International Standardization Activities on Optical Interfaces

Masahito Tomizawa†, Akira Hirano, Shigeki Ishibashi, and Takeshi Sakamoto

Abstract

This article reviews international standardization activities on optical interfaces over the last four years. Standardization is the key to the cost-effective manufacture, purchase, and installation of large-capacity high-speed optical network elements. This article mainly focuses on the activities related to wavelength division multiplexing (WDM) interfaces in ITU-T (International Telecommunication Union-Telecommunication sector) and also mentions very short reach (VSR) interfaces in OIF (Optical Internetworking Forum) and ITU-T.

1. Introduction

Optical interface technology is one of the main R&D topics for telecommunication networks. The advances that have been made—very rapid increases in transmission capacity and bit-rate—have resulted from using wavelength division multiplexing (WDM) and ultra-fast time division multiplexing (TDM). To manufacture, purchase, and install large-capacity and high-speed network elements (NEs) in a cost-effective manner, standardization of the optical interfaces is the key issue because more products are being shipped from fewer product-lines. Standardization is very important for network operators too because compatibility and connectivity between products from different manufacturers are indispensable for network planning and design.

Several organizations are involved with the standardization of optical interface technology, such as ITU-T (International Telecommunication Union-Telecommunication), OIF (Optical Internetworking Forum), IEEE (Institute of Electrical and Electronics Engineers), and IEC (International Electrotechnical Commission). ITU-T SG15 (Study Group 15) is the lead study group for optical transport network and access technologies. It has an expert group (called "Question") for optical interface specifications (mainly of long-haul optical interfaces so far) for carriers' networks. OIF has an expert group (called "Working Group") for the physical link layer. It is studying intra-office optical interfaces between routers and transmission NEs. IEEE focuses on optical Ethernet applications, such as Gigabit Ethernet (GbE) and 10 Gigabit-Ethernet (10GE). IEC TC76 (Technical Committee 76) is responsible for general requirements on optical safety aspects. IEC TC86 defines terms and measurement methods for optical components and sub-systems. This article focuses on the activities of ITU-T and OIF.

2. Standardization activities on WDM interfaces

ITU-T, an authorized organization established by the United Nations, is playing the most important role in WDM interface standardization.

2.1 Classification of wavelength bands and definition of WDM categories

In response to the demand to use optical amplification in bands other than the 1550-nm band, ITU-T has classified several new wavelength bands for telecommunication usage in Sup.dsn [1]. They are the O-band (original band with a wavelength range from 1260 to 1360 nm), the E-band (extended band: 1360

† NTT Network Innovation Laboratories
Yokosuka-shi, 239-0847 Japan
E-mail: tomizawa@MIT.EDU

to 1460 nm), the S-band (short wavelength band: 1460 to 1530 nm), the C-band (conventional band: 1530 to 1565 nm), the L-band (long wavelength band: 1565 to 1625 nm), and the U-band (ultra-long wavelength band: 1625 to 1675 nm).

ITU-T has also defined, in G.671 [2], WDM categories according to the frequency/wavelength spacing of the channels multiplexed onto a single optical fiber: WWDM (Wide WDM) has a channel spacing larger than 50 nm, CWDM (Coarse WDM) smaller than 50 nm and larger than 1000 GHz, and DWDM (Dense WDM) smaller than 1000 GHz.

2.2 Two types of compatibility on optical interfaces

ITU-T has specified two types of compatibility in terms of optical interfaces (Fig. 1). The first is called "transverse compatibility", which is defined as multivendor interoperability along the optical fiber. Compatible interfaces of this type allow a transmitter from one manufacturer to communicate with a receiver from another manufacturer. To get this compatibility, we need to specify a full set of optical parameters, such as output power, channel central frequency, central frequency deviation, line-coding of each channel, maximum attenuation of the fiber, chromatic dispersion, maximum bit error ratio, and optical path penalty. The second type of compatibility is called "longitudinal compatibility", where the manufacturers produce transmitter and receiver sets that offer identical transmission distances. The benefit of longitudinal compatibility is that the network operator can design NE locations (buildings) without being locked into one manufacturer. Longitudinal compatibility does not demand a full set of specifications, only maximum values of attenuation, chromatic dispersion, and frequency/wavelength "grid" (described below).

