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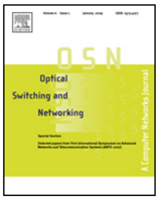

A concurrent two-layer restoration scheme for GMPLS WDM networks[☆]

Rabindra Ghimire[a], Seshadri Mohan[b,*], Michael Leary[c], Terry Tidwell[c]

[a] *Applied Science Department, University of Arkansas at Little Rock, Little Rock, AR 72204, United States*
[b] *Systems Engineering Department, University of Arkansas at Little Rock, Little Rock, AR 72204, United States*
[c] *Space Photonics, Inc., 700 Research Center Blvd., Fayetteville, AR 72701, United States*

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ABSTRACT

Next generation backbone networks will likely consist of IP routers as well as optical cross connects (OXCs) and will deploy an optical control plane protocol. Generalized Multi Protocol Label Switching (GMPLS) has been proposed as the candidate of choice for the control plane. Optical fibers may carry large volumes of traffic and therefore adequate mechanisms must exist to enable the network to automatically recover from failures of fiber. In mission critical networks survivability becomes very important. We investigate the problem of autonomous recovery in such networks. The literature contains work in this area that investigates the problem of multilayer recovery. Such recovery had only been sequential in the sense that the published work recovers first in the optical domain, assuming the availability of redundant resources, and then proceeds to recover packet label switched paths. We report a recovery procedure for recovering packet label switch paths (packet LSPs) and lambda label switch paths (λLSP) concurrently. We have conducted an OPNET-based simulation study that compares the performance of the concurrent scheme with the previously published sequential two-layer recovery scheme. The study shows that the concurrent two-layer recovery scheme performs as much as forty-four percent faster than the sequential two-layer recovery scheme.

1. Introduction

With the explosive growth in internet traffic, the next generation backbone networks will likely consist of IP routers as well as optical cross connects (OXCs), hereafter referred to as photonic GMPLS router [1]. The network will have the capability to perform packet switching together with wavelength path switching in order to provide quality of service (QoS). Wavelength division multiplexing (WDM) and dense wavelength division multiplexing (DWDM) technologies are playing a dominant role in providing high bandwidth optical transport. GMPLS has emerged as the leading control plane protocol for optical networks and utilizes the color of wavelengths as labels to establish lightpaths, referred to as lambda label switched path (λLSP) [2]. GMPLS controls both the establishment of packet label switched paths (packet LSPs) and λLSPs. In this paper, we refer to the λLSPs as the optical plane and the packet LSPs as the MPLS plane.

Photonic GMPLS routers use GMPLS as the control plane protocol. The primary components of the GMPLS protocol engine include an OSPF-TE extension module, Path Computation Elements (PCE) and a Resource Reservation Protocol module with traffic engineering (RSVP-TE). In order to provision or restore a connection, a route and a wavelength (label) must be identified for each connection. The OSPF-TE protocol distributes link state information, and determines a route for the connection; the RSVP-TE protocol reserves the necessary resources along the identified route. Consider the case in which GMPLS routers generate

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[*] Corresponding author. Tel.: +1 501 683 7475.
E-mail addresses: rxghimire@ualr.edu (R. Ghimire), sxmohan@ualr.edu (S. Mohan).

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packet label switched paths (packet LSP) with a fixed bandwidth, routed over the optical network as λLSP. λLSPs are setup and released based on GMPLS. While λLSPs provide a coarse level of granularity, packet LSPs provide a finer level of granularity. Generally, bandwidth occupied by a packet LSP is less than the bandwidth occupied by a λLSP, since a λLSP may contain multiple packet LSPs. Consequently, to improve resource utilization, packet LSPs are merged at some node into a λLSP [3]. Reference [4] proposes a two-layer route computation in which, after the arrival of a request for packet LSP, the node first tries to find one or multiple hop routes using existing λLSP; if it is not possible to establish such a route, a new λLSP will be established. Reference [1] proposes another scheme in which after the arrival of a request for packet LSP, the node first tries to allocate a route via an existing λLSP that directly connects the source and destination with one hop. If such a route is not available the node tries to establish a new one hop path by establishing a new λLSP between the source and destination.

