Interoperability Test Paper

Testing Juniper Networks M40 Router MPLS Interoperability with Cisco Systems 7513 and 12008 Routers

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Executive Summary

Juniper Networks, Inc. conducted a series of interoperability tests at our facilities. The purpose is to demonstrate that the MPLS implementation of the M40™ Internet backbone router interoperates with Cisco Systems 7513 and 12008 routers. You can use the procedures in this paper to replicate the tests.

The interoperability test includes the creation and use of label switched paths (LSPs), including the control plane using the Resource Reservation Protocol (RSVP) to setup LSPs and the forwarding plane that forwards packets through LSPs. It also includes the testing of IS-IS traffic engineering extensions. The tests were successful in that they demonstrated that Juniper Networks® and Cisco Systems MPLS implementations are interoperable.

Scope

Appendix A lists the specific configuration used for all three configuration tests. This configuration enables you to test the MPLS interoperability between the M40 router running JUNOS™ Internet software release 3.4, Cisco Systems 7513 routers running IOS 12.0(6)S, and 12008 routers running IOS 12.0(7)S. Particularly, these tests verify LSPs and RSVP, as well as IS-IS traffic engineering extensions.

Features not tested include Juniper Networks enhancements, such as MPLS Fast Reroute, Circuit Cross Connect, and OSPF traffic engineering. Other features not tested include the set of tag-switching features that Cisco Systems calls *MPLS features*, such as MPLS VPN.

These tests do not include performance testing.

Test Environment

The test environment consists of a four-router network topology: two M40 routers, one Cisco Systems GSR 12008, and one Cisco Systems 7513 (Figure 1).

Figure 1: MPLS Interoperability Test Topology
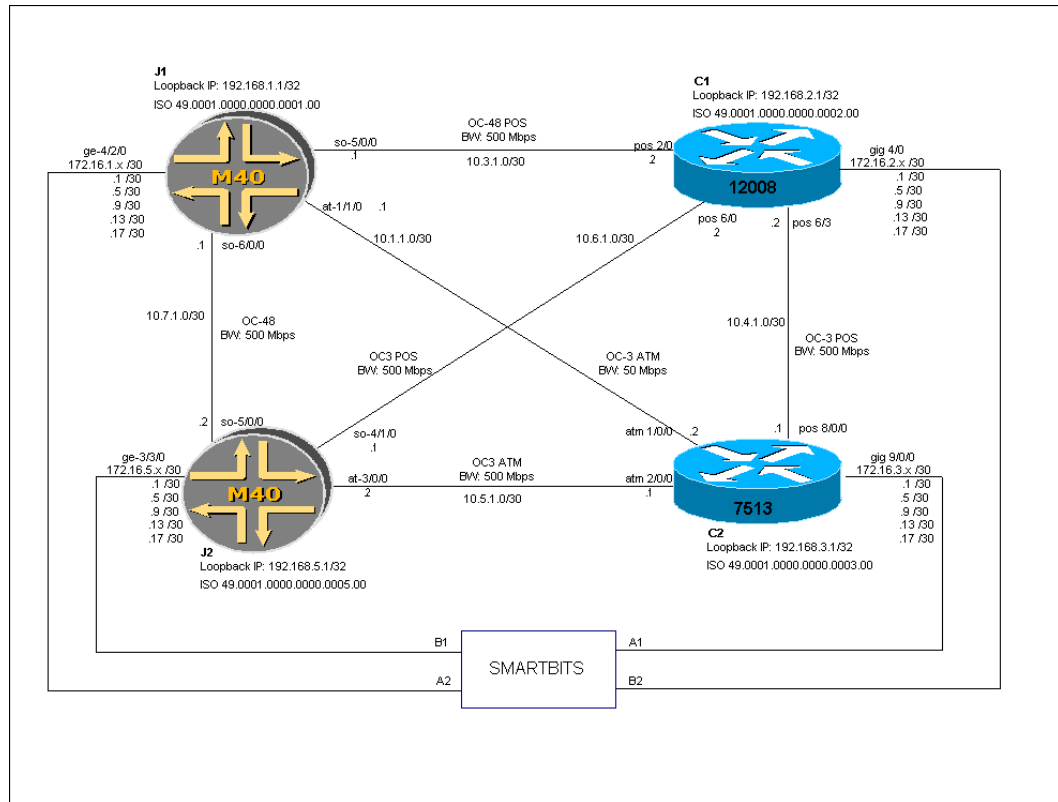
LSP Interoperability Test

This test determines whether you can create an LSP across an arbitrarily heterogeneous path, as well as whether static routing correctly operates.

