Traffic engineering and multiprotocol label switching as mean to improve network efficiency

Master’s Thesis in Computer Network Engineering

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Preface
We are Thankful to Almighty Allah, who helped us to finish the thesis.

We want to give honor and privilege to our respected resource person Olga Torstensson and Tony Larsson, who provided us the opportunity to learn about Multiprotocol Label Switching application to traffic engineering and signaling protocols involved in it.

We would also like to thank our families who are financing us for our studies and who are giving us absolutely everything they can to make us a better individual. At the end we would like to thank all those friends who helped us whenever we needed it most.

Muhammad Uzair Suleman & Sheheryar Khan
Halmstad University, January 2010
Abstract
Multiprotocol label switching (MPLS) is an emerging technology that provides scalability, flexibility and use the available bandwidth in the network in an efficient way. Signaling protocols like constraint based routing; the label distribution protocol and the resource reservation protocol can be used to enable good traffic engineering. Interior gateway protocols work in conjunction with signaling protocols and their strong binding result in better performance of the network.

In this thesis, we have analyzed the performance of the signaling protocols used in the MPLS paradigm for traffic engineering. These signaling protocols are meant to provide support for traffic engineering using MPLS and in this way help to increase the performance of the network. Some issues related to increase the efficiency of the signaling protocols are scrutinized. How the resource reservation protocol has been extended to support traffic engineering in multi protocol label switching paradigm is also discussed. Moreover, application of multiprotocol label switching to traffic engineering is implemented in a proposed network.
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1 Introduction

1.1 Traffic Engineering

During the last decade rapid growth of all kinds of network has been observed. In this on going network expansion, there is a need for engineering and this engineering can be divided in two kinds: one is network engineering and the other is traffic engineering.

1. Network engineering is about selection of network devices such as router, switches and dimensioning of the network. It deals with installation of new equipments which can be a more or less continuous process over longer periods.

2. Traffic engineering is related to dimensioning issues and more specifically about how to handle the traffic with respect to an actual network design, network traffic load and network capacity available.

The principal goal of Traffic Engineering is to move and balance the traffic load in space and time in order to use the available network resources more evenly and efficiently. In this way it also aims to reduce the risk for congestion in the network. Traffic engineering gains efficiency through load balancing for parallel paths. It can provide fault recovery procedures on path failure in the network. It is difficult to carry out traffic engineering on IP networks because traffic to the same destination is treated in the same way.

Traffic Engineering is a general term and it is not a terminology specific to MPLS. Prior to MPLS, IP traffic engineering was widely used even with its pretty vague behavior like it doesn’t care from where the traffic is coming from and only take into its account the destination of the traffic flows therefore it’s difficult to maintain the constraint based routing. There are some more problems with IP traffic engineering discussed in comparison with MPLS TE later on.

1.1.1 IP Packet Routing and Forwarding

IP routing is a process of packet forwarding which depends upon destination IP address. IP layer calculate the path and make a decision through which the packets must travel to reach the destination. For this purpose routing table is used which is created at the time of TCP/IP initializes.

The routing table is build up either manually or automatically by the router. In a network like a LAN, the routing table can be created and managed by the network administrator manually whereas in dynamic routing, routing tables are build up and maintained automatically. Routing protocols are solely responsible for exchanging the information between routers. In order to route the traffic inside an autonomous system, internal routing protocols such as RIP (Routing information protocol) and OSPF (Open shortest path first) are used. Whereas for routing the traffic outside the autonomous system external routing protocols are used such as BGP (border gateway protocol). Hence packet forwarding can be more efficient by using appropriate routing protocol for the network as it has a tendency to eradicate the routing loops as well.
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A routing table contains information about all destinations present in a network and the routes through which packet can travel to reach the destination overall. However, in hop by hop routing scheme routing table is referred for the address of the next hop only until the data reach to the destination node. In the network every node has the routing table for lookup in order to forward the packet. Routing table has the number of entries as shown in the figure 1.1. Network destination field contains the final destination IP address and combined with the network mask to find out the destination route. Here, 0.0.0.0 entry point out the default gateway. Gateway field contains the IP address to which the packet is forwarded. Interface field tells the path to the next hop while forwarding the packet. Protocol field tells about the source of the routing table. Age field tells us the number of seconds this route was last updated. For default, local and static route 0 is specified. Metric field contains the cost of the route.

<table>
<thead>
<tr>
<th>Network Destination</th>
<th>Network Mask</th>
<th>Gateway</th>
<th>Interface</th>
<th>Protocol</th>
<th>Age</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0.0.0</td>
<td>0.0.0.0</td>
<td>157.60.38</td>
<td>157.60.136.2</td>
<td>Default</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>127.0.0.0</td>
<td>255.0.0.0</td>
<td>127.0.0.1</td>
<td>127.0.0.1</td>
<td>Local</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>157.60.136.0</td>
<td>255.255.252.0</td>
<td>157.60.136.41</td>
<td>157.60.136.41</td>
<td>Static</td>
<td>0</td>
<td>20</td>
</tr>
</tbody>
</table>

Table 1-1: Routing Table

1.1.2 Multiprotocol Label Switching

Multiprotocol label switching is a packet forwarding scheme. The edge router in the network simply inserts a MPLS label to the packet or frame called ingress. As the packet pass through the network each node on the path called label switch router get information and compare it with routing table to get the next hop of the packet. Hence, a fixed length label is attached to the packet by edge router and forwarding based upon that inserted label. In a similar fashion the edge router removes the label to forward the packet outside the MPLS domain called egress router.
In MPLS, Forwarding equivalence class is a group of packets to forward across the network with a single label. Labels assigned to packets are based on FECs (forwarding equivalence classes) means packets required same resources along the path are grouped together. Thus, packets belonging to the same class get the similar treatment. It is done only once when packet enters into the MPLS domain means Ingress is responsible for performing the mapping of IP packets into FEC’s.

MPLS is composed of two planes, a control plane and a data plane. However MPLS is a control plane driven protocol mean control plane is responsible for all the tasks except forwarding which is done in data plane as shown in fig 1.2. If we look at the data plane, it contains the label forwarding table also called “label forwarding information base (LFIB)” carries the information to simply forward the packet. On the other hand control plane exhibits the routing protocol along with the routing table and signaling protocol.

The IETF (Internet Engineering Task Force) approved label switching shim header is composed of 32 bits with the following fields: 20 bits label field hold the real value of MPLS header. 3 bits experimental field usually carries information regarding to quality of service. 1 bit stack field maintain label stack order. 8 bits time to live field is conventionally used as shown in figure 1.3.
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This label is inserted in between layer 2 and layer 3 headers shown in figure 1.4 and 1.5. In case of ATM networks it is inserted in between VPI/VCI fields shown in figure 1.6. Frame header exhibits label in between its frame and IP header shown in figure 1.7.

<table>
<thead>
<tr>
<th>Label</th>
<th>Exp</th>
<th>S</th>
<th>TTL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Figure 1-3: MPLS Label Format*

<table>
<thead>
<tr>
<th>PPP Header</th>
<th>Label Header</th>
<th>Layer 3 Header</th>
</tr>
</thead>
</table>

*Figure 1-4: PPP Header*

<table>
<thead>
<tr>
<th>MAC Header</th>
<th>Label Header</th>
<th>Layer 3 Header</th>
</tr>
</thead>
</table>

*Figure 1-5: LAN Tag Header*

<table>
<thead>
<tr>
<th>GFC</th>
<th>VPI</th>
<th>VCI</th>
<th>PTI</th>
<th>CLP</th>
<th>HEC</th>
<th>Data</th>
</tr>
</thead>
</table>

*Figure 1-6: ATM Header*

<table>
<thead>
<tr>
<th>Frame Header</th>
<th>Label</th>
<th>IP Header</th>
<th>Payload</th>
</tr>
</thead>
</table>

*Figure 1-7: Frame Header*

If we compare the conventional routing with the label switch routing than we come to know that in label switching only one forwarding algorithm is required as well as only once the IP header is analyzed whereas conventional routing need multicast routing and forwarding algorithms and also IP header is analyzed at each intermediate node in the network as shown in table 1.8. The entire intermediate router in the MPLS domain are called label switched router (LSR). At each LSR, incoming label tells the path to the destination and thus label is swapped.

<table>
<thead>
<tr>
<th>Routing Decision</th>
<th>Full IP Header Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Label Switching</strong></td>
<td>It is based on different parameters e.g. Traffic Engineering, QoS and VPN. It occurs once only at label edge router during assigning a label to the packet.</td>
</tr>
<tr>
<td><strong>Hop By Hop Routing</strong></td>
<td>It is based on address only It occurs at every node</td>
</tr>
</tbody>
</table>

*Figure 1-8: Difference between Label Switching and Hop by Hop Routing*
1.1.3 **Label Switching**

Label switching basically replaces the traditionally hop by hop routing. Each packet is assigned a label which tends the network devices to forward the packet more efficiently and rapidly. In MPLS, packets are forwarded on the basis of labels assigned to them. Label switched paths (LSP’s) are setup between label switch routers (LSR’s). Label switch routers exchanges label information in a way that label mapping is performed in the first phase after receiving request for it. Labels are swapped accordingly when traffic flows later on.

A typical label switching table includes interface field belong to the previous hop, a label field assigned by the previous hop, a forwarding equivalence class field as described earlier and than two more fields for next hop’s interface and label to be swapped with the previous one. In the example as shown in figure 1.9 we have a small MPLS network as the left router is an ingress router, right one is egress router and the middle one is label switch router (LSR). Ingress request for the label mappings and receive it along the path. Now if we have a closer look on LSR label switching table, it contains the ingress interface from where the traffic is coming from and the ingress label which was defined earlier at label mapping stage. Forwarding equivalence class field contains the similar destination for the different traffic flows. The second last field has the egress interface and the last field having the egress label to be swapped out with the previous one.

---

**Figure 1-9: Label Switching Table**

<table>
<thead>
<tr>
<th>Ingress Interface</th>
<th>Ingress Label</th>
<th>FEC</th>
<th>Egress Interface</th>
<th>Egress Label</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>4</td>
<td>192.168</td>
<td>4</td>
<td>9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ingress Interface</th>
<th>Ingress Label</th>
<th>FEC</th>
<th>Egress Interface</th>
<th>Egress Label</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-</td>
<td>192.168</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ingress Interface</th>
<th>Ingress Label</th>
<th>FEC</th>
<th>Egress Interface</th>
<th>Egress Label</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>9</td>
<td>192.168</td>
<td>6</td>
<td>-</td>
</tr>
</tbody>
</table>
1.2 Problems and Goals
Convergence of the network results in frequently sending of updates across the network. Flooding of these updates use network resources and bandwidth which reduce the network performance as all the network devices do not need these updates. Link state update messages are sent to all the devices in the network which decreases the efficiency of the network. Similarly resource reservation protocol update message in a similar way increase the congestion.

Our goal is to limit these update packets to the routers in the network that needs to be installed. In order to increase the performance of the network we have to control flooding in the network. We will also investigate the ways that how we can achieve fast reservations and rapid data delivery with the help of resource reservation protocol. Moreover by implementation of MPLS and traffic engineering in the proposed network we will demonstrate the working at real environment.
2 MPLS TRAFFIC ENGINEERING

In MPLS, layer 3 has the characteristics of layer 2, which allows traffic engineering as application of MPLS. MPLS-TE creates and retains the tunnels with subject to the available resources. In MPS-TE paradigm interior gateway protocol provides information about the available resources. Hence, MPLS TE calculate path from source to destination with respect to the available resources.

There are following traffic engineering components:-

- **Information sharing in a MPLS network:** Information such as the state, available resources and topology of the network is shared in the network through conventional link state routing protocols.

- **Path Selection in a MPLS network:** In path selection, a suitable route is selected for explicit routing in MPLS network by constraint based routing (CBR). CBR is used to find the paths that are capable of certain specifications required by the traffic.

- **Path Management in a MPLS network:** Path management includes label distribution and path maintenance. It is done by label distribution protocol (LDP). Two label switched paths create, maintain and terminate a session between them with the help of a signaling protocol called resource reservation protocol (RSVP).

**2.1 MPLS Traffic engineering tasks**

MPLS Traffic Engineering has three main tasks as described in RFC 2702 in order to perform smooth MPLS TE procedures. First, incoming packets are classified into different streams called Forwarding equivalence classes. Secondly, each FEC is map into a traffic trunk. It is a one to one process means each FEC corresponds to a single traffic trunk. Thirdly, once traffic trunk has been distinguished now they are to deliver on the physical paths with respect to the specific requirements. Constraint based routing is used to complete this task through which suitable path or route in the network is chosen and followed by the traffic trunks.

**2.2 Advantages of MPLS Traffic engineering**

There are number of benefits MPLS TE provides to the network as follows:

1) Traffic engineering makes sure that all the devices present in the network is neither underutilized nor over utilized.

2) Label switch paths are used to identify the blockage in the network.

3) Constraint base routing allows the label switch path to meet the required requirement of the data flow before the data is delivered to the destination.

4) In order to achieve the best performance of the network traffic engineering use the available bandwidth in very efficient way no matter whether there is congestion in the network or not.
2.3 Traffic Trunks

A traffic trunk is placed inside a LSP and it’s a sum of the traffic flows in a domain. Traffic trunks are pretty much similar to the virtual circuits like in ATM means that they are routable objects. But there is a difference between path and a traffic trunk. Traffic between two routers can be put in a nutshell using a traffic trunk. Traffic trunk differs with LSP in a way that it can be moved to any other path in the network.

Traffic trunk is always a unidirectional but it can be used as a bidirectional. In a way that two unidirectional traffic trunks are created on a same LSR but their direction is opposite to each other in order to carry the packets. From which the traffic trunk carries packets from source to destination will be a forward trunk and the traffic trunk carries packets back to the source will be a backward trunk.

Both traffic trunks are created and destroyed together which means two unidirectional traffic trunks are coupled together to be a single bi directional traffic trunk as shown in figure 2.1.

![Figure 2-1: Traffic Trunks](image)

There are two types of bi directional trunks.

**Topologically Asymmetric:** Traffic trunks are said to be Topologically Asymmetric, if there are different physical routing paths through which bi directional traffic trunks are routed.

**Topologically Symmetric:** Traffic trunks are said to be Topologically Symmetric, if there is a same physical routing paths through which bi directional traffic trunks are routed.

2.4 Constraint Based Routing

Constraint Based Routing deals with network traffic uniformly and it computes routes that are subject to constraint for e.g. bandwidth and path cost. CBR can route the traffic to a longer but relatively less loaded path than a shorter and heavily loaded path. An enhanced link state IGP will be used to propagate link attributes with the normal link state information to compute LSP paths. Constraint-based routing automatically finds realistic paths which satisfies the set of constraints for traffic trunks.

In CBR paradigm, we have some inputs like attributes associated with traffic trunks and with resources. A CBR model reduces the impact of manual configuration to the great extent.
2.5 Constrained Shortest Path First Algorithm
CSPF is used in MPLS TE and it is an extension of SPF algorithm. CSPF calculate shortest path with the set of constraints. There are number of constraint like bandwidth guaranteed constraint and maximum nodes limitation. Constraint based routing use CSPF.

Let us take an example, considering the figure 2.2 we have to find a route from router A to C. If we have bandwidth constraint of 30 units than CSPF will give us a path A → B → C. If we have bandwidth constraint of 50 units than CSPF will give us a path A → D → C. If we have bandwidth constraint of 90 units than CSPF will give us a path A → D → E → C. But if we consider OSPF and ISIS than we can conclude easily that in all the above cases we will get the path A → B → C.

Hence, we can see how Traffic engineering helps in load sharing and load balancing in the MPLS domain while using Constraint based routing.

**Figure 2-2: CSPFA (Constraint shortest path first algorithm)**

2.6 Problem in Link State Update Packet Exchange
In OSPF TE link state update packet is composed of LSA’s and it is send to other nodes by means of flooding in the network. Each node present in the network sends LSU packet to all the nodes attached to it except from where it has received the packet as shown in fig 2.3. Here we can see the edge router C receives the LSU packet three times from A, D and E. Once edge router C receives an LSU packet, it will discard the other packets because they contain the same information. Hence LSU packet coordinates the entire routers present in the network by LSU packet exchange mechanism.
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2.6.1 Projected solution to exchange Link State Update packet

In MPLS domain, we have resource reservation protocol having label switched paths. So whenever a path is reserved then all the link state advertisements of LSP route can be combined and put into the updated packet. The updated packet will have the information about routers as well as the reservations along LSP route and it is send not by flooding but only to the edge router. This process will decrease the number of packets to be transferred all over the network and an updated packet can only be transferred between edge routers as shown in figure 2.3.1.

2.7 Implementation

Here is the proposed network in which routing is performed according to MPLS TE set-up. We consider five routers and one switch connected as shown in the figure 5.1. We can see that there are two paths for traffic flows from router 1 to router 5 and vice versa. Router 1 and Router 5 are label edge routers and one is ingress while the other is egress at a time. If traffic flows from Router 1 to Router 5 than we can say Router 1 is ingress and Router 5 is egress and its opposite when traffic flows in other direction. However, Router 2, Router 3 and Router 4 are intermediate
nodes called label switched routers. Detailed configurations and results of the routers and a switch are depicted in the appendix.

In traditional routing or even when we use routing protocol such as OSPF (which is actually implemented here as a part of MPLS TE) single path will be utilized for traffic creating network congestion as discussed earlier. So, let us see how we can use this proposed network under configuring it with MPLS TE. First we configured basic MPLS using OSPF routing protocol, during which following are the key commands used for the implementation and for the verification:

- **Ip cef:** Enabling ip cef on router introduce layer 3 routing to it. Cisco express forwarding provides the fastest way to transfer packet from ingress router to egress router by creating its own table known as forwarding information base.

- **Show ip cef:** It shows Cisco express forwarding table structured differently than the routing table for fast traffic flows.

