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Optical Communication Technologies for Next Generation Network

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Changes for the Better

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Optical Communication Technologies for Next Generation Network

Cover Story

Japan launched its world's first commercial-based services for the next generation network, which can provide advanced, diversified services.
Mitsubishi Electric has developed devices and systems used in wired- and wireless-communication networks. It now aims to create a society with both vitality and comfort, not only by developing products and providing solutions for the next generation network, but also by promoting technological innovation with aggressive contributions to international standardization activities.
The photos on the front cover are Mitsubishi Electric's representative products related with the next generation network: (1) Reconfigurable optical add/drop multiplexer (ROADM), (2) IP-Set Top Box (IP-STB), (3) Optical network unit which is installed in each subscriber's house (GE-PON ONU), (4) Optical line terminal which is installed in a central office (GE-PON OLT), and (5) Wavelength division multiplexing (WDM) system that supports large-capacity and long distance transmission.
(1) (Upper left): ROADM system
(2) (Upper right): IP-Set Top Box (IP-STB)
(3) (Middle): Optical network unit for subscriber circuit (GE-PON ONU)
(4) (Lower left): Optical line terminal for subscriber circuit (GE-PON OLT)
(5) (Lower right): WDM system

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Technical Reports

Overview

Author: *Masatoshi Kato**

The number of broadband subscribers was 28.7 million in Japan as of the end of March 2008. The significance of the communication networks as social infrastructure to support general consumers and corporate activities is increasing accompanied by the rapid spread of the Internet.

Conventional broadband services have been provided via best-effort IP networks, which are now considered to be insufficient in terms of communication stability, quality of services, and security, as the number of subscribers continues to steadily increase.

The rapidly growing next generation network has been introduced as new social infrastructure which utilizes the openness of the Internet while maintaining the reliability and the security of the conventional telephone network system (Public Switched Telephone Network). The deployment of the next generation network is expected to reduce prices of conventional services and to create new enhanced services which are to change individual lifestyles and corporate business models drastically.

Mitsubishi Electric, based on our accumulated technological assets in optical access systems, wavelength division multiplexing transmission systems, submarine cable systems, etc., promotes not only standardization activities, but also the development of various technologies and products in fields such as transportation systems and customer premises equipment for the realization of the next generation network. This issue introduces Mitsubishi Electric's activities for those technological developments.

**Communication Networks Center*

WDM for Next Generation Network

Authors: *Yojiro Osaki** and *Toshiya Morita**

Abstract

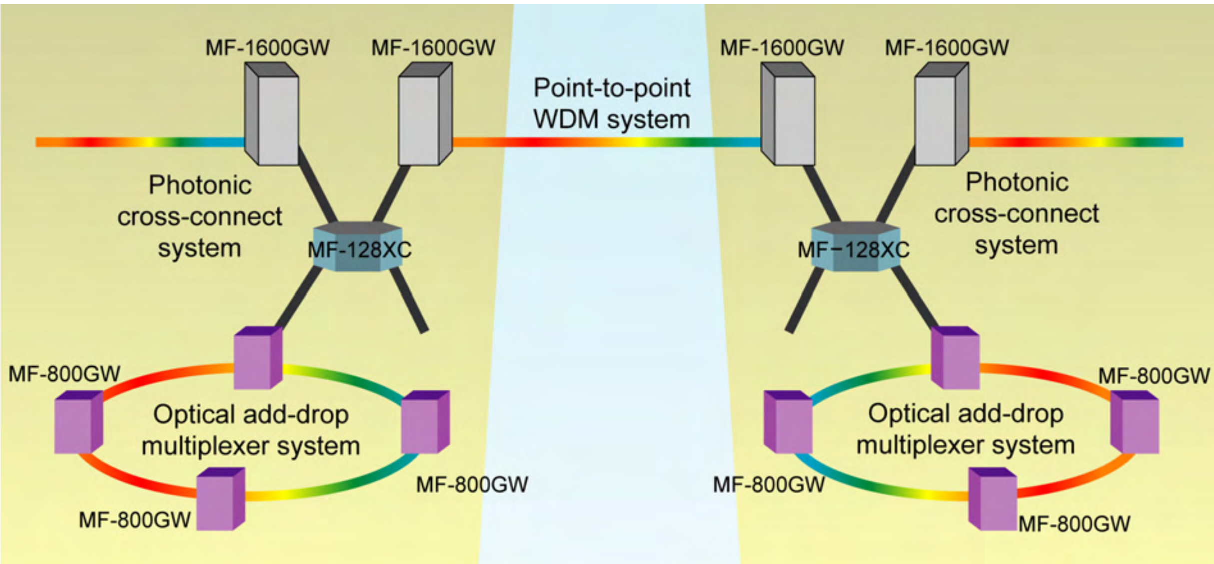
The transport layer that governs NGN data transfer as defined in ITU-T Recommendation Y.2011, “General Principles and General Reference Model for NGNs,” requires not only point-to-point arrangement, but also mesh-type connections between cities and multiple metro-ring network connections within each city. These requirements can only be met by point-to-point WDM systems of much larger capacity and longer transmission distance, and photonic routing systems that can open and/or release optical paths of arbitrary capacity between arbitrary nodes as necessary according to fluctuations in communication demand. Optical add-drop multiplexing (OADM) and photonic cross-connect (PXC) technologies are highly expected to support such photonic routing methods. Mitsubishi Electric has developed three different wavelength division multiplexing systems for the NGN as described below.

(1) Point-to-point WDM system that supports 500-km transmission of 40-Gbps signals (MF-1600GW)

(2) Reconfigurable optical add-drop multiplexer (ROADM) system that can reconfigure optical paths and is considered a promising next generation version of OADM (MF-800GW)

(3) Photonic cross-connect system conforming to generalized MPLS (GMPLS) that not only realizes a remarkable improvement in operability but also supports linkage with multi-protocol label switching (MPLS) routers (MF-128XC)

With these three systems integrated as shown below, broadband transport technologies are realized.



Mitsubishi Electric’s wavelength division multiplexing systems for networking between and within cities

Wavelength division multiplexing systems

A method for transmitting multiple signals by multiplexing carrier waves of different wavelengths in a single optical fiber, which not only significantly reduces the transmission cost per channel but also increases or decreases the number of wavelengths in accordance with the actual communication demand by using a single fiber divided for multiple wavelengths.

**Communication Networks Center*

1. Point-to-Point WDM System

Point-to-point WDM systems are used as large-capacity backbone networks between cities. Mitsubishi Electric commercialized 2.5-Gbps point-to-point WDM systems in the mid 1990s for introduction as backbone networks in and outside Japan. Since the late 1990s, Mitsubishi Electric has provided mainly 10-Gbps WDM systems, such as for large-scale marine cable systems installed across oceans. With the recent increase in communication data volume, 40-Gbps WDM systems are now in high demand. The impetus for this demand is the fact that 40-Gbps WDM would support time-division multiplexing, connection with a 40-Gbps core router, and bulk transfer and would simplify wavelength handling not only by simply increasing the capacity but also by increasing the degree of time-division multiplexing.

To meet such market needs, Mitsubishi Electric has developed a prototype 40-Gbps point-to-point WDM system, the MF-1600GW. Table 1 lists the specifications of the prototype, and Fig. 1 shows the appearance. Forty wavelengths are multiplexed at intervals of 100 GHz in the L-band and 500-km transmission is realized by concatenated optical amplifiers. Five 40-Gbps transponder cards are installed on one shelf of a 19-inch rack. Serving as a client interface, it not only accommodates 40-Gbps signals such as STM256, but also multiplexes 10-Gbps signals such as 10-GbE LAN PHY.

In order to overlay 40-Gbps signals on the conventional 10-Gbps WDM system, we employed carrier-suppressed return-to-zero differential quadrature phase-shift keying (CSRZ-DQPSK) modulation, which uses frequency very efficiently, because it was necessary to multiplex wavelengths at intervals of at least 100 GHz. Figure 2 shows the transmission signal spectrum with wavelengths multiplexed at intervals of 100 GHz, and indicates sufficiently low cross-talk levels between adjacent channels.

The difficulty in transmitting 40-Gbps signals, compared with that of 10-Gbps signals, lies in controlling the polarization mode dispersion (PMD), which is four times greater. DQPSK is 4-value modulation and the symbol rate is 20 Gsymbol/s, half of 40 Gbps; thus, a PMD resistance level that is two times that of the conventional 40-Gbps on-off keying or DPSK is expected with DQPSK. Figure 3 shows the measurement results for the Q-value penalty with respect to the differential group delay (DGD) as the indicator of the PMD resistance of the system we developed. The penalty against 18-ps DGD was 1 dB, which is equivalent to the indication that no signal quality deterioration will occur in PMD over a standard transmission line 500 km in length.

Table 1 Main specifications of MF-1600GW

Item	Specification
Network topology	Point-to-point
Max. transmission capacity	1600 Gbps (per fiber)
Permissible zone loss	22dB
Optical amplification relay transmission distance	500km
Wavelength band	L-band
Client interface types	STM64/OC192 × Quadruplexing 10 GbE × Quadruplexing STM256/OC768
Max. wavelength number	5 (per shelf)

Fig. 1 Appearance of MF-1600GW

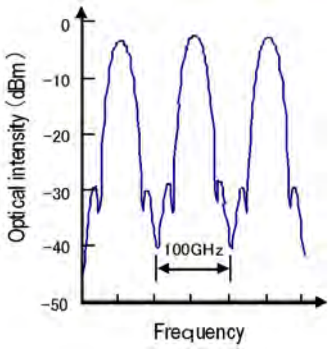


Fig. 2 40-Gbps signal spectrum of CSRZ-DQPSK system

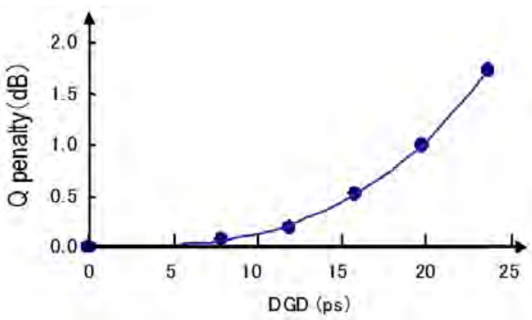


Fig. 3 PMD resistance

2. Optical Add-Drop Multiplexer

An optical add-drop multiplexer (OADM) is a means of reducing the cost and improving the reliability of networks. It is a circuit-switching method for optically inserting or dropping wavelength-multiplexed signals at predetermined nodes. It reduces electrical switching costs and prevents delays due to routing, which is detrimental to packet switching, and any dramatic increase in computation volume. Conventional systems use mainly fixed OADM, in which the wavelength is fixed and insertion and dropping are conducted manually. However, it has become increasingly necessary to incorporate a reconfigurable OADM (ROADM) that can remotely change the add-drop nodes and wavelength to flexibly and promptly cope with changes in communication demand.

Fig. 4 Appearance of MF-800GW

Table 2 Main specifications of MF-800GW

Item	Specification
Network topology	Ring/linear
Protection method	1+1
Path control protocol	GMPLS (RSVP-TE)
Max. transmission capacity	800 Gbps
Permissible zone loss	0~33dB
Wavelength band	L-band
Transponder wavelength	50-GHz interval/variable throughout L-band
Client interface types	STM16/OC16, STM16/OC48 STM64/OC192 1000BASE-SX/-LX, 10GbE
Max. wavelength number	20 (per shelf)

Mitsubishi Electric has developed an ROADM system, the MF-800GW, having a transmission capacity of 10 Gbps × 80 waves to meet increased demand. Figure 4 shows the appearance of the product, Table 2 lists the main specifications, and Fig. 5 depicts the system configuration.

