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PCE-based fast path control in multi-domain photonic networks

Yohei Iizawa [a,*], Soichiro Araki [a,b], Shinya Ishida [c], Itaru Nishioka [c], Kohei Shimada [b], Hiroshi Hasegawa [b], Ken-ichi Sato [b]

[a] NEC Corporation, Japan
[b] Nagoya University, Japan
[c] NEC Corporation of America, USA

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ABSTRACT

We discuss issues for controlling an optical path in large-scale photonic networks, and introduce an inter-domain path control system based on Path Computation Elements (PCEs). In the system, maximum flow information enables the load balancing of traffic, and Path Key scheme preserve the confidentiality of internal topology information among carrier networks. Based on the experimental results, we show the path setup in the introduced system is significantly faster than the manual path setup among domains in current carriers' networks. For the additional reduction of the path setup time, we propose the domain-wise paralleled signaling method. We also show that decreasing the number of nodes per domain makes path setup faster in the introduced system with deployment of the proposed signaling method.

1. Introduction

The amount of traffic in core networks has been exponentially increasing due to rapid adoption of broadband services, such as Asymmetric Digital Subscriber Line (ADSL), Fiber To The Home (FTTH), and mobile wireless access. Moreover, cloud services provided by large datacenters have also been increasing traffic recently. Photonic network technology is a key for cost-effective and energy-efficient core networks, which can reduce costly OEO and electrical routing at intermediate nodes [1]. Furthermore, end-to-end rapid provisioning of connection service requests through metro and core photonic networks is becoming more important for accommodating increasing and unpredictable IP traffic.

Automatic Switched Optical Network (ASON)/Generalized Multi-Protocol Label Switching (GMPLS) [2] control plane technologies have been developed for automated path control of photonic networks over the past decade. In the past few years, the control plane technologies have been deployed in commercial networks, and their advantage in terms of operational expenditure (OPEX) reduction was reported [3]. Since most of these networks are still relatively small, constructed with a few tens of nodes, OPEX can be reduced more effectively when those control plane technologies are deployed to larger nation-wide networks. To control larger networks, typically thousands of nodes, the dynamic optical path control system should be developed considering scalability of routing protocol, confidentiality among carrier domains, and guarantee of the optimal routes.

We introduce a dynamic optical path control system for large-scale photonic networks, and show its performance in terms of the path setup time based on the experimental results. For the additional reduction of the path setup time, we propose the domain-wise paralleled signaling, and show the relation between the path setup time and domain size. In practice, the domain size is determined by not only the path setup time but also

* Correspondence to: NEC Corporation, 1753, Shimonumabe, Nakahara-ku, Kawasaki, Kanagawa JAPAN 211-8666.
Tel.: +81 44 396 2610; fax: +81 44 431 7644.
E-mail address: y-iizawa@cd.jp.nec.com (Y. Iizawa).

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policies of each carrier. The rest of this paper is organized as follows. In Section 2, we discuss issues of optical path control in large-scale photonic networks. In Section 3, we introduce the PCE-based inter-domain path control system for large-scale photonic networks and propose the domain-wise paralleled signaling method. In Section 4, we evaluate the path setup in our system through experiments.

2. Issues of optical path control in large-scale photonic networks

There are three issues to apply GMPLS to a large-scale photonic network. First, the scalability of routing protocol should be ensured, second, confidentiality among carrier networks should be preserved, and finally, the inter-domain routing model should be able to guarantee the optimality of routes. For solving these issues, a photonic network is made up of domains, which are routing areas or administrative regions, and PCEs enable optimal path computation in the multi-domain network.

2.1. Scalability of routing protocol

Open Shortest Path First with Traffic Engineering (OSPF-TE) is standardized as a routing protocol of the GMPLS protocol suite [4]. Link states in a network are advertised by flooding among network nodes. Therefore, the control messages of OSPF-TE increases as the number of nodes in the network increases. As a result, not only the load of the control plane but also the convergence time of topology information in each node increases. When path provisioning is performed without convergence of the topology information, improper routes are selected or path setups are failed. To solve the problem, dividing a network into two or more domains is effective. Because the advertisement area of the link state update message is limited within each domain, the load of the control plane and the convergence time of the topology information can be decreased.

