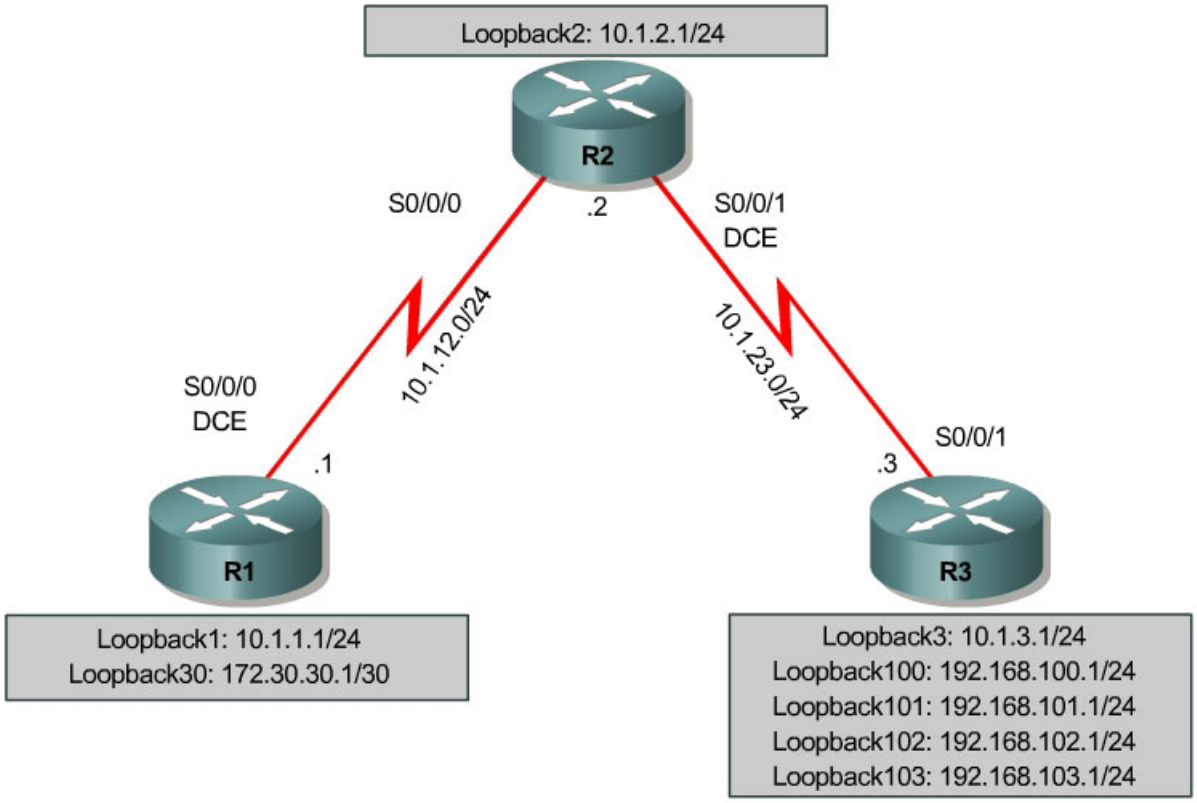
Lab 3-3 OSPF Virtual Links and Area Summarization

Learning Objectives

- Configure multiple-area OSPF on a router
- Verify multiple-area behavior
- Create an OSPF virtual link
- Summarize an area
- Generate a default route into OSPF

Topology



Scenario

You are responsible for configuring the new network to connect your company's Engineering, Marketing, and Accounting departments, represented by loopback interfaces on each of the three routers. The physical devices have just been installed and connected by serial cables. Configure multiple-area OSPF to allow full connectivity between all departments.

In addition, R1 will also have a loopback interface representing a connection to the Internet. This connection will not be added into OSPF. R3 will have four additional loopback interfaces representing connections to branch offices.

This topology may appear again in future labs, so save your configuration when you are done.

