A Directory Enabled Solution for MPλS Path Protection and Restoration*

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Abstract
It is very important that the large amount of traffic carried by optical channels is protected against potential failures in the network. The MPλS recovery approaches can be classified as local recovery or global recovery. In case of local recovery, the switch over to recovery path is performed by the O-LSR that is immediately upstream of the point of failure, whereas in case of global recovery, the switch over is performed by a pre-determined O-LSR known as O-Protection Switch LSR (O-PSL). The failure notification plays an important role in the global recovery approach, as the O-PSL has to be notified about the failure in order for the recovery procedure to be initiated. This paper proposes the use of a directory service as part of the global MPλS recovery framework. The proposed architecture enables fast and effective notification of MPλS O-LSP failures, which facilitates quick recovery to the backup O-LSPs. The proposed architecture also scales effectively to all O-LSPs affected by the failure and promotes improved utilization of network resources by greatly reducing the involvement of the O-LSRs in MPλS path protection and restoration.
Keywords: Optical Path Protection and Restoration, MPλS, Survivability in Optical Networks.

1. Introduction
Recent standards proposals have focused on extending IP-based MPLS path protection and restoration to optical networks [2]. The possibilities of extending MPLS path protection schemes to MPλS paradigm are detailed in [1] [2]. The different protection and restoration schemes in the MPLS domain [4] [5] [6] can be extended to the MPλS domain. This paper presents an architecture involving a directory service to improve global MPλS path protection. The other path protection approaches [1] [3] [4] [5] [6] suffer from two major drawbacks: slow notification and poor scalability.

The proposed architecture enables fast notification of node or link failures to the O-PSL, which in turn can initiate recovery action. The major advantage of this approach is that it scales effectively to all O-LSPs affected by a failure, even in case of complex and large-scale MPλS networks. This architecture also promotes improved utilization of network resources, as it greatly reduces the involvement of O-LSRs in MPλS path protection and restoration. This paper is organized as follows: Section 2 contains an overview of MPλS path protection and restoration. Section 3 describes the related work. Section 4 describes the architecture for Directory-enabled MPλS path protection and restoration. Section 5 describes the implementation. Finally, Section 6 concludes the paper.

2. Overview of MPλS Path Protection - Restoration
MPλS recovery can be performed in a centralized manner (global recovery) or distributed manner (local recovery). The intent of local recovery is to protect against a link or neighboring node failure and to minimize the amount of time required for failure propagation. The local recovery approach suffers from the drawback that it may require significant backup computation, and management tasks to protect the entire O-LSP, particularly in case of complex and large scale optical networks. The aim of the global recovery approach is to protect against any link or node failure on the entire path or on a segment of the path. The global recovery approach is more effective in providing end-to-end path recovery. In case of global recovery, the switch over to the backup path is performed by a pre-determined O-LSR, also known as O-Protection Switch LSR (O-PSL). However, the O-PSL is usually distant from the point of failure and has to be notified about the failure.

MPλS path protection scheme can either use dynamic protection or pre-negotiated protection. The pre-negotiated protection involves a pre-established protection lightpath (i.e., backup O-LSP), which allows fast restoration time. The dynamic protection, may however, require longer restoration time, since more processing is involved to switch over to a recovery path. The MPλS path protection mechanism may also involve switch back or restoration. The switch back or restoration is the transfer of traffic from the recovery path to the working path, once the working path is repaired.

3. Related Work
The recent developments in the area of optical technologies have allowed MPLS-based recovery techniques to be implemented in the MPλS domain. In [1], authors discuss how the MPLS local and global protection schemes

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can be implemented in the MPλS domain and two different restoration schemes - single-ended backup tree and multi-ended backup tree restoration schemes have been proposed. [2] highlights the key requirements for speeding up the restoration capabilities in MPλS. [3] involves a new scheme named SLSP for the end to end path protection for the optical Internet. There have been many approaches to provide global MPLS path protection [4] [5] [6] that can be extended to the MPλS domain.

