MPLS Traffic Engineering with IS-IS

« MPLS Traffic Engineering with OSPF (/workbook/view/service-provider-v4/task/mpls-traffic-engineering-with-ospf-Mjg3OQ%3D%3D) | MPLS TE Explicit Paths (/workbook/view/service-provider-v4/task/mpls-te-explicit-paths-Mjg4MQ%3D%3D) »

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Note:

Initial Configuration & Diagrams: Load the initial configuration files for the section named **MPLS TE with IS-IS**, which can be found in CCIE SPv4 Topology Diagrams & Initial Configurations (http://labs.ine.com/workbook/view/service-provider-v4/task/ccie-spv4-topology-diagrams-initial-configs). Refer to the **Base IPv4 Diagram** in order to complete this task.

Task

- R2 and XR1 are preconfigured as PE routers for the MPLS L3VPN customer routers R1 and XR2, respectively, but the core of the Service Provider network is not running LDP.
- Configure the core of the Service Provider network to support MPLS TE tunnels as follows:
  - Enable MPLS TE support for the IS-IS Level 2 core.
  - Set the IS-IS MPLS TE Router-ID to be the Loopback0 interfaces.
  - Enable support for RSVP and MPLS TE on all transit interfaces running IS-IS in the core.
- Configure an MPLS TE tunnel from R2 to XR1 as follows:
  - Unnumber the tunnel to R2’s Loopback0 interface.
  - Set the tunnel destination as XR1’s Loopback0 interface.
  - Set the tunnel’s path option to dynamic.
  - Configure Autoroute Announce on the tunnel so that the IS-IS core can use it for dynamic routing.
- Configure an MPLS TE tunnel from XR1 to R2 as follows:
  - Unnumber the tunnel to XR1’s Loopback0 interface.
  - Set the tunnel destination as R2’s Loopback0 interface.
  - Set the tunnel’s path option to dynamic.
  - Configure Autoroute Announce on the tunnel so that the IS-IS core can use it for dynamic routing.
- When complete, the following reachability should be achieved:
  - R1 and XR2 should have full IP reachability to each other, and a traceroute should indicate that their L3VPN tunnel is transiting over the MPLS TE tunnels in the core of the SP network.

Configuration

Click to *collapse*

```
R2:
mpls traffic-eng tunnels
!
interface Tunnel0
 ip unnumbered Loopback0
 tunnel mode mpls traffic-eng
 tunnel destination 19.19.19.19
 tunnel mpls traffic-eng autoroute announce
 tunnel mpls traffic-eng path-option 1 dynamic
!
interface GigabitEthernet1.23
 mpls traffic-eng tunnels
 ip rsvp bandwidth
!
interface GigabitEthernet1.24
 mpls traffic-eng tunnels
 ip rsvp bandwidth
!
router isis
 metric-style wide
 mpls traffic-eng router-id Loopback0
 mpls traffic-eng level-2

R3:
mpls traffic-eng tunnels
!
interface GigabitEthernet1.23
 mpls traffic-eng tunnels
 ip rsvp bandwidth
!
interface GigabitEthernet1.34
 mpls traffic-eng tunnels
 ip rsvp bandwidth
!
interface GigabitEthernet1.36
 mpls traffic-eng tunnels
 ip rsvp bandwidth
!
router isis
 metric-style wide
 mpls traffic-eng router-id Loopback0
 mpls traffic-eng level-2

R4:
mpls traffic-eng tunnels
!
interface GigabitEthernet1.24
 mpls traffic-eng tunnels
 ip rsvp bandwidth
!
interface GigabitEthernet1.34
 mpls traffic-eng tunnels
 ip rsvp bandwidth
```

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```
!
interface GigabitEthernet1.45
 mpls traffic-eng tunnels
 ip rsvp bandwidth
!
interface GigabitEthernet1.46
 mpls traffic-eng tunnels
 ip rsvp bandwidth
!
router isis
 metric-style wide
 mpls traffic-eng router-id Loopback0
 mpls traffic-eng level-2

R5:
mpls traffic-eng tunnels
!
interface GigabitEthernet1.45
 mpls traffic-eng tunnels
 ip rsvp bandwidth
!
interface GigabitEthernet1.56
 mpls traffic-eng tunnels
 ip rsvp bandwidth
!
interface GigabitEthernet1.519
 mpls traffic-eng tunnels
 ip rsvp bandwidth
!
router isis
 metric-style wide
 mpls traffic-eng router-id Loopback0
 mpls traffic-eng level-2

