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TECHNOLOGY WHITE PAPER

Testing Riverstone RS MPLS **Interoperability** with Cisco GSR and Juniper M Series Routers

Ray Qiu, Riverstone Networks

ABSTRACT

MPLS interoperability is an important concern for service providers deploying or considering the deployment of MPLS networks. This paper demonstrates the interoperability of the Riverstone RS Router's MPLS implementation with that of two important core routers: the Cisco Systems GSR and Juniper Networks M series routers. You can use the procedures in this paper to replicate the tests.

The interoperability tests here described focus on two aspects of MPLS interoperability: the creation and use of Label Switch Paths (LSPs), and use of the control plane with RSVP-TE and LDP to setup LSPs and the forwarding plane that forwards packets through LSPs.

IS-IS is used as the IGP in the tests, and IS-IS Traffic Engineering Extension interoperability is verified. Sample OSPF configurations are shown in Appendix D, which can be used to do the tests with OSPF as the IGP.

Due to limitations of the GSR and M20, the tests do not include testing of L2 tunneling LSPs (based on the Martini draft). The GSR and M20 can only act as the LSR and not the LER in a Martini setup. For this reason the tests focus on LDP and RSVP-TE.

The tests successfully demonstrate that the MPLS implementations of Riverstone Networks, Cisco Systems, and Juniper Networks are highly interoperable.

TEST ENVIRONMENT

The test environment consists of four routers in a fully meshed network topology as shown in Figure 1. All links between routers are Gigabit Ethernet.

Hardware:

2 x Riverstone RS8000 with two MPLS GE modules each
1 x Cisco GSR 12008 with one 3-port GE module
1 x Juniper M20 with 3 GE ports

Software:

Riverstone RS:	ROS 8.0.0.2
Cisco GSR 12008:	IOS 12.0(18)ST
Juniper M20:	JUNOS 4.4R2.3

The appendix lists all of the configurations used in the tests. These tests do not include performance testing, as this is outside the scope of an interoperability test.

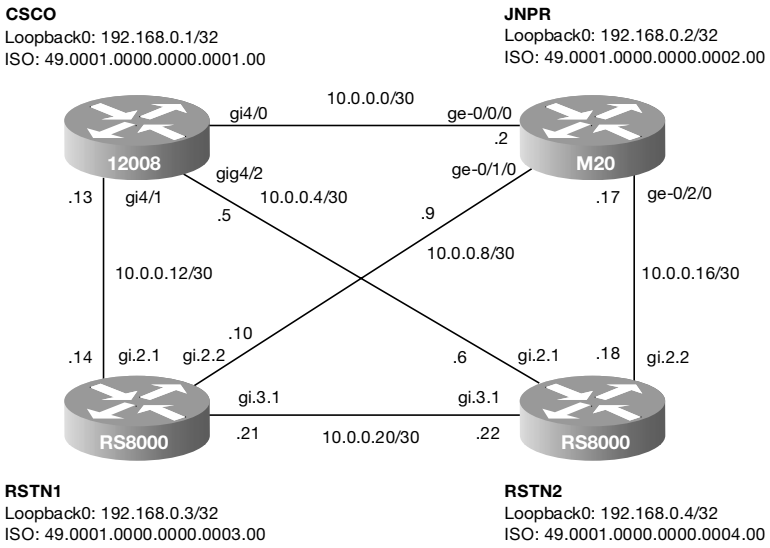

Figure 1 — MPLS Interoperability Test Topology

RSVP-TE INTEROPERABILITY TEST

This test verifies the creation of LSPs across different paths using the RSVP-TE signaling protocol, and tests RSVP-TE interoperability.

Parameters

There are three different label switching router (LSR) functions: ingress, transit, and egress. In order to demonstrate interoperability over an arbitrary path, a set of permutations of possible paths are created as shown in Table 1.

TABLE 1

Ingress	Transit	Egress
RSTN1	CSCO	RSTN2
RSTN1	JNPR	RSTN2
RSTN1	RSTN2	CSCO
RSTN1	RSTN2	JNPR
RSTN1	JNPR	CSCO
CSCO	RSTN2	JNPR
JNPR	RSTN1	CSCO
RSTN1	CSCO, JNPR	RSTN2

Results

All LSPs were created and became operational. The testing, therefore, successfully demonstrates that the MPLS RSVP-TE implementations are interoperable. Specifically, the following RSVP objects are interoperable between Riverstone Networks, Cisco Systems, and Juniper Networks routers:

✓ EXPLICIT_ROUTE
✓ LABEL_REQUEST
✓ LABEL
✓ SESSION
✓ RECORD_ROUTE

Riverstone and Juniper both support RSVP hello extension, and the RSVP hello implementations are interoperable. Cisco does not support RSVP hello extensions at this time.

All configurations and show output are listed in Appendix A.

IS-IS TRAFFIC ENGINEERING INTEROPERABILITY TEST

This test determines if the routers can interoperate to setup LSPs according to constraints. It determines whether the routers are sending correct information in the sub-TLVs in the new IS-IS extended IS reachability TLV (type 22).

Parameters

Riverstone Networks and Juniper Networks routers support creating administrative groups, while Cisco Systems routers assign the link color directly using a 32-bit affinity value. Administrative groups are created according to Table 2. The links between the routers are colored, that is, given different administrative groups as shown in Figure 2. All LSPs are created with administrative group constraints. LSP path selection is computed using CSPF.

Administrative Groups

TABLE 2
Administrative groups

	Riverstone Networks	Juniper Networks
Blue	0	0
Red	1	1
Yellow	2	2

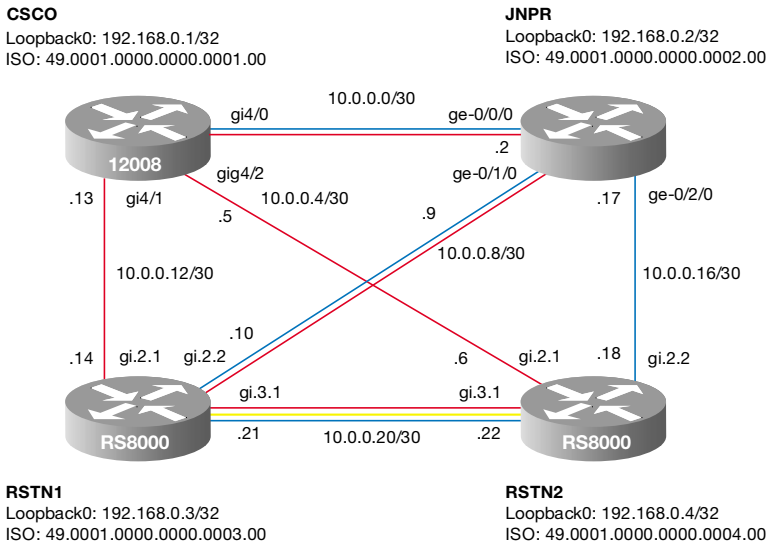

Figure 2: Topology with Link Colors

Results

All LSPs are correctly created and become operational. The testing demonstrates that the administrative group and the ISIS-TE implementations are interoperable.

The following sub-TLVs are successfully exchanged. These sub-TLVs comprise the entire set as described in the I-D "draft-ietf-isis-traffic-03.txt".

TABLE 3
IS-IS sub-TLVs exchanged

Sub-TLV number	Sub-TLV name
3	Administrative group (color)
6	IPv4 interface address
8	IPv4 neighbor address
9	Maximum link bandwidth
10	Reservable link bandwidth
11	Unreserved bandwidth
18	TE Default metric

All configurations and show output are listed in Appendix B.

Administrative Group Implementation Differences

Please note that the administrative group implementations are the same between Riverstone Networks and Juniper Networks, but are different with Cisco Systems.

In Riverstone's ROS and Juniper's JUNOS, you can place circuits in different administrative groups, that is, color circuits. LSPs without constraints can traverse circuits of any colors including uncolored circuits. LSPs constrained to include circuits of specified colors are only allowed to traverse circuits of at least one of the included colors. This selection is a logical OR. LSPs constrained to exclude circuits of a specified color are not allowed to traverse the circuits that contain the color.

In Cisco's IOS, you can also color circuits and constrain the LSPs to a set of colors. However, the default behaviors are different. LSPs with no constraints can traverse only uncolored circuits. Cisco IOS uses a logical AND, rather than a logical OR. Cisco's implementation also uses affinity bits and masks to constrain circuits and LSPs to administrative groups.

Table 4 identifies the differences of the administrative group implementations in detail.

TABLE 4
Differences in administrative groups

Riverstone/Juniper Include/exclude	Cisco Affinity bits and masks	Description
Include group 0	0x1 mask 0x1	Include circuits that contain group 0. The circuits can contain other groups.
Include group 0 Exclude group 2	0x1 mask 0x5	Include circuits that contain group 0 and that do not contain group 2. The circuits can contain other groups.
Exclude group 1	0x0 mask 0x2	Exclude circuits that contain group 1. The circuits can contain other groups.
Exclude all	0x0 mask 0xFFFFFFFF	Uncolored circuits.
Include group 0,2 Exclude group 1	No equivalent	Include circuits that contain group 0 or 2 and that do not contain group 1.
No equivalent	0x7 mask 0xFFFFFFFF	Include circuits that contain group 0, 1 and 2. The circuits can not contain other groups.

LDP INTEROPERABILITY TEST

This test determines if the routers can interoperate to setup LSPs using LDP. It also determines whether the routers can correctly use the LSPs as in BGP next-hop resolution.

Parameters

Riverstone Networks, Juniper Networks, and Cisco Systems routers support unsolicited LDP by default. That is, the MPLS labels are provided by the downstream LDP peers automatically.

In this test, the circuit between the two RS routers are disabled. All routers are assigned to AS 65500. The two RS routers run IBGP sessions between each other, but the Cisco GSR and Juniper M20 only run IS-IS as the IGP. The IS-IS metrics are set up so that RSTN1 will prefer to use CSCO to get to RSTN2, but RSTN2 will prefer to use JNPR to get back to RSTN1. RSTN1 and RSTN2 introduce some external routes into the AS which are not redistributed into IS-IS. So by verifying that RSTN1 and RSTN2 can access the external routes generated by the opposite remote peer, we know that the routers are using the LSPs to pass traffic. In this test, the BGP next-hop self option is set.

The test topology is shown below in Figure 3.

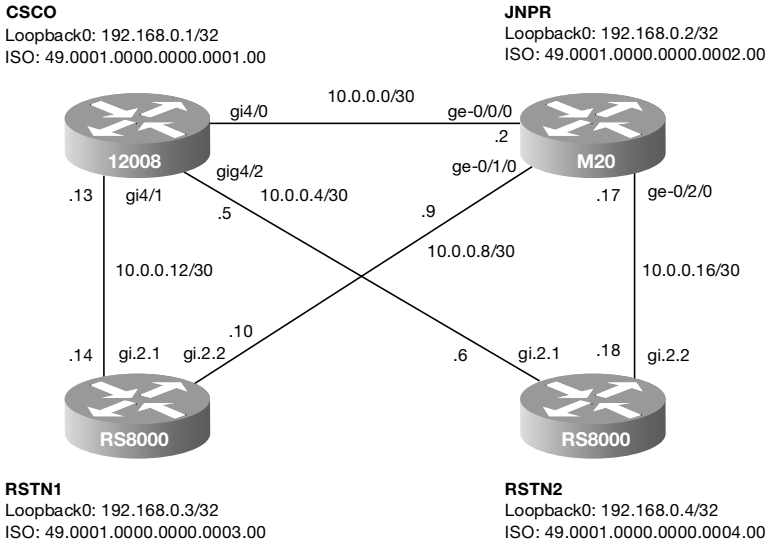

Figure 3: LDP Interoperability Test Topology

Results

The LDP prefix/label mappings are advertised correctly.
RSTN1 and RSTN2 can access the external routes through the LDP LSPs.