MF-800GW is an ROADM system applicable to ring and linear networks comprising more than 10 nodes. Its features are described below.

(1) The "1+1" protection method recommended by ITU-T G.873.1 protects the optical path, which must have high reliability against transmission path failure, even during an instantaneous service interruption of 50 ms or less.

(2) Optical path open/release is realized by signaling provided by the Resource Reservation Protocol – Traffic Engineering Extensions (RSVP-TE) conforming to Generalized Multi-Protocol Label Switching (GMPLS).

(3) Failure control by the optical transport network (OTN) conforming to ITU-T G.709 can easily identify the failure location and affected sections.

(4) The element management system (EMS), which is active/standby duplexed, can display a list of current alarms and history of alarms, with alarm levels displayed by color. It is also equipped with sort/filter functions that allow easy identification and analysis of failure causes.

(5) The hardware is downsized and designed to be energy-efficient, so up to 20 transponder cards can be installed per shelf of a 19-inch rack, thus saving power and space at stations.

(6) A function to indicate optical fiber connection ports with lamps by means of interlock with optical path set-up prevents faulty connection or disconnection of many optical fibers, thus supporting maintenance and operation of the system.

(7) Wavelengths for 80 waves can be remotely set or altered for addition or dropping. The transponders can be changed to desired wavelength grids in all ranges.

(8) The product supports a multibit rate; desired signals can be accommodated by switching the client optical interface of the pluggable module.

(9) By means of 8- or 4-channel multiplexing for GbE or STM16 each, wavelengths are efficiently used. If a large number of nodes are to be connected, the optical path can be extended by using regeneration and relay (3R) transponders.

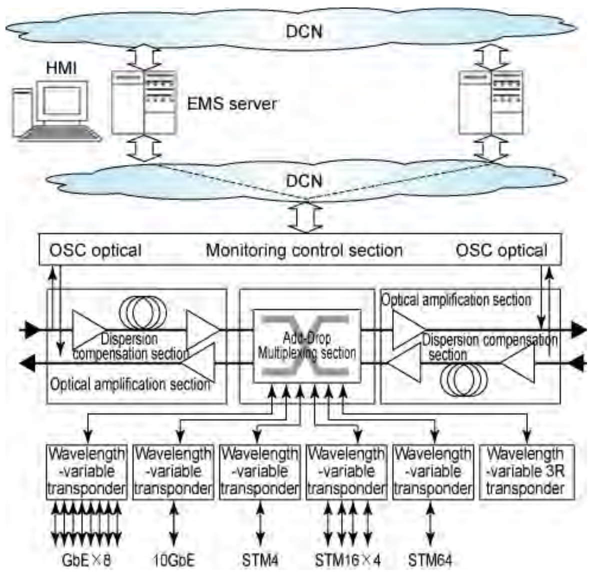


Fig. 5 MF-800GW system configuration

3. Photonic Cross-Connect System

Introduction of circuit switching using a photonic cross-connect (PXC) system can suppress the delay time in multiple router stages and reduce power consumption by optical pass-through. Some applications look to PXC as a system that can effectively provide multi-degree connections for multiple ROADM rings as described above.

To meet such needs, Mitsubishi Electric has developed a PXC system, the MF-128XC, conforming to GMPLS. Figure 6 shows the appearance of the product, and Table 3 lists the major specifications.

For the GMPLS protocol, RSVP-TE, Open Shortest Path First – Traffic Engineering Extensions (OSPF-TE) and Link Management Protocol (LMP) are applied; linking of failure control or other functions is possible with the WDM system. This PXC system provides a transmission line failure recovery function that evacuates traffic to an auxiliary transmission line in the event of a failure such as optical fiber cable disconnection, etc.

Figure 7 shows the node configuration when the developed PXC system is applied to full LSP rerouting. Not only is it possible to establish an alternate path in the case of failure, but also the optical switch can be duplexed within the system; thus, the reliability of the data plane is increased. Furthermore, the control plane itself is redundant and the monitoring control card in the system is duplexed so that continuous protection and rerouting is realized.

Fig. 6 Appearance of MF-128XC

Table 3 Main specifications of MF-128XC

Item		Specification
Shelf	Chassis Dimensions	12U - 19 inch 795(W) x 600(D) x 2200(H:max)
Power supply	Voltage Power consumption	DC-48V, 1+1 redundancy 250W max
Interface	Number of ports Bit rate	16 ports/card, 8 cards/chassis No dependence
Optical switch	Structure	3D MEMS
	Switch capacity	16x16, 32x32, 64x64, 128x128
	Insertion loss	<12 dB (1+1 redundancy), 8 dB typ.
	Switching time	30ms max.
GMPLS	Signaling	RSVP-TE (RFC 3471, RFC 3473, RFC 3477, RFC 2961 & RFC 3209)
	Routing	OSPF-TE (RFC 3630, draft-ccamp-ospf-gmpls-extensions-12.txt)
	Link control	LMP, LMP-WDM: CCM, LPC, FM (draft-ietf-ccamp-lmp-09 & draft-ietf-ccamp-lmp-wdm-03)
	Protection	1+1, Full LSP re-routing, Unprotected

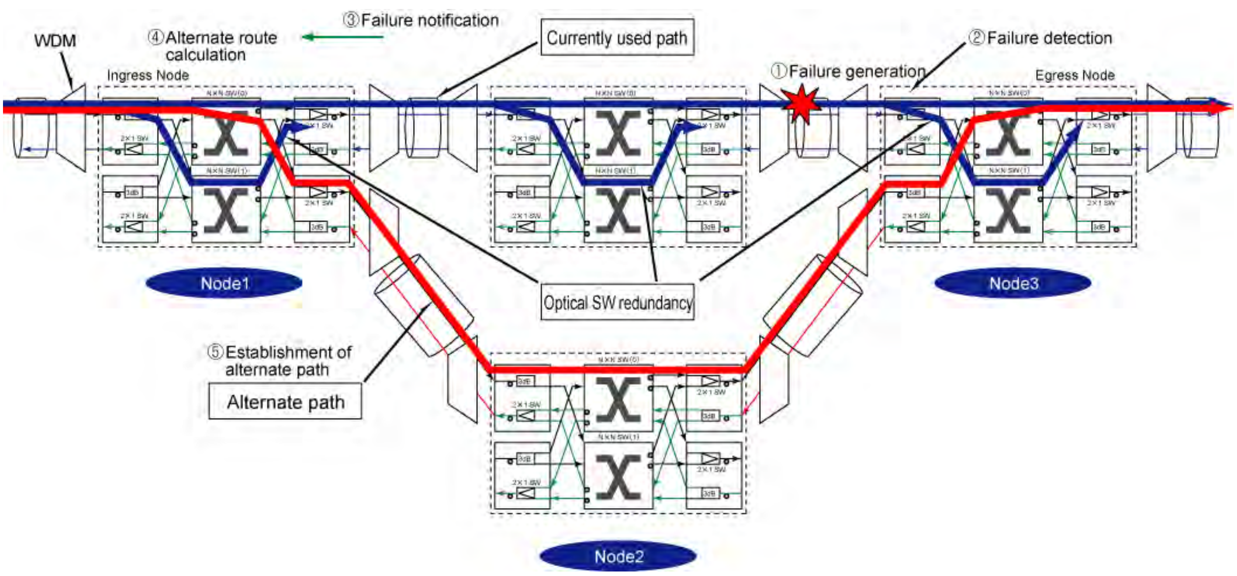


Fig. 7 Node configuration for full LSP rerouting with MF-128XC

Next Generation Optical Transport Technology

Authors: *Hiroshi Ichibangase** and *Kuniaki Motoshima***

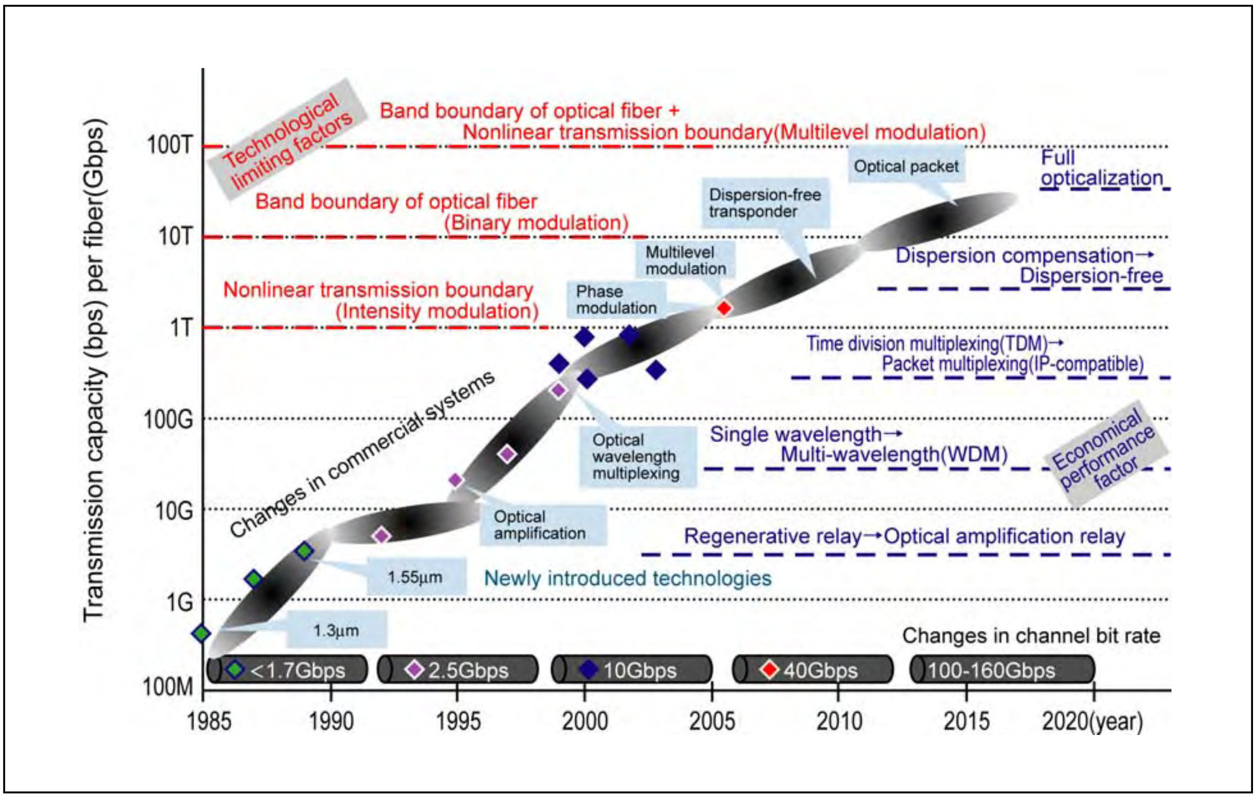
Abstract

The transmission capacities of the optical transport technology commercialized for core network applications in the 1980s has been developed remarkably both for submarine and land systems due to the optical amplifier technology and optical wavelength multiplexing technology developed in the 1990s. With the opticalization of the access network in the 2000s, almost all of the networks have entered the age of optical communications. This paper outlines the optical transmission technologies that support the development of these networks together with the technological trend in the future.

The figure shown below represents the road map of optical transport technologies.