- **Tag-switching ip:** It enables dynamic tag or label switching and must be done not only at the global configuration of the router but also at each interface.

- **Show tag-switching forwarding table:** It exhibits six fields. The first one is *local tag* corresponds to the label assign by the current router. Second is *outgoing tag or VC* contains the label allocated by the next hop. Third is *prefix or tunnel id* means the tunnel through which packets are forwarding. Fourth is *bytes tag switched* is self explanatory that how many bytes are switched with the specific incoming label. Fifth is *outgoing interface* means the packet will be sent to this interface now. Last is *next hop* telling the address of the neighbor for outgoing label allocation.
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Once we have MPLS prepared network we can configure its application i.e. traffic engineering. Under traffic engineering development we have defined four tunnels in all. Two are from Router 1 to Router 5 following each path having names Tunnel12345 and Tunnel1245. On the other hand two tunnels are from Router 5 to Router 1 having names Tunnel10 and Tunnel20. The key instructions for its implementation and verification are as follows:

- **Mpls traffic-eng area 1:** In order to enable the traffic engineering in the OSPF area, we have used this command in configuration.

- **Tunnel mode mpls traffic-eng:** When we define a tunnel we have to classify it as a MPLS TE tunnel so this command is used to make the tunnel as MPLS TE one.

- **Show ip ospf mpls traffic-eng link:** It shows the number of links supported by traffic engineering.

- **Show ip ospf database opaque-area:** It provides the detailed information on Traffic engineering LSA’s (link state advertisements) e.g. length of the LSA in bytes and the id of the router advertising it.

Figure 2-6: Proposed Network Scenario

![Network Diagram]

During the course of network configuration, various parameters like the network mask, tunnel names, and various other details were recorded, including the following:

- **Router 1:**
  - Loop back 0: 172.16.1.1/24
  - Loop back 1: 10.10.10.10

- **Router 2:**
  - Loop back 0: 172.16.2.1/24
  - Loop back 1: 10.10.10.20

- **Switch 1:**
  - 192.168.0.0/24

- **Router 3:**
  - Loop back 0: 172.16.3.1/24
  - Loop back 1: 10.10.10.30

- **Router 4:**
  - Loop back 0: 172.16.4.1/24
  - Loop back 1: 10.10.10.40

- **Router 5:**
  - Loop back 0: 172.16.5.1/24
  - Loop back 1: 10.10.10.50

![Tunnels Name]

- **Tunnels Name:**
  - **Tunnel 12345**
  - **Tunnel 1245**
  - **Tunnel 10**
  - **Tunnel 20**
- **Show mpls traffic-eng tunnels brief**: It shows the number of tunnels in the network and the information regarding them e.g. name and the destination of the tunnels.

- **Ip rsvp bandwidth**: In order to enable resource reservation protocol above command is used on the interfaces.

- **Show ip rsvp interface**: Resource reservation protocol detailed information is displayed with respect to the specific interface. The first field tells about the interface. Second *allocate* field notify the current allocated bandwidth. Third field *i/f max* shows the maximum bandwidth that can be allocated. Fourth field *flow max* tells about the biggest single flow that can be allocated to the interface.

### 2.7.1 MPLS TE Tunnels

Multiprotocol label switching traffic engineering tunnels implementation result is shown in table 5.3. All the tunnels in the network are listed with their specific destinations.

<table>
<thead>
<tr>
<th>Router1</th>
<th>TUNNEL NAME</th>
<th>DESTINATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1 t1245</td>
<td>10.10.10.50</td>
<td></td>
</tr>
<tr>
<td>R1 t12345</td>
<td>10.10.10.50</td>
<td></td>
</tr>
<tr>
<td>R5 t10</td>
<td>10.10.10.10</td>
<td></td>
</tr>
<tr>
<td>R5 t20</td>
<td>10.10.10.10</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Router5</th>
<th>TUNNEL NAME</th>
<th>DESTINATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>R5 t10</td>
<td>10.10.10.10</td>
<td></td>
</tr>
<tr>
<td>R5 t20</td>
<td>10.10.10.10</td>
<td></td>
</tr>
<tr>
<td>R1 t1245</td>
<td>10.10.10.50</td>
<td></td>
</tr>
<tr>
<td>R1 t12345</td>
<td>10.10.10.50</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2-6-1: MPLS TE tunnels**

### 2.7.2 Resource reservation protocol

Resource reservation protocol running in the network can be seen as shown in table 5.3. There are number of fields as explained earlier. Here, we can see that “allocated” field contains different values which is the current allocated bandwidth for the traffic flow whereas *i/f max* is the maximum bandwidth of that interface and *flow max* is the biggest single flow that can be allocated to the interface.
Traffic Engineering and Multiprotocol label switching as means to increase network efficiency

<table>
<thead>
<tr>
<th>Router1</th>
<th>Interface</th>
<th>Allocated</th>
<th>i/f max</th>
<th>flow max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Se0/0/1</td>
<td>260K</td>
<td>512K</td>
<td>256K</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Router2</th>
<th>Interface</th>
<th>Allocated</th>
<th>i/f max</th>
<th>flow max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fa0/1</td>
<td>132K</td>
<td>512K</td>
<td>256K</td>
<td></td>
</tr>
<tr>
<td>Se0/0/0</td>
<td>128K</td>
<td>512K</td>
<td>256K</td>
<td></td>
</tr>
<tr>
<td>Se0/0/1</td>
<td>144K</td>
<td>512K</td>
<td>256K</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Router3</th>
<th>Interface</th>
<th>Allocated</th>
<th>i/f max</th>
<th>flow max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Se0/1/0</td>
<td>0</td>
<td>512K</td>
<td>256K</td>
<td></td>
</tr>
<tr>
<td>Se0/1/1</td>
<td>128K</td>
<td>512K</td>
<td>256K</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Router4</th>
<th>Interface</th>
<th>Allocated</th>
<th>i/f max</th>
<th>flow max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Se0/1/0</td>
<td>260K</td>
<td>512K</td>
<td>256K</td>
<td></td>
</tr>
<tr>
<td>Se0/1/1</td>
<td>0</td>
<td>512K</td>
<td>256K</td>
<td></td>
</tr>
<tr>
<td>Fa0/1</td>
<td>144K</td>
<td>512K</td>
<td>256K</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Router5</th>
<th>Interface</th>
<th>Allocated</th>
<th>i/f max</th>
<th>flow max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Se0/0/0</td>
<td>144K</td>
<td>512K</td>
<td>256K</td>
<td></td>
</tr>
</tbody>
</table>

Table 2-6-2: Resource reservation protocol
3 Resource Reservation Protocol (RSVP)

Resource reservation protocol was extended to RSVP TE for label switched paths in MPLS network. RSVP is a signaling protocol which support both uni-cast as well as multi-cast data flows. It supports the requirement of integrated service models by using weighted fair queuing.

3.1 RSVP Vs RSVP TE

Difference between standard RSVP and RSVP TE is that RSVP can only work on hosts in order to request and reserve the network resources whereas RSVP TE work on label switch routers to create and maintain LSP tunnels and it also reserve network resources for LSP tunnels.

Secondly, standard RSVP requires supporting large numbers of RSVP sessions. A session is defined for a specific destination as a single data flow. On the other hand RSVP TE allows RSVP sessions between ingress and egress routers of LSP tunnel. RSVP TE applies to a collection of traffic trunks sharing the same path and network resources. In the network, if the number of flows increases than in RSVP TE the LSP tunnels do not increase.

3.2 RSVP TE Features

We can describe RSVP TE features as follows;

- RSVP TE create LSPs are capable of carrying traffic trunks. Moreover, Multiple LSPs can share the load of the network by sharing single traffic trunk and also a single LSP carry multiple traffic trunks. This is also the foundation of Classes of Service.
- It exhibits receiver initiated reservations.
- It is not necessary for an LSP to reserve the resource because LSPs can access the resource without reservation.
- It supports dynamic and multipoint-to-multipoint communication.
- Loops can be detected in RSVP TE.
- LSP tunnels, once established can be rerouted dynamically.
- The traffic flowing through LSP is not transparent that’s why LSP act as a LSP tunnel having filtering mechanism.

3.3 RSVP Message Types

There are two types of resource reservation protocol messages but before explaining the message types we took an example as shown in figure 3.1. Router A is a source router and router B is the destination router. So traffic flows from router A to router C. For router B, router A is a “previous hop” with “incoming interface” and router C is a “next hop” with “outgoing interface”.

![Figure 3-1: RSVP Message Types](image)

There are two RSVP message types:
• **Resv**: Receiver sends reservation request “Resv” message to sender in upstream. The message flows in opposite direction of the data flow direction. A “reservation state” is maintained along the path. The “Resv” message is delivered to the source so that required data flow path can be established till the next node.

• **Path**: Source sends “Path” message to the destination along with the routing protocol specified routes. “Path” message save the “path state” at each router on the way.

### 3.4 RSVP Update Message Problem

Let us depict the working of RSVP TE in figure 3.2. over the time. Once the router A reserve the resource than link state update packet is sent to all the routers on that label switch path. Hence, again the flooding problem occurs here and due to which overhead will increase in the network.

![Figure 3-2: RSVP Update Problem](image)

### 3.5 RSVP Update Message Proposed Solutions

In proposed solution, source router sends a PATH packet to the destination and receives a RESV message in response. RESV message reserve the resource along the LSP route. After receiving the RESV message source router sends the update message to destination router only instead of flooding as shown in figure 3.3.

Even more fast reservation and data delivery can be achieved by decreasing the number of messages exchange between edge routers in the following way as shown in figure 3.4. The source router has the complete picture of the network with updated database by LSU’s.
It can send RESV message to the destination router and reserve the required path instead of asking destination router to reserves the path. In this way data can be transmitted just after the RESV message sent to destination router by the source router.
3.6 RSVP Authentication

RSVP authentication is used to restrict unauthorized LSRs from path reservations. RSVP TE sessions cannot only be secured with transport protocols like TCP. It is secured with message digest 5 signature authentication means LSRs present in the same IP subnet use the same secret key. Moreover, LSRs having matching secret keys can only access and take part in the running RSVP TE process. In RSVP TE, there is an integrity object which carry the cryptographic data is used for the authentication of LSR and their RSVP messages.
4 Label Distribution Protocol (LDP)

It is a signaling protocol which is used to establish Label switched path (LSP) between Label switch routers (LSRs) in MPLS domain. In MPLS based network LDP defines a set of procedures and messages through which a label switch router tell the other LSR about the label bindings and the forwarding equivalence class. Functionally, LDP Peers are two LSRs which used LDP to exchanges labels with each other and their state is called LDP session. TCP is used in session communication of LDP to make sure that state information does not require periodically update. LDP has the ability to discover the LSR in the network and establish a session to make them LDP peers. LDP is an individual protocol in a way that it does not depend upon the existing routing protocol in the network.

FEC is associated with each label distributed by LDP. LSR exchanging the label are called LDP peers and till the time they communicate with each other is referred as LDP session. TCP is used by LDP for session communication in order to consistent data delivery. Once an LSR identify another, it starts an LDP session which leads them to agree upon common parameters.

4.1 LDP Message Types

There are four types of LDP messages:

4.1.1 Discovery message

This message makes sure the existence of LSR in the network. A hello message is send to the network by LSR for this purpose and it is broadcast as UDP packet. LSR are known to the network due to discovery messages sent from time to time.

4.1.2 Session message

Session messages are responsible for session management in the network between LSR. They create, sustain and stop sessions. Once an LSR receives the hello message, as discussed above, from other LSR present in the network the label distribution protocol is initialized between them. After completion of process both LSR are called LDP peers. Hence, advertisement messages can be exchanged between two LDP peers.

4.1.3 Notification message

It provides recommended or optional information to LSR by label distribution protocol. There are two types of notification messages produced by LDP:

- **Advisory notification:** These notifications are received from LDP to LSR telling about the LDP current session history.

- **Error notification:** These notifications cause the LDP session to be end between two LSR. Once an LSR get an error message from its LDP peer, it finishes the session and removes all label mapping regarding to the specific session.

4.1.4 Advertisement message

Advertisement message is used by LDP to ask or provide its peer, information about label mapping. In account of forwarding equivalence classes, these messages can also initiate, alter or remove label mappings.
4.2 LDP Sessions
Steps of LDP sessions are shown in figure 4.1. At peer discovery Hello message is exchanged between the nodes. Session is initialized by sending TCP open message. Once session has been setup, labels are exchanged between the peers and session is maintained for the future correspondence.

![Figure 4-1: Steps of LDP Session](image)

4.3 Downstream Distribution
There are two ways of downstream distribution: First one is on demand downstream distribution in which LSR forward packet after getting unique request from its peer. The other is spontaneous downstream distribution in which LSR announce label binding and send packets when it is ready.

4.4 LDP Failure Detection and Prevention
Router can detect failure itself. Neighboring routers exchange Keep Alive messages periodically during LDP sessions. LSRs do self test in both planes (data and control) called LSR self test. The control plane use LSP ping and the data plane use extension of LSP ping. LSR do self test by exchanging loopback labels using LDP.

LDP is configured manually on each interface and LDP failure can be prevented by allowing LSR to have the IGP in co-ordination with LDP on its interface. It will help in a way that anything missing in LDP configuration will be found. LDP failure can also be prevented by using validation methods for their implementations.
4.5  **LDP Failure Notification**

Failure should be reported to routing protocols otherwise routing protocols will not know about the failure by themselves.

Two most common types of LDP failure notifications are:

4.5.1  **NMS (Network Management System)**

Network Management System broadcast the failure information of a node in the network so that other nodes present in the network must know about the failure node in the network. NMS come to know about the failure from the failed node itself. Since the failure is reported by the failed node itself therefore it is the fastest way of LDP failure notification.

4.5.2  **IGP Notification**

IGP Notification tells all the effected nodes present in the network about the failure. It works in the fashion that cost of the links is increased fallaciously for those who are connected. Label switched paths choose alternate paths for the destination having higher cost. When LSP change their path to destination, routing protocol also come to know about the failure. After the recovery of the failure paths are assigned to original cost as previously before failure.

4.6  **LDP Recovery**

Once, the LDP failure has been notified to routing protocol than there is a need to recover the failure. There are two ways of recovery as follows;

4.6.1  **Automatic**

In automatic recovery of the fault, the root cause is not determined and the main theme of the recovery is to make sure that data is being transferred on alternative path. In this technique two nodes can also tell each other about the fault and can cooperate in order to fix it or flow the traffic to any other route.

4.6.2  **Manual**

In manual recovery first the basis of the failure has to be diagnosed before the recovery. The most common defect is the configuration of LDP interface not done. Other failure is the fault in protocol operation of LDP and can be overcome by resetting the LDP.
5 Conclusions
Traffic engineering is an application of multiprotocol label switching. The main advantage is utilization of under-realized path in the network and reduction of the overall cost. Constraint based routing fulfill the resource requirement of the data to be delivered across the MPLS domain.

Flooding has been the major participant introducing delays in data transmission. Link state update packet is used to be broadcasted to all the nodes present in the network. The proposed solution depicts the delivery of the link state update packet directly to the label edge router reducing network congestion.

Resource reservation protocol is a signaling protocol used to reserve the path between edge routers of MPLS network. A path is reserved before sending the data to destination. It increases the load on the network. By combining the route reservation with the data delivery decrease the number of packets exchange during the resource reservation.

