Research and Development of IP and Optical Networking

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Abstract

This article presents the targets, technology overview, status, and future outlook of R&D of IP (Internet protocol) and optical multilayer networking technologies. This R&D is being conducted with the aim of innovating network control and management of backbone networks. These technologies include network architecture, services, and control and operation technologies.

1. IP and optical networking

NTT Network Service Systems Laboratories is conducting research and development of IP (Internet protocol) and optical networking technologies, which consist of technology elements such as the architecture, services, and control and operation (traffic engineering) methods. This article gives an overview of the IP and optical networking technologies (**Fig. 1**). The following three articles [1]–[3] give more details about three key elements: the multilayer service network, L1VPNs (layer-1 virtual private networks), and multilayer traffic engineering.

2. R&D motivation

IP and optical networking technologies aim to create an innovative backbone network, in which both IP and optical layers are controlled and managed in a unified manner. These technologies enable us to build advanced control and operation methods for the backbone network (**Fig. 2**).

Traditionally IP and optical layers have been separately and independently controlled using different technologies. By unifying the control of both layers, IP and optical networking technologies will accelerate efficient network resource utilization and make the backbone network flexible and resilient against unexpected traffic fluctuations and network failures.

Multimedia traffic including voice and video will be transported over the backbone network based on IP technology. As this IP-based backbone network prevails, new services will emerge, and these may cause unexpected fluctuations in traffic demand. To enable the backbone network to handle these fluctuations, R&D is necessary in order to produce advanced control and operation of the backbone network.

As information technology becomes central to our daily life, the role of the telecommunication network is becoming more and more important. The impact of network outage due to failure or natural disaster should be minimized. Recovery from the outage should be performed quickly. The backbone network should be resilient. Thus, R&D of advanced control and operation of the backbone network is becoming more important.

Integrated control and management of network resource across IP and optical layers will enable us to optimize network resource across both layers and improve utilization. Moreover, integrated resource management across IP and optical layers will enable dynamic reconfiguration of the IP network topology in response to unexpected changes in traffic, which might be caused by future killer applications and/or network outages. It also simplifies the process of designing a reliable IP network topology. However, if diverse routes are computed separately and independently of other layers, two routes that are diverse in

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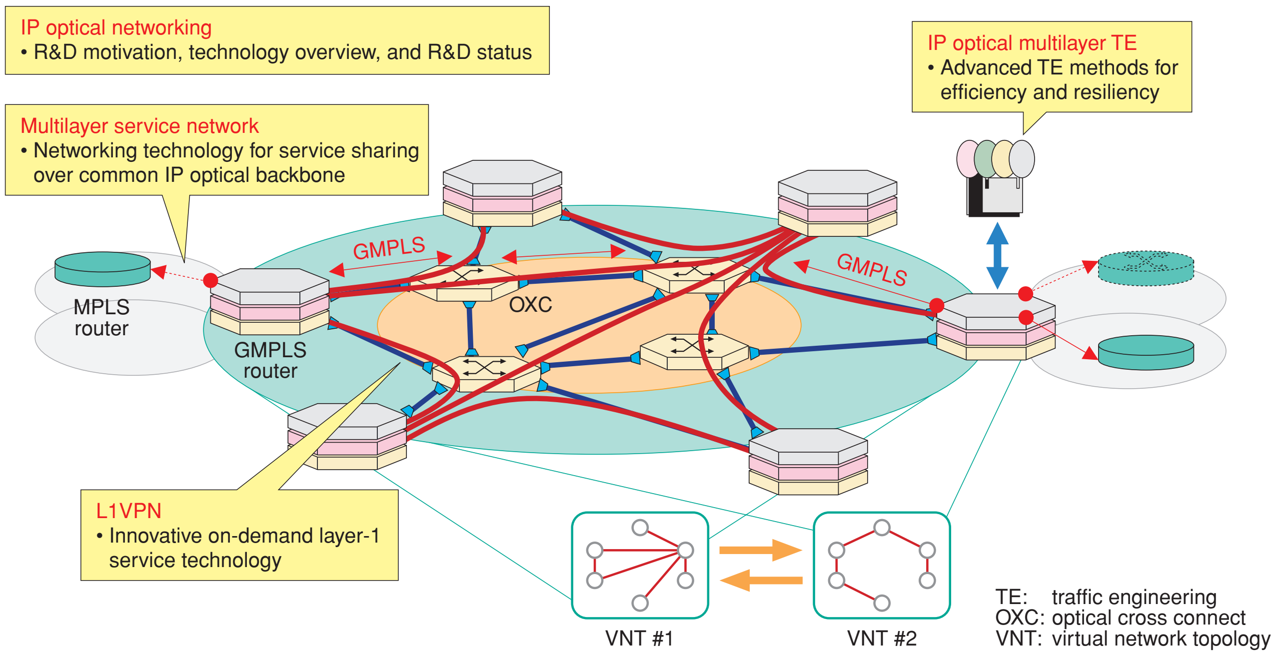

Fig. 1. IP optical networking.

