Abstract
The integration of multi-layer switching capabilities within one box, such as the packet-switch capability (PSC) and the lambda-switch capability (LSC) under MPLS/Generalized-MPLS control mechanism, paves the way for realizing network resource optimization with consideration of multi-layer routing. This document clarifies the model of the GMPLS-controlled integrated PSC/LSC label switch router (LSR) and discusses the requirements of the routing extensions needed to realize optimized multi-layer traffic engineering.
1. Introduction

Generalized-MPLS (GMPLS) makes it easier to realize the seamless integration of IP Networks with legacy SDH/SONET or Photonic networks. In particular, integration of the packet switching capability and the photonic switching technology under a unified GMPLS control plane would significantly enhance the forwarding capacity of the IP network [Shimano01]. One of the other forces driving the construction of a unified GMPLS control plane is the desire to implement multi-layer routing capability, which would enable effective network resource utilization of both the IP-layer and the SDH/SONET or Photonic-layer in the next generation large capacity IP+Photonic network [Oki02].

In such network, each LSR would contain multiple-type switching capabilities such as PSC and Time-Division-Multiplexing (or SDH/SONET XC) (TDM), PSC and Lambda switching (LSC), LSC and Fiber switching (FSC), etc. These LSRs with integrated switch capabilities are required to hold resource information of not only their own link states and network topology but also those of other LSR’s, since circuit switch capable units such as TDMs, LSCs, FSCs require rigid resource reservation unlike PSCs. In addition, these LSRs are also required to discriminate link state data as to which layer these links belong, so as to provide multi-layer routing functionality.

The implementation of such functionality enables seamless multi-layer optimized route calculation such that the conventional label switched path (LSP) call setup automatically triggers new optical label switched path (OLSP) setup where the unused resources of inner interfaces between PSC functional block and LSC functional block in the OLSP destination node are considered.

If it is not possible to reserve the resources of the inner interface between PSC and LSC in the OLSP destination node, a different OLSP is setup that connects to a different intermediate LSR, and the LSP-call can be accommodated by the new OLSP and subsequent hops through other existing OLSPs until it reaches the destination node of the LSP-call.

This draft proposes several extensions to the link state information of OSPF/ISIS disseminated to all LSRs in the routing area to realize multi-layer routing. The extension of link state information includes the basic concept of the interface switching capability descriptor as discussed in [GMPLS-ROUTING] and [GMPLS-OSPF]. The content of this document is as follows. First, it models the GMPLS-based LSR with...
2. The node model of GMPLS based LSRs with lambda switching capability

This section clarifies the model of switching capable in GMPLS-based LSRs to clarify the requirements for multi-layer routing under the unified GMPLS-control plane.

2.1 LSC-LSR

The first model is LSR with LSC only. The LSC handles each OLSP to switch from fiber to fiber. This type of LSR does not have packet-level switching capability. Therefore, other LSRs in the same routing area (or domain) shall recognize that the LSR does not have the functionalities of IP packet routing and LSP switching.

Requirement: When there is no unused input and output port in the LSR, the LSR shall be identified as an LSC router that has no OLSP forwarding capability.
If the LSC-LSR does not have wavelength conversion capability (common in most all-optical networks), the information as to which wavelength channel can be reserved in a fiber link plays the most important role in route selection within OLSP setup. Thus, LSC-LSR shall also recognize and advertise the status of the unused wavelength channel number as described in the document [OKI-OLI]. In the process of constructing the network topology from fiber link state data, each fiber link connected to LSRs may be identified as a TE-link between neighboring LSRs. Component links, which may correspond to wavelength channels or LSC switch ports in one or multiple fibers, are bundled into a TE-link, where all wavelength information is aggregated [LINK-BUNDLE].

2.2 LSR with PSC+LSC

The second model is LSR with PSC+LSC. The PSC is connected to the LSC via internal interfaces between the PSC function block and the LSC function block. The LSC handles each OLSP to switch from fiber to fiber. This type of LSR offers the switching capabilities of both conventional LSPs and OLSPs. Therefore, other LSRs in the same routing area (or domain) shall recognize that the LSR has the capability of forwarding both IP packets and OLSPs.