Although most of the hitches in multiprotocol label switching traffic engineering are resolved and have been implemented yet there are some issues like VoD (Video on demand) before it can be deployed practically.
6 References


7 Appendix

Router 1

R1#show running configuration
Building configuration...
Current configuration : 2265 bytes
!
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname R1
!
boot-start-marker
boot-end-marker
!
no aaa new-model
memory-size iomem 10
!
!
ip cef
!
!
ip host PAGENT-SECURITY-V3 97.32.43.85 87.84.0.0
!
multilink bundle-name authenticated
mpls traffic-eng tunnels
!
!
voice-card 0
no dspfarm
!
!
interface Loopback0
ip address 172.16.1.1 255.255.255.0
ip ospf network point-to-point
!
interface Loopback1
ip address 10.10.10.10 255.255.255.255
ip ospf network point-to-point
!
interface Tunnel1245
ip unnumbered Loopback1
tunnel destination 10.10.10.50
tunnel mode mpls traffic-eng
tunnel mpls traffic-eng autoroute announce
tunnel mpls traffic-eng priority 6 6
tunnel mpls traffic-eng bandwidth 132
tunnel mpls traffic-eng path-option 1 explicit name ViaSwitch
no routing dynamic
!
interface Tunnel12345
  ip unnumbered Loopback1
tunnel destination 10.10.10.50
tunnel mode mpls traffic-eng
tunnel mpls traffic-eng autoroute announce
tunnel mpls traffic-eng priority 3 3
tunnel mpls traffic-eng bandwidth 128
tunnel mpls traffic-eng path-option 1 explicit name Via135
no routing dynamic
!
interface FastEthernet0/0
  no ip address
  shutdown
duplex auto
speed auto
!
interface FastEthernet0/1
  no ip address

A  Update  B
    | Path     | C
    |           |
-----------
Data

shutdown
duplex auto
speed auto
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interface Serial0/0/0
no ip address
shutdown
clock rate 125000

interface Serial0/0/1
ip address 192.168.1.1 255.255.255.0
mpls ip
mpls traffic-eng tunnels
ip rsvp bandwidth 512 256

router ospf 1
mpls traffic-eng router-id Loopback1
mpls traffic-eng area 1
log-adjacency-changes
network 10.10.10.0 0.0.0.255 area 1
network 172.16.0.0 0.0.255.255 area 1
network 192.168.0.0 0.0.255.255 area 1

ip http server
no ip http secure-server

ip explicit-path name Via135 enable
next-address 192.168.1.2
next-address 192.168.2.3
next-address 192.168.3.4
next-address 192.168.4.5

ip explicit-path name ViaSwitch enable
next-address 192.168.1.2
next-address 192.168.0.4
next-address 192.168.4.5

control-plane

line con 0
exec-timeout 0 0
line aux 0
line vty 0 4
login


scheduler allocate 20000 1000
!
!
End

R1#sh ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
  D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
 N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
 E1 - OSPF external type 1, E2 - OSPF external type 2
  i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
 ia - IS-IS inter area, * - candidate default, U - per-user static route
 o - ODR, P - periodic downloaded static route
Gateway of last resort is not set
172.16.0.0/24 is subnetted, 5 subnets
O 172.16.4.0 [110/66] via 192.168.1.2, 00:51:11, Serial0/0/1
O 172.16.5.0 [110/130] via 0.0.0.0, 00:51:11, Tunnel12345

C 172.16.1.0 is directly connected, Loopback0
O 172.16.2.0 [110/65] via 192.168.1.2, 00:51:11, Serial0/0/1
O 172.16.3.0 [110/130] via 192.168.1.2, 00:51:11, Serial0/0/1
O 192.168.4.0/24 [110/129] via 192.168.1.2, 00:51:11, Serial0/0/1

10.0.0.0/32 is subnetted, 5 subnets
C 10.10.10.10 is directly connected, Loopback1
O 10.10.10.30 [110/130] via 192.168.1.2, 00:51:12, Serial0/0/1
O 10.10.10.20 [110/65] via 192.168.1.2, 00:51:12, Serial0/0/1
O 10.10.10.40 [110/66] via 192.168.1.2, 00:51:12, Serial0/0/1
O 10.10.10.50 [110/130] via 0.0.0.0, 00:51:13, Tunnel12345

O 192.168.0.0/24 [110/65] via 192.168.1.2, 00:51:13, Serial0/0/1
C 192.168.1.0/24 is directly connected, Serial0/0/1
O 192.168.2.0/24 [110/193] via 192.168.1.2, 00:51:13, Serial0/0/1
O 192.168.3.0/24 [110/129] via 192.168.1.2, 00:51:13, Serial0/0/1

R1#sh ip int brief

<table>
<thead>
<tr>
<th>Interface</th>
<th>IP-Address</th>
<th>OK?</th>
<th>Method</th>
<th>Status</th>
<th>Protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td>FastEthernet0/0</td>
<td>unassigned</td>
<td>YES</td>
<td>manual</td>
<td>administratively down</td>
<td>down</td>
</tr>
<tr>
<td>FastEthernet0/1</td>
<td>unassigned</td>
<td>YES</td>
<td>manual</td>
<td>administratively down</td>
<td>down</td>
</tr>
<tr>
<td>Serial0/0/0</td>
<td>unassigned</td>
<td>YES</td>
<td>manual</td>
<td>administratively down</td>
<td>down</td>
</tr>
<tr>
<td>Serial0/0/1</td>
<td>192.168.1.1</td>
<td>YES</td>
<td>manual</td>
<td>up</td>
<td>up</td>
</tr>
<tr>
<td>Loopback0</td>
<td>172.16.1.1</td>
<td>YES</td>
<td>manual</td>
<td>up</td>
<td>up</td>
</tr>
<tr>
<td>Loopback1</td>
<td>10.10.10.10</td>
<td>YES</td>
<td>manual</td>
<td>up</td>
<td>up</td>
</tr>
<tr>
<td>Tunnel1245</td>
<td>10.10.10.10</td>
<td>YES</td>
<td>TFTP</td>
<td>up</td>
<td>up</td>
</tr>
<tr>
<td>Tunnel12345</td>
<td>10.10.10.10</td>
<td>YES</td>
<td>TFTP</td>
<td>up</td>
<td>up</td>
</tr>
</tbody>
</table>
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**R1#sh ip ospf mpls traffic-eng link**

OSPF Router with ID (172.16.1.1) (Process ID 1)
Area 1 has 1 MPLS TE links. Area instance is 4.
Links in hash bucket 8.
Link is associated with fragment 0. Link instance is 4
  Link connected to Point-to-Point network
  Link ID : 172.16.2.1
  Interface Address : 192.168.1.1
  Neighbor Address : 192.168.1.2
  Admin Metric te: 64 igp: 64
  Maximum bandwidth : 193000
  Maximum reservable bandwidth : 64000
  Number of Priority : 8
  Priority 0 : 64000  Priority 1 : 64000
  Priority 2 : 64000  Priority 3 : 48000
  Priority 4 : 48000  Priority 5 : 48000
  Priority 6 : 31500  Priority 7 : 31500
  Affinity Bit : 0x0

**R1#sh ip ospf database opaque-area**

OSPF Router with ID (172.16.1.1) (Process ID 1)
  Type-10 Opaque Link Area Link States (Area 1)

  LS age: 1118
  Options: (No TOS-capability, DC)
  LS Type: Opaque Area Link
  Link State ID: 1.0.0.0
  Opaque Type: 1
  Opaque ID: 0
  Advertising Router: 172.16.1.1
  LS Seq Number: 80000008
  Checksum: 0x7829
  Length: 140
  Fragment number : 0
  MPLS TE router ID : 10.10.10.10
  Link connected to Point-to-Point network
    Link ID : 172.16.2.1
    Interface Address : 192.168.1.1
    Neighbor Address : 192.168.1.2
    Admin Metric : 64
    Maximum bandwidth : 193000
    Maximum reservable bandwidth : 64000
    Number of Priority : 8
    Priority 0 : 64000  Priority 1 : 64000
    Priority 2 : 64000  Priority 3 : 48000

30
Priority 4: 48000  Priority 5: 48000
Priority 6: 31500  Priority 7: 31500
Affinity Bit: 0x0
IGP Metric: 64
Number of Links: 1
LS age: 1200
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 1.0.0.0
Opaque Type: 1
Opaque ID: 0
Advertising Router: 172.16.2.1
LS Seq Number: 80000008
Checksum: 0x9443
Length: 132
Fragment number: 0
MPLS TE router ID: 10.10.10.20
Link connected to Broadcast network
  Link ID: 192.168.0.4
  Interface Address: 192.168.0.2
  Admin Metric: 1
  Maximum bandwidth: 12500000
  Maximum reservable bandwidth: 64000
Number of Priority: 8
Priority 0: 64000  Priority 1: 64000
Priority 2: 64000  Priority 3: 64000
Priority 4: 64000  Priority 5: 64000
Priority 6: 47500  Priority 7: 47500
Affinity Bit: 0x0
IGP Metric: 1
Number of Links: 1
LS age: 1653
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 1.0.0.0
Opaque Type: 1
Opaque ID: 0
Advertising Router: 172.16.3.1
LS Seq Number: 80000007
Checksum: 0x2C47
Length: 140
Fragment number: 0
MPLS TE router ID: 10.10.10.30
Link connected to Point-to-Point network
  Link ID: 172.16.2.1
  Interface Address: 192.168.2.3
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Neighbor Address: 192.168.2.2
Admin Metric: 64
Maximum bandwidth: 193000
Maximum reservable bandwidth: 64000
Number of Priority: 8
Priority 0: 64000  Priority 1: 64000
Priority 2: 64000  Priority 3: 64000
Priority 4: 64000  Priority 5: 64000
Priority 6: 64000  Priority 7: 64000
Affinity Bit: 0x0
IGP Metric: 64
Number of Links: 1
LS age: 1459
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 1.0.0.0
Opaque Type: 1
Opaque ID: 0
Advertising Router: 172.16.4.1
LS Seq Number: 80000008
Checksum: 0xDC1A
Length: 132
Fragment number: 0
MPLS TE router ID: 10.10.10.40
Link connected to Broadcast network
  Link ID: 192.168.0.4
  Interface Address: 192.168.0.4
  Admin Metric: 1
  Maximum bandwidth: 1250000
  Maximum reservable bandwidth: 64000
Number of Priority: 8
Priority 0: 64000  Priority 1: 64000
Priority 2: 53000  Priority 3: 53000
Priority 4: 46000  Priority 5: 46000
Priority 6: 46000  Priority 7: 46000
Affinity Bit: 0x0
IGP Metric: 1
Number of Links: 1
LS age: 1463
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 1.0.0.0
Opaque Type: 1
Opaque ID: 0
Advertising Router: 172.16.5.1
LS Seq Number: 8000000A
Checksum: 0x9E7
Length: 140
Fragment number: 0
MPLS TE router ID: 10.10.10.50
Link connected to Point-to-Point network
  Link ID: 172.16.4.1
  Interface Address: 192.168.4.5
  Neighbor Address: 192.168.4.4
  Admin Metric: 64
  Maximum bandwidth: 193000
  Maximum reservable bandwidth: 64000
  Number of Priority: 8
  Priority 0: 64000   Priority 1: 64000
  Priority 2: 53000   Priority 3: 53000
  Priority 4: 46000   Priority 5: 46000
  Priority 6: 46000   Priority 7: 46000
  Affinity Bit: 0x0
  IGP Metric: 64
  Number of Links: 1
LS age: 436
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 1.0.0.1
Opaque Type: 1
Opaque ID: 1
Advertising Router: 172.16.2.1
LS Seq Number: 80000008
Checksum: 0x90A
Length: 132
Fragment number: 1
Link connected to Point-to-Point network
  Link ID: 172.16.3.1
  Interface Address: 192.168.2.2
  Neighbor Address: 192.168.2.3
  Admin Metric: 781
  Maximum bandwidth: 16000
  Maximum reservable bandwidth: 64000
  Number of Priority: 8
  Priority 0: 64000   Priority 1: 64000
  Priority 2: 64000   Priority 3: 48000
  Priority 4: 48000   Priority 5: 48000
  Priority 6: 48000   Priority 7: 48000
  Affinity Bit: 0x0
  IGP Metric: 781
  Number of Links: 1
Traffic Engineering and Multiprotocol label switching as means to increase network efficiency

LS age: 649
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 1.0.0.1
Opaque Type: 1
Opaque ID: 1
Advertising Router: 172.16.3.1
LS Seq Number: 80000008
Checksum: 0xDE8F
Length: 132
Fragment number: 1
Link connected to Point-to-Point network
  Link ID: 172.16.4.1
  Interface Address: 192.168.3.3
  Neighbor Address: 192.168.3.4
  Admin Metric: 64
  Maximum bandwidth: 193000
  Maximum reservable bandwidth: 64000
  Number of Priority: 8
    Priority 0: 64000
    Priority 1: 64000
    Priority 2: 64000
    Priority 3: 48000
    Priority 4: 48000
    Priority 5: 48000
    Priority 6: 48000
    Priority 7: 48000
  Affinity Bit: 0x0
  IGP Metric: 64
  Number of Links: 1
LS age: 1265
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 1.0.0.1
Opaque Type: 1
Opaque ID: 1
Advertising Router: 172.16.4.1
LS Seq Number: 80000008
Checksum: 0x19AA
Length: 132
Fragment number: 1
Link connected to Point-to-Point network
  Link ID: 172.16.5.1
  Interface Address: 192.168.4.4
  Neighbor Address: 192.168.4.5
  Admin Metric: 64
  Maximum bandwidth: 193000
  Maximum reservable bandwidth: 64000
  Number of Priority: 8
Priority 0 : 64000    Priority 1 : 64000
Priority 2 : 64000    Priority 3 : 48000
Priority 4 : 48000    Priority 5 : 48000
Priority 6 : 31500    Priority 7 : 31500
Affinity Bit : 0x0
IGP Metric : 64
Number of Links : 1
LS age: 1468
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 1.0.0.2
Opaque Type: 1
Opaque ID: 2
Advertising Router: 172.16.2.1
LS Seq Number: 80000009
Checksum: 0x3FBE
Length: 132
Fragment number : 2
Link connected to Point-to-Point network
  Link ID : 172.16.1.1
  Interface Address : 192.168.1.2
  Neighbor Address : 192.168.1.1
  Admin Metric : 781
  Maximum bandwidth : 16000
  Maximum reservable bandwidth : 64000
Number of Priority : 8
Priority 0 : 64000    Priority 1 : 64000
Priority 2 : 53000    Priority 3 : 53000
Priority 4 : 46000    Priority 5 : 46000
Priority 6 : 46000    Priority 7 : 46000
Affinity Bit : 0x0
IGP Metric : 781
Number of Links : 1
LS age: 1789
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 1.0.0.2
Opaque Type: 1
Opaque ID: 2
Advertising Router: 172.16.4.1
LS Seq Number: 80000007
Checksum: 0x8AC
Length: 132
Fragment number : 2
Link connected to Point-to-Point network
  Link ID : 172.16.3.1
Traffic Engineering and Multiprotocol label switching as mean to increase network efficiency

Interface Address : 192.168.3.4
Neighbor Address : 192.168.3.3
Admin Metric : 64
Maximum bandwidth : 193000
Maximum reservable bandwidth : 64000
Number of Priority : 8
Priority 0 : 64000 Priority 1 : 64000
Priority 2 : 64000 Priority 3 : 64000
Priority 4 : 64000 Priority 5 : 64000
Priority 6 : 64000 Priority 7 : 64000
Affinity Bit : 0x0
IGP Metric : 64
Number of Links : 1

R1#sh mpls traffic-eng tunnels brief
Signalling Summary:
LSP Tunnels Process: running
RSVP Process: running
Forwarding: enabled
Periodic reoptimization: every 3600 seconds, next in 1865 seconds
Periodic auto-bw collection: disabled

<table>
<thead>
<tr>
<th>TUNNEL NAME</th>
<th>DESTINATION</th>
<th>UP IF</th>
<th>DOWN IF</th>
<th>STATE/PROT</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1_t1245</td>
<td>10.10.10.50</td>
<td>-</td>
<td>Se0/0/1</td>
<td>up/up</td>
</tr>
<tr>
<td>R1_t12345</td>
<td>10.10.10.50</td>
<td>-</td>
<td>Se0/0/1</td>
<td>up/up</td>
</tr>
<tr>
<td>R5_t10</td>
<td>10.10.10.10</td>
<td>Se0/0/1</td>
<td>-</td>
<td>up/up</td>
</tr>
<tr>
<td>R5_t20</td>
<td>10.10.10.10</td>
<td>Se0/0/1</td>
<td>-</td>
<td>up/up</td>
</tr>
</tbody>
</table>

Displayed 2 (of 2) heads, 0 (of 0) midpoints, 2 (of 2) tails

R1#sh ip rsvp interface

<table>
<thead>
<tr>
<th>interface</th>
<th>allocated</th>
<th>i/f max</th>
<th>flow max</th>
<th>sub max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Se0/0/1</td>
<td>260K</td>
<td>512K</td>
<td>256K</td>
<td>0</td>
</tr>
</tbody>
</table>

R1#sh mpls traffic-eng tunnels summary
Signalling Summary:
LSP Tunnels Process: running
RSVP Process: running
Forwarding: enabled
Head: 2 interfaces, 2 active signalling attempts, 2 established
2 activations, 0 deactivations
Midpoints: 0, Tails: 2
Periodic reoptimization: every 3600 seconds, next in 1832 seconds
Periodic auto-bw collection: disabled
R1_t10245345
Name: R1_t12345 (Tunnel12345) Destination: 10.10.10.50
Status:
  Admin: up  Oper: up  Path: valid  Signalling: connected
  path option 1, type explicit Via135 (Basis for Setup, path weight 973)
Config Parameters:
  Bandwidth: 128 kbps (Global)  Priority: 3 3  Affinity: 0x0/0xFFFF
  Metric Type: TE (default)
  AutoRoute: enabled  LockDown: disabled  Loadshare: 128  bw-based
  auto-bw: disabled
  InLabel : -
  OutLabel : Serial0/0/1, 26
RSVP Signalling Info:
  Src 10.10.10.10, Dst 10.10.10.50, Tun_Id 12345, Tun_Instance 9
RSVP Path Info:
  My Address: 10.10.10.10
  Explicit Route: 192.168.1.2 192.168.2.3 192.168.3.4 192.168.4.5 10.10.10.50
  Record Route: NONE
  Tspec: ave rate=128 kbits, burst=1000 bytes, peak rate=128 kbits
RSVP Resv Info:
  Record Route: NONE
  Fspec: ave rate=128 kbits, burst=1000 bytes, peak rate=128 kbits
History:
  Tunnel:
    Time since created: 1 hours, 47 minutes
    Time since path change: 1 hours, 41 minutes
  Current LSP:
    Uptime: 1 hours, 41 minutes
Traffic Engineering and Multiprotocol label switching as means to increase network efficiency

R1_t123450 23450 245
Name: R1_t1245 (Tunnel1245) Destination: 10.10.10.50
Status:
  Admin: up  Oper: up  Path: valid  Signalling: connected
  path option 1, type explicit ViaSwitch (Basis for Setup, path weight 129)
Config Parameters:
  Bandwidth: 132 kbps (Global)  Priority: 6 6  Affinity: 0x0/0xFFFF
  Metric Type: TE (default)
  AutoRoute: enabled  LockDown: disabled  Loadshare: 132 bw-based
  auto-bw: disabled
  InLabel: -
  OutLabel: Serial0/0/1, 27
RSVP Signalling Info:
  Src 10.10.10.10, Dst 10.10.10.50, Tun_Id 1245, Tun_Instance 8
RSVP Path Info:
  My Address: 10.10.10.10
  Explicit Route: 192.168.1.2 192.168.0.2 192.168.0.4 192.168.4.5
  10.10.10.50
  Record Route: NONE
  Tspec: ave rate=132 kbits, burst=1000 bytes, peak rate=132 kbits
RSVP Resv Info:
  Record Route: NONE
  Fspec: ave rate=132 kbits, burst=1000 bytes, peak rate=132 kbits
History:
  Tunnel:
    Time since created: 1 hours, 34 minutes
    Time since path change: 1 hours, 19 minutes
  Current LSP:
    Uptime: 1 hours, 19 minutes
R1#sh mpls traffic-eng tunnels name R5_t10
LSP Tunnel R5_t10 is signalled, connection is up
  InLabel : Serial0/0/1, implicit-null
  OutLabel : -
RSVP Signalling Info:
  Src 10.10.10.50, Dst 10.10.10.10, Tun_Id 10, Tun_Instance 1
RSVP Path Info:
  My Address: 10.10.10.10
  Explicit Route: NONE
  Record Route: NONE
  Tspec: ave rate=56 kbits, burst=1000 bytes, peak rate=56 kbits
RSVP Resv Info:
  Record Route: NONE
  Fspec: ave rate=56 kbits, burst=1000 bytes, peak rate=56 kbits

R1#sh mpls traffic-eng tunnels name R5_t500
LSP Tunnel R5_t500 is signalled, connection is up
  InLabel : Serial0/0/1, implicit-null
  OutLabel : -
RSVP Signalling Info:
  Src 10.10.10.50, Dst 10.10.10.10, Tun_Id 20, Tun_Instance 1
RSVP Path Info:
  My Address: 10.10.10.10
  Explicit Route: NONE
  Record Route: NONE
  Tspec: ave rate=88 kbits, burst=1000 bytes, peak rate=88 kbits
RSVP Resv Info:
  Record Route: NONE
  Fspec: ave rate=88 kbits, burst=1000 bytes, peak rate=88 kbits
Router 2

sh runn
Building configuration...
Current configuration : 1501 bytes
!
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname R2
!
boot-start-marker
boot-end-marker
!

no aaa new-model
!
resource policy
!
memory-size iomem 10
ip subnet-zero
!

