Layer-1 Virtual Private Networks—Service Concepts and Enabling Technologies

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Abstract

Internet protocol (IP) and optical networking technologies based on generalized multiprotocol label switching (GMPLS) enable not only improved operation, but also new services offered by optical networks. One such promising service is the layer-1 virtual private network (L1VPN). This article introduces NTT's research and development of L1VPNs, focusing on service concepts and enabling technologies.

1. Background

With the progress of optical technologies and GMPLS technologies [1], which provide tools for flexible network operation, it is becoming possible to offer new services characterized by high bandwidth, efficient support for packet-based services, and advanced control and management functions. These services are expected to be new sources of revenue for carriers. Advanced control and management functions are important elements in achieving service differentiation, such as security, safety, and user convenience.

2. Service concepts

Carriers currently offer private line services between a pair of static end points and the line's bandwidth is also static. Such services are usually based on transport technologies such as SONET/SDH (synchronous optical network and synchronous digital hierarchy). Recently, however, multiprotocol label switching (MPLS) pseudowire*1 technologies have begun emerging as an alternative way to offer private line services.

In traditional SONET/SDH networks, bandwidth must follow the digital hierarchy, so it is not possible to support packet-based services efficiently. For example, in order to support a 1-Gbit/s Ethernet line, one must allocate an OC48/STM16 line, that is 2.4 Gbit/s. Furthermore, network operations were designed to offer static services with uniform features across all customers. That is, flexibility and customization are not well considered. Thus, they are not suitable for supporting applications that transmit a huge amount of data within a short period. Another example is that since there was little consideration of offering different sets of service features to different customers, it is not straightforward to offer customer-specific monitoring information (e.g., reports of bit error rate or loss of light (failure detected by monitoring the optical signal power)) to the corresponding customers. This feature is desirable, especially when private line services are deployed to support various service networks of the same carrier, such as an MPLS network for layer-3 virtual private network (VPN) services.

Various technologies are emerging to solve these problems. By using optical cross connects (OXCs) and reconfigurable optical add/drop multiplexers (ROADMs), which offer wavelength switching capabilities, it is possible to make high-bandwidth ser-

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*1 Pseudowire: A mechanism that carries the essential elements of an emulated service from one provider edge router to one or more other provider edge routers over a packet-switched network.

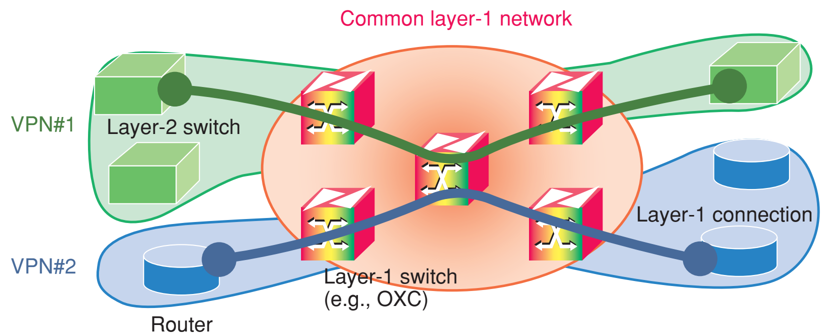

Fig. 1. Concept of L1VPN.

vices. In addition, by using next-generation SONET/SDH [2], which offers efficient support for Ethernet signals, it is possible to achieve efficient support for packet-based services. Furthermore, by using GMPLS, it is possible to achieve advanced control and management functions, such as flexible connection setup and service customization.

Combinations of these technologies are expected to make it possible to offer new services. Among such new services, layer-1 VPNs (L1VPNs) give users the impression of having a private network. The concept of the L1VPN is shown in **Fig. 1**. It is a VPN service offered by the high-bandwidth layer-1 (or optical) network, which makes it possible to flexibly form and operate a private network for each service, network operator, or user on a common infrastructure.

