Multilayer Traffic Engineering (TE) Based on IP Optical TE Server

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Abstract

This article presents an IP (Internet protocol) optical traffic engineering server, which performs traffic control in cooperation with IP routers and optical cross-connects (OXCs) in IP optical networks. This server utilizes network resources, responds flexibly to unexpected changes in traffic demand, and restores network connectivity quickly in the event of a system failure or natural disaster.

1. Introduction

The network is required to be both flexible and reliable. It should have sufficient flexibility to cope with unexpected traffic fluctuations and should provide highly reliable services while utilizing network resources efficiently. Therefore, it is expected that the network topology will be controlled by integrated management of both IP (Internet protocol) routers and optical cross connects (OXCs).

NTT Network Service Systems Laboratories has researched and developed an IP optical backbone network that can achieve integrated management of both IP routers and OXCs [1]. As a result, NTT has developed an IP optical TE server for linking the IP routers and OXCs in an IP optical backbone network and controlling traffic. It has conducted successful testbed trials of dynamic network control in an IP optical backbone network configured with IP routers and OXCs.

2. Multilayer traffic engineering

Multilayer traffic engineering can optimize network resource utilization considering all layers, rather than performing optimization independently for each layer. As shown in **Fig. 1**, IP routers and OXCs are managed and operated by the optical TE server considering the network resources of both layers. The IP optical server computes path routes across different layers and controls them upon request from users and operators. The optical TE server dynamically reconfigures an IP network topology that consists of several optical paths, known as a virtual network topology (VNT), in response to traffic demand fluctuations and network failures. The detailed functions of the IP optical TE server are described below.

(1) Multilayer path computation and several constraints

Let us consider computing a route between a source router and a destination router in an IP optical network. There are two possible ways to do this: by a single-layer or multilayer path computation. In the single-layer path computation, only IP links that have already been established are considered. They may be optical paths. On the other hand, in the multilayer path computation, the possibility of new IP links, which are optical paths that will be established later, are considered as well as IP links that have already been established. For example, if the source router is not connected to the destination router in the current IP topology, the IP optical TE server may decide to establish a new optical path for the requested end-to-end packet path based on both IP and optical network resources. In the calculation, constraints such as bandwidth, delay, link attributes, inclusive/exclusive routes, and protection class are taken into account. Which multilayer route is selected also depends on a

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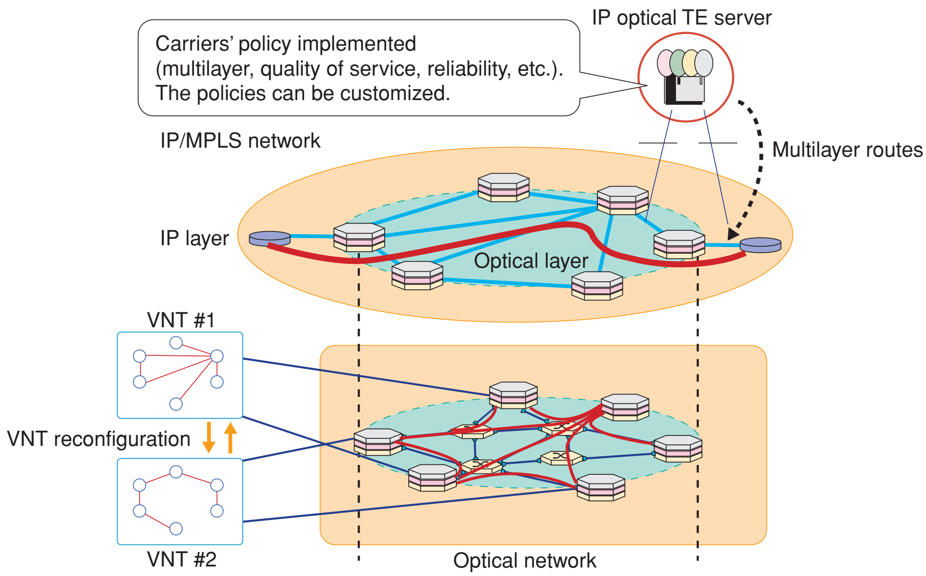

Fig. 1. Multilayer traffic engineering based on IP optical TE server.

carrier's policy. For example, one policy might try to find available existing optical paths as much as possible, while another might try to establish a new optical path in order to minimize the number of hops between source and destination routers.