The testing demonstrates that the LDP implementations of Riverstone Networks, Juniper Networks, and Cisco Systems routers are interoperable.

All configurations and show output are listed in Appendix C.

APPENDIX A: RSVP-TE TEST CONFIGURATIONS AND SHOW OUTPUT

CSCO (Cisco GSR 12008) Configuration

```
version 12.0
no service pad
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
hostname CSCO
!
boot system flash slot0:gsr-p-mz.120-18.ST.bin
enable password cisco
!
!
!
!
ip subnet-zero
no ip domain-lookup
mpls traffic-eng tunnels
mpls traffic-eng signalling advertise implicit-null
mpls traffic-eng reoptimize timers frequency 0
no tag-switching ip
no tag-switching advertise-tags
clns routing
!
!
interface Loopback0
 ip address 192.168.0.1 255.255.255.255
 ip router isis
!
interface Tunnel0
 no ip address
 no ip directed-broadcast
 tunnel destination 192.168.0.2
 tunnel mode mpls traffic-eng
 tunnel mpls traffic-eng path-option 1 explicit identifier 1
 tunnel mpls traffic-eng record-route
!
interface GigabitEthernet4/0
 ip address 10.0.0.1 255.255.255.252
 no ip directed-broadcast
 ip router isis
 negotiation auto
 mpls traffic-eng tunnels
 no cdp enable
 ip rsvp bandwidth 750000 750000
!
interface GigabitEthernet4/1
 ip address 10.0.0.13 255.255.255.252
 no ip directed-broadcast
 ip router isis
 negotiation auto
 mpls traffic-eng tunnels
 no cdp enable
 ip rsvp bandwidth 750000 750000
!
interface GigabitEthernet4/2
 ip address 10.0.0.5 255.255.255.252
 no ip directed-broadcast
 ip router isis
 negotiation auto
 mpls traffic-eng tunnels
 no cdp enable
 ip rsvp bandwidth 750000 750000
!
```

```
router isis
 mpls traffic-eng router-id Loopback0
 mpls traffic-eng level-1
 net 49.0001.0000.0000.0001.00
 is-type level-1
 metric-style wide
!
ip classless
no ip pim bidir-enable
!
ip explicit-path identifier 1 enable
 next-address 10.0.0.6
 next-address 10.0.0.17
 next-address 192.168.0.2
!
!
no cdp run
!
!
line con 0
 exec-timeout 0 0
 timeout login response 0
 login
 ip netmask-format hexadecimal
line aux 0
line vty 0 3
 timeout login response 0
 password cisco
 login
line vty 4
 access-class 1 in
 timeout login response 0
 password cisco
 login
 autocommand show version
!
end
```

CSCO Show Output

```
CSCO#show mpls traffic-eng tunnels

Name: CSCO_t0                                 (Tunnel0) Destination:
192.168.0.2
  Status:
    Admin: up          Oper: up     Path: valid       Signalling: connected

    path option 1, type explicit 1 (Basis for Setup, path weight 15)

  Config Parameters:
    Bandwidth: 0         kbps (Global)  Priority: 7  7   Affinity: 0x0/0xFFFF
    Metric Type: TE (default)
    AutoRoute:  disabled  LockDown: disabled  Loadshare: 0         bw-based
    auto-bw: disabled(0/32) 0  Bandwidth Requested: 0

  InLabel  :  -
  OutLabel : GigabitEthernet4/2, 18
  RSVP Signalling Info:
       Src 192.168.0.1, Dst 192.168.0.2, Tun_Id 0, Tun_Instance 7
    RSVP Path Info:
      My Address: 10.0.0.5
      Explicit Route: 10.0.0.6 10.0.0.18 10.0.0.17 192.168.0.2
      Record   Route:
      Tspec: ave rate=0 kbits, burst=1000 bytes, peak rate=0 kbits
```

```
    RSVP Resv Info:
      Record   Route: 10.0.0.6 10.0.0.17
      Fspec: ave rate=0 kbits, burst=0 bytes, peak rate=0 kbits
  History:
    Tunnel:
      Time since created: 52 minutes, 58 seconds
      Time since path change: 3 minutes, 59 seconds
    Current LSP:
      Uptime: 3 minutes, 59 seconds
      Selection: reoptimation
    Prior LSP:
      ID: path option 1 [6]
      Removal Trigger: path verification failed

LSP Tunnel lsp1-JNPR-RSTN1-CSCO is signalled, connection is up
  InLabel  : GigabitEthernet4/1, implicit-null
  OutLabel :  -
  RSVP Signalling Info:
       Src 192.168.0.2, Dst 192.168.0.1, Tun_Id 27, Tun_Instance 1
    RSVP Path Info:
      My Address: 10.0.0.13
      Explicit Route:  NONE
      Record   Route: 10.0.0.9 10.0.0.14
      Tspec: ave rate=0 kbits, burst=0 bytes, peak rate=Inf
    RSVP Resv Info:
      Record   Route:  NONE
      Fspec: ave rate=0 kbits, burst=0 bytes, peak rate=Inf

LSP Tunnel lsp1_RSTN1-CSCO-RSTN2 is signalled, connection is up
  InLabel  : GigabitEthernet4/1, 16
  OutLabel : GigabitEthernet4/2, implicit-null
  RSVP Signalling Info:
       Src 192.168.0.3, Dst 192.168.0.4, Tun_Id 16392, Tun_Instance 205
    RSVP Path Info:
      My Address: 10.0.0.13
      Explicit Route: 10.0.0.6
      Record   Route: 10.0.0.14
      Tspec: ave rate=0 kbits, burst=0 bytes, peak rate=0 kbits
    RSVP Resv Info:
      Record   Route: 10.0.0.6
      Fspec: ave rate=0 kbits, burst=0 bytes, peak rate=0 kbits

LSP Tunnel lsp3_RSTN1-RSTN2-CSCO is signalled, connection is up
  InLabel  : GigabitEthernet4/2, implicit-null
  OutLabel :  -
  RSVP Signalling Info:
       Src 192.168.0.3, Dst 192.168.0.1, Tun_Id 16393, Tun_Instance 204
    RSVP Path Info:
      My Address: 10.0.0.5
      Explicit Route:  NONE
      Record   Route: 10.0.0.21 10.0.0.6
      Tspec: ave rate=0 kbits, burst=0 bytes, peak rate=0 kbits
    RSVP Resv Info:
      Record   Route:  NONE
      Fspec: ave rate=0 kbits, burst=0 bytes, peak rate=Inf

LSP Tunnel lsp5_RSTN1-CSCO-JNPR_RSTN2 is signalled, connection is up
  InLabel  : GigabitEthernet4/1, 17
  OutLabel : GigabitEthernet4/0, 100039
  RSVP Signalling Info:
       Src 192.168.0.3, Dst 192.168.0.4, Tun_Id 16395, Tun_Instance 203
    RSVP Path Info:
      My Address: 10.0.0.13
      Explicit Route: 10.0.0.2 10.0.0.18
      Record   Route: 10.0.0.14
      Tspec: ave rate=0 kbits, burst=0 bytes, peak rate=0 kbits
```

```
    RSVP Resv Info:
      Record   Route: 10.0.0.2 10.0.0.18
      Fspec: ave rate=0 kbits, burst=0 bytes, peak rate=0 kbits

LSP Tunnel lsp6_RSTN1-JNPR-CSCO is signalled, connection is up
  InLabel  : GigabitEthernet4/0, implicit-null
  OutLabel :  -
  RSVP Signalling Info:
       Src 192.168.0.3, Dst 192.168.0.1, Tun_Id 16396, Tun_Instance 43
    RSVP Path Info:
      My Address: 10.0.0.1
      Explicit Route:  NONE
      Record   Route: 10.0.0.2 10.0.0.10
      Tspec: ave rate=0 kbits, burst=0 bytes, peak rate=0 kbits
    RSVP Resv Info:
      Record   Route:  NONE
      Fspec: ave rate=0 kbits, burst=0 bytes, peak rate=Inf
```

JNPR (Juniper M20) Configuration

```
version 4.4R2.3;
system {
    host-name JNPR;
    syslog {
        user * {
            any emergency;
        }
        file messages {
            any notice;
            authorization info;
        }
    }
}
interfaces {
    ge-0/0/0 {
        unit 0 {
            family inet {
                address 10.0.0.2/30;
            }
            family iso;
            family mpls;
        }
    }
    ge-0/1/0 {
        unit 0 {
            family inet {
                address 10.0.0.9/30;
            }
            family iso;
            family mpls;
        }
    }
    ge-0/2/0 {
        unit 0 {
            family inet {
                address 10.0.0.17/30;
            }
            family iso;
            family mpls;
        }
    }
```

```
    lo0 {
        unit 0 {
            family inet {
                address 127.0.0.1/32;
                address 192.168.0.2/32;
            }
            family iso {
                address 49.0001.0000.0000.0002.00;
            }
        }
    }
}
routing-options {
    router-id 192.168.0.2;
}
protocols {
    rsvp {
        interface ge-0/0/0.0;
        interface ge-0/1/0.0;
        interface ge-0/2/0.0;
    }
    mpls {
        label-switched-path lsp1-JNPR-RSTN1-CSCO {
            to 192.168.0.1;
            primary JNPR-RSTN1-CSCO {
                no-cspf;
            }
        }
        path JNPR-RSTN1-CSCO {
            10.0.0.10;
            10.0.0.13;
        }
        interface ge-0/0/0.0;
        interface ge-0/1/0.0;
        interface ge-0/2/0.0;
    }
    isis {
        level 2 disable;
        level 1 wide-metrics-only;
        interface ge-0/0/0.0;
        interface ge-0/1/0.0;
        interface ge-0/2/0.0;
        interface lo0.0;
    }
}
```