Parameters

Appendix A lists the configurations for the four routers in the LSP and static routing tests.

To demonstrate interoperability over an arbitrary path, a set of permutations of possible paths is created (Table 1). This set represents all the possible paths. Each member of the set contains a different combination of routers for three different label switching router (LSR) functions: ingress, transit, and egress. These six paths are overlaid on top of the topology in Figure 2.

Table 1: LSP Created		
Ingress	**Transit**	**Egress**
Cisco Systems	Cisco Systems	Juniper Networks
Cisco Systems	Juniper Networks	Juniper Networks
Juniper Networks	Cisco Systems	Juniper Networks
Cisco Systems	Juniper Networks	Cisco Systems
Juniper Networks	Juniper Networks	Cisco Systems
Juniper Networks	Cisco Systems	Cisco Systems

Figure 2: LSP Test Topology
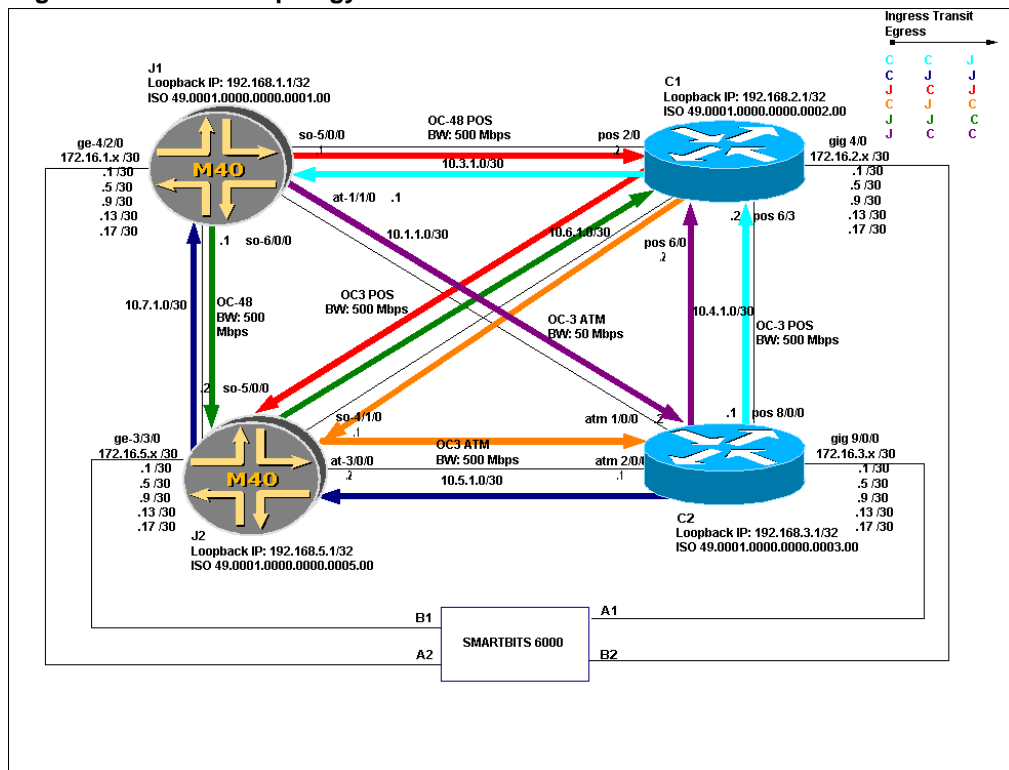
To test different means of path selection, the LSPs in Figure 2 are configured in a variety of ways. Most LSPs are configured with explicit paths to constrain them to a single path. Others, like the C2-J2-J1 LSP, are configured to dynamically choose a path that meets the bandwidth requirements of the LSP.

IP traffic is sent over all the LSPs using a Smartbits (SMB) 6000. The SMB 6000 is connected through a Gigabit Ethernet port directly to each router. To route IP traffic through the LSPs, each Gigabit Ethernet circuit is advertised via BGP.