(2) VNT reconfiguration

The optical TE server can reconfigure the VNT in response to a change in traffic demand change, a network failure, or a change in topology or under the control of an operator. These trigger cases are explained below.

(a) Traffic demand change: A traffic matrix is defined as the traffic volume between border routers, which are located at the edges of optical networks. The traffic information is periodically collected from networks, the optimal VNT is computed, and the VNT is changed by setting up and releasing optical paths.

(b) Network failure: If a network failure occurs, the optical TE server detects it by means of a trap or advertisements of a routing protocol such as OSPF (open shortest path first). Based on new network resources and the traffic matrix, VNT reconfiguration is performed.

(c) Topology change: When a new link is added or some existing links are deleted, the optical TE server detects the topology change through the advertisement of a routing protocol. If a network failure occurs, then based on new network resources and the traffic matrix, VNT reconfiguration is performed.

(d) Operator initiation: An operator can also initiate the VNT reconfiguration using the IP optical TE server.

When the VNT is reconfigured, the concept of shared risk link group (SRLG) should be considered. As shown in **Fig. 2**, separate logical links that are accommodated in the same fiber, fiber cable, or conduit may all be simultaneously affected by a single failure. Consider two different IP links, which are optical paths. If these links belong to the same SRLG, such as the same fiber, then a single failure in the network will cause multiple link failure. Therefore, our VNT design algorithm considers SRLG constraints.

(3) Traffic matrix estimation

The VNT design algorithm uses a traffic matrix as input information. Each element of the traffic matrix is the traffic volume between a pair of border routers. When the network becomes large, the number of border routers increases and it becomes difficult to measure all the traffic volumes between border routers. In addition, in the case of IP packet networks, it also becomes difficult to analyze the IP headers of all the IP packets to determine their destination border routes. Therefore, the traffic matrix derivation method must be scalable in terms of network size.

Our approach is to estimate the traffic matrix based

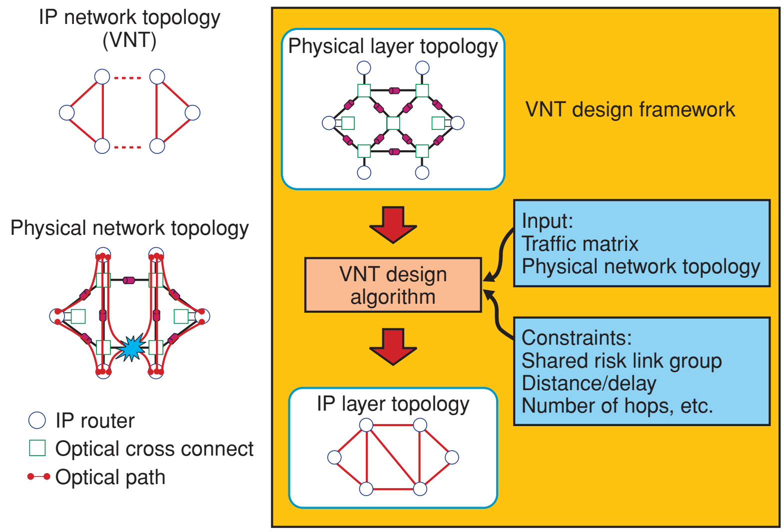

Fig. 2. Reliable IP network topology (VNT) design.

