able topology should never operate in that severely congested state. Network capacity increment is a more proper viewpoint when talking about reconfiguration benefits. This is achieved through more efficient allocation of network resources, which can diverge loads on congested links to less utilized ones (see Figure 4).

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References

TuP5 3:30 pm
A Heuristic Multi-Layer Optimum Topology Design Scheme Based on Traffic Measurement for IP + Photonic Networks
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1. Introduction
The explosion of Internet traffic has led to a greater need for high-speed backbone networks. The speed of Internet-protocol (IP) traffic growth exceeds that of IP packet processing capability. Therefore, next-generation backbone networks should consist of IP routers with IP packet switching capability and optical cross-connects (OXC) with wavelength-path switching capability to reduce the burden of heavy IP packet switching loads. In addition, IP traffic fluctuates often over hours and days.

A photonic MPLS router has been developed by NTT. It has both IP packet switching and wavelength-path switching capabilities. Wavelength paths, called optical label switch paths (OLSP) are set and released in a distributed manner based on the generalized multi-protocol label switch (GMPLS). Since the photonic MPLS router has both switching capabilities and can handle GMPLS, it enables us to create the optimum network configuration considering IP and photonic network resources in a distributed manner.

Multi-layer traffic engineering, which yields the dynamic cooperation of IP and photonic layers, is required to provide IP services cost-effectively. This paper proposes a heuristic-based multi-layer topology design scheme that uses IP traffic measurements. The proposed scheme yields the optimum OLSP network topology, i.e. OLSP placement, to minimize network cost, in response to fluctuations in IP traffic demand. In other words, OLSP network topology is dynamically reconfigured to match IP traffic demand.

2. Framework of multi-layer traffic engineering based on IP traffic measurements
The structure of the photonic MPLS router is shown in Figure 1.1,2 It consists of an IP router, wavelength router, and photonic-MPLS-router manager. In the photonic-MPLS-router manager, the GMPLS controller distributes own IP and photonic link states, and collects link states of other photonic MPLS routers. IP traffic is always monitored, and the captured data is passed through a low-pass filter and reported to the GMPLS controller. A multi-layer topology design algorithm processes the collected IP and photonic link states and the collected traffic data.

An example of the photonic-MPLS-router network is shown in Figure 2. Some source-destination IP router pairs use a transit IP router to carry their IP traffic while others pass their IP traffic across a direct OLSP. Each IP router monitors IP traffic and, when the traffic volume becomes heavy, a cut-through path is set by using the GMPLS signaling protocol of the constrained-based routing label distribution protocol (CR-LDP).

3. Topology design scheme
The bandwidth granularity of the photonic layer is coarse and equal to wavelength bandwidth, A, i.e. 2.5 Gbit/s or 10 Gbit/s. On the other hand, the granularity of the IP layer is flexible and well engineered.

When traffic demand between source and destination IP routers is much less than λ, the cut-through wavelength path between the source-destination IP routers is not fully utilized and so is not cost-effective. In this case, the IP traffic should be merged at some IP transit routers with other source-destination IP traffic to utilize the wavelength bandwidth at the cost of IP-packet processing at the transit nodes. On the other hand, when traffic demand between source and destination IP routers approaches or exceeds λ, a cut-through wavelength path should be set between the source-destination IP routers.

Thus, the setting of cut-through paths between source-destination IP routers depends on IP traffic. Therefore, the OLSP topology of the photonic layer would change dynamically according to the fluctuation in IP-traffic demand to optimize network resource utilization.

For this purpose, our objective is to minimize network cost Z formulated as follows.

\[
Z = C_{\text{node}} + C_{\text{link}} = \alpha \sum_{p} \sum_{l} p_{l} + \beta \sum_{l} \sum_{j} \sum_{k} \sum_{p} i_{pk} l_{jk} \quad (1)
\]

where \( p_{l} \) is the cost of port \( p \) in router \( l \), \( l_{jk} \) is the cost of wavelength path \( k \) at port \( p \) in fiber link \( ji \), \( \alpha / \beta \) is the node/link ratio. \( \alpha / \beta \) is set to more than one, because IP routers have IP-packet processing functions such as table lookup and packet-based switching in addition to wavelength routing functions.