R6:
mpls traffic-eng tunnels
!
interface GigabitEthernet1.36
 mpls traffic-eng tunnels
 ip rsvp bandwidth
!
interface GigabitEthernet1.46
 mpls traffic-eng tunnels
 ip rsvp bandwidth
!
interface GigabitEthernet1.56
 mpls traffic-eng tunnels
 ip rsvp bandwidth
!
interface GigabitEthernet1.619
 mpls traffic-eng tunnels
 ip rsvp bandwidth
!
router isis
```

```
 metric-style wide
 mpls traffic-eng router-id Loopback0
 mpls traffic-eng level-2

XR1:
interface tunnel-te0
 ipv4 unnumbered Loopback0
 autoroute announce
 destination 2.2.2.2
 path-option 1 dynamic
!
router isis 1
 address-family ipv4 unicast
  metric-style wide
  mpls traffic-eng level-2-only
  mpls traffic-eng router-id Loopback0
!
rsvp
 interface GigabitEthernet0/0/0/0.519
 !
 interface GigabitEthernet0/0/0/0.619
 !
mpls traffic-eng
 interface GigabitEthernet0/0/0/0.519
 !
 interface GigabitEthernet0/0/0/0.619
 !
mpls ldp
```

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Verification

This example is similar to the previous MPLS Traffic Engineering with OSPF, except that IS-IS is used to compute the MPLS TE topology in the core of the network. Note that with IS-IS, you must enable the wide metric styles for the MPLS TE attributes to be encoded in the IS-IS TLVs. This can be done with either the `metric-style wide` command or the `metric-style transition` command, depending on whether all routers in the IS-IS network run the wide metric style, or if some still run narrow.

ISIS was extended with additional TLVs in order to support MPLS TE. The following TLVs were added:

TLV	Name	Description
22	Extended IS Reachability TLV	Contains the ISIS neighbors, and carries Sub-TLVs describing the additional attributes used during CSPF
134	Traffic Engineering Router ID TLV	Contains the MPLS TE Router-ID of the advertising router
135	Extended IP Reachability TLV	Contains a 32 bit metric and carries IP Prefixes, also contains the Up/Down bit

Verification of this configuration is identical to the last, except that the MPLS TE topology shows IS-IS related information. Below we see output similar to the last example, but the IGP identifiers are the routers' IS-IS NET addresses as opposed to the IPv4 formatted OSPF Router-IDs.

```
RP/0/0/CPU0:XR1#show mpls traffic-eng topology

Wed May 27 22:02:19.936 UTC

My_System_id: 0000.0000.0019.00 (IS-IS 1 level-2)

My_BC_Model_Type: RDM


Signalling error holddown: 10 sec Global Link Generation 87


 IGP Id: 0000.0000.0002.00, MPLS TE Id: 2.2.2.2 Router Node  (IS-IS 1 level-2)


   Link[0]:Broadcast, DR:0000.0000.0002.02, Nbr Node Id:2, gen:52

       Frag Id:0, Intf Address:20.2.4.2, Intf Id:0

       Nbr Intf Address:0.0.0.0, Nbr Intf Id:0

       TE Metric:10, IGP Metric:10

       Attribute Flags: 0x0

       Ext Admin Group:

           Length: 256 bits

           Value : 0x::

       Attribute Names:

       Switching Capability:None, Encoding:unassigned

       BC Model ID:RDM

        Physical BW:1000000 (kbps), Max Reservable BW Global:750000 (kbps)

       Max Reservable BW Sub:0 (kbps)

                                  Global Pool       Sub Pool

                Total Allocated   Reservable        Reservable

                BW (kbps)         BW (kbps)         BW (kbps)

                ---------------   -----------       ----------

         bw[0]:            0         750000              0

         bw[1]:            0         750000              0

         bw[2]:            0         750000              0

         bw[3]:            0         750000              0

         bw[4]:            0         750000              0

         bw[5]:            0         750000              0

         bw[6]:            0         750000              0

         bw[7]:            0         750000              0


   Link[1]:Broadcast, DR:0000.0000.0003.01, Nbr Node Id:4, gen:53

       Frag Id:0, Intf Address:20.2.3.2, Intf Id:0

       Nbr Intf Address:0.0.0.0, Nbr Intf Id:0

       TE Metric:10, IGP Metric:10

       Attribute Flags: 0x0

       Ext Admin Group:

           Length: 256 bits

           Value : 0x::

       Attribute Names:

       Switching Capability:None, Encoding:unassigned

       BC Model ID:RDM

       Physical BW:1000000 (kbps), Max Reservable BW Global:750000 (kbps)

       Max Reservable BW Sub:0 (kbps)

                                  Global Pool       Sub Pool

                Total Allocated   Reservable        Reservable

                BW (kbps)         BW (kbps)         BW (kbps)

