12th Optoelectronics and Communications Conference/16th International Conference on Integrated Optics and Optical Fiber Communication (OECC/IOOC2007)
Technical Digest, July 2007, Pacifico Yokohama

12A2-2

A Field Trial of On-Demand Optical Grid Lightpath Network Services

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Abstract--This paper summarizes our field trial of on-demand optical grid lightpath network service for e-Science applications. The end-users can take advantage of the flexibility on network control provided by our GMPLS based optical grid network infrastructure. To support end-to-end lightpaths, we propose a RSVP-TE extension for bidirectional lightpath with the same wavelength in both directions.

1. Introduction

Scientific research communities need very-long distance communication networks because their observation and computing facilities are distributed in world-wide range. For example, e-VLBI (Very Long Baseline Interferometry) [1] as one effective observation approach has been employed on the most frontiers of the research in Astronomy, Geodesy, and Spacecraft Navigation. During observation 256M-1Gbps (60TB per day) of data is generated at each observation site. Three essential requirements of e-VLBI (long baseline for high angular resolution, large bandwidth for high sensitivity, and real-time data transfer for fast/rapid turnaround) make a WDM based lightpath network the ideal candidate for high-quality data transmission.

GMPLS (Generalized Multi-Protocol Label Switching) suite of protocols allows carriers to automate the provisioning and management of the network, and promises to lower the cost of operation by several orders of magnitude compared with manual operation. More automation is helpful to the scientific communities. We provide GMPLS's user interfaces that drive GMPLS function for supporting application users.

In this paper, we address our developed WDM based lightpath network called optical grid infrastructure. We also propose a new bidirectional lightpath setup method.

2. Optical Grid Network

Figure 1 depicts the network topology that we installed. This is an optical grid infrastructure in which multiple lightpaths can be setup by a user's (i.e., end-host PC) request [2]. Two pairs of optical fibers between Koganei and Otemachi (about 50km), Otemachi and Akihabara (about 5km) have been employed. All sites are located in Tokyo. The fibers are JGN2 [3] service. Three PCs were distributed at these three sites to fulfill specific application tasks. Two L2 switches were placed at Koganei and Otemachi, respectively, for switching data outside optical grid infrastructure. End hosts or L2 switches have multiple MCs (media converters) equipping with DWDM wavelength and 1000Base-T SFP modules. These MCs were used as the fixed wavelength transceivers. The wavelength is any of 1548.5, 1549.3, 1550.1, 1550.9 nm. Optical switches (i.e., no O/E/O) pass lightwave in wavelength granularity. AWGs were employed for wavelength multiplexing and de-multiplexing only on optical fibers which connect two sites.

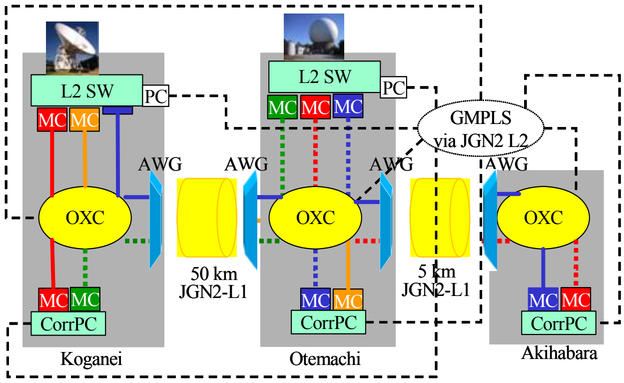

Fig. 1. Network topology for e-VLBI experiment

The dashed lines in Fig, 1 show the Control-Plane of the network. It was constructed with a VLAN established via JGN2 VLAN service, which was separated from the DWDM circuits. In fact, besides VLAN, we can construct the Control-Plane with any other feasible approaches from private infrastructure to the Internet. Using this Control-Plane, a lightpath network, which is a set of multiple lightpaths, was established among three sites, say, Koganei, Otemachi and Akihabara. We should note that to simplify our system, end host PCs for application use were running as GMPLS edge nodes as well. The wavelength lightpaths were connected to network interface cards (NICs) of these PCs directly to attain the full bandwidth of the lightpaths for performance requirement of the application.

We have used such infrastructure for e-VLBI application. Before the data transmission, when a demand of lightpath network comes, at a proper network node, this network request was decomposed into multiple bidirectional lightpath creation requests starting at different source end/edge nodes. Then these bidirectional lightpaths were established automatically with a path message extension of RSVP-TE [4]. Totally, there are six bidirectional lightpaths were established on four different wavelengths (1548.5, 1549.3, 1550.1, 1550.9 nm). Three lightpaths started from Koganei L2 switch, with each to one end-host PC for correlation calculation purpose, another three were started from Otemachi L2 switch, terminated at each PC. After setup of the lightpahts, datum from Haystack and Kashima observation sites were transferred to the three PCs for parallel correlation computation via Otamachi and Koganei L2 switches.