JNPR Show Output

```
root@JNPR# run show mpls lsp detail
Ingress LSP: 1 sessions

192.168.0.1
  From: 192.168.0.2, State: Up, ActiveRoute: 0, LSPname: lsp1-JNPR-RSTN1-CSCO
  ActivePath: JNPR-RSTN1-CSCO (primary)
  LoadBalance: Random
 *Primary    JNPR-RSTN1-CSCO  State: Up
Total 1 displayed, Up 1, Down 0

Egress LSP: 3 sessions
```

```
192.168.0.2
  From: 192.168.0.1, LSPstate: Up, ActiveRoute: 0, LSPname: CSCO_t0
  Resv style: 1 SE, Label in: 3, Label out: -
  Time left:  135,  Since: Tue Aug 28 07:04:40 2001
  Tspec: rate 0bps size 8kbps peak 0bps m 0 M 0
  Port number: sender 9 receiver 0 protocol 0
  PATH rcvfrom: 10.0.0.18  (ge-0/2/0.0) 38 pkts
  PATH sentto: localclient
  RESV rcvfrom: localclient

192.168.0.2
  From: 192.168.0.3, LSPstate: Up, ActiveRoute: 0, LSPname: lsp4_RSTN1-RSTN2-
JNPR
  Resv style: 1 FF, Label in: 3, Label out: -
  Time left:   33,  Since: Tue Aug 28 07:20:29 2001
  Tspec: rate 0bps size 0bps peak 0bps m 20 M 1436
  Port number: sender 215 receiver 16394 protocol 0
  PATH rcvfrom: 10.0.0.18  (ge-0/2/0.0) 3 pkts
  PATH sentto: localclient
  RESV rcvfrom: localclient
  Record route: 10.0.0.18  10.0.0.21  <self>

192.168.0.2
  From: 192.168.0.3, LSPstate: Up, ActiveRoute: 0, LSPname: lsp4_RSTN1-RSTN2-
JNPR
  Resv style: 1 FF, Label in: 3, Label out: -
  Time left:  138,  Since: Tue Aug 28 07:22:14 2001
  Tspec: rate 0bps size 0bps peak 0bps m 20 M 1436
  Port number: sender 216 receiver 16394 protocol 0
  PATH rcvfrom: 10.0.0.18  (ge-0/2/0.0) 3 pkts
  PATH sentto: localclient
  RESV rcvfrom: localclient
  Record route: 10.0.0.18  10.0.0.21  <self>
Total 3 displayed, Up 3, Down 0

Transit LSP: 3 sessions

192.168.0.1
  From: 192.168.0.3, LSPstate: Up, ActiveRoute: 0, LSPname: lsp6_RSTN1-JNPR-
CSCO
  Resv style: 1 FF, Label in: 100034, Label out: 3
  Time left:  132,  Since: Tue Aug 28 02:41:59 2001
  Tspec: rate 0bps size 0bps peak 0bps m 20 M 1436
  Port number: sender 43 receiver 16396 protocol 0
  PATH rcvfrom: 10.0.0.10  (ge-0/1/0.0) 563 pkts
  PATH sentto: 10.0.0.1 (ge-0/0/0.0) 389 pkts
  RESV rcvfrom: 10.0.0.1  (ge-0/0/0.0) 798 pkts
  Explct route: 10.0.0.1
  Record route: 10.0.0.10  <self>  10.0.0.1

192.168.0.4
  From: 192.168.0.3, LSPstate: Up, ActiveRoute: 0, LSPname: lsp2_RSTN1-JNPR-
RSTN2
  Resv style: 1 FF, Label in: 100038, Label out: 3
  Time left:  153,  Since: Tue Aug 28 02:43:50 2001
  Tspec: rate 0bps size 0bps peak 0bps m 20 M 1436
  Port number: sender 51 receiver 16391 protocol 0
  PATH rcvfrom: 10.0.0.10  (ge-0/1/0.0) 560 pkts
  PATH sentto: 10.0.0.18 (ge-0/2/0.0) 386 pkts
  RESV rcvfrom: 10.0.0.18  (ge-0/2/0.0) 560 pkts
  Explct route: 10.0.0.18
  Record route: 10.0.0.10  <self>  10.0.0.18
```

```
192.168.0.4
  From: 192.168.0.3, LSPstate: Up, ActiveRoute: 0, LSPname: lsp5_RSTN1-CSCO-
JNPR_RSTN2
  Resv style: 1 FF, Label in: 100039, Label out: 3
  Time left:  154,  Since: Tue Aug 28 07:03:22 2001
  Tspec: rate 0bps size 0bps peak 0bps m 20 M 1436
  Port number: sender 203 receiver 16395 protocol 0
  PATH rcvfrom: 10.0.0.1  (ge-0/0/0.0) 40 pkts
  PATH sentto: 10.0.0.18 (ge-0/2/0.0) 29 pkts
  RESV rcvfrom: 10.0.0.18  (ge-0/2/0.0) 41 pkts
  Explct route: 10.0.0.18
  Record route: 10.0.0.14  10.0.0.1  <self>  10.0.0.18
Total 3 displayed, Up 3, Down 0
```

RSTN1 (Riverstone RS8000) Configuration

```
version 8.0
interface create ip to_CSCO address-netmask 10.0.0.14/30 port gi.2.1
interface create ip to_JNPR address-netmask 10.0.0.10/30 port gi.2.2
interface create ip to_RSTN2 address-netmask 10.0.0.21/30 port gi.3.1
interface add ip lo0 address-netmask 192.168.0.3/32
ip-router global set router-id 192.168.0.3
isis add area 49.0001
isis add interface to_CSCO
isis add interface lo0
isis add interface to_JNPR
isis add interface to_RSTN2
isis set level 1
isis set traffic-engineering enable
isis set wide-metrics-only
isis set system-id 0000.0000.0003
isis start
mpls add interface to_JNPR
mpls add interface to_CSCO
mpls add interface to_RSTN2
mpls create path RSTN1-CSCO-RSTN2 num-hops 3
mpls create path RSTN1-JNPR-RSTN2 num-hops 3
mpls create path RSTN1-RSTN2-CSCO num-hops 3
mpls create path RSTN1-RSTN2-JNPR num-hops 3
mpls create path RSTN1-CSCO-JNPR_RSTN2 num-hops 4
mpls create path RSTN1-JNPR-CSCO num-hops 3
mpls set path RSTN1-CSCO-RSTN2 hop 1 ip-addr 10.0.0.14 type strict
mpls set path RSTN1-CSCO-RSTN2 hop 2 ip-addr 10.0.0.13 type strict
mpls set path RSTN1-CSCO-RSTN2 hop 3 ip-addr 10.0.0.6 type strict
mpls set path RSTN1-JNPR-RSTN2 hop 1 ip-addr 10.0.0.10 type strict
mpls set path RSTN1-JNPR-RSTN2 hop 2 ip-addr 10.0.0.9 type strict
mpls set path RSTN1-JNPR-RSTN2 hop 3 ip-addr 10.0.0.18 type strict
mpls set path RSTN1-RSTN2-CSCO hop 1 ip-addr 10.0.0.21 type strict
mpls set path RSTN1-RSTN2-CSCO hop 2 ip-addr 10.0.0.22 type strict
mpls set path RSTN1-RSTN2-CSCO hop 3 ip-addr 10.0.0.5 type strict
mpls set path RSTN1-RSTN2-JNPR hop 1 ip-addr 10.0.0.21 type strict
mpls set path RSTN1-RSTN2-JNPR hop 2 ip-addr 10.0.0.22 type strict
mpls set path RSTN1-RSTN2-JNPR hop 3 ip-addr 10.0.0.17 type strict
mpls set path RSTN1-CSCO-JNPR_RSTN2 hop 1 ip-addr 10.0.0.14 type strict
mpls set path RSTN1-CSCO-JNPR_RSTN2 hop 2 ip-addr 10.0.0.13 type strict
mpls set path RSTN1-CSCO-JNPR_RSTN2 hop 3 ip-addr 10.0.0.2 type strict
mpls set path RSTN1-CSCO-JNPR_RSTN2 hop 4 ip-addr 10.0.0.18 type strict
mpls set path RSTN1-JNPR-CSCO hop 1 ip-addr 10.0.0.10 type strict
mpls set path RSTN1-JNPR-CSCO hop 2 ip-addr 10.0.0.9 type strict
mpls set path RSTN1-JNPR-CSCO hop 3 ip-addr 10.0.0.1 type strict
mpls create label-switched-path lsp1 to 192.168.0.4
mpls create label-switched-path lsp2 to 192.168.0.4
```

```
mpls create label-switched-path lsp3 to 192.168.0.1
mpls create label-switched-path lsp4 to 192.168.0.2
mpls create label-switched-path lsp5 to 192.168.0.4
mpls create label-switched-path lsp6 to 192.168.0.1
mpls set label-switched-path lsp2 primary RSTN1-JNPR-RSTN2 no-cspf
mpls set label-switched-path lsp1 primary RSTN1-CSCO-RSTN2 no-cspf
mpls set label-switched-path lsp3 primary RSTN1-RSTN2-CSCO no-cspf
mpls set label-switched-path lsp4 primary RSTN1-RSTN2-JNPR no-cspf
mpls set label-switched-path lsp5 primary RSTN1-CSCO-JNPR_RSTN2 no-cspf
mpls set label-switched-path lsp6 primary RSTN1-JNPR-CSCO no-cspf
mpls start
rsvp add interface to_JNPR
rsvp add interface to_CSCO
rsvp add interface to_RSTN2
rsvp set interface to_JNPR hello-enable
rsvp set interface to_RSTN2 hello-enable
rsvp start
system set name RSTN1
system set idle-timeout serial 0
```