The approaches in [4] and [5] suffer from the drawbacks that they involve extensive use of the intermediate O-LSRs for fault notification that leads to a delay in the notification. The delay may be even more significant in case of complex and large scale networks. The architecture proposed in [6] suffers from the drawback, that it requires a reverse O-LSP to be setup for each protected O-LSP. This approach may face scalability problems, particularly in cases involving complex and large-scale networks. [1] also suffers from the drawback of excessive involvement of intermediate O-LSRs and slow fault notification. The approach proposed in [3] allows some reduction in fault notification time using the SLSP scheme. However in [3], the overall complexity increases as the topology grows.

4. Directory-enabled MPλS Path Protection – Restoration

This paper proposes an architecture that uses the directory service to implement MPλS path protection and restoration and thereby provides a survivability framework for optical networks. The information related to the operational state or the accessibility of the O-LSRs on the working and recovery path i.e. whether the O-LSRs are operational or accessible is maintained in a standard directory. The MPλS nodes function as LDAP clients. The O-PSLs register dynamically for change notification, upon the establishment of the MPλS working and recovery paths. The standard LDAP protocol [7] is used as the means of communication between the O-LSRs and the directory. The O-PSLs registered for change notification are notified about any related change in the operational state of the MPλS path in order to enable the O-PSLs to initiate recovery or restoration procedures.

Our approach provides dynamic notification of changes in the directory to the O-LSRs without requiring an active LDAP session. We have developed LDAP extended operations to implement change registration and change notification mechanisms. The O-PSLs can use the change registration extended operation to register at the directory server for change notification. The registration is followed by the termination of the LDAP session. The O-PSLs specify the directory entries that are to be monitored as part of the change registration extended operation. The directory server maintains a list of all valid registration requests and associates the requests with the related O-PSLs. The directory server monitors the directory information tree (DIT) for any changes. The changes to the DIT are compared to the change registration requests registered at the server. The change notification extended operation notifies the related O-PSL(s) regarding the associated changes made to the DIT, which actually represent changes in the operational state of the MPλS working or recovery path.

Figure 1 depicts the functional architecture of Directory-enabled MPλS path protection and restoration. The directory server includes the functionality to implement the change registration and change notification mechanisms. The directory entries associated with MPλS path protection can be implemented in a very simple manner. A directory entry can be associated with a particular O-LSR and the entry has a related boolean attribute which specifies the operational state of the O-LSR i.e. whether the O-LSR is in an operational state or not or whether the O-PSL is accessible or not. The O-PSL is notified whenever there is a change in the value of the boolean attribute of the related O-LSRs.

The following functional units are implemented in the O-LSRs - the LDAP client, notification unit, and the Local Decision Point (LDP). The LDAP client allows the O-PSL to register change registration requests at the directory server. The change registration requests are meant to monitor the operational state of the MPλS working or recovery path. Upon detecting a node or link failure, the LDAP client of the O-LSR that detects the failure updates the directory information tree (DIT) regarding the failure. The directory server notifies the notification unit of the concerned O-PSL(s) about the changes in the operational state of the MPλS working or recovery path.

The LDP acts as the interface to the O-PSL. The LDP uses network programming to initiate the path protection and restoration procedures. The standard network programming interfaces can be used for this purpose. The notification messages may be transmitted using any suitable data communications protocol. In order to make Directory-enabled MPλS path protection and restoration effective, the notification messages should be transmitted as high priority messages.

In case the node or link failure that had caused the switchover to the recovery path has been repaired, the restoration process may be followed. The MPλS node that detects the link or node repair updates the directory information tree, which is followed by a notification to the O-PSL regarding the link or node repair. The O-PSL may initiate the restoration process upon receiving the recovery notification.

