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Demonstration of a GMPLS-controlled Transparent Optical Network with Wavelength Continuity Constraint

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Abstract *The applicability of a GMPLS extension supporting global wavelength information was investigated to efficiently establish an end-to-end light path. A GMPLS-controlled multi-ring transparent optical network was successfully demonstrated considering wavelength continuity and a multi-vendor environment.*

Introduction

By eliminating expensive O/E/O conversion in intermediate optical nodes, an optical transparent network can simplify architecture and reduce capital expenditure as compared with an existing opaque network. Furthermore, its bit-rate and data-format free features enable the optical transparent network not only to offer higher and flexible transparent bandwidth to the client, but also to be easily upgraded to meet future unpredictable bandwidth demands if required. On the other hand, the introduction of a Generalized Multi-Protocol Label Switching (GMPLS) control plane [1] into the optical transparent network is expected to bring more intelligence and to control the end-to-end light path in a cost-effective manner.

However, in order to provision a light path with acceptable signal integrity in such a transparent network, some physical parameters need to be fully considered. One of them is the wavelength continuity constraint due to the lack of wavelength converters, which may result in a high blocking probability and inefficient utilization of wavelength channels if dealt with improperly. Therefore, it is necessary to advertise wavelength availability information and consider it in the Constrained-based Shortest Path First (CSPF) calculation. In the current Open Shortest Path First with Traffic Engineering extensions (OSPF-TE) [2] definition, the Link Color attribute can be used to carry the wavelength availability information [3]. Only 32 bits are available at maximum in the Link Color field, which is not enough to cover all wavelengths in the current DWDM channels with more than 80. Although the introduction of a dedicated sub-Type Length Value (TLV) for the top-level TE-link TLV in the OSPF-TE type 10 opaque Link Status Advertisement (LSA) was proposed [4] in order to provide a wavelength mask with a variable length, actually the single wavelength bit-mask only has local meaning and could not precisely identify the specific DWDM wavelength. This will result in the degradation of network scalability or even fail to interwork in a multi-vendor environment unless the same bit-mask is commonly configured at all nodes.

As for Resource Reservation Protocol with Traffic Engineering extensions (RSVP-TE) [5], the current solution only provides a Label Set object to restrict labels equivalent to wavelengths, which could be used on the downstream side. When precise wavelength availability information is not available, however, a loose hop expansion scheme has to be employed, which may require crankback signaling and inevitably degrade the performance. Therefore, wavelength information with global meaning in the whole network is indispensable [6].

This paper presents experimental results for the applicability of a GMPLS extension to define a standardizing wavelength label to advertise wavelength availability information with global meaning. A GMPLS-controlled multi-ring network was successfully demonstrated considering wavelength continuity and a multi-vendor environment.

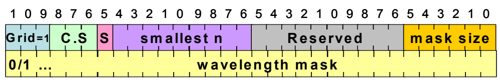
Implemented GMPLS extensions supporting global wavelength information

In order to support the global wavelength information, a definition of wavelength, which we are jointly proposing to standardize [6], as shown in Fig. 1, was employed but modified to support a 200 GHz spacing. Based on the ITU-T DWDM grid, a central frequency of 193.0 THz was selected and all wavelengths were calculated as:

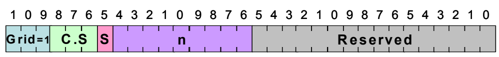
$$f\ (\mathrm{THz}) = 193.0\ \mathrm{THz} + n * CS\ (\mathrm{THz})$$

where 'CS' is set to 1, 2, 3, 4 or 5 to indicate the channel spacing of 12.5, 25, 50, 100 or 200 GHz respectively; 'n' represents the positive ('s'=0) or negative ('s'=1) offset to the central frequency.

Therefore, as shown in Fig. 1 (a), when the smallest wavelength is specified in the sub-TLV for the TE-link, each bit in the wavelength mask field can identify the availability of a specific wavelength. On the other hand, when this standardizing label with global meaning is applied in RSVP-TE as shown in Fig. 1 (b), a Label Switch Path (LSP) with an explicitly specified wavelength can be provisioned.



a) Wavelength availability information in OSPF-TE



b) Wavelength label in RSVP-TE

Fig.1 GMPLS extension supporting wavelength information

Experimental results

As shown in Fig. 2, a GMPLS-controlled multi-ring transparent network was constructed with two Reconfigurable Optical Add-Drop Multiplexer (ROADM) nodes and one Wavelength Cross Connect (WXC) node, which were based on Wavelength Selective Switches

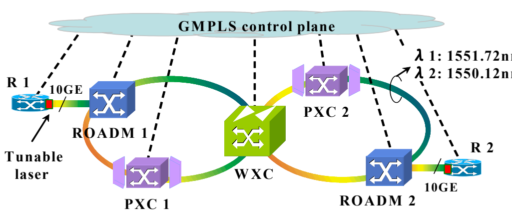


Fig.2 Experimental setup for evaluating a GMPLS-controlled transparent optical network

(WSS) with 100 GHz spacing. Fig. 3 shows the architecture of the ROADM and WXC nodes. In order to investigate the applicability of standardizing wavelength labels in a multi-vendor environment, two Photonic Cross Connect (PXC) nodes integrated with DWDM MUX/DEMUX optical filters with 200 GHz spacing were intentionally inserted into the ring. Furthermore, core routers were utilized at the ingress and the egress and equipped with a 10 Gigabit Ethernet (GbE)-based colored interface of Optical Transport Network (OTN) framing and a C-band full tunable laser with a 50 GHz step [3]. For simplicity, only two wavelengths (λ1=1551.72 nm / 193.2 THz, λ2=1550.12 nm / 193.4 THz) were supposed as the available TE link resource along rings.

