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Traffic Engineering with MPLS

Abstract

Multi-protocol label switching (MPLS) is a layer 2.5 technology, sharing both routing (layer 3) and switching (layer 2) characteristic. It supports scalable virtual private networks (VPNs), end-to-end quality of service (QoS), and traffic engineering service on existing IP networks. In this paper, I describe how MPLS traffic engineering works, products that deploy this technology, and how they support QoS feature.

1. Introduction

Initially, MPLS was intended to simplify IP lookup of traditional routers because IP lookup required referring to the longest prefix match in the forwarding table causing slow packet transmissions. However, due to advanced hardware technology over the past decade that enabled faster packet forwarding in IP network, the goal of deploying MPLS technology has shifted.

Before discussing details of MPLS, it is helpful to review mechanism of IP network. In a traditional IP network, each router performs an IP lookup, determines a next hop based on its routing table, and forwards the packet to that next hop.These processes are repeated for every router, each making its own decisions until an IP packet reaches its final destination.

Unlike traditional IP networks, MPLS network establishes predetermined paths called label-switched paths (LSP) for particular source-destination pairs. Labels are imposed on the packets and instead of using the IP header to determine the next hop, the labels are used to forward packets. The label is a 20 bit information which is a part of MPLS header located between link and network layer headers as shown in Figure 1. This label is swapped with the outgoing label and send packets to the next hop. The labels get assigned with different values based on forwarding equivalence classes (FECs) that groups packets by providing different treatment. The MPLS standard was in fact originated from the Cisco Tag Switching implementation and later published by IETF. The IETF recommends to use the header format shown in Figure 1. The Exp bits will be discussed later in this paper.

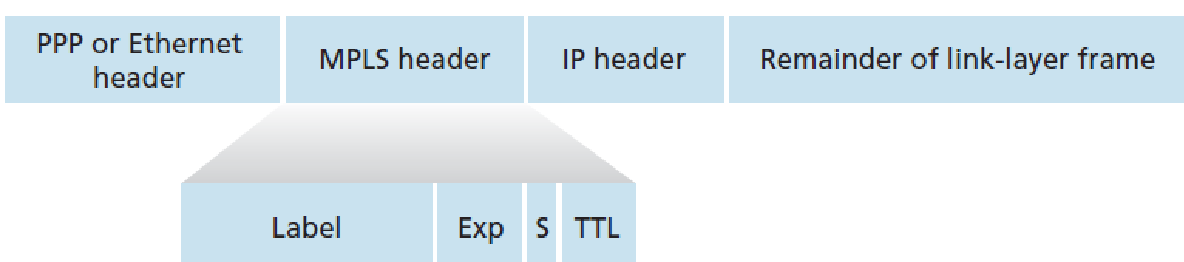


Figure 1: MPLS Shim Header

MPLS domain has two types of routers, label switching router (LSR) and label edge router (LER) as shown in Figure 2. LERs are egress or ingress of the MPLS domain and LSR forwards packets based on the value of a label attached inside the packets. LSP is the path established between these two LERs.