For opticalization of the access systems, one-to-N connection topology with optical splitters installed along the transmission route is applied. The technologies used for this arrangement include instantaneous bit synchronization and high-speed automatic gain control (AGC) technologies for burst transmission and avalanche photo diode (APD) receiving technology for the expanded dynamic range.

As for the technologies related to the metro and core networks, the phase modulation technology and multilevel modulation technology shown in the figure have been studied. The technologies are considered effective for overcoming the difficulty that the distance of optical transmission at 10 Gbps or higher is limited due to wavelength dispersion and polarization dispersion of optical fibers.



Roadmap of Optical Transport Technologies

This figure shows the roadmap of optical transport technologies. The technologies were introduced for the marine and land core networks in the 1980s. Then, optical amplification and wavelength multiplexing technologies remarkably increased the transmission capacities. The technologies were also introduced in the access systems, thus realizing FTTH in the 2000s. Expansion of metro and core network transmission capacities has been increasingly demanded due to the influence of the achievement with the access systems. New technologies such as phase modulation and multilevel modulation are expected to serve the applications.

**Information Technology R&D Center   **Communication Networks Center*

1. History and Technological Trends of Optical Access System

In Japan, optical fiber was first introduced in the trunk line network in the 1980s and optical amplifiers and optical wavelength multiplexing technology were introduced to promote the opticalization of metro and core networks in the late 1990s, with the long-distance transmission capacities of the networks remarkably increased.

At the beginning of the 1990s, optical fibers were introduced in the access network for increased economic efficiency obtained by multiple subscriber access and multiple service distribution. Then, in the 2000s, the passive optical network (PON) of 1Gbps was standardized [1] to prevail as FTTH in Japan in particular.

Figure 1 shows the configuration of the networks. This paper outlines the optical transmission technologies which have supported the evolution of these networks and the future of the networks. For details concerning respective technologies, refer to the references indicated in the text below.

1.1 Configuration of networks

The GE-PON method is employed for the access network. For details on the configuration, etc. refer to each report included in this issue. The trend in optical transmission technologies is introduced here.

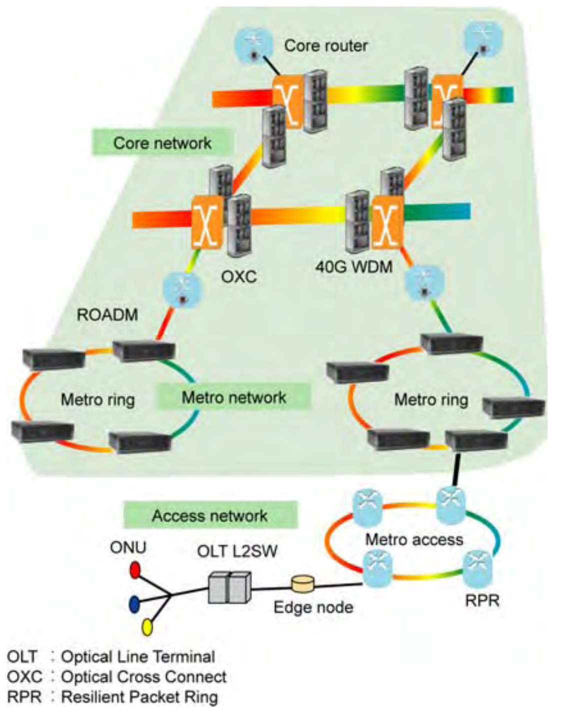


Fig. 1 Configuration of networks

1.2 Transport technologies to support passive optical network (PON)

PON, with splitters positioned on the transmission route, provides bi-directional optical communications. Its specific technological requirements include the burst transmitter and receiver for time division multiplex communication in the upward direction and a wide dynamic range to compensate for the optical level loss at splitters. Mitsubishi Electric has solved these issues by using high-output LD send and APD receive technologies and burst bit synchronization technology. As for this burst bit synchronization technology, Mitsubishi Electric has developed digital phase selection type technology in which proper phase is selected by detecting the bit timing burst signals by preparing multiple-phase clocks synchronized with the station-side clocks that are frequency-synchronized.

1.3 Trend of research in future

The standardization of the next generation PON, in the form of 10G PON in which the bit rate is increased by a factor of ten, was started by the IEEE and ITU-T. Multi-rate arrangement in which the ONUs used in the conventional 1-Gbps PON are also accommodated for the simultaneous use with 10-Gbps ONUs is being considered for the 10G PON. Other technologies under consideration for applications in the future are transmission distance extension technology using optical amplifiers for a distance of 20 km or longer, multisplit technology for 64 splits or more, outdoor installation of optical network units (ONUs), and triple wave multiplexing technology for providing image stream services in the downstream direction. Also in the future, technologies such as optical code division multiple access (OCDMA) and optical frequency division multiplexing (OFDM) will be applied in the same way as with radio transmission.

2. Optical Transport Technologies for Metro and Core Networks

2.1 Metro network

Figure 2 shows the history of the technologies applied to optical metro and core networks. The mainstream in the conventional technologies were point-to-point transmission using SONET/SDH system optical transmission devices or other network methods that configure such transmission arrangements in the form of a ring. However, networks based on an optical add drop multiplexer (OADM) that converts all the signals at one node into electric signals without processing the signals with all information passing through remaining as optical data are confirmed to be efficient and OADM is becoming the mainstream technology. The major devices that compose Reconfigurable OADM (ROADM) are wavelength-tunable optical transponder and OADM circuit provided with optical switching function. It is important to transmit with stable performance with respect to the set wavelength also with the wavelength variation range on the transmitter side secured as wide as possible, regardless of the temperature or the length of service.

Mitsubishi Electric has also proposed photonic cross connect (PXC) that can connect light into a mesh-shaped structure for increased optical path accommodation efficiency [(2), (3)]. The reliability and maintainability of optical switches themselves are very important for PXC. However, since optical paths are formed into a mesh structure, the control of the optical paths is also a very important matter to be considered. As a control method, Mitsubishi Electric has been working on the development of a dispersion control method using generalized multi-protocol label switch (GMPLS).

Though it is a technology to be realized in the future, Mitsubishi Electric has started a study on optical node technology based on wavelength conversion by using semiconductor amplifiers [(4), (5)].

2.2 Core network

One of the features of the core network is its economical efficiency owing to the optical communication scheme: 10-Gpbs ring type or linear type network devices are commercially available for both marine and land systems today. The challenge with the long distance optical transmission system is the technologies that can reduce transmission penalties; the most important technologies are dispersion compensation technology and error correction technology.

As a dispersion compensation technology, a method of compensation that uses dispersion compensation fibers having the opposite characteristics of the transmission channels has been used so far. However, the operational problem with the method is that different dispersion compensation fibers must be introduced newly when the transmission distance changes due to removal for problems or the like. Mitsubishi Electric has proposed a tunable dispersion compensation device using fiber grating as a solution; dispersion compensation is automatically performed with ps/nm of several hundreds.

The error correction method performs well with the WDM system using optical amplifiers: Originally the Reed-Solomon code having a redundancy of 7%, specified in ITU Standard G.975, was used for optical communications. To further improve the coding gain, Mitsubishi Electric proposed repetitive decoding in which the redundant codes are designed two dimensionally, in both the vertical and horizontal directions, and decoding in vertical and horizontal directions is performed alternately. As a result, coding gain was improved from 6 dB to 8 dB. In addition, Mitsubishi Electric realized a coding gain of 10 dB, to mark further improvement, by applying the turbo codes for block codes to suppress the coding redundancy low and combining the codes with a soft decision circuit [(6), (7)].

When it comes to an increase in bit rate, the industry's expectations include a 40-Gbps class. However, 40-Gbps systems are likely to confront several difficulties. For example, the influence of dispersion on a 40-Gbps system will be 16 times that on a 10-Gbps system and it will also be necessary to improve the S/N ratio when structuring the network without changing the installation intervals of transponders. Lowering the symbol rate by multilevel optical modulation to reduce the influence of dispersion and employing more powerful error correction technology to improve the S/N ratio could be an option. But the option still has to face the challenges associated with the size of the circuit or the like. Mitsubishi Electric has been working on a highly efficient error correction circuit of a moderate size [(8)].

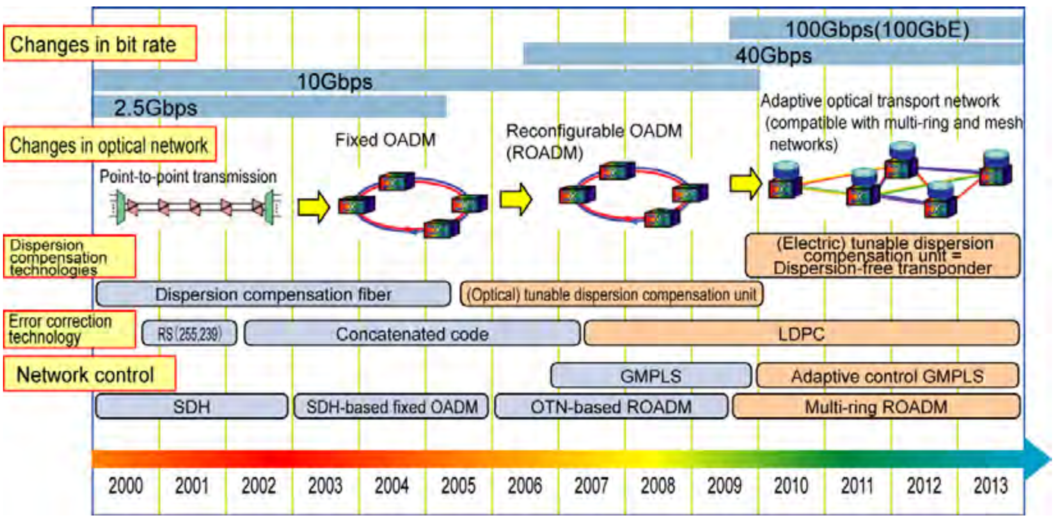


Fig. 2 Changes in Optical Metro/Core Network Technologies

2.3 Future technologies for optical transmission and optical network

Optical communications have provided communication services with information carried by optical on and off signals. Today a new technology that can make optical phases and frequencies carry information by using vector modulation such as phase modulation and optical delay detection technologies is being developed for practical applications with enhanced transmission characteristics. Furthermore, with the LSI micromachining technologies developed, A/D and D/A converters for several tens of Gbps capacity have become practical realities. Consequently, many research institutions have started studies on dispersion equalization technologies based on optical phase modulation, multilevel modulation and demodulation, and electric processing by the combination of electric signal processing with those optical circuits. In the future, various types of modulation methods combining signal processing by electric circuits and optical technologies will be introduced and format conversion technologies for the different modulation methods will also be studied. When dispersion equalization is realized by an electrical scheme, the dispersion compensation fibers used in 10-Gbps WDM systems will be eliminated completely, thus probably reducing the cost remarkably.

Optical interfaces of 100-Gbps Ethernet signals, multiplexig with four parallel transmissions at 25 Gbps, are being examined by the IEEE. On the other hand, ITU is now discussing the method to transfer 100-Gbps Ethernet by the next generation optical transport network (OTN) frame. Expectations are high for interfaces of over 100-Gbps class; we predict that systems of such a class will be practically available in a few years. Development of optical transmission technologies that support such bit rates has also started by different sectors of the industries.

