Standardization Activities on Optical Networking

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Abstract

This article overviews global standardization activities on next-generation optical networking, which has been promoted in ITU-T SG15/WP3. Work on OTN (Optical Transport Network) and ASON (Automatic Switched Optical Network) and their intended objectives are introduced, highlighting the relationship between ASON and GMPLS (Generalized MultiProtocol Label Switching), which is undergoing standardization in IETF (Internet Engineering Task Force).

1. Introduction

The amount of Internet traffic has been explosively increasing. In Japan, for instance, the amount of traffic handled at an Internet Exchange is growing at the rate of 150% or higher every six months [1]. Such a significant growth in IP-based traffic in Japan is caused by the recent rapid penetration of inexpensive but bandwidth-abundant Internet access using ADSL (Asynchronous Digital Subscriber Line). Furthermore, taking into account the possible growth of FTTH (Fiber-To-The-Home) services, which are already available, the amount of IP-based traffic is expected to continue to grow, maintaining a pace of approximately trebling every year. It must also be recognized that IP-based traffic exhibits rapid changes in its distribution pattern, which may occasionally be associated with social events and other incidents, and that may severely impact the quality of service (QoS). There is therefore a need for network operators to deploy a robust and future-proof IP backbone into their networks. The aim of the optical network is to meet such a requirement. One of the key technologies of the optical network is WDM (Wavelength Division Multiplexing), and ITU-T plays the most important role in standardizing the specifications of optical network systems that employ WDM technologies. The coverage of ITU-T's concern has been extensively expanded to deal with the networking aspects of WDM-based optical networks, which SG15/WP3 has the responsibility to standardize. The particular task of SG15/WP3 is to specify requirements, network/functional architecture, signal format and multiplexing structure, protection/restoration mechanisms, and network element management and control architecture/functionality/protocols, all of which are necessitated by optical networking, wherein the term "OTN", rather than "optical network", and ASON are used. The OTN is assumed to use management systems such as EMS (Element Management System) and/or NMS (Network Management System) for its operation, while ASON also employs control plane functions, which can be similar to those that IP routers provide. The ASON work in SG15/WP3 is closely related to GMPLS work in IETF. This article therefore overviews the recent standardization activities on OTN and ASON in ITU-T SG15/WP3, and then makes some remarks regarding the relationship between ASON and GMPLS.

2. OTN standardization

2.1 OTN

In response to the rapid increase in the amount of IP-based traffic, so-called DWDM (Dense WDM) systems have been deployed in existing networks. In a DWDM system, several tens of wavelengths are multiplexed into an optical fiber (each wavelength can be a bearer at 2.5 Gbit/s, 10 Gbit/s, or higher). Since DWDM systems, can only enhance the capaci-

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ty of point-to-point links, electrical processing using a lower speed switching regime such as IP packet routing or lower-order SDH (Synchronous Digital Hierarchy) path cross-connection is required at every node, where a bunch of traffic, comprising streams that have different source and destination node pairs, is aggregated to form a 2.5- or 10-Gbit/s signal. This point-to-point nature of the DWDM system makes it difficult to achieve cost-effective transport of IP-based traffic between two remote nodes across multiple intermediate nodes, if gigabit-class direct traffic is provisioned between them. An OTN is intended to offer an end-to-end connection to convey such high-bit-rate traffic directly. This direct connection is denoted as an "OCh" (Optical Channel)[*1]. An OCh corresponds to a wavelength path and is routed by OXCs (Optical Cross-Connects) or OADMs (Optical Add/Drop Multiplexers) along its route to offer a direct connection between two remote nodes (Fig. 1). There is no low-speed regime switching at each intermediate node, wherein only the necessary portion of electrical switching or termination equipment needs to be installed to process only the added or dropped traffic. This significantly reduces the necessary scale or amount of electrical equipment at each node.