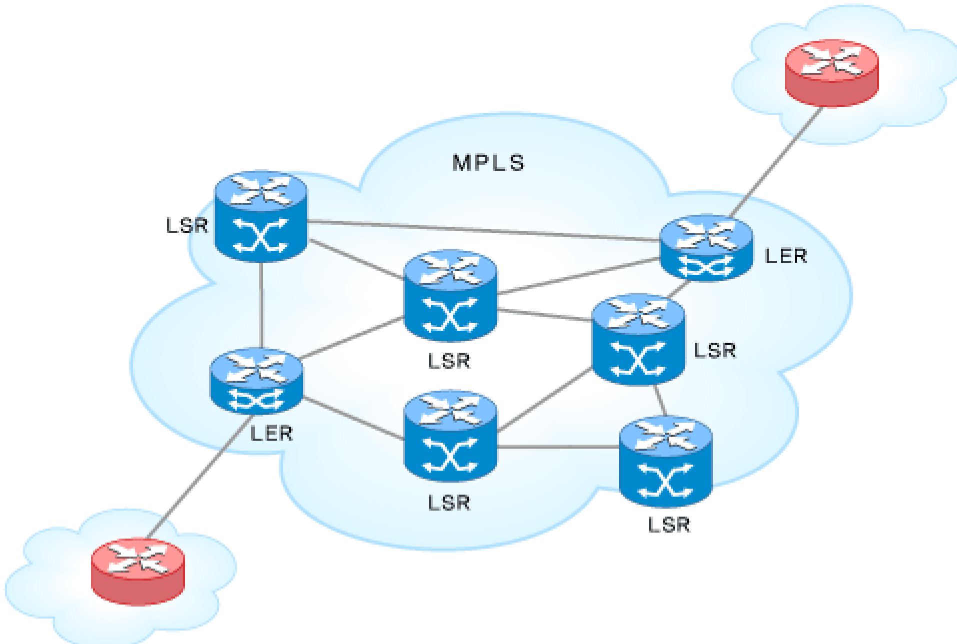


Figure 2: MPLS domain

1.1 MPLS Traffic Engineering

This section discusses about features of MPLS traffic engineering and why it is used. Traffic Engineering (TE) is engineering of a given network so that the underlying network can support the services with requested quality. It selects established paths calculated based on routing protocols to facilitate efficient and reliable network operations, optimize network resource utilization, and traffic performance. The interior gateway protocols (IGPs) like OSPF have existing problems of creating traffic congestion in some scenarios as any packets that have the same destination would all utilize the same shortest path. Traffic congestion causes violation of constraints such as bandwidth guarantee. Thus, MPLS-TE is necessary to consider bandwidth availability or traffic characteristics into account.

1.2 DiffServ

DiffServ was developed to provide QoS in IP networks after the attempt of IntServ which was based on a per-application-flow model. DiffServ introduces the concept of classes by dividing traffic flow and allocating network resources on a per-class basis. This is achieved by marking the 6-bit DiffServ Code Point (DSCP) field on the packet. Per-hop behavior (PHB) contains scheduling and drop priority information for a single packet at particular node, determined by DSCP. How DiffServ is used in MPLS network is described in the next section. While DiffServ requires no signalling and state maintenance, this model alone cannot guarantee QoS without adequate resources.

1.3 MPLS DiffServ

With support of MPLS on DiffServ, IETF added three experimental (EXP) bits on MPLS header to carry DiffServ information in MPLS network (Refer back to Figure 1). For simplicity of application scenarios, this report only considers LSPs for which the PHB is inferred from the EXP bits called E-LSPs. Given that EXP has three bits, eight distinct PHBs can be expressed in a single LSP.

2. Company Products

I have chosen Juniper M series multiservice edge routers and Cisco ASR 1000 series aggregation services routers for my research. Supported features are implemented by network operating systems that run under these physical routers.

2.1 Cisco IOS

Cisco ASR 1000 series is categorized under edge routers and support a wide range of 4 to 130 Mpps packet forwarding capabilities as well as 2.5 to 200 Gbps of system bandwidth. Network operating system that run inside these routers is called Cisco IOS and it is targeted to solve challenges faced by service providers and equipment suppliers with creating differentiated IP services, spending cost of mapping IP over layer 2 networks, and difficulties in identifying better network utilization. To account for bandwidth availability in the existing IGP, Cisco IOS uses an overlay model to build virtual topologies on top of the physical networks. The overlay model is expected to solve the condition of traffic being over subscribed at one link by offering following features: constraint based routing, traffic shaping and traffic policing functionality, and survivability of the virtual links.

2.2 Juniper Junos

Juniper M series is a multiservice edge routers for service provider networks. It span from 10 to 320 Gbps of throughput and advertises that a consistent set of capabilities is available at all network locations. Juniper Junos (the operating system used in Juniper Networks hardware routers) supports the DiffServ-TE technology and tools that can control the utilization of resources that are reserved.