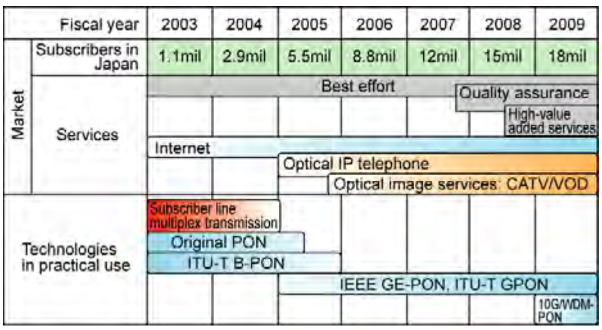


Fig. 3 Roadmap of optical access

3. Conclusion

We mainly discussed the recent trend of the technological developments associated with optical transport technologies above. An increase in the capacity of today's access network will lead to an increase in the demand for the metro and core networks in the future with much larger capacities required respectively.

Under the circumstances mentioned above, technologies of much higher levels are required for optical communications/optical transport technologies in the future. Mitsubishi Electric will continue research and development to develop new technologies that will contribute to the innovation of social infrastructure.

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Optical Access System for Next Generation Network

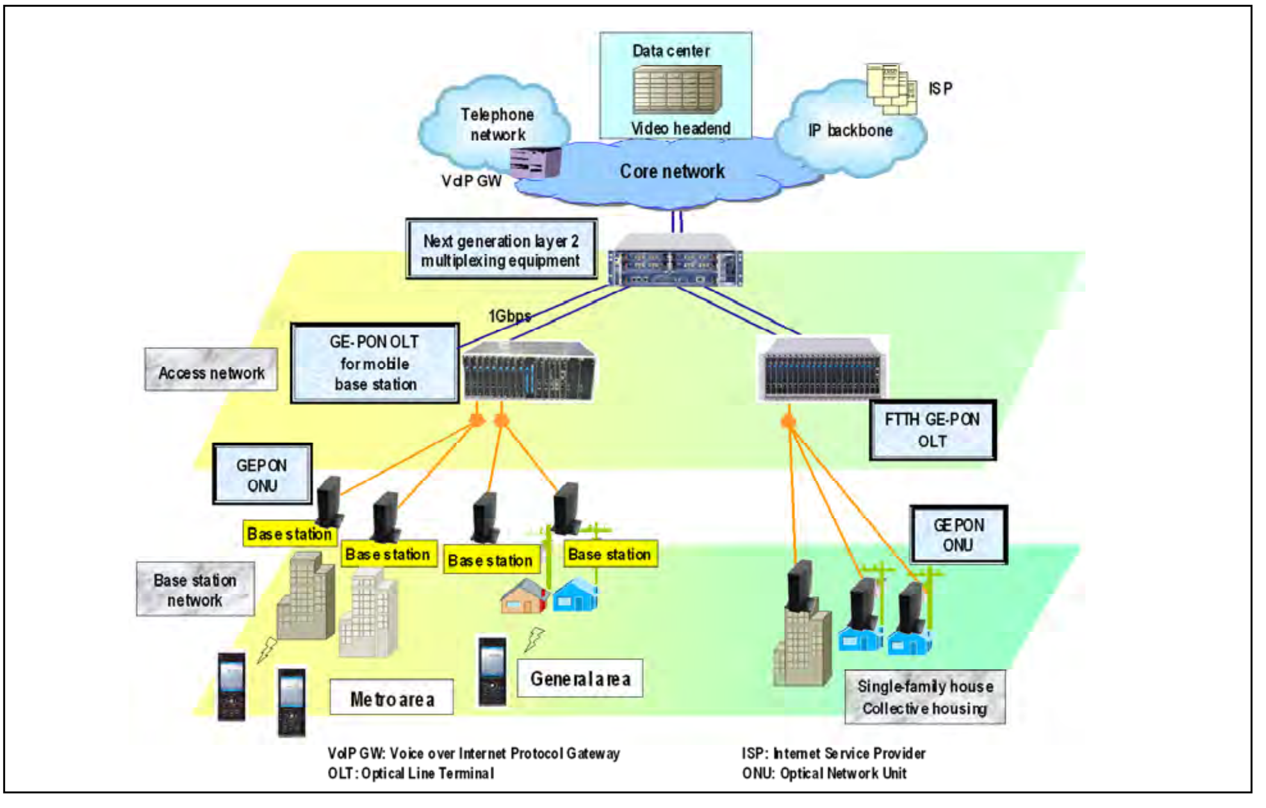
Authors: *Ken Murakami** and *Kazuumi Koguchi***

Abstract

Broadband services using optical access are steadily increasing in number. With optical access technologies advancing, the diversification of services, including fixed-mobile convergence (FMC) services, Internet Protocol (IP) retransmission of terrestrial digital broadcasting, and high definition visual contents transmission, as well as an increase in the traffic are expected.

Mitsubishi Electric has developed a gigabit Ethernet passive optical network (GE-PON) system for mobile communication base stations, which can be applied to the FMC services, as one of the efforts to support the next generation network scheme. This system aims at accommodating IP-based mobile base stations and features high reliability by employing a redundant access circuit and high efficiency by incorporating layer 2 switches.

In the next generation network, traffic with various types of communication quality demands becomes heavy in the access network as a result of an increase in traffic and diversified services. Mitsubishi Electric has developed the next generation layer 2 multiplexing equipment that will be positioned at an edge of the access network and can secure the communication quality and high throughput by means of the traffic control provided at high processing speeds.



Optical Access System

The GE-PON system for mobile base stations features high efficiency with the redundant access circuit and layer 2 switches within the system. The next generation layer 2 multiplexing equipment can secure the communication quality and high throughput even at a traffic flow of several tens of thousands.

*Communication Networks Center **Information Technology R&D Center

1. Optical Access System (GE-PON) for Mobile Base Stations

1.1 Development of OLT to accommodate mobile base stations

Mitsubishi Electric has developed the GE-PON system for mobile base stations that accommodate mobile phone and personal handyphone system (PHS) base stations on the basis of the GE-PON system for FTTH, which Mitsubishi Electric previously developed, with an eye to FMC services in the next generation network.

Mobile phone and PHS base stations in the conventional arrangements were connected with the switching equipment via synchronous digital hierarchy (SDH) circuits or integrated services digital network (ISDN) circuits. Base stations, on the other hand, have been increasingly configured in accordance with the IP. Accommodating a number of IP-based base stations in the GE-PON system efficiently in a single optical fiber leads to an operation cost reduction.

Challenges we faced with the base station accommodation by the GE-PON system include the following:

(1) Clock information transmission between base stations and switching equipment
(2) Line concentration for the core side network
(3) Improved reliability

The respective solutions for the challenges above are described below.

1.1.1 Clock information transmission between base stations and switching equipment

As a solution, a digital clock supply (DCS) clock synchronized with the switching equipment clock frequency (master clock) from the core side network is given to optical line terminal (OLT), in which a clock receiver (CREC) board is installed to operate DCS synchronization. The CREC board distributes the clock to all of the PON interface boards, so that PON ports will be operated by the distributed clock. Furthermore, the optical network unit (ONU) extracts the clock from the PON port to distribute it to the base station, thus establishing clock synchronization between base stations and switching equipment.

1.1.2 Line concentration for the core side network

A PON interface board is equipped with one network node interface (NNI) port. With all NNI ports of PONs connected with the core side network, a lot of ports will be necessary on the core side equipment which will lead to an increase in hardware cost. To deal with the situation, the layer 2 switch (L2SW) is built in the OLT for line concentration. With eight PON ports concentrated to a single NNI port, the number of ports necessary in the core side equipment has been reduced by a factor of eight.

1.1.3 Improved reliability

Telephone services by mobile terminals are becoming a lifeline as mobile phones and PHS have prevailed in society. And the GE-PON system has been required to have high reliability.

(1) PON port redundancy

N+1 redundancy has been achieved with the PON port that accommodates base stations. A single PON interface board stands by as a backup system. In the event of failures with the PON interface board in operation, the PON port is switched to that on the backup PON interface board. With this method employed, the time required from the detection of failure to the switchover of the PON circuit is shorter than one second.

(2) L2SW board redundancy

The L2SW board accommodated in the OLT is duplexed. The live-or-dead status of the L2SW board is periodically monitored from the equipment control board of the OLT. In the event of failures with the L2SW board in operation, the remaining L2SW board will transmit traffic.

(3) CREC board redundancy

Clock information transmission between the base station and switching equipment is indispensable to maintain services; the CREC board that governs clock information transmission is duplexed. Under normal conditions, one of the clocks from the duplexed CREC boards is selected by the PON interface board. If disconnection of the selected clock is detected, the operation immediately takes in the remaining clock for hitless switchover

Table 1 shows the main specifications of the OLT that accommodates mobile base stations.

1.2 Development of ONU that accommodates mobile base stations

One base station is accommodated by the user network interface (UNI) port of 100 Mbps. As discussed in 1.1.1 above, the clock is extracted from the PON port and the clock is distributed to the base station by an installed clock port, for the clock information transmission between the base station and switching equipment.

Table 2 shows the main specifications of the ONU that accommodates mobile base stations.

Table 1 Main specification of OLT for mobile base station

Item		Specification
PON port		
	Number of ports	1 port/PON interface board Max. 8+1 (redundant) ports/OLT unit
	Number of ONU connected	32 ONUs/PON interface board
	Redundancy	N:1
	Encryption	AES128 CFB mode
NNI port		
	Number of ports	1 port/L2SW board Max. 2 ports/OLT unit
	Port type	100BASE-TX
	Redundancy	1+1
Clock port		
	Interface	64kHz+8kHz+0.4kHz AMI signal (DCS interface)
	Redundancy	1+1

Table 2 Main specification of ONU for mobile base station

Item		Specification
PON port		
	Number of ports	1 port
	Decryption	AES128 CFB mode
UNI port		
	Number of ports	3 ports
	Application	2 ports: for data (10/100BASE-TX) 1 port: for clock and control

2. Next Generation Layer 2 Multiplexing Equipment

The access circuits are provided with the systems discussed above. For effective relay of the traffic over these circuits, equipment must be provided at an edge of the access network for multiplexing and forwarding the traffic. Mitsubishi Electric is developing layer 2 multiplexing equipment that can be applied to the next generation network. This chapter discusses the elemental technologies such as high-reliability technology and traffic control technology.

(1) High-reliability technology

For management of operation and maintenance of the next generation network, the OAM function used in the conventional synchronous optical network SONET/SDH and ATM circuits is necessary. Furthermore, for providing services even in the event of failure, a protection switching function to duplex the circuit and operate switch-over in the event of failure is necessary.

A prototype was prepared for implementation and verification of the Ethernet OAM function and protection function standardized by the ITU-T. Figure 1 shows the appearance of the experimental equipment. The prototype is equipped with the continuity check function and alarm transfer function conforming to the ITU-T Y.1731 and 1:1 bidirectional protection switching function conforming to ITU-T G.8031. Normal function of this equipment has been verified.

(2) Traffic control technology

To assure the end-to-end quality of service (QoS) required of the next generation network, it is necessary to control the traffic for each user application program. The volume of traffic to be controlled will be remarkably increased than in the past due to increased interface speed and a great number of application programs. Required under the circumstances is a control function that can maintain QoS control and multiplexing operation against high-speed and various types of traffic input patterns. With the conventional QoS control algorithms such as weighted fair queuing (WFQ) and the like that have been used commonly, it was not possible to operate QoS control at a high speed for large volumes of traffic and to multiplex the traffic, since the control logics increased with increasing multiplexed traffic volume thus requiring a longer processing time.