Step 1: Addressing

Set up the physical serial interfaces on R1, R2, and R3 with IP addresses and bring them up. You may need to add clock rates to the DCE end of each connection. Verify that you can ping across each serial link. Add the loopbacks shown in the diagram to each router.

```
R1# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)# interface loopback 1
R1(config-if)# ip address 10.1.1.1 255.255.255.0
R1(config-if)# interface loopback 30
R1(config-if)# ip address 172.30.30.1 255.255.255.252
R1(config-if)# interface serial 0/0/0
R1(config-if)# ip address 10.1.12.1 255.255.255.0
R1(config-if)# clockrate 64000
R1(config-if)# no shutdown

R2# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)# interface loopback 2
R2(config-if)# ip address 10.1.2.1 255.255.255.0
R2(config-if)# interface serial 0/0/0
R2(config-if)# ip address 10.1.12.2 255.255.255.0
R2(config-if)# no shutdown
R2(config-if)# interface serial 0/0/1
R2(config-if)# ip address 10.1.23.2 255.255.255.0
R2(config-if)# clockrate 64000
R2(config-if)# no shutdown

R3# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)# interface loopback 3
R3(config-if)# ip address 10.1.3.1 255.255.255.0
R3(config-if)# interface loopback 100
R3(config-if)# ip address 192.168.100.1 255.255.255.0
R3(config-if)# interface loopback 101
R3(config-if)# ip address 192.168.101.1 255.255.255.0
R3(config-if)# interface loopback 102
R3(config-if)# ip address 192.168.102.1 255.255.255.0
R3(config-if)# interface loopback 103
R3(config-if)# ip address 192.168.103.1 255.255.255.0
R3(config-if)# interface serial 0/0/1
R3(config-if)# ip address 10.1.23.1 255.255.255.0
R3(config-if)# no shutdown
```

Step 2: Adding Interfaces into OSPF

Create OSPF process 1 on all three routers. Using the **network** command, configure the subnet of the serial link between R1 and R2 to be in OSPF area 0.

Add loopback 1 on R1 and loopback 2 on R2 into OSPF area 0. Verify that you can see OSPF neighbors in the **show ip ospf neighbors** output on both routers and that they can see each other's loopback with the **show ip route** command. Change the network type on the loopback interfaces so that they are advertised with the correct subnet.

```
R1(config)# router ospf 1
R1(config-router)# network 10.1.12.0 0.0.0.255 area 0
R1(config-router)# network 10.1.1.0 0.0.0.255 area 0
R1(config-router)# interface loopback 1
R1(config-if)# ip ospf network point-to-point

R2(config)# router ospf 1
R2(config-router)# network 10.1.12.0 0.0.0.255 area 0
R2(config-router)# network 10.1.2.0 0.0.0.255 area 0
R2(config-router)# interface loopback 2
R2(config-if)# ip ospf network point-to-point

R1# show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
10.1.2.1          0   FULL/  -        00:00:38    10.1.12.2       Serial0/0/0

R1# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/24 is subnetted, 3 subnets
C       10.1.12.0 is directly connected, Serial0/0/0
O       10.1.2.0 [110/65] via 10.1.12.2, 00:00:10, Serial0/0/0
C       10.1.1.0 is directly connected, Loopback1

R2# show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
10.1.1.1          0   FULL/  -        00:00:35    10.1.12.1       Serial0/0/0

R2# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/24 is subnetted, 4 subnets
C       10.1.12.0 is directly connected, Serial0/0/0
C       10.1.2.0 is directly connected, Loopback2
O       10.1.1.0 [110/65] via 10.1.12.1, 00:00:30, Serial0/0/0
C       10.1.23.0 is directly connected, Serial0/0/1
```


Add the subnet between R2 and R3 into OSPF area 23 using the **network** command. Add loopback 3 on R3 into area 23. Verify that this neighbor relationship comes up using the **show ip ospf neighbors** command.

```
R2(config)# router ospf 1
R2(config-router)# network 10.1.23.0 0.0.0.255 area 23

R3(config)# router ospf 1
R3(config-router)# network 10.1.23.0 0.0.0.255 area 23
R3(config-router)# network 10.1.3.0 0.0.0.255 area 23
R3(config-router)# interface loopback 3
R3(config-if)# ip ospf network point-to-point

R2# show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
10.1.1.1          0   FULL/  -        00:00:36    10.1.12.1       Serial0/0/0
172.20.200.1      0   FULL/  -        00:00:36    10.1.23.3       Serial0/0/1
```

Verify that you can ping all interfaces from any router, with the exception of loopback 30 on R1, and R3 loopbacks 100 through 103.

