Interworking DWDM Equipment and PXC Operation using GMPLS for a Reliable Optical Network

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Abstract: GMPLS interworking operation between DWDM equipment and PXC was demonstrated for the first time to achieve SONET/SDH-grade reliability. PXC has successfully initiated restoration and managed resources based on DWDM equipment information via control plane.

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1. Introduction

One requirement for an optical network with SONET/SDH-grade reliability is communication between dense wavelength division multiplexing equipment (DWDM) and photonic cross-connects (PXC) based on all-optical switches. In terms of operation, the PXC does not always provide adequate performance monitoring and alarm management over DWDM links and generally only detect loss of light (LOL) as a fault, though optical cross connect equipment based on O-E-O switches can deliver very stringent performance monitoring using well-established SONET/SDH technologies. PXCs switching operation triggered by performance monitoring has been so far demonstrated [1]. The trigger indication, however, was still based on only LOL, and luck of reliability and manageability restricts the practical deployment of such a network. To attain the all-optical switching network with SONET/SDH-grade reliability, integrating DWDM equipment with PXC by using a control plane is required to enhance performance monitoring and alarm management, while utilizing plenty of monitoring functionalities in the overhead of SONET/SDH or optical transport networks (OTN) [2] as well as various alarms over DWDM links.

Generalized multi-protocol label switching (GMPLS) protocols [3] are extensions of the existing MPLS protocol for an control plane of IP routers, and are developed to control generalized optical nodes such as the PXC. Link management protocol (LMP) is one of GMPLS protocols for managing traffic-engineering (TE) links including fault isolation between optical nodes which participate in signaling and routing [4]. Though DWDM does not participate in these operations, the LMP, however, can be extended between PXC and DWDM equipment as an LMP-WDM protocol [5]. By implementing this protocol on the DWDM, the PXC can be notified of various types of information on DWDM links via the control plane and initiate recovery operations as well as manage and monitor pooled (standby) TE link resources, being different from only LOL-based indication.

In this paper, we present the first results demonstrating the integrating of DWDM and PXC operation by the control plane to attain a reliable GMPLS-enabled optical network. We describe how the LMP-WDM protocol was implemented on two types of DWDM and the PXC so that the PXC is successfully notified of DWDM performance monitoring and equipment alarm information and can then initiate recovery operations. We also demonstrate how this protocol is used to supervise the health of standby links.

2. Integrating DWDM and PXC operation

Fig. 1 shows the basic mechanism for integrating DWDM and PXC operation. Various types of information such as performance monitored results as well as equipment alarms are reported to the PXC from a DWDM controller. In general, there are two types of DWDM equipment in terms of transponder operation at the client side. One type has shutdown functionality. The other type has alarm indication signal (AIS) functionality conforming to the SONET/SDH standard. The first type (shutdown functionality) is ideal for PXC because LOL is notified in-band as soon as a failure occurs such as the cable break indicated as 1. In this case, transponders will detect the cable break and are forced to shut off the light at on client side. On the other hand, since the other type (AIS) cannot generate LOL, it must indicate the failure via an out of band route. The alarm is then transferred to transponders and they report the cable break to the controller. In the case of optical amplifier alarms such as the pump laser diode (LD) failure indicated as 2, the alarm information on output degradation is transferred through an optical supervisory channel of the DWDM system to the controller. Once a transponder failure indicated as 3 occurs, such as an LD temperature failure, the wavelength mismatch alarm is transferred to the controller. Transponders are being

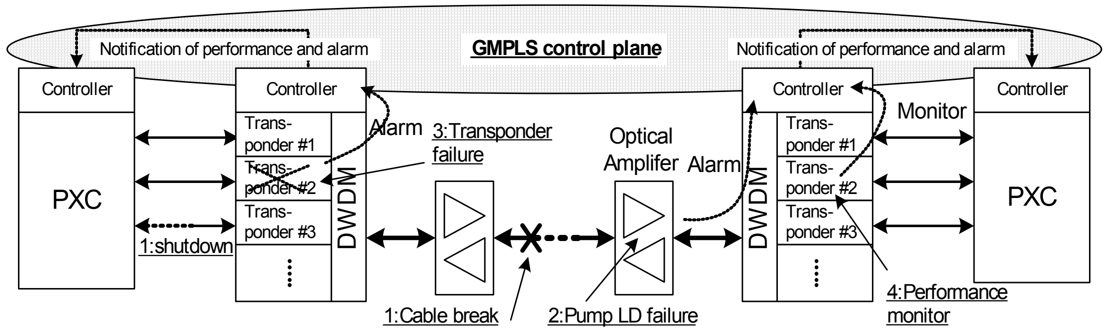

Fig. 1: Basic configuration for integrating DWDM and PXC operation.

currently equipped with a strong performance monitoring based on overhead of OTN. The monitored results are transferred for example to the controller, once the error ratio exceeds a threshold indicated as 4. The controller collects alarm and performance information through the Transaction Languages 1 (TL1) command. This command is commonly supported by telecommunication equipment for operation, administration and maintenance (OA&M) purposes. This information is then reported to the PXC controller.