40
ip cef

mpls traffic-eng tunnels

voice-card 0
no dspfarm

interface Loopback0
  ip address 172.16.2.1 255.255.255.0
  ip ospf network point-to-point

interface Loopback1
  ip address 10.10.10.20 255.255.255.255
  ip ospf network point-to-point

interface FastEthernet0/0
  no ip address
  shutdown
duplex auto
speed auto

interface FastEthernet0/1
  ip address 192.168.0.2 255.255.255.0
duplex auto
speed auto
mpls ip
mpls traffic-eng tunnels
ip rsvp bandwidth 512 256

interface Serial0/0/0
  ip address 192.168.2.2 255.255.255.0
mpls ip
mpls traffic-eng tunnels
no fair-queue
clock rate 56000
ip rsvp bandwidth 512 256

interface Serial0/0/1
  ip address 192.168.1.2 255.255.255.0
mpls ip
mpls traffic-eng tunnels
clock rate 56000
ip rsvp bandwidth 512 256

router ospf 1
mpls traffic-eng router-id Loopback1
mpls traffic-eng area 1
log-adjacency-changes
network 10.10.10.0 0.0.0.255 area 1
network 172.16.0.0 0.0.255.255 area 1
network 192.168.0.0 0.0.255.255 area 1
!
ip classless
!
!
ip http server
no ip http secure-server
!
!
!
control-plane
!
!
!
voice-port 0/3/0
!
voice-port 0/3/1
!
!
line con 0
line aux 0
line vty 0 4
login
!
scheduler allocate 20000 1000
!
End

R2#sh ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
         D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
         N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
         E1 - OSPF external type 1, E2 - OSPF external type 2
         i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
         ia - IS-IS inter area, * - candidate default, U - per-user static route
         o - ODR, P - periodic downloaded static route
Gateway of last resort is not set
172.16.0.0/24 is subnetted, 5 subnets
O     172.16.4.0 [110/2] via 192.168.0.4, 04:15:36, FastEthernet0/1
O 172.16.5.0 [110/66] via 192.168.0.4, 04:15:36, FastEthernet0/1
O 172.16.1.0 [110/782] via 192.168.1.1, 04:15:36, Serial0/0/1
C 172.16.2.0 is directly connected, Loopback0
O 172.16.3.0 [110/66] via 192.168.0.4, 04:15:36, FastEthernet0/1
O 192.168.4.0/24 [110/65] via 192.168.0.4, 04:15:36, FastEthernet0/1
10.0.0.0/32 is subnetted, 5 subnets
O 10.10.10.10 [110/782] via 192.168.1.1, 04:15:38, Serial0/0/1
O 10.10.10.30 [110/66] via 192.168.0.4, 04:15:38, FastEthernet0/1
C 10.10.10.20 is directly connected, Loopback1
O 10.10.10.40 [110/2] via 192.168.0.4, 04:15:38, FastEthernet0/1
O 10.10.10.50 [110/66] via 192.168.0.4, 04:15:38, FastEthernet0/1
C 192.168.0.0/24 is directly connected, FastEthernet0/1
C 192.168.1.0/24 is directly connected, Serial0/0/1
C 192.168.2.0/24 is directly connected, Serial0/0/0
O 192.168.3.0/24 [110/65] via 192.168.0.4, 04:15:38, FastEthernet0/1

R2#sh ip int brief

<table>
<thead>
<tr>
<th>Interface</th>
<th>IP-Address</th>
<th>OK?</th>
<th>Method</th>
<th>Status</th>
<th>Protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td>FastEthernet0/0</td>
<td>unassigned</td>
<td>YES</td>
<td>manual</td>
<td>administratively down</td>
<td>down</td>
</tr>
<tr>
<td>FastEthernet0/1</td>
<td>192.168.0.2</td>
<td>YES</td>
<td>manual</td>
<td>up</td>
<td>up</td>
</tr>
<tr>
<td>Serial0/0/0</td>
<td>192.168.2.2</td>
<td>YES</td>
<td>manual</td>
<td>up</td>
<td>up</td>
</tr>
<tr>
<td>Serial0/0/1</td>
<td>192.168.1.2</td>
<td>YES</td>
<td>manual</td>
<td>up</td>
<td>up</td>
</tr>
<tr>
<td>Loopback0</td>
<td>172.16.2.1</td>
<td>YES</td>
<td>manual</td>
<td>up</td>
<td>up</td>
</tr>
<tr>
<td>Loopback1</td>
<td>10.10.10.20</td>
<td>YES</td>
<td>manual</td>
<td>up</td>
<td>up</td>
</tr>
</tbody>
</table>

R2#sh ip ospf mpls traffic-eng link

    OSPF Router with ID (172.16.2.1) (Process ID 1)
    Area 1 has 3 MPLS TE links. Area instance is 10.
    Links in hash bucket 16.
    Link is associated with fragment 2. Link instance is 10
    Link connected to Point-to-Point network
    Link ID : 172.16.1.1
    Interface Address : 192.168.1.2
    Neighbor Address : 192.168.1.1
    Admin Metric te: 781  igp: 781
    Maximum bandwidth : 16000
    Maximum reservable bandwidth : 64000
    Number of Priority : 8
    Priority 0 : 64000   Priority 1 : 64000
    Priority 2 : 53000   Priority 3 : 53000
    Priority 4 : 46000   Priority 5 : 46000
Traffic Engineering and Multiprotocol label switching as mean to increase network efficiency

Priority 6 : 46000   Priority 7 : 46000
Affinity Bit : 0x0
Link is associated with fragment 1. Link instance is 10
   Link connected to Point-to-Point network
   Link ID : 172.16.3.1
Interface Address : 192.168.2.2
   Neighbor Address : 192.168.2.3
   Admin Metric te: 781 igp: 781
   Maximum bandwidth : 16000
   Maximum reservable bandwidth : 64000
   Number of Priority : 8
   Priority 0 : 64000   Priority 1 : 64000
   Priority 2 : 64000   Priority 3 : 48000
   Priority 4 : 48000   Priority 5 : 48000
   Priority 6 : 48000   Priority 7 : 48000
   Affinity Bit : 0x0
Links in hash bucket 17.
   Link is associated with fragment 0. Link instance is 10
   Link connected to Broadcast network
   Link ID : 192.168.0.4
Interface Address : 192.168.0.2
   Admin Metric te: 1 igp: 1
   Maximum bandwidth : 12500000
   Maximum reservable bandwidth : 64000
   Number of Priority : 8
   Priority 0 : 64000   Priority 1 : 64000
   Priority 2 : 64000   Priority 3 : 64000
   Priority 4 : 64000   Priority 5 : 64000
   Priority 6 : 47500   Priority 7 : 47500
   Affinity Bit : 0x0

R2#sh ip ospf database opaque-area
   OSPF Router with ID (172.16.2.1) (Process ID 1)
   Type-10 Opaque Link Area Link States (Area 1)
   LS age: 350
   Options: (No TOS-capability, DC)
   LS Type: Opaque Area Link
   Link State ID: 1.0.0.0
   Opaque Type: 1
   Opaque ID: 0
   Advertising Router: 172.16.1.1
   LS Seq Number: 80000009
   Checksum: 0x762A
   Length: 140
   Fragment number : 0

44
MPLS TE router ID: 10.10.10.10
Link connected to Point-to-Point network
  Link ID: 172.16.2.1
  Interface Address: 192.168.1.1
  Neighbor Address: 192.168.1.2
  Admin Metric: 64
  Maximum bandwidth: 193000
  Maximum reservable bandwidth: 64000
  Number of Priority: 8
    Priority 0: 64000
    Priority 1: 64000
    Priority 2: 64000
    Priority 3: 48000
    Priority 4: 48000
    Priority 5: 48000
    Priority 6: 31500
    Priority 7: 31500
  Affinity Bit: 0x0
  IGP Metric: 64
  Number of Links: 1
  LS age: 402
  Options: (No TOS-capability, DC)
  LS Type: Opaque Area Link
  Link State ID: 1.0.0.0
  Opaque Type: 1
  Opaque ID: 0
  Advertising Router: 172.16.2.1
  LS Seq Number: 80000009
  Checksum: 0x9244
  Length: 132
  Fragment number: 0

MPLS TE router ID: 10.10.10.20
Link connected to Broadcast network
  Link ID: 192.168.0.4
  Interface Address: 192.168.0.2
  Admin Metric: 1
  Maximum bandwidth: 12500000
  Maximum reservable bandwidth: 64000
  Number of Priority: 8
    Priority 0: 64000
    Priority 1: 64000
    Priority 2: 64000
    Priority 3: 64000
    Priority 4: 64000
    Priority 5: 64000
    Priority 6: 47500
    Priority 7: 47500
  Affinity Bit: 0x0
  IGP Metric: 1
  Number of Links: 1
  LS age: 857
  Options: (No TOS-capability, DC)
  LS Type: Opaque Area Link
  Link State ID: 1.0.0.0
Traffic Engineering and Multiprotocol label switching as mean to increase network efficiency

Opaque Type: 1
Opaque ID: 0
Advertising Router: 172.16.3.1
LS Seq Number: 80000008
Checksum: 0x2A48
Length: 140
Fragment number : 0
MPLS TE router ID : 10.10.10.30
Link connected to Point-to-Point network
  Link ID : 172.16.2.1
  Interface Address : 192.168.2.3
  Neighbor Address : 192.168.2.2
  Admin Metric : 64
  Maximum bandwidth : 193000
  Maximum reservable bandwidth : 64000
Number of Priority : 8
  Priority 0 : 64000  Priority 1 : 64000
  Priority 2 : 64000  Priority 3 : 64000
  Priority 4 : 64000  Priority 5 : 64000
  Priority 6 : 64000  Priority 7 : 64000
  Affinity Bit : 0x0
  IGP Metric : 64
Number of Links : 1
LS age: 743
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 1.0.0.0
Opaque Type: 1
Opaque ID: 0
Advertising Router: 172.16.4.1
LS Seq Number: 80000009
Checksum: 0xDA1B
Length: 132
Fragment number : 0
MPLS TE router ID : 10.10.10.40
Link connected to Broadcast network
  Link ID : 192.168.0.4
  Interface Address : 192.168.0.4
  Admin Metric : 1
  Maximum bandwidth : 12500000
  Maximum reservable bandwidth : 64000
Number of Priority : 8
  Priority 0 : 64000  Priority 1 : 64000
  Priority 2 : 53000  Priority 3 : 53000
  Priority 4 : 46000  Priority 5 : 46000
  Priority 6 : 46000  Priority 7 : 46000
  Affinity Bit : 0x0
  IGP Metric : 64
Number of Links : 1
LS age: 743
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 1.0.0.0
Opaque Type: 1
Opaque ID: 0
Advertising Router: 172.16.4.1
LS Seq Number: 80000009
Checksum: 0xDA1B
Length: 132
Fragment number : 0
MPLS TE router ID : 10.10.10.40
Link connected to Broadcast network
  Link ID : 192.168.0.4
  Interface Address : 192.168.0.4
  Admin Metric : 1
  Maximum bandwidth : 12500000
  Maximum reservable bandwidth : 64000
Number of Priority : 8
  Priority 0 : 64000  Priority 1 : 64000
  Priority 2 : 53000  Priority 3 : 53000
  Priority 4 : 46000  Priority 5 : 46000
  Priority 6 : 46000  Priority 7 : 46000
  Affinity Bit : 0x0
  IGP Metric : 64
Number of Links : 1
LS age: 743
Options: (No TOS-capability, DC)
Priority 6 : 46000    Priority 7 : 46000
Affinity Bit : 0x0
IGP Metric : 1
Number of Links : 1
LS age: 692
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 1.0.0.0
Opaque Type: 1
Opaque ID: 0
Advertising Router: 172.16.5.1
LS Seq Number: 8000000B
Checksum: 0x7E8
Length: 140
Fragment number : 0
MPLS TE router ID : 10.10.10.50
Link connected to Point-to-Point network
    Link ID : 172.16.4.1
    Interface Address : 192.168.4.5
    Neighbor Address : 192.168.4.4
    Admin Metric : 64
    Maximum bandwidth : 193000
    Maximum reservable bandwidth : 64000
Number of Priority : 8
Priority 0 : 64000    Priority 1 : 64000
Priority 2 : 53000    Priority 3 : 53000
Priority 4 : 46000    Priority 5 : 46000
Priority 6 : 46000    Priority 7 : 46000
Affinity Bit : 0x0
IGP Metric : 64
Number of Links : 1
LS age: 1668
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 1.0.0.1
Opaque Type: 1
Opaque ID: 1
Advertising Router: 172.16.2.1
LS Seq Number: 80000008
Checksum: 0x90A
Length: 132
Fragment number : 1
Link connected to Point-to-Point network
    Link ID : 172.16.3.1
    Interface Address : 192.168.2.2
    Neighbor Address : 192.168.2.3
Traffic Engineering and Multiprotocol label switching as mean to increase network efficiency

Admin Metric : 781
Maximum bandwidth : 16000
Maximum reservable bandwidth : 64000
Number of Priority : 8
Priority 0 : 64000       Priority 1 : 64000
Priority 2 : 64000       Priority 3 : 48000
Priority 4 : 48000       Priority 5 : 48000
Priority 6 : 48000       Priority 7 : 48000
Affinity Bit : 0x0
IGP Metric : 781
Number of Links : 1
LS age: 1881
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 1.0.0.1
Opaque Type: 1
Opaque ID: 1
Advertising Router: 172.16.3.1
LS Seq Number: 80000008
Checksum: 0xDE8F
Length: 132
Fragment number : 1
Link connected to Point-to-Point network
   Link ID : 172.16.4.1
   Interface Address : 192.168.3.3
   Neighbor Address : 192.168.3.4
   Admin Metric : 64
   Maximum bandwidth : 193000
   Maximum reservable bandwidth : 64000
Number of Priority : 8
Priority 0 : 64000       Priority 1 : 64000
Priority 2 : 64000       Priority 3 : 48000
Priority 4 : 48000       Priority 5 : 48000
Priority 6 : 48000       Priority 7 : 48000
Affinity Bit : 0x0
IGP Metric : 64
Number of Links : 1
LS age: 493
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 1.0.0.1
Opaque Type: 1
Opaque ID: 1
Advertising Router: 172.16.4.1
LS Seq Number: 80000009
Checksum: 0x17AB
Length: 132
Fragment number : 1
  Link connected to Point-to-Point network
    Link ID : 172.16.5.1
    Interface Address : 192.168.4.4
    Neighbor Address : 192.168.4.5
    Admin Metric : 64
    Maximum bandwidth : 193000
    Maximum reservable bandwidth : 64000
    Number of Priority : 8
    Priority 0 : 64000       Priority 1 : 64000
    Priority 2 : 64000       Priority 3 : 48000
    Priority 4 : 48000       Priority 5 : 48000
    Priority 6 : 31500       Priority 7 : 31500
    Affinity Bit : 0x0
    IGP Metric : 64
    Number of Links : 1
    LS age: 667
    Options: (No TOS-capability, DC)
    LS Type: Opaque Area Link
    Link State ID: 1.0.0.2
    Opaque Type: 1
    Opaque ID: 2
    Advertising Router: 172.16.2.1
    LS Seq Number: 8000000A
    Checksum: 0x3DBF
    Length: 132
    Fragment number : 2
  Link connected to Point-to-Point network
    Link ID : 172.16.1.1
    Interface Address : 192.168.1.2
    Neighbor Address : 192.168.1.1
    Admin Metric : 781
    Maximum bandwidth : 16000
    Maximum reservable bandwidth : 64000
    Number of Priority : 8
    Priority 0 : 64000       Priority 1 : 64000
    Priority 2 : 53000       Priority 3 : 53000
    Priority 4 : 46000       Priority 5 : 46000
    Priority 6 : 46000       Priority 7 : 46000
    Affinity Bit : 0x0
    IGP Metric : 781
    Number of Links : 1
    LS age: 1003
    Options: (No TOS-capability, DC)
Traffic Engineering and Multiprotocol label switching as means to increase network efficiency

LS Type: Opaque Area Link
Link State ID: 1.0.0.2
Opaque Type: 1
Opaque ID: 2
Advertising Router: 172.16.4.1
LS Seq Number: 80000008
Checksum: 0x6AD
Length: 132
Fragment number: 2
Link connected to Point-to-Point network
Link ID: 172.16.3.1
Interface Address: 192.168.3.4
Neighbor Address: 192.168.3.3
Admin Metric: 64
Maximum bandwidth: 193000
Maximum reservable bandwidth: 64000
Number of Priority: 8
Priority 0: 64000 Priority 1: 64000
Priority 2: 64000 Priority 3: 64000
Priority 4: 64000 Priority 5: 64000
Priority 6: 64000 Priority 7: 64000
Affinity Bit: 0x0
IGP Metric: 64
Number of Links: 1