                ---------------   -----------       ----------

         bw[0]:            0         750000              0
```

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```
       bw[1]:            0        750000               0

       bw[2]:            0        750000               0

       bw[3]:            0        750000               0

       bw[4]:            0        750000               0

       bw[5]:            0        750000               0

       bw[6]:            0        750000               0

       bw[7]:            0        750000               0


IGP Id: 0000.0000.0003.00, MPLS TE Id: 3.3.3.3 Router Node  (IS-IS 1 level-2)


  Link[0]:Broadcast, DR:0000.0000.0003.03, Nbr Node Id:6, gen:56

      Frag Id:0, Intf Address:20.3.6.3, Intf Id:0

      Nbr Intf Address:0.0.0.0, Nbr Intf Id:0

      TE Metric:10, IGP Metric:10

      Attribute Flags: 0x0

      Ext Admin Group:

          Length: 256 bits

          Value : 0x::

      Attribute Names:

      Switching Capability:None, Encoding:unassigned

      BC Model ID:RDM

      Physical BW:1000000 (kbps), Max Reservable BW Global:750000 (kbps)

      Max Reservable BW Sub:0 (kbps)

                             Global Pool       Sub Pool

               Total Allocated   Reservable        Reservable

               BW (kbps)         BW (kbps)         BW (kbps)

               ---------------   -----------       ----------

       bw[0]:            0        750000               0

       bw[1]:            0        750000               0

       bw[2]:            0        750000               0

       bw[3]:            0        750000               0

       bw[4]:            0        750000               0

       bw[5]:            0        750000               0

       bw[6]:            0        750000               0

       bw[7]:            0        750000               0


  Link[1]:Broadcast, DR:0000.0000.0003.02, Nbr Node Id:5, gen:57

      Frag Id:0, Intf Address:20.3.4.3, Intf Id:0

      Nbr Intf Address:0.0.0.0, Nbr Intf Id:0

      TE Metric:10, IGP Metric:10

      Attribute Flags: 0x0

      Ext Admin Group:

          Length: 256 bits

          Value : 0x::

      Attribute Names:

  Switching Capability:None, Encoding:unassigned

  BC Model ID:RDM

  Physical BW:1000000 (kbps), Max Reservable BW Global:750000 (kbps)

  Max Reservable BW Sub:0 (kbps)

                         Global Pool       Sub Pool

           Total Allocated   Reservable        Reservable

           BW (kbps)         BW (kbps)         BW (kbps)

           ---------------   -----------       ----------

    bw[0]:            0        750000               0
```

```
    bw[1]:           0        750000              0

    bw[2]:           0        750000              0

    bw[3]:           0        750000              0

    bw[4]:           0        750000              0

    bw[5]:           0        750000              0

    bw[6]:           0        750000              0

    bw[7]:           0        750000              0


Link[2]:Broadcast, DR:0000.0000.0003.01, Nbr Node Id:4, gen:58

  Frag Id:0, Intf Address:20.2.3.3, Intf Id:0

  Nbr Intf Address:0.0.0.0, Nbr Intf Id:0

  TE Metric:10, IGP Metric:10

  Attribute Flags: 0x0

  Ext Admin Group:

      Length: 256 bits

      Value : 0x::

  Attribute Names:

  Switching Capability:None, Encoding:unassigned

  BC Model ID:RDM

  Physical BW:1000000 (kbps), Max Reservable BW Global:750000 (kbps)

  Max Reservable BW Sub:0 (kbps)

                             Global Pool       Sub Pool

           Total Allocated   Reservable        Reservable

           BW (kbps)         BW (kbps)         BW (kbps)

           ---------------   -----------       ----------

    bw[0]:           0        750000              0

    bw[1]:           0        750000              0

    bw[2]:           0        750000              0

    bw[3]:           0        750000              0

    bw[4]:           0        750000              0

    bw[5]:           0        750000              0

    bw[6]:           0        750000              0

    bw[7]:           0        750000              0

<snip>



R2#show isis database XR1.00-00 verbose


Tag null:


IS-IS Level-2 LSP XR1.00-00

LSPID                 LSP Seq Num  LSP Checksum  LSP Holdtime      ATT/P/OL

XR1.00-00             0x000003E8   0x90DA        792               0/0/0

  Area Address: 49.0001

  NLPID:        0xCC

  Hostname: XR1

  IP Address:   19.19.19.19

   Router ID:    19.19.19.19

  Metric: 10          IS-Extended XR1.01

    Affinity: 0x00000000

    Interface IP Address: 20.5.19.19

    Neighbor IP Address: 20.5.19.19

    Physical BW: 1000000 kbits/sec

    Reservable Global Pool BW: 0 kbits/sec
```

