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Challenges and Requirements for ASON/GMPLS Photonic Networks

(Invited Paper)

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Abstract: This paper discusses the issues and requirements pertaining to Automatically Switched Optical Networks (ASONs) and Generalized Multi-Protocol Label Switching (GMPLS) control functionality to achieve dynamically reconfigurable photonic networks.

I. Introduction

There are mainly two directions for the evolution of photonic network architecture. The first one is the convergence of functionalities in photonic transport equipment. In particular, this is exemplified by the integration of packet switching functionality such as an Ethernet frame switching capability into photonic transport nodes such as Optical Cross-Connects (OXCs) and Reconfigurable Optical Add Drop Multiplexers (ROADMs). The other direction is the continuous effort to expand the dimensions of transparent optical networking. Thanks to the evolution of long-haul and high capacity optical transmission technologies, transparency in the ROADM ring has become a very common network architecture, and now transparent optical networking even in optical mesh networks is a reality. Both of these directions provide opportunities for network operators not only to provide low-cost and reconfigurable network operation, but also to enhance network reliability if elaborate network design is successfully achieved.

The Automatically Switched Optical Network (ASON) [1] and Generalized Multi-Protocol Label Switching (GMPLS) technologies [2] represent a logical framework that support or drive such technical trends by unifying the control of various types of switching capabilities. The concept of an LSP (Label Switched Path) hierarchy in particular ensures flexibility and scalability of control for such converged networks. The objective of this paper is to present an evaluation of the ASON/GMPLS control plane technology, which includes inter-operability testing and the trial in the JGN II testbed [3]. Then, this paper discusses the remaining issues and requirements for the ASON/GMPLS photonic networks.

II. Field Tests of Multi-area (G)MPLS Network

Many network engineers contributed to the standardization activities in the Internet Engineering Task Force (IETF), and have performed a number of MPLS/GMPLS interoperability trials [4,5]. Thanks to these efforts, the main technical target of

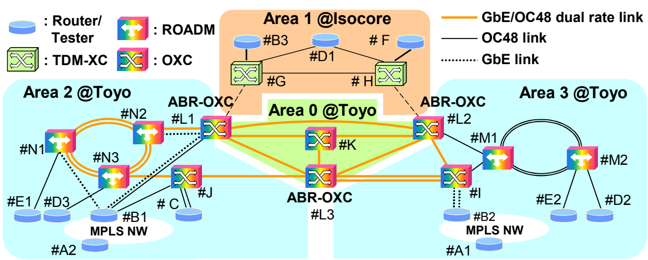

Figure 1. Configuration of multi-area MPLS/GMPLS interoperability testbed

Table I. List of Evaluated Network Elements

Vendor	Equipment Type
A,D	IP/MPLS routers
B, C	IP/MPLS/GMPLS routers
E, F	IP/MPLS/GMPLS testers
G, H	TDM-XC(STM-16c/OC-48c XC)
I, J, K, L	OXC
M, N	ROADM

the ASON/GMPLS technology has progressed toward further realistic deployment issues such as the ASON/GMPLS control over intra/inter-carrier multiple routing domains and GMPLS network deployment in existing IP/MPLS networks.

The latest inter-operability test on the GMPLS technologies reports on intra-carrier multi-area MPLS/GMPLS ROADM/OXC hybrid photonic networks evaluated using the network elements given in Table I [6] at Tokyo and Isocore in Washington D.C. This trial was a test to ensure the routing scalability of the GMPLS controlled networks through the evaluation of principal technologies required in multi-area routing architecture. Since the IETF specification recommends "not" to advertise link state information to outside areas for the sake of routing scalability, the Area Border (ABR) OXCs in Fig. 1 located in the sub-area border should perform "per-area hop route calculation." Namely, the ABR-OXCs should calculate and determine the LSP route within the sub-areas to which the ABR-OXCs belong [7].

Regarding the "per-area hop route calculation," we successfully confirmed the insertion of an Explicit Route Object (ERO) into the Resource reSerVation Protocol for Traffic Engineering (RSVP-TE) messages to assign the route within the sub-routing area at each ABR-OXC. Table II shows a list of the successful LSP creation scenarios and the round trip time for a two-way RSVP-TE signaling message.

Another issue is the optical LSP routing across multi-rate links. The ITU-T G.709 based Optical Transport Network (OTN) architecture provides the capability to transport various rate client signals [8]. We evaluated the capability of the routing protocol and path computation elements to route optical LSPs over GbE/STM-16 hybrid links as shown in Fig. 1. The trial did not yield successful results and this remains as a real issue even in the current OTN [9]. More detailed implementation agreements such as the advertisement of wavelength channel status information and transportable signal rate are required to adapt the GMPLS control plane even to the transparent optical networks.