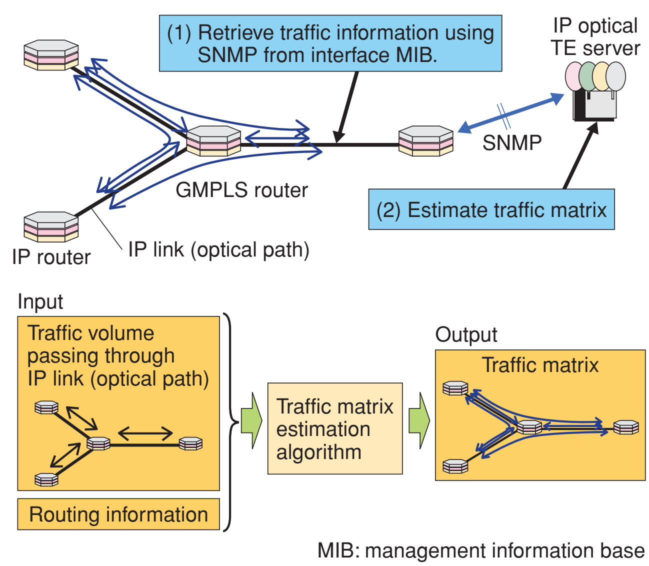

Fig. 3. Traffic matrix estimation.

on the traffic volume passing through IP links (which are optical paths) and on IP/MPLS routing information, instead of directly measuring each traffic volume between border routers. We implemented our traffic matrix estimation function in the IP optical TE server. The traffic matrix estimation procedure is shown in **Fig. 3**. In step 1, the traffic volume passing through IP links is retrieved using SNMP (simple network management protocol)*1 from the interface management information base. In step 2, the traffic matrix is estimated using the retrieved traffic volume and the IP/MPLS routing information. This estimation reduces the complexity of the traffic measurement, making it proportional to the number of IP links, whereas in the conventional approach it is proportional to the number of border router pairs. As a result, VNT reconfiguration is possible even when network size is large.

*1 SNMP is used by network management systems to monitor network-attached devices for conditions that warrant administrative attention.

Table 1. Functions of IP optical TE server.

Functions			Interfaces
MPLS/GMPLS path computation		Single layer	
		Multiple layer	
Route control			
Path state management			
IP network topology (VNT) control			
Traffic matrix estimation			
Multivendor interfaces			PCEP (working in progress)
Customization of path computation/control algorithms			
Retrieval	Topology	Single layer	OSPF
		Multiple layer	OSPF
	Traffic volume		SNMP
	Established path states		SNMP

3. Separation of traffic control algorithm from node equipment

Implementing this IP optical traffic control algorithm for the IP optical backbone network in the IP optical TE server separately from node equipment enables a carrier to apply traffic control policies considering quality of service, reliability, and efficiency. This allows the carrier to differentiate its network operations from those of other carriers. As a result, NTT can provide stable, reliable, and flexible services using its own policies and algorithms. The control interface between the server and node equipment is currently being standardized in the Path Computation Element (PCE) Working Group of the Internet Engineering Task Force (IETF) based on the participation of NTT, several overseas telecommunication carriers, and various communications equipment vendors.

4. Functions of IP optical TE server

The functions of the IP optical TE server are shown in **Table 1**. To perform multilayer traffic engineering, it requires several types of information, including the IP and optical topologies, traffic volume, and path attributes. In addition, requests and replies for path computation and path setup/release require interfaces between the IP optical TE server and router. As much as possible, the IP optical TE server uses standardized interfaces between the server and routers, such as OSPF, SNMP, and PCEP (PCE communication protocol)[*2].

5. Experiments

The functions of multilayer traffic engineering, including path computation across multiple layers and dynamic VNT reconfiguration in response to traffic fluctuation, were tested in an IP optical backbone network consisting of an IP optical interlinking server, IP routers, and OXCs. The experimental network configuration is shown in **Fig. 4**. The network consisted of four GMPLS routers, two MPLS routers, a distributed traffic generation tool, and a VNT viewer. The distributed traffic generation tool generated traffic from multiple terminals and consists of a traffic controller and traffic generators. It could emulate the traffic fluctuation that occurs in a real network environment. The VNT viewer is a tool for displaying the topology of each layer and the network status. A schematic screen image is shown in **Fig. 5**. The viewer provided a realtime display of the physical network topology, IP network topology (VNT), traffic volume passing through optical paths and MPLS paths, and lists of MPLS and optical paths including their routes and attributes.

