs require a managed IP network, and to achieve this, the ITU-T (International Telecommunication Union–Telecommunication Standardization Sector) has been studying an approach whereby the IP network uses an architecture that separates the routing control function from the packet transfer function. In this method, the routing control function is removed from the router/switches and integrated into the network's management and control system, which thereby becomes the control plane. This makes it possible to provide an end-to-end QoS guarantee by managing the network resources centrally to provide the packet transfer function (the data plane) with path provisioning and resource allocation. Removing the routing control function from the router/switches also enables more stable routing control.

The ITU-T and the IETF (Internet Engineering Task Force) are standardizing the Transport-MPLS (multi-protocol label switching) technology as a network configuration method that separates the control plane and data plane. Transport-MPLS is based on MPLS, which is a connection-oriented packet switching protocol standardized by the IETF. Whereas MPLS uses the routing control function provided by the routers, Transport-MPLS uses the network management and control system for routing control. The following OAM (operation, administration, and maintenance) functions are standardized to offer fine-grained management equivalent to that in the widely used ATM (asynchronous transfer mode) networks.

(a) Connectivity verification
(b) Path defect indication (forward and backward) to connected equipment
(c) Path connectivity check by loopback test
(d) Fast failure detection
(e) Path protection

(2) Migration from existing networks

A requirement for facilitating the conversion of metro access networks into IP networks is the ability to provide existing TDM (time-division multiplexing) and ATM services over IP networks.

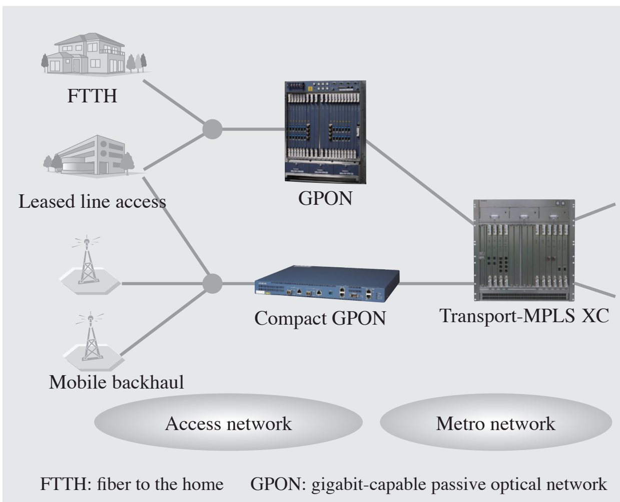

Fig.2—Example Configuration of Metro Access Networks.
High-quality IP access metro networks are built on Transport-MPLS and GPONs.

CEP (circuit emulation over packet) is a technology that can be used to meet the requirement to retain existing TDM and ATM services in IP networks by encapsulating TDM time slots or ATM cells in IP packets.

System Configurations for FTTH, Leased Lines, and Cell Base Stations Backhaul

The Hitachi Group recognizes that an architecture that separates the control and data planes is a key technology for NGNs and has been carrying out further research and development on Transport-MPLS systems along with the moves of the ITU-T and others (see Fig. 2). The Hitachi Group has also focused efforts on the development of PON (passive optical network) devices to increase the speed and reduce the cost of access lines. Features of these devices are as follows.

(1) Transport-MPLS cross connect for metro access

This device aggregates access lines such as Gigabit Ethernet* and ATM and supports them in MPLS networks. Consequently, high-quality metro access networks can be implemented using the OAM and protection functions.

(2) GPON (gigabit-capable PON) system

This is an optical access system consisting of an OLT (optical line termination) accommodating up to 1,538 pieces of ONT (optical network termination) with an Ethernet UNI (user network interface). The system is suitable for access lines used in FTTH (fiber to the home) and Ethernet leased line services.

(3) Compact GPON system

This is a compact GPON OLT with a height of only 1U (about 44 mm). This system is suitable for access lines used for cell base station backhaul and for Ethernet leased line services.