2.3 Frequency/wavelength grid

Longitudinal compatibility was the first step to DWDM interface standardization, partly because the world market for DWDM grew very rapidly before ITU-T could specify a full set of parameters for transverse compatibility. The main discussion point was the specification of the frequency grid [3]. The frequency grid is a set of candidates for channel frequencies. Which frequencies are used is up to the operator or manufacturer; however, they should be selected from the frequency candidates on the "ITU grid". This specification drastically reduced the possible number of laser frequencies to a finite number and contributed to the cost reduction of laser/filter products. The DWDM frequency grid is specified with reference to its anchor frequency of 193.1 THz (basically the center of optical amplifier bandwidth) according to proposals from NTT and other organizations. Channel spacing is specified as 200, 100, 50, 25, and 12.5 GHz, in ITU-T Recommendation G.694.1 [4].

On the other hand, CWDM for metropolitan or access networks is a recent hot topic in standardization. ITU-T also specifies (in G.694.2) that the CWDM wavelength grid has 20-nm spacing, such as 1290, 1310, 1550, 1570 nm, and so on [5]. The ration-

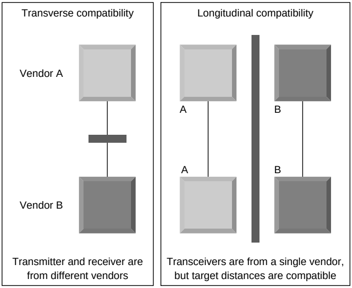


Fig. 1. Two types of compatibility.

ale for the 20-nm spacing is cost-effectiveness using uncooled lasers: operators' buildings can experience temperatures ranging from 0 to 50 ºC.

2.4 Transverse compatible WDM interfaces

Transverse compatible interfaces are also specified in ITU-T because they are very important for network operators. Transverse compatible WDM interface specifications assume that the system configuration is simple, such as point-to-point without in-line amplifiers.

2.4.1 DWDM

The DWDM transverse compatible specifications in G.959.1 assume a short-haul (40 km), point-to-point configuration without in-line amplifiers and 16 channels with a channel spacing of 200 GHz [6]. The interfaces are called IrDI (Inter Domain Interface) because a multi-vendor configuration using DWDM is required at inter-carrier interface points, or at the points between single-vendor-subnetworks: note that ITU-T uses the general word "administrative domain". The important agreement on 16-channel frequency assignment was achieved through discussions involving Japanese manufacturers (Fujitsu, NEC, Hitachi, and Oki) and NTT proposals. The agreed frequency assignment is 192.1+ 0.2 m (THz), where m is an integer from 0 to 15. A full set of optical parameters is specified for each application, and it should be noted that some parameter sets are identical regardless of fiber types: SMF (Single Mode Fiber) is covered by G.652, DSF (Dispersion Shifted Fiber) by G.653, and NZDSF (Non-Zero Dispersion Shifted Fiber) by G.655, based on NTT's proposal. At present, G.959.1 is under new revision, where the main topic is the transverse compatible interface for 40 Gbit/s. Standardization of the 40-Gbit/s optical interface was originally proposed by NTT and by Deutsche Telekom, as a bit-rate class for the optical channel in optical transport networks. The current revision focuses on a single channel 40-Gbit/s interface, for which the new line-coding of RZ (Return-to-Zero) is being considered.