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```
    Global Pool BW Unreserved:
      [0]:        0 kbits/sec, [1]:        0 kbits/sec
      [2]:        0 kbits/sec, [3]:        0 kbits/sec
      [4]:        0 kbits/sec, [5]:        0 kbits/sec
      [6]:        0 kbits/sec, [7]:        0 kbits/sec
    Admin. Weight: 10
   Unknown Sub TLV: 252
 Metric: 10         IS-Extended R6.04
   Affinity: 0x00000000
   Interface IP Address: 20.6.19.19
   Neighbor IP Address: 20.6.19.6
   Physical BW: 1000000 kbits/sec
   Reservable Global Pool BW: 0 kbits/sec
    Global Pool BW Unreserved:
      [0]:        0 kbits/sec, [1]:        0 kbits/sec
      [2]:        0 kbits/sec, [3]:        0 kbits/sec
      [4]:        0 kbits/sec, [5]:        0 kbits/sec
      [6]:        0 kbits/sec, [7]:        0 kbits/sec
    Admin. Weight: 10
   Unknown Sub TLV: 252
 Metric: 10        IP 10.19.20.0/24
 Metric: 0         IP 19.19.19.19/32
 Metric: 10        IP 20.5.19.0/24
 Metric: 10        IP 20.6.19.0/24
```

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The goal of this verification is still the same though, which is to check the constraint attributes of the individual links in the core of the network, and to see what current and available bandwidth reservations there are.

An additional verification that is useful for troubleshooting the setup of the MPLS TE tunnels is the debug of either the RSVP PATH & RESV messages, or the `debug mpls traffic-eng tunnels signalling` , which essentially shows the same thing. Below, routers R2, R4, R5, R6, and XR1 have this debug enabled, and R2 configures its TE tunnel to XR1.

```
R2#debug mpls traffic-eng tunnels signalling
MPLS traffic-eng tunnels signalling debugging is on

R4#debug mpls traffic-eng tunnels signalling
MPLS traffic-eng tunnels signalling debugging is on

R5#debug mpls traffic-eng tunnels signalling
MPLS traffic-eng tunnels signalling debugging is on

R6#debug mpls traffic-eng tunnels signalling
MPLS traffic-eng tunnels signalling debugging is on

RP/0/0/CPU0:XR1#debug mpls traffic-eng tunnel signaling


R2#config t
Enter configuration commands, one per line. End with CNTL/Z.
R2(config)#interface Tunnel0
R2(config-if)# ip unnumbered Loopback0
R2(config-if)# tunnel mode mpls traffic-eng
R2(config-if)# tunnel destination 19.19.19.19
R2(config-if)# tunnel mpls traffic-eng autoroute announce
R2(config-if)# tunnel mpls traffic-eng path-option 1 dynamic
```

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When R2 initiates the tunnel, this should cause an RSVP reservation request message to be generated along the path. In this case, the path option is dynamic, so the RSVP messages follow the IGP path to XR1's Loopback 19.19.19.19/32.

After R2 runs CSPF, signaling of the tunnel beings by sending an RSVP PATH message to the next-hop router in the ERO (Explicit Route). Note that the ERO in this example is computed based on IGP cost, as no constrains have been included in building the LSP.

```
R2#show mpls traffic-eng tunnels | sec Explicit Route|Src
    Src 2.2.2.2, Dst 19.19.19.19 , Tun_Id 0, Tun_Instance 1
    Explicit Route : 20.2.4.4 20.4.5.4 20.4.5.5 20.5.19.5
                  20.5.19.19 19.19.19.19
```

The next-hop router in the ERO for the tunnel to XR1 from R2's perspective is R4. R4 receives and processes the PATH message sent by R2, ensuring that the message's formatting is correct, and performing admission control to ensure that the bandwidth being requested via the PATH message is available. Note that there is no bandwidth being requested of the tunnel in this example. This same process takes place on all other routers in the ERO between R2 and XR1 (R5 and XR1 in this case). R4 forwards the PATH message to R5, and then R5 to XR1.

After the tail end router receives the PATH message and performs the checks/admission control, it generates and sends a RESV message in the reverse direction. The RESV message serves as an ACK to the PATH message and also carries the labels allocated by each router in the path. The RESV message is sent hop by hop from the tail towards the head end (reverse direction). The RESV message instructs each router in the path which label to use for the LSP. Note that the tail router detects that it is the tail by seeing itself as the last node in the ERO.

If there is an error with the PATH message, or if there are not enough resources to service the tunnel, the detecting router sends back an ERROR message to the head end and the tunnel does not come up.