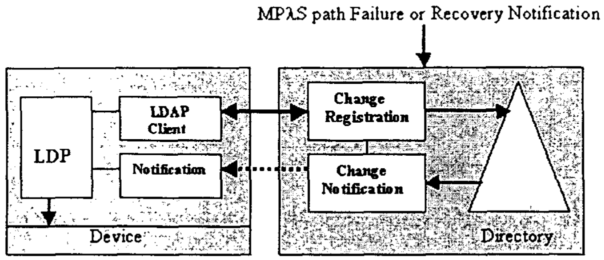

Figure 1. Functional architecture of Directory-enabled MPλS path protection and restoration

It is relevant to mention here that there are some concerns regarding the usage of directory for storing routing information or for storing dynamically changing information. We wish to emphasize that our approach does not involve storage of routing information on the directory. In case of our approach, the directory entries associated with an O-LSR have related boolean attributes that specify the operational condition of the O-LSR. Besides, it is not expected that the core MPλS routers will be failing very frequently and this fact should allay concerns regarding using the directory for frequently changing information. The fact that the directory is based on the principle of logical centralization and physical distribution and the effective information replication across multiple directory servers also ensures that there is no central point of failure. Figure 2 illustrates our directory based path protection approach.

In figure 2, when O-LSR4 fails or the link to O-LSR4 fails, O-LSR3 updates the DIT regarding the failure. O-LSR3 sends the failure notification signal to the directory server. In case the update to the DIT matches any of the change registration requests, the directory notifies the related O-PSL(s) about the update. This notification is done using the active connection that exists between the O-PSL and the LDAP server thereby allowing great reduction in notification time as processing delays are minimal and no connection setup is involved. Upon receiving the failure notification signal from LDAP server the O-PSL can initiate the switchover to the recovery path, i.e. O-LSR5 – O-LSR6 – O-LSR7 – O-LSR8.

The directory server notifies all the O-PSL(s) that have registered for change notifications related to that particular node or link failure thereby allowing effective and fast switchover to the recovery paths with minimal usage of network resources. This approach scales effectively to all the O-LSPs affected by the failure, even in case of complex and large scale networks. Once the link or node failure is repaired, the restoration process may be followed. The O-LSR that detects the link or node repair updates the directory information tree, which is followed by a notification to the O-PSL regarding the link or node repair. The O-PSL may initiate the restoration process upon receiving the recovery notification.

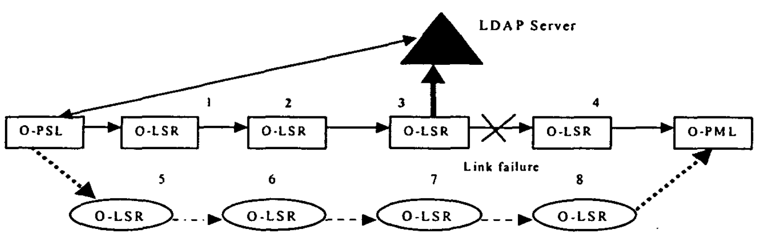

Figure 2. Directory based path protection in MPλS

5. Implementation

The prototype of the Directory-enabled MPλS path protection and restoration system was built using the Oplet Runtime Environment [8]. The Oplet Runtime Environment (ORE) supports dynamically injecting customized software services into network devices. The implemented architecture is composed of an embedded Java Virtual machine (JVM) and the ORE. Figure 3 depicts the prototype implementation of the Directory-enabled MPλS path protection and restoration system along with the information exchange among the various units.

The ORE component provides the substrate on the network device to support the secure downloading, installation and safe execution of services. Customized ORE services, which run locally on network devices includes monitoring, routing, diagnostic, or other user specified functions. The ORE architecture consists of the ORE environment, oplets and services. Oplets are self-contained downloadable units that encapsulate one or more services, service attributes, authentication information, and resource requirements. The ORE services use the Java Forwarding API (JFWD API) to instruct the forwarding engine regarding the handling of packets.

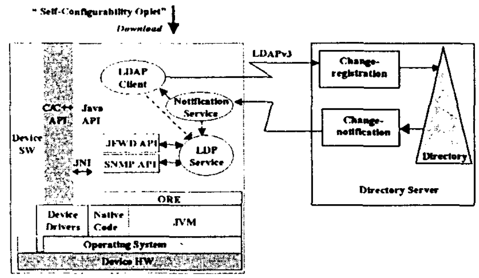

Figure 3. Prototype for Directory-enabled MPλS path protection and restoration

During the network element initialization, the MPλS node downloads a "self-configuration oplet". The self-configuration oplet installs the following services – LDAP client, notification unit, and the Local Decision Point (LDP). The LDAP client of the O-PSL registers its interest for change notification related to the operational state of all the MPλS nodes on the working and recovery path. We have used the Netscape directory server to implement the directory service.