3. L1VPN service features

The key service features of an L1VPN are listed in **Table 1**. In terms of transmission, it offers layer-1 connections with a range of bandwidths from high to low. The use of layer-1 connections enables various data formats to be transmitted and should lead to improvements in service quality, such as performance, resiliency, and security. In terms of control and management, an L1VPN has the following features.

- It establishes connections in response to customer requests, so it offers convenient services to users. Both on-demand and reservation services are supported. In the on-demand service, a connection is established at the time of a request. In the reservation service, a customer specifies the starting and ending times as part of the request, and a connection is established or deleted based on this request.
- It provides monitoring information to customers, so it helps make network operation efficient.

Table 1. L1VPN service features.

Transmission	Provides high-bandwidth to low-bandwidth layer-1 connections
Control and management	Enables flexible connection setup in response to customer requests
	Provides monitoring information to customers
	Provides resource management for each customer
	Provides various recovery options
	Supports intranets and extranets

- It manages resources for each customer, so it performs admission control based on resource usage.
- Among its recovery options, it offers various recovery features provided by GMPLS.
- It supports various connectivity models, such as intranets and extranets.

These features can be customized for each customer. For example, the network can be configured to allow connection setup requests from one customer, but not from another customer. There are various alternatives for the interface for receiving connection setup requests from customers. These lead to various service models, as shown in **Fig. 2**.

In the management mode where connection setup requests are received over the management interface (e.g., web), both on-demand and reservation services are supported. This service model operates in a similar manner to the current one, so it is suitable for initial deployment. When connection setup requests are received over the control interface (i.e., GMPLS signaling), only the on-demand service is supported. This service model is further classified based on whether or not the network topology is provided to customers.

In the basic mode where the network topology is not provided, GMPLS signaling makes it possible to provide strong recovery options, which protects a connection end-to-end between two pieces of cus-

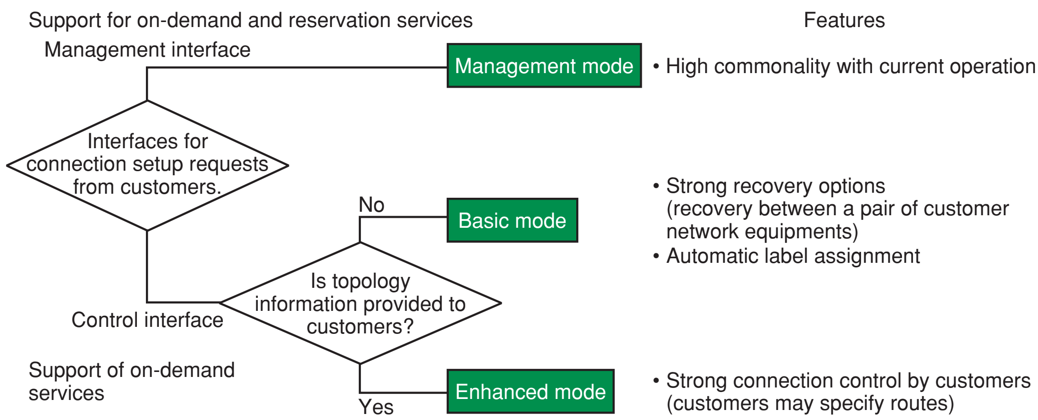

Fig. 2. L1VPN service model classification.

tomer network equipment. In addition, label assignment with customer network equipment is automated, which helps to reduce the operator's workload.

In the enhanced mode where network topology information is provided, customers may also specify routes in connection setup requests.

One example of an L1VPN deployment scenario is a multiservice network, that is, support for multiple service networks over a common transport network. L1VPNs are designed to allow independent operation of each VPN. Therefore, L1VPNs allow us to keep today's unit of operation, but allow more flexible network operation, such as establishing a connection based on a customer's request and sharing monitoring information.

Another example of an L1VPN deployment scenario is to offer new services by establishing layer-1 connections either on demand or based on a reservation. Such services could be suitable for data backup to remote data centers, delivery of huge content (e.g., video), and advanced applications such as grid computing.