```
R2#
 TE-SIG-HE: Tunnel0 [0]: Attempting to activate
TE-SIG-HE: Tunnel0 [95]->19.19.19.19: RSVP head-end open
TE-SIG-HE: Tunnel0 [95]: Activation succeeded
 TE-SIG-LM: 2.2.2.2_95->19.19.19.19_0 {7}: received ADD RESV request
TE-SIG-LM: 2.2.2.2_95->19.19.19.19_0 {7}:  path next hop is 20.2.4.4 (GigabitEthernet1.24)
TE-SIG: Installed up_tag 4294967294
 TE-SIG: Installed down_tag 16
 TE-SIG-LM: 2.2.2.2_95->19.19.19.19_0 {7}: sending ADD RESV reply
 TE-SIG-HE: Tunnel0 [95]->19.19.19.19: received RESV CREATE
TE-SIG-HE: Tunnel0 [95]->19.19.19.19:  notified of new label information GigabitEthernet1.24, nhop 20.2.4.4, frame, 16
TE-SIG-HE: Tunnel0 [95]->19.19.19.19: label information Changed
TE-SIG-HE: Tunnel0: route change: :none->unknown:16
%LINEPROTO-5-UPDOWN:  Line protocol on Interface Tunnel0, changed state to up

R4#
 TE-SIG-LM: 2.2.2.2_1->19.19.19.19_0 {7}: received ADD RESV request
TE-SIG-LM: 2.2.2.2_1->19.19.19.19_0 {7}:  path previous hop is 20.2.4.2 (GigabitEthernet1.24)
TE-SIG-LM: 2.2.2.2_1->19.19.19.19_0 {7}:  path next hop is 20.4.5.5 (GigabitEthernet1.45)
TE-SIG:  Installed up_tag 16
TE-SIG:  Installed down_tag 16
 TE-SIG-LM: 2.2.2.2_1->19.19.19.19_0 {7}: sending ADD RESV reply


R5#
 TE-SIG-LM: 2.2.2.2_1->19.19.19.19_0 {7}: received ADD RESV request
TE-SIG-LM: 2.2.2.2_1->19.19.19.19_0 {7}:  path previous hop is 20.4.5.4 (GigabitEthernet1.45)
TE-SIG-LM: 2.2.2.2_1->19.19.19.19_0 {7}:  path next hop is 20.5.19.19 (GigabitEthernet1.519)
TE-SIG:  Installed up_tag 16
TE-SIG:  Installed down_tag 1
 TE-SIG-LM: 2.2.2.2_1->19.19.19.19_0 {7}: sending ADD RESV reply


RP/0/0/CPU0:XR1#
RP/0/0/CPU0:May 27 22:11:22.779 : te_control[1045]: DBG-TUNNEL-SIG[1]: te_sig_rsvp_api_recv_path:915:  Rcv Path message for LSP type P2P-pac
ket
RP/0/0/CPU0:May 27 22:11:22.779 : te_control[1045]: DBG-TUNNEL-SIG[1]: te_sig_rsvp_api_recv_path:1107 (T:0,L:1,P:2147483647,E:2.2.2.2 ,SI:0,
SO:0.0.0.0,S:2.2.2.2,D:19.19.19.19 ,CT:7): Successfully processed PATH_CR
RP/0/0/CPU0:May 27 22:11:22.779 : te_control[1045]: DBG-TUNNEL-SIG[1]: te_sig_rsvp_api_perf_handler:156: batch_size: 1, direction: RX
RP/0/0/CPU0:May 27 22:11:22.779 : te_control[1045]: DBG-TUNNEL-SIG[1]: te_rsvp_api_check_class_type_priority:441 (T:0,L:1,P:2147483647,E:2.
2.2.2,SI:0,SO:0.0.0.0,S:2.2.2.2,D:19.19.19.19,CT:7): CT: 0, Setup_priority: 7, Hold_priority: 7, DS-TE mode: 1
RP/0/0/CPU0:May 27 22:11:22.779 : te_control[1045]: DBG-TUNNEL-SIG[1]: te_process_incoming_xro:150 (T:0,L:1,P:2147483647,E:2.2.2.2,SI:0,SO:
0.0.0.0,S:2.2.2.2,D:19.19.19.19,CT:7): Ingress XRO not supported execpt for GMPLS-UNI tails
RP/0/0/CPU0:May 27 22:11:22.779 : te_control[1045]: DBG-TUNNEL-SIG[1]: te_s2l_validate_incoming_if:1065 (T:0,L:1,P:2147483647,E:2.2.2.2,SI:
0,SO:0.0.0.0,S:2.2.2.2,D:19.19.19.19,CT:7): te_s2l_validate_incoming_if: Ingress interface GigabitEthernet0_0_0.519 validated
RP/0/0/CPU0:May 27 22:11:22.779 : te_control[1045]: DBG-TUNNEL-SIG[1]: te_s2l_compute_and_set_local_rid:669 (T:0,L:1,P:2147483647,E:2.2.2.2,
SI:0,SO:0.0.0.0,S:2.2.2.2,D:19.19.19.19,CT:7):  Setting Local RID to 19.19.19.19
RP/0/0/CPU0:May 27 22:11:22.779 : te_control[1045]: DBG-TUNNEL-SIG[1]: te_s2l_compute_and_set_upstream_rid:908 (T:0,L:1,P:2147483647,E:2.2.
2.2,SI:0,SO:0.0.0.0,S:2.2.2.2,D:19.19.19.19,CT:7): Existing upstream RID (0.0.0.0) may change
RP/0/0/CPU0:May 27 22:11:22.779 : te_control[1045]: DBG-TUNNEL-SIG[1]: te_s2l_compute_and_set_upstream_rid:1004 (T:0,L:1,P:2147483647,E:2.
2.2.2,SI:0,SO:0.0.0.0,S:2.2.2.2,D:19.19.19.19,CT:7):  Set Upstream RID to 5.5.5.5
RP/0/0/CPU0:May 27 22:11:22.779 : te_control[1045]: DBG-TUNNEL-SIG[1]: te_s2l_proc_recovery_lbl:2387 (T:0,L:1,P:2147483647,E:2.2.2.2,SI:0,S
O:0.0.0.0,S:2.2.2.2,D:19.19.19.19,CT:7): Recovery label is not set
```