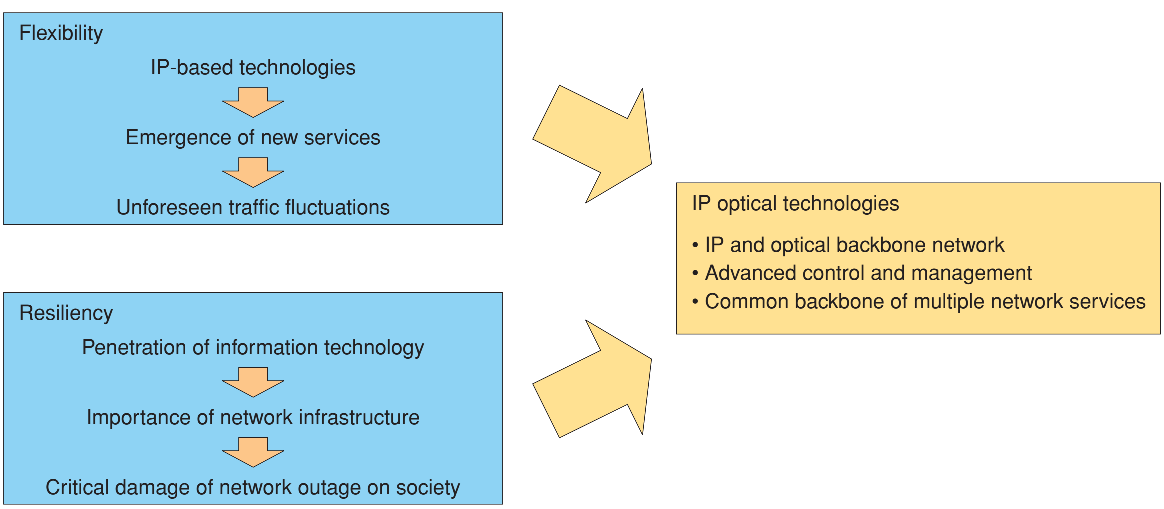

Fig. 2. Targets of IP and optical technologies.

the IP layer may actually exist in the same physical conduit in the optical layer.

A key technology driving integrated control and management across IP and optical layers is GMPLS[*1], which is a generalized version of MPLS (multiprotocol label switching). MPLS, which has been used to innovate IP layer network management, introduces the notion of a path called a label switched path (LSP) to innovate network control and management in the IP layer. GMPLS controls LSPs not only in the IP layer but also in the optical layer, so it enables integrated control and management of both layers.

*1 GMPLS: Generalized multiprotocol label switching. The concept of a label used in MPLS is extended to treat in a unified way various kinds of switching technologies such as L2 (layer-2), TDM (time division multiplexing), lambda (wavelength), and fiber switching. Standardization is under way in the IETF [4].