OPTICAL TRANSPORT NETWORKS

Requirements for Optical Transport Networks

In response to the emerging all-IP era, next-generation optical transport systems used in optical networks need to maintain interoperability with existing networks as well as provide new multimedia services and support end-to-end quality control. In addition to the international standard SDH (synchronous digital hierarchy) interface, this also requires the IP optical interfaces that are standard features on router/switches and a level of quality monitoring for the IP optical signals that is equivalent to that available for SDH optical signals. Also, meeting the diverse traffic demands placed on these networks requires a balance between economics and support for reliable, high-capacity and flexible network configuration.

* Ethernet is a registered trademark of Xerox Corp.

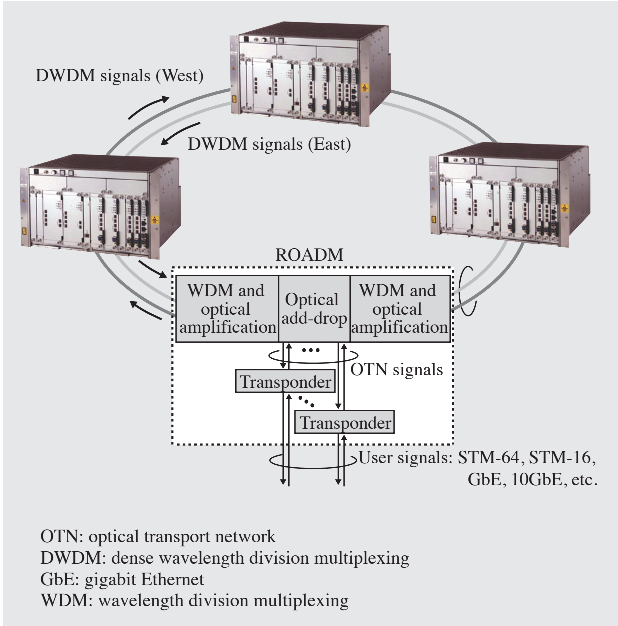

Fig.3—ROADM.
This system is able to map SDH (synchronous digital hierarchy) and IP user signals to the OTN, signals which are wavelength-multiplexed and "drop," "add" or "through" can be selected independently for each wavelength

Configurations for Optical Transport Systems

Given the above requirements, an effective solution is to combine DWDM (dense wavelength division multiplexing) with an OADM (optical add-drop multiplexer) ring. The former is highly economical and makes efficient use of the optical fiber while the optical add-drop capability of the latter allows flexible network configuration. The OADM system allows connections between user devices by mapping user signals into a wavelength suitable for dense wavelength multiplexing and then allowing the wavelength-multiplexed optical signals either be passed through, dropped or added. This system can efficiently interconnect multiple nodes using a ring topology by connecting each add or drop point via a single fiber pair and provides economical high-capacity transmission because it does not require an optical/electrical converter at through-points.

Hitachi has developed ROADM (reconfigurable OADM) technology for wavelength mesh networks (see Fig. 3). This technology delivers high-capacity transmission, being able to handle at least 80 wavelengths with a speed of 10 Gbits per second per wavelength. Its abundant wavelength resources mean it can support user devices that require a logical mesh or star topology by using a wavelength mesh configuration in which the user devices are physically interconnected via fiber in a ring topology. Its dedicated management software allows changes to the logical network configuration to be made flexibly via a remote control function that can select "drop," "add" or "through" independently for each wavelength. For interfacing to user equipment, the device offers the STM-64 (Synchronous Transport Module Level 64) and STM-16 SDH standards as well as Gigabit Ethernet and 10 Gigabit Ethernet IP interfaces. In order to ensure adequate quality control and high reliability for SDH and IP user signals, the system features a 1+1 protection function and uses the ITU-T G.709 OTN (optical transport network) frame for signals between nodes on the ring that provides ample overhead. Since powerful error correction technology developed by Hitachi enables as large as 300-km-or-more long ring on both SMFs (single-mode fibers) and DSFs (dispersion-shifted fibers) as its transmission lines, installed fibers can be used in an effective manner. The transponders that map user signals to a wavelength signal capable of long-distance transmission have full-band wavelength tunable transmitters and use a unique modulation format with high dispersion tolerance that limits the wavelength distortion attributable to the fiber characteristics. These technologies help reduce the types and quantity of inventory that needs to be maintained, extend the transmission distance without use of dispersion compensators, and shorten lead times. The use of transponders with an electrical multiplexing function, universal slots that allow additional equipment to be installed efficiently as required, and the high density assembly technology save on space (being about one-quarter smaller than Hitachi's previous design)[1] and reduce power consumption.