Fig. 1 shows measured convergence times of OSPF-TE. In the experiment, the convergence time means the term from the first advertisement of the link state update message to the last receipt of the link state acknowledgement message by a path setup. The link state update ("LS Update" in Fig. 1) and the link state acknowledgement ("LS Ack" in Fig. 1) messages of OSPF-TE were counted for single-domain and multi-domain networks, each of which consists of 1000 emulated nodes and controlled by GMPLS. And we measured the convergence time in 15 trials of a 27-hop path provisioning. The 27-hop path traversed five domains in the multi-domain network, in which each domain consists of 40–50 nodes. The average of the convergence time was 19.5 s in the single-domain network while it was 6.9 s in the multi-domain network. As a result, even if it is a large-scale network, the convergence time of OSPF-TE can be significantly decreased by dividing into multiple domains compared to a single-domain network.

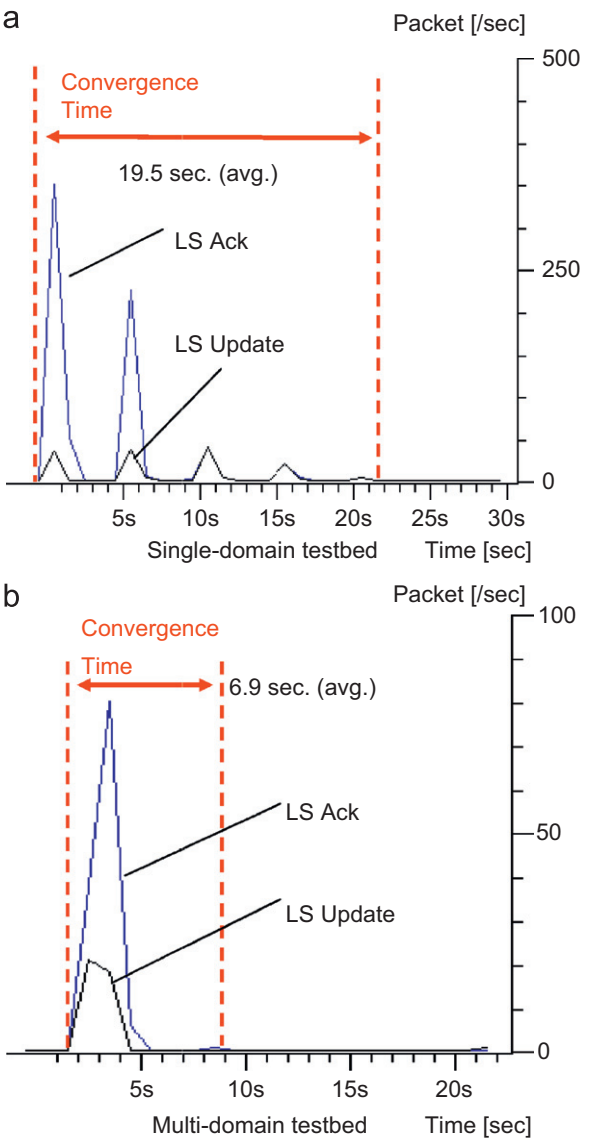

Fig. 1. Comparison of OSPF-TE convergence time between single-domain and multi-domain networks. (a) Single-domain network and (b) multi-domain network.

2.2. Information confidentiality among carrier networks

Carriers conceal internal topology information of their networks from other carriers since the information includes essential management information, and each carrier network is separated as a domain. When a path over different carrier networks is set up, the visibility of all carriers' networks allows optimization of the end-to-end route. However, it is not possible to preserve the confidentiality of carrier networks while attaining full routing efficiency.

Therefore, the inter-domain routing model in a large-scale photonic network should enable optimal route computation without sharing internal topology information among domains.