Results

Testing demonstrates that the MPLS LSP implementations and static routing implementations are interoperable.

For each Gigabit Ethernet circuit, the BGP next hop advertises for the loopback interface of the router connected to it. Likewise, every LSP is established between the loopback interfaces of the originating and terminating routers. Any LSP originating on an M40 router dynamically uses this information to route traffic over the LSP. When a Cisco Systems-initiated LSP is configured with *autoroute announce*, the same behavior occurs on the Cisco Systems router.

Implementation Differences

The two implementations differ in how traffic is routed through the LSP.

◗ In JUNOS software, there are three ways to route traffic into LSPs.

  ◗ The primary means is with BGP. If any BGP route exists using the LSP destination as the BGP next hop, then BGP automatically uses the LSP to reach the next hop instead of using IGP.

  ◗ JUNOS software enables you to use IGP next hops in addition to BGP next hops to route traffic through LSPs.

  ◗ You can statically map routes into an LSP.

◗ In Cisco Systems IOS, there are two ways to route traffic into LSPs: static routes and automatic routes. Cisco Systems' Autoroute feature sends all traffic to a specific destination through the same LSP and routes to all the IGP interfaces on the destination router. There is no Cisco Systems equivalent to the JUNOS default of using solely BGP to place routes through the LSP.

RSVP Interoperability

By successfully creating and configuring the LSPs in the above LSP test, the interoperability of RSVP signalling is tested indirectly.

Parameters

Appendix A lists the configurations for the four routers in the RSVP test.

Results

Testing demonstrates that the RSVP implementations are interoperable. Specifically, the following RSVP objects are interoperable between Juniper Networks and Cisco Systems routers.

◗ Explicit-Route
◗ Label
◗ Label-Request
◗ Session

The only object not interoperable is the Record-Route object. This exception, which is being addressed by both Juniper Networks and Cisco Systems, does not affect the creation or use of LSPs.

Implementation Differences

Juniper Networks supports the RSVP Hello packet and Cisco Systems does not. This difference does not prevent Cisco Systems from creating and using LSPs.

To signal penultimate hop popping, a Cisco egress router sends label 0 to the penultimate hop in the control plane, whereas a Juniper Networks egress router sends label 3 (implicit NULL). When a Cisco egress router is connected to a penultimate Juniper Networks router, it is recommended that you use the following IOS command to require the egress router to send label 3 (as defined by the standard).

```
mpls traffic-eng signalling advertise implicit-null
```

IS-IS Traffic Engineering Extensions Interoperability

The inspection of the Traffic Engineering Database (TED) during the LSP test indicates whether Cisco Systems and Juniper Networks are sending the correct information in the sub-TLVs in the new IS-IS extended IS reachability TLV type 22. The identical use of the information in the TED is established by adding a few more steps to the existing test as described in the *Parameters* section.

Parameters

Appendix A lists the basic configurations for the four routers in the tests, though the following changes are made.

Bandwidth Reservation

Some additional LSPs are created between J1 and C2 to determine whether the routers in the path correctly update the unreserved bandwidth in the sub-TLV. The configuration of one of these LSPs is as follows.

```
label-switched-path to-C2-100m {
    to 192.168.3.1;
    bandwidth 100m;
}
```

After a number of such LSPs are configured, all of the available RSVP bandwidth is reserved and you cannot establish other LSPs along the same paths.

Administrative Groups

To test the interoperability of administrative groups, a few circuits are *colored*; that is, they are given different administrative groups. LSPs in the original test are then modified to include or exclude specific colored circuits. The administrative group information is carried in the TED. All administrative group constraints configured on the LSPs are honored. For comparison purposes, the following section lists sections of the configuration. The two configuration examples mirror each other exactly, except for the inability to name administration groups in Cisco Systems IOS.

JUNOS Software Configuration Example

```
protocols {
    mpls {
        admin-groups {
          orange 10;
          blue 5;
        }
        label-switched-path orange-notblue {
            to 192.168.5.1;
            admin-group {
              include orange;
              exclude blue;
            }
        }
        interface so-5/0/0 {
          admin-group {
            orange;
          }
        }
    }
}
```

Cisco Systems IOS Configuration Example

```
interface Tunnel0
 description orange-notblue
 ip unnumbered Loopback0
 tunnel destination 192.168.5.1
 tunnel mode mpls traffic-eng
 tunnel mpls traffic-eng affinity 0x400 mask 0x420
 tunnel mpls traffic-eng path-option 1 dynamic
...
interface POS5/0/0
...
 mpls traffic-eng attribute-flags 0x400
```

Results

Testing demonstrates that the IS-IS traffic engineering implementations are interoperable. The following sub-TLVs are correctly exchanged. (As of this writing, this table lists the entire set.)