NTT demonstrated multilayer traffic engineering based on the IP optical TE server in the iPOP2006 Interoperability Showcase using multivendor equipment at this international conference held on June 22–23 in Tokyo.

*2 PCEP is a protocol for communication between a path computation client (PCC) and a path computation element (PCE), or between two PCEs. The communication consists mainly of path computation requests and path computation replies as well as notifications and error messages.

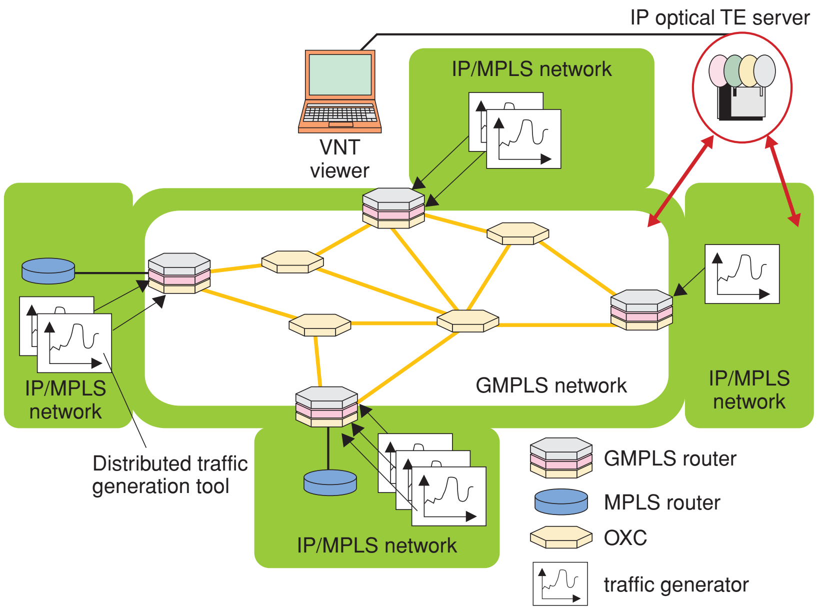

Fig. 4. Configuration of experimental network.

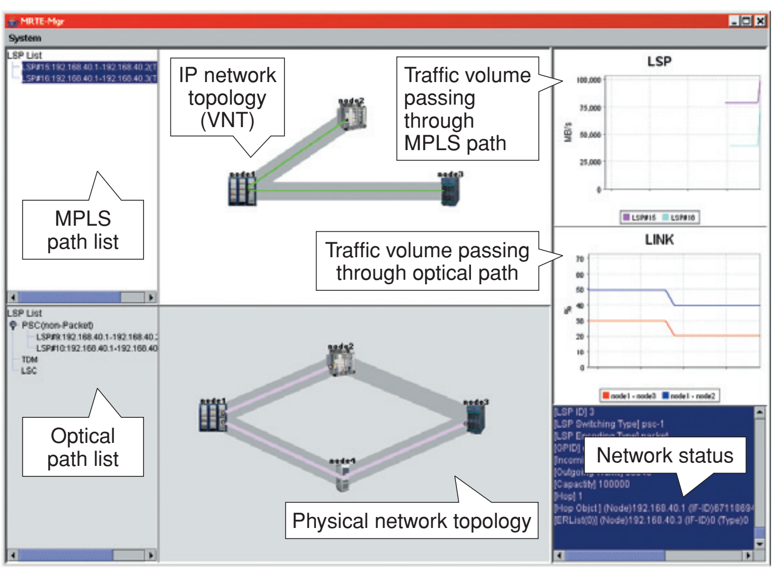

Fig. 5. VNT viewer.

6. Future development

In the future, in anticipation of unexpected traffic changes, we plan to promote international standards at IETF, conduct interoperability trials with vendors, and add functions needed for operation and control scenarios in actual networks.

Reference

[1] K. Shiomoto, E. Oki, I. Inoue, and S. Urushidani, "A server-based traffic engineering method in IP + Optical multi-layer networks," Int. Conf. on IP + Optical Network (iPOP) 2006 Session T3-4, June 2006.

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