Step 3: Creating a Virtual Link

Add loopbacks 100 through 103 on R3 to the OSPF process in area 100 using the **network** command. Change the network type to advertise the correct subnet mask. If you look at the output of **show ip route** on R2, you see that the routes to those networks do not appear.

```
R3(config)# router ospf 1
R3(config-router)# network 192.168.100.0 0.0.3.255 area 100
R3(config-router)# interface loopback 100
R3(config-if)# ip ospf network point-to-point
R3(config-if)# interface loopback 101
R3(config-if)# ip ospf network point-to-point
R3(config-if)# interface loopback 102
R3(config-if)# ip ospf network point-to-point
R3(config-if)# interface loopback 103
R3(config-if)# ip ospf network point-to-point

R2# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/24 is subnetted, 5 subnets
C       10.1.12.0 is directly connected, Serial0/0/0
O       10.1.3.0 [110/65] via 10.1.23.3, 00:01:00, Serial0/0/1
C       10.1.2.0 is directly connected, Loopback2
O       10.1.1.0 [110/65] via 10.1.12.1, 00:03:10, Serial0/0/0
C       10.1.23.0 is directly connected, Serial0/0/1
```


The reason for this behavior is that area 100 is not connected to the backbone; it is only connected to area 23. If an area is not connected to the backbone, its routes are not advertised outside of its area.

What would happen if routes could pass between areas without going through the backbone?

We can get around this situation by creating what is called a virtual link. This is an OSPF feature that creates a logical extension of the backbone area across a regular area, without actually adding any physical interfaces into area 0. To create a virtual link, use the OSPF configuration command **area *transit_area* virtual-link *router-id***. Use this command on both R2 and R3. After you see the adjacency over the virtual interface come up, issue the **show ip route** command on R2 and see the routes from area 100. You can verify the virtual link with the **show ip ospf neighbor** and **show ip ospf interface** commands.

```
R2(config)# router ospf 1
R2(config-router)# area 23 virtual-link 192.168.103.1

R3(config)# router ospf 1
R3(config-router)# area 23 virtual-link 10.1.2.1


R2# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/24 is subnetted, 5 subnets
C       10.1.12.0 is directly connected, Serial0/0/0
O       10.1.3.0 [110/65] via 10.1.23.3, 00:01:35, Serial0/0/1
C       10.1.2.0 is directly connected, Loopback2
O       10.1.1.0 [110/65] via 10.1.12.1, 00:01:35, Serial0/0/0
C       10.1.23.0 is directly connected, Serial0/0/1
O IA 192.168.102.0/24 [110/65] via 10.1.23.3, 00:00:05, Serial0/0/1
O IA 192.168.103.0/24 [110/65] via 10.1.23.3, 00:00:05, Serial0/0/1
O IA 192.168.100.0/24 [110/65] via 10.1.23.3, 00:00:57, Serial0/0/1
O IA 192.168.101.0/24 [110/65] via 10.1.23.3, 00:00:16, Serial0/0/1

R2# show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.103.1     0   FULL/  -            -        10.1.23.3       OSPF_VL0
10.1.1.1          0   FULL/  -        00:00:30    10.1.12.1       Serial0/0/0
192.168.103.1     0   FULL/  -        00:00:30    10.1.23.3       Serial0/0/1

R2# show ip ospf interface
```



```
OSPF_VL0 is up, line protocol is up
  Internet Address 10.1.23.2/24, Area 0
  Process ID 1, Router ID 10.1.2.1, Network Type VIRTUAL_LINK, Cost: 64
  Configured as demand circuit.
  Run as demand circuit.
  DoNotAge LSA allowed.
  Transmit Delay is 1 sec, State POINT_TO_POINT,
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    oob-resync timeout 40
    Hello due in 00:00:03
  Supports Link-local Signaling (LLS)
  Index 3/4, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 1
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 1, Adjacent neighbor count is 1
    Adjacent with neighbor 192.168.103.1  (Hello suppressed)
  Suppress hello for 1 neighbor(s)
<output omitted>
```

When are virtual links useful?