4. Enabling technologies

L1VPNs require development in two important areas: 1) optical transport network equipment supporting high-bandwidth transmission and 2) control and management technologies supporting flexible operation. In this article, we focus on the latter and discuss enabling technologies, which are summarized in **Fig. 3**. There are two key elements.

The first element is a server, called an L1VPN server. It administers the logical separation of the common optical network. Namely, it performs not only networkwide configuration and performance management, but also VPN-specific configuration and performance management. This helps to quickly identify VPNs affected by failures, which reduces operator workload. The L1VPN server also supports the management mode, by receiving and admitting customer requests via the management interface, and by providing customized services. It communicates with network equipment or an element management system (EMS), and its role includes initiating connection setup based on customer requests.

The second element is a network equipment control entity, where GMPLS is the key component. It communicates with the L1VPN server or EMS, and when it receives a connection setup initiation request, it establishes a connection by GMPLS signaling. This mode of connection setup, which is called soft permanent connection (SPC), allows multivendor interoperability and the use of GMPLS recovery techniques. The network equipment control entity also supports the basic and enhanced modes, by receiving and admitting signaling directly from customer network equipment. This mode of connection setup is called switched connection (SC). It also performs admission control based on VPN membership.

Note that it is possible to use a TE (traffic engineering) server for advanced path computation. In such a case, the L1VPN server or network equipment communicates with a TE server.

5. R&D activities

NTT Network Service System Laboratories is engaged in various activities aimed at achieving L1VPNs. The network equipment control entity requires the implementation of functions in vendor network equipment, so NTT is leading standardiza-

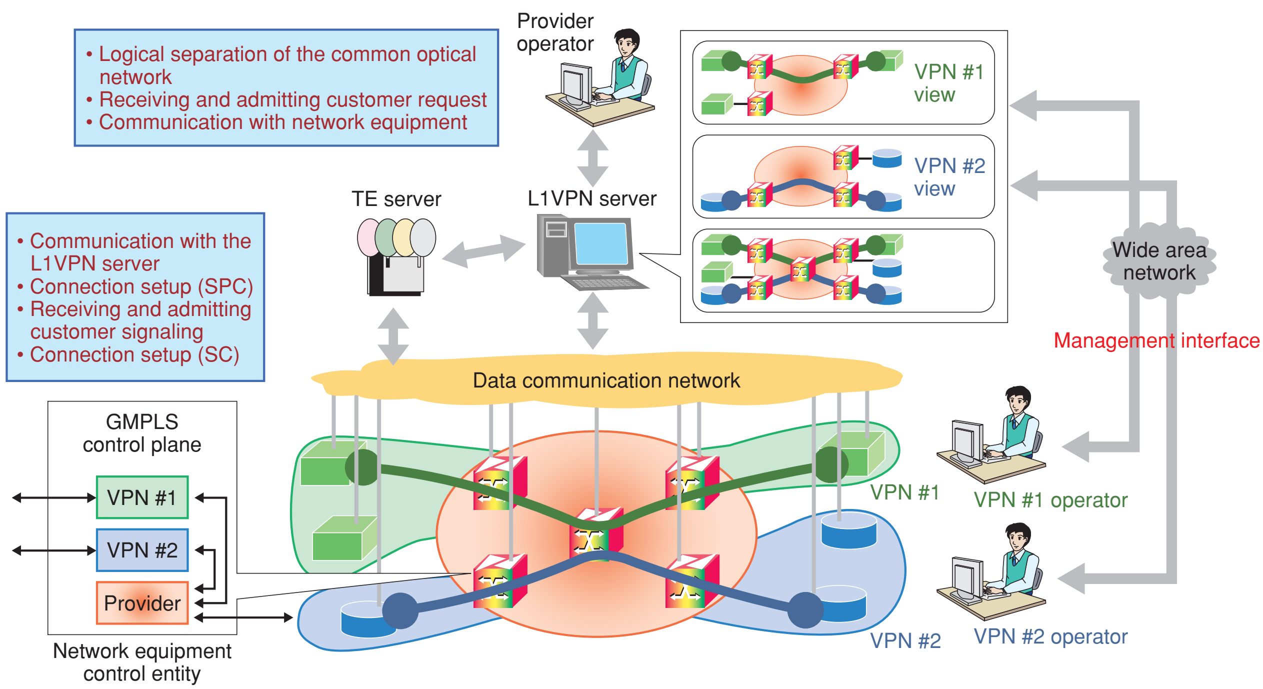

Fig. 3. L1VPN enabling technologies.