RSTN1 Show Output

```
RSTN1# mpls show label-switched-paths all verbose

Ingress LSP:

 Label-Switched-Path: "lsp6"
       state: Up              lsp-id: 0x18
       to: 192.168.0.1          from: 192.168.0.3
       proto: <rsvp>          protection: primary
       setup-pri: 7           hold-pri: 0
       attributes: <PRI>

       Protection-Path "RSTN1-JNPR-CSCO": <Active, Primary>
           state: Up          lsp-id: 0x4006
           attributes: <>
           inherited-attributes: <>
       Path-Signalling-Parameters:
           attributes: <STANDBY NO-CSPF>
           inherited-attributes: <>
           retry-limit: 5000 retry-int: 15 sec.
           retry-count: 5000 next_retry_int: 0.000000 sec.
           bps: 0                preference: 7
           hop-limit: 255       opt-int: 600 sec.
           mtu: 1500
           ott-index: 1         ref-count: 1
            explicit-path: "RSTN1-JNPR-CSCO"    num-hops: 3
              10.0.0.10        - strict
              10.0.0.9         - strict
              10.0.0.1         - strict
           record-route:
              10.0.0.9
              10.0.0.1


    Label-Switched-Path: "lsp5"
       state: Up              lsp-id: 0x17
       to: 192.168.0.4          from: 192.168.0.3
       proto: <rsvp>          protection: primary
       setup-pri: 7           hold-pri: 0
       attributes: <PRI>
```

```
   Protection-Path "RSTN1-CSCO-JNPR_RSTN2": <Active, Primary>
       state: Up          lsp-id: 0x4005
       attributes: <>
       inherited-attributes: <>
   Path-Signalling-Parameters:
       attributes: <STANDBY NO-CSPF>
       inherited-attributes: <>
        retry-limit: 5000   retry-int: 15 sec.
       retry-count: 5000 next_retry_int: 0.000000 sec.
       bps: 0               preference: 7
       hop-limit: 255      opt-int: 600 sec.
       mtu: 1500
       ott-index: 2         ref-count: 1
       explicit-path: "RSTN1-CSCO-JNPR_RSTN2"   num-hops: 4
          10.0.0.14        - strict
          10.0.0.13        - strict
          10.0.0.2         - strict
          10.0.0.18        - strict
       record-route:
          10.0.0.13
          10.0.0.2
          10.0.0.18


Label-Switched-Path: "lsp4"
   state: Up              lsp-id: 0x16
   to: 192.168.0.2          from: 192.168.0.3
   proto: <rsvp>          protection: primary
   setup-pri: 7           hold-pri: 0
   attributes: <PRI>

   Protection-Path "RSTN1-RSTN2-JNPR": <Active, Primary>
       state: Up          lsp-id: 0x4004
       attributes: <>
       inherited-attributes: <>
   Path-Signalling-Parameters:
       attributes: <STANDBY NO-CSPF>
       inherited-attributes: <>
       retry-limit: 5000 retry-int: 15 sec.
       retry-count: 5000 next_retry_int: 0.000000 sec.
       bps: 0               preference: 7
       hop-limit: 255      opt-int: 600 sec.
       mtu: 1500
       ott-index: 6         ref-count: 1
       explicit-path: "RSTN1-RSTN2-JNPR"        num-hops: 3
          10.0.0.21        - strict
          10.0.0.22        - strict
          10.0.0.17        - strict
       record-route:
          10.0.0.22
          10.0.0.17


Label-Switched-Path: "lsp3"
   state: Up              lsp-id: 0x15
   to: 192.168.0.1          from: 192.168.0.3
   proto: <rsvp>          protection: primary
   setup-pri: 7           hold-pri: 0
   attributes: <PRI>
```

```
   Protection-Path "RSTN1-RSTN2-CSCO": <Active, Primary>
       state: Up          lsp-id: 0x4003
       attributes: <>
       inherited-attributes: <>
   Path-Signalling-Parameters:
       attributes: <STANDBY NO-CSPF>
       inherited-attributes: <>
       retry-limit: 5000 retry-int: 15 sec.
       retry-count: 5000 next_retry_int: 0.000000 sec.
       bps: 0                preference: 7
       hop-limit: 255       opt-int: 600 sec.
       mtu: 1500
       ott-index: 5         ref-count: 1
       explicit-path: "RSTN1-RSTN2-CSCO"       num-hops: 3
          10.0.0.21        - strict
          10.0.0.22        - strict
              10.0.0.5         - strict
       record-route:
          10.0.0.22
          10.0.0.5


Label-Switched-Path: "lsp2"
   state: Up              lsp-id: 0x14
   to: 192.168.0.4          from: 192.168.0.3
   proto: <rsvp>          protection: primary
   setup-pri: 7           hold-pri: 0
   attributes: <PRI>

   Protection-Path "RSTN1-JNPR-RSTN2": <Active, Primary>
       state: Up          lsp-id: 0x4001
       attributes: <>
       inherited-attributes: <>
   Path-Signalling-Parameters:
       attributes: <STANDBY NO-CSPF>
       inherited-attributes: <>
       retry-limit: 5000 retry-int: 15 sec.
       retry-count: 5000 next_retry_int: 0.000000 sec.
       bps: 0                preference: 7
        hop-limit: 255       opt-int: 600 sec.
       mtu: 1500
       ott-index: 4         ref-count: 1
       explicit-path: "RSTN1-JNPR-RSTN2"       num-hops: 3
          10.0.0.10        - strict
          10.0.0.9         - strict
          10.0.0.18        - strict
       record-route:
          10.0.0.9
          10.0.0.18


Label-Switched-Path: "lsp1"
   state: Up              lsp-id: 0x13
   to: 192.168.0.4          from: 192.168.0.3
   proto: <rsvp>          protection: primary
   setup-pri: 7           hold-pri: 0
   attributes: <PRI>

   Protection-Path "RSTN1-CSCO-RSTN2": <Active, Primary>
       state: Up          lsp-id: 0x4002
       attributes: <>
       inherited-attributes: <>
```

```
        Path-Signalling-Parameters:
           attributes: <STANDBY NO-CSPF>
           inherited-attributes: <>
           retry-limit: 5000 retry-int: 15 sec.
           retry-count: 5000 next_retry_int: 0.000000 sec.
           bps: 0               preference: 7
           hop-limit: 255      opt-int: 600 sec.
           mtu: 1500
           ott-index: 3        ref-count: 1
           explicit-path: "RSTN1-CSCO-RSTN2"       num-hops: 3
              10.0.0.14       - strict
              10.0.0.13       - strict
              10.0.0.6        - strict
           record-route:
              10.0.0.13
              10.0.0.6

Transit LSP:

    Label-Switched-Path: "lsp1-JNPR-RSTN1-CSCO"
        state:                   lsp-id: 27
        to: 192.168.0.1         from: 192.168.0.2
        Path-Signalling-Parameters:
            setup-pri: 7                holding-pri: 0
            label in: 17                label out: 3
            path recvfrom: 10.0.0.9     path sendto: 10.0.0.13
            explicit-path: 10.0.0.13
            record-route:
                10.0.0.13

Egress LSP:
```

RSTN2 (Riverstone RS8000) Configuration

```
version 8.0
interface create ip to_CSCO address-netmask 10.0.0.6/30 port gi.2.1
interface create ip to_JNPR address-netmask 10.0.0.18/30 port gi.2.2
interface create ip to_RSTN1 address-netmask 10.0.0.22/30 port gi.3.1
interface add ip lo0 address-netmask 192.168.0.4/32
ip-router global set router-id 192.168.0.4
isis add area 49.0001
isis add interface to_CSCO
isis add interface lo0
isis add interface to_JNPR
isis add interface to_RSTN1
isis set level 1
isis set traffic-engineering enable
isis set wide-metrics-only
isis set system-id 0000.0000.0004
isis start
mpls add interface to_JNPR
mpls add interface to_CSCO
mpls add interface to_RSTN1
mpls start
rsvp add interface to_JNPR
rsvp add interface to_CSCO
rsvp add interface to_RSTN1
rsvp set interface to_JNPR hello-enable
rsvp set interface to_RSTN1 hello-enable
rsvp start
system set name RSTN2
system set idle-timeout serial 0
```

RSTN2 Show Output

```
RSTN2# mpls show label-switched-paths all verbose

Transit LSP:

    Label-Switched-Path: "lsp3_RSTN1-RSTN2-CSCO"
        state:                   lsp-id: 16393
        to: 192.168.0.1         from: 192.168.0.3
        Path-Signalling-Parameters:
            setup-pri: 7                holding-pri: 0
            label in: 17                label out: 3
            path recvfrom: 10.0.0.21    path sendto: 10.0.0.5
            explicit-path: 10.0.0.5
            record-route:
                10.0.0.5

    Label-Switched-Path: "lsp4_RSTN1-RSTN2-JNPR"
        state:                   lsp-id: 16394
        to: 192.168.0.2         from: 192.168.0.3
        Path-Signalling-Parameters:
            setup-pri: 7                holding-pri: 0
            label in: 18                label out: 3
            path recvfrom: 10.0.0.21    path sendto: 10.0.0.17
            explicit-path: 10.0.0.17
            record-route:
                10.0.0.17

    Label-Switched-Path: "CSCO_t0"
state:                   lsp-id: 0
to: 192.168.0.2         from: 192.168.0.1
Path-Signalling-Parameters:
    setup-pri: 7                holding-pri: 7
    label in: 17                label out: 3
    path recvfrom: 10.0.0.5     path sendto: 10.0.0.17
    explicit-path: 10.0.0.17=>192.168.0.2
    record-route:

Egress LSP:

    Label-Switched-Path: "lsp1_RSTN1-CSCO-RSTN2"
        state:                   lsp-id: 16392
        to: 192.168.0.4         from: 192.168.0.3
        Path-Signalling-Parameters:
            setup-pri: 7                holding-pri: 0
            label in: 3                 label out:
            path recvfrom: 10.0.0.5     path sendto: 192.168.0.4
            explicit-path:
            record-route:

    Label-Switched-Path: "lsp5_RSTN1-CSCO-JNPR_RSTN2"
        state:                   lsp-id: 16395
        to: 192.168.0.4         from: 192.168.0.3
        Path-Signalling-Parameters:
            setup-pri: 7                holding-pri: 0
            label in: 3                 label out:
            path recvfrom: 10.0.0.17    path sendto: 192.168.0.4
            explicit-path:
            record-route:

    Label-Switched-Path: "lsp2_RSTN1-JNPR-RSTN2"
        state:                   lsp-id: 16391
        to: 192.168.0.4         from: 192.168.0.3
        Path-Signalling-Parameters:
            setup-pri: 7                holding-pri: 0
            label in: 3                 label out:
            path recvfrom: 10.0.0.17    path sendto: 192.168.0.4
            explicit-path:
            record-route:
```

APPENDIX B: IS-IS TE TEST CONFIGURATIONS AND SHOW OUTPUT

CSCO Configuration

```
version 12.0
no service pad
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
hostname CSCO
!
boot system flash slot0:gsr-p-mz.120-18.ST.bin
enable password cisco
!
!
!
!
ip subnet-zero
no ip domain-lookup
mpls traffic-eng tunnels
mpls traffic-eng signalling advertise implicit-null
mpls traffic-eng reoptimize timers frequency 0
no tag-switching ip
no tag-switching advertise-tags
clns routing
!
!
interface Loopback0
 ip address 192.168.0.1 255.255.255.255
 ip directed-broadcast
 ip router isis
!
interface Tunnel0
 no ip address
 no ip directed-broadcast
 tunnel destination 192.168.0.3
 tunnel mode mpls traffic-eng
 tunnel mpls traffic-eng affinity 0x1 mask 0x1
 tunnel mpls traffic-eng path-option 1 dynamic
!
interface GigabitEthernet4/0
 ip address 10.0.0.1 255.255.255.252
 no ip directed-broadcast
 ip router isis
 negotiation auto
 mpls traffic-eng tunnels
 mpls traffic-eng attribute-flags 0x3
 no cdp enable
 ip rsvp bandwidth 750000 750000
!
interface GigabitEthernet4/1
 ip address 10.0.0.13 255.255.255.252
 no ip directed-broadcast
 ip router isis
 negotiation auto
 mpls traffic-eng tunnels
 mpls traffic-eng attribute-flags 0x2
 no cdp enable
 ip rsvp bandwidth 750000 750000
!
```

```
interface GigabitEthernet4/2
 ip address 10.0.0.5 255.255.255.252
 no ip directed-broadcast
 ip router isis
 negotiation auto
 mpls traffic-eng tunnels
 mpls traffic-eng attribute-flags 0x2
 no cdp enable
 ip rsvp bandwidth 750000 750000
!
router isis
 mpls traffic-eng router-id Loopback0
 mpls traffic-eng level-1
 net 49.0001.0000.0000.0001.00
 is-type level-1
 metric-style wide
!
ip classless
no ip pim bidir-enable
!
!
no cdp run
!
!
line con 0
 exec-timeout 0 0
 timeout login response 0
 login
 ip netmask-format hexadecimal
line aux 0
line vty 0 3
 timeout login response 0
 password cisco
 login
line vty 4
 access-class 1 in
 timeout login response 0
 password cisco
 login
 autocommand show version
!
end
```