Table 2: Sub-TLVs Exchanged	
Sub-TLV Number	**Sub-TLV Name**
3	Administrative group (color)
6	IPv4 interface address
8	IPv4 neighbor address
9	Maximum circuit bandwidth
10	Reservable circuit bandwidth
11	Unreserved bandwidth
18	TE Default metric

Implementation Differences

In JUNOS software, you can place circuits in different administrative groups; that is, you can *color* circuits. Similarly, you can constrain an arbitrary LSP to include or exclude circuits of a specified color. LSPs with no constraints can traverse circuits of any color, including non-colored circuits. LSPs constrained to include circuits of specified colors are only allowed to traverse circuits of at least one of the included colors. This configuration is a logical *OR*. LSPs constrained to exclude circuits of a specified color are allowed to traverse all other circuits that do not contain that color.

In IOS software, you can color circuits and constrain LSPs to a sets of colors, too. However, the defaults do not match. An LSP without constraints can traverse only uncolored circuits. In contrast to JUNOS software, IOS software can constrain LSPs to circuits colored with multiple colors, but cannot constrain LSPs in the same manner as a Juniper Networks *INCLUDE* configuration. Cisco Systems uses a logical *AND*, rather than an *OR*. Cisco Systems uses affinity bits and masks to constrain circuits and LSPs to administrative groups.

Table 3 identifies the differences in how Juniper Networks and Cisco Systems routers implement administrative groups. The information in this table does not represent actual syntax.

NOTE The JUNOS software uses *INCLUDE* and *EXCLUDE* statements when creating a constrained shortest path calculation to determine which circuits are valid.

Table 3: Example Differences in the Configuration of Administrative Groups		
Juniper Networks LSP: include/exclude	**Cisco Systems LSP: Affinity bits/mask**	**Description**
exclude "all"	0x00000000 mask 0xFFFFFFFF	Include only non-colored circuits
include group 1	0x00000002 mask 0x00000002	Include all circuits that contain group 1. The circuits can contain other groups.
exclude group 1 no include	0x00000000 mask 0x00000002	Exclude all circuits that contain group 1. The circuits can contain other groups.
exclude group 1 include groups 2, 3, 4	No equivalent	Include all circuits that contain groups 2, 3, or 4 and that do not include group 1. The circuits can contain other groups.
exclude group 1 include group 2	0x00000004 mask 0x00000006	Include all circuits that contain group 2 and that do not include group 1. The circuits can contain other groups.
no equivalent	0x00000421 mask 0xFFFFFFFF	Include all circuits that contain groups 0, 5, and 10. The circuits cannot contain any other groups.