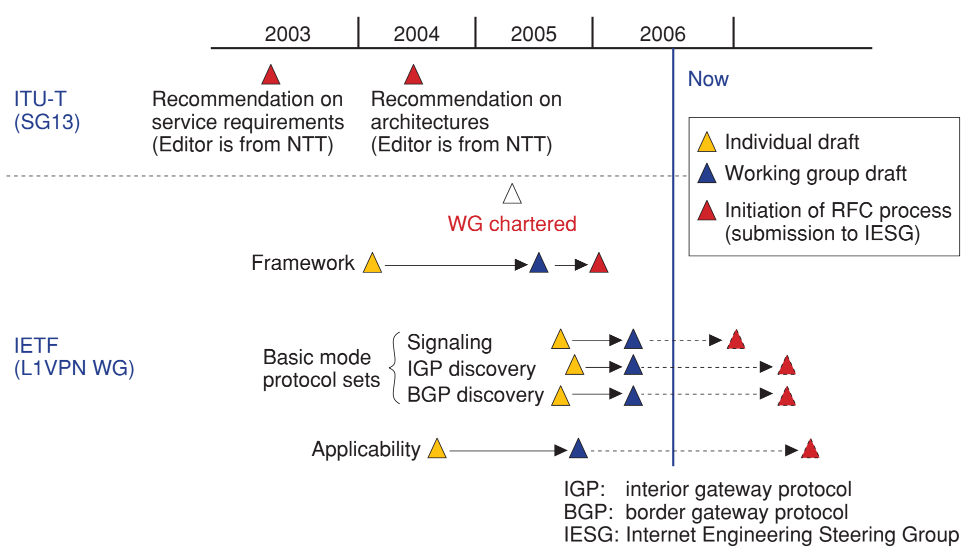

Fig. 4. L1VPN standardization progress.

tion for that purpose, as shown in **Fig. 4**. ITU-T SG 13 (International Telecommunication Union Telecommunication Standardization Sector Study Group 13) was responsible for approving Recommendations on L1VPN service requirements [3] and architectures [4], and NTT provided an Editor for each Recommendation.

In response to ITU-T standardization, a framework for using GMPLS and a scope of applicability have been proposed in the Internet Engineering Task Force (IETF) at the initiative of NTT. After that, the L1VPN Working Group (WG) was chartered, and one of co-chairs is from NTT [5]. Currently, a set of protocols to support the basic mode is being discussed. These are now working group drafts, but they are expected to become Requests for Comments (RFCs) as discussion progresses.

For the server, NTT is developing an L1VPN server prototype. Some snapshots of its graphical user interface are shown in **Fig. 5**. The provider view shows the status of the whole network, while the VPN views show the status of each VPN. These features help VPN-context-aware network operation.

Furthermore, to promote implementation on vendor network equipment, NTT is driving interoperability testing, in addition to standardization. Interoperability tests performed in the University of New Hampshire Interoperability Laboratory (UNH-IOL) [6] and in ISOCORE [7] are shown in **Figs. 6** and **7**, respectively.

