Experimental Evaluation of OMS Protection in GMPLS-Based Optical Networks

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ABSTRACT

In this paper we propose and evaluate a complete solution to build ring-based optical networks with OMS-DPRing protection capability. The solution consists of 1) a mechanism based on extensions to GMPLS Link Management Protocol (LMP) to coordinate protection actions, and 2) a new Reconfigurable Optical Add/Drop Multiplexer (ROADM) design to support OMS-DPRing protection. The performance of the complete solution is experimentally evaluated.

Keywords: GMPLS, ROADM, LMP, OMS-DPRing.

1. INTRODUCTION

Given the large installed base of ring fiber-plants and the extensive experience operators have gained in operating SONET/SDH ring based networks, optical rings are becoming increasingly important, playing a crucial role in the migration to the more dynamic ASON/GMPLS network paradigm. Ring architectures are well-known for their inherently fast protection switching capabilities since service recovery within 50ms after fault detection can be achieved. An interruption of 50 ms or less in a transmission signal is perceived by higher layers as a transmission error. On the IP layer it may cause a packet retransmission handle by TCP/IP, but no TCP sessions will be affected at all [1].

Currently, only Optical Channel (OCh) resilience is supported by the GMPLS recovery framework [2],[3]. In this paper we propose the GMPLS Automatic Protection Switching (GAPS) mechanism, which provides dedicated section protection (hereafter OMS-DPRing) in GMPLS-based optical ring networks and it is based on extensions to GMPLS LMP [4]. GAPS aims to provide service recovery within 50ms after the fault detection.

There are previous works in the literature regarding protection at OMS level which have been taken into consideration, i.e. [5]-[7]. The study which is the most similar to this work is the one presented in [7], where the authors propose a protection mechanism based on extensions to RSVP-TE protocol for fault location and notification and they assume out-of-band in-fiber signaling. Our proposal assumes not only in-fiber but also out-of-fiber signaling and it is based on extensions to LMP for fault management, which, from the obtained results, allows better scalability.

The remainder of the paper is organized as follows: Section 2 provides an overview of protection mechanisms for ring based networks. Section 3 is devoted to present GAPS and the node design. In Section 4 experimental results are presented. Finally, Section 5 draws the main conclusions of this work.

2. PROTECTION MECHANISMS FOR RING-BASED NETWORKS

Many of the failures occur at the optical network layer. Fiber cuts resulting from, for instance, digging works or the failure of an individual transmitter or receiver are quite common. The recovery schemes at the optical layer work either at Optical Multiplex Section (OMS) or at Optical Channel (OCh) levels. The recovery action is carried out using the large granularity of an optical channel or even a complete multiplexed bundle of optical channels, respectively. A detailed resilience schemes classification can be found in [1],[8].

An OMS Dedicated Protection Ring (OMS-DPRing) consists of two counter-rotating rings, each transmitting in opposite directions relative to each other (Figure 1). Only one fiber is dedicated for working traffic while the other fiber is reserved for protection. Both flows of a bidirectional lightpath are routed on the different sides of the ring, using the same wavelength. There is thus no possibility to reuse wavelengths on the ring for different lightpaths. Therefore, the maximum capacity that can be allocated on the ring is limited to the capacity of a single span. When a failure occurs, it is detected by the two optical nodes adjacent to the failure. Both nodes loop back the affected multiplexed bundle of optical channels on the protection ring in the opposite direction. An Automatic Protection Switching (APS) protocol is required to manage the efficient switching to the protection fiber in case of failures.