Appendix A: Test Configurations

J1 (M40 Router) Configuration

```
version "3.4I0 [tlim]";
system {
    host-name J1;
    domain-name juniper.net;
    name-server {
        208.197.169.254;
    }
    login {
        user lab {
            uid 2000;
            class super-user;
            authentication {
                encrypted-password
"$1$VknQ.$QwaJQLIXh3nQgIF4MsGm6.";
            }
        }
    }
    services {
        telnet;
        ftp;
    }
}
interfaces {
    at-1/1/0 {
        atm-options {
            vpi 0 maximum-vcs 1024;
        }
        unit 32 {
            vci 0.32;
            family inet {
                address 10.1.1.1/30;
            }
            family iso;
            family mpls;
        }
    }
    fxp0 {
        unit 0 {
            family inet {
                address 172.19.33.251/24;
            }
        }
    }
    ge-4/2/0 {
        unit 0 {
            family inet {
                address 172.16.1.1/30 {
                    arp 172.16.1.2 mac 0000.0000.0012;
                }
                address 172.16.1.5/30 {
                    arp 172.16.1.6 mac 0000.0000.0012;
                }
                address 172.16.1.9/30;
                address 172.16.1.13/30;
                address 172.16.1.17/30;
            }
        }
    }
    lo0 {
        unit 0 {
```

```
                    family inet {
                        address 192.168.1.1/32;
                    }
                    family iso {
                        address 49.0001.0000.0000.0001.00;
                    }
                    family mpls;
                }
            }
            so-5/0/0 {
                clocking internal;
                encapsulation cisco-hdlc;
                unit 0 {
                    family inet {
                        address 10.3.1.1/30;
                    }
                    family iso;
                    family mpls;
                }
            }
            so-6/0/0 {
                clocking internal;
                encapsulation cisco-hdlc;
                unit 0 {
                    family inet {
                        address 10.7.1.1/30;
                    }
                    family iso;
                    family mpls;
                }
            }
        }
        routing-options {
            static {
                route 0.0.0.0/0 {
                    nexthop 172.19.33.254;
                    retain;
                    no-readvertise;
                }
            }
            autonomous-system 1;
        }
        protocols {
            rsvp {
                interface all;
                interface at-1/1/0.32 {
                    bandwidth 50m;
                }
                interface so-5/0/0.0 {
                    bandwidth 500m;
                }
                interface so-6/0/0.0 {
                    bandwidth 500m;
                }
            }
            mpls {
                label-switched-path red-J1-C1-J2 {
                    to 192.168.5.1;
                    primary J1-C1-J2;
                }
                label-switched-path green-J1-J2-C1 {
                    to 192.168.2.1;
                    primary J1-J2-C1;
                }
                label-switched-path purple-J1-C2-C1 {
                    to 192.168.2.1;
```

```
                        primary J1-C2-C1;
                }
                path J1-C1-J2 {
                    10.3.1.2 strict;
                    10.6.1.1 strict;
                }
                path J1-J2-C1 {
                    10.7.1.2 strict;
                    10.6.1.2 strict;
                }
                path J1-C2-C1 {
                    10.1.1.2;
                    10.4.1.2;
                }
                interface all;
            }
            bgp {
                group ibgp {
                    type internal;
                    local-address 192.168.1.1;
                    export redistribute-connected;
                    neighbor 192.168.2.1;
                    neighbor 192.168.3.1;
                    neighbor 192.168.5.1;
                }
            }
            isis {
                interface all;
            }
        }
        policy-options {
            policy-statement redistribute-connected {
                from protocol direct;
                then accept;
            }
        }
    }
```

J2 (M40 Router) Configuration

```
        version "3.4I0 [tlim]";
        system {
            host-name J2;
            domain-name juniper.net;
            name-server {
                208.197.169.254;
            }
            login {
                user lab {
                    uid 2000;
                    class super-user;