We have extended the functionality of the Netscape directory server with two server plug-ins, providing the pre-operation and post-operation functions. The directory server, at start-up, loads the server plug-ins and appropriately accesses the plug-in functions during the processing of LDAP operations. The pre-operation function allows the O-PSL to register for a change notification. The post-operation function allows the directory server to send the notification to the notification unit of the O-PSL(s).

If the notification unit receives path related information from the directory server, then it passes the information to the LDP. If the notification unit receives a change notification from the directory server, it informs the LDAP client about the notification. The LDAP client initiates a LDAP session with the directory server in order to retrieve the changed MPλS path information. The LDAP client upon receiving the information terminates the LDAP session, thereby promoting effective utilization of network and computing resources. The LDP is responsible for initiating the path protection and restoration procedures. The process of self-protection and self-restoration is repeated by the O-PSL whenever there is a related change in the operational state of the MPλS working or recovery path.

We performed simulation to compare our approach with Makam approach [4] [9] in the non-optical domain (i.e., MPLS). We were able to demonstrate improved performance using our directory-enabled approach. Although our comparative study is not based on MPλS, it gives us the confidence that similar performance can be achieved in the optical domain as well. The simulation for the Directory-enabled MPλS path protection is in progress. Following is a brief description of our experiments in MPLS domain.

We have compared the directory-enabled approach with the Makam approach using a simulation environment. We used the MPLS Network Simulator (MNS) version 2.0 [9]. MNS is an extension to the Network Simulator (NS) version 2.1. Figure 4 shows the simulation results and the packet loss comparison between the Makam approach and the directory-enabled approach.

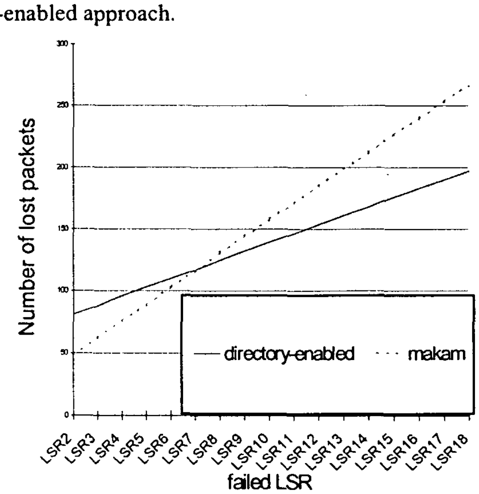

Figure 4. Performance Comparison

The schemes were measured and evaluated in terms of packet loss and reordering of packets respectively. The number of reordered packets is constant and negligible in case of the proposed directory-enabled approach as well as the Makam approach respectively. The merit of the directory-enabled approach is that it has a reduced packet loss as the size of the LSP increases. Besides, we have considered only a single LSP. However a LSR failure is expected to affect multiple LSPs and in case of Makam approach, there will be traffic propagation along all the affected LSPs. In case of the directory-enabled approach, once the directory is notified, only the related PSLs shall be notified without any involvement of intermediate LSRs thereby promoting reduced traffic propagation and increased utilization of network resources.

6. Conclusion

We have proposed a directory-enabled MPλS path protection and restoration scheme for providing survivability in optical networks. The proposed architecture enables fast notification of node or link failures to the O-PSL, which in turn can initiate recovery procedures. The major advantage of this approach is that besides providing fast fault notification, it scales effectively to all O-LSPs affected by a failure, even in cases of complex and large-scale MPλS networks. This architecture also promotes improved utilization of network resources, as it greatly reduces the involvement of additional lightpaths, which is required in other approaches for propagating the notification signal through intermediate O-LSRs. It also provides a simple and robust architecture even for large-scale MPλS networks.

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