Requirements:
If all switch ports of the LSC function block are occupied, an OLSP setup call transferring or terminating at the LSR shall be rejected. In such a case, other LSRs in the same routing area (or domain) shall recognize that the PSC+LSC router has no LSC reservation capability. If all inner interfaces between the LSC function block and the PSC function block are reserved, the LSR shall be identified as a PSC+LSC router that has no OLSP termination capability. If the PSC function block is in a failure state, the LSR shall be identified as a PSC+LSC router that has no usable PSC.
3. Multi-layer routing aspects

In this section, we explain the routing aspects of a generic LSP+OLSP multi-layer network comprising LSRs with only LSC and PSC+LSC. In such multi-layer network, an LSP layer has LSP switching capability through the combination of PSC-LSRs and PSC+LSC-LSRs. On the other hand, an OLSP layer has OLSP switching capability through the combination of LSC-LSRs and PSC+LSC-LSRs. Therefore, the LSR with PSC+LSC shall have both layers’ link states and network topology data to realize both LSP and OLSP route selection. To provide the route selection functionality, the LSR shall discriminate link state data as to which layer they belong. Path route selection of LSPs and OLSPs shall be done with reference to link the state data corresponding to each layer.

The link state of an existing OLSP within the multi-layer GMPLS network can be advertised as a point to point link by using conventional Router LSA in the case of OSPF. This enables the conventional IP routers, which are connected to the multi-layer GMPLS network, to realize an IP network plane topology within the network.
Alternatively, the link state of existing OLSPs can be advertised in conformance with the concept of FA-LSPs [LSP-HIER]. The OLSP can be identified as the links forming "forwarding adjacency" (FA) between LSRs connected by the OLSP. The corresponding LSA of the OLSP (FA-OLSP) shall contain the interface switching capability descriptor, which indicates the OLSP being terminated by PSCs, and information about this LSA is used to configure LSP layer network topology. The forwarding of IP packets or LSPs shall be done by using the next-hop database created from this network topology data. The link state of existing fiber-links can be advertised by conforming to the concept of TE extension to routing protocols [TE-OSPF] -[TE-ISIS]. The fiber links connected to LSRs are identified as TE-links that forms "routing adjacency" between LSRs. The corresponding LSA of the TE-Fiber Link shall contain the interface switching capability descriptor, which indicates the fiber link being terminated by LSCs, and information about this LSA is used to configure OLSP layer network topology. The routing of OLSPs shall be done by using the next-hop database created from this network topology data.

Also, these LSRs with integrated PSC+LSC switching capabilities shall be required to advertise resource information in terms of switching capability. The reservation capability of the integrated switching node capability shall be varied to match the state of resource utilization as discussed in the previous section. The route of OLSPs can be calculated by the selection of LSCs that have OLSP forwarding or termination capability and fiber links that have unreserved wavelength channels. Thus, the LSR can have multi-layer routing capability that enables IP packet forwarding routes to be constructed considering both existing OLSP and fiber-link state. If the unused bandwidth of each OLSP is insufficient, a new OLSP can be automatically set-up in response to an IP-traffic surge or LSP setup calls. This means that the LSR can realize the IP-centric flexible Photonic network essential to the next generation large capacity backbone network.

4. Enhancements to interface switching capabilities descriptor

The draft of [GMPLS-OSPF] defines the Interface Switching Capability...
Descriptor with a sub-TLV of the Link TLV with type 15. The length is the length of the value field in octets.

The Switching Capability (Switching Cap) field contains one of the following values:

1. Packet-Switch Capable-1 (PSC-1)
2. Packet-Switch Capable-2 (PSC-2)
3. Packet-Switch Capable-3 (PSC-3)
4. Packet-Switch Capable-4 (PSC-4)
51. Layer-2 Switch Capable (L2SC)
100. Time-Division-Multiplex Capable (TDM)
150. Lambda-Switch Capable (LSC)
200. Fiber-Switch Capable (FSC)

If there is no Interface Switching Capability Descriptor for an interface, the interface is assumed to be packet-switch capable (PSC-1).

Interface Switching Capability Descriptors present a new constraint for LSP path computation.

The detail extensions to Interface Switching Capability Descriptor for integrated PSC/LSC LSR will be discussed in the next version of this document.

The Switching Cap field for integrated multi-layer LSRs: TBD.

The format of the value field: TBD.

5. Security Considerations

Security issues are not discussed in this draft.

6. References

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