2.4.2 CWDM

In metropolitan and access networks, transverse compatibility is indispensable for improving system cost-effectiveness, because system installation, repair, and replacement is very frequent. ITU-T Recommendation G.695 for CWDM point-to-point application is now being drafted under NTT's editorship [7]. A recent key agreement was the "colored interface" option, where tributary "colored" optical signals, from a router or switch etc., are directly multiplexed into the fiber. This option is attractive because it can reduce costs by reducing the number of expensive 3R (regeneration, reshaping, and re-timing) functions. It was agreed to study two "colored" interface configurations, as shown in Figs. 2(a) and (b). In Fig. 2, Tx is the transmitter, Rx is the receiver, OM is an optical multiplexer, and OD is an optical demultiplexer. Figure 2(a) shows the ideal and final goal configuration of the fully transverse compatible colored interface, where each device (transmitter, multiplexer, demultiplexer, or receiver) can be from a different manufacturer: *e.g.*, vendors A to D. It is necessary to specify the power levels of the transmitter output, multiplexer output, demultiplexer input, and receiver input. Figure 2(b) is an intermediate but pragmatic solution-the partly transverse compatible colored interface-where multiplexer and demultiplexer sets are from different manufacturers. In the configuration of Fig. 2(b), it is not necessary to specify the power levels of multiplexer output and demultiplexer input, only the necessary power difference between the two points, *e.g.*, the loss budget of the fiber. From the maximum attenuation from transmitter to receiver and from the loss budget of the fiber, we can derive the total loss of the multiplexer and demultiplexer. Within the total loss value, the loss design of the multiplexer and demultiplexer is up to

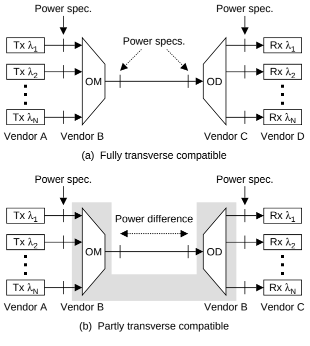


Fig. 2. Two types of "colored" interface configuration.

the manufacturer. Note that the "colored" interface study has been initiated only for DWDM metropolitan and access applications.

2.5 Safety aspect of high-power optical systems

Since WDM combines several optical channels into a single fiber, it increases the total optical power in the fiber. Moreover, a recent technical trend is to support distributed Raman amplification. The technology is fascinating because it offers very wide-band optical amplification and improved signal-to-noise ratio; the installed fiber is used as an amplification medium. Given that Raman amplification generally requires extremely high pump-powers, from several hundred milliwatts to several watts, safety is a significant issue. When using such extreme pump-power, we need safety solutions not only in terms of conventional "eye-hazard" but also in terms of the relatively new "fire-hazard". The latter represents a temperature increase at a loss point along the transmission line. ITU-T agreed to study how to assure safety against these hazards, and also agreed on an optical shutdown mechanism for distributed Raman amplification, in G.664 (consented in January 2003) based on NTT's proposal [8]. IEC TC76 is responsible for laser safety and agreed on the general text and requirements for the "fire-hazard" according to the Japanese proposal. One member from NTT is the liaison officer between ITU-T SG15 and IEC TC76 and coordinates the joint correspondence between the two standardization organizations.

3. Standardization activities on VSR interfaces

The intra-office optical interface is called VSR (Very Short Reach), and it is important for router-to-WDM and router-to-router connections based on data-center business. VSR interfaces are specified in two organizations: ITU-T and OIF. ITU-T focuses on serial transmission over single-mode fibers, while OIF pays attention to parallel interfaces and also to serial interfaces on multi-mode fibers.

3.1 VSR in OIF

OIF specifies five types of VSR interfaces for 10 Gbit/s (called VSR4) [9]-[13]: 12 paralleled 1.24G, 4 paralleled 2.5G, serial on multi-mode fibers, and two serial interfaces on single-mode fibers. OIF also specifies three types of 40-Gbit/s VSR (called VSR5) [14]: 12 paralleled 3.3G, 4 channels CWDM of 10 Gbit/s/ch, and a serial interface on single-mode fibers. Reference configurations of VSR include the application where a photonic cross connect is inserted in the VSR link, so the loss budget is more than 11 dB in some specifications. There are several options for the VSR target distance: 50, 100, 300, and 600 m.

3.2 VSR in ITU-T

ITU-T is focusing on serial transmission over single-mode fibers up to 2 km in G.693 [15]. ITU-T and OIF have an official liaison relationship for exchanging information and discovering mutual gaps/overlaps. The serial interfaces on single-mode fiber in OIF mentioned above are identical with those in ITU-T, because OIF copied the parameters from ITU-T, with only one exception.

4. Conclusion

This article reviewed recent activities toward the international standardization of optical interfaces. International standardization does and will play an important role in achieving cost-effective installation and network design. As can be seen from ITU-T activities, the trend is toward metropolitan and access areas.