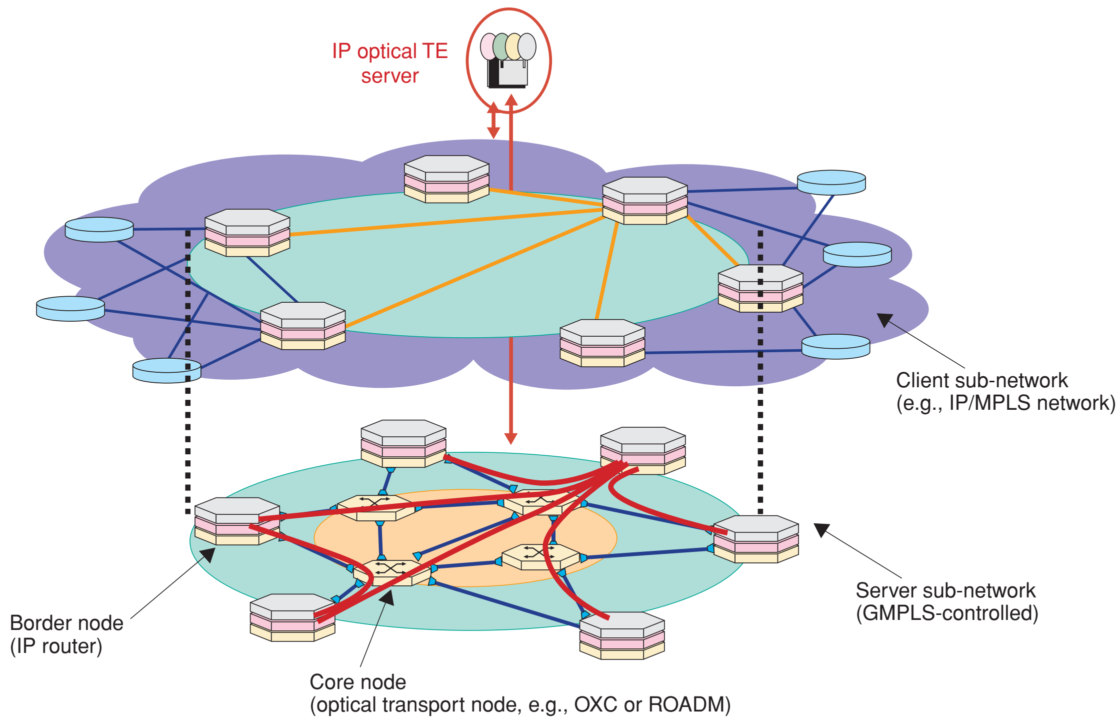

Fig. 3. IP and optical network architecture.

3. Technology overview

First, we describe the IP and optical network architecture. Then, we overview three key technology elements: the multilayer service network, L1VPNs, and multilayer traffic engineering.

3.1 Network architecture

Figure 3 shows the network architecture, where IP and optical networking technologies are used. The network consists of server and client sub-networks. The former provides the functionality of the backbone network, while the latter instantiates various network services.

The server sub-network consists of core and border nodes. A border node is an IP router, which is located between the server and client sub-networks. A core node is an optical transport node such as optical cross-connect (OXC) node or reconfigurable optical add-drop multiplexer (ROADM), which does not perform packet processing in the data plane but performs high-bandwidth circuit switching.

The server sub-network is controlled via GMPLS, which is capable of integrated control of IP and optical layers. The GMPLS protocol suite consists of signaling, routing, and link-management protocols, which enable LSP establishment, topology information retrieval, and link management [5], [6]. For example, an LSP is established using the signaling protocol along the route, which is computed using the topology information collected by the routing protocol. A link between an IP router and an optical transport node is managed by the link management protocol.

An IP optical TE server is a key element in the IP and optical networking technologies. It provides multilayer traffic engineering*2 (TE) functions across IP and optical layers. It communicates with IP routers and optical transport nodes using standard protocol technologies including PCE*3 [3]. It lets network operators customize their TE algorithms for multilayer path computation and optical path establishment/release facilitating IP topology reconfiguration based on their policies [3]. In Fig. 3, the IP optical TE serv-

*2 Traffic engineering: A framework for optimizing network performance such as delay, loss, or throughput while reducing the required amount of network resources by conducting path computation and topology computation.

*3 PCE: Path computation element. A path computation function is defined as an entity logically separated from forwarding and routing entities. It is implemented as either part of a node (e.g., an IP router or optical transport node) or in a separate server.

er is responsible for multilayer path computation across IP and optical layers and optical path establishment/release, which facilitates IP topology reconfiguration.

3.2 Multilayer service network [1]

The multilayer service network is a technology for building multiple service networks over a single common backbone network based on IP and optical networking technologies. It aims at reduced network cost by having multiple network services share the common backbone network resource. There is a clear separation of control and management between the client network and the server network. The routing, network, and addressing designs of the client network are independent of those of the server network.

The border node plays a central role in the correlation between service networks (client networks) and backbone network (server network). It has interface functionalities to the client network, which are implemented in separate control plane instances. This provides independence between the client and server networks. On the other hand, the border node performs resource optimization between the client and server networks. In addition, the impact of the server network's behavior on the client network is minimized by virtualization, which controls the resource mapping between the client and server networks [1].

3.3 L1VPN [2]

L1VPN provides a virtual private network using layer-1 paths with various capacities ranging from low to high bandwidth. Optical paths are established on demand between nodes where high volumes of traffic demand are requested. The layer-1 path provides format-free data transport and enhances the quality, reliability, and security of the service.