2.2.1 Junos DiffServ-TE Implementation

Junos DiffServ-TE is a combination of DiffServ and TE technologies. It aims to offer strict QoS guarantees in different classes of service (voice, ATM, and Frame Relay) by making MPLS-TE aware of the class of service. Juniper claims following advantages (within the scope of this report) of Junos implementation:

- Low latency and jitter for queues below bandwidth allocation
- Resiliency in the event of link failure with path protection, fast-reroute and link-node protection mechanisms

3. Use Cases

This section describes application scenarios that require product features introduced above to solve existing problems.

3.1 Limiting the proportion of traffic from a particular class on a link

Consider a small network with voice and data traffic. The goal of this scenario is to guarantee low jitter, delay, and loss for voice traffic as well as data traffic. Juniper Junos featuring MPLS DiffServ-TE can achieve this requirement by limiting the proportion of voice traffic on each link. Even in the case of link failure of the shortest path, it can help the traffic reroute on the next best path by considering available bandwidth thanks to MPLS-TE. Details of this scenario is illustrated in Figure 3.

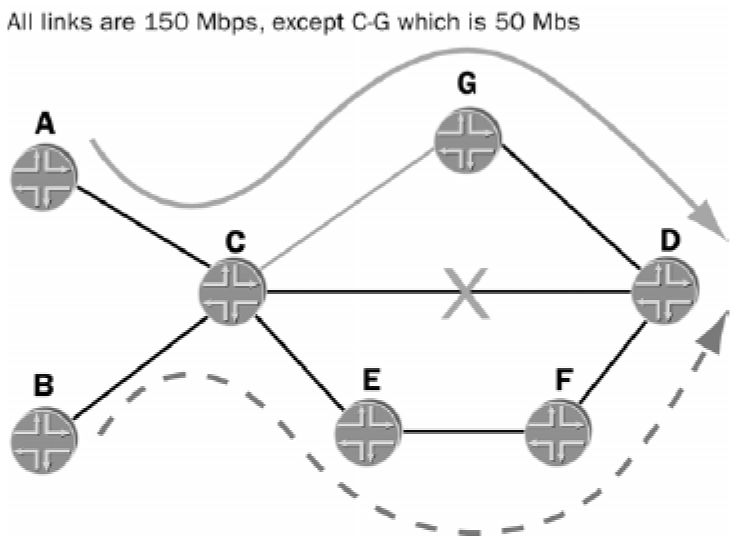
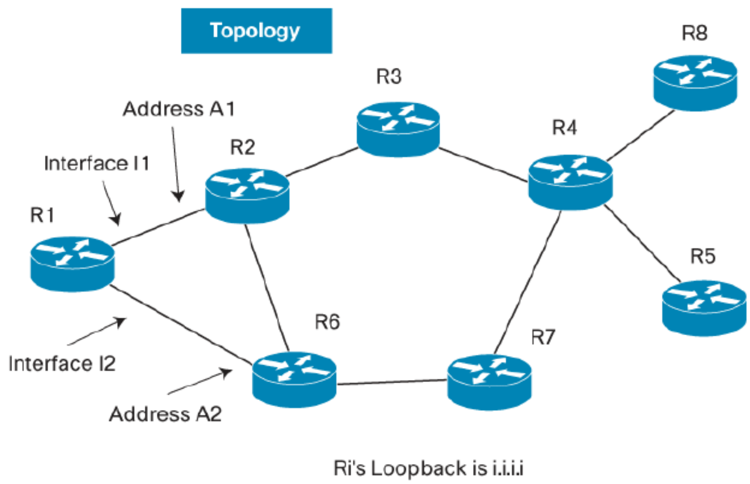


Figure 3: A small network with a link failure

Solution to the scenario in the past was overprovisioning available bandwidth. However, it does not work specifically in this case as it automatically selects the alternate shortest path, A-C-G-D. Given that the link C-G has only one third of all other links, this path has lower capacity than the other path A-C-E-F-D. As a result, higher percentage of voice traffic will be consumed at C-G link with very limited bandwidth for data traffic.