                    authentication {
                        encrypted-password
"$1$BPaQ.$4idu6X69DRB1GpHmTTaMV/";
                    }
                }
            }
            services {
                telnet;
            }
            syslog {
                user * {
                    any emergency;
                }
                file messages {
                    any notice;
```

```
                                    authorization info;
                                }
                            }
                        }
                    interfaces {
                        at-3/0/0 {
                            atm-options {
                                vpi 0 maximum-vcs 1024;
                            }
                            unit 0 {
                                vci 0.32;
                                family inet {
                                    address 10.5.1.2/30;
                                }
                                family iso;
                                family mpls;
                            }
                        }
                        fxp0 {
                            unit 0 {
                                family inet {
                                    address 172.19.33.252/24;
                                }
                            }
                        }
                        ge-3/3/0 {
                            unit 0 {
                                family inet {
                                    address 172.16.5.1/30 {
                                        arp 172.16.5.2 mac 0000.0000.0019;
                                    }
                                    address 172.16.5.5/30;
                                    address 172.16.5.9/30;
                                    address 172.16.5.13/30;
                                    address 172.16.5.17/30;
                                }
                            }
                        }
                        lo0 {
                            unit 0 {
                                family inet {
                                    address 192.168.5.1/32;
                                }
                                family iso {
                                    address 49.0001.0000.0000.0005.00;
                                }
                                family mpls;
                            }
                        }
                        so-4/1/0 {
                            encapsulation cisco-hdlc;
                            unit 0 {
                                family inet {
                                    address 10.6.1.1/30;
                                }
                                family iso;
                                family mpls;
                            }
                        }
                        so-5/0/0 {
                            clocking internal;
                            encapsulation cisco-hdlc;
                            unit 0 {
                                family inet {
                                    address 10.7.1.2/30;
                                }
```

```
                family iso;
                family mpls;
            }
        }
    }
    routing-options {
        static {
            route 0.0.0.0/0 {
                nexthop 172.19.33.254;
                no-readvertise;
            }
        }
        autonomous-system 1;
    }
    protocols {
        rsvp {
            interface all;
            interface at-3/0/0.0 {
                bandwidth 500m;
            }
            interface so-7/0/0.0 {
                bandwidth 500m;
            }
            interface so-5/0/0.0 {
                bandwidth 500m;
            }
        }
        mpls {
            label-switched-path to-C1 {
                disable;
                to 192.168.2.1;
                bandwidth 500k;
            }
            path C2 {
                10.5.1.1 strict;
            }
            interface all;
            interface fxp0.0 {
                disable;
            }
        }
        bgp {
            group ibgp {
                type internal;
                local-address 192.168.5.1;
                export redistribute-connected;
                neighbor 192.168.1.1;
                neighbor 192.168.2.1;
                neighbor 192.168.3.1;
            }
        }
        isis {
            interface all;
            interface fxp0.0 {
                disable;
            }
        }
    }
    policy-options {
        policy-statement redistribute-connected {
            from protocol direct;
            then accept;
        }
    }
```