The DWDM controller, which has LMP-WDM functionality, translates these TL1 event reports into LMP-WDM protocols. Messages implemented by LMP-WDM protocols are summarized in Table 1. A control channel is configured between controllers of the DWDM and the PXC for an LMP-WDM session. Each controller negotiates configuration parameters such as the *HelloInterval* and the *HelloDeadInterval* by *Config* messages. After the completion of parameter negotiation, LMP *hello* messages are periodically exchanged and the LMP session is established. LMP messages are transported over the UDP with a temporary port number for LMP-WDM. A non-numbered interface identifier (ID) of each end point on the TE link is configured and its TE links properties are correlated between the DWDM and the PXC by exchanging *LinkSummary* messages. Each TE link corresponds to one data link and its parameters can be configured according to the physical and logical characteristics of the DWDM transponders. The TL1 event reports from the DWDM are mapped to alarm information on LMP-WDM protocols and reflected in *ChannelStatus* messages as well as in *LinkSummary* messages for fault management. ChannelStatus messages are designed to be immediately generated when alarms are reported to the DXDM controller, and *LinkSummary* messages are designed to report the state of the TE link. Unlike a conventional LMP session, the fault isolation process between the DWDM and the PXC is not mandatory since the LMP-WDM protocol is for a local link, which provides only fault notification.

3. Demonstrated results

Fig. 2 shows the demonstrated configuration for evaluating LMP-WDM protocol use between the DWDM and the PXC. The Ethernet interfaces on each of the DWDM and PXC controllers were interconnected via an Ethernet switching hub to create an IP control channel (IPCC). LMP-WDM *hello* messages were periodically exchanged between the DWDM and PXC in order to maintain the IPCC connection. Over four different LMP-WDM sessions, *LinkSummary* messages were successfully exchanged while reflecting parameters of TE links and data links such as one OC-192 link and two OC-48 links in each DWDM system. We evaluated two types of DWDM, as previously

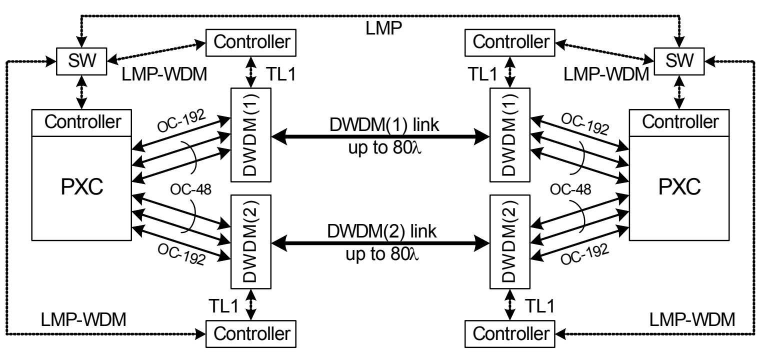

Fig. 2: Demonstrated configuration for evaluating LMP-WDM interoperability between PXC and 2 types of DWDM (DWDM(1) having shutdown functionality, DWDM(2) having AIS functionality).

Function	Messages
Control channel management	*Config*
	ConfigAck
	ConfigNack
	Hello
Link property correlation	*LinkSummary*
	LinkSummaryAck
	LinkSummaryNack
Fault management	*ChannelStatus*
	ChannelStatusAck
	ChannelStatusRequest
	ChannelStatusResponse

Table 1: Summarized LMP-WDM messages in the DWDM and the PXC.

described. One type having shutdown functionality and the other having AIS functionality. We also evaluated the LMP-WDM interoperability between the DWDM and PXC.

