Multi-area multi-layer traffic engineering using hierarchical LSPs in GMPLS networks

draft-shiomoto-ccamp-multiarea-te-01.txt

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Abstract

This draft proposes a traffic engineering framework for multi-layer path networks using dynamic virtual topology configuration capability of GMPLS protocols. The electrical label switched path is routed over the virtual topology built on a set of optical label switched path in multi-layer path networks. The virtual topology is dynamically altered by setting up or tearing down optical label switched paths. Virtual topology is configured in response to traffic demand change so that congestion of the network is mitigated. Utilization of label switched path is measured at ingress node and disseminated with routing protocol.
extensions for the individual node to decide whether the virtual topology should be altered or not without centralized coordination.

1. Summary for Sub-IP Area

1.1. Summary
See the Abstract above.

1.2. RELATED DOCUMENTS
"Multi-area MPLS traffic engineering," draft-kompella-mpls-multiarea-te-03.txt (work in progress), 5/02.

1.3. Where does it fit in the Picture of the Sub-IP Work
This work fits the CCAMP box.

1.4. Why is it Targeted at this WG
This draft is targeted at the CCAMP WG because it addresses the traffic engineering in multi-area multi-layer domain. The topic is in the scope of the work item on how the properties of network resources gathered by the measurement protocol can be distributed in existing routing protocols, such as OSPF and IS-IS.

1.5. Justification of Work
The WG should consider this document as it addresses a new traffic engineering framework using dynamic virtual topology configuration mechanism in multi-layer path network, which is enabled by GMPLS protocols.

2. Conventions used in this document
The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC-2119.
3. Introduction

GMPLS provides a protocol framework for multi-layer path network control. Label switched paths (LSPs) in fiber-, lambda-, SDH/SONET-, and IP-layers can be set up by using GMPLS signaling and routing protocols. The lower-layer LSP provides a (virtual) topology for the upper-layer LSP routing in multi-layer path network. In particular non-packet capable LSP (fiber, lambda, SDH/SONET), which has a fixed capacity, constructs a "hard" virtual topology for packet capable LSP routing. The virtual topology can be quickly re-configured using GMPLS routing and signaling protocols to set up the lower-layer LSPs.

Promising application of GMPLS-based multi-layer path network control includes traffic engineering. A new traffic engineering framework can be constructed in multi-layer path networks. This draft proposes a traffic engineering method based on the quick virtual topology configuration. The rest of the draft is organized as follows. Firstly we briefly review the current traffic engineering methods for fixed network topology. Secondly we show the concept of the proposed traffic engineering method based on the quick virtual topology configuration. Multi-area network whose backbone area is optical-layer network and other areas are electrical IP-layer networks is used for network model. Thirdly we provide protocol extensions for the proposed method.

4. Current traffic engineering in MPLS

Conventional routing protocol computes the path which minimizes its cost using the shortest path algorithm [OSPF, ISIS]. Packets are forwarded along with the shortest path even if the intermediate links do not have sufficient bandwidth, which result in congestion. To overcome the congestion caused by IGP’s shortest path routing, MPLS-based traffic engineering has been extensively studied recently [RFC2702]. Explicit route for LSP can be used so as to avoid congestion in MPLS framework. Constraint-based shortest path first (CSPF) algorithm selects the path with minimum cost assuming that links which do not have sufficient bandwidth are excluded from the network topology. If the requested bandwidth for the LSP is given, the CSPF algorithm calculates the path which satisfies the requested bandwidth. The path for the LSP is specified at the source node and the LSP is set up along with the path [RFC3209, RFC3212].

LSP which requests a specified bandwidth is served in first-come-first-served basis. As the number of such LSPs increases, the network utilization might not get optimized: some links might be congested while others not. Explicit route for existing LSPs need to be re-optimized
for better network utilization. Several network optimization methods have been developed. In [Wang99], given the traffic demand matrix whose (i,j) element corresponds to the traffic demand from the node i to j, linear and integer programming formulations are used to minimize the utilization of the most congested link. In [Xiao00], LSP is arbitrarily routed at first to obtain the traffic demand matrix and a simple CSPF algorithm is applied to find the route of the LSP in descending order of its traffic demand volume.

Those traffic engineering methods are developed under the assumption that the underlying network topology is fixed. The network utilization is, however, limited under the fixed underlying network topology. This draft proposes a traffic engineering method using the dynamic reconfiguration of virtual topology in multi-layer path network. In particular we address the method for two-layer network in which the lower-layer is photonic network and the upper-layer is IP packet network.

5. Dynamic reconfiguration of virtual topology in Photonic IP multi-layer network

5.1. Network model

Multi-area network whose backbone area is optical-layer network and other areas are electrical IP-layer networks is used for network model [ID-Kompella02]. Photonic layer provides a virtual topology for IP layer in Photonic IP multi-layer network. Optical LSP, which is set up to connect two electrical LSRs, is advertised as FA-LSP [LSP-HIER]. A set of those FA-LSPs forms the virtual network topology for electrical LSP routing. Electrical LSP is routed over the virtual network topology.