R2#sh mpls traffic-eng tunnels brief

Signalling Summary:
LSP Tunnels Process: running
RSVP Process: running
Forwarding: enabled
Periodic reoptimization: every 3600 seconds, next in 202 seconds
Periodic auto-bw collection: disabled

<table>
<thead>
<tr>
<th>TUNNEL NAME</th>
<th>DESTINATION 10.10.10.50</th>
<th>UP IF Se0/0/1</th>
<th>DOWN IF Fa0/1</th>
<th>STATE/PROT up/up</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1 t1245</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R1 t12345</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R5 t10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R5 t20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Displayed 0 (of 0) heads, 4 (of 4) midpoints, 0 (of 0) tails

R2#sh ip rsvp interface

<table>
<thead>
<tr>
<th>interface</th>
<th>allocated</th>
<th>i/f max</th>
<th>flow max</th>
<th>sub max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fa0/1</td>
<td>132K</td>
<td>512K</td>
<td>256K</td>
<td>0</td>
</tr>
<tr>
<td>Se0/0/0</td>
<td>128K</td>
<td>512K</td>
<td>256K</td>
<td>0</td>
</tr>
<tr>
<td>Se0/0/1</td>
<td>144K</td>
<td>512K</td>
<td>256K</td>
<td>0</td>
</tr>
</tbody>
</table>
### R2#sh tag-switching forwarding-table

<table>
<thead>
<tr>
<th>Local tag</th>
<th>Outgoing tag or VC</th>
<th>Prefix or Tunnel Id</th>
<th>Bytes tag switched</th>
<th>Outgoing interface</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>Pop tag</td>
<td>172.16.4.0/24</td>
<td>0</td>
<td>Fa0/1</td>
<td>192.168.0.4</td>
</tr>
<tr>
<td>17</td>
<td>16</td>
<td>172.16.5.0/24</td>
<td>0</td>
<td>Fa0/1</td>
<td>192.168.0.4</td>
</tr>
<tr>
<td>18</td>
<td>Pop tag</td>
<td>172.16.1.0/24</td>
<td>0</td>
<td>Se0/0/1</td>
<td>point2point</td>
</tr>
<tr>
<td>19</td>
<td>19</td>
<td>172.16.3.0/24</td>
<td>0</td>
<td>Fa0/1</td>
<td>192.168.0.4</td>
</tr>
<tr>
<td>20</td>
<td>Pop tag</td>
<td>192.168.4.0/24</td>
<td>570</td>
<td>Fa0/1</td>
<td>192.168.0.4</td>
</tr>
<tr>
<td>21</td>
<td>Pop tag</td>
<td>10.10.10.10/32</td>
<td>1040</td>
<td>Se0/0/1</td>
<td>point2point</td>
</tr>
<tr>
<td>22</td>
<td>21</td>
<td>10.10.10.30/32</td>
<td>0</td>
<td>Fa0/1</td>
<td>192.168.0.4</td>
</tr>
<tr>
<td>23</td>
<td>Pop tag</td>
<td>10.10.10.50/32</td>
<td>0</td>
<td>Fa0/1</td>
<td>192.168.0.4</td>
</tr>
<tr>
<td>24</td>
<td>23</td>
<td>10.10.10.10/32</td>
<td>0</td>
<td>Fa0/1</td>
<td>192.168.0.4</td>
</tr>
<tr>
<td>25</td>
<td>Pop tag</td>
<td>192.168.3.0/24</td>
<td>0</td>
<td>Fa0/1</td>
<td>192.168.0.4</td>
</tr>
<tr>
<td>26</td>
<td>27</td>
<td>10.10.10.10 12345 [9]</td>
<td>540</td>
<td>Se0/0/0</td>
<td>point2point</td>
</tr>
<tr>
<td>27</td>
<td>27</td>
<td>10.10.10.10 1245 [8]</td>
<td>0</td>
<td>Fa0/1</td>
<td>192.168.0.4</td>
</tr>
<tr>
<td>28</td>
<td>Pop tag</td>
<td>10.10.10.50 10 [1]</td>
<td>0</td>
<td>Se0/0/1</td>
<td>point2point</td>
</tr>
<tr>
<td>29</td>
<td>Pop tag</td>
<td>10.10.10.50 20 [1]</td>
<td>0</td>
<td>Se0/0/1</td>
<td>point2point</td>
</tr>
</tbody>
</table>

### R2#sh ip cef

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Next Hop</th>
<th>Interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0.0.0/0</td>
<td>drop</td>
<td>Null0 (default route handler entry)</td>
</tr>
<tr>
<td>0.0.0.0/32</td>
<td>receive</td>
<td></td>
</tr>
<tr>
<td>10.10.10.10/32</td>
<td>192.168.1.1</td>
<td>Serial0/0/1</td>
</tr>
<tr>
<td>10.10.10.20/32</td>
<td>receive</td>
<td></td>
</tr>
<tr>
<td>10.10.10.30/32</td>
<td>192.168.0.4</td>
<td>FastEthernet0/1</td>
</tr>
<tr>
<td>10.10.10.40/32</td>
<td>192.168.0.4</td>
<td>FastEthernet0/1</td>
</tr>
<tr>
<td>10.10.10.50/32</td>
<td>192.168.0.4</td>
<td>FastEthernet0/1</td>
</tr>
<tr>
<td>172.16.1.0/24</td>
<td>192.168.1.1</td>
<td>Serial0/0/1</td>
</tr>
<tr>
<td>172.16.2.0/24</td>
<td>attached</td>
<td>Loopback0</td>
</tr>
<tr>
<td>172.16.2.0/32</td>
<td>receive</td>
<td></td>
</tr>
<tr>
<td>172.16.2.1/32</td>
<td>receive</td>
<td></td>
</tr>
<tr>
<td>172.16.2.255/32</td>
<td>receive</td>
<td></td>
</tr>
<tr>
<td>172.16.3.0/24</td>
<td>192.168.0.4</td>
<td>FastEthernet0/1</td>
</tr>
<tr>
<td>172.16.4.0/24</td>
<td>192.168.0.4</td>
<td>FastEthernet0/1</td>
</tr>
<tr>
<td>172.16.5.0/24</td>
<td>192.168.0.4</td>
<td>FastEthernet0/1</td>
</tr>
<tr>
<td>192.168.0.0/24</td>
<td>attached</td>
<td>FastEthernet0/1</td>
</tr>
<tr>
<td>192.168.0.0/32</td>
<td>receive</td>
<td></td>
</tr>
<tr>
<td>192.168.0.2/32</td>
<td>receive</td>
<td></td>
</tr>
<tr>
<td>192.168.0.4/32</td>
<td>192.168.0.4</td>
<td>FastEthernet0/1</td>
</tr>
<tr>
<td>192.168.0.255/32</td>
<td>receive</td>
<td></td>
</tr>
<tr>
<td>192.168.1.0/24</td>
<td>attached</td>
<td>Serial0/0/1</td>
</tr>
<tr>
<td>192.168.1.0/32</td>
<td>receive</td>
<td></td>
</tr>
</tbody>
</table>

Prefix | Next Hop | Interface

---

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Traffic Engineering and Multiprotocol label switching as mean to increase network efficiency

192.168.1.2/32 receive
192.168.1.255/32 receive
192.168.2.0/24 attached Serial0/0/0
192.168.2.0/32 receive
192.168.2.2/32 receive
192.168.2.255/32 receive
192.168.3.0/24 192.168.0.4 FastEthernet0/1
192.168.4.0/24 192.168.0.4 FastEthernet0/1
224.0.0.0/4 drop
224.0.0.0/24 receive
255.255.255.255/32 receive

R2#sh mpls traffic-eng tunnels summary
Signalling Summary:
  LSP Tunnels Process: running
  RSVP Process: running
  Forwarding: enabled
  Head: 0 interfaces, 0 active signalling attempts, 0 established
    0 activations, 0 deactivations
  Midpoints: 4, Tails: 0
  Periodic reoptimization: every 3600 seconds, next in 139 seconds
  Periodic auto-bw collection: disabled
Router 3

sh runn
Building configuration...
Current configuration : 1427 bytes
!
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname R3
!
boot-start-marker
boot-end-marker
!
!
no aaa new-model
!
resource policy
!
memory-size iomem 15
mmi polling-interval 60
no mmi auto-configure
no mmi pvc
mmi snmp-timeout 180
ip subnet-zero
ip cef
!
!
!
!

mpls traffic-eng tunnels
!

voice-card 0
!
!
!

interface Loopback0
  ip address 172.16.3.1 255.255.255.0
  ip ospf network point-to-point
!

interface Loopback1
  ip address 10.10.10.30 255.255.255.255
  ip ospf network point-to-point
!

interface FastEthernet0/0
  no ip address
  shutdown
duplex auto
  speed auto
!

interface FastEthernet0/1
  no ip address
  shutdown
duplex auto
  speed auto
!

interface Serial0/1/0
  ip address 192.168.2.3 255.255.255.0
  mpls ip
  mpls traffic-eng tunnels
  no fair-queue
  ip rsvp bandwidth 512 256
!

interface Serial0/1/1
  ip address 192.168.3.3 255.255.255.0
  mpls ip
  mpls traffic-eng tunnels
ip rsvp bandwidth 512 256

router ospf 1
mpls traffic-eng router-id Loopback1
mpls traffic-eng area 1
log-adjacency-changes
network 10.10.10.0 0.0.0.255 area 1
network 172.16.0.0 0.0.255.255 area 1
network 192.168.0.0 0.0.255.255 area 1

ip classless

ip http server
no ip http secure-server

control-plane

line con 0
line aux 0
line vty 0 4
login

scheduler allocate 20000 1000

R3#sh ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
        D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
        N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
        E1 - OSPF external type 1, E2 - OSPF external type 2
        i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
        ia - IS-IS inter area, * - candidate default, U - per-user static route
        o - ODR, P - periodic downloaded static route
Gateway of last resort is not set
172.16.0.0/24 is subnetted, 5 subnets
O    172.16.4.0 [110/65] via 192.168.3.4, 04:07:32, Serial0/1/1
O    172.16.5.0 [110/129] via 192.168.3.4, 04:07:32, Serial0/1/1
O    172.16.1.0 [110/846] via 192.168.2.2, 04:07:32, Serial0/1/0
Traffic Engineering and Multiprotocol label switching as mean to increase network efficiency

O  172.16.2.0 [110/65] via 192.168.2.2, 04:07:32, Serial0/1/0
C  172.16.3.0 is directly connected, Loopback0
O  192.168.4.0/24 [110/128] via 192.168.3.4, 04:07:32, Serial0/1/1
10.0.0.0/32 is subnetted, 5 subnets
O  10.10.10.10 [110/846] via 192.168.2.2, 04:07:32, Serial0/1/0
C  10.10.10.30 is directly connected, Loopback1
O  10.10.10.20 [110/65] via 192.168.2.2, 04:07:32, Serial0/1/0
O  10.10.10.40 [110/65] via 192.168.3.4, 04:07:32, Serial0/1/1
O  10.10.10.50 [110/129] via 192.168.3.4, 04:07:32, Serial0/1/1
O  192.168.0.0/24 [110/65] via 192.168.3.4, 04:07:34, Serial0/1/1
[110/65] via 192.168.2.2, 04:07:34, Serial0/1/0
O  192.168.1.0/24 [110/845] via 192.168.2.2, 04:07:34, Serial0/1/0
C  192.168.2.0/24 is directly connected, Serial0/1/0
C  192.168.3.0/24 is directly connected, Serial0/1/1

R3#sh ip int brief

<table>
<thead>
<tr>
<th>Interface</th>
<th>IP-Address</th>
<th>OK?</th>
<th>Method</th>
<th>Status</th>
<th>Protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td>FastEthernet0/0</td>
<td>unassigned</td>
<td>YES</td>
<td>manual</td>
<td>administratively down</td>
<td>down</td>
</tr>
<tr>
<td>FastEthernet0/1</td>
<td>unassigned</td>
<td>YES</td>
<td>manual</td>
<td>administratively down</td>
<td>down</td>
</tr>
<tr>
<td>Serial0/1/0</td>
<td>192.168.2.3</td>
<td>YES</td>
<td>manual</td>
<td>up</td>
<td>up</td>
</tr>
<tr>
<td>Serial0/1/1</td>
<td>192.168.3.3</td>
<td>YES</td>
<td>manual</td>
<td>up</td>
<td>up</td>
</tr>
<tr>
<td>Loopback0</td>
<td>172.16.3.1</td>
<td>YES</td>
<td>manual</td>
<td>up</td>
<td>up</td>
</tr>
<tr>
<td>Loopback1</td>
<td>10.10.10.30</td>
<td>YES</td>
<td>manual</td>
<td>up</td>
<td>up</td>
</tr>
</tbody>
</table>

R3#sh ip ospf mpls traffic-eng link

OSPF Router with ID (172.16.3.1) (Process ID 1)

Area 1 has 2 MPLS TE links. Area instance is 5.

Links in hash bucket 24.

Link is associated with fragment 1. Link instance is 5
Link connected to Point-to-Point network
Link ID : 172.16.4.1
Interface Address : 192.168.3.3
Neighbor Address : 192.168.3.4
Admin Metric te: 64 igp: 64
Maximum bandwidth : 193000
Maximum reservable bandwidth : 64000
Number of Priority : 8
Priority 0 : 64000 Priority 1 : 64000
Priority 2 : 64000 Priority 3 : 48000
Priority 4 : 48000 Priority 5 : 48000
Priority 6 : 48000 Priority 7 : 48000
Affinity Bit : 0x0

Link is associated with fragment 0. Link instance is 5
Link connected to Point-to-Point network
Link ID : 172.16.2.1
Interface Address : 192.168.2.3
  Neighbor Address : 192.168.2.2
  Admin Metric te: 64  igp: 64
  Maximum bandwidth : 193000
  Maximum reservable bandwidth : 64000
  Number of Priority : 8
  Priority 0 : 64000  Priority 1 : 64000
  Priority 2 : 64000  Priority 3 : 64000
  Priority 4 : 64000  Priority 5 : 64000
  Priority 6 : 64000  Priority 7 : 64000
  Affinity Bit : 0x0

R3#sh ip ospf database opaque-area
  OSPF Router with ID (172.16.3.1) (Process ID 1)
  Type-10 Opaque Link Area Link States (Area 1)
    LS age: 1737
    Options: (No TOS-capability, DC)
    LS Type: Opaque Area Link
    Link State ID: 1.0.0.0
    Opaque Type: 1
    Opaque ID: 0
    Advertising Router: 172.16.1.1
    LS Seq Number: 80000008
    Checksum: 0x7829
    Length: 140
    Fragment number : 0
    MPLS TE router ID : 10.10.10.10
    Link connected to Point-to-Point network
      Link ID : 172.16.2.1
      Interface Address : 192.168.1.1
      Neighbor Address : 192.168.1.2
      Admin Metric : 64
      Maximum bandwidth : 193000
      Maximum reservable bandwidth : 64000
      Number of Priority : 8
      Priority 0 : 64000  Priority 1 : 64000
      Priority 2 : 64000  Priority 3 : 48000
      Priority 4 : 48000  Priority 5 : 48000
      Priority 6 : 31500  Priority 7 : 31500
      Affinity Bit : 0x0
      IGP Metric : 64
      Number of Links : 1
    LS age: 1817
    Options: (No TOS-capability, DC)
Traffic Engineering and Multiprotocol label switching as mean to increase network efficiency

LS Type: Opaque Area Link
Link State ID: 1.0.0.0
Opaque Type: 1
Opaque ID: 0
Advertising Router: 172.16.2.1
LS Seq Number: 80000008
Checksum: 0x9443
Length: 132
Fragment number : 0
MPLS TE router ID : 10.10.10.20
Link connected to Broadcast network
  Link ID : 192.168.0.4
  Interface Address : 192.168.0.2
  Admin Metric : 1
  Maximum bandwidth : 1250000
  Maximum reservable bandwidth : 64000
  Number of Priority : 8
  Priority 0 : 64000       Priority 1 : 64000
  Priority 2 : 64000       Priority 3 : 64000
  Priority 4 : 64000       Priority 5 : 64000
  Priority 6 : 47500       Priority 7 : 47500
  Affinity Bit : 0x0
  IGP Metric : 1
Number of Links : 1
LS age: 236
Options: (No TOS-capability, DC)

LS Type: Opaque Area Link
Link State ID: 1.0.0.0
Opaque Type: 1
Opaque ID: 0
Advertising Router: 172.16.3.1
LS Seq Number: 80000008
Checksum: 0x2A48
Length: 140
Fragment number : 0
MPLS TE router ID : 10.10.10.30
Link connected to Point-to-Point network
  Link ID : 172.16.2.1
  Interface Address : 192.168.2.3
  Neighbor Address : 192.168.2.2
  Admin Metric : 64
  Maximum bandwidth : 193000
  Maximum reservable bandwidth : 64000
  Number of Priority : 8
  Priority 0 : 64000       Priority 1 : 64000

