Multilayer Service Network Architecture and Its Key Technologies

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Abstract

In this article, we outline the requirements and key technologies of our new optical-based network architecture called the "multilayer service network architecture". This combines the existing IP (Internet protocol) control technologies with the GMPLS (generalized multiprotocol label switching) control plane and provides a backbone network that can accommodate multiple service networks efficiently.

1. Introduction

Broadband services, such as HDTV-quality (high-definition television) video-on-demand and IP (Internet protocol) broadcast services, have recently been spreading rapidly and legacy services will soon be provided on an IP-based network in the form of an IP phone service. With these trends, the volume of IP traffic is increasingly growing and it is becoming difficult to forecast the demand for it.

GMPLS (generalized multiprotocol label switching) technologies, which are currently being developed, will be able to control an optical network composed of optical cross connects (OXCs) and time division multiplexing (TDM) switches.

Against this background, NTT Network Service Systems Laboratories is working on a GMPLS-based network architecture called the "multilayer service network architecture" [1]. This architecture is suitable for a carrier's backbone network because it can accommodate various service networks and facilitate multilayer traffic engineering (TE) to cope with the growing but uncertain demand for IP traffic and changes in this demand (**Fig. 1**).

The multilayer service network (MLSN) architecture essentially accommodates multiple layers of service networks such as IP networks and L2 (layer-2) networks. In this article, we describe the requirements and key technologies of the MLSN architecture.

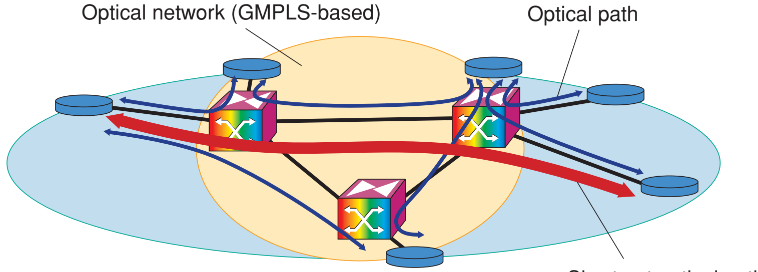

Fig. 1. GMPLS-based backbone network.

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2. Multilayer service network architecture

2.1 Requirements

Large service providers need a backbone network that accommodates multiple IP networks, enables rapid and flexible control and provisioning of an optical network, provides easy migration from existing networks, and has multilayer TE functions. They usually offer a wide variety of services at first by building a different IP network for each service. Each IP network (service network) is composed of routers and/or L2 switches that have sufficient functions, quality, and reliability for the service specifications, and it is operated and managed according to its own policies. On the other hand, an optical network, which gives optical connectivity to those service networks, consists of TDM switches, WDM (wavelength division multiplexing) switches, and OXCs and is shared among multiple service networks. We need a new network architecture that can integrate multiple service networks and accommodate them in a single optical network while enabling each service network to be operated and managed independently. As shown in **Fig. 2**, for instance, the optical network can provide optical connectivity to large service networks that need high-capacity links and also IP connectivity to small service networks such as a VoIP (voice over IP) network.

Service providers face fierce competition and are expected to provide services very rapidly to customers. To date, communication facilities have been expanded every few months as the traffic volume threatened to exceed the network capacity, so service providers cannot provide services very rapidly. Therefore, for service providers, how to provide services rapidly and flexibly and overcome the fierce service competition is an important problem. A promising solution is a new network architecture composed of a GMPLS-based optical network and IP networks. GMPLS technologies, which can provision optical paths rapidly and flexibly, allow service providers to provide services to customers without incurring great risks even if demand is uncertain.

To prevent the interruption of running services when we migrate from the existing IP-based network to a new optical-based network, we need an architecture that enables as much feature expansion as possible on existing equipment.