In order to solve this problem, Mitsubishi Electric has proposed a method called Simplified WFQ as a multiplexing technology that can hold the performance unchanged regardless of the volume of multiplexed traffic [(1)]. This method can reduce the processing volume by employing approximation in the WFQ algorithm and the volume of computation does not depend on the volume of multiplexed traffic, thus allowing much faster processing compared to the conventional methods.

In addition, in order to transfer the application traffic with which real-time mode is required for video, audio and the like with minimum delays, Mitsubishi Electric has also proposed the modified Simplified WFQ method [(2)]. Figure 2 shows the configuration.

Figure 2 shows a method that assures total band used for low-delay applications and standard applications for users who use both the real-time applications handling voice or the like and delay-tolerant applications handling e-mail or file transfer operation. This method can support a large-scale system since the method can be improved by modifying the calculation method of the Simplified WFQ method and can process at high speeds.

Fig. 1 Prototype for Ethernet OAM/protection functions

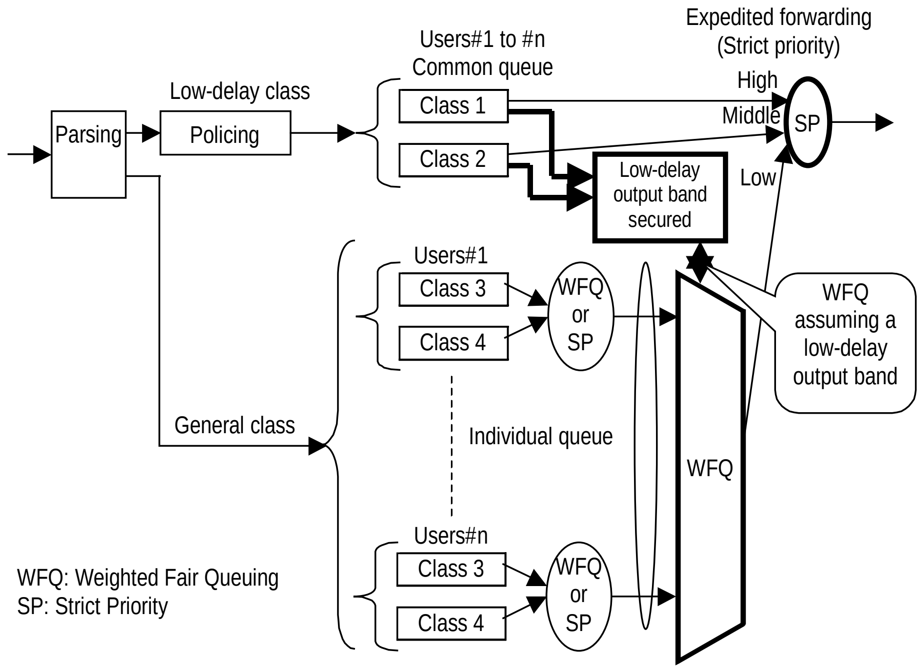


Fig. 2 QoS control mechanism for guaranteeing bandwidth per user

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Technologies for Next Generation Home Networking

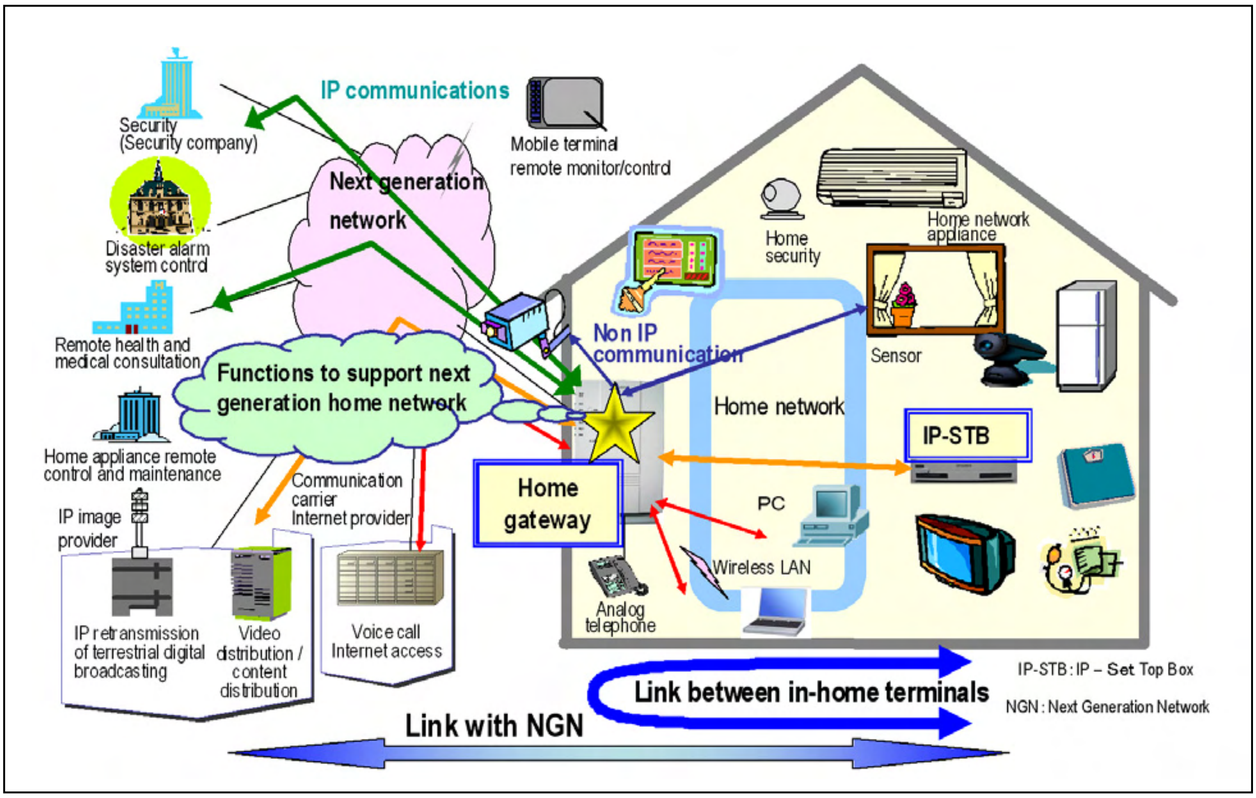
Authors: *Koji Sato** and *Tetsuya Yokotani**

Abstract

With the advancement of image and information system terminal devices, home networks have been increasingly constructed involving various types of home equipment so as to enhance the control of component devices and access to the content information. The linkage between types of terminal devices installed within homes in the future and also the linkage between the terminal devices and out-of-home networks are expected to be further increased. Under such circumstances, studies on the home networks that connect types of home equipment have been conducted intensively, along with the active discussions by ITU-T for the standardization of home networks.

As for the out-of-home carrier networks, technologies to support NGN are being increasingly proposed and developed. A new challenge for realizing the establishment of connection with NGN from in-home terminals has also been recognized.

Mitsubishi Electric has been conducting R&D activities aiming at constructing the next generation network centering on the home gateway. Mitsubishi Electric plans to realize the next generation home network through the implementation of the Open Service Gateway Initiative (OSGi) framework that enables interconnection of various types of terminals and the introduction of the SIP adaptation function that enables value-added services to be provided to users.



Technologies for Linkage between Terminals in the Next Generation Home Network and Linkage with NGN

Against the trends in the communication capability of various types of in-home terminal devices, such as NGN communication compatibility, NGN communication incompatibility, IP communication compatibility, and IP communication incompatibility, connections based on the home gateway scheme will make it possible to provide users with new services as the linkage between the terminals as well as the linkage between the terminals and NGN will be secured.

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1. Challenges to Next Generation Home Networking

This chapter discusses challenges based on the current technological circumstances and future trends with respect to linking various types of terminal devices as home equipment and linking the home terminal devices to out-of-home networks, to realize next generation home networking.

1.1 Diversification of home networking systems

Terminals installed in private residences are highly diverse and include PC systems, audio visual systems, telephone systems, in-home appliances, and sensor systems.

With PC systems, IP communications via wired LAN or wireless LAN communication interfaces are supported as standard specifications and communications of different types of protocols are available. With AV system devices of comparatively high processing capacity, IP communications is possible between AV devices or between AV devices and the PC terminal via wired LAN; these devices can be connected to each other in accordance with such standards as DLNA(1), etc. Telephones or TV phones that support Voice over IP (VoIP) are connected for communications based on such protocols as Session Initiation Protocol (SIP) and Real-Time Transport Protocol (RTP) via wired LAN interfaces.

On the other hand, in-home appliances, health and fitness devices, and sensors and cameras for home security applications are equipped with standard LAN communication interfaces or are designed to be connected through various types of external interfaces such as power line communication (PLC), special electric power saving communications, serial communications, USB-based connection, and contact input. They support ECHONET or other proprietary protocols for communication and control.

In order to link home terminals that employ different connection methods and/or protocols, it is effective to absorb the difference in connection specifications by means of home gateways.

A home gateway in which the connected terminals support IP communications is provided with an Ethernet interface using RJ45 connectors or a wireless LAN access point function such as IEEE802.11a/b/g. However, serial communication interfaces or USB interfaces are indispensable for connecting different types of in-home terminal devices. Ideally, general-purpose extended interfaces should be provided in preparation for PLC communication or electric power saving wireless communication including the growing ZigBee technology.

Communication between the various devices installed in a private residence is generally confined to within the type of communication field except for the link with PC systems. From now on, however, different combinations of these devices will have to be linked for new, higher value services.

The challenge in realizing such services is how to link devices that have different communication interfaces and/or protocols. The answer lies in developing flexible devices for which the interface and/or protocols can be expanded.

1.2 Conformance to Next Generation network

Out-of-home networks, on the other hand, are in transition from best-effort IP-based networks to NGN(2) that utilizes the same IP technology but also secures quality of service (QoS) and higher security levels. Communications via the NGN require communication paths using SIP. By exchanging the required protocol parameters with the NGN, appropriate QoS is secured and functions such as identity theft prevention can offer much higher security than that in the conventional scheme.

For the terminals connected to the home network for communication via the NGN, communication paths must be established according to SIP conforming to the NGN. However, it is extremely difficult at present, due to limited computing resources as well as cost, to implement NGN-compatible communication functions in all terminals.

These circumstances require a system that can link the NGN that is out-of-home and the NGN-compatible terminals connected to the home network; the terminals that support standard IP communication only; and the terminals that can be controlled or can perform communication by serial connection or USB connections, only without an IP communication function (see Fig. 1). Non NGN-compatible terminals, such as those that can perform standard IP communication only or that do not support IP communication at all, must either be provided with additional NGN-compatible functions inside or realize the NGN-compatible function outside the terminals.

As for the method for realizing NGN-compatible functions outside the terminals, conformance to NGN can be achieved, even with terminals that do not support IP communication. In addition, in the case of providing NGN-compatible functions outside the terminals, such functions should be mounted on the home gateway where the home network is connected to the NGN, or in other words, on the boundary between the home network and the NGN. Achieving this arrangement is a challenge to be overcome.