3. Bidirectional Lightpath on Same Wavelength

As we mainly employed commercial product Ethernet NICs (1000Base-T), which need to work in full-duplex mode, we have to establish bidirectional lightpaths for node pairs who have data to exchange. Moreover, because we hoped to use relatively cost-effective fixed wavelength MCs as the fixed wavelength transceiver arrays, each end-host NIC is fixed to one MC, and DWDM SFP module of each MC is physically connected to one wavelength channel/port of AWG or OXC, it implies that both transmitting and receiving of a MC work on the same wavelength. Thus, we also need that the bidirectional lightpath uses the same wavelength on both directions, say upstream and downstream directions. Although drafts for Upstream Label [4] even Upstream Label Set [5] have been proposed, and they do deal with the general cases which need bidirectional LSPs, there is not any definition for bidirectional lightpath on the same wavelength.

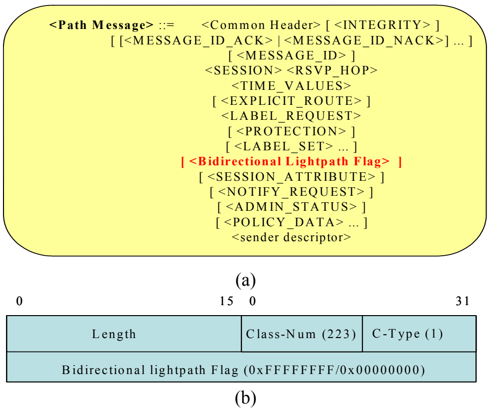

Fig. 3. Support for bidirectional lightpath on the same wavelength: (a) Path Message, and (b) Bidirectional Lightpath Flag Object

Considering our system configuration, we need to add a new function into RSVP-TE to support bidirectional lightpath with same wavelength on both directions. Our lightpath setup procedure is briefly described as below:

1) Ingress node adds new ligthpath type indication in Path message. It is propagated in the Path message in the same way as a Label Set for downstream;
2) Upon receiving Path message containing both such indication and Label Set, the receiver checks the local LSP database to see if the Label Set TLVs (type-length-value) are acceptable on both directions jointly. If there are acceptable labels, then copy the values of them in to new Label Set TLVs, and forward the Path Message to the downstream node. Otherwise the Path message will be terminated, and a PathErr message with a "Routing problem/Label Set" indication will be generated;
3) Upon receiving Label Set combined with new lightpath type indication, egress node verifies whether the Label Set TLVs are acceptable, if at least one label is available on both directions, then the first available label is selected. A Resv message is generated and propagated to upstream node;
4) When a Resv message is received at an intermediate node, the intermediate node allocates the label to interfaces on both directions and update internal database, then configures the local OXC for lightpaths of both directions.

The descriptions of other procedures are omitted due to space limitation. Regarding the new lightpath type indication in Path message, several options might be considered. For example, we can make use of the reserved bits in Label Set, or Upstream Label/ Upstream Label Set. However, as we consider our future possible RSVP-TE extensions which might also need new indications, without changing other formats, we newly define a multiple-purposes object. It will be used to carry different Flags, for example, the Bidirectional Lightpath Flag Object for our purpose is depicted in Fig.3.

4. Demonstration

To verify the possibility of new on-demand services that support the emerging large-scale distributed computing applications, we have implemented a GMPLS based lightpath control system on a DWDM optical network. Moreover, for special users who might require dynamical underlying network reconfiguration according to their data transmission needs, it is necessary to provide them the capability and flexibility of fast lightpath setup/release directly. Thus we created GMPLS's user interfaces that drive GMPLS function for supporting application users. Figure 4 is a snapshot of a RSVP-TE console showing the users issued unidirectional and bidirectional lightpaths, where the bidirectional lightpath employs the same wavelength on both directions.

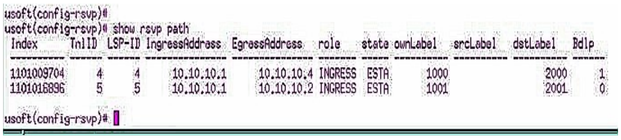

Fig. 4. A snapshot of RSVP-TE console showing a "Bdlp" field (bidirectional and unidirectional lightpath provisioning).

5. Conclusion

To provide on-demand high-performance networks service, in the field trial, we have successfully established a GMPLS based DWDM optical grid network infrastructure, which supports bidirectional lightpath with the same wavelength in both directions. The end-users can take advantage of the flexibility on network control.

Reference:

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