Finally, after multiple service networks have been integrated into an optical network, multilayer TE functions are needed in order to coordinate the control of the optical network and the service networks. To date, network design and provisioning on the optical network and service networks have been done separately. However, by taking advantage of GMPLS features that can totally control various layers of the network, we will be able to perform optimum network design considering resource and traffic infor-

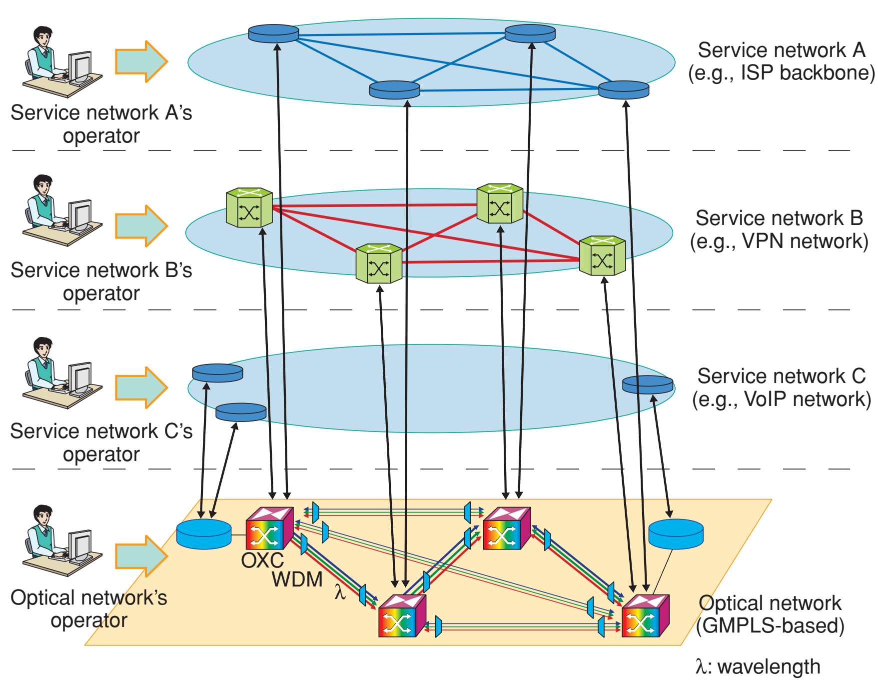


Fig. 2. Accommodation of multiple service networks.

mation of the optical network and the service networks. Thus, we will be able to handle the uncertainty by utilizing multilayer TE.

2.2 Architecture

The MLSN is composed of an optical network with GMPLS-enabled OXCs and multilayer service (MLS) routers placed on the edge of the optical network (**Fig. 3**). OXCs and MLS routers maintain a GMPLS instance, which runs OSPF-TE (open shortest path first traffic engineering) and RSVP-TE (resource reservation protocol traffic engineering). OSPF-TE is a routing protocol for advertising resource and topology information about the optical network (such as wavelength information) to the control plane of the optical network. Defined in RFC4203, it is an extension to OSPF. RSVP-TE, which is defined in RFC3473, is a signaling protocol for establishing and releasing optical paths. A GMPLS instance also has a database of resource and topology information about the optical network. MLS routers also have one or more service network instances. A service network instance runs an ordinary routing protocol such as OSPF and maintains a routing table of a service network.

The best of the unique features of the MLSN architecture is that MLS routers have both a GMPLS instance and one or more service network instances. This enables them to establish and release optical paths and makes possible flexible optical path provisioning. It also facilitates multilayer TE such as dynamic optical path control taking into consideration unused resources in multiple layers. For instance, an MLS router can monitor the IP traffic volume in its service network instance and establish an additional optical path to a particular site if the traffic volume exceeds the threshold. MLS routers can accommodate multiple service networks by means of multiple service network instances. Router interfaces and wavelengths can be shared among multiple service networks efficiently. For instance, if an Internet access service and a virtual private network (VPN) service are accommodated in a single MLS router, we can assign more resources such as router interfaces and wavelengths to the VPN service during the daytime and more to the Internet service at night.

Interface virtualization is also a unique feature of the MLSN architecture. The service network instances can treat an optical path as a logical interface. Thus, we can prevent any instability of the optical network from impacting the IP routing of the service network during an optical path failure.

As for easy migration, only MLS routers need to support GMPLS features: other routers in the service network do not have to. Therefore, transition from the existing IP-based network is easy.