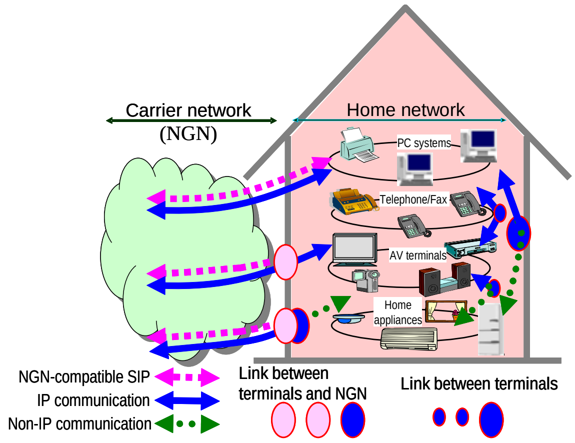

Fig. 1 Link between in-home terminals and between in-home terminals and out-of-home networks

2. Technologies to Support Next Generation Home Networking

Mitsubishi Electric is conducting research and development on the home gateway to meet the advances in terminals and out-of-home networks, including various connection methods for terminals and technological support for linking terminals, and compatibility with NGN communication. This section introduces solution technologies for the respective challenges.

2.1 Technologies for linking in-home terminals

To control terminals that do not support IP communication, such as home information appliances, many different protocols and control logic will be involved. A system that can add such functions as necessary will be indispensable for effective control of these devices. OSGi Framework[3] is a service platform that can run on Java virtual machines and multiple applications called bundles can be installed, started, stopped, or uninstalled as necessary. The OSGi Framework is essential for realizing flexible home gateways that support different types of protocols and control logic required for controlling home information appliances and for linking different types of terminals.

Mitsubishi Electric has made it possible to control and link different home information appliances by installing Java virtual machines and OSGi Framework in home gateways. The configuration of the arrangement allows terminals employing different communication programs to be connected via the home gateway and supports individual control logic by means of the bundle (see Fig. 2).

2.2 Technologies for linking in-home terminals and out-of-home networks

At the NGN Field Trial held by the NTT Group, Mitsubishi Electric proved that network communication is possible using a system with non NGN-compatible terminals via the NGN by implementing the above-mentioned NGN-compatible function (SIP adaptation function[4]) in the home gateway (see Fig. 3).

The SIP adaptation function is interlocked with the startup of TCP/IP communication (detection of TCP SYN packet) from existing non NGN-compatible systems or with the startup of UDP/IP communication (detection of the first UDP packet) and automatically activates the session establishment procedure in accordance with the NGN-compatible SIP. The gateways equipped with this function communicate with the net-side SIP server by using the required bandwidth information which is either permanently set or identified from the data of the existing IP communication for each transmission from the existing systems. As a result, not only can the existing systems be used as they are on the NGN, but the QoS guarantee function, which is one of the NGN features, can also be used from the existing systems (see Fig. 4).

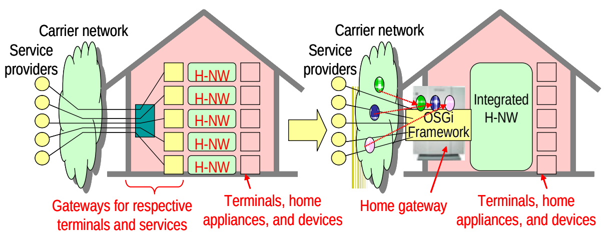

Fig. 2 Link between terminals via OSGi Framework

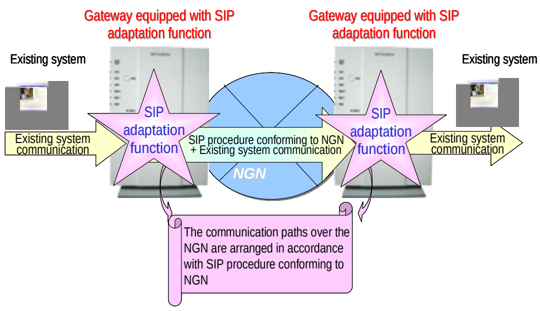

Fig. 3 Conformance to NGN by means of SIP adaptation

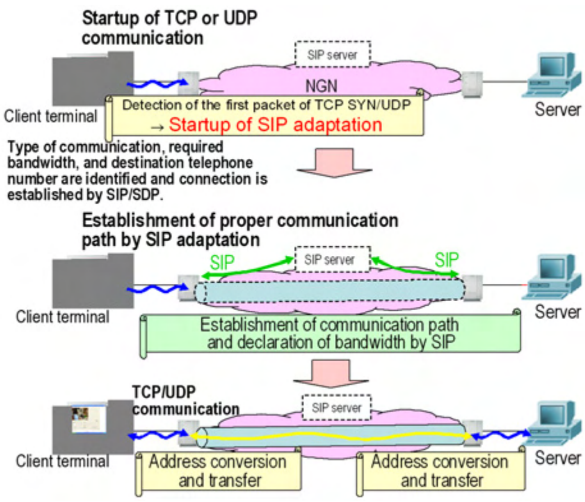

Fig. 4 Outline of SIP adaptation function

2.3 NGN Field Trial

The NGN Field Trial (called NGN-FT hereafter) was held by the NTT Group from the end of 2006 to the end of 2007, with the aim of verifying new technologies that support the NGN and new services over the NGN prior to commercialization, and also to clarify user needs.

Mitsubishi Electric connected the non NGN-compatible "DIGITAL MELOOK" that was designed to realize remote surveillance with high-definition digital images, to the NGN via a home gateway equipped with the SIP adaptation function, thus verifying the types of communication used within the system as shown in Table 1.

Table 1 Types of communications

Application	Sending device/receiving device	Protocol	Priority class	Required bandwidth
Camera image	Camera ⇒ Viewer/recorder	RTP/UDP/IP	High priority	About 4 Mbps
Video recording	Recorder ⇒ Viewer	RTP/UDP/IP	High priority	About 4 Mbps
Camera setup/control	Viewer ⇒ Camera	TCP/IP	Priority	Several Kbps
Video recording replay control	Viewer ⇒ Recorder	RTSP/TCP/IP	Priority	Several Kbps
Control between PCs	Viewer ⇒ Application proxy	TCP/IP	Priority	Several Kbps
Voice call	Analog telephone ⇒ Analog telephone	RTP/UDP/IP	Highest priority	144Kbps

At the NGN-FT, we confirmed that not only video distribution but also existing non NGN-compatible systems including certain types of TCP/IP-based control communications required by the systems can be operated with ease by using the SIP adaptation function. We also verified that video-based communication, compared to the previous service provided over the network on a best-effort basis, can provide video service of higher stability and definition by declaring the necessary video communication bandwidth to the NGN, which makes it possible to utilize the QoS guarantee function from the existing system.

Parts of the achievements discussed above were obtained through research sponsored by the Ministry of Internal Affairs and Communications "R&D on Technologies for Advanced Use of Networked Consumer Electronics." We thank all those concerned.

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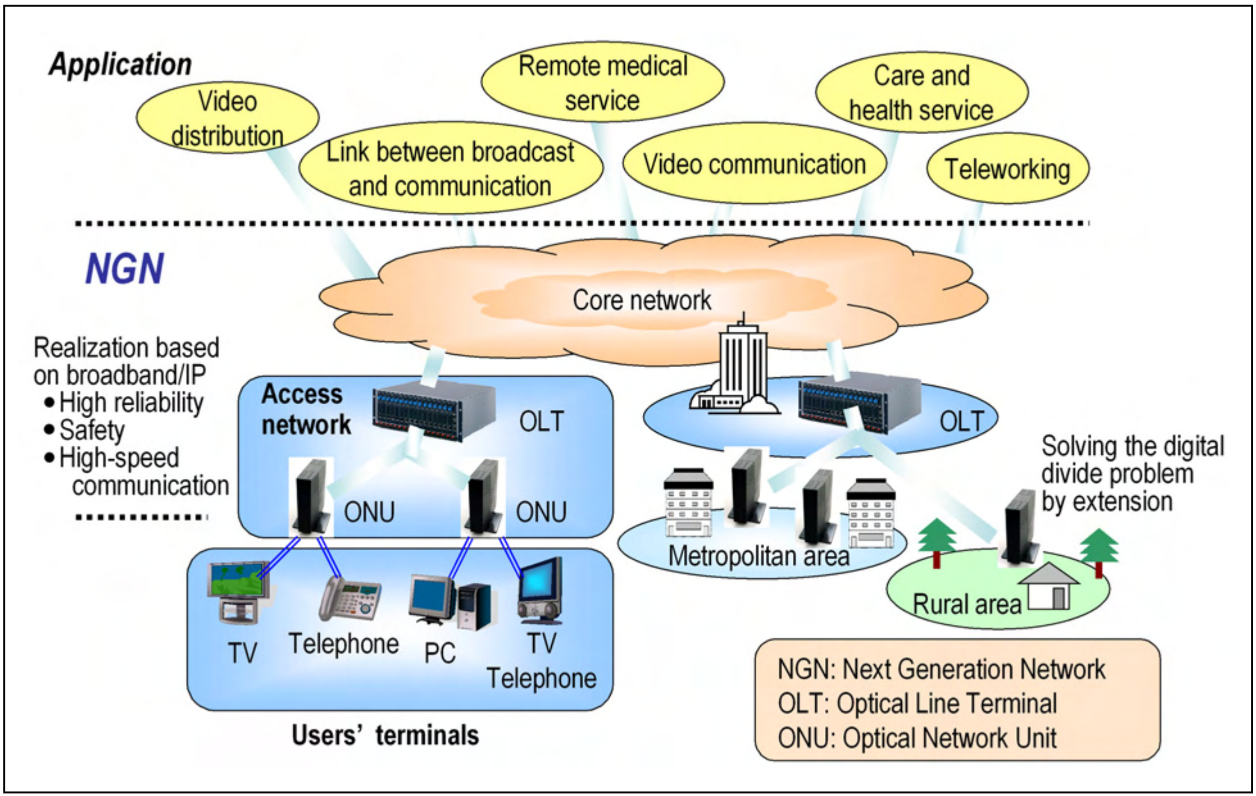
Technologies for Next Generation Optical Access Network

Authors: *Yoshifumi Hotta** and *Seiji Kozaki**

Abstract

Introduction of the GE-PON system has accelerated the use of FTTH in Japan, changing the access network from simply an Internet connection to a social infrastructure that provides services directly related to daily life, such as IP telephone service. Mitsubishi Electric has the largest share of the GE-PON market in Japan and is now working on the next generation GE-PON. The role of the NGN is becoming increasingly important as the communication network is expected to provide rich content such as real-time applications including video communications. Along with this trend, the next generation optical access system requires new features including (1) Links to service-related functions such as QoS for smooth use of different applications and bandwidth control function; (2) Link function for full IP communication and broadcasting that are highly compatible with the NGN; and (3) Measures to prevent the digital divide in local areas. This paper discusses these technological challenges, their solutions, and the technologies required for realizing coexistence with GE-PON for standardization toward second-generation FTTH currently under way.



Development efforts for Next Generation optical access system

As the GE-PON system is now widely used, the number of FTTH users in Japan is steadily increasing. In the near future, a high-grade QoS function will have to be installed in the access network with an eye toward the NGN. The optical network, which is already part of the social infrastructure, will have to incorporate measures against the digital divide by extending the service range.

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1. Evolution of Access Network

The Internet access environment has changed from dial-up connection (up to 128 kbps) to asymmetric digital subscriber line (ADSL, up to 50 Mbps), and further to fiber-to-the-home (FTTH, up to 1 Gbps), with transmission speed increasing in that order. First, the change from dial-up to ADSL increased the transmission speed by two orders of magnitude. At the same time, a flat-rate system was introduced for data communications. These improvements expanded the number of Internet users. However, the transmission speed was limited in proportion to the distance between the users and the central office (CO); different bandwidths were allocated even though all users paid the same charge. Meanwhile, since its introduction in 2004, FTTH via the Gigabit Ethernet Passive Optical Network (GE-PON) has steadily grown in Japan. The initial user interface speed was 100 Mbps, which is larger than that of ADSL by one order of magnitude, and service was provided equally regardless of the distance from the CO. In addition, the quality of IP telephone service reached almost the same level as that of conventional fixed-line telephone service, and video distribution service became available with the utilization of optical fiber broadband characteristics. Video distribution using a combination of communication and broadcasting is expected in the future.