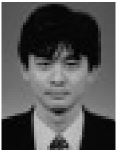
References

[1] ITU-T Supplement Sup.dsn, "Optical system design and engineering considerations," to be approved in Oct. 2003.
[2] ITU-T Recommendation G.671, "Transmission characteristics of passive optical components," May 2002.
[3] ITU-T G.692, "Optical interfaces of multichannel systems with optical amplifiers," Oct. 1998.
[4] ITU-T G.694.1, "Spectral grids for WDM applications: DWDM frequency grid," May 2002.
[5] ITU-T G.694.2, "Spectral grids for WDM applications: CWDM wavelength grid," May 2002.
[6] ITU-T G.959.1, "Optical transport networks physical layer interfaces," to be approved in Oct. 2003.
[7] ITU-T G.695, "Optical interfaces for Coarse WDM applications," to be approved in Oct. 2003.
[8] ITU-T G.664, "Optical safety procedures and requirements for optical transport systems," Jan. 2003.
[9] OIF VSR4-01.0, "Very Short Reach (VSR) OC-192/STM-64 Interface Based on Parallel Optics," Dec. 2000.
[10] OIF VSR4-02.0, "Serial OC-192 1310nm Very Short Reach (VSR) Interfaces," Nov. 2000.
[11] OIF VSR4-03.0, "Very Short Reach (VSR) OC-192 four fiber Interface Based on Parallel Optics," Aug. 2000.
[12] OIF VSR4-04.0, "Serial Shortwave Very Short Reach (VSR) OC-192 Interface for Multimode Fiber," Jan. 2001.
[13] OIF VSR4-05.0, "Very Short Reach (VSR)OC-192 Interface Using 1310 nm Wavelength and 4dB and 11dB Link Budgets," Oct. 2002.
[14] OIF VSR5-01.0, "Very Short Reach Interface Level 5 (VSR-5): SONET/SDH OC-768 interface for Very Short Reach (VSR) applications," Sep. 2002.
[15] ITU-T G.693, "Optical interfaces for intra-office systems," Oct. 2001.

Masahito Tomizawa
Senior Research Engineer, Photonic Transport Network Laboratory, NTT Network Innovation Laboratories.
He received B.E., M.S, and D.Eng. degrees in applied physics from Waseda University in 1990, 1992, and 2000, respectively. In 1992, he joined NTT Transmission Systems Labs, where he was engaged in research and development of 10G/40G optical transmission and network architectures. From 1997 to 1999, he devoted himself to the installation of 10-Gbit/s ring systems throughout NTT's network. Since 1999, his main job has been international standardization of fiber optic systems in ITU-T. He received the Young Engineer Award from IEICE (Institute of Electronics, Information and Communication Engineers) in 1998. He is in Massachusetts Institute of Technology (MIT) as a visiting scientist in 2003. Dr. Tomizawa is a member of IEEE and IEICE.

Akira Hirano
Research Engineer, Photonic Transport Network Laboratory, NTT Network Innovation Laboratories.
He received the B.S. degree in physical chemistry and the M.S. degree in astrophysics from Osaka University, Japan, in 1990 and 1993, respectively. In 1993, he joined NTT working in the lightwave communications area. His main interests are in high-speed lightwave transport systems and optical signal processing. He received the Best Paper Award from IEICE in 2003. He is a member of IEICE.

Shigeki Ishibashi
Senior Research Engineer, Optical Access Systems Project, NTT Access Network Service Systems Laboratories.
He received the M.E. degree from Kyushu University in 1984 and joined NTT the same year. He has been working mainly on polymer optical materials and devices, and now on standardization. He is a member of IEICE and the Chemical Society of Japan.



Takeshi Sakamoto
Researcher, Smart Devices Laboratory, Microsystem Integration laboratories.
He received the B.S and M.S degrees from Kyoto University, 1994 and 1996, respectively. In 1996, He joined NTT Opto-electrical Laboratories. His current research areas are high-speed optical modules and packaging technologies. He received the IEEE CPMT Young Author Award in 2002. He is a member of IEEE and IEICE.