To minimize \( Z \), we adopt the extended version of a BXCQ (branch exchange with quality-of-service constraints) scheme presented in, named EBXCQ. The BXCQ scheme was originally intended for multi-layer ATM network design. In EBXCQ, the addition-and-elimination of links is iterated to solve a topological optimization problem with quality-of-service constraints, such as delay and blocking probability. In EBXCQ, the number of ports in both IP routers and wavelength routers, as well as the number of wavelengths per fiber are also considered as constraints in addition to the constraints considered in BXCQ.

4. Numerical results
We demonstrate the effectiveness of EBXCQ by using a LATA network model, see Figure 3.5

Figure 4(a) shows that the optimum OLSP topology changes with the IP traffic demand between source-destination IP routers. We assume that IP traffic demands between source-destination IP routers are evenly distributed and that each wavelength is converted to another one at each photonic MPLS router. Wavelength bandwidth is set to 2.5 Gbit/s. In order to evaluate OLSP network topologies, the average node degree, \( \bar{D} \), is used. We use \( \bar{D} \) to characterize the OLSP network topology. \( \bar{D} \) is the average number of other IP routers to which individual IP routers are connected by OLSPs. As traffic demand increases, the optimum OLSP topology becomes a mesh because each OLSP bandwidth would then be effectively utilized.

Changing the OLSP topology according to traffic demand fluctuations dramatically reduces network cost. An estimation of network cost re-
The paper presents a heuristic-based multi-layer topology design scheme, called EBXCQ, for photonic networks. By monitoring IP traffic loads, photonic MPLS routers are controlled to dynamically change the network configuration to efficiently utilize the network resources in a distributed manner.

References:

TuP6 Fig. 1. NJ LATA.

TuP6 Network architectures for supporting survivable WDM rings

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1. Introduction
Wavelength Division Multiplex (WDM) based networks consist of a logical topology, defined by a set of nodes and lightpath connections and a physical topology, defined by the set of nodes and the fiber connecting them. Although both the logical and physical topologies may be independently tolerant to single link failures, once the logical topology is embedded on the physical topology, the logical topology may no longer be survivable to single physical link failures. Each physical fiber link may carry multiple lightpaths. Hence, the failure of a single physical link, can lead to the failure of multiple links in the logical topology which may subsequently leave the logical topology disconnected. Our focus is on the design of physical topologies capable of supporting ring logical topologies in a survivable manner. While there has been a great deal of work in the area of optical layer protection, this survivable routing formulation is a new approach: to network protection that has significant implications on the design of future WDM-based networks.

We considered the problem of embedding ring logical topologies on a given physical topology in a manner that ensures the logical topology remains connected in the event of a physical link failure. We call such embeddings "survivable." One of the key results observed is that for many physical topologies it is not possible to embed ring logical topologies in a survivable manner. For example, nearly 50% of 9 node rings cannot be embedded, in a survivable manner, in the 11 node NJLATA network shown in Figure 1. Similar results were also obtained for other commonly used physical topologies. Hence, in this paper we focus on the dual problem: How should the physical topology be designed so that it can support logical rings in a survivable manner? In particular, we investigate properties of physical topologies that enable multiple logical rings to be established in a survivable manner and use these properties to design suitable physical topologies.

We consider the design of N node physical topologies that can support survivable routings of ring logical topologies of size K ≤ N. Note that a ring of size 3 can be embedded in a survivable manner on any 2-connected physical topology.

TuP5 Fig. 2. Cut-through path set up driven by traffic measurements.

TuP5 Fig. 3. LATA network model.

TuP5 Fig. 4. Numerical examples produced by the proposed design scheme.