In this way, the Internet connection environment has improved dramatically and the access network has advanced from a mere Internet connection to a communication network that can provide various applications such as telephone service and video contents distribution. Technological challenges in enhancing the functions of the access system include the following.

(1) Priority control compatible with real-time applications
(2) High-grade functions for IP broadcasting
(3) Extension of transmission distance

As the video distribution service improves and numerous services such as remote medical service, video-type communication, teleworking, and nursing and health care services are expected in the future, the access network will require better priority control over real-time applications and IP broadcasting service. The optical access network, which is now a key social infrastructure that is replacing the conventional telephone network, must be equipped with measures against the digital divide, such as the technology for extending the transmission distance.

2. High-Grade Functions for Optical Access Network

First, improvement of priority control is described below. As services diversify, the network will gradually conform to the next generation network (NGN) concept, and the system will require significantly enhanced QoS (quality of service). For example, simple two-class communication (i.e., IP telephone + data communication) will have to be upgraded to allow users to more fully enjoy the services by mapping versatile real-time applications to multiple delay classes or priority classes provided by the network.

On the other hand, as shown in Fig. 1, the GE-PON system uses time-division access control for upstream and broadcast access control for downstream, for which the logical link identifier (LLID) allocated to the optical network unit (ONU) is used as an identifier for access control. The optical line terminal (OLT) controls bandwidth allocation for each LLID to prevent the collision of upstream signals transmitted from the ONUs. The dynamic bandwidth allocation (DBA) algorithm, which determines the policy of bandwidth allocation for each ONU, is the heart of the system.

One of the most important technological challenges with the NGN is associating the transport technologies of Layer 2 such as GE-PON with the service stratum (service-related technologies), which is represented by a session initiation protocol (SIP) server. To apply GE-PON to NGN, as shown in Fig. 2, the grouping function for the resource assignment control protocol, a DBA function to allocate bandwidth in accordance with resource allocation instructions from the service stratum, and a mapping function that can flexibly map users' sessions to the LLID, are promising.

Next, the functions required for linking communication and broadcasting in an IP-based environment are discussed. There are two methods for video distribution: (1) Wavelength division multiplexing in which the modulated video signal wavelength is multiplexed to the communication wavelength; and (2) Distribution of video signal at the same wavelength as the communication wavelength, using IP multicasting technology.

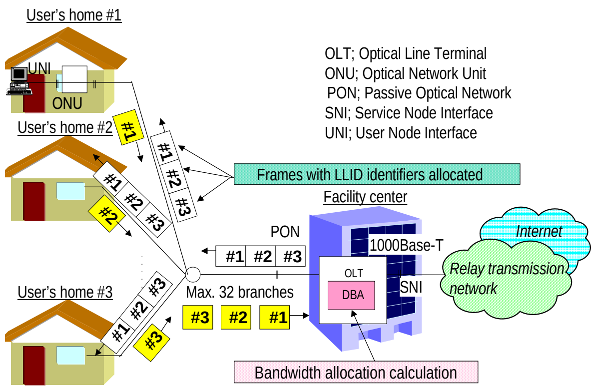

Fig. 1 GE-PON system

The former distributes broadcast waves by optical fiber and can efficiently provide a number of broadcast programs to the users' homes. The latter distributes IP-compatible video and is expected to provide diverse content in the future; it is considered a promising solution having high compatibility with the NGN, although related regulations are yet to be established.

When delivering broadcast programs via the communication network, it is necessary to distribute only those programs being viewed by the subscribers, using the minimum network resources so that the bandwidth in the downstream direction is not wasted. Furthermore, in consideration of the diversity of broadcasts and services in each region, the system should limit the distribution addresses to specific areas.

The challenges described above are resolved by the GE-PON system's applied Source-Specific Multicast (SSM) defined in Internet Group Management Protocol, Version 3 (IGMPv3) and Multicast Listener Discover, Version 2 (MLDv2). The system is highly broadcast-compatible since the PON has a star-shaped topology and uses the data broadcasting mode in the downstream direction, as shown in Fig. 1.

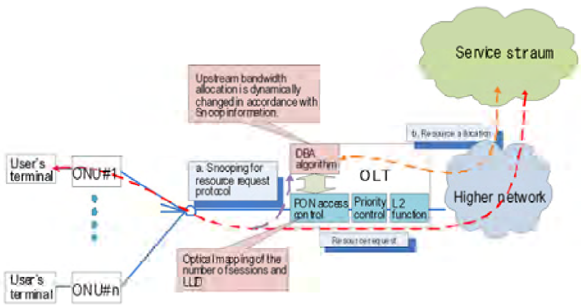

Fig. 2 Improved QoS function in GE-PON system

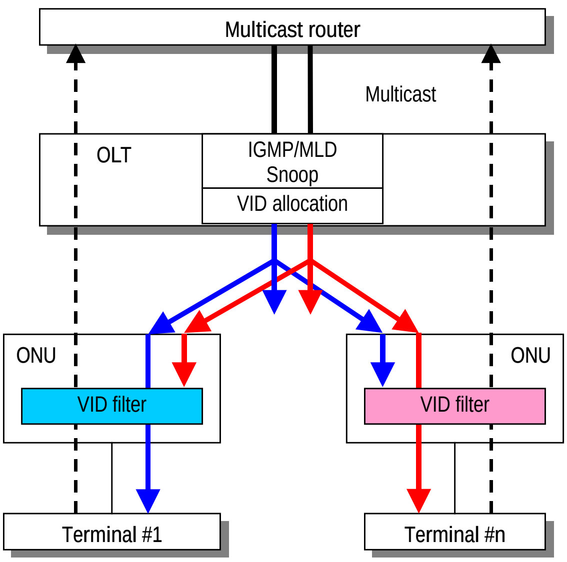

Fig. 3 GE-PON system to realize link between communication and broadcast

In practice, as shown in Fig. 3, IGMP/MLD Snooping is mounted in the OLT of the GE-PON, the Layer 3 parameters allocated for each program such as source and group IP address and the Layer 2 parameter Virtual LAN Identifier (VID) are linked, then VID filter configuration is made to forward the requested multicast from the OLT to the ONU. Furthermore, multicast is transmitted by broadcasting LLID in the optical distribution network for reception by all ONUs, so that a system can be established in which only ONUs permitted to forward can view the broadcast programs(1). This method achieves efficient multicast distribution. The main advantage is that since not only the destination IP address but also the source IP address is referenced for setting the identifier, the method can be applied to limited distribution-area services .

As the importance of ICT in daily life increases, measures against the digital divide are urgently required, meaning that identical services must be provided in both rural and metropolitan areas. There are three main methods of extending the transmission distance between OLT and ONU for the expansion of GE-PON service areas: (1) reducing the number of branches in PON; (2) using 3R repeaters; and (3) using optical amplifiers.

Table 1 and Fig. 4 compare the respective methods. Branch-number reduction allocates most of the GE-PON power budget to transmission loss by reducing the number of branches. If the number is reduced to around 4 branches, the transmission distance can be extended up to approximately 40 km. On the other hand, if the number of branches is required, extension of the transmission path by means of 3R repeaters or optical amplifiers is necessary, although the characteristic passivity of the PON transmission path will be lost. The 3R repeater method provides regenerative repeating signals along the extended transmission path. The optical amplifier method also extends the transmission distance by amplifying attenuated signals along the transmission path.

Table 1 Comparison between extension methods

	Branch number reduction method	3R repeater method	Optical amplifier method
Passivity of transmission path	Good	Not good	Not good
Transmission distance	~40km	~50km	~50km
Impact to existing equipment	Very high	Medium	Medium

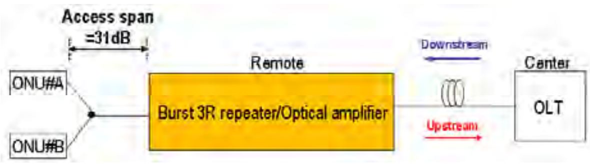

Fig. 4 Extension of transmission path


Fig. 5 Coexistence of 10G-EPON and GE-PON

3. Optical Access System in Future

Along with the increased popularity of FTTH, traffic levels have also been rapidly increasing. The speed of FTTH as an access network supporting various services must be increased. Studies on 10-gigabit-class access system have also been conducted[2]. The 10G-EPON standardized by the IEEE 802.3av Task Force is a promising candidate for the next generation optical access system. The scope of standardization is focused on the physical layer. For higher layers, existing standards will be applied, such as the 10 Gigabit Ethernet (10GbE) standardized in IEEE 802.3ae and the Multipoint Control Protocol (MPCP) standardized in IEEE 802.3. Taking into consideration the recent FTTH circumstances in Japan, coexistence with the GE-PON will be examined. The solution may employ time-division multiplexing for upstream and wavelength multiplexing for downstream, as shown in Fig. 5.

Other issues must be resolved before constructing the final system. In particular, continuous development is required for the encryption method between OLT and ONU, bandwidth allocation control for the upstream direction, and QoS control, which are key technologies for realizing the 10G-EPON system.

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Optical Network Systems for Overseas Market

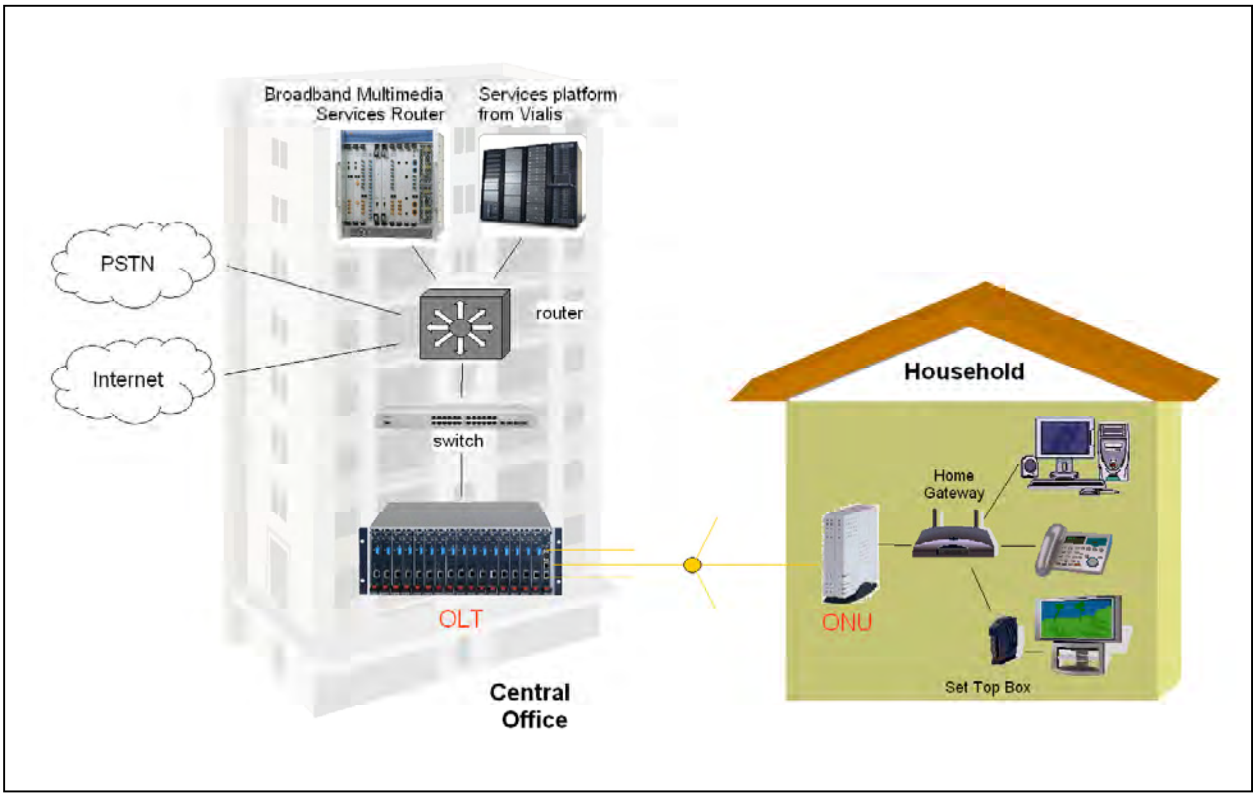
Authors: *Toshimichi Kida** and *Sophie Pautonnier***

Abstract

In Japan, the number of subscribers to fiber-to-the-home (FTTH) service providing the triple play package of high-speed Internet, telephone, and video distribution has been increasing rapidly. In Europe, however, the mainstream service is still asymmetric digital subscriber line (ADSL), which uses copper wire.