CSCO Show Output

```
CSCO#show mpls tr tunnels

Name: CSCO_t0                                 (Tunnel0) Destination:
192.168.0.3
  Status:
    Admin: up          Oper: up     Path: valid        Signalling: connected

    path option 1, type dynamic (Basis for Setup, path weight 20)

  Config Parameters:
    Bandwidth: 0         kbps (Global)  Priority: 7  7   Affinity: 0x1/0x1
    Metric Type: TE (default)
    AutoRoute:  disabled  LockDown: disabled  Loadshare: 0         bw-based
    auto-bw: disabled(0/159) 0  Bandwidth Requested: 0
```

```
  InLabel  :  -
  OutLabel : GigabitEthernet4/0, 100043
  RSVP Signalling Info:
       Src 192.168.0.1, Dst 192.168.0.3, Tun_Id 0, Tun_Instance 9
    RSVP Path Info:
      My Address: 10.0.0.1
      Explicit Route: 10.0.0.2 10.0.0.9 10.0.0.10 192.168.0.3
      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=0 bytes, peak rate=0 kbits
  History:
    Tunnel:
      Time since created: 1 hours, 6 minutes
      Time since path change: 11 minutes, 3 seconds
    Current LSP:
      Uptime: 11 minutes, 3 seconds
    Prior LSP:
      ID: path option 1 [3]
      Removal Trigger: path verification failed

LSP Tunnel JNPR-lsp1 is signalled, connection is up
  InLabel  : GigabitEthernet4/0, 17
  OutLabel : GigabitEthernet4/2, implicit-null
  RSVP Signalling Info:
       Src 192.168.0.2, Dst 192.168.0.4, Tun_Id 31, Tun_Instance 1
    RSVP Path Info:
      My Address: 10.0.0.1
      Explicit Route: 10.0.0.6
      Record   Route: 10.0.0.2
      Tspec: ave rate=0 kbits, burst=0 bytes, peak rate=Inf
    RSVP Resv Info:
      Record   Route: 10.0.0.6
      Fspec: ave rate=0 kbits, burst=0 bytes, peak rate=1000000 kbits

LSP Tunnel lsp2 is signalled, connection is up
  InLabel  : GigabitEthernet4/1, 16
  OutLabel : GigabitEthernet4/2, implicit-null
  RSVP Signalling Info:
       Src 192.168.0.3, Dst 192.168.0.4, Tun_Id 10, Tun_Instance 13
    RSVP Path Info:
      My Address: 10.0.0.13
      Explicit Route: 10.0.0.6
      Record   Route: 10.0.0.14
      Tspec: ave rate=0 kbits, burst=0 bytes, peak rate=0 kbits
    RSVP Resv Info:
      Record   Route: 10.0.0.6
      Fspec: ave rate=0 kbits, burst=0 bytes, peak rate=0 kbits
```

JNPR Configuration

```
root@JNPR# show
version 4.4R2.3;
system {
    host-name JNPR;
    syslog {
        user * {
            any emergency;
        }
        file messages {
            any notice;
            authorization info;
```

```
        }
    }
}
interfaces {
    ge-0/0/0 {
        unit 0 {
            family inet {
                address 10.0.0.2/30;
            }
            family iso;
            family mpls;
        }
    }
    ge-0/1/0 {
        unit 0 {
            family inet {
                address 10.0.0.9/30;
            }
            family iso;
            family mpls;
        }
    }
    ge-0/2/0 {
        unit 0 {
            family inet {
                address 10.0.0.17/30;
            }
            family iso;
            family mpls;
        }
    }
    lo0 {
        unit 0 {
            family inet {
                address 127.0.0.1/32;
                address 192.168.0.2/32;
            }
            family iso {
                address 49.0001.0000.0000.0002.00;
            }
        }
    }
}
routing-options {
    router-id 192.168.0.2;
}
protocols {
    rsvp {
        interface ge-0/0/0.0;
        interface ge-0/1/0.0;
        interface ge-0/2/0.0;
    }
    mpls {
        admin-groups {
            blue 0;
            red 1;
            yellow 2;
        }
        label-switched-path JNPR-lsp1 {
            to 192.168.0.4;
            admin-group {
                include red;
                exclude yellow;
            }
        }
```

```
        interface ge-0/0/0.0 {
            admin-group [ blue red ];
        }
        interface ge-0/1/0.0 {
            admin-group [ red blue ];
        }
        interface ge-0/2/0.0 {
            admin-group blue;
        }
    }
    isis {
        level 2 disable;
        level 1 wide-metrics-only;
        interface ge-0/0/0.0;
        interface ge-0/1/0.0;
        interface ge-0/2/0.0;
        interface lo0.0;
    }
}
```

JNPR Show Output

```
root@JNPR# run show mpls lsp detail
Ingress LSP: 1 sessions

192.168.0.4
  From: 192.168.0.2, State: Up, ActiveRoute: 0, LSPname: JNPR-lsp1
  ActivePath:  (primary)
  LoadBalance: Random
  Include: red  Exclude: yellow
 *Primary                        State: Up
    Computed ERO (S [L] denotes strict [loose] hops): (CSPF metric: 20)
                10.0.0.1 S          10.0.0.6 S
Total 1 displayed, Up 1, Down 0

Egress LSP: 1 sessions

192.168.0.2
  From: 192.168.0.3, LSPstate: Up, ActiveRoute: 0, LSPname: lsp5
  Resv style: 1 FF, Label in: 3, Label out: -
  Time left:  142,  Since: Tue Aug 28 08:47:01 2001
  Tspec: rate 0bps size 0bps peak 0bps m 20 M 1436
  Port number: sender 10 receiver 14 protocol 0
  PATH rcvfrom: 10.0.0.10  (ge-0/1/0.0) 15 pkts
  PATH sentto: localclient
  RESV rcvfrom: localclient
  Record route: 10.0.0.10  <self>
Total 1 displayed, Up 1, Down 0

Transit LSP: 2 sessions

192.168.0.3
  From: 192.168.0.1, LSPstate: Up, ActiveRoute: 0, LSPname: CSCO_t0
  Resv style: 1 SE, Label in: 100043, Label out: 3
  Time left:  154,  Since: Tue Aug 28 08:41:54 2001
  Tspec: rate 0bps size 8kbps peak 0bps m 0 M 0
  Port number: sender 9 receiver 0 protocol 0
  PATH rcvfrom: 10.0.0.1  (ge-0/0/0.0) 38 pkts
  PATH sentto: 10.0.0.10 (ge-0/1/0.0) 18 pkts
  RESV rcvfrom: 10.0.0.10  (ge-0/1/0.0) 25 pkts
  Explct route: 10.0.0.10  192.168.0.3
```

```
192.168.0.4
  From: 192.168.0.3, LSPstate: Up, ActiveRoute: 0, LSPname: lsp3
  Resv style: 1 FF, Label in: 100044, Label out: 3
  Time left:  142,  Since: Tue Aug 28 08:47:01 2001
  Tspec: rate 0bps size 0bps peak 0bps m 20 M 1436
  Port number: sender 12 receiver 11 protocol 0
  PATH rcvfrom: 10.0.0.10  (ge-0/1/0.0) 15 pkts
  PATH sentto: 10.0.0.18 (ge-0/2/0.0) 11 pkts
  RESV rcvfrom: 10.0.0.18  (ge-0/2/0.0) 15 pkts
  Explct route: 10.0.0.18
  Record route: 10.0.0.10  <self>  10.0.0.18
Total 2 displayed, Up 2, Down 0
```

RSTN1 Configuration

```
version 8.0
interface create ip to_CSCO address-netmask 10.0.0.14/30 port gi.2.1
interface create ip to_JNPR address-netmask 10.0.0.10/30 port gi.2.2
interface create ip to_RSTN2 address-netmask 10.0.0.21/30 port gi.3.1
interface add ip lo0 address-netmask 192.168.0.3/32
ip-router global set router-id 192.168.0.3
isis add area 49.0001
isis add interface to_CSCO
isis add interface lo0
isis add interface to_JNPR
isis add interface to_RSTN2
isis set level 1
isis set traffic-engineering enable
isis set wide-metrics-only
isis set system-id 0000.0000.0003
isis start
mpls create admin-group blue group-value 0
mpls create admin-group red group-value 1
mpls create admin-group yellow group-value 2
mpls add interface to_JNPR
mpls add interface to_CSCO
mpls add interface to_RSTN2
mpls set interface to_CSCO admin-group red
mpls set interface to_JNPR admin-group blue,red
mpls set interface to_RSTN2 admin-group blue,red,yellow
mpls create label-switched-path lsp1 to 192.168.0.4
mpls create label-switched-path lsp2 to 192.168.0.4
mpls create label-switched-path lsp3 to 192.168.0.4
mpls create label-switched-path lsp4 to 192.168.0.4
mpls create label-switched-path lsp5 to 192.168.0.2
mpls set label-switched-path lsp2 include red exclude blue,yellow
mpls set label-switched-path lsp3 include blue exclude yellow
mpls set label-switched-path lsp4 include yellow
mpls set label-switched-path lsp5 include blue,yellow
mpls start
rsvp add interface to_JNPR
rsvp add interface to_CSCO
rsvp add interface to_RSTN2
rsvp set interface to_JNPR hello-enable
rsvp set interface to_RSTN2 hello-enable
rsvp start
system set name RSTN1
system set idle-timeout serial 0
```