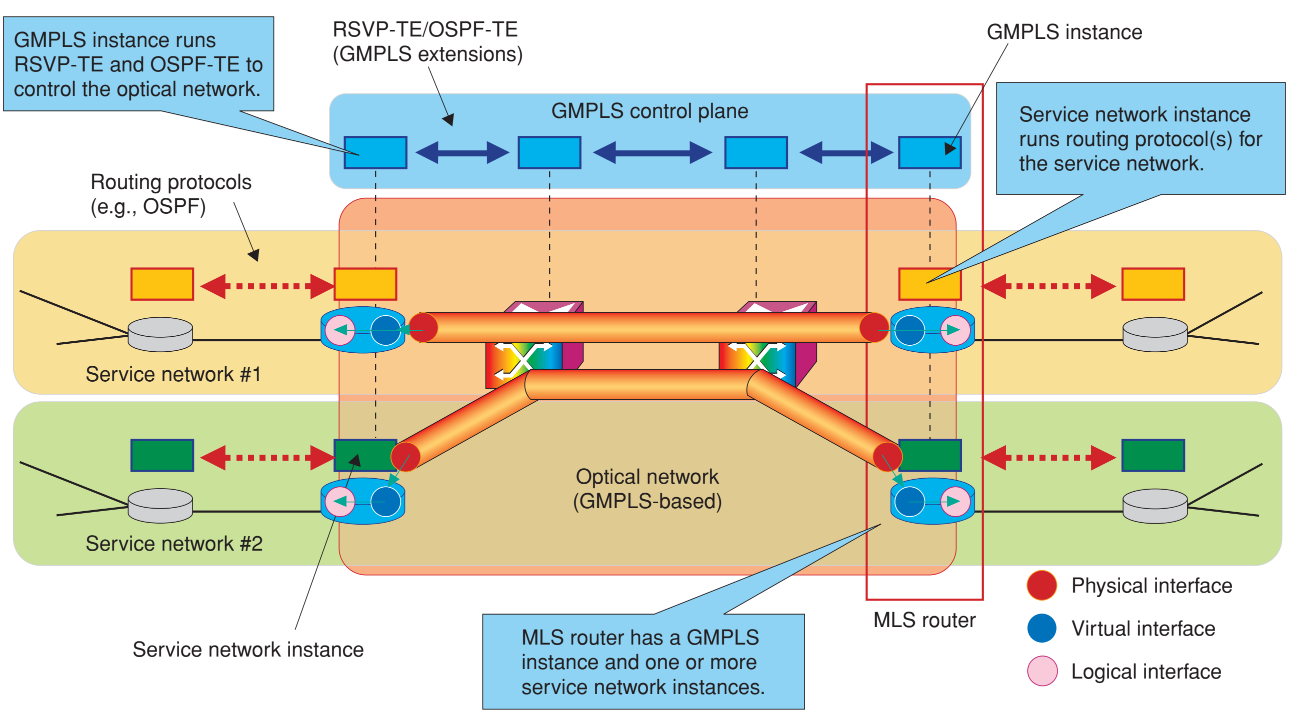
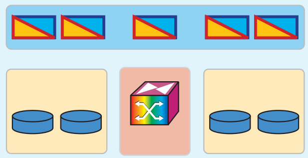
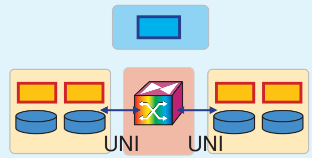
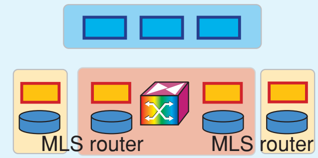


Fig. 3. Multilayer service network architecture.

Table 1. Comparison of IP optical network architectures.

	Peer model	Overlay model	MLSN architecture
Architecture	 All the nodes including OXCs and routers share the resource and topology information of the optical network.	 Only OXCs have the resource and topology information of the optical network.	 OXCs and MLS routers have the resource and topology information of the optical network.
1) Flexible control of optical paths	**Good:** Using GMPLS	**Good:** Using GMPLS	**Good:** Using GMPLS
2) Multiple service network accommodation	**Poor:** All the routers must have multiple instances.	**Good:** OXCs do not have the information related to any service network.	**Good:** Only MLS routers must have multiple instances.
3) Multilayer TE	**Good:** All the routers have the optical network information.	**Poor:** Routers do not have the optical network information.	**Good:** MLS routers have the optical network information.
4) Easy migration	**Poor:** All the routers must support GMPLS functions.	**Good:** Only border routers facing UNI have to support extended functions.	**Good:** Only MLS routers must support GMPLS functions.