Slowly but steadily, however, introduction of FTTH is gaining ground as governments recognize its importance in IT advancement and economic and social development on both the national and local level. Through the initiative of local governments, major carriers are developing FTTH. In addition to the business plans of major carriers, comparatively small-scaled FTTH introduction projects under the initiative of local governments have been increasingly implemented.

Mitsubishi Electric has conducted trial operations in cooperation with foreign carriers for overseas deployment of FTTH systems using Japan's mainstream Gigabit Ethernet-Passive Optical Network (GE-PON) technology. In January 2007, Mitsubishi Electric launched an FTTH pilot project in cooperation with a local network operator in Colmar in the Alsace region of northeast France.



Configuration of pilot network

The network is a GE-PON configuration that is the mainstream in domestic FTTH systems in Japan, with the OLTs and ONUs provided by Mitsubishi Electric. Home gateways are connected downstream from the ONUs, making it possible to provide triple play services including video, voice, and data transmission.

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1. Trend in the FTTH Market in Europe

1.1 Introduction of FTTH and market trend

In Europe, ADSL service has expanded rapidly since about 2003 to record about 60 million subscribers by the end of 2006. On the other hand, FTTH was introduced to North European countries around 2004 and the number of subscribers today is only about 1.1 million in all of Europe.

As the upstream transmission bandwidth in ADSL depends on the quality of the existing local loop network or the distance between the central office and subscriber, studies are presently focused on "FTTx", which can realize super-broadband service by combining optical fiber and VDSL technologies. At the same time, communication policies in conjunction with unbundling of optical fiber cables are also being studied[2]. This issue in particular is one of the challenges affecting the development of FTTH networks.

FTTH is thus in the initial stage compared with ADSL, but is considered to be the driving force behind economic and social growth in local towns and cities. Not only communications carriers but also national and local governments are deeply interested and engaged in efforts to promote FTTH. As of the end of 2006, more than 80% of the FTTH projects in Europe were initiated by local authorities, power utilities and housing corporations. Future deployment of FTTH may involve the following two business models.

- <u>Vertically integrated business model</u>

Major communications carriers or newly organized operators will invest in the network hardware including optical fiber cables and will also be responsible for providing broadband services to users.

- <u>Horizontally shared business model</u>

Local governments or local public power utilities will invest in the optical fiber arrangement as representative organizers of the respective local communities; the access network operators will make the network available to ISPs that will provide services via the optical fiber cables. Thus, multiple business entities will share the operation of network business. The access network operators will not have direct contact with the end users. The ISPs will be responsible for collecting all necessary service charges and other fees. This scheme is still under consideration.

As of the end of 2006, 95% of all FTTH service subscribers in Europe were limited to five countries: Denmark, Sweden, Norway, the Netherlands, and Italy. Excluding these countries, the most aggressive country in Europe in terms of positive endeavors to deploy FTTH in and after 2006 was France. Activities based on the two business models described above have been actively promoted in France since mid 2006. France Telecom and newly organized operators intend to start services in Paris and other major cities in France and pilot systems initiated by local governments have already been launched in many of the nation's cities. Full-fledged commercial services will likely start in the latter half of 2008, with successful deployment expected.

1.2 Current FTTH technologies in Europe

The majority of FTTH systems in Europe today employ a point-to-point transmission system (referred to as "P-P" hereinafter). The situation appears to be the same as that when FTTH was introduced in Japan and P-P transmission was generally used. Now, however, the advantages of PON-based systems will likely result in its intensive utilization toward full-fledged deployment of FTTH.

IEEE-conforming GE-PON (generally referred to as E-PON in Europe) rapidly introduced for commercial applications in Japan and other Asian nations, and ITU-T-conforming G-PON are the base technologies expected to be used for PON systems in Europe, as of the middle of 2007. Related movements include plans for substantial application of G-PON according to the demand for FTTH in the latter half of 2008 and earlier plans to try PON systems by incorporating GE-PON in FTTH systems initiated by local governments, etc.

2. Outline of Pilot FTTH System

In January 2007, Mitsubishi Electric launched a pilot FTTH project using GE-PON in cooperation with Vialis, a local network operator in Colmar in the Alsace region of northeast France.

Vialis is a conglomerate of companies running public power and gas utilities, CATV service, and Internet service in many cities in the Alsace region, centering on Colmar, which provides financing for the company.

In this pilot project, Mitsubishi Electric provided the GE-PON system (OLT, ONU, EMS (element management system), etc.) as well as technical support, while Vialis installed the optical fiber cables and hardware, operated the network, and evaluated the FTTH service. During the pilot project period, FTTH service was provided to a selection of subscribers who had expressed their wish to help evaluate the service. The service and hardware arrangements were improved step by step during the pilot project period. In parallel with the pilot FTTH project, another project was implemented to study the feasibility of new broadband services. This second project involved the evaluation of FTTH network characteristics and QoS (Quality of Service) management technologies, in cooperation with network research development at the Institute of Technology of the University of Haute Alsace in Colmar (IUT-UHA).

2.1 Configuration of pilot FTTH system

The configuration presented in the "Abstract" describes the pilot FTTH system in Colmar including the access network for providing triple play services for household subscribers in the first phase and the operator-side network.

In the first phase, lead-in optical fiber cables from nearby trunk cable cabinets were installed in three apartment buildings, with optical splitters furnished in the machine rooms of each building. A total of 50 residences were provided with optical fiber cables as a result of work conducted in the buildings. Each residence was then provided with an optical network unit (ONU) as the GE-PON termination device in the subscriber household, an IP telephone adapter, and set top box (STB) for receiving video services. The same set of hardware was installed on the premises of UHA for evaluating the services and functions and studying new services. Figure 1 shows a photo of the optical splitter installed in the machine room of the apartment building.

The GE-PON optical line terminal (OLT) was installed in the central office of the network operator and was connected with the service platform and broadband multi-service router for video delivery to the operator via the Layer 3 (L3) switch and router. The OLT was also connected with the external Internet network and telephone network of the carrier (PSTN).

2.2 Multi-channel delivery

In April 2007, 18-channel video delivery was launched via the operator's broadband multimedia service router (BMR) using the video IP packet multicast flow method. With this configuration, users can switch channels instantly from their residence.

Two methods are available for the video delivery service: one is a simplified method in which users install video viewing software in their PCs in accordance with their video system configuration, and the other is an STB method in which users view videos on a standard TV set connected with STBs. The project also evaluates the simple multicast method in which all channels selected by the users are delivered to all users, and the IGMP multicast method that uses an Internet Group Management Protocol (IGMP) proxy and snooping function. Control of the latter prevents the videos on the channels selected by other users from being delivered to the ONUs of other users. This technology is expected to realize efficient use of transmission bandwidth in multi-channel video transmission service.

2.3 Results of pilot project first-phase evaluation

Vialis took charge of installation and operation of the PON system for the first time in this pilot project. Their optical fiber work, continuity inspection of optical signals, and operation of hardware were all completed smoothly, which has assured us that the GE-PON system operated in Japan is highly compatible with the deployment environment and it interfaces with the peripheral devices available in the European market

Initial system operation used a basic network configuration without VLAN management technology. Today, however, after verifying the basic operation mode, the VLAN management system, which has a QoS control function called "ToS-CoS," is employed for the operation. With this function, the Type of Service (ToS) field in the IP frame is converted to Class of Service (CoS) in the Ethernet frame to realize QoS control, thus providing high-grade triple play service.

According to the results of evaluation by the monitoring subscribers in the first phase of the project, which centered on provision of service for residential areas, the service was highly valued by more than 95% of the

Fig. 1 Optical splitter located in the apartment basement

Fig. 2 GE-PON located in the central office

subscribers, except for several subscribers who viewed video programs via PCs with insufficient capacity. In particular, the quick response of Web browsers and excellent broadband characteristics for uploading were favorably accepted by the users.

As for multi-channel video receiving, the project has proved that the IGMP multicast method is a very important function for both the video distribution service and large-volume data transmission.

The monitoring subscribers have requested improved security such as firewalls and anti-virus measures. They are also interested in the provision of a fixed IP address and expansion of home network including wireless interfaces in their residences. These points are challenges to be studied in terms of services to be provided in the future.

2.4 Major specifications

Tables 1 and 2 show the major specifications of the GE-PON system used in the pilot project.

2.5 Future plans

As the second phase of the pilot FTTH project in Colmar, we plan to deploy PON-based fiber-to-the-business (FTTB) by connecting the system with business-use systems called SME (small and medium enterprises). Mitsubishi Electric will conduct continuous verification and evaluation of the project system in cooperation with Vialis.

References:

(1) Roland Montagne, IDATE: FTTx deployments – Key issues, DigiWorld Summit 2006

(2) ARCEP: Le Très Haut Débit – Points de repères et perspectives – November 10th, 2006

Table 1 Major specifications of GE-PON OLT

Item		Specification
PON interface	Applicable standards	Conforming to IEEE802.3ah
		1000BASE-PX20
	Number of ONUs	32/PON-IF
	Network interface	100/1000BASE-T
	Number per unit	16
Element management interface	Applicable standards	10/100BASE-TX
	Protocols	SNMP, TELNET, FTP
Functions		ONU authentication , DBA , encryption , VLAN , loopback , IGMP , and snooping
Other specifications	Power source conditions	DC-48V (redundant configuration)
	Cooling method	Forced air-cooling (redundant fan)
	Installation style	Mounted on 19-inch rack
	Dimensions	177H x 437W x 492D (mm)

Table 2 Major specifications of GE-PON ONU

Item		Specification
PON interface	Applicable standards	Conforming to IEEE802.3ah 1000BASE-PX10 or 1000BASE-PX20
UNI	Applicable standards	10/100BASE-TX or 10/100/1000BASE-T
Functions		Bridge , priority control , loopback
Other specifications	Power source conditions	AC100V~220V (AC adapter)
	Cooling method	Natural air-cooling
	Installation style	Horizontally placed / hung on wall
	Dimensions	150Hx 39.5W x 135D (mm)

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