L1VPN provides a customer control mechanism such as network monitoring, resource management, usage-based admission control, availability class of service, and connection services such as intranet and extranet, which are customized for each user. An example of the application of L1VPN is the provision of multiple service networks over a single common optical network. Independent network management is provided while keeping existing operation scenarios. This feature is attractive, especially when different business units provide different services. Another application includes optical path provisioning with a relatively short hold time, either on demand or based on scheduling. This service will be attractive for high-volume data backup between distant data centers, video transmission, and grid computing.

3.4 Multilayer traffic engineering [3]

Multilayer traffic engineering is a technology for unified resource management across IP and optical layers. It enhances network resource utilization and provides network resiliency. IP and optical layers have traditionally been controlled and managed independently, which means that network resources are managed and optimized independently. Another problem is that network resiliency may be compromised even if diverse routes are prepared in the IP layer because they may share a common link in the optical layer. If IP and optical layers are controlled and managed in a coordinated manner, network resources can be optimized across layers and completely diverse routes can be easily computed across layers. Multilayer traffic engineering algorithms are implemented in the IP optical TE server, in which network operators can implement their own algorithms based on their own network policies [3].

4. R&D status

Several telecom operators and vendors are conducting R&D of the backbone network based on IP and optical networking technologies. Efforts have been made in the area of network elements including IP routers and optical transport nodes, servers including network management systems and traffic engineering server, and communication protocols. In this article, we report on the status of R&D conducted in NTT Network Service Systems Laboratories.

We are actively involved in international standardization efforts in the IETF and the ITU, collaborating with telecom operators and vendors (**Fig. 4**). We are conducting experiments on a testbed built in our laboratories using commercial network element equipment (IP routers and optical transport nodes) controlled by the standard GMPLS protocols. In addition, we have been participating in the interoperability test events held by ISOCORE [7] and UNH [8] in North America and have been contributing to interoperability enhancement [9]. We have also been developing a prototype system of the IP optical TE server and conducting experiments on multilayer traffic engineering over this testbed, where commercial IP routers and optical transport nodes are controlled by GMPLS protocols [10], [11]. The initial proof of concept has been demonstrated publicly at several international conferences such as iPOP 2006.

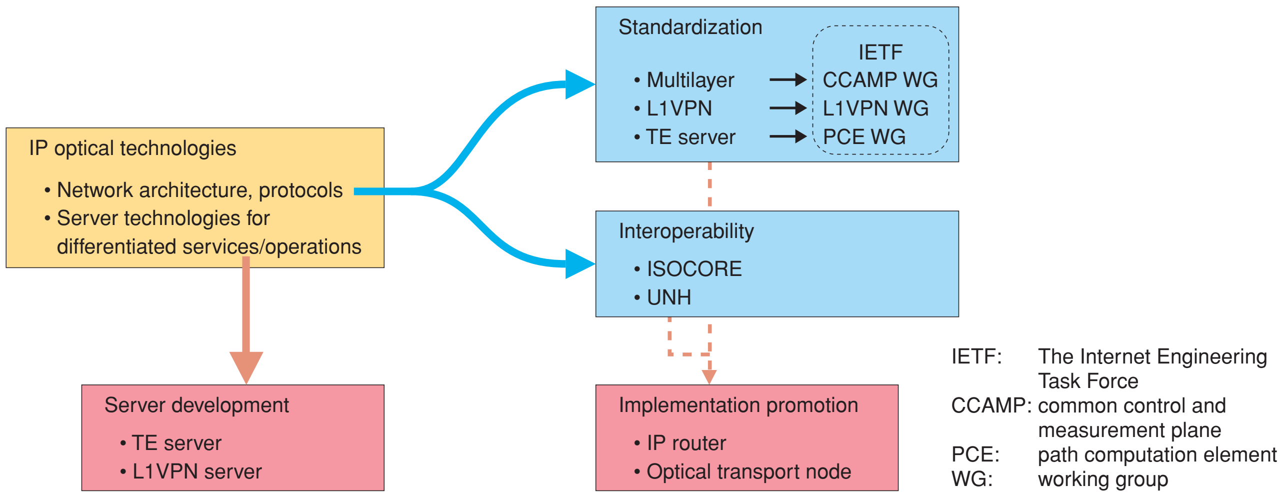

Fig. 4. R&D status of IP and optical networking technologies.

5. Future outlook

We intend to continue promoting R&D of IP optical networking technologies. We will evaluate them by conducting large-scale experiments on nationwide networks, promote their introduction in commercial network element equipment, and conduct R&D to enhance the IP and optical TE server by adding features for realistic operational scenarios.

As IP-based networking technologies are deployed in the telecommunication infrastructure, various unforeseen network services will emerge. IP and optical networking technologies will bring about the innovations in network control and operation needed for such an era.

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