GMPLS instance   Service network instance   UNI: user-network interface

Table 2. Functional planes of routers.

	Functions	Components
Control plane	Functions for controlling the user-plane such as routing and signaling protocols	• Routing and signaling protocols such as OSPF, BGP, and RSVP-TE • Routing table and LSP database
User plane	Functions for forwarding packets	• Packet forwarding engine • Forwarding table
Management plane	Router management function	• Management protocols such as SNMP, SNMP trap, and TELNET • Management database, e.g., MIB

BGP: border gateway protocol
LSP: label switched path
SNMP: simple network management protocol
MIB: management information base

The MLSN architecture is compared with other optical-based network models in **Table 1**. It meets all the requirements whereas the peer and overlay models cannot meet them all at the same time. Details of this evaluation are available elsewhere [1].

2.3 Key technologies

The key technologies of the MLSN architecture are multiple instances of MLS routers and interface virtualization of the MLS router's interface.

The logical router technique for dividing a physical router into multiple logical routers, such as the VR (virtual router) feature, can be used to implement multiple instances of MLS routers. A physical MLS router has multiple logical routers, where each logical router corresponds to one instance.

A router is composed of three functional planes, as shown in **Table 2**. In the MLSN architecture, several models are applicable depending on the degree of separation of these planes. Considering the accommodation of multiple service networks, each of which has been designed and operated according to an independent policy, we must ensure the independency of routing and IP address design among service networks. Specifically, routing protocols must run in the service network without interfering with those of other service networks and IP address duplication among service networks must be tolerated. There-

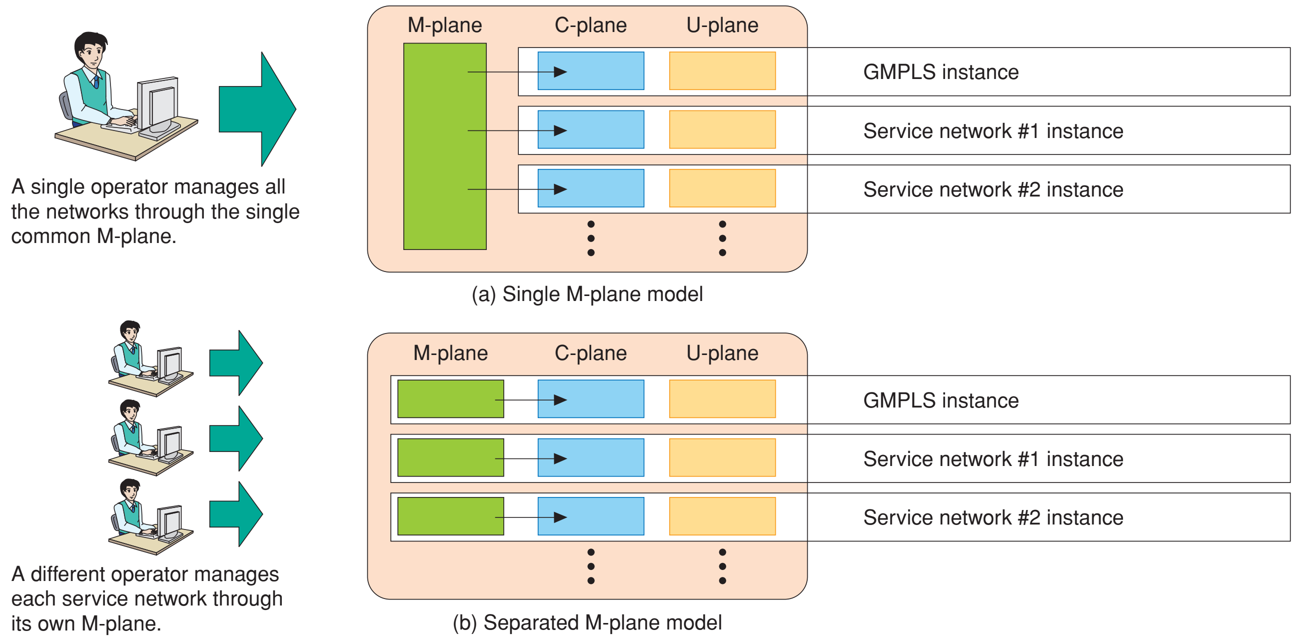


Fig. 4. Management models for multilayer service network architecture.