The architecture of OTN has been standardized in Recommendation G.872 (1st version Feb. 02). This recommendation specifies the functional architecture of OTN layers, management capability of the OTN layers, connection supervision techniques, protection architecture, interworking principles, and so forth. Note that, from a functional viewpoint, an OTN is divided into three layers including the OCh that provides end-to-end networking capability.

There were extensive discussions as to the concept of OTN and in particular on the capability of OCh in the early stage of G.872 work. NTT significantly contributed to the development of the current OTN concepts. The management capabilities at the OCh level, as defined in G.872, are assured by introducing a digital frame structure for it. Recommendation G.709 (1st version Feb. 01) specifies the signal structure of the OTN layers including the digital frame structure for OCh. Three classes of bit rates for this digital frame have been specified, i.e., approx. 2.5, 10, and 40 Gbit/s, to allow for various mapping of digital client signals such as STM-N (Synchronous Transport Module level N, where N=16, 64, and 256), ATM-VP (Asynchronous Transfer Mode - Virtual Path), GFP (Generic Framing Procedure) packets, and other CBR (Constant Bit Rate) signals with the same bit rates as specified above.

2.2 Extensions of OTN standards

From the viewpoint of IP-based networking, GFP has the potential to be a major client signal of OTN. It is a brand-new data link protocol that encapsulates IP-based signals including Ethernet for efficient mapping to SDH/OTN. To date there seems to be no OTN equipment that enables direct mapping of GFP packets, though GFP itself has already gained considerable popularity in the SDH world. This should be noted as one of the successful cases in which ITU-T has led the Telecom industry to a brand-new standard,

*1 OCh is defined such that it is characterized by physical parameters, and as such it is intended to be all-optical between its two termination points. Current optical technologies, however, may not allow for all-optical end-to-end OCh networking; therefore, a specific implementation based on a digital frame was also standardized, using different terminologies from OCh. In this article, the term "OCh" is used in a general sense that it may hold such a particular implementation.

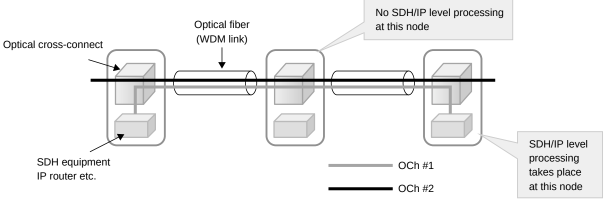

Fig. 1. End-to-end OCh networking in OTN.

i.e., GFP. In addition to GFP, ITU-T has put forth great effort to extend the virtual concatenation function, which is truly of great importance in the data-oriented era. LCAS (Link Capacity Adjustment Scheme) was specified as a mechanism for achieving dynamic link capacity adjustment according to the change in the amount of traffic. It varies the link capacity by changing the number of virtually concatenated payloads according to the requests from the management systems. LCAS will soon be widely available for SDH cross-connect systems. Both GFP and LCAS are expected to play important roles in the OTN.

3. ASON/GMPLS standardization

3.1 ASON

An OTN is operated using centralized management systems such as NMS or EMS. In general, these are specifically used to supervise and control a particular technology-based network, i.e., OTN, SDH, and so forth. On the other hand, a transport network has a layered structure to accommodate these different technology-based networks. Therefore, multiple management systems, each specific to a particular technology-based network or type of equipment, are operated at the same time in existing networks. To provide a connection across different technology-based networks, it is essential to maintain the database of each network or set of equipment so that their correlation can be fully ensured. To date, however, most of such correlation work entails complicated manual processes, which can only be achieved by skilled operators (Fig. 2 (a)). It is therefore difficult, e.g., in private line services, to instantaneously provision a connection upon request from a customer, resulting in the loss of business opportunities. Stimulated by such problems, ITU-T initiated ASON standardization around 1999. Since then, the capabilities of IP-like distributed control have been examined to automate OTN/SDH control by introducing the control plane functions, as can be seen in Fig. 2(b). ASON is characterized by (1) its instantaneous path provisioning capability, (2) more flexible failure recovery scheme attained by IP-like distributed control rather than the conventional protection scheme, and (3) synergy of centralized and distributed control schemes. The first application of ASON is thought to be the SPC (Soft Permanent Connection), which is instantaneously setup/released using the control plane upon request initiated by the management system.