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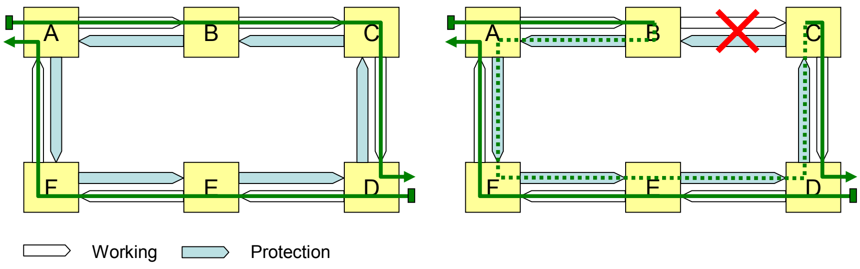
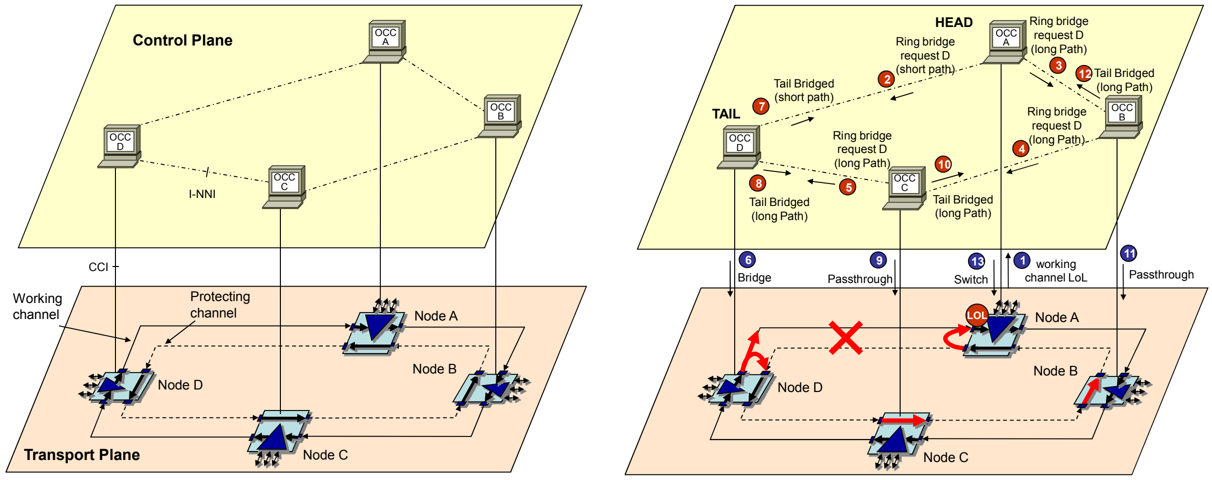


Figure 1. OMS DPRing architecture.

3. THE GAPS MECHANISM AND OPTICAL NODE DESIGN

We define GAPS as an LMP extension, running in the control plane of ASON/GMPLS networks. GAPS protocol manages protection messages signaling, being complementary to the automatic provisioning functionalities.

Figure 2a shows the basics of the GAPS protocol. Under normal conditions (i.e. without any failure), the working channel in the transport plane is used to carry regular traffic while the protection channel carries unprotected extra traffic. This state of the ring is called normal state. When a network component fails a switch event occurs and the working channel is protected using the protection channel.



a) OMS DPRing under normal conditions

b) OMS DPRing after a LoL condition

Figure 2. OMS DPRing controlled by GAPS.

A span failure implies a Loss of Light (LoL). A failure on a span is detected and corrected by its adjacent nodes. Those nodes are called switching nodes and they use the bridge and switch actions for the protection of the working channel (Figure 2b). The bridge action consists in transmitting identical traffic on both the working and the protection channels, while the switch action consists in selecting traffic from the protection channel instead of the working channel. The head optical node will be aware of the repair when it starts receiving signal from the working channel after a failure. When a node detects a failure through LoL, it notifies the failure to the OCC in the control plane which becomes the head end, i.e. it requests that the previous node behaves like a bridge. Conversely, an OCC that is notified of a failure becomes the tail end and its transport plane associated node executes a bridge. A more detailed description of the GAPS protocol can be found in [9].

GAPS protocol uses control channel management functionalities provided by LMP protocol. Once a control channel is activated between two adjacent nodes, the LMP Hello protocol can be used to maintain control channel connectivity between the nodes. Our proposal for extending LMP with GAPS consists in the definition of a new LMP Message:

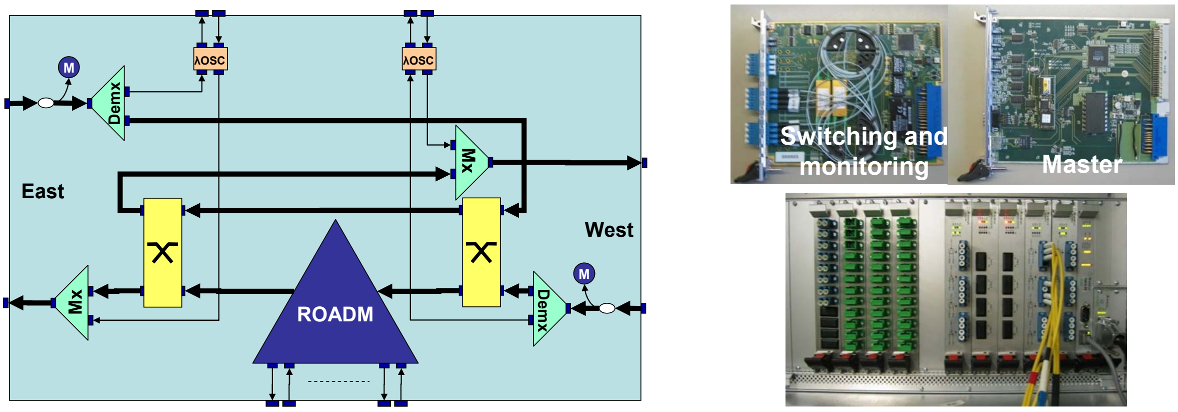
```
GAPS Message
  <GAPS Message> ::= <Common Header> <GAPS>
```