6. Future direction

The demand for high-bandwidth services is expected to grow and more efficient support for packet-based services will be required in response to

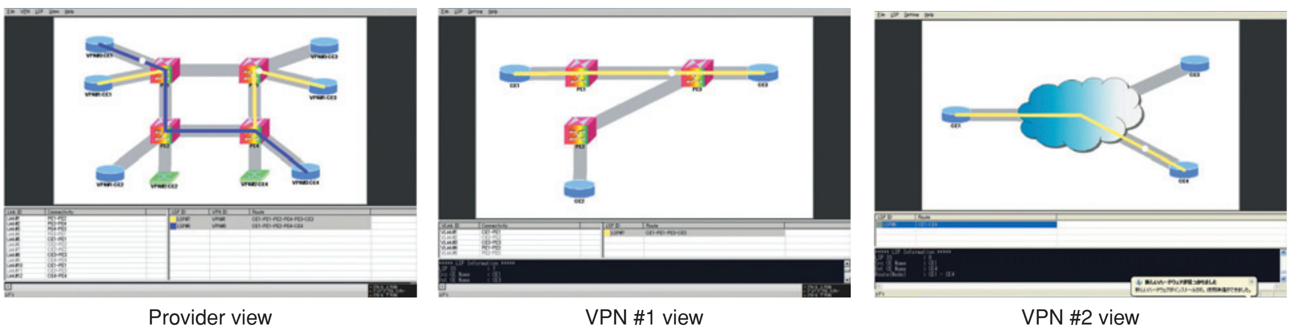

Fig. 5. Graphical user interface of the L1VPN server prototype.

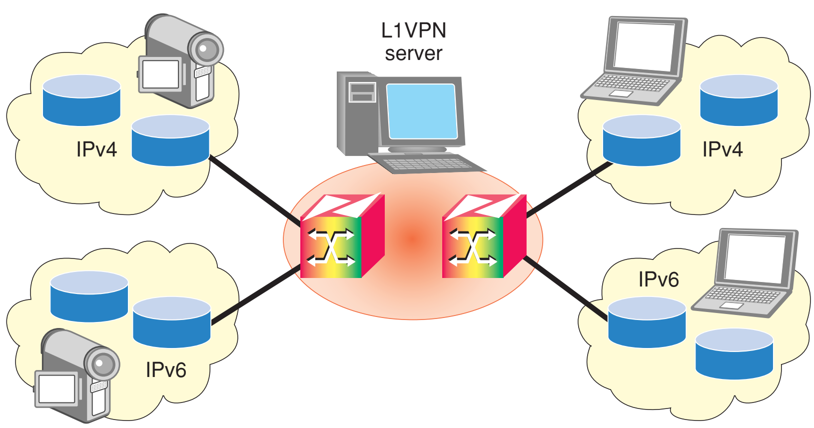

Fig. 6. Interoperability testing with an L1VPN server (UNH).

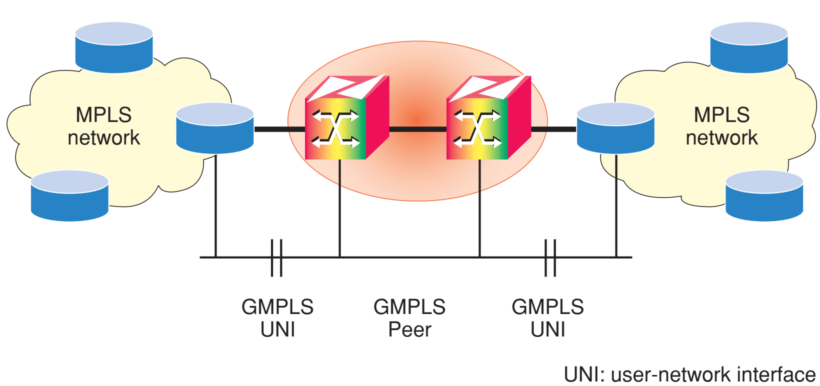

Fig. 7. Interoperability testing with signaling (ISOCORE).

progress in broadband access lines and broadband content services. Advanced control and management functions will be essential for service differentiation. In order to create such new services, we need to develop and deploy optical transport network equipment, as well as control and management technologies. This article introduced NTT R&D activities for that purpose, including standardization, server prototype development, and interoperability testing.

References

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