In the experiment, transparent TE links in the ring were advertised as having a switching type of Lambda Switching Capability (LSC) and an encoding type of Lambda. Considering the current limitation of optical transmission, the bandwidth per wavelength of TE links was set to 40 Gbit/s. Such a transparent link can be selected as a transit link for a LSP whose required bandwidth is less than 40 Gbit/s [7]. Wavelength availability information as shown in Fig. 4 was also observed in OSTF-TE flooding messages. Due to the different channel spacing at PXCs, ROADM/WXCs and Routers, the smallest wavelength, which was set to λc (193.0 THz) at all nodes for simplicity, was encoded as 0x34000000, 0x30000000 and 0x2C000000 respectively. In terms of the wavelength mask, PXC nodes set it to '011', where the 2nd and 3rd nonzero bits indicated the two supposed wavelengths λ1 (0x34010000) and λ2 (0x34020000) were available. On the other hand, the bit-mask was set to '00101' corresponding to λ1 (0x30020000) and λ2 (0x30040000) at ROADM/WXCs. The all-one bit-mask was used at routers to indicate all C-band wavelengths were supported by the tunable laser.

After these sets of advertised wavelength information were successfully exchanged and injected into the Traffic Engineering (TE)-Database, an enhanced CSPF calculation with consideration of wavelength continuity constraint could be conducted. When a LSP with 10 GbE bandwidth from R1 to R2 was initiated, the ingress link and egress link with 10 GbE bandwidth were firstly selected, and then a series of transit links with wavelength continuity constraint were selected along the shortest path of ROADM1-WXC-ROADM2, and the wavelength would also be determined. Since both λ1 and λ2 were available, the first-fit wavelength λ1 was selected by default. Then, the laser in R1 was controlled to be tuned to λ1, and simultaneously a PATH message with Label Set of λ1 was sent out. All intermediate nodes parsed the label in the received Label Set object based on the local wavelength configuration, and then forwarded it to the downstream side. After the PATH message arrived at the egress router R2, it acknowledged the PATH creation request by sending back a RESV message. R2 also controlled the laser to tune to λ1 since the GMPLS LSP is bidirectional by default.

When λ1 in the TE link between ROADM1 and WXC and λ2 in the TE link between WXC and ROADM2 were intentionally occupied and the aforementioned LSP was re-initiated, the previous shortest path was pruned out due to the wavelength

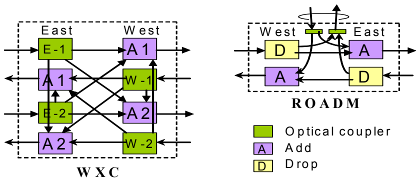
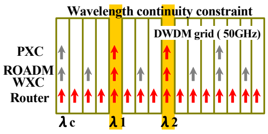
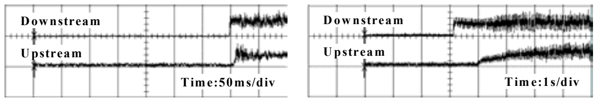


Fig.3 Node architecture of WXC and ROADM



Available wavelengths		OSPF-TE	
λ1	λ2	Smallest λ = λc	Mask
0x34010000	0x34010000	0x34000000	0b0110 …
0x30020000	0x30040000	0x30000000	0b001010…
0x2C040000	0x2C080000	0x2C000000	0b111111…

Fig.4 Wavelength availability information with different channel spacing



a) Without tuning of the laser b) With tuning of the laser
Fig.5 Optical path setup latency along R1-ROADM1-PXC1-WXC-ROADM2-R2

continuity constraint and the transit links were selected along the second shortest path via ROADM1, PXC1, WXC and ROADM2.

Finally, the setup latency of LSPs was evaluated. In the case of no tuning, the latency to establish the second route was about 300 ms on the control plane and 350 ms on the data plane. The difference resulted from the switch setup latency, but it was not so large. On the other hand, in the case of tuning to a new wavelength, the final bidirectional path was established up to 4 seconds, as shown in Fig. 5. For faster path establishment, it is indispensable to speed up tuning the wavelength.

Conclusions

We have investigated and implemented a GMPLS extension in support of global wavelength information so that wavelength availability information with global meaning could be advertised by OSPF-TE, and generalized label could be used to control optical nodes by RSVP-TE. By using this extension, an end-to-end light path with consideration of wavelength continuity constraint was successfully established even in a transparent optical network consisting of all-optical switching nodes with different wavelength spacing. We have confidence that this extension is quite beneficial for further improving the network control and management in future transparent optical networks and is expected to be standardized.

Acknowledgement

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