This message is used to transmit GAPS information when the LMP adjacency is part of an OMS-DPRing structure GAPS controlled. The GAPS object contains all the information needed by the GAPS protocol.

```
GAPS Class
                0                   1                   2                   3
                0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
                +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                |                       Source  Node  ID                        |
                +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                |                    Destination  Node  ID                      |
                +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                |       K1  Request  Type       |    K2 Path     |   K2 Status  |
                +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

From the functional point of view, GAPS agent is located on the top of two LMP agents, LMP east and LMP west. This way, GAPS messages can be sent either through the east control channel or through the west control channel.

In parallel with the GAPS protocol a new optical node has been designed to support OMS-DPRing protection scheme [9]. The optical node is based on existing unidirectional ROADMs. Two 2x2 optical switches have been added to the basic unidirectional ROADM allowing OMS protection. The two pairs of optical Mux/demux are responsible for coupling the WDM-multiplexed bundle with the in-fiber Optical Supervisory Channel (OSC) which transports the control channel (Figure 3a). Two 1300 nm optical transponders (λ_{OSC}) are used to convert electrical fast Ethernet signal into the optical domain. Incoming optical power levels at west and east inputs are monitored by means of two optical meters, which advertise to the node controller upon the reception of out of bounds levels. Node controller will send a LoL notification to the OCC upon receiving out of bounds optical power level. Note that if the span is not affected by a failure, optical power must always be received at each end of the span. Figure 3b shows both the physical layout of some cards and the frontal view of the optical node.



a) Optical Node Design. *b) Cards and node physical layout.*

Figure 3. Optical Node to support OMS-DPRing.

4. EXPERIMENTAL RESULTS

The feasibility and obtained performance of GAPS mechanisms has been experimentally evaluated over rings with up to 18 nodes over the ASON/GMPLS CARISMA network testbed [10]. The CARISMA GMPLS control plane uses the RSVP-TE protocol for signaling, the OSPF-TE protocol for routing and the LMP protocol for Control Channel Management and Link Property Correlation. The OCCs have been implemented using Linux-based routers. Each pair of OCC communicates through the use of a single IP control channel implemented with full duplex Fast Ethernet links. Finally, each OCC has also a CCI interface for communicating with the optical nodes.

Let us define the switch completion time (T_{DPRing}) as the interval from the decision to switch to the completion of the switch operation at the node initiating the bridge request. It includes notification from the initiating optical node to its OCC (T_{config}), the propagation delay in each control network link (T_{link}), the processing time in each OCC ($T_{control}$), the time to configure (T_{config}) each optical node in the ring to perform the switching action and the time to switch itself (T_{switch}). Then, T_{DPRing} can be expressed as:

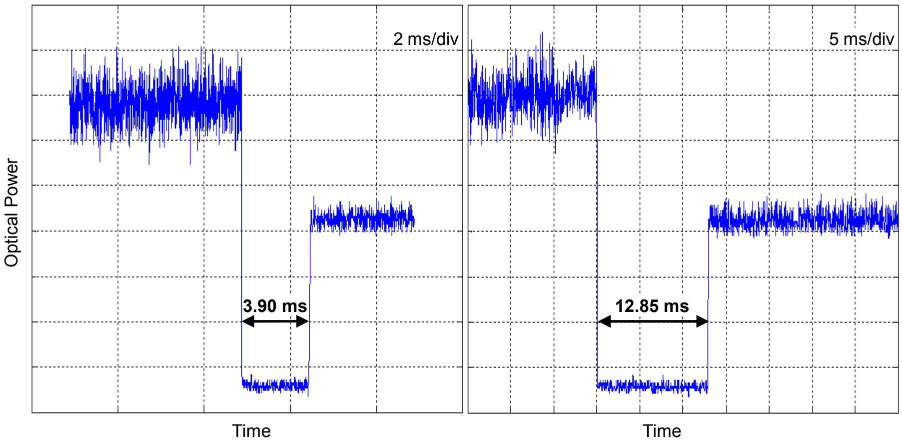
$$T_{DPRing} = 2T_{config} + T_{switch} + (2n-1)T_{control} + 2(n-1)T_{link} \quad (1)$$

T_{switch} comes predefined by the switching device. We use a switch with a response time below 1ms.

Figure 4a shows the resulting switching time when the protection decision is taken by the equipment itself ($T_{equipment}$). This measure includes the needed communication between the switching card and the master card within the optical node. It does not include the time needed to communicate transport plane and control plane (T_{CCI}), as expressed in (2).

$$T_{equipment} = 2T_{config} + T_{switch} - 2T_{CCI} \tag{2}$$

Figure 4b shows the experimental T_{DPRing} for a ring with 18 nodes. T_{link} depends on the length (L) of the link and on the signal speed through the fiber (we assume a refractive index of 1.5). Notice that for metropolitan ring networks, T_{link} is negligible.



a) Equipment Protection **b) GAPS protection (18 nodes)**

Figure 4. Experimental results.

Thus, we can conclude that GAPS in conjunction with the designed ROADM provide under 50 ms OMS protection in rings with a high number of nodes.

5. CONCLUSIONS

In this paper we have presented a complete solution to build ring-based networks with OMS-DPRing protection capability. Firstly we have introduced the GAPS mechanism, based on the extension of the standardized GMPLS LMP protocol in order to support efficient protection for OMS-DPRings. Specifically, OMS-DPRing support has been developed, defining the messages exchanged by OCCs in the control plane. Secondly, a new ROADM architecture has been designed and built to support OMS-DPRing protection. The increment in the total cost of the ROADM due to the OMS-DPRing support is very low. In fact, this support consists only in some additional cards.

From the obtained results we conclude that a ring-based network using the designed ROADM as node and controlled by the GAPS protocol will provide survivability at low prices and with a SDH-like service recovery time (< 50 ms), even in large optical rings.

REFERENCES

[1] W. D. Grover, Mesh-Based Survivable Networks, Prentice Hall PTR, New Jersey, 2004.

[2] L. Berger, *et al.*: GMPLS Based Segment Recovery, IETF draft-ietf-ccamp-gmpls-segment-recovery-03.txt, Work in progress, 2006.

[3] J.P. Lang, *et al.*: RSVP-TE Extensions in support of End-to-End Generalized Multi-Protocol Label Switching (GMPLS) Recovery, IETF draft-ietf-ccamp-gmpls-recovery-e2e-signaling-04.txt, Work in progress, 2006.

[4] J. Lang, Link Management Protocol (LMP), RFC 4202, 2005.

[5] P. Arijs, *et al.*: Design of Ring and Mesh based WDM Transport Networks, *Optical Networks Magazine*, 3 2000, pp. 25-40.

[6] M-J. Li, *et al.*: Transparent Optical Protection Ring Architectures and Applications, vol. 23, 10 2005, pp. 3388-3403.

[7] R. Muñoz, *et al.*: Experimental GMPLS fault management for OULSR transport networks, *Optical Fiber Communications, OFC/NFOEC*, vol. 3, 2005, paper JWA50.

[8] J-P. Vasseur, M. Pickavet, P. Demeester: Network Recovery - Protection and Restoration of Optical, SONET-SDH, IP and MPLS, Elsevier, San Francisco, 2004.

[9] L. Velasco, *et al.*: ROADM design for OMS_DPRing protection in GMPLS based optical networks, accepted in 6th International Workshop on Design and Reliable Communication Networks (DRCN) 2007.

[10] E. Escalona, *et al.*: Establishing Source-Routed Bidirectional Connections over the Unidirectional ASON/GMPLS CARISMA Testbed, in *Proc. of ICTON*, vol. 2, 2005, pp. 21-24.