C1 (Cisco Systems 12008 Router) Configuration

```
Current configuration:
!
version 12.0
no service pad
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
hostname C1
!
boot system flash slot0:gsr-p-mz.120-7.S
enable secret 5 $1$qnX8$X8qN0O
!
!
!
!
!
!
!
!
ip subnet-zero
ip domain-name juniper.net
ip name-server 208.197.169.254
ip multicast-routing distributed
clns routing
mpls traffic-eng tunnels
mpls traffic-eng link-management timers bandwidth-hold 300
mpls traffic-eng reoptimize timers frequency 0
no tag-switching ip
no tag-switching advertise-tags
!
!
interface Loopback0
 ip address 192.168.2.1 255.255.255.255
 no ip directed-broadcast
 ip router isis
!
interface Tunnel4
 description orange-C1-J2-C2
 ip unnumbered Loopback0
 no ip directed-broadcast
 load-interval 30
 tunnel destination 192.168.3.1
 tunnel mode mpls traffic-eng
 tunnel mpls traffic-eng affinity 0x0 mask 0x0
 tunnel mpls traffic-eng path-option 1 explicit identifier 2
 tunnel mpls traffic-eng record-route
!
interface POS0/0
 no ip address
 no ip directed-broadcast
 ip router isis
 no ip mroute-cache
 load-interval 30
 shutdown
 mpls traffic-eng tunnels
 crc 16
 pos scramble-atm
 no cdp enable
 ip rsvp bandwidth 500000 500000
!
interface ATM1/0
 no ip address
 no ip directed-broadcast
```

```
 shutdown
 no atm ilmi-keepalive
!
interface ATM1/1
 no ip address
 no ip directed-broadcast
 shutdown
 no atm ilmi-keepalive
!
interface ATM1/2
 no ip address
 no ip directed-broadcast
 shutdown
 no atm ilmi-keepalive
!
interface ATM1/3
 no ip address
 no ip directed-broadcast
 shutdown
 no atm ilmi-keepalive
!
interface POS2/0
 ip address 10.3.1.2 255.255.255.252
 no ip directed-broadcast
 ip router isis
 no ip mroute-cache
 load-interval 30
 mpls traffic-eng tunnels
 mpls traffic-eng attribute-flags 0x20
 crc 16
 pos scramble-atm
 no cdp enable
 ip rsvp bandwidth 500000 500000
!
interface GigabitEthernet4/0
 ip address 172.16.2.5 255.255.255.252 secondary
 ip address 172.16.2.9 255.255.255.252 secondary
 ip address 172.16.2.13 255.255.255.252 secondary
 ip address 172.16.2.17 255.255.255.252 secondary
 ip address 172.16.2.1 255.255.255.252
 no ip directed-broadcast
 load-interval 30
 no cdp enable
!
interface GigabitEthernet5/0
 no ip address
 no ip directed-broadcast
 ip router isis
 no ip mroute-cache
 load-interval 30
 shutdown
 mpls traffic-eng tunnels
 no cdp enable
 ip rsvp bandwidth 500000 500000
!
interface POS6/0
 ip address 10.6.1.2 255.255.255.252
 no ip directed-broadcast
 ip router isis
 no ip mroute-cache
 load-interval 30
 mpls traffic-eng tunnels
 crc 16
 pos scramble-atm
 no cdp enable
 ip rsvp bandwidth 500000 500000
```

```
!
interface POS6/1
 no ip address
 no ip directed-broadcast
 shutdown
 crc 16
 no cdp enable
!
interface POS6/2
 no ip address
 no ip directed-broadcast
 shutdown
 crc 16
 no cdp enable
!
interface POS6/3
 ip address 10.4.1.2 255.255.255.252
 no ip directed-broadcast
 ip router isis
 no ip mroute-cache
 load-interval 30
 mpls traffic-eng tunnels
 crc 16
 clock source internal
 no cdp enable
 ip rsvp bandwidth 500000 500000
!
interface Ethernet0
 ip address 172.19.33.248 255.255.255.0
 no ip directed-broadcast
 no ip proxy-arp
 no cdp enable
!
router isis
 net 49.0001.0000.0000.0002.00
 metric-style wide
 mpls traffic-eng router-id Loopback0
 mpls traffic-eng level-1
!
router bgp 1
 no synchronization
 redistribute connected
 neighbor ibgp peer-group
 neighbor ibgp remote-as 1
 neighbor ibgp update-source Loopback0
 neighbor ibgp next-hop-self
 neighbor 192.168.1.1 peer-group ibgp
 neighbor 192.168.3.1 peer-group ibgp
 neighbor 192.168.5.1 peer-group ibgp
 no auto-summary
!
ip classless
ip route 0.0.0.0 0.0.0.0 Null0
ip route 172.16.3.0 255.255.255.252 Tunnel4
ip route 172.17.0.0 255.255.0.0 172.19.33.254
ip route 172.19.0.0 255.255.0.0 172.19.33.254
ip route 207.79.80.0 255.255.255.0 172.19.33.254
ip route 208.197.169.0 255.255.255.0 172.19.33.254
ip http server
!
ip explicit-path identifier 1 enable
 next-address 10.6.1.1
 next-address 10.5.1.1
!
ip explicit-path identifier 2 enable
 next-address 10.3.1.1
```

```
 next-address 10.7.1.2
 next-address 10.5.1.1
 next-address 192.168.3.1
!
arp 172.16.2.18 0000.0000.001a ARPA
arp 172.16.2.14 0000.0000.001a ARPA
arp 172.16.2.10 0000.0000.001a ARPA
arp 172.16.2.6 0000.0000.001a ARPA
arp 172.16.2.2 0000.0000.001a ARPA
no cdp run
!
alias exec ls dir slot0:
!
line con 0
 transport input none
line aux 0
line vty 0 4
 exec-timeout 0 0
 password lab
 login
!
end
```