It is of great importance to specify how to create the control plane that performs the call and connection control functions (Note that, through signaling, the control plane establishes and releases connections, and may restore a connection in the case of a failure). The work on ASON had been promoted on the aspect of the architecture of the control plane and its requirements, and as a consequence Recommendations G.807 and G.8080 were approved in May and October 2001, respectively. Recommendation G.807 specifies high-level requirements that are applicable to other automatically switched transport networks as well as ASON, whereas G.8080 specifies the set of control plane components that are used to manipulate transport network resources to provide the functionality of establishing, maintaining, and releasing connections. The focus of ASON work has been expanded to cover the details of specific control plane func-

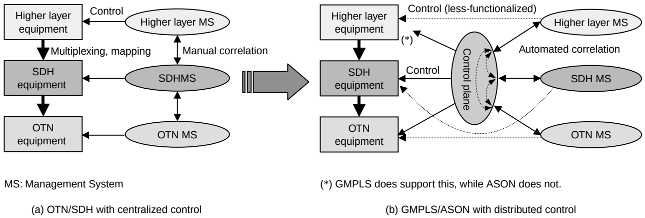

Fig. 2. OTN/SDH and GMPLS/ASON.

tions such as signaling, auto-discovery, routing, link resource management, and connection admission control functions.

3.2 GMPLS and ASON

The original intention of ASON standardization work was to develop protocol independent specifications. This approach allows for various protocol specific implementations, and specifically implies that the PNNI (Private Network to Network Interface), a protocol suite for ATM signaling/routing standardized in the ATM Forum, can also be reused for the ASON control plane. Taking into account the need to provide concrete specifications to industry, however, ITU-T subsequently developed protocol specific recommendations by translating its generic signaling specifications to the specific protocols such as RSVP-TE (Resource reSerVation Protocol with Traffic Engineering extension), CR-LDP (Constraint-based Routed Label Distribution Protocol), and PNNI. Note that the first two protocols, i.e., RSVP-TE and CR-LDP, are derived from the MPLS paradigm described below.

In IETF, considerable effort has been devoted to the development of label switching standards to realize effective packet forwarding mechanisms, and MPLS is the resultant standard reached by IETF consensus. MPLS brings connection-oriented features to the packet-based IP network, and this consequently enables sophisticated networking in IP-based networks such as QoS control, routing control, and VPN (Virtual Private Network). Its connection-oriented feature as above may be regarded as the driving force of the current MPLS paradigm rather than its original concept, i.e., effective packet forwarding. GMPLS is an extension of MPLS, and its standardization was initiated in response to the proposals from NTT and others that presented the concept of Photonic MPLS, also known as MPLambdaS where “Lambda” stands for wavelength or OCh, in early 2000 at IETF and OIF (Optical Internetworking Forum). These original concepts have been more generically extended to the current GMPLS, where MPLS-based control can be applied to transport entities other than the packet, i.e., TDM (Time Division Multiplexing) time slot, wavelength, wavelength band, and optical fiber. The implications of the TDM time slot and wavelength are the application of MPLS to SDH virtual containers and OTN OCh, respectively.

Currently, IETF’s GMPLS has attracted much attention from both the IP and Telecom industries, and efforts on bilateral collaboration between IETF and ITU-T have been examined. This may lead to successful updates of each standard, and in fact, to date, some of the functional requirements raised by ITU-T ASON have drawn much attention from IETF, and vice versa (Note that ITU-T has also examined RSVP-TE and CR-LDP in their standards as previously stated).

4. Conclusion

This article overviewed recent standardization activities on optical networking. OTN and ASON/GMPLS are keys to optical networking, and as such continuous efforts should be made toward their standardization.

Reference

[1] http://www.jpix.ad.jp/en/techncal/traffic.html

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