3.2 Cisco IOS MPLS Autoroute Announce Feature (IGP Shortcut)

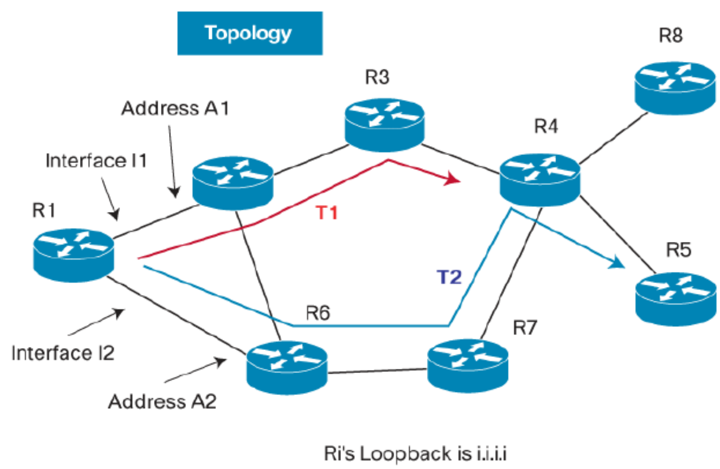
Autoroute is an extra phase that is taken after the route selection made by IGP routing protocols. In order for routing algorithms to push the traffic into an MPLS TE tunnel, they can either announce autoroute or use policy based routing. Until then, head-end router will not use MPLS TE tunnel to forward the data traffic. Cisco Autoroute Announce let IP traffic routers (non-MPLS routers) use MPLS LSPs as next hops for BGP/IGP routes by modifying the SPF algorithm. In other words, destination router without MPLS capability can be reached via LSP. All the traffic directed to prefixes topologically behind the tunnel head-end is pushed on to the tunnel. Figures below compares network topology with and without LSP. Note that tunnels are up in routing table for R1 in Figure 4.



Routing Table

Dest	O Intf	Next Hop	Metric
2.2.2.2	I1	A1	1
3.3.3.3	I1	A1	2
4.4.4.4	I1	A1	3
	I2	A2	3
5.5.5.5	I1	A1	4
	I2	A2	4
6.6.6.6	I2	A2	1
7.7.7.7	I2	A2	2
8.8.8.8	I1	A1	4
	I2	A2	4

Figure 4: Topology without tunnels and R1 routing table without Autoroute Announce



Routing Table

Dest	O Intf	Next Hop	Metric
2.2.2.2	I1	A1	1
3.3.3.3	I1	A1	2
4.4.4.4	T1	R4	3
5.5.5.5	T2	R5	4
6.6.6.6	I2	A2	1
7.7.7.7	I2	A2	2
8.8.8.8	T1	R4	4

Figure 5: Topology with tunnels and R1 routing table with Autoroute Announce

4. Conclusions

Both product features offered comprehensive solutions to the example scenarios. The first scenario has two types (voice and data) of traffic, requiring distinct treatment. This is not a condition that can be dealt by MPLS-TE alone as it operates at the aggregate level across all the DiffServ classes of service giving no bandwidth guarantees specific to different classes. Similarly, DiffServ alone cannot reduce queue size and queueing delay at the same to guarantee bounded delay.

The second scenario clearly represents how product feature is applied to solve the given problem. Routing table after enabling Autoroute Announce on two tunnels T1 and T2 indicates router R1 can reach R8 via R4 without the “physical” connection.

Discovering any potential missing product features is difficult at this point unless I can critically come up with specific application scenario that is not solvable by products introduced here.

References

https://cours.etsmtl.ca/mgr816/MPLS-TE.pdf
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