Figure 1 shows the multi-area network with photonic core backbone area. Electrical areas (areas 1, 2, and 3) consist of LSRs while the photonic backbone-area consists of PXCs. The electrical areas are connected with the photonic backbone area (area 0) at the ABRs 1, 2, and 3, respectively.
E-LSPs are set up between ABRs in distant area so that all areas are mutually interconnected in a full-mesh manner. Those E-LSPs are used to carry packets over the photonic backbone area. The photonic backbone area provides a virtual topology for E-LSP routing. The O-LSP is set up over the photonic backbone area to connect ABRs in distant electrical areas. The O-LSPs need to be set up so that all areas are mutually interconnected via E-LSPs in a full-mesh manner. We should note that not all ABRs are directly connected each other via an O-LSP. E-LSP uses single-hop or multi-hop O-LSPs from ingress to egress areas. In some cases an E-LSP may be routed over a single-hop O-LSP, which directly connects the ingress and egress areas. In other cases an E-LSP may be routed over multi-hop O-LSPs, by which the ingress area is electrically reachable to the egress area.

Two virtual optical backbone area topologies are explained using the sample network in Figure 1. Suppose that the O-LSP is already set up between ABR 2 and ABR 3. In this situation if the traffic demand between area 1 and area 2 is higher than that between area 1 and area 3, the O-LSP should be set up between ABR 1 and ABR 2. In this case the
A virtual optical backbone area topology is shown in Figure 2 (a). The E-LSPs are routed over the virtual optical backbone area topology. The E-LSP from area 1 to area 3 is routed over a two-hop path passing through area 1, 2, and 3 while the E-LSP from area 1 to area 2 is routed over a single-hop path passing through area 1 and 2. On the other hand, if the traffic demand between area 1 and area 3 is higher than that between area 1 and area 2, the O-LSP should be set up between ABR 1 and ABR 3. In this case the virtual optical backbone area topology is shown in Figure 2 (b).

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{virtual_topology.png}
\caption{Virtual topology of backbone area.}
\end{figure}

### 5.2. Dynamic reconfiguration of virtual topology

The virtual backbone area topology should adjust to traffic demand change [Ramaswami96, Kar00, Oki02]. If traffic demand for E-LSPs are given, appropriate virtual optical backbone area topology could be determined. In determining the virtual topology we use a heuristic method in which O-LSP is set up between node pair in the descending order of traffic demand between them. The idea behind the method is that sending most of traffic in a single-hop may reduce congestion. We need to determine the virtual topology such that we make the best use of the O-LSP bandwidth because the O-LSP occupies the fixed bandwidth once it is established. When the O-LSP gets underutilized, it should be released for future demand of another O-LSP.

The dynamic reconfiguration of the virtual topology can be implemented with either centralized or distributed approach. In centralized approach, a central network management system collects traffic demand over the E-LSP measured by all nodes in the network, calculates a new
virtual topology, and dictates appropriate nodes to initiate O-LSP setup procedure. In distributed approach, each node decides whether it should initiate O-LSP setup procedure or not. In this draft we take the distributed approach because the centralized one suffers from reliability problem due to single point of failure.

The distributed approach requires a mechanism for coordination between nodes. Unless coordination mechanism is properly implemented, a new virtual topology might be formed inconsistently. To overcome this problem, LSP bandwidth utilization is measured at ingress node and it is disseminated to all nodes in the domain. Each node calculates the next virtual topology to mitigate the congestion using bandwidth utilization for E-LSP and O-LSP disseminated by its ingress node. Each node decides whether it should initiate O-LSP setup procedure or not by comparing the current virtual topology and the next one.

6. Protocol extensions

6.1. Routing protocol extensions for LSP utilization dissemination

O-LSP utilization is measured at ingress LSR. Measured O-LSP utilization is disseminated by routing protocol. Area local Opaque LSA (type 10) is used to carry the measured O-LSP utilization [GMPLS-ROUT, GMPLS-OSPF, TE-OSPF]. Format of sub-TLV for the measured O-LSP utilization is shown in Figure 3. The measured O-LSP utilization is disseminated to notify individual nodes of that congestion occurs in the network.

E-LSP utilization is measured at ingress LSR. Measured E-LSP utilization is disseminated by routing protocol. Area local Opaque LSA (type 10) is used to carry the measured E-LSP utilization. Format of sub-TLV for the measured E-LSP utilization is shown in Figure 3. The measured E-LSP utilization is used for individual node to calculate the next virtual topology to mitigate congestion.
7. Conclusions

GMPLS protocols open a new vista for multi-layer path network control. The traffic engineering method using dynamic reconfiguration of virtual topology is a promising application of GMPLS protocols in multi-layer path networks. Detailed protocol mechanisms for interwork between layers in multi-path network need further study and will be developed in the future version of this draft.

8. Security considerations

Security issues are not discussed in this draft.

9. Reference


[ID-Kompella02] "Multi-area MPLS traffic engineering," draft-kompella-mpls-multiarea-te-03.txt (work in progress), 5/02.


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