Why are virtual links a poor long-term solution?

Step 4: Summarizing an Area

Loopbacks 100 through 103 can be summarized into one supernet of 192.168.100.0 /22. We can configure area 100 to be represented by this single summary route. To do this, configure R3 (the ABR) to summarize this area using the **area *area* range *network mask*** command.

```
R3(config)# router ospf 1
R3(config-router)# area 100 range 192.168.100.0 255.255.252.0
```

You can see the summary route on R2 with the **show ip route** and **show ip ospf database** commands.

```
R2# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set
```



```
     10.0.0.0/24 is subnetted, 5 subnets
C       10.1.12.0 is directly connected, Serial0/0/0
O       10.1.3.0 [110/65] via 10.1.23.3, 00:07:25, Serial0/0/1
C       10.1.2.0 is directly connected, Loopback2
O       10.1.1.0 [110/65] via 10.1.12.1, 00:07:25, Serial0/0/0
C       10.1.23.0 is directly connected, Serial0/0/1
O IA 192.168.100.0/22 [110/65] via 10.1.23.3, 00:00:01, Serial0/0/1

R2# show ip ospf database

            OSPF Router with ID (10.1.2.1) (Process ID 1)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.1.1.1        10.1.1.1        969         0x80000002 0x00C668 3
10.1.2.1        10.1.2.1        498         0x80000005 0x00924E 4
192.168.103.1   192.168.103.1   5     (DNA) 0x80000002 0x00A573 1

                Summary Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.1.3.0        10.1.2.1        537         0x80000001 0x00EFEF
10.1.3.0        192.168.103.1   11    (DNA) 0x80000001 0x00FD5E
10.1.23.0       10.1.2.1        557         0x80000001 0x0009C3
10.1.23.0       192.168.103.1   11    (DNA) 0x80000001 0x00996F
192.168.100.0   192.168.103.1   1     (DNA) 0x80000001 0x009C03

                Router Link States (Area 23)

Link ID         ADV Router      Age         Seq#       Checksum Link count
10.1.2.1        10.1.2.1        498         0x80000009 0x00D191 2
192.168.103.1   192.168.103.1   499         0x80000004 0x00A7DC 3

                Summary Net Link States (Area 23)

Link ID         ADV Router      Age         Seq#       Checksum
10.1.1.0        10.1.2.1        563         0x80000001 0x0006DB
10.1.2.0        10.1.2.1        563         0x80000001 0x0078A8
10.1.12.0       10.1.2.1        563         0x80000001 0x008255
192.168.100.0   192.168.103.1   51          0x80000002 0x009A04
```

Notice on R3 that OSPF has generated a summary route pointing toward null0.

```
R3# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/24 is subnetted, 5 subnets
O       10.1.12.0 [110/128] via 10.1.23.2, 00:01:18, Serial0/0/1
C       10.1.3.0 is directly connected, Loopback3
O       10.1.2.0 [110/65] via 10.1.23.2, 00:01:18, Serial0/0/1
O       10.1.1.0 [110/129] via 10.1.23.2, 00:01:18, Serial0/0/1
C       10.1.23.0 is directly connected, Serial0/0/1
C    192.168.102.0/24 is directly connected, Loopback102
C    192.168.103.0/24 is directly connected, Loopback103
```



```
C    192.168.100.0/24 is directly connected, Loopback100
C    192.168.101.0/24 is directly connected, Loopback101
O    192.168.100.0/22 is a summary, 00:01:19, Null0
```

This behavior is known as sending unknown traffic to the “bit bucket.” This means that if the router advertising the summary route receives a packet destined for something covered by that summary but not in the routing table, it drops it.