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Priority 2 : 64000  Priority 3 : 64000
Priority 4 : 64000  Priority 5 : 64000
Priority 6 : 64000  Priority 7 : 64000
Affinity Bit : 0x0
IGP Metric : 64
Number of Links : 1
LS age: 123
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 1.0.0.0
Opaque Type: 1
Opaque ID: 0
Advertising Router: 172.16.4.1
LS Seq Number: 80000009
Checksum: 0xDA1B
Length: 132
Fragment number : 0
MPLS TE router ID : 10.10.10.40
Link connected to Broadcast network
   Link ID : 192.168.0.4
   Interface Address : 192.168.0.4
   Admin Metric : 1
   Maximum bandwidth : 12500000
   Maximum reservable bandwidth : 64000
Number of Priority : 8
Priority 0 : 64000  Priority 1 : 64000
Priority 2 : 53000  Priority 3 : 53000
Priority 4 : 46000  Priority 5 : 46000
Priority 6 : 46000  Priority 7 : 46000
Affinity Bit : 0x0
IGP Metric : 1
Number of Links : 1
LS age: 72
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 1.0.0.0
Opaque Type: 1
Opaque ID: 0
Advertising Router: 172.16.5.1
LS Seq Number: 8000000B
Checksum: 0x7E8
Length: 140
Fragment number : 0
MPLS TE router ID : 10.10.10.50
Link connected to Point-to-Point network
   Link ID : 172.16.4.1
Traffic Engineering and Multiprotocol label switching as mean to increase network efficiency

Interface Address : 192.168.4.5
Neighbor Address : 192.168.4.4
Admin Metric : 64
Maximum bandwidth : 193000
Maximum reservable bandwidth : 64000
Number of Priority : 8
Priority 0 : 64000 Priority 1 : 64000
Priority 2 : 53000 Priority 3 : 53000
Priority 4 : 46000 Priority 5 : 46000
Priority 6 : 46000 Priority 7 : 46000
Affinity Bit : 0x0
IGP Metric : 64
Number of Links : 1
LS age: 1049
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 1.0.0.1
Opaque Type: 1
Opaque ID: 1
Advertising Router: 172.16.2.1
LS Seq Number: 80000008
Checksum: 0x90A
Length: 132
Fragment number : 1

Link connected to Point-to-Point network
Link ID : 172.16.3.1
Interface Address : 192.168.2.2
Neighbor Address : 192.168.2.3
Admin Metric : 781
Maximum bandwidth : 16000
Maximum reservable bandwidth : 64000
Number of Priority : 8
Priority 0 : 64000 Priority 1 : 64000
Priority 2 : 64000 Priority 3 : 48000
Priority 4 : 48000 Priority 5 : 48000
Priority 6 : 48000 Priority 7 : 48000
Affinity Bit : 0x0
IGP Metric : 781
Number of Links : 1
LS age: 1259
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 1.0.0.1
Opaque Type: 1
Opaque ID: 1
Advertising Router: 172.16.3.1
LS Seq Number: 80000008
Checksum: 0xDE8F
Length: 132
Fragment number : 1
Link connected to Point-to-Point network
   Link ID : 172.16.4.1
   Interface Address : 192.168.3.3
   Neighbor Address : 192.168.3.4
   Admin Metric : 64
   Maximum bandwidth : 193000
   Maximum reservable bandwidth : 64000
   Number of Priority : 8
   Priority 0 : 64000   Priority 1 : 64000
   Priority 2 : 64000   Priority 3 : 48000
   Priority 4 : 48000   Priority 5 : 48000
   Priority 6 : 48000   Priority 7 : 48000
   Affinity Bit : 0x0
   IGP Metric : 64
   Number of Links : 1
   LS age: 1877
   Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
   Link State ID: 1.0.0.1
   Opaque Type: 1
   Opaque ID: 1
   Advertising Router: 172.16.4.1
   LS Seq Number: 80000008
   Checksum: 0x19AA
   Length: 132
   Fragment number : 1
   Link connected to Point-to-Point network
      Link ID : 172.16.5.1
      Interface Address : 192.168.4.4
      Neighbor Address : 192.168.4.5
      Admin Metric : 64
      Maximum bandwidth : 193000
      Maximum reservable bandwidth : 64000
      Number of Priority : 8
      Priority 0 : 64000   Priority 1 : 64000
      Priority 2 : 64000   Priority 3 : 48000
      Priority 4 : 48000   Priority 5 : 48000
      Priority 6 : 31500   Priority 7 : 31500
      Affinity Bit : 0x0
      IGP Metric : 64
Traffic Engineering and Multiprotocol label switching as mean to increase network efficiency

Number of Links : 1
LS age: 47
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 1.0.0.2
Opaque Type: 1
Opaque ID: 2
Advertising Router: 172.16.2.1
LS Seq Number: 8000000A
Checksum: 0x3DBF
Length: 132
Fragment number : 2
Link connected to Point-to-Point network
  Link ID : 172.16.1.1
  Interface Address : 192.168.1.2
  Neighbor Address : 192.168.1.1
  Admin Metric : 781
  Maximum bandwidth : 16000
  Maximum reservable bandwidth : 64000
Number of Priority : 8
  Priority 0 : 64000  Priority 1 : 64000
  Priority 2 : 53000  Priority 3 : 53000
  Priority 4 : 46000  Priority 5 : 46000
  Priority 6 : 46000  Priority 7 : 46000
  Affinity Bit : 0x0
  IGP Metric : 781
Number of Links : 1
LS age: 383
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 1.0.0.2
Opaque Type: 1
Opaque ID: 2
Advertising Router: 172.16.4.1
LS Seq Number: 80000008
Checksum: 0x6AD
Length: 132
Fragment number : 2
Link connected to Point-to-Point network
  Link ID : 172.16.3.1
  Interface Address : 192.168.3.4
  Neighbor Address : 192.168.3.3
  Admin Metric : 64
  Maximum bandwidth : 193000
  Maximum reservable bandwidth : 64000
Number of Priority : 8
Priority 0 : 64000       Priority 1 : 64000
Priority 2 : 64000       Priority 3 : 64000
Priority 4 : 64000       Priority 5 : 64000
Priority 6 : 64000       Priority 7 : 64000
Affinity Bit : 0x0
IGP Metric : 64
Number of Links : 1

**R3#sh mpls traffic-eng tunnels brief**

Signalling Summary:
- LSP Tunnels Process: running
- RSVP Process: running
- Forwarding: enabled
- Periodic reoptimization: every 3600 seconds, next in 936 seconds
- Periodic auto-bw collection: disabled

<table>
<thead>
<tr>
<th>TUNNEL NAME</th>
<th>DESTINATION</th>
<th>UP IF</th>
<th>DOWN IF</th>
<th>STATE/PROT</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1_t12345</td>
<td>10.10.10.50</td>
<td>Se0/1/0</td>
<td>Se0/1/1</td>
<td>up/up</td>
</tr>
</tbody>
</table>

Displayed 0 (of 0) heads, 1 (of 1) midpoints, 0 (of 0) tails

**R3#sh ip rsvp interface**

<table>
<thead>
<tr>
<th>interface</th>
<th>allocated</th>
<th>i/f max</th>
<th>flow max</th>
<th>sub max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Se0/1/0</td>
<td>0</td>
<td>512K</td>
<td>256K</td>
<td>0</td>
</tr>
<tr>
<td>Se0/1/1</td>
<td>128K</td>
<td>512K</td>
<td>256K</td>
<td>0</td>
</tr>
</tbody>
</table>

**R3#sh tag-switching forwarding-table**

<table>
<thead>
<tr>
<th>Local tag</th>
<th>Outgoing tag or VC</th>
<th>Prefix or Tunnel Id</th>
<th>Bytes tag switched</th>
<th>Outgoing interface</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>Pop tag</td>
<td>172.16.4.0/24</td>
<td>0</td>
<td>Se0/1/1</td>
<td>point2point</td>
</tr>
<tr>
<td>17</td>
<td>16</td>
<td>172.16.5.0/24</td>
<td>0</td>
<td>Se0/1/1</td>
<td>point2point</td>
</tr>
<tr>
<td>18</td>
<td>18</td>
<td>172.16.1.0/24</td>
<td>0</td>
<td>Se0/1/0</td>
<td>point2point</td>
</tr>
<tr>
<td>19</td>
<td>Pop tag</td>
<td>172.16.2.0/24</td>
<td>0</td>
<td>Se0/1/0</td>
<td>point2point</td>
</tr>
<tr>
<td>20</td>
<td>Pop tag</td>
<td>192.168.4.0/24</td>
<td>0</td>
<td>Se0/1/1</td>
<td>point2point</td>
</tr>
<tr>
<td>21</td>
<td>21</td>
<td>10.10.10.10/32</td>
<td>0</td>
<td>Se0/1/0</td>
<td>point2point</td>
</tr>
<tr>
<td>22</td>
<td>Pop tag</td>
<td>10.10.10.20/32</td>
<td>0</td>
<td>Se0/1/0</td>
<td>point2point</td>
</tr>
<tr>
<td>23</td>
<td>Pop tag</td>
<td>10.10.10.40/32</td>
<td>0</td>
<td>Se0/1/1</td>
<td>point2point</td>
</tr>
<tr>
<td>24</td>
<td>23</td>
<td>10.10.10.50/32</td>
<td>0</td>
<td>Se0/1/1</td>
<td>point2point</td>
</tr>
<tr>
<td>25</td>
<td>Pop tag</td>
<td>192.168.0.0/24</td>
<td>0</td>
<td>Se0/1/1</td>
<td>point2point</td>
</tr>
<tr>
<td>26</td>
<td>Pop tag</td>
<td>192.168.1.0/24</td>
<td>0</td>
<td>Se0/1/0</td>
<td>point2point</td>
</tr>
<tr>
<td>27</td>
<td>26</td>
<td>10.10.10.10 12345 [9]</td>
<td>540</td>
<td>Se0/1/1</td>
<td>point2point</td>
</tr>
</tbody>
</table>
Traffic Engineering and Multiprotocol label switching as mean to increase network efficiency

**R3#sh mpls TRAFFic-eng tunnels summary**
Signalling Summary:
- LSP Tunnels Process: running
- RSVP Process: running
- Forwarding: enabled
- Head: 0 interfaces, 0 active signalling attempts, 0 established
  - 0 activations, 0 deactivations
- Midpoints: 1, Tails: 0
- Periodic reoptimization: every 3600 seconds, next in 847 seconds
- Periodic auto-bw collection: disabled

---

**Router 4**

sh runn
Building configuration...

Current configuration : 1517 bytes
!
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname R4
!
boot-start-marker
boot-end-marker
!
!
no aaa new-model
!
resource policy
!

64
mmi polling-interval 60
no mmi auto-configure
no mmi pvc
mmi snmp-timeout 180
ip subnet-zero
ip cef
!

mpls traffic-eng tunnels
!
voice-card 0
!
!

interface Loopback0
   ip address 172.16.4.1 255.255.255.0
   ip ospf network point-to-point
!
interface Loopback1
   ip address 10.10.10.40 255.255.255.255
   ip ospf network point-to-point
!
interface FastEthernet0/0
   no ip address
   shutdown
duplex auto
speed auto
!
interface FastEthernet0/1
   ip address 192.168.0.4 255.255.255.0
duplex auto
speed auto
mpls ip
mpls traffic-eng tunnels
ip rsvp bandwidth 512 256
!
interface Serial0/1/0
   ip address 192.168.4.4 255.255.255.0
mpls ip
mpls traffic-eng tunnels
no fair-queue
clock rate 56000
ip rsvp bandwidth 512 256
!
interface Serial0/1/1
   ip address 192.168.3.4 255.255.255.0
Traffic Engineering and Multiprotocol label switching as mean to increase network efficiency

mpls ip
mpls traffic-eng tunnels
clock rate 56000
ip rsvp bandwidth 512 256
!
router ospf 1
mpls traffic-eng router-id Loopback1
mpls traffic-eng area 1
log-adjacency-changes
network 10.10.10.0 0.0.0.255 area 1
network 172.16.0.0 0.0.255.255 area 1
network 192.168.0.0 0.0.255.255 area 1
!
ip classless
!
!
ip http server
no ip http secure-server
!
!
control-plane
!
!
line con 0
line aux 0
line vty 0 4
login
scheduler allocate 20000 1000
end

R4#sh ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
    D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
    N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
    E1 - OSPF external type 1, E2 - OSPF external type 2
    i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
    ia - IS-IS inter area, * - candidate default, U - per-user static route
    o - ODR, P - periodic downloaded static route
Gateway of last resort is not set
172.16.0.0/24 is subnetted, 5 subnets
C    172.16.4.0 is directly connected, Loopback0
O    172.16.5.0 [110/65] via 192.168.4.5, 04:11:46, Serial0/1/0
O    172.16.1.0 [110/783] via 192.168.0.2, 04:11:46, FastEthernet0/1
O    172.16.2.0 [110/2] via 192.168.0.2, 04:11:46, FastEthernet0/1
O    172.16.3.0 [110/65] via 192.168.3.3, 04:11:46, Serial0/1/1
C 192.168.4.0/24 is directly connected, Serial0/1/0
10.0.0.0/32 is subnetted, 5 subnets
O 10.10.10.10 [110/783] via 192.168.0.2, 04:11:46, FastEthernet0/1
O 10.10.10.30 [110/65] via 192.168.3.3, 04:11:46, Serial0/1/1
O 10.10.10.20 [110/2] via 192.168.0.2, 04:11:46, FastEthernet0/1
C 10.10.10.40 is directly connected, Loopback1
O 10.10.10.50 [110/65] via 192.168.4.5, 04:11:46, Serial0/1/0
C 192.168.0.0/24 is directly connected, FastEthernet0/1
O 192.168.1.0/24 [110/782] via 192.168.0.2, 04:11:48, FastEthernet0/1
O 192.168.2.0/24 [110/128] via 192.168.3.3, 04:11:48, Serial0/1/1
C 192.168.3.0/24 is directly connected, Serial0/1/1

### R4#sh ip int brief

<table>
<thead>
<tr>
<th>Interface</th>
<th>IP-Address</th>
<th>OK?</th>
<th>Method</th>
<th>Status</th>
<th>Protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td>FastEthernet0/0</td>
<td>unassigned</td>
<td>YES</td>
<td>manual</td>
<td>administratively down</td>
<td>down</td>
</tr>
<tr>
<td>FastEthernet0/1</td>
<td>192.168.0.4</td>
<td>YES</td>
<td>manual</td>
<td>up</td>
<td>up</td>
</tr>
<tr>
<td>Serial0/1/0</td>
<td>192.168.4.4</td>
<td>YES</td>
<td>manual</td>
<td>up</td>
<td>up</td>
</tr>
<tr>
<td>Serial0/1/1</td>
<td>192.168.3.4</td>
<td>YES</td>
<td>manual</td>
<td>up</td>
<td>up</td>
</tr>
<tr>
<td>Loopback0</td>
<td>172.16.4.1</td>
<td>YES</td>
<td>manual</td>
<td>up</td>
<td>up</td>
</tr>
<tr>
<td>Loopback1</td>
<td>10.10.10.40</td>
<td>YES</td>
<td>manual</td>
<td>up</td>
<td>up</td>
</tr>
</tbody>
</table>

### R4#sh ip ospf mpls traffic-eng link

OSPF Router with ID (172.16.4.1) (Process ID 1)
Area 1 has 3 MPLS TE links. Area instance is 10.
Links in hash bucket 32.
Link is associated with fragment 2. Link instance is 10
Link connected to Point-to-Point network
Link ID : 172.16.3.1
Interface Address : 192.168.3.4
Neighbor Address : 192.168.3.3
Admin Metric te: 64 igp: 64
Maximum bandwidth : 193000
Maximum reservable bandwidth : 64000
Number of Priority : 8
Priority 0 : 64000  Priority 1 : 64000
Priority 2 : 64000  Priority 3 : 64000
Priority 4 : 64000  Priority 5 : 64000
Priority 6 : 64000  Priority 7 : 64000
Affinity Bit : 0x0
Link is associated with fragment 1. Link instance is 10
Link connected to Point-to-Point network
Link ID : 172.16.5.1
Interface Address : 192.168.4.4
Neighbor Address : 192.168.4.5
Admin Metric te: 64 igp: 64
Maximum bandwidth : 193000
Maximum reservable bandwidth : 64000
Number of Priority : 8
Priority 0 : 64000       Priority 1 : 64000
Priority 2 : 64000       Priority 3 : 48000
Priority 4 : 48000       Priority 5 : 48000
Priority 6 : 31500       Priority 7 : 31500
Affinity Bit : 0x0

Links in hash bucket 33.
Link is associated with fragment 0. Link instance is 10
  Link connected to Broadcast network
  Link ID : 192.168.0.4
  Interface Address : 192.168.0.4
  Admin Metric te: 1 igp: 1
  Maximum bandwidth : 12500000
  Maximum reservable bandwidth : 64000
  Number of Priority : 8
  Priority 0 : 64000       Priority 1 : 64000
  Priority 2 : 53000       Priority 3 : 53000
  Priority 4 : 46000       Priority 5 : 46000
  Priority 6 : 46000       Priority 7 : 46000
  Affinity Bit : 0x0

**R4#sh ip ospf database opaque-area**

  OSPF Router with ID (172.16.4.1) (Process ID 1)
  Type-10 Opaque Link Area Link States (Area 1)

  LS age: 1976
  Options: (No TOS-capability, DC)
  LS Type: Opaque Area Link
  Link State ID: 1.0.0.0
  Opaque Type: 1
  Opaque ID: 0
  Advertising Router: 172.16.1.1
  LS Seq Number: 80000008
  Checksum: 0x7829
  Length: 140
  Fragment number : 0
  MPLS TE router ID : 10.10.10.10
  Link connected to Point-to-Point network
  Link ID : 172.16.2.1
  Interface Address : 192.168.1.1
Neighbor Address : 192.168.1.2
Admin Metric : 64
  Maximum bandwidth : 193000
  Maximum reservable bandwidth : 64000
Number of Priority : 8
  Priority 0 : 64000  Priority 1 : 64000
  Priority 2 : 64000  Priority 3 : 48000
  Priority 4 : 48000  Priority 5 : 48000
  Priority 6 : 31500  Priority 7 : 31500
Affinity Bit : 0x0
IGP Metric : 64
  Number of Links : 1
LS age: 23
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 1.0.0.0
Opaque Type: 1
Opaque ID: 0
Advertising Router: 172.16.2.1
LS Seq Number: 80000009
Checksum: 0x9244
Length: 132
Fragment number : 0
  MPLS TE router ID : 10.10.10.20
Link connected to Broadcast network
  Link ID : 192.168.0.4
  Interface Address : 192.168.0.2
  Admin Metric : 1
  Maximum bandwidth : 1250000
  Maximum reservable bandwidth : 64000
Number of Priority : 8
  Priority 0 : 64000  Priority 1 : 64000
  Priority 2 : 64000  Priority 3 : 64000
  Priority 4 : 64000  Priority 5 : 64000
  Priority 6 : 47500  Priority 7 : 47500
Affinity Bit : 0x0
IGP Metric : 1
  Number of Links : 1
LS age: 476
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 1.0.0.0
Opaque Type: 1
Opaque ID: 0
Advertising Router: 172.16.3.1
LS Seq Number: 80000008
Traffic Engineering and Multiprotocol label switching as mean to increase network efficiency