```
RP/0/0/CPU0:May 27 22:11:22.799 : te_control[1045]: DBG-TUNNEL-SIG[12]: te_sig_rsvp_api_handler_create_resv_argblock:1647 (T:0,L:1,P:214748
3647,E:2.2.2.2,SI:0,SO:0.0.0.0,S:2.2.2.2,D:19.19.19.19,CT:7): Successfully sent RESV to RSVP
RP/0/0/CPU0:May 27 22:11:22.799 : te_control[1045]: DBG-TUNNEL-SIG[12]: te_sig_rsvp_api_perf_handler:156: batch_size: 1, direction: TX
```

This output means that each router along the path asks the next router if it can make a reservation based on the particular constraints of this tunnel. Specifically, this is what the RSVP PATH message does. If all the routers agree that the reservation can be fulfilled, the tail of the tunnel will reply with the RESV message to actually make the reservation, which then occurs on a hop-by-hop basis back toward the head of the tunnel (the originator). Because in this case the reservation is successful, R2 learns the MPLS TE transport label binding for the tunnel. Notice also that since the path-option is dynamic, the routing decision to get towards the head end is based on the current IGP cost. In the debug outputs we can see that labels are being allocated at each hop in a downstream fashion - from the tail end back towards the head. The notion of 'down' vs 'up' in the debug outputs confirms this. XR1 assigns a label of 1 (Explicit Null) towards R5, R5 then assigns label 16 towards R4, and finally R4 assigns label 16 towards R2. This successful result can be verified as follows.

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```
R2#show mpls traffic-eng tunnels

P2P TUNNELS/LSPs:

Name: R2_t0                                (Tunnel0) Destination: 19.19.19.19
  Status:
    Admin: up         Oper: up     Path: valid       Signalling: connected
    path option 1, type dynamic (Basis for Setup, path weight 30)

  Config Parameters:
    Bandwidth: 0        kbps (Global)  Priority: 7  7   Affinity: 0x0/0xFFFF
    Metric Type: TE (default)
    AutoRoute: enabled  LockDown: disabled Loadshare: 0 [0] bw-based
    auto-bw: disabled
  Active Path Option Parameters:
    State: dynamic path option 1 is active
    BandwidthOverride: disabled  LockDown: disabled  Verbatim: disabled



  InLabel  :  -
  OutLabel : GigabitEthernet1.24, 16
  Next Hop : 20.2.4.4
  RSVP Signalling Info:
       Src 2.2.2.2, Dst 19.19.19.19 , Tun_Id 0, Tun_Instance 1
    RSVP Path Info:
      My Address: 20.2.4.2
      Explicit Route: 20.2.4.4 20.4.5.4 20.4.5.5 20.5.19.5
                      20.5.19.19 19.19.19.19
      Record   Route:   NONE
      Tspec: ave rate=0 kbits, burst=1000 bytes, peak rate=0 kbits
    RSVP Resv Info:
      Record   Route:   NONE
      Fspec: ave rate=0 kbits, burst=1000 bytes, peak rate=0 kbits
  History:
    Tunnel:
      Time since created: 10 minutes, 2 seconds
      Time since path change: 10 minutes, 2 seconds
      Number of LSP IDs (Tun_Instances) used: 1
    Current LSP: [ID: 1]
      Uptime: 10 minutes, 2 seconds

P2MP TUNNELS:

P2MP SUB-LSPS:
```

The labels can be verified by looking at the LFIB. Notice that when we try to look at the FEC binding for 19.19.19.19/32 on R2, the output states that forwarding is being done through an LSP tunnel and the outgoing interface is Tunnel0. The label assigned here is for the unidirectional point-to-point LSP tunnel from R2 to XR1, not necessarily for the prefix 19.19.19.19/32. By looking at the detailed output on R2, we see that the encapsulation is being done using Gig1.24 instead of "Tunnel0" in the non-detailed output. If we look at the LFIB on one of the midpoint routers such as R4 or R5, there will not be a FEC binding for 19.19.19.19/32. The label itself must be looked at in order to display the entry in the LFIB for the particular LSP at a midpoint router.