The emerging infrastructure could provide high bandwidth on demand, flexible and scalable support for QoS for transmission of multimedia services with small delay. Due to the large volumes of traffic a fiber carries, survivability of WDM optical networks is very important. Towards this end, we investigate the problem of autonomous recovery in such networks. Procedures for such recovery can recover either λLSPs in the optical plane or packet LSPs in the MPLS plane. The literature contains work in this area that investigates the problem of multilayer recovery, but only sequentially by first recovering λLSPs in the optical domain, assuming the availability of redundant resources, and then proceeding to recover packet LSPs in the MPLS plane. In this paper, we report a procedure for concurrently recovering in the optical and MPLS plane. The present work on concurrent recovery investigates a single link failure scenario. The OSPF-TE extension proposed here requires that the link state information propagated by the protocol must carry a total number of unoccupied wavelengths in each link and unused bandwidth in existing λLSPs. After a link failure, the nodes closest to the failure detect the failure and inform all the source nodes of the disrupted lightpath with a *Notify* message [5]. Each node then updates the network topology. The connection head end that is affected by the failure determines the availability of a new λLSP and switches over an impacted λLSP to the new λLSP in the optical plane and, concurrently, switches over impacted packet LSPs over already established λLSPs that have unoccupied bandwidth.

An OPNET-based simulation study we conducted compares the performance of the proposed concurrent scheme with the previously published sequential two-layer recovery scheme [6]. The study shows that the concurrent two-layer recovery scheme proposed here performs as much as forty-four percent faster than the sequential two-layer recovery scheme.

The remainder of the paper is organized as follows. Section 2 briefly describes multilayer routing. Section 3 provides a brief background on network survivability. Section 4 describes the proposed concurrent two-layer restoration mechanism. Section 5 presents the concurrent recovery procedure. Section 6 presents the simulation methodology and results that provide valuable insights regarding the performance of the proposed concurrent two-layer recovery scheme. Section 7 presents the conclusions from this study.

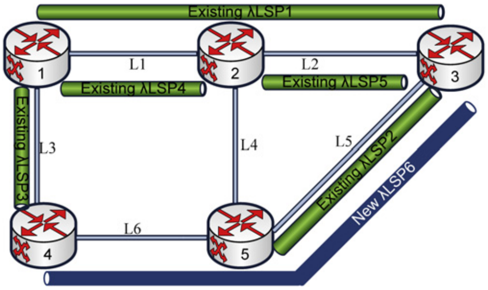

Fig. 1a. Example network.

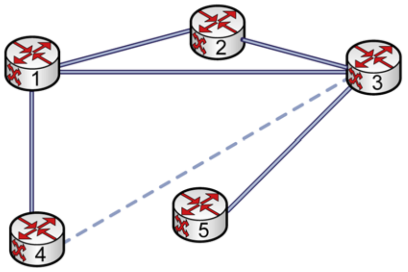

Fig. 1b. λLSP network (Virtual toplogy).

2. Multi-layer routing

Each node of GMPLS controlled optical network consists of a wavelength router, IP/MPLS router and a GMPLS route manager. The GMPLS controller in the GMPLS route manager maintains a database with information on the actual network topology and virtual topology. Control plane communications take place out of band. In such a multilayer network, a packet LSP is forwarded over a λLSP. GMPLS uses RSVP-TE to establish a packet LSP and a λLSP. If there is the arrival of a request for a packet LSP, the node first tries to find a route using an existing λLSP; if it is not possible to establish such a route, it will invoke to establish a new λLSP. Once the λLSP is established it forms the virtual topology. The OSPF-TE advertises the unoccupied bandwidth of the virtual topology which information is used for routing packet LSPs. This paper has adapted the scheme proposed in [1] in the case when there is no failure in the network, referred to as *Scheme* I. Fig. 1a shows the part of example network where *L*1, *L*2, *L*3, *L*4, *L*5 and *L*6 represent fiber links. Suppose λLSP 1, λLSP 2, λLSP 3, λLSP 4 and λLSP 5 are already established between *Node* 1–*Node* 3, *Node* 3–*Node* 5, *Node* 1–*Node* 4, *Node* 1–*Node* 2 and *Node* 2–*Node* 3, respectively. Fig. 1b represents the corresponding virtual topology of Fig. 1a. Figs. 2a and 2b show the example of RSVP signaling using *Scheme* I. As shown in Fig. 2a, upon the arrival of a request to set up a packet LSP from *Node* 4 to *Node* 3, *Node* 4 computes the path to destination *Node* 3, and initiates the RSVP-TE protocol. In order to establish a connection, destination initiated routing is used in which