RSTN1 Show Output

```
RSTN1# mpls show label-switched-paths all verbose

Ingress LSP:

    Label-Switched-Path: "lsp5"
       state: Up             lsp-id: 0xe
       to: 192.168.0.2         from: 192.168.0.3
       proto: <rsvp>         protection: none
       setup-pri: 7          hold-pri: 0
       attributes: <INCLUDE>

       Path-Signalling-Parameters:
           attributes: <>
           inherited-attributes: <>
           retry-limit: 5000 retry-int: 15 sec.
           retry-count: 5000 next_retry_int: 0.000000 sec.
           bps: 0               preference: 7
           hop-limit: 255      opt-int: 600 sec.
           include:          blue yellow
           mtu: 1500
           ott-index: 2         ref-count: 1
           cspf-path:        num-hops: 2
              10.0.0.10        - strict
              10.0.0.9         - strict
            record-route:
              10.0.0.9


    Label-Switched-Path: "lsp4"
       state: Up             lsp-id: 0xc
       to: 192.168.0.4         from: 192.168.0.3
       proto: <rsvp>         protection: none
       setup-pri: 7          hold-pri: 0
       attributes: <INCLUDE>

       Path-Signalling-Parameters:
           attributes: <>
           inherited-attributes: <>
           retry-limit: 5000 retry-int: 15 sec.
           retry-count: 5000 next_retry_int: 0.000000 sec.
           bps: 0               preference: 7
           hop-limit: 255      opt-int: 600 sec.
           include:          yellow
           mtu: 1500
           ott-index: 1         ref-count: 1
           cspf-path:        num-hops: 2
              10.0.0.21        - strict
                 10.0.0.22        - strict
           record-route:
              10.0.0.22


    Label-Switched-Path: "lsp3"
       state: Up             lsp-id: 0xb
       to: 192.168.0.4         from: 192.168.0.3
       proto: <rsvp>         protection: none
       setup-pri: 7          hold-pri: 0
       attributes: <EXCLUDE INCLUDE>
```

```
   Path-Signalling-Parameters:
        attributes: <>
        inherited-attributes: <>
        retry-limit: 5000 retry-int: 15 sec.
        retry-count: 5000 next_retry_int: 0.000000 sec.
        bps: 0                preference: 7
        hop-limit: 255       opt-int: 600 sec.
        include:           blue
        exclude:           yellow
        mtu: 1500
        ott-index: 5         ref-count: 1
         cspf-path:  num-hops: 3
           10.0.0.10        - strict
           10.0.0.9         - strict
           10.0.0.18        - strict
        record-route:
           10.0.0.18
           10.0.0.9


Label-Switched-Path: "lsp2"
   state: Up              lsp-id: 0xa
   to: 192.168.0.4          from: 192.168.0.3
   proto: <rsvp>          protection: none
   setup-pri: 7           hold-pri: 0
   attributes: <EXCLUDE INCLUDE>

   Path-Signalling-Parameters:
        attributes: <>
        inherited-attributes: <>
        retry-limit: 5000 retry-int: 15 sec.
        retry-count: 5000 next_retry_int: 0.000000 sec.
        bps: 0                preference: 7
        hop-limit: 255       opt-int: 600 sec.
         include:              red
        exclude:           blue yellow
        mtu: 1500
        ott-index: 4         ref-count: 1
        cspf-path:         num-hops: 3
           10.0.0.14         - strict
           10.0.0.13         - strict
           10.0.0.6          - strict
        record-route:
           10.0.0.6
           10.0.0.13


Label-Switched-Path: "lsp1"
   state: Up              lsp-id: 0x9
   to: 192.168.0.4          from: 192.168.0.3
   proto: <rsvp>          protection: none
   setup-pri: 7           hold-pri: 0
   attributes: <>

   Path-Signalling-Parameters:
        attributes: <>
        inherited-attributes: <>
         retry-limit: 5000   retry-int: 15 sec.
        retry-count: 5000 next_retry_int: 0.000000 sec.
        bps: 0                preference: 7
        hop-limit: 255       opt-int: 600 sec.
        mtu: 1500
        ott-index: 3         ref-count: 1
        cspf-path:         num-hops: 2
           10.0.0.21         - strict
           10.0.0.22         - strict
        record-route:
           10.0.0.22
```

```
Transit LSP:

Egress LSP:

    Label-Switched-Path: "CSCO_t0"
       state:                lsp-id: 0
       to: 192.168.0.3              from: 192.168.0.1
       Path-Signalling-Parameters:
           setup-pri: 7             holding-pri: 7
           label in: 3                  label out:
            path recvfrom: 10.0.0.9     path sendto: 192.168.0.3
           explicit-path:
           record-route:
```

RSTN2 Configuration

```
version 8.0
interface create ip to_CSCO address-netmask 10.0.0.6/30 port gi.2.1
interface create ip to_JNPR address-netmask 10.0.0.18/30 port gi.2.2
interface create ip to_RSTN1 address-netmask 10.0.0.22/30 port gi.3.1
interface add ip lo0 address-netmask 192.168.0.4/32
ip-router global set router-id 192.168.0.4
isis add area 49.0001
isis add interface to_CSCO
isis add interface lo0
isis add interface to_JNPR
isis add interface to_RSTN1
isis set level 1
isis set traffic-engineering enable
isis set wide-metrics-only
isis set system-id 0000.0000.0004
isis start
mpls create admin-group blue group-value 0
mpls create admin-group red group-value 1
mpls create admin-group yellow group-value 2
mpls add interface to_JNPR
mpls add interface to_CSCO
mpls add interface to_RSTN1
mpls set interface to_CSCO admin-group red
mpls set interface to_RSTN1 admin-group blue,red,yellow
mpls set interface to_JNPR admin-group blue
mpls start
rsvp add interface to_JNPR
rsvp add interface to_CSCO
rsvp add interface to_RSTN1
rsvp set interface to_JNPR hello-enable
rsvp set interface to_RSTN1 hello-enable
rsvp start
system set name RSTN2
system set idle-timeout serial 0
```

RSTN2 Show Output

```
RSTN2# mpls show label-switched-paths all verbose

Transit LSP:

Egress LSP:

    Label-Switched-Path: "lsp4"
       state:                lsp-id: 12
       to: 192.168.0.4              from: 192.168.0.3
```

```
        Path-Signalling-Parameters:
            setup-pri: 7              holding-pri: 0
            label in: 3                   label out:
            path recvfrom: 10.0.0.21  path sendto: 192.168.0.4
            explicit-path:
            record-route:

    Label-Switched-Path: "lsp3"
        state:                lsp-id: 11
        to: 192.168.0.4               from: 192.168.0.3
        Path-Signalling-Parameters:
            setup-pri: 7              holding-pri: 0
            label in: 3                   label out:
            path recvfrom: 10.0.0.17  path sendto: 192.168.0.4
            explicit-path:
             record-route:

    Label-Switched-Path: "lsp2"
        state:                lsp-id: 10
        to: 192.168.0.4               from: 192.168.0.3
        Path-Signalling-Parameters:
            setup-pri: 7              holding-pri: 0
            label in: 3                   label out:
            path recvfrom: 10.0.0.5   path sendto: 192.168.0.4
            explicit-path:
            record-route:

    Label-Switched-Path: "lsp1"
        state:                lsp-id: 9
        to: 192.168.0.4               from: 192.168.0.3
        Path-Signalling-Parameters:
            setup-pri: 7              holding-pri: 0
            label in: 3                   label out:
            path recvfrom: 10.0.0.21  path sendto: 192.168.0.4
            explicit-path:
            record-route:

    Label-Switched-Path: "JNPR-lsp1"
         state:                   lsp-id: 31
        to: 192.168.0.4               from: 192.168.0.2
        Path-Signalling-Parameters:
            setup-pri: 7              holding-pri: 0
            label in: 3                   label out:
            path recvfrom: 10.0.0.5   path sendto: 192.168.0.4
            explicit-path:
            record-route:
```

CSCO configuration

```
version 12.0
no service pad
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
hostname CSCO
!
boot system flash slot0:gsr-p-mz.120-18.ST.bin
enable password cisco
!
!
!
!
ip subnet-zero
no ip domain-lookup
mpls label protocol ldp
no tag-switching advertise-tags
tag-switching tdp router-id Loopback0
clns routing
!
```

```
!
interface Loopback0
 ip address 192.168.0.1 255.255.255.255
 ip directed-broadcast
 ip router isis
!
interface GigabitEthernet4/0
 ip address 10.0.0.1 255.255.255.252
 no ip directed-broadcast
 ip router isis
 negotiation auto
 mpls label protocol ldp
 tag-switching ip
 no cdp enable
!
interface GigabitEthernet4/1
 ip address 10.0.0.13 255.255.255.252
 no ip directed-broadcast
 ip router isis
 negotiation auto
 mpls label protocol ldp
 tag-switching ip
 no cdp enable
!
interface GigabitEthernet4/2
 ip address 10.0.0.5 255.255.255.252
 no ip directed-broadcast
 ip router isis
 negotiation auto
 mpls label protocol ldp
 tag-switching ip
 no cdp enable
!
router isis
 mpls traffic-eng router-id Loopback0
 mpls traffic-eng level-1
 net 49.0001.0000.0000.0001.00
 is-type level-1
 metric-style wide
!
ip classless
no ip pim bidir-enable
!
!
no cdp run
!
!
line con 0
 exec-timeout 0 0
 timeout login response 0
 login
 ip netmask-format hexadecimal
line aux 0
line vty 0 3
 timeout login response 0
 password cisco
 login
line vty 4
 access-class 1 in
 timeout login response 0
 password cisco
 login
 autocommand show version
!
end
```

APPENDIX C: LDP TEST CONFIGURATIONS

CSCO Show Output

```
CSCO#show mpls ip binding
  10.0.0.0 0xFFFFFFFC
        in label:      imp-null
  10.0.0.4 0xFFFFFFFC
        in label:      imp-null
  10.0.0.8 0xFFFFFFFC
        in label:      16
  10.0.0.12 0xFFFFFFFC
        in label:      imp-null
  10.0.0.16 0xFFFFFFFC
        in label:      17
  10.51.0.0 0xFFFF0000
        in label:      imp-null
  134.141.178.0 0xFFFFFF00
        in label:      imp-null
  192.168.0.1 0xFFFFFFFF
        in label:      imp-null
        out label:     2056       lsr: 192.168.0.3:0
        out label:     100051     lsr: 192.168.0.2:0
        out label:     2052       lsr: 192.168.0.4:0
  192.168.0.2 0xFFFFFFFF
        in label:      18
        out label:     imp-null   lsr: 192.168.0.2:0    inuse
        out label:     2058       lsr: 192.168.0.3:0
         out label:     2054       lsr: 192.168.0.4:0
  192.168.0.3 0xFFFFFFFF
        in label:      19
        out label:     imp-null   lsr: 192.168.0.3:0    inuse
        out label:     100052     lsr: 192.168.0.2:0
  192.168.0.4 0xFFFFFFFF
        in label:      20
        out label:     2057       lsr: 192.168.0.3:0
        out label:     imp-null   lsr: 192.168.0.4:0    inuse
        out label:     100053     lsr: 192.168.0.2:0

CSCO#show mpls forwarding-table
Local  Outgoing     Prefix              Bytes tag  Outgoing    Next Hop
tag    tag or VC    or Tunnel Id        switched   interface
16     Untagged     10.0.0.8 0xFFFFFFFC    \
                                           0           Gi4/0       10.0.0.2
       Untagged     10.0.0.8 0xFFFFFFFC    \
                                           0           Gi4/1      10.0.0.14
17     Untagged     10.0.0.16 0xFFFFFFFC    \
                                           0           Gi4/2       10.0.0.6
18     Pop tag      192.168.0.2 0xFFFFFFFF    \
                                           0           Gi4/0       10.0.0.2
19     Pop tag      192.168.0.3 0xFFFFFFFF    \
                                           0           Gi4/1      10.0.0.14
20     Pop tag      192.168.0.4 0xFFFFFFFF    \
                                           2950        Gi4/2       10.0.0.6

CSCO#show ip ro
Codes: C - connected, S - static, I - IGRP, 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, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter
area
       * - candidate default, U - per-user static route, o - ODR

Gateway of last resort is not set
```

```
      10.0.0.0 0xFF000000 is variably subnetted, 6 subnets, 2 masks
i L1     10.0.0.8 0xFFFFFFFC [115/20] via 10.0.0.2, GigabitEthernet4/0
                             [115/20] via 10.0.0.14, GigabitEthernet4/1
C        10.0.0.12 0xFFFFFFFC is directly connected, GigabitEthernet4/1
C        10.0.0.0 0xFFFFFFFC is directly connected, GigabitEthernet4/0
C        10.0.0.4 0xFFFFFFFC is directly connected, GigabitEthernet4/2
i L1     10.0.0.16 0xFFFFFFFC [115/15] via 10.0.0.6, GigabitEthernet4/2
C        10.51.0.0 0xFFFF0000 is directly connected, Ethernet0
      192.168.0.0 0xFFFFFFFF is subnetted, 4 subnets
C        192.168.0.1 is directly connected, Loopback0
i L1     192.168.0.2 [115/10] via 10.0.0.2, GigabitEthernet4/0
i L1     192.168.0.3 [115/10] via 10.0.0.14, GigabitEthernet4/1
i L1     192.168.0.4 [115/10] via 10.0.0.6, GigabitEthernet4/2
```