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```
R2#show mpls forwarding-table 19.19.19.19

Local      Outgoing   Prefix           Bytes Label   Outgoing   Next Hop

Label      Label      or Tunnel Id     Switched      interface

None  [T]  16         19.19.19.19/32   0             Tu0        point2point


[T]     Forwarding through a LSP tunnel.

        View additional labelling info with the 'detail' option


R2#show mpls forwarding-table 19.19.19.19 detail

Local      Outgoing   Prefix           Bytes Label   Outgoing   Next Hop

Label      Label      or Tunnel Id     Switched      interface

None       16         19.19.19.19/32   0             Tu0        point2point

        MAC/Encaps=18/22, MRU=1500, Label Stack{16}, via Gi1.24

        0050569E13020050569E35D1810000188847 00010000

        No output feature configured


R4#show mpls forwarding-table labels 16 detail

Local      Outgoing   Prefix           Bytes Label   Outgoing   Next Hop

Label      Label      or Tunnel Id     Switched      interface

16         16         2.2.2.2 0 [1]    2235          Gi1.45     20.4.5.5

        MAC/Encaps=18/22, MRU=1500, Label Stack{16}

        0050569E09620050569E13028100002D8847 00010000

        No output feature configured


R5#show mpls forwarding-table labels 16 detail

Local      Outgoing   Prefix           Bytes Label   Outgoing   Next Hop

Label      Label      or Tunnel Id     Switched      interface

16         Pop Label  2.2.2.2 0 [1]    2115          Gi1.519    20.5.19.19

        MAC/Encaps=18/18, MRU=1504, Label Stack{}

        0050569E59FE0050569E0962810000207 8847

        No output feature configured



R4#show mpls forwarding-table 19.19.19.19 detail

Local      Outgoing   Prefix           Bytes Label   Outgoing   Next Hop

Label      Label      or Tunnel Id     Switched      interface

None       No Label   19.19.19.19/32   0             Gi1.45     20.4.5.5

        MAC/Encaps=18/18, MRU=1504, Label Stack{}

        0050569E09620050569E13028100002D0800

        No output feature configured

    Per-destination load-sharing, slots: 0 2 4 6 8 10 12 14

           No Label   19.19.19.19/32   0             Gi1.46     20.4.6.6

        MAC/Encaps=18/18, MRU=1504, Label Stack{}

        0050569E5CEC0050569E13028100002E0800

        No output feature configured

    Per-destination load-sharing, slots: 1 3 5 7 9 11 13 15


R5#show mpls forwarding-table 19.19.19.19 detail

Local      Outgoing   Prefix           Bytes Label   Outgoing   Next Hop

Label      Label      or Tunnel Id     Switched      interface

None       No Label   19.19.19.19/32   0             Gi1.519    20.5.19.19

        MAC/Encaps=18/18, MRU=1504, Label Stack{}

        0050569E59FE0050569E09628100020 70800
```

```
        No output feature configured
```

The reverse is also true when XR1 initiates its tunnel. In the below output, we see the `debug ip rsvp signalling` on R5, which is in the transit path of the tunnel from XR1 to R2.

```
R5#debug ip rsvp signalling


RP/0/0/CPU0:XR1#conf t

Wed Apr 4 17:28:35.824 UTC

RP/0/0/CPU0:XR1(config)#interface tunnel-te0

RP/0/0/CPU0:XR1(config-if)# ipv4 unnumbered Loopback0

RP/0/0/CPU0:XR1(config-if)# autoroute announce

RP/0/0/CPU0:XR1(config-if)# destination 2.2.2.2

RP/0/0/CPU0:XR1(config-if)# path-option 1 dynamic

RP/0/0/CPU0:XR1(config-if)#commit




R5#

RSVP: 19.19.19.19_2->2.2.2.2_0[Src] {7}:  Received Path message from 20.5.19.19 (on GigabitEthernet1.519)

RSVP: new path message passed parsing, continue...

