Optical Path Generation Strategy and Network Performance in Dynamic Multi-Layered IP+Photonic GMPLS Network

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Abstract: This paper proposes dynamic optical-path generation algorithms and evaluates the impact of these on the performance of the IP+Photonic multi-layered GMPLS network comprising label-switching routers with integrated packet and lambda switching capability. The optical label-switched path (O-LSP) Creation First (OCF) strategy provides excellent throughput in the case of high network capacity.

I. Introduction

Photonic routers (PRs) with unified packet switching and lambda switching capabilities that are controlled by Generalized Multi-Protocol Label Switching (GMPLS) can dynamically establish both electrical/optical label-switched paths (E-LSP/O-LSP) [1]. This paper discusses the algorithms that generate O-LSPs and evaluates the impact of these algorithms on the performance of the dynamic multi-layered IP+Photonic GMPLS network employing PRs.

II. IP+Photonic GMPLS Network and Photonic Router

The architecture of the GMPLS based PR and dynamic IP+Photonic multi-layered network discussed in this paper are shown in Fig. 1. The PR mainly comprises packet switch capable (PSC) switching IP packets and E-LSPs, lambda switch capable (LSC) switching O-LSPs, and a GMPLS controller. The GMPLS controller contains extended functional blocks such as RSVP-TE/CR-LDP and OSPF/IS-IS protocols for dynamic routing of IP packets, E-LSPs, and O-LSPs [2]. Therefore, the PR recognizes the network topology of both an IP network comprising PSCs and established O-LSPs, and a photonic network comprising LSCs and fiber links. The GMPLS controller has the capability to determine the routing path of E-LSPs using not only existing O-LSPs, but also fiber links with unused bandwidth. In some cases, the GMPLS controller dynamically creates new O-LSPs, if there is no usable O-LSP along the routing path of an E-LSP (E-LSP driven O-LSP generation). In another case, the PR generates a so-called cut-through O-LSP triggered by packet monitoring in the PR (IP flow driven O-LSP generation). The O-LSP is generated by using RSVP-TE or CR-LDP. The control signals are transferred via out-of-band control channels.

III. E-LSP Routing and O-LSP Generation Strategy

In the IP+Photonic network, one O-LSP transports multiple E-LSPs. The routing path of the E-LSP is determined by calculating not only the existing O-LSP, but also fiber links. When the path of the E-LSP through these fiber links is advantageous, the GMPLS controller dynamically creates a new O-LSP to accommodate the E-LSP. The GMPLS controller identifies the cost of the fiber links as the creation cost of new O-LSPs along these routes. Therefore, the cost ratio of established O-LSPs and fiber links between the same span easily affect the incidence of O-LSP generation. Also, a limit on the number of hops of O-LSPs that transport one E-LSP affects the network performance. From these viewpoints, this paper evaluates the following E-LSP routing/O-LSP generation strategies.

A. O-LSP Creation Last (OCF) routing strategy:

This routing strategy imposes no constraints on the number of hops of O-LSPs to transport one E-LSP. Also, this strategy allocates a low cost to existing O-LSPs. In this strategy, the GMPLS controller minimizes the cost to create new O-LSPs and takes a conservative approach towards creating new O-LSPs.

B. O-LSP Creation First (OCF) routing strategy without an O-LSP hop limit:

This routing strategy searches for a one-hop O-LSP path to accommodate the E-LSP in the first attempt in route calculation. If the generation or the use of an existing one-hop O-LSP is blocked, this routing strategy searches for a new route for the E-LSP. In the second attempt, this routing strategy imposes no constraints on the number of hops of O-LSPs to accommodate one E-LSP. As for creating new O-LSPs, this routing strategy adopts a positive approach.

C. OCF routing strategy with an O-LSP hop limit:

This routing strategy searches for a one-hop O-LSP path. If the generation and the use of one-hop O-LSP are blocked, the generation of the E-LSP is also blocked.

IV. Simulation

In this paper, the LATA network [1] with 11 nodes, wavelength converters, and 23 fiber links was used as the simulation network. Figure 2 shows the network topology and the normalized network capacity (NNC) for the LATA network. Here, the NNC was defined as the required number of wavelength channels in each fiber link and the switch size in each node to accommodate full-mesh 55 bi-directional O-LSPs between all 11 nodes. Here, we...
assumed each node has wavelength converters for all wavelength channels. In the simulation, the routing paths of the E-LSPs were calculated by the Dijkstra algorithm using the cost metric. The cost of the fiber links was allocated to have the same cost regardless of the span length. On the other hand, the cost of the O-LSPs to accommodate E-LSPs was given as 0.9 times the cost of the fiber links that transport the O-LSP in the case of the OCF routing strategy, and 0.1 times in the case of the OCL routing strategy. We assumed each O-LSP can accommodate 16 E-LSPs. The average volume of E-LSP traffic originating from the nodes was evenly distributed and each E-LSP bandwidth was assumed constant. In this paper, we evaluate two kinds of E-LSP traffic models. The first is an incremental and semi-permanent E-LSP traffic model. This model assumes the addition of Soft Permanent Connections (SPCs) of E-LSPs. The second is a dynamic and generation-annihilation traffic model. This model assumes future burst switching networks.

V. Results

Figure 3 shows the supportable E-LSP traffic load for the OCL and OCF routing strategies in the case of the incremental and semi-permanent traffic models. The OCL routing strategy achieves better performance for low network capacity, while the OCF routing strategy achieves better performance for high network capacity larger than 1.5 times that of the NNC. It is obvious that there is a trade-off between these strategies as a function of the network capacity. In a low capacity network, generating O-LSPs is more advantageous than E-LSPs so that the blocking probability of the OCF quickly increases with the network load. However, the OCF is advantageous when the probability of establishing an O-LSP is high, since the number of O-LSPs used to transport one E-LSP tends to be small compared to the OCL strategy.

Figure 4 shows the supportable E-LSP traffic load in the case of the dynamic and generation/annihilation traffic model. The OCL routing strategy achieves better performance for low network capacity, while the OCF routing strategy achieves better performance for high network capacity. However, the difference between the OCF and OCL strategies becomes small in the case of high network capacity. In the dynamic model, an inefficient E-LSP that hops multiple O-LSPs is also annihilated as time progresses. The probability of discovering a direct O-LSP to accommodate the E-LSP becomes high, in a consistently high capacity network. For a network that is larger than two times that of the NNC, neither the O-LSP generation nor E-LSP grooming strategy significantly impact the networking performance. In such high capacity networks, the efficient usage of fiber links becomes an important issue.

VI. Conclusion

This paper investigated O-LSP generation algorithms driven by E-LSP traffic for both of incremental and dynamic E-LSP traffic models. The simulation results showed that the performance of the IP+Photonic network is heavily dependent on the strategy of the E-LSP grooming and O-LSP generation as discussed in /3/. This paper elucidated that the OCF routing strategy outperforms the OCL routing strategy, if the normalized network capacity is greater than 1.5 for the incremental traffic model, and greater than 2.0 for the dynamic traffic model.

Acknowledgement

The authors thank Mr. I. Yamawaku for his help with the simulation. The authors also thank Dr. K.-I. Sato and Dr. M. Kawachi for their support of the study.

References

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