C2 (Cisco Systems 7513 Router) Configuration

```
Current configuration:
!
version 12.0
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
hostname C2
!
boot system flash slot0:rsp-pv-mz.120-6.S
enable secret 5 $1$o.H/$XNac3jI22S
!
ip subnet-zero
ip cef distributed
ip domain-name juniper.net
ip name-server 208.197.169.254
ip multicast-routing distributed
ip dvmrp route-limit 20000
clns routing
mpls traffic-eng tunnels
mpls traffic-eng link-management timers bandwidth-hold 300
mpls traffic-eng reoptimize timers frequency 0
no tag-switching ip
!
!
!
interface Loopback0
 ip address 192.168.3.1 255.255.255.255
 no ip directed-broadcast
 ip router isis
!
interface Tunnel1
 description blue-C2-C1-J1
 ip unnumbered Loopback0
 no ip directed-broadcast
 load-interval 30
 tunnel destination 192.168.1.1
 tunnel mode mpls traffic-eng
 tunnel mpls traffic-eng autoroute announce
 tunnel mpls traffic-eng affinity 0x0 mask 0x0
 tunnel mpls traffic-eng path-option 1 explicit identifier 1
!
interface Tunnel4
 description blue-C2-J2-J1
 ip unnumbered Loopback0
 no ip directed-broadcast
 tunnel destination 192.168.1.1
 tunnel mode mpls traffic-eng
 tunnel mpls traffic-eng autoroute announce
 tunnel mpls traffic-eng priority 7 7
 tunnel mpls traffic-eng bandwidth 100000
 tunnel mpls traffic-eng path-option 1 dynamic
!
interface ATM1/0/0
 no ip address
 no ip directed-broadcast
 ip route-cache distributed
 no atm ilmi-keepalive
!
interface ATM1/0/0.32 point-to-point
 ip address 10.1.1.2 255.255.255.252
 no ip directed-broadcast
 ip router isis
 atm pvc 32 0 32 aal5snap
```

```
 mpls traffic-eng tunnels
 ip rsvp bandwidth 50000 50000
!
interface FastEthernet1/1/0
 no ip address
 no ip directed-broadcast
 ip pim sparse-dense-mode
 ip route-cache distributed
 shutdown
 full-duplex
 no cdp enable
!
interface ATM2/0/0
 no ip address
 no ip directed-broadcast
 ip route-cache distributed
 no atm ilmi-keepalive
!
interface ATM2/0/0.32 point-to-point
 ip address 10.5.1.1 255.255.255.252
 no ip directed-broadcast
 ip router isis
 atm pvc 32 0 32 aal5snap
 mpls traffic-eng tunnels
 ip rsvp bandwidth 500000 500000
!
interface GigabitEthernet3/0/0
 no ip address
 no ip directed-broadcast
 ip route-cache distributed
 load-interval 30
 shutdown
 negotiation auto
 no cdp enable
!
interface POS8/0/0
 ip address 10.4.1.1 255.255.255.252
 no ip directed-broadcast
 ip router isis
 ip route-cache distributed
 mpls traffic-eng tunnels
 no cdp enable
 ip rsvp bandwidth 100000 100000
!
interface GigabitEthernet9/0/0
 ip address 172.16.3.5 255.255.255.252 secondary
 ip address 172.16.3.9 255.255.255.252 secondary
 ip address 172.16.3.13 255.255.255.252 secondary
 ip address 172.16.3.17 255.255.255.252 secondary
 ip address 172.16.3.1 255.255.255.252
 no ip directed-broadcast
 ip route-cache distributed
 load-interval 30
 no keepalive
 no negotiation auto
 no cdp enable
!
router isis
 net 49.0001.0000.0000.0003.00
 metric-style wide
 mpls traffic-eng router-id Loopback0
 mpls traffic-eng level-1
!
router bgp 1
 no synchronization
 redistribute connected
```

```
 neighbor ibgp peer-group
 neighbor ibgp remote-as 1
 neighbor ibgp update-source Loopback0
 neighbor ibgp next-hop-self
 neighbor 192.168.1.1 peer-group ibgp
 neighbor 192.168.2.1 peer-group ibgp
 neighbor 192.168.5.1 peer-group ibgp
 no auto-summary
!
ip classless
ip route 172.16.1.0 255.255.255.252 Tunnel1
ip route 172.16.1.4 255.255.255.252 Tunnel4
!
ip explicit-path identifier 1 enable
 next-address 10.4.1.2
 next-address 10.3.1.1
!
ip explicit-path identifier 2 enable
 next-address 10.5.1.2
 next-address 10.7.1.1
!
ip explicit-path identifier 3 enable
 next-address 10.5.1.2
!
ip explicit-path identifier 4 enable
 next-address 10.1.1.1
 next-address 10.7.1.2
!
arp 172.16.3.2 0000.0000.0011 ARPA
no cdp run
!
alias exec ls dir slot0:
!
line con 0
 exec-timeout 0 0
 transport preferred none
 transport input none
line aux 0
line vty 0 4
 exec-timeout 0 0
 password lab
 login
!
end
```

Appendix B: Acronyms

BGP	Border Gateway Protocol
IGP	Interior Gateway Protocol
IPv4	Internet Protocol version 4
IS-IS	Intermediate System-to-Intermediate System
LSP	Label switched paths
LSR	Label switching router
MPLS	Multiprotocol Label Switching
OSPF	Open Shortest Path First
RSVP	Resource Reservation Protocol
SMB	Smartbits
TE	Traffic Engineering
TED	Traffic Engineering Database
TLV	Type Length Value
VPN	Virtual private networks