fore, at least the control-plane (C-plane) and user-plane (U-plane) functionalities must be separated among the service networks and the GMPLS instances. As for the management plane (M-plane), we considered the two models shown in **Fig. 4** depending on whether or not the management functionality is separated between the optical network and the service networks. When one operator or organization manages all of the networks, the best model is the single M-plane model, in which the management information about all the networks can be accessed from a single M-plane. This model could be useful when we provide a service network such as a VPN to an enterprise customer. On the other hand, the separated M-plane model is desirable when each service network is operated by a different operator. For instance, the backbone network of a large carrier, where one corporate division manages the optical network and other divisions each manage their own service network, needs the separated M-plane model.

Interface virtualization is a technique that offers a physical interface to the service network instance as a logical interface. As shown in Fig. 3, a physical interface used to establish an optical path is offered to both the GMPLS instance and the service network instances. From the viewpoint of the GMPLS instance, an optical path is recognized as a "virtual interface". The service network instance retrieves these virtual interfaces from the GMPLS instance and stores only what it uses of them as "logical interfaces" in its routing table.

There are several benefits to interface virtualization. First, an optical path can be shared among multiple service networks. In the service network instance, a logical interface is treated in much the same way as a normal physical interface. We can assign a different IP address to the logical interface of each service network. Another benefit is stabilizing the service network when using multilayer TE. For instance, during optical path switchover in response to a link failure, the logical interface corresponding to the optical path does not go down but can maintain its state. That allows the service network to maintain the routing neighbor during the switchover and improves the stability of the routing of the service network.

3. Future steps

We are now aiming to introduce the MLSN architecture into our backbone network. One of the major challenges is to promote the implementation of its key technologies: multiple instances and interface virtualization. To do that, we intend to contribute actively to the standardization of our architecture and to interoperability events.

Reference

[1] H. Kojima, T. Takeda, and I. Inoue, "A study on multi-layer service network architecture in IP optical networks," APCC2003, Sept. 2003.

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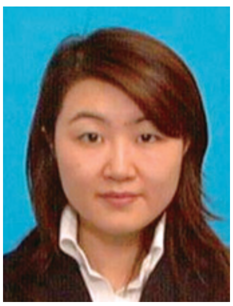

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He received the B.E., M.E., and Ph.D. degrees in information and computer sciences from Osaka University, Osaka, in 1987, 1989, and 1998, respectively. He joined NTT in 1989 and engaged in R&D of ATM traffic control and ATM switching system architecture design. During 1996–1997, he was engaged in research on high-speed networking as a Visiting Scholar at Washington University in St. Louis, MO, USA. During 1997–2001, he was directing architecture design for the high-speed IP/MPLS label switching router research project at NTT Network Service Systems Laboratories. Since July 2001, he has been engaged in the research fields of photonic IP router design and routing algorithms and in GMPLS routing and signaling standardization, first at NTT Network Innovation Laboratories and then at NTT Network Service Systems Laboratories. He is active in GMPLS standardization in IETF. He is a member of IEEE, IEICE, and the Association for Computing Machinery. He was the Secretary for International Relations of the Communications Society of IEICE from June 2003 to May 2005. He was the Vice Chair of Information Services of the IEEE ComSoc Asia Pacific Board from January 2004 to December 2005. He has been involved in the organization of several international conferences including HPSR 2002, WTC 2002, HPSR 2004, WTC 2004, MPLS 2004, iPOP 2005, MPLS 2005, iPOP 2006, and MPLS 2006. He received the Young Engineer Award from IEICE in 1995 and the Switching System Research Award from IEICE in 1995 and 2000. He is one of the authors of "GMPLS Technologies: Broadband Backbone Networks and Systems".