(1) DWDM with shutdown functionality

An OC-48 label switched path (LSP) or an OC-192 LSP was created between SONET testers over this DWDM link. When a cable fault occurred, the controller of the DWDM notified the neighboring PXC of the signal failure by sending *ChanneStatus* messages. The DWDM however, shut off the light at the client side of the transponder prior to these messages, and the PXC consequently initiated recovery operation by this LOL. Signal degradation was then made to occur by gradually increasing the cable loss upstream of the optical transponder at the 0.1dB step every 5 seconds. In this case, the DWDM generated the alarm without shutdown when the input power crossed the signal degradation threshold and sent the *ChannelStatus* messages showing the signal failure. Fig. 3 shows the time variance of the bit error ratio (BER) over the degraded link. The PXC, which received these *ChannelStatus* messages, conducted the LMP fault isolation process and initiated the recovery operation. The BER was therefore successfully restored by changing to an alternate path. However, the BER will become worse when there is no recovery operation. A fast recovery from the signal degradation was successfully achieved since the disruption time for recovery was only 480 milliseconds. The threshold value for judging signal degradation was set on the DWDM so as to maintain the required signal quality.

(2) DWDM with AIS functionality

Differing from the previous case, another DWDM in this case reported the failure by *ChannelStatus* messages rather than the LOL. Once the cable fault was made to occur, the transponder at the client side generated AIS as a fault indication. At the same time, the DWDM controller received the TL1 event report indicating the cable fault and sent a corresponding *ChannelStatus* message reporting the signal failure. The PXC, which received these *ChannelStatus* messages, initiated the LMP fault isolation process and restored the LSP to an alternate path. Integrated operation between DWDM and the PXC was therefore successfully achieved.

(3) Health status indication

Finally, the health status indication of unused standby links from the DWDM was evaluated. Once a failure on the transponder was made to occur, the DWDM notified the PXC that the TE link was unavailable by using a *LinkSummary* message with a failed link. Under this condition, PXC responded to a path error message indicating a routing error when establishing an LSP over a failed link was attempted. After this failure was recovered, the LSP was then successfully established after *LinkSummary* messages indicating a successful link were exchanged. Status indications for OTN monitoring were also evaluated. The loss of frame (LOF) in the OTN forward error correction (FEC) frame was selected as the OTN interface monitoring parameter and optical noise to one specific transponder was intentionally increased to cause the FEC LOF. Once the FEC frame was no longer synchronized with that at the transponder at the other end due to the optical noise, the transponder sent an alarm indication and the DWDM controller consequently notified the PXC of this status by *LinkSummary* messages showing a failed link. In this way, we demonstrated for the first time how the health of standby links can be monitored using LMP-WDM protocols.

4. Conclusions

Integrating DWDM and PXC operation by GMPLS was successfully demonstrated for achieving SONET/SDH-grade reliable optical networks. Performance monitoring results and equipment alarms on the DWDM could be successfully notified to PXC so as to initiate restoration operation as well as to manage and supervise pooled (standby) TE link resources by using the LMP-WDM protocol. This evaluation proved that intelligent optical networks can be deployed using GMPLS-enabled DWDM and PXC, to convey increased data traffic loads and achieve high reliability.

5. References

[1] T. Otani, et al, "PXC protection switching triggered by performance monitoring with FEC for submarine cable networks", OFC2002 ThG7, 2002.

[2] ITU-T G. 709, "Interfaces for the optical transport network (OTN)"

[3] E. Mannie, et al, "Generalized Multi-Protocol Label Switching (GMPLS) Architecture", Internet draft (work in progress), draft-ietf-ccamp-gmpls-architecture-04.txt, 2003.

[4] J. P. Lang, "Link Management Protocol (LMP)", Internet draft (work in progress), draft-ietf-ccamp-lmp-10.txt, 2003.

[5] A. Fredette and J. P. Lang, "Link Management Protocol (LMP) for Dense Wavelength Division Multiplexing (DWDM) Optical Line Systems", Internet draft (work in progress), draft-ietf-ccamp-lmp-wdm-02.txt, 2003.

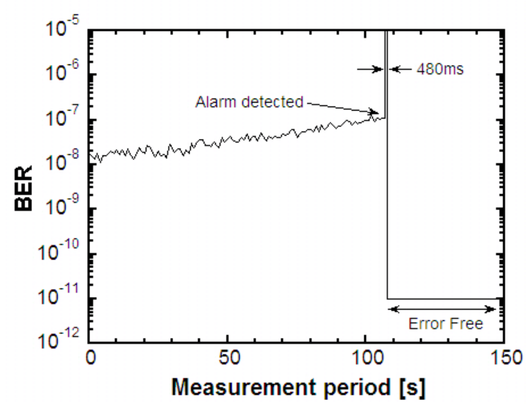

Fig. 3: Time variance of BER before/after restoration