JNPR Configuration

```
version 4.4R2.3;
system {
    host-name JNPR;
    syslog {
        user * {
            any emergency;
        }
        file messages {
            any notice;
            authorization info;
        }
    }
}
interfaces {
    ge-0/0/0 {
        unit 0 {
            family inet {
                address 10.0.0.2/30;
            }
            family iso;
            family mpls;
        }
    }
    ge-0/1/0 {
        unit 0 {
            family inet {
                address 10.0.0.9/30;
            }
            family iso;
            family mpls;
        }
    }
    ge-0/2/0 {
        unit 0 {
            family inet {
                address 10.0.0.17/30;
            }
            family iso;
            family mpls;
        }
    }
    lo0 {
        unit 0 {
            family inet {
                address 127.0.0.1/32;
                address 192.168.0.2/32;
            }
```

```
            family iso {
                address 49.0001.0000.0000.0002.00;
            }
        }
    }
}
routing-options {
    router-id 192.168.0.2;
}
protocols {
    rsvp {
        disable;
        interface ge-0/0/0.0;
        interface ge-0/1/0.0;
        interface ge-0/2/0.0;
    }
    mpls {
        interface all;
    }
    isis {
        level 2 disable;
        level 1 wide-metrics-only;
        interface ge-0/0/0.0;
        interface ge-0/1/0.0;
        interface ge-0/2/0.0;
        interface lo0.0;
    }
    ldp {
        interface all;
    }
}
```

JNPR Show Output

```
root@JNPR# run show ldp database

Input label database, 192.168.0.2:0-192.168.0.1:0
  Label      Prefix
     19      192.168.0.3/32
      3      192.168.0.1/32
     18      192.168.0.2/32
     20      192.168.0.4/32

Output label database, 192.168.0.2:0-192.168.0.1:0
  Label      Prefix
 100052      192.168.0.3/32
      3      192.168.0.2/32
 100051      192.168.0.1/32
 100053      192.168.0.4/32

Input label database, 192.168.0.2:0-192.168.0.3:0
  Label      Prefix
   2058      192.168.0.2/32
      3      192.168.0.3/32
   2057      192.168.0.4/32
   2056      192.168.0.1/32

Output label database, 192.168.0.2:0-192.168.0.3:0
  Label      Prefix
 100052      192.168.0.3/32
      3      192.168.0.2/32
 100051      192.168.0.1/32
 100053      192.168.0.4/32
```

```
Input label database, 192.168.0.2:0-192.168.0.4:0
  Label      Prefix
      3      192.168.0.4/32
   2054      192.168.0.2/32
   2052      192.168.0.1/32

Output label database, 192.168.0.2:0-192.168.0.4:0
  Label      Prefix
 100052      192.168.0.3/32
      3      192.168.0.2/32
 100051      192.168.0.1/32
 100053      192.168.0.4/32

root@JNPR# run show route

inet.0: 13 destinations, 13 routes (12 active, 0 holddown, 1 hidden)
+ = Active Route, - = Last Active, * = Both

10.0.0.0/30         *[Direct/0] 20:20:41
                      > via ge-0/0/0.0
10.0.0.2/32         *[Local/0] 1d 00:28:45
                       Local
10.0.0.4/30         *[IS-IS/15] 12:10:01, metric 20, tag 1
                      > to 10.0.0.1 via ge-0/0/0.0
                        to 10.0.0.18 via ge-0/2/0.0
10.0.0.8/30         *[Direct/0] 12:15:41
                      > via ge-0/1/0.0
10.0.0.9/32         *[Local/0] 21:40:23
                       Local
10.0.0.12/30        *[IS-IS/15] 01:03:31, metric 15, tag 1
                      > to 10.0.0.10 via ge-0/1/0.0
10.0.0.16/30        *[Direct/0] 12:10:38
                      > via ge-0/2/0.0
10.0.0.17/32        *[Local/0] 21:44:11
                       Local
192.168.0.1/32      *[IS-IS/15] 20:20:20, metric 20, tag 1
                      > to 10.0.0.1 via ge-0/0/0.0
192.168.0.2/32      *[Direct/0] 1d 00:33:54
                      > via lo0.0
192.168.0.3/32      *[IS-IS/15] 12:15:09, metric 10, tag 1
                      > to 10.0.0.10 via ge-0/1/0.0
192.168.0.4/32      *[IS-IS/15] 12:10:01, metric 10, tag 1
                      > to 10.0.0.18 via ge-0/2/0.0

inet.3: 3 destinations, 3 routes (3 active, 0 holddown, 0 hidden)
+ = Active Route, - = Last Active, * = Both

192.168.0.1/32      *[LDP/9] 01:29:10, metric 1
                      > to 10.0.0.1 via ge-0/0/0.0
192.168.0.3/32      *[LDP/9] 01:29:00, metric 1
                      > to 10.0.0.10 via ge-0/1/0.0
192.168.0.4/32      *[LDP/9] 00:55:37, metric 1
                      > to 10.0.0.18 via ge-0/2/0.0

iso.0: 1 destinations, 1 routes (1 active, 0 holddown, 0 hidden)
+ = Active Route, - = Last Active, * = Both

49.0001.0000.0000.0002.00/80
                     *[Direct/0] 21:29:57
                      > via lo0.0

mpls.0: 8 destinations, 8 routes (8 active, 0 holddown, 0 hidden)
+ = Active Route, - = Last Active, * = Both
```

```
0                   *[MPLS/0] 21:00:26, metric 1
                      Receive
1                   *[MPLS/0] 21:00:26, metric 1
                      Receive
100051              *[LDP/9] 01:29:10, metric 1
                      > to 10.0.0.1 via ge-0/0/0.0, Pop
100051(S=0)         *[LDP/9] 01:29:10, metric 1
                      > to 10.0.0.1 via ge-0/0/0.0, Pop
100052              *[LDP/9] 01:29:00, metric 1
                      > to 10.0.0.10 via ge-0/1/0.0, Pop
100052(S=0)         *[LDP/9] 01:29:00, metric 1
                      > to 10.0.0.10 via ge-0/1/0.0, Pop
100053              *[LDP/9] 00:55:37, metric 1
                      > to 10.0.0.18 via ge-0/2/0.0, Pop
100053(S=0)         *[LDP/9] 00:55:37, metric 1
                      > to 10.0.0.18 via ge-0/2/0.0, Pop
```

RSTN1 Configuration

```
version 8.0
port disable gi.3.1 force-link-down
interface create ip to_CSCO address-netmask 10.0.0.14/30 port gi.2.1
interface create ip to_JNPR address-netmask 10.0.0.10/30 port gi.2.2
interface create ip et11 address-netmask 172.16.1.1/24 port et.1.1
interface add ip lo0 address-netmask 192.168.0.3/32
ip-router global set router-id 192.168.0.3
ip-router global set autonomous-system 65500
ip-router policy redistribute from-proto aggregate to-proto bgp target-as
65500 network 172.16.0.0/16
bgp create peer-group ibgp autonomous-system 65500 type routing
bgp add peer-host 192.168.0.4 group ibgp
bgp set peer-group ibgp local-address 192.168.0.3
bgp set peer-group ibgp next-hop-self
bgp start
isis add area 49.0001
isis add interface to_CSCO
isis add interface lo0
isis add interface to_JNPR
isis set level 1
isis set traffic-engineering enable
isis set wide-metrics-only
isis set system-id 0000.0000.0003
isis set interface to_CSCO l1-metric 5
isis start
mpls add interface to_JNPR
mpls add interface to_CSCO
mpls start
ldp add interface to_JNPR
ldp add interface to_CSCO
ldp start
system set name RSTN1
system set idle-timeout serial 0
ip-router policy summarize route 172.16.0.0/16 type aggregate
```

RSTN1 Show Output

```
RSTN1# ldp show database

Input label database, 192.168.0.3:0-192.168.0.1:0
  Label     Prefix
      3     192.168.0.1/32
     18     192.168.0.2/32
     19     192.168.0.3/32
     20     192.168.0.4/32
```

```
Output label database, 192.168.0.3:0-192.168.0.1:0
  Label      Prefix
      3      192.168.0.3/32
   2056      192.168.0.1/32
   2057      192.168.0.4/32
   2058      192.168.0.2/32


Input label database, 192.168.0.3:0-192.168.0.2:0
  Label      Prefix
      3      192.168.0.2/32
 100051      192.168.0.1/32
 100052      192.168.0.3/32
 100053      192.168.0.4/32

Output label database, 192.168.0.3:0-192.168.0.2:0
  Label      Prefix
      3      192.168.0.3/32
   2056      192.168.0.1/32
   2057      192.168.0.4/32
   2058      192.168.0.2/32

RSTN1# ip show routes

Destination           Gateway               Owner      Netif
-----------           -------               -----      -----
10.0.0.0/30           10.0.0.13             ISIS_L1    to_CSCO
10.0.0.4/30           10.0.0.13             ISIS_L1    to_CSCO
10.0.0.8/30           directly connected    -          to_JNPR
10.0.0.12/30          directly connected    -          to_CSCO
10.0.0.16/30          10.0.0.9              ISIS_L1    to_JNPR
                       10.0.0.13             ISIS_L1    to_CSCO
127.0.0.1             127.0.0.1             -          lo0
172.16.0.0/16         127.0.0.1             Aggregate  lo0
172.16.1.0/24         directly connected    -          et11
172.17.0.0/16         10.0.0.13             BGP        to_CSCO
192.168.0.1           10.0.0.13             ISIS_L1    to_CSCO
192.168.0.2           10.0.0.9              ISIS_L1    to_JNPR
192.168.0.3           192.168.0.3           -          lo0
192.168.0.4           10.0.0.13             ISIS_L1    to_CSCO

RSTN1# ip-router show route 172.17.0.0
    172.17            mask 255.255
              entries 1    announce 1
                        Instability Histories:
         *BGP    Preference: 170         Source: 192.168.0.4
              *NextHop: 10.0.0.13           Interface: (to_CSCO) !
               MPLS labels: 20

              State: <Int Ext Active Gateway MergeCandidate>
              Local AS: 65500    Peer AS: 65500
              Age: 15:55    Metric: -1    Metric2: 100    Tag: 0
              Task: BGP_65500.192.168.0.4+1030
              AS Path: (65500) IGP (Id 3)

RSTN1# ping 172.17.1.1 sip 172.16.1.1 packets 5
PING 172.17.1.1 (172.17.1.1): 36 data bytes
44 bytes from 172.17.1.1: icmp_seq=0 ttl=254 time=1.380 ms
44 bytes from 172.17.1.1: icmp_seq=1 ttl=254 time=1.064 ms
44 bytes from 172.17.1.1: icmp_seq=2 ttl=254 time=1.020 ms
44 bytes from 172.17.1.1: icmp_seq=3 ttl=254 time=1.056 ms
44 bytes from 172.17.1.1: icmp_seq=4 ttl=254 time=1.074 ms

--- 172.17.1.1 ping statistics ---
5 packets transmitted, 5 packets received, 0% packet loss
round-trip min/avg/max = 1.020/1.118/1.380 ms
```

```
RSTN1# mpls show ott-table all
Interface        OTT RefCount   HW-OTT RefCount    NextHop          Vlan Labels
-------------------------------------------------------------------------------
lo                1    1           0        0        10.0.0.13       2    [3]
                  2    1           2        1        10.0.0.13       2    [20]
                  3    1           0        0        10.0.0.9        3    [3]


to_CSCO           0    0           1        1        10.0.0.13       0    [3]
                  2    1           2        1        10.0.0.13       2    [20]


to_JNPR           0    0           1        1        10.0.0.9        0    [20]
                  0    0           2        1        10.0.0.9        0    [3]

RSTN1# mpls show hw-ott-tbl port gi.2.1 index 2

Port: gi.2.1
-------------
Entry 2, Total: 7680
 dot1p source         : 0            output_vlan id : 2
 dot1p enabled        : 0     output vlan priority : 0
 dot1q enabled        : 0                      mtu : 1568
 overwrite_ttl        : 1             next_hop_mac : 00d0:ff64:1a01
 rate limit violated : 0                 php_etype : 34887
 rate limit enable    : 0                    label0 : 20:0:1:255
 no exp support       : 0                    label1 : 0:0:0:0
 start of l2 tunnel   : 0                    label2 : 0:0:0:0
 trunk lsp            : 0                     ip_da : 0
 ip tunnel            : 0                byte count : 13152
 lsr hop hide         : 0              packet count : 163
 llc snap encaps      : 0    malformed_label_drops : 0
 send to cpu          : 0                    pop_n : 0
 state                : 1                   push_n : 1
```