STANDARDIZATION TRENDS AND HITACHI GROUP'S ACTIVITIES

Standardization Trends in NGN Transmission Networks

The ITU-T has taken the central role in the standardization of operation and maintenance technologies for connection-oriented communications networks such as telephony networks and has also led discussion of NGNs. With its considerable know-how in the fields of network operations and maintenance technologies including OAM functionality, the ITU-T has recently achieved significant results in standardizing OAM functionality for Ethernet networks in cooperation with the IEEE (Institute of Electrical and Electronics Engineers)[2].

QoS control is one of the most important concepts required for managed IP networks. Packet-based transport technologies have already been discussed at the ITU-T, the IEEE, and the IETF. A number of different standardization organizations have considered extensions of OAM functionality in Ethernet networks and protection techniques have attracted attention as one application of this. The concept of operation and maintenance in Ethernet OAM lies at the core of IP packet transmission platforms and is an essential technology for NGNs.

At present, the standardization of packet-based transmission networks centers on Ethernet and Transport-MPLS. MPLS is suitable for the migration phase to next-generation networks because it facilitates interconnection with existing synchronous networks by separating the data and control planes. Meanwhile, the range of subjects for discussion is now beyond the framework of traditional point-to-point communication systems, and extends to such new topics as telecommunications technologies for the future including how to build packet-based ring networks and how to support the IP multicast capability.

Transmission network technologies for NGNs including optical network systems remain on the agenda of the ITU-T's new study period starting in 2008. Along with the addition of control plane managing IP networks as a topic, other items to be discussed include the requirements for transmission networks and the addition of new functions. Realizing the ideal transmission network technologies upon which NGNs will be built will require not only cooperation between standardization organizations but also open discussion across the various types of business that rely on the network infrastructure.

Hitachi Group's Activities in NGN Transmission Network Standardization

The Hitachi Group has participated as a core member in OAM standardization for SDH and ATM at the ITU-T, and has considerable experience in operation and maintenance technologies for transmission networks. Its recent vigorous activities include the standardization of OAM functionality for Ethernet networks.

OAM functionality is not the only function required for the transmission networks that will provide the platform for NGNs. A mechanism to make information from the service level available in the transmission network level is also vital. More specifically, an important consideration is how to incorporate technologies standardized by non-ITU-T organizations such as the multicast function in IP networks and the address learning function. This is because these functions represent the characteristics of packet multiplexing systems. They are different from the existing concepts used in fixed network maintenance but will play a central role in the transmission network functionality of NGNs.

The Hitachi Group has the following two key concepts for the optical network systems used in NGNs.

(1) Build flexible and safe transmission networks that reflect the requirements of the service level, and establish methods for operation and maintenance

(2) Enhance the information transmission functions at the intermediate level that links the service level and transmission network level.

To support diversified services, the NGN platforms will need to deal with the characteristics of service traffic more directly. For example, the IPTV services that have become popular in recent years require support for the multicasting feature of IP packet communications at the transmission network level.

Transmission network technologies based on Ethernet (or its enhancements) are currently the most promising for future NGN transmission networks. Focusing on this technology, the Hitachi Group will continue participating in standardization activities as a creator of change in order to support strongly the NGNs promoted by telecommunications carriers.

CONCLUSIONS

This article has discussed technologies of optical network systems for NGNs.

The construction of metro access systems and optical transport for NGNs has just begun and is still developing. The Hitachi Group will continue proposing new concepts by closely watching market requirements and standardization trends.

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