What is the reasoning behind this behavior?

Step 5: Generating a Default Route into OSPF

We can simulate loopback 30 on R1 to be a connection to the Internet. We do not necessarily need to advertise this specific network to the rest of the network. Rather, we can just have a default route for all unknown traffic to go here. To have R1 generate a default route, use the OSPF configuration command **default-information originate always**. The **always** keyword is necessary for generating a default route in this scenario. Without this keyword, a default route is generated only into OSPF if one exists in the routing table.

```
R1(config)# router ospf 1
R1(config-router)# default-information originate always
```

Verify that the default route appears on R2 and R3 with the **show ip route** command.

```
R2# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is 10.1.12.1 to network 0.0.0.0

     10.0.0.0/24 is subnetted, 5 subnets
C       10.1.12.0 is directly connected, Serial0/0/0
O       10.1.3.0 [110/65] via 10.1.23.3, 00:10:36, Serial0/0/1
C       10.1.2.0 is directly connected, Loopback2
O       10.1.1.0 [110/65] via 10.1.12.1, 00:00:19, Serial0/0/0
C       10.1.23.0 is directly connected, Serial0/0/1
O*E2 0.0.0.0/0 [110/1] via 10.1.12.1, 00:00:09, Serial0/0/0
O IA 192.168.100.0/22 [110/65] via 10.1.23.3, 00:00:19, Serial0/0/1

R3# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
```



```
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is 10.1.23.2 to network 0.0.0.0

     10.0.0.0/24 is subnetted, 5 subnets
O       10.1.12.0 [110/128] via 10.1.23.2, 00:00:35, Serial0/0/1
C       10.1.3.0 is directly connected, Loopback3
O       10.1.2.0 [110/65] via 10.1.23.2, 00:00:35, Serial0/0/1
O       10.1.1.0 [110/129] via 10.1.23.2, 00:00:35, Serial0/0/1
C       10.1.23.0 is directly connected, Serial0/0/1
C    192.168.102.0/24 is directly connected, Loopback102
C    192.168.103.0/24 is directly connected, Loopback103
C    192.168.100.0/24 is directly connected, Loopback100
C    192.168.101.0/24 is directly connected, Loopback101
O*E2 0.0.0.0/0 [110/1] via 10.1.23.2, 00:00:26, Serial0/0/1
O    192.168.100.0/22 is a summary, 00:03:28, Null0
```

You should be able to ping the interface connecting to the Internet from R2 or R3, despite never being advertised into OSPF.

```
R3# ping 172.30.30.1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.30.30.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/30/32 ms
```

Challenge: Configure OSPF Authentication

Configure OSPF authentication on the link between R2 and R3 for MD5 authentication, using key ID 1 and the password cisco.