RSTN2 Configuration

```
version 8.0
port disable gi.3.1 force-link-down
interface create ip to_CSCO address-netmask 10.0.0.6/30 port gi.2.1
interface create ip to_JNPR address-netmask 10.0.0.18/30 port gi.2.2
interface create ip et11 address-netmask 172.17.1.1/24 port et.1.1
interface add ip lo0 address-netmask 192.168.0.4/32
ip-router global set router-id 192.168.0.4
ip-router global set autonomous-system 65500
ip-router policy redistribute from-proto aggregate to-proto bgp target-as
65500 network 172.17.0.0/16
bgp create peer-group ibgp autonomous-system 65500 type routing
bgp add peer-host 192.168.0.3 group ibgp
bgp set peer-group ibgp local-address 192.168.0.4
bgp set peer-group ibgp next-hop-self
bgp start
isis add area 49.0001
isis add interface to_CSCO
isis add interface lo0
isis add interface to_JNPR
isis set level 1
isis set traffic-engineering enable
isis set wide-metrics-only
isis set system-id 0000.0000.0004
isis set interface to_JNPR l1-metric 5
isis start
```

```
mpls add interface to_JNPR
mpls add interface to_CSCO
mpls start
ldp add interface to_JNPR
ldp add interface to_CSCO
ldp start
system set name RSTN2
system set idle-timeout serial 0
ip-router policy summarize route 172.17.0.0/16 type aggregate
```

RSTN2 Show Output

```
RSTN2# ldp show database

Input label database, 192.168.0.4:0-192.168.0.2:0
  Label      Prefix
      3      192.168.0.2/32
 100051      192.168.0.1/32
 100052      192.168.0.3/32
 100053      192.168.0.4/32

Output label database, 192.168.0.4:0-192.168.0.2:0
  Label      Prefix
      3      192.168.0.4/32
   2052      192.168.0.1/32
   2054      192.168.0.2/32


Input label database, 192.168.0.4:0-192.168.0.1:0
  Label      Prefix
      3      192.168.0.1/32
     18      192.168.0.2/32
     19      192.168.0.3/32
     20      192.168.0.4/32

Output label database, 192.168.0.4:0-192.168.0.1:0
  Label      Prefix
      3      192.168.0.4/32
   2052      192.168.0.1/32
   2054      192.168.0.2/32

RSTN2# ip show routes

Destination           Gateway               Owner      Netif
-----------           -------               -----      -----
10.0.0.0/30           10.0.0.17             ISIS_L1    to_JNPR
10.0.0.4/30           directly connected    -          to_CSCO
10.0.0.8/30           10.0.0.17             ISIS_L1    to_JNPR
10.0.0.12/30          10.0.0.5              ISIS_L1    to_CSCO
                       10.0.0.17             ISIS_L1    to_JNPR
10.0.0.16/30          directly connected    -          to_JNPR
127.0.0.1             127.0.0.1             -          lo0
172.16.0.0/16         10.0.0.17             BGP        to_JNPR
172.17.0.0/16         127.0.0.1             Aggregate  lo0
172.17.1.0/24         directly connected    -          et11
192.168.0.1           10.0.0.5              ISIS_L1    to_CSCO
192.168.0.2           10.0.0.17             ISIS_L1    to_JNPR
192.168.0.3           10.0.0.17             ISIS_L1    to_JNPR
192.168.0.4           192.168.0.4           -          lo0
```

```
RSTN2# ip-router show route 172.16.0.0
    172.16            mask 255.255
             entries 1    announce 1
                      Instability Histories:
        *BGP    Preference: 170        Source: 192.168.0.3
             *NextHop: 10.0.0.17          Interface: (to_JNPR) !
              MPLS labels: 100052

             State: <Int Ext Active Gateway MergeCandidate>
             Local AS: 65500    Peer AS: 65500
             Age: 18:49    Metric: -1    Metric2: 100    Tag: 0
             Task: BGP_65500.192.168.0.3+179
             AS Path: (65500) IGP (Id 3)

RSTN2# ping 172.16.1.1 sip 172.17.1.1 packets 5
PING 172.16.1.1 (172.16.1.1): 36 data bytes
44 bytes from 172.16.1.1: icmp_seq=0 ttl=254 time=1.064 ms
44 bytes from 172.16.1.1: icmp_seq=1 ttl=254 time=0.998 ms
44 bytes from 172.16.1.1: icmp_seq=2 ttl=254 time=1.016 ms
44 bytes from 172.16.1.1: icmp_seq=3 ttl=254 time=1.008 ms
44 bytes from 172.16.1.1: icmp_seq=4 ttl=254 time=0.998 ms

--- 172.16.1.1 ping statistics ---
5 packets transmitted, 5 packets received, 0% packet loss
round-trip min/avg/max = 0.998/1.016/1.064 ms

RSTN2# mpls show ott-table all
Interface       OTT RefCount  HW-OTT RefCount   NextHop         Vlan Labels
-------------------------------------------------------------------------
lo               1    1          0       0       10.0.0.5       2    [3]
                 3    1          0       0       10.0.0.17      3    [3]
                 4    1          2       1       10.0.0.17      3
[100052]


to_CSCO          0    0          1       1       10.0.0.5       0    [3]


to_JNPR          0    0          1       1       10.0.0.17      0    [3]
                 4    1          2       1       10.0.0.17      3
[100052]

RSTN2# mpls show hw-ott-tbl port gi.2.2 index 2

Port: gi.2.2
------------
Entry 2, Total: 7680
 dot1p source         : 0           output_vlan id : 3
 dot1p enabled        : 0     output vlan priority : 0
 dot1q enabled        : 0                  mtu : 1568
 overwrite_ttl        : 1            next_hop_mac : 0090:699a:103e
 rate limit violated : 0               php_etype : 34887
 rate limit enable   : 0                   label0 : 100052:0:1:255
 no exp support       : 0                  label1 : 0:0:0:0
 start of l2 tunnel  : 0                   label2 : 0:0:0:0
 trunk lsp            : 0                    ip_da : 0
 ip tunnel            : 0              byte count : 12004
 lsr hop hide         : 0            packet count : 151
 llc snap encaps      : 0    malformed_label_drops : 0
 send to cpu          : 0                   pop_n : 0
 state                : 1                  push_n : 1
```

CSCO Configuration

```
router ospf 1
 log-adjacency-changes
 network 10.0.0.0 0.255.255.255 area 0
 network 192.168.0.1 0.0.0.0 area 0
 mpls traffic-eng router-id Loopback0
 mpls traffic-eng area 0
```

JNPR Configuration

```
ospf {
    traffic-engineering;
    area 0.0.0.0 {
        interface all;
    }
}
```

RSTN1 Configuration

```
ospf create area backbone
ospf add interface to_JNPR to-area backbone
ospf add interface to_CSCO to-area backbone
ospf add interface to_RSTN2 to-area backbone
ospf add stub-host 192.168.0.3 to-area backbone cost 10
ospf start
ospf set traffic-engineering on
```

RSTN2 Configuration

```
ospf create area backbone
ospf add interface to_JNPR to-area backbone
ospf add interface to_CSCO to-area backbone
ospf add interface to_RSTN1 to-area backbone
ospf add stub-host 192.168.0.4 to-area backbone cost 10
ospf start
ospf set traffic-engineering on
```

Acronyms

ACL	Access Control List
ANSI	American National Standards Institute
ASIC	Application-Specific Integrated Circuit
ASP	Application Service Provider
ATM	Asynchronous Transfer Mode
CBR	Constant Bit Rate
CWDM	Coarse Wave Division Multiplexing
DS1/DS3	Digital Signal, Level 1 (1.54 Mbps) or 3 (44.7 Mbps)
DSL	Digital Subscriber Line
DWDM	Dense Wave Division Multiplexing
DVMRP	Distance Vector Multicast Protocol
E1/E2	European Trunk 1/2 (2 Mbps/34.3 Mbps)
ERP	Enterprise Resource Planning
HSSI	High Speed Serial Interface
ISP	Internet Service Provider
ITU	International Telecommunications Union
LAN	Local Area Network
LEC	Local Exchange Carrier
MAC	Media Access Control
MAN	Metropolitan Area Network
MDU	Multiple Dwelling Unit
MLPPP	Multi Layer Point-to-Point Protocol
MPLS	Multiple Protocol Label Switching. See "MPLS in Metro IP Networks," http://www.riverstonenet.com/technology/mpls.shtml
MTU	Multiple Tenant Unit
OC-3/OC-12	Optical Carrier 3/12 (155 Mbps/622 Mbps)
PDH	Plesiochronous Digital Hierarchy
PIM	Protocol Independent Multicast
POS	Packet over SONET
PPP	Point-to-Point Protocol
PVC	Private Virtual Circuit
QoS	Quality of Service
RED	Random Early Discard
SONET	Synchronous Optical NETwork See http://www.techguide.com/comm/sec_html/sonet.shtml
SLA	Service Level Agreement
SPE	Synchronous Payload Envelope
SRP	Spatial Reuse Protocol See RFC 2892
T1	Trunk 1 (1.544 Mbps)
TCP/IP	Transport Control Protocol/Internet Protocol
TDM	Time Division Multiplexing
UBR	Undefined Bit Rate
VBR	Variable Bit Rate
VLAN	Virtual LAN
VoD	Video on Demand
WAN	Wide Area Network
WDM	Wave Division Multiplexing
WRED	Weighted Random Early Discard

Riverstone Networks, Inc.
5200 Great America Parkway, Santa Clara, CA 95054 USA

877 / 778-9595 *or* ***408 / 878-6500*** *or* ***www.riverstonenet.com***