 RSVP: 19.19.19.19_2->2.2.2.2_0[Src] {7}: [rsvp_examine_and_mark_md_events] Incoming PSB MD = Ignore

 RSVP: 19.19.19.19_2->2.2.2.2_0[Src] {7}: [rsvp_examine_and_mark_tspec_events] Incoming PSB TSpec = Ignore

RSVP: Triggering outgoing Path due to incoming Path change or new Path

RSVP: Triggering outgoing Path refresh

RSVP: 19.19.19.19_2->2.2.2.2_0[Src] {7}: Path refresh, Event: rmsg not enabled or ack rcvd, State: trigger to normal

RSVP: 19.19.19.19_2->2.2.2.2_0[Src] {7}: Path refresh (msec), config: 30000 curr: 30000 xmit: 30000

RSVP: Triggering outgoing Path due to incoming Path change or new Path

RSVP: Triggering outgoing Path refresh

RSVP: 19.19.19.19_2->2.2.2.2_0[Src] {7}: Path refresh, Event: rmsg not enabled or ack rcvd, State: trigger to normal

RSVP: 19.19.19.19_2->2.2.2.2_0[Src] {7}: Path refresh (msec), config: 30000 curr: 30000 xmit: 30000

RSVP: 19.19.19.19_2->2.2.2.2_0[Src] {7}:  Sending Path message to 20.4.5.4

RSVP: 19.19.19.19_2->2.2.2.2_0[Src] {7}:  building hop object with src addr: 20.4.5.5

RSVP: session 2.2.2.2_0[19.19.19.19] (7):  Received Resv message from 20.4.5.4 (on GigabitEthernet1.45)

RSVP: 19.19.19.19_2->2.2.2.2_0[Src] {7}:  Successfully parsed Resv message from 20.4.5.4 (on GigabitEthernet1.45)

RSVP: 19.19.19.19_2->2.2.2.2_0[Src] {7}: reservation not found--new one

RSVP-RESV:  Admitting new reservation: 7FA4D1F3F6 F0

RSVP-RESV:  reservation (RSB 0x7FA4D1F3F6F0) was installed on GigabitEthernet1.45

RSVP: 19.19.19.19_2->2.2.2.2_0[Src] {7}: start requesting 0 kbps SE reservation on GigabitEthernet1.519, neighbor 20.5.19.19

RSVP: 19.19.19.19_2->2.2.2.2_0[Src] {7}: Refresh RESV, req=7FA4D1E82B58 [cleanup timer is not awake]

RSVP: 19.19.19.19_2->2.2.2.2_0[Src] {7}: Resv refresh, Event: rmsg not enabled or ack rcvd, State: trigger to normal

RSVP: 19.19.19.19_2->2.2.2.2_0[Src] {7}: Resv refresh (msec), config: 30000 curr: 30000 xmit: 30000

RSVP: 19.19.19.19_2->2.2.2.2_0[Src] {7}:  Sending Resv message to 20.5.19.19 from 20.5.19.5

RSVP: 19.19.19.19_2->2.2.2.2_0[Src] {7}:  building hop object with src addr: 20.5.19.5
```

The above output shows that R5 receives the RSVP PATH message from XR1, which is XR1 initiating the signaling for the tunnel. R5 then forwards the PATH message along the ERO (XR1, R5, R4, R2). The reservation then occurs in the reverse path, with R2 replying to R4 with the RSVP RESV message, R4 to R5, and then R5 sending RESV to XR1.

The final result of having both tunnels established is that the customer's MPLS L3VPN traffic is tunneled over the MPLS TE tunnels in the Service Provider core.

```
R1#traceroute 20.20.20.20 source 1.1.1.1


Type escape sequence to abort.
Tracing the route to 20.20.20.20
VRF info: (vrf in name/id, vrf out name/id)
  1 10.1.2.2 4 msec 1 msec 1 msec
   2 20.2.4.4 [MPLS: Labels 16/16011 Exp 0] 7 msec 6 msec 7 msec
   3 20.4.5.5 [MPLS: Labels 16/16011 Exp 0] 25 msec 31 msec 31 msec
  4 20.5.19.19 21 msec 14 msec 15 msec
  5 10.19.20.20 19 msec *  10 msec
```

```
RP/0/0/CPU0:XR2#traceroute 1.1.1.1 source 20.20.20.20
Wed May 27 23:30:07.405 UTC


Type escape sequence to abort.
Tracing the route to 1.1.1.1


 1  10.19.20.19 0 msec  0 msec  0 msec
 2  20.5.19.5 [MPLS: Labels 19/19 Exp 0] 9 msec  9 msec  9 msec
 3  20.4.5.4 [MPLS: Labels 19/19 Exp 0] 0 msec  0 msec  9 msec
 4  10.1.2.2 [MPLS: Label 19 Exp 0] 0 msec  9 msec  0 msec
 5  10.1.2.1 9 msec  *  0 msec
```

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