Table II. List of Successful Scenarios

LSP Route	RTT (msec)
B1-L1-K-L2-I-B2	694
B1-N1-N2-L1-L3-I-B2	5,216
B1-L1-L2-I-B2	583

III. Operational Evaluation in JGN II Testbed

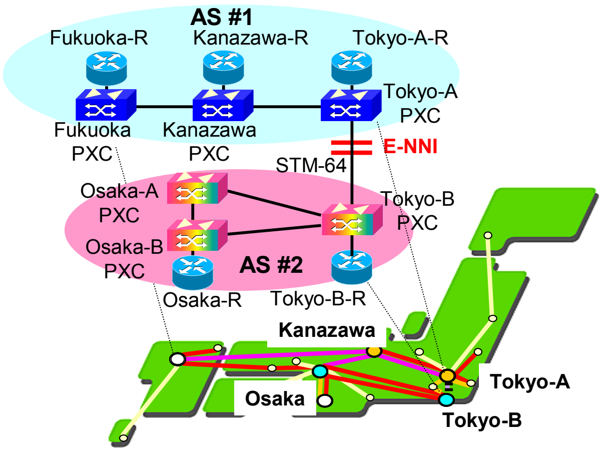

Figure 2. Experimental network over JGN II testbed

Figure 2 shows the JGN II ASON/GMPLS network testbed comprising two administrative domains connected by 10-Gbit/s SONET/SDH links. Each domain consists of different types of GMPLS controlled optical cross-connects (OXCs) and routers, called Type A and Type B. The Type A and Type B OXCs are based on a three-dimensional micro electro-mechanical system (3D-MEMS) optical switch fabric and planar lightwave circuits (PLCs) controlled using the thermal effect, respectively. The domain comprising a Type-B OXC provides an O-UNI interface. Namely, the Tokyo-B-R and Osaka-B-R are located in different administrative domains from the Type-B OXC.

Considering the basic inter-carrier operational environment, independent LSP control in each domain is desired. Furthermore, the support of not only end-to-end LSP recovery operation, but also a domain-to-domain basis recovery operation is desired to prevent affecting failure from one domain to another. The "logically" hierarchical LSP architecture as shown in Fig. 3 is one solution to enhance the independency of LSP control in each domain while ensuring end-to-end LSP control over multiple administrative domains [9].

Figure 4 shows the statistical performance of sub-network restoration for inter-domain LSP over User Network Interfaces (UNIs) between the Tokyo-B-R and Osaka-R based on the "logically" hierarchical LSP architecture. Here, the fiber accommodating the primary optical path was cut at the egress side of the optical path. The average time to recover from the cut fiber to the STM-64 signal level is 432 msec. This is longer than the 200 msec measured in the optical domain evaluation of the 2-hop backup path scenario. Here, the recovery time of the STM-64 signal is measured using the SDH analyzer by monitoring the Alarm Indication Signal (AIS).

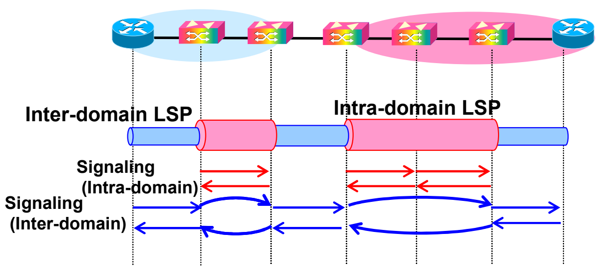

Figure 3. "Logically" hierarchical LSP architecture

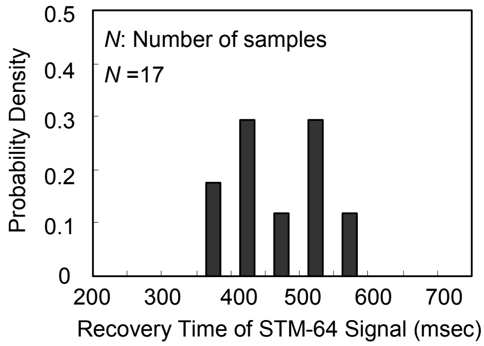

Figure 4. Histogram of restoration time measured in STM-64 layer.

IV. Challenging issues and Requirements

Through the evaluation of the ASON/GMPLS, the "logically" stitched LSP architecture provides a novel solution to achieve independent operation of LSPs across multiple domains. However, the scalable routing architecture and effective routing scheme in the layer converged networks is still an open issue. The use of a Path Computation Element (PCE) [11] with inter-layer traffic engineering capability is one choice in such a network. Another issue is the extension of the GMPLS capability to route optical LSPs in transparent networks. The GMPLS control plane should take over the capability to solve not only the Routing and Wavelength Assignment (RWA) problem but also other constraints such as selectivity of links in ROADMs. The dynamic control mechanism of the chromatic dispersion compensation mechanism [12] and the employment of a fast response optical receiver becomes indispensable, if the restoration functionality is allocated to the transparent optical networking layer.

V. Conclusions

Interoperability and operational evaluation results showed that the ASON/GMPLS technology can be applied to unify the control of networks across multiple domains. The ASON/GMPLS technology, especially the signaling mechanism is now becoming a mature technology toward commercial service deployment. However, the routing mechanism is still requires further development from the viewpoints of architecture and implementation. Continuous research and inter-operability evaluation as well as standardization activities are indispensable toward achieving layer-converged and transparent photonic networks.

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