Checksum: 0x2A48  
Length: 140  
Fragment number : 0  
MPLS TE router ID : 10.10.10.30  
Link connected to Point-to-Point network  
Link ID : 172.16.2.1  
Interface Address : 192.168.2.3  
Neighbor Address : 192.168.2.2  
Admin Metric : 64  
Maximum bandwidth : 193000  
Maximum reservable bandwidth : 64000  
Number of Priority : 8  
Priority 0 : 64000  
Priority 1 : 64000  
Priority 2 : 64000  
Priority 3 : 64000  
Priority 4 : 64000  
Priority 5 : 64000  
Priority 6 : 64000  
Priority 7 : 64000  
Affinity Bit : 0x0  
IGP Metric : 64  
Number of Links : 1  
LS age: 361  
Options: (No TOS-capability, DC)  
LS Type: Opaque Area Link  
Link State ID: 1.0.0.0  
Opaque Type: 1  
Opaque ID: 0  
Advertising Router: 172.16.4.1  
LS Seq Number: 80000009  
Checksum: 0xDA1B  
Length: 132  
Fragment number : 0  
MPLS TE router ID : 10.10.10.40  
Link connected to Broadcast network  
Link ID : 192.168.0.4  
Interface Address : 192.168.0.4  
Admin Metric : 1  
Maximum bandwidth : 1250000  
Maximum reservable bandwidth : 64000  
Number of Priority : 8  
Priority 0 : 64000  
Priority 1 : 64000  
Priority 2 : 53000  
Priority 3 : 53000  
Priority 4 : 46000  
Priority 5 : 46000  
Priority 6 : 46000  
Priority 7 : 46000  
Affinity Bit : 0x0  
IGP Metric : 1  
Number of Links : 1
LS age: 312
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 1.0.0.0
Opaque Type: 1
Opaque ID: 0
Advertising Router: 172.16.5.1
LS Seq Number: 8000000B
Checksum: 0x7E8
Length: 140
Fragment number : 0
MPLS TE router ID : 10.10.10.50
Link connected to Point-to-Point network
  Link ID : 172.16.4.1
  Interface Address : 192.168.4.5
  Neighbor Address : 192.168.4.4
  Admin Metric : 64
  Maximum bandwidth : 193000
  Maximum reservable bandwidth : 64000
  Number of Priority : 8
  Priority 0 : 64000   Priority 1 : 64000
  Priority 2 : 53000   Priority 3 : 53000
  Priority 4 : 46000   Priority 5 : 46000
  Priority 6 : 46000   Priority 7 : 46000
  Affinity Bit : 0x0
  IGP Metric : 64
  Number of Links : 1
LS age: 1289
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 1.0.0.1
Opaque Type: 1
Opaque ID: 1
Advertising Router: 172.16.2.1
LS Seq Number: 80000008
Checksum: 0x90A
Length: 132
Fragment number : 1
Link connected to Point-to-Point network
  Link ID : 172.16.3.1
  Interface Address : 192.168.2.2
  Neighbor Address : 192.168.2.3
  Admin Metric : 781
  Maximum bandwidth : 16000
  Maximum reservable bandwidth : 64000
  Number of Priority : 8
Priority 0 : 64000   Priority 1 : 64000  
Priority 2 : 64000   Priority 3 : 48000  
Priority 4 : 48000   Priority 5 : 48000  
Priority 6 : 48000   Priority 7 : 48000  
Affinity Bit : 0x0  
IGP Metric : 781  
Number of Links : 1  
LS age: 1500  
Options: (No TOS-capability, DC)  
LS Type: Opaque Area Link  
Link State ID: 1.0.0.1  
Opaque Type: 1  
Opaque ID: 1  
Advertising Router: 172.16.3.1  
LS Seq Number: 80000008  
Checksum: 0xDE8F  
Length: 132  
Fragment number : 1  
Link connected to Point-to-Point network  
Link ID : 172.16.4.1  
Interface Address : 192.168.3.3  
Neighbor Address : 192.168.3.4  
Admin Metric : 64  
Maximum bandwidth : 193000  
Maximum reservable bandwidth : 64000  
Number of Priority : 8  
Priority 0 : 64000   Priority 1 : 64000  
Priority 2 : 64000   Priority 3 : 48000  
Priority 4 : 48000   Priority 5 : 48000  
Priority 6 : 48000   Priority 7 : 48000  
Affinity Bit : 0x0  
IGP Metric : 64  
Number of Links : 1  
LS age: 110  
Options: (No TOS-capability, DC)  
LS Type: Opaque Area Link  
Link State ID: 1.0.0.1  
Opaque Type: 1  
Opaque ID: 1  
Advertising Router: 172.16.4.1  
LS Seq Number: 80000009  
Checksum: 0x17AB  
Length: 132  
Fragment number : 1  
Link connected to Point-to-Point network
Introduction

Link ID: 172.16.5.1
Interface Address: 192.168.4.4
Neighbor Address: 192.168.4.5
Admin Metric: 64
Maximum bandwidth: 193000
Maximum reservable bandwidth: 64000
Number of Priority: 8
Priority 0: 64000   Priority 1: 64000
Priority 2: 64000   Priority 3: 48000
Priority 4: 48000   Priority 5: 48000
Priority 6: 31500   Priority 7: 31500
Affinity Bit: 0x0
IGP Metric: 64
Number of Links: 1
LS age: 290
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 1.0.0.2
Opaque Type: 1
Opaque ID: 2
Advertising Router: 172.16.2.1
LS Seq Number: 8000000A
Checksum: 0x3DBF
Length: 132
Fragment number: 2

Link connected to Point-to-Point network
  Link ID: 172.16.1.1
  Interface Address: 192.168.1.2
  Neighbor Address: 192.168.1.1
  Admin Metric: 781
  Maximum bandwidth: 16000
  Maximum reservable bandwidth: 64000
  Number of Priority: 8
  Priority 0: 64000   Priority 1: 64000
  Priority 2: 53000   Priority 3: 53000
  Priority 4: 46000   Priority 5: 46000
  Priority 6: 46000   Priority 7: 46000
  Affinity Bit: 0x0
  IGP Metric: 781
  Number of Links: 1
  LS age: 624
  Options: (No TOS-capability, DC)
  LS Type: Opaque Area Link
  Link State ID: 1.0.0.2
  Opaque Type: 1
Traffic Engineering and Multiprotocol label switching as mean to increase network efficiency

Opaque ID: 2
Advertising Router: 172.16.4.1
LS Seq Number: 80000008
Checksum: 0x6AD
Length: 132
Fragment number : 2
Link connected to Point-to-Point network
  Link ID : 172.16.3.1
  Interface Address : 192.168.3.4
  Neighbor Address : 192.168.3.3
  Admin Metric : 64
  Maximum bandwidth : 193000
  Maximum reservable bandwidth : 64000
Number of Priority : 8
  Priority 0 : 64000       Priority 1 : 64000
  Priority 2 : 64000       Priority 3 : 64000
  Priority 4 : 64000       Priority 5 : 64000
  Priority 6 : 64000       Priority 7 : 64000
  Affinity Bit : 0x0
  IGP Metric : 64
  Number of Links : 1

R4#sh mpls traffic-eng tunnels brief

Signalling Summary:
  LSP Tunnels Process: running
  RSVP Process: running
  Forwarding: enabled
  Periodic reoptimization: every 3600 seconds, next in 531 seconds
  Periodic auto-bw collection: disabled

<table>
<thead>
<tr>
<th>TUNNEL NAME</th>
<th>DESTINATION</th>
<th>UP IF</th>
<th>DOWN IF</th>
<th>STATE/PROT</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>10.10.10.50</td>
<td>Fa0/1</td>
<td>Se0/1/0</td>
<td>up/up</td>
</tr>
<tr>
<td>R1</td>
<td>10.10.10.50</td>
<td>Se0/1/1</td>
<td>Se0/1/0</td>
<td>up/up</td>
</tr>
<tr>
<td>R5</td>
<td>10.10.10.10</td>
<td>Se0/1/0</td>
<td>Fa0/1</td>
<td>up/up</td>
</tr>
<tr>
<td>R5</td>
<td>10.10.10.10</td>
<td>Se0/1/0</td>
<td>Fa0/1</td>
<td>up/up</td>
</tr>
</tbody>
</table>

Displayed 0 (of 0) heads, 4 (of 4) midpoints, 0 (of 0) tails

R4#sh ip rsvp interface

<table>
<thead>
<tr>
<th>interface</th>
<th>allocated</th>
<th>i/f max</th>
<th>flow max</th>
<th>sub max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Se0/1/0</td>
<td>260K</td>
<td>512K</td>
<td>256K</td>
<td>0</td>
</tr>
<tr>
<td>Se0/1/1</td>
<td>0</td>
<td>512K</td>
<td>256K</td>
<td>0</td>
</tr>
</tbody>
</table>
R4#sh mpls traffic-eng tunnels summary
Signalling Summary:
LSP Tunnels Process:          running
RSVP Process:                 running
Forwarding:                   enabled
Head: 0 interfaces, 0 active signalling attempts, 0 established
    0 activations, 0 deactivations
Midpoints: 4, Tails: 0
Periodic reoptimization:     every 3600 seconds, next in 483 seconds
Periodic auto-bw collection: disabled

R4#sh ip cef
Prefix     Next Hop     Interface
0.0.0.0/0   drop         Null0 (default route handler entry)
0.0.0.0/32  receive
10.10.10.10/32  192.168.0.2  FastEthernet0/1
10.10.10.20/32  192.168.0.2  FastEthernet0/1
10.10.10.30/32  192.168.3.3  Serial0/1/1
10.10.10.40/32  receive
10.10.10.50/32  192.168.4.5  Serial0/1/0
172.16.1.0/24   192.168.0.2  FastEthernet0/1
172.16.2.0/24   192.168.0.2  FastEthernet0/1
172.16.3.0/24   192.168.3.3  Serial0/1/1
172.16.4.0/24   attached    Loopback0
172.16.4.0/32  receive
172.16.4.1/32  receive
172.16.4.255/32 receive
172.16.5.0/24   192.168.4.5  Serial0/1/0
192.168.0.0/24  attached   FastEthernet0/1
192.168.0.0/32  receive
192.168.0.2/32  192.168.0.2  FastEthernet0/1
192.168.0.4/32  receive
192.168.0.255/32 receive
192.168.1.0/24   192.168.0.2  FastEthernet0/1
192.168.2.0/24   192.168.3.3  Serial0/1/1
192.168.3.0/24  attached   Serial0/1/1
192.168.3.0/32  receive
192.168.3.4/32  receive
192.168.3.255/32 receive
192.168.4.0/24  attached   Serial0/1/0
192.168.4.0/32  receive
192.168.4.4/32  receive
192.168.4.255/32 receive
Traffic Engineering and Multiprotocol label switching as means to increase network efficiency

224.0.0.0/4  drop
224.0.0.0/24  receive
255.255.255.255/32  receive

R4#sh tag-switching forwarding-table

<table>
<thead>
<tr>
<th>Local tag</th>
<th>Outgoing tag or VC</th>
<th>Prefix or Tunnel Id</th>
<th>Bytes tag switched</th>
<th>Outgoing interface</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>Pop tag</td>
<td>172.16.5.0/24</td>
<td>0</td>
<td>Se0/1/0</td>
<td>point2point</td>
</tr>
<tr>
<td>17</td>
<td>18</td>
<td>172.16.1.0/24</td>
<td>0</td>
<td>Fa0/1</td>
<td>192.168.0.2</td>
</tr>
<tr>
<td>18</td>
<td>Pop tag</td>
<td>172.16.2.0/24</td>
<td>0</td>
<td>Fa0/1</td>
<td>192.168.0.2</td>
</tr>
<tr>
<td>19</td>
<td>Pop tag</td>
<td>172.16.3.0/24</td>
<td>28698</td>
<td>Se0/1/1</td>
<td>point2point</td>
</tr>
<tr>
<td>20</td>
<td>21</td>
<td>10.10.10.10/32</td>
<td>1180</td>
<td>Fa0/1</td>
<td>192.168.0.2</td>
</tr>
<tr>
<td>21</td>
<td>Pop tag</td>
<td>10.10.10.30/32</td>
<td>520</td>
<td>Se0/1/1</td>
<td>point2point</td>
</tr>
<tr>
<td>22</td>
<td>Pop tag</td>
<td>10.10.10.20/32</td>
<td>570</td>
<td>Fa0/1</td>
<td>192.168.0.2</td>
</tr>
<tr>
<td>23</td>
<td>Pop tag</td>
<td>10.10.10.50/32</td>
<td>0</td>
<td>Se0/1/0</td>
<td>point2point</td>
</tr>
<tr>
<td>24</td>
<td>Pop tag</td>
<td>192.168.1.0/24</td>
<td>0</td>
<td>Fa0/1</td>
<td>192.168.0.2</td>
</tr>
<tr>
<td>25</td>
<td>Pop tag</td>
<td>192.168.2.0/24</td>
<td>0</td>
<td>Se0/1/1</td>
<td>point2point</td>
</tr>
<tr>
<td>26</td>
<td>Pop tag</td>
<td>10.10.10.10 12345 [9]</td>
<td>520</td>
<td>Se0/1/0</td>
<td>point2point</td>
</tr>
<tr>
<td>27</td>
<td>Pop tag</td>
<td>10.10.10.10 1245 [8]</td>
<td>0</td>
<td>Se0/1/0</td>
<td>point2point</td>
</tr>
<tr>
<td>28</td>
<td>28</td>
<td>10.10.10.50 10 [1]</td>
<td>0</td>
<td>Fa0/1</td>
<td>192.168.0.2</td>
</tr>
<tr>
<td>29</td>
<td>29</td>
<td>10.10.10.50 20 [1]</td>
<td>0</td>
<td>Fa0/1</td>
<td>192.168.0.2</td>
</tr>
</tbody>
</table>

Router 5

sh runn
Building configuration...

Current configuration : 1961 bytes

! version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname R5
!
boot-start-marker
boot-end-marker
!
no aaa new-model
memory-size iomem 10
!
ip cef

ip host PAGENT-SECURITY-V3 57.79.21.41 55.86.0.0

multilink bundle-name authenticated
mpls traffic-eng tunnels

voice-card 0
no dspfarm

interface Loopback0
  ip address 172.16.5.1 255.255.255.0
  ip ospf network point-to-point

interface Loopback1
  ip address 10.10.10.50 255.255.255.255
  ip ospf network point-to-point

interface Tunnel10
  ip unnumbered Loopback1
  tunnel destination 10.10.10.10
  tunnel mode mpls traffic-eng
  tunnel mpls traffic-eng autoroute announce
  tunnel mpls traffic-eng priority 4 4
  tunnel mpls traffic-eng bandwidth 56
  tunnel mpls traffic-eng path-option 1 dynamic
  no routing dynamic

interface Tunnel20
  ip unnumbered Loopback1
  tunnel destination 10.10.10.10
  tunnel mode mpls traffic-eng
  tunnel mpls traffic-eng autoroute announce
  tunnel mpls traffic-eng priority 2 2
  tunnel mpls traffic-eng bandwidth 88
  tunnel mpls traffic-eng path-option 2 dynamic
  no routing dynamic

interface FastEthernet0/0
  no ip address
  shutdown
duplex auto
speed auto
!
interface FastEthernet0/1
  no ip address
  shutdown
duplex auto
  speed auto
!
interface Serial0/0/0
  ip address 192.168.4.5 255.255.255.0
  mpls ip
  mpls traffic-eng tunnels
  ip rsvp bandwidth 512 256
!
interface Serial0/0/1
  no ip address
  shutdown
clock rate 125000
!
router ospf 1
  mpls traffic-eng router-id Loopback1
  mpls traffic-eng area 1
  log-adjacency-changes
  network 10.10.10.0 0.0.0.255 area 1
  network 172.16.0.0 0.0.255.255 area 1
  network 192.168.0.0 0.0.255.255 area 1
!
!
ip http server
  no ip http secure-server
!
!
control-plane
!
!
line con 0
  exec-timeout 0 0
line aux 0
line vty 0 4
  login
!
scheduler allocate 20000 1000
!
end
Introduction

**R5#sh ip route**

Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
E1 - OSPF external type 1, E2 - OSPF external type 2
i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
ia - IS-IS inter area, * - candidate default, U - per-user static route
o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

172.16.0.0/24 is subnetted, 5 subnets

O 172.16.4.0 [110/65] via 192.168.4.4, 00:17:28, Serial0/0/0
C 172.16.5.0 is directly connected, Loopback0
O 172.16.1.0 [110/847] via 0.0.0.0, 00:17:28, Tunnel10
[110/847] via 0.0.0.0, 00:17:28, Tunnel20
O 172.16.2.0 [110/66] via 192.168.4.4, 00:17:28, Serial0/0/0
O 172.16.3.0 [110/129] via 192.168.4.4, 00:17:28, Serial0/0/0
C 192.168.4.0/24 is directly connected, Serial0/0/0
10.0.0.0/32 is subnetted, 5 subnets
O 10.10.10.10 [110/847] via 0.0.0.0, 00:17:29, Tunnel10
[110/847] via 0.0.0.0, 00:17:29, Tunnel20
O 10.10.10.30 [110/129] via 192.168.4.4, 00:17:29, Serial0/0/0
O 10.10.10.20 [110/66] via 192.168.4.4, 00:17:29, Serial0/0/0
O 10.10.10.40 [110/65] via 192.168.4.4, 00:17:30, Serial0/0/0
C 10.10.10.50 is directly connected, Loopback1
O 192.168.0.0/24 [110/65] via 192.168.4.4, 00:17:30, Serial0/0/0
O 192.168.1.0/24 [110/846] via 192.168.4.4, 00:17:30, Serial0/0/0
O 192.168.2.0/24 [110/129] via 192.168.4.4, 00:17:30, Serial0/0/0
O 192.168.3.0/24 [110/128] via 192.168.4.4, 00:17:30, Serial0/0/0