Appendix A: TCL Connectivity Verification

```
R1# tclsh
R1(tcl)#
R1(tcl)#foreach address {
+>(tcl)#10.1.1.1
+>(tcl)#10.1.2.1
+>(tcl)#10.1.3.1
+>(tcl)#172.30.30.1
+>(tcl)#192.168.100.1
+>(tcl)#192.168.101.1
+>(tcl)#192.168.102.1
+>(tcl)#192.168.103.1
+>(tcl)#10.1.12.1
+>(tcl)#10.1.12.2
+>(tcl)#10.1.23.2
+>(tcl)#10.1.23.3
+>(tcl)#} {
```



```
+>(tcl)#ping $address }

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.1.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/4 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.2.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/28/32 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.3.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/29/32 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.30.30.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/4 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.100.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/29/32 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.101.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/29/32 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.102.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/29/32 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.103.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/29/32 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.12.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 56/56/56 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.12.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/28/32 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.23.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/28/28 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.23.3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/29/32 ms

R2# tclsh
R2(tcl)#
R2(tcl)#foreach address {
+>(tcl)#10.1.1.1
+>(tcl)#10.1.2.1
+>(tcl)#10.1.3.1
+>(tcl)#172.30.30.1
+>(tcl)#192.168.100.1
+>(tcl)#192.168.101.1
+>(tcl)#192.168.102.1
+>(tcl)#192.168.103.1
+>(tcl)#10.1.12.1
```



```
+>(tcl)#10.1.12.2
+>(tcl)#10.1.23.2
+>(tcl)#10.1.23.3
+>(tcl)#} {
+>(tcl)#ping $address }

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.1.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/28/32 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.2.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/4 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.3.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/4 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.30.30.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/28/32 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.100.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/4 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.101.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/4 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.102.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/4 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.103.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/4 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.12.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/28/32 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.12.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 56/57/64 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.23.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/3/4 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.23.3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/4 ms


R3# tclsh
R3(tcl)#foreach address {
+>(tcl)#10.1.1.1
+>(tcl)#10.1.2.1
+>(tcl)#10.1.3.1
+>(tcl)#172.30.30.1
+>(tcl)#192.168.100.1
```



```
+>(tcl)#192.168.101.1
+>(tcl)#192.168.102.1
+>(tcl)#192.168.103.1
+>(tcl)#10.1.12.1
+>(tcl)#10.1.12.2
+>(tcl)#10.1.23.2
+>(tcl)#10.1.23.3
+>(tcl)#} {
+>(tcl)#ping $address }

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.1.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/28/32 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.2.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/4 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.3.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.30.30.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/29/32 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.100.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/4 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.101.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/4 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.102.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/4 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.103.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.12.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/29/32 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.12.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/4 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.23.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/4 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.23.3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/4 ms
```


Final Configuration

```
R1# show run
!
hostname R1
!
interface Loopback1
 ip address 10.1.1.1 255.255.255.0
 ip ospf network point-to-point
!
interface Loopback30
 ip address 172.30.30.1 255.255.255.252
!
interface Serial0/0/0
 ip address 10.1.12.1 255.255.255.0
 clock rate 64000
 no shutdown
!
router ospf 1
 network 10.1.1.0 0.0.0.255 area 0
 network 10.1.12.0 0.0.0.255 area 0
 default-information originate always
!
end

R2# show run
!
hostname R2
!
interface Loopback2
 ip address 10.1.2.1 255.255.255.0
 ip ospf network point-to-point
!
interface Serial0/0/0
 ip address 10.1.12.2 255.255.255.0
 no shutdown
!
interface Serial0/0/1
 ip address 10.1.23.2 255.255.255.0
 no shutdown
!
router ospf 1
 area 23 virtual-link 192.168.103.1
 network 10.1.2.0 0.0.0.255 area 0
 network 10.1.12.0 0.0.0.255 area 0
 network 10.1.23.0 0.0.0.255 area 23
!
end

R3# show run
!
hostname R3
!
interface Loopback3
 ip address 10.1.3.1 255.255.255.0
 ip ospf network point-to-point
!
interface Loopback100
 ip address 192.168.100.1 255.255.255.0
 ip ospf network point-to-point
!
```



```
interface Loopback101
 ip address 192.168.101.1 255.255.255.0
 ip ospf network point-to-point
!
interface Loopback102
 ip address 192.168.102.1 255.255.255.0
 ip ospf network point-to-point
!
interface Loopback103
 ip address 192.168.103.1 255.255.255.0
 ip ospf network point-to-point
!
interface Serial0/0/1
 ip address 10.1.23.3 255.255.255.0
 clock rate 2000000
 no shutdown
!
router ospf 1
 area 23 virtual-link 10.1.2.1
 area 100 range 192.168.100.0 255.255.252.0
 network 10.1.3.0 0.0.0.255 area 23
 network 10.1.23.0 0.0.0.255 area 23
 network 192.168.100.0 0.0.3.255 area 100
!
end


tclsh

foreach address {
10.1.1.1
10.1.2.1
10.1.3.1
172.30.30.1
192.168.100.1
192.168.101.1
192.168.102.1
192.168.103.1
10.1.12.1
10.1.12.2
10.1.23.2
10.1.23.3
} {
ping $address }
```

