WDM for Next Generation Network

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Abstract

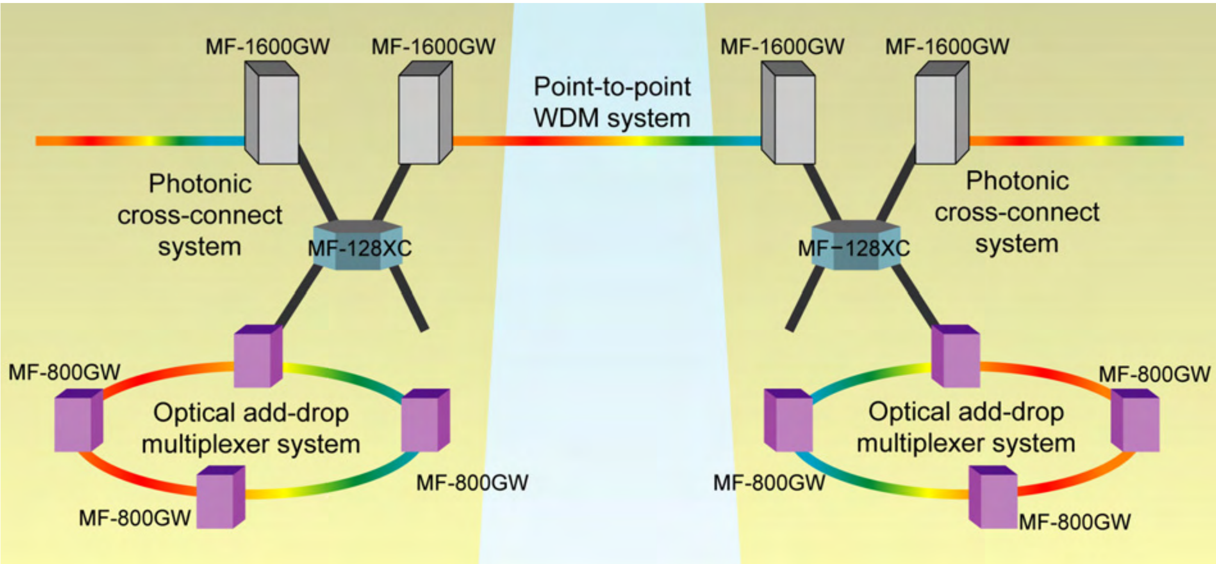
The transport layer that governs NGN data transfer as defined in ITU-T Recommendation Y.2011, "General Principles and General Reference Model for NGNs," requires not only point-to-point arrangement, but also mesh-type connections between cities and multiple metro-ring network connections within each 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.

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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

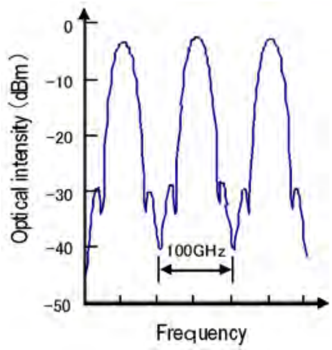

Fig. 2 40-Gbps signal spectrum of CSRZ-DQPSK system

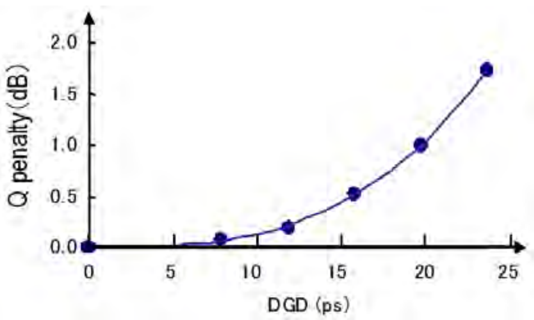

Fig. 3 PMD resistance

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.

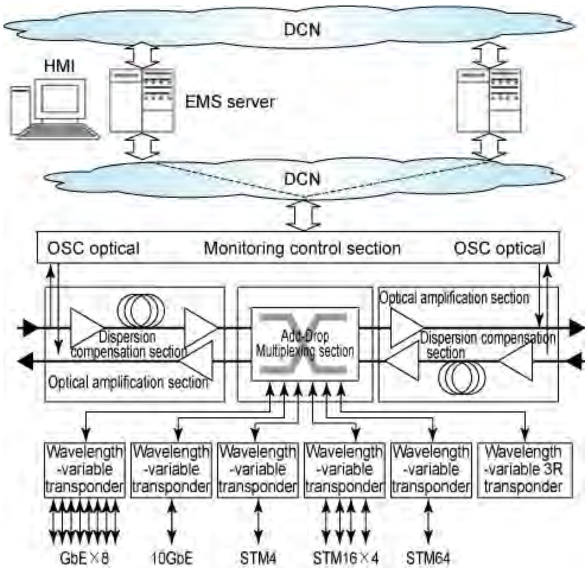

Fig. 5 MF-800GW system configuration

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.

Fig. 6 Appearance of MF-128XC

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.

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

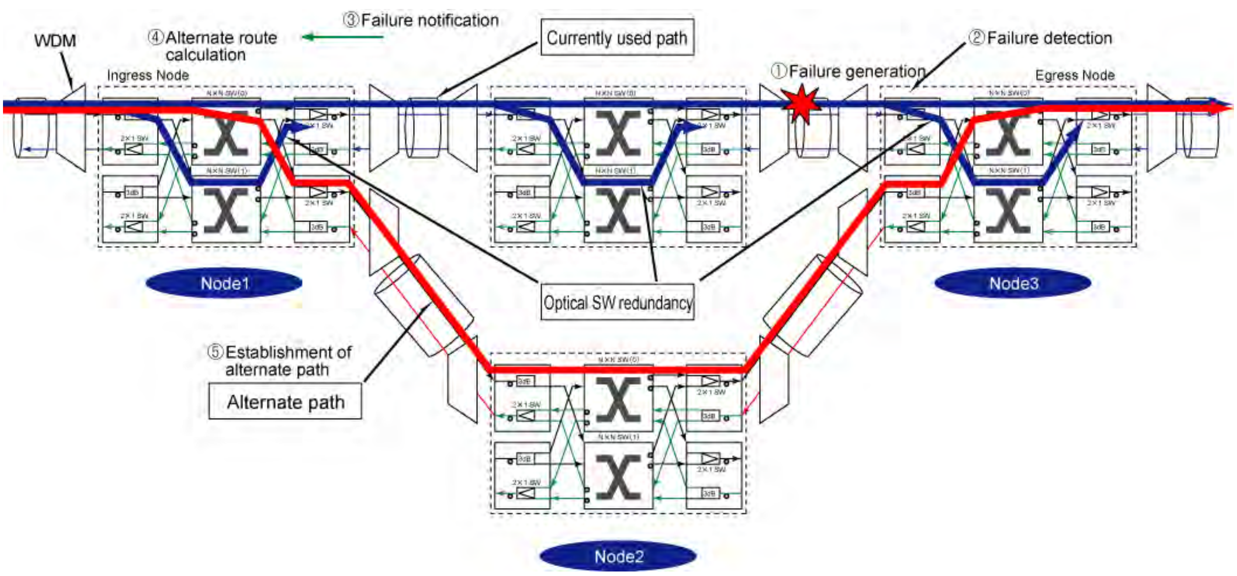

Fig. 7 Node configuration for full LSP rerouting with MF-128XC