**R5#sh ip int brief**

<table>
<thead>
<tr>
<th>Interface</th>
<th>IP-Address</th>
<th>OK?</th>
<th>Method</th>
<th>Status</th>
<th>Protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td>FastEthernet0/0</td>
<td>unassigned</td>
<td>YES</td>
<td>manual</td>
<td>administratively down</td>
<td>down</td>
</tr>
<tr>
<td>FastEthernet0/1</td>
<td>unassigned</td>
<td>YES</td>
<td>manual</td>
<td>administratively down</td>
<td>down</td>
</tr>
<tr>
<td>Serial0/0/0</td>
<td>192.168.4.5</td>
<td>YES</td>
<td>manual</td>
<td>up</td>
<td>up</td>
</tr>
<tr>
<td>Serial0/0/1</td>
<td>unassigned</td>
<td>YES</td>
<td>manual</td>
<td>administratively down</td>
<td>down</td>
</tr>
<tr>
<td>Loopback0</td>
<td>172.16.5.1</td>
<td>YES</td>
<td>manual</td>
<td>up</td>
<td>up</td>
</tr>
<tr>
<td>Loopback1</td>
<td>10.10.10.50</td>
<td>YES</td>
<td>manual</td>
<td>up</td>
<td>up</td>
</tr>
<tr>
<td>Tunnel10</td>
<td>10.10.10.50</td>
<td>YES</td>
<td>TFTP</td>
<td>up</td>
<td>up</td>
</tr>
<tr>
<td>Tunnel20</td>
<td>10.10.10.50</td>
<td>YES</td>
<td>TFTP</td>
<td>up</td>
<td>up</td>
</tr>
</tbody>
</table>

**R5#sh ip ospf mpls traffic-eng link**

OSPF Router with ID (172.16.5.1) (Process ID 1)
Area 1 has 1 MPLS TE links. Area instance is 5.
Links in hash bucket 40.
Link is associated with fragment 0. Link instance is 5
Traffic Engineering and Multiprotocol label switching as means to increase network efficiency

Link connected to Point-to-Point network
Link ID: 172.16.4.1
Interface Address: 192.168.4.5
Neighbor Address: 192.168.4.4
Admin Metric: te: 64 igp: 64
Maximum bandwidth: 193000
Maximum reservable bandwidth: 64000
Number of Priority: 8
Priority 0: 64000 Priority 1: 64000
Priority 2: 53000 Priority 3: 53000
Priority 4: 46000 Priority 5: 46000
Priority 6: 46000 Priority 7: 46000
Affinity Bit: 0x0

R5#sh ip ospf database opaque-area
OSPF Router with ID (172.16.5.1) (Process ID 1)
Type-10 Opaque Link Area Link States (Area 1)
LS age: 774
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 1.0.0.0
Opaque Type: 1
Opaque ID: 0
Advertising Router: 172.16.1.1
LS Seq Number: 80000008
Checksum: 0x7829
Length: 140
Fragment number: 0
MPLS TE router ID: 10.10.10.10
Link connected to Point-to-Point network
Link ID: 172.16.2.1
Interface Address: 192.168.1.1
Neighbor Address: 192.168.1.2
Admin Metric: 64
Maximum bandwidth: 193000
Maximum reservable bandwidth: 64000
Number of Priority: 8
Priority 0: 64000 Priority 1: 64000
Priority 2: 64000 Priority 3: 48000
Priority 4: 48000 Priority 5: 48000
Priority 6: 31500 Priority 7: 31500
Affinity Bit: 0x0
IGP Metric: 64
Number of Links: 1
LS age: 855
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 1.0.0.0
Opaque Type: 1
Opaque ID: 0
Advertising Router: 172.16.2.1
LS Seq Number: 80000008
Checksum: 0x9443
Length: 132
Fragment number : 0
MPLS TE router ID : 10.10.10.20
Link connected to Broadcast network
  Link ID : 192.168.0.4
  Interface Address : 192.168.0.2
  Admin Metric : 1
  Maximum bandwidth : 12500000
  Maximum reservable bandwidth : 64000
  Number of Priority : 8
    Priority 0 : 64000   Priority 1 : 64000
    Priority 2 : 64000   Priority 3 : 64000
    Priority 4 : 64000   Priority 5 : 64000
    Priority 6 : 47500   Priority 7 : 47500
  Affinity Bit : 0x0
  IGP Metric : 1
  Number of Links : 1
LS age: 1307
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 1.0.0.0
Opaque Type: 1
Opaque ID: 0
Advertising Router: 172.16.3.1
LS Seq Number: 80000007
Checksum: 0x2C47
Length: 140
Fragment number : 0
MPLS TE router ID : 10.10.10.30
Link connected to Point-to-Point network
  Link ID : 172.16.2.1
  Interface Address : 192.168.2.3
  Neighbor Address : 192.168.2.2
  Admin Metric : 64
  Maximum bandwidth : 193000
  Maximum reservable bandwidth : 64000
  Number of Priority : 8
    Priority 0 : 64000   Priority 1 : 64000
Traffic Engineering and Multiprotocol label switching as mean to increase network efficiency

- Priority 2 : 64000
- Priority 4 : 64000
- Priority 6 : 64000
- Priority 7 : 64000
- Affinity Bit : 0x0
- IGP Metric : 64
- Number of Links : 1
- LS age: 1112
- Options: (No TOS-capability, DC)
- LS Type: Opaque Area Link
- Link State ID: 1.0.0.0
- Opaque Type: 1
- Opaque ID: 0
- Advertising Router: 172.16.4.1
- LS Seq Number: 80000008
- Checksum: 0xDC1A
- Length: 132
- Fragment number : 0
- MPLS TE router ID : 10.10.10.40
- Link connected to Broadcast network
  - Link ID : 192.168.0.4
  - Interface Address : 192.168.0.4
  - Admin Metric : 1
  - Maximum bandwidth : 12500000
  - Maximum reservable bandwidth : 64000
- Number of Priority : 8
- Priority 0 : 64000
- Priority 2 : 53000
- Priority 4 : 46000
- Priority 6 : 46000
- Priority 7 : 46000
- Affinity Bit : 0x0
- IGP Metric : 1
- Number of Links : 1
- LS age: 1114
- Options: (No TOS-capability, DC)
- LS Type: Opaque Area Link
- Link State ID: 1.0.0.0
- Opaque Type: 1
- Opaque ID: 0
- Advertising Router: 172.16.5.1
- LS Seq Number: 8000000A
- Checksum: 0x9E7
- Length: 140
- Fragment number : 0
- MPLS TE router ID : 10.10.10.50
- Link connected to Point-to-Point network
Link ID : 172.16.4.1
Interface Address : 192.168.4.5
Neighbor Address : 192.168.4.4
Admin Metric : 64
Maximum bandwidth : 193000
Maximum reservable bandwidth : 64000
Number of Priority : 8
Priority 0 : 64000       Priority 1 : 64000
Priority 2 : 53000       Priority 3 : 53000
Priority 4 : 46000       Priority 5 : 46000
Priority 6 : 46000       Priority 7 : 46000
Affinity Bit : 0x0
IGP Metric : 64
Number of Links : 1
LS age: 90
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 1.0.0.1
Opaque Type: 1
Opaque ID: 1
Advertising Router: 172.16.2.1
LS Seq Number: 80000008
Checksum: 0x90A
Length: 132
Fragment number : 1
Link connected to Point-to-Point network
   Link ID : 172.16.3.1
   Interface Address : 192.168.2.2
   Neighbor Address : 192.168.2.3
   Admin Metric : 781
   Maximum bandwidth : 16000
   Maximum reservable bandwidth : 64000
   Number of Priority : 8
   Priority 0 : 64000       Priority 1 : 64000
   Priority 2 : 64000       Priority 3 : 48000
   Priority 4 : 48000       Priority 5 : 48000
   Priority 6 : 48000       Priority 7 : 48000
   Affinity Bit : 0x0
   IGP Metric : 781

   Number of Links : 1
   LS age: 302
   Options: (No TOS-capability, DC)
   LS Type: Opaque Area Link
   Link State ID: 1.0.0.1
   Opaque Type: 1

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Opaque ID: 1
Advertising Router: 172.16.3.1
LS Seq Number: 80000008
Checksum: 0xDE8F
Length: 132
Fragment number: 1
Link connected to Point-to-Point network
   Link ID: 172.16.4.1
   Interface Address: 192.168.3.3
   Neighbor Address: 192.168.3.4
   Admin Metric: 64
   Maximum bandwidth: 193000
   Maximum reservable bandwidth: 64000
   Number of Priority: 8
   Priority 0: 64000  Priority 1: 64000
   Priority 2: 64000  Priority 3: 48000
   Priority 4: 48000  Priority 5: 48000
   Priority 6: 48000  Priority 7: 48000
   Affinity Bit: 0x0
   IGP Metric: 64
   Number of Links: 1
LS age: 918
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 1.0.0.1
Opaque Type: 1
Opaque ID: 1
Advertising Router: 172.16.4.1
LS Seq Number: 80000008
Checksum: 0x19AA
Length: 132
Fragment number: 1
Link connected to Point-to-Point network
   Link ID: 172.16.5.1
   Interface Address: 192.168.4.4
   Neighbor Address: 192.168.4.5
   Admin Metric: 64
   Maximum bandwidth: 193000
   Maximum reservable bandwidth: 64000
   Number of Priority: 8
   Priority 0: 64000  Priority 1: 64000
   Priority 2: 64000  Priority 3: 48000
   Priority 4: 48000  Priority 5: 48000
   Priority 6: 31500  Priority 7: 31500
   Affinity Bit: 0x0
IGP Metric : 64
Number of Links : 1
LS age: 1123
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 1.0.0.2
Opaque Type: 1
Opaque ID: 2
Advertising Router: 172.16.2.1
LS Seq Number: 8000009
Checksum: 0x3FBE
Length: 132
Fragment number : 2
Link connected to Point-to-Point network
  Link ID : 172.16.1.1
  Interface Address : 192.168.1.2
  Neighbor Address : 192.168.1.1
  Admin Metric : 781
  Maximum bandwidth : 16000
  Maximum reservable bandwidth : 64000
Number of Priority : 8
  Priority 0 : 64000  Priority 1 : 64000
  Priority 2 : 53000  Priority 3 : 53000
  Priority 4 : 46000  Priority 5 : 46000
  Priority 6 : 46000  Priority 7 : 46000
  Affinity Bit : 0x0
IGP Metric : 781
Number of Links : 1
LS age: 1443
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 1.0.0.2
Opaque Type: 1
Opaque ID: 2
Advertising Router: 172.16.4.1
LS Seq Number: 8000007
Checksum: 0x8AC
Length: 132
Fragment number : 2
Link connected to Point-to-Point network
  Link ID : 172.16.3.1
  Interface Address : 192.168.3.4
  Neighbor Address : 192.168.3.3
  Admin Metric : 64
  Maximum bandwidth : 193000
  Maximum reservable bandwidth : 64000
Traffic Engineering and Multiprotocol label switching as mean to increase network efficiency

Number of Priority : 8
Priority 0 : 64000       Priority 1 : 64000
Priority 2 : 64000       Priority 3 : 64000
Priority 4 : 64000       Priority 5 : 64000
Priority 6 : 64000       Priority 7 : 64000
Affinity Bit : 0x0
IGP Metric : 64
Number of Links : 1

R5#sh mpls traffic-eng tunnels brief
Signalling Summary:
LSP Tunnels Process: running
RSVP Process: running
Forwarding: enabled
Periodic reoptimization: every 3600 seconds, next in 2256 seconds
Periodic auto-bw collection: disabled

<table>
<thead>
<tr>
<th>TUNNEL NAME</th>
<th>DESTINATION</th>
<th>UP IF</th>
<th>DOWN IF</th>
<th>STATE/PROT</th>
</tr>
</thead>
<tbody>
<tr>
<td>R5 t10</td>
<td>10.10.10.10</td>
<td>-</td>
<td>Se0/0/0</td>
<td>up/up</td>
</tr>
<tr>
<td>R5 t20</td>
<td>10.10.10.10</td>
<td>-</td>
<td>Se0/0/0</td>
<td>up/up</td>
</tr>
<tr>
<td>R1 t1245</td>
<td>10.10.10.50</td>
<td>Se0/0/0</td>
<td>-</td>
<td>up/up</td>
</tr>
<tr>
<td>R1 t12345</td>
<td>10.10.10.50</td>
<td>Se0/0/0</td>
<td>-</td>
<td>up/up</td>
</tr>
</tbody>
</table>

Displayed 2 (of 2) heads, 0 (of 0) midpoints, 2 (of 2) tails

R5#sh ip rsvp interface

<table>
<thead>
<tr>
<th>interface</th>
<th>allocated</th>
<th>i/f max</th>
<th>flow max</th>
<th>sub max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Se0/0/0</td>
<td>144K</td>
<td>512K</td>
<td>256K</td>
<td>0</td>
</tr>
</tbody>
</table>

R5#sh mpls traffic-eng tunnels summary
Signalling Summary:
LSP Tunnels Process: running
RSVP Process: running
Forwarding: enabled
Head: 2 interfaces, 2 active signalling attempts, 2 established
  2 activations, 0 deactivations
Midpoints: 0, Tails: 2
Periodic reoptimization: every 3600 seconds, next in 2170 seconds
Periodic auto-bw collection: disabled

R5#sh mpls traffic-eng tunnels name R5_t10
Name: R5_t10 (Tunnel10) Destination: 10.10.10.10
Status:
Admin: up Oper: up Path: valid Signalling: connected
path option 1, type dynamic (Basis for Setup, path weight 846)
Config Parameters:
Bandwidth: 56 kbps (Global) Priority: 4 4 Affinity: 0x0/0xFFFF
Metric Type: TE (default)
AutoRoute: enabled LockDown: disabled Loadshare: 56 bw-based
auto-bw: disabled
InLabel : -
OutLabel : Serial0/0/0, 28
RSVP Signalling Info:
  Src 10.10.10.50, Dst 10.10.10.10, Tun_Id 10, Tun_Instance 1
  My Address: 10.10.10.50
  Explicit Route: 192.168.4.4 192.168.0.4 192.168.0.2 192.168.1.1
    10.10.10.10
  Record Route: NONE
  Tspec: ave rate=56 kbits, burst=1000 bytes, peak rate=56 kbits
RSVP Resv Info:
  Record Route: NONE
  Fspec: ave rate=56 kbits, burst=1000 bytes, peak rate=56 kbits
History:
Tunnel:
  Time since created: 1 hours, 1 minutes
  Time since path change: 59 minutes, 18 seconds
Current LSP:
  Uptime: 59 minutes, 18 seconds
Traffic Engineering and Multiprotocol label switching as mean to increase network efficiency

Config Parameters:
- Bandwidth: 88 kbps (Global) Priority: 2 Affinity: 0x0/0xFFFF
- Metric Type: TE (default)
- AutoRoute: enabled LockDown: disabled Loadshare: 88 bw-based
- auto-bw: disabled
- InLabel : -
- OutLabel : Serial0/0/0, 29
- RSVP Signalling Info:
  - Src 10.10.10.50, Dst 10.10.10.10, Tun_Id 20, Tun_Instance 1
- RSVP Path Info:
  - My Address: 10.10.10.50
  - Explicit Route: 192.168.4.4 192.168.0.4 192.168.0.2 192.168.1.1 10.10.10.10
  - Record Route: NONE
  - Tspec: ave rate=88 kbits, burst=1000 bytes, peak rate=88 kbits
- RSVP Resv Info:
  - Record Route: NONE
  - Fspec: ave rate=88 kbits, burst=1000 bytes, peak rate=88 kbits

History:
- Tunnel:
  - Time since created: 56 minutes, 29 seconds
  - Time since path change: 53 minutes, 33 seconds
- Current LSP:
  - Uptime: 53 minutes, 33 seconds

R5# sh mpls traffic-eng tunnels name

R5_t20_t20 1_t20_t20 12345
LSP Tunnel R1_t12345 is signalled, connection is up
- InLabel : Serial0/0/0, implicit-null
- OutLabel : -
RSVP Signalling Info:
- Src 10.10.10.10, Dst 10.10.10.50, Tun_Id 12345, Tun_Instance 9

RSVP Path Info:
- My Address: 10.10.10.50
- Explicit Route: NONE
- Record Route: NONE
- Tspec: ave rate=128 kbits, burst=1000 bytes, peak rate=128 kbits

RSVP Resv Info:
- Record Route: NONE
- Fspec: ave rate=128 kbits, burst=1000 bytes, peak rate=128 kbits

R1_t1234545
LSP Tunnel R1_t1245 is signalled, connection is up
- InLabel : Serial0/0/0, implicit-null
- OutLabel : -

RSVP Signalling Info:
- Src 10.10.10.10, Dst 10.10.10.50, Tun_Id 1245, Tun_Instance 8

RSVP Path Info:
- My Address: 10.10.10.50
- Explicit Route: NONE
- Record Route: NONE
- Tspec: ave rate=132 kbits, burst=1000 bytes, peak rate=132 kbits

RSVP Resv Info:
- Record Route: NONE
- Fspec: ave rate=132 kbits, burst=1000 bytes, peak rate=132 kbits