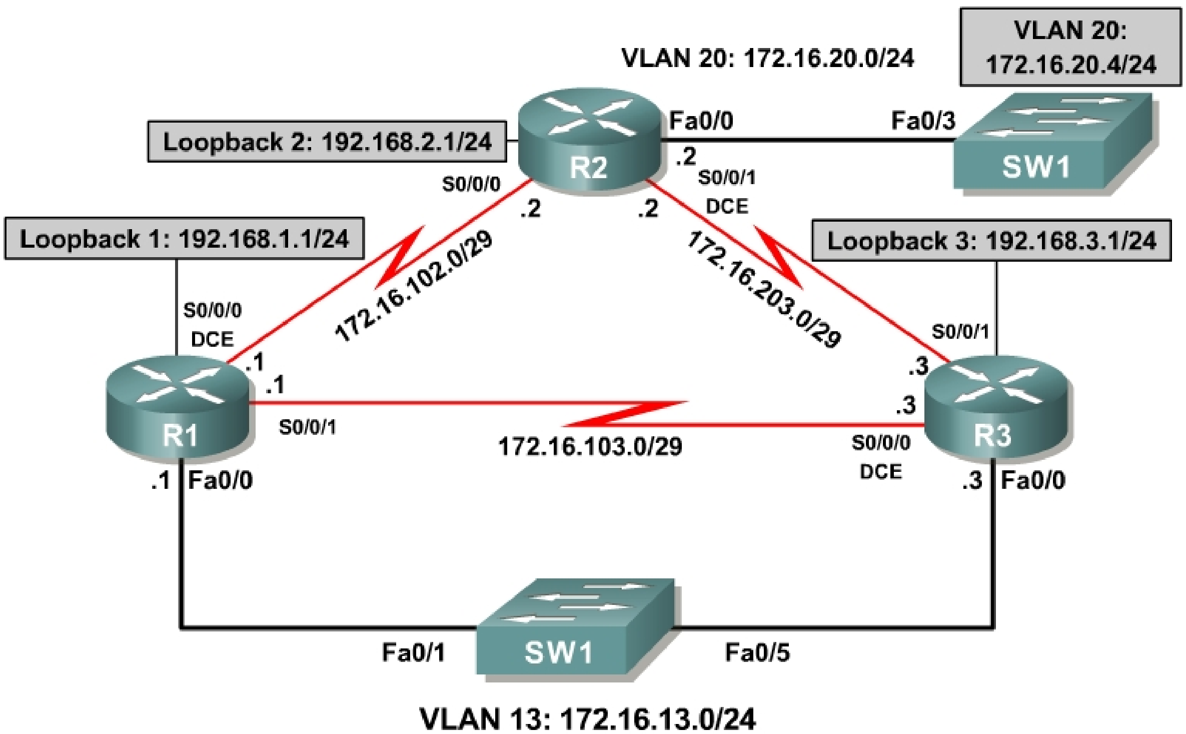
Lab 7-2 Routing IP Multicast with PIM Dense Mode

Learning Objectives

- Implement IGMP
- Review configuration of EIGRP
- Implement and verify PIM-DM operation and adjacencies
- Verify IGMP operation of PIM-DM flooding and pruning
- Explore the multicast routing table

Topology Diagram



Scenario

A community action organization, CrushASodaCan.com, contracted you as a consultant to set up IP multicast in their network. At the end of the week, the public relations department wants to multicast a live video feed of the CEO crushing a soda can to encourage citizens to compact their recyclable material before sending it to the recycling center. As a consultant working on this network, you are concerned about the use of the network resources.

The three remote sites are connected by a full mesh of serial leased lines. Sites 1 and 3 (R1 and R3) are also connected via Fast Ethernet.

The multicast source is a host on VLAN 20, which connects at Layer 3 to R2's Fast Ethernet interface. A remote network at each site represented by a loopback interface should receive the press feed of the CEO's message. While performing testing in this scenario, you will use a switched virtual interface (SVI) on SW1 to simulate the multicast source. At each multicast group member interface network, you should prefer the shortest cost path to the multicast source according to the underlying unicast routing table.

Step 1: Configure Addressing and Implement IGMP

Paste in the following initial configurations:

R1:

```
!
hostname R1
!
interface Loopback1
 ip address 192.168.1.1 255.255.255.0
!
interface FastEthernet0/0
 ip address 172.16.13.1 255.255.255.0
 no shutdown
!
interface Serial0/0/0
 bandwidth 64
 ip address 172.16.102.1 255.255.255.248
 clock rate 64000
 no shutdown
!
interface Serial0/0/1
 bandwidth 64
 ip address 172.16.103.1 255.255.255.248
 no shutdown
!
end
```

R2:

```
!
hostname R2
!
interface Loopback2
 ip address 192.168.2.1 255.255.255.0
!
interface FastEthernet0/0
 ip address 172.16.20.1 255.255.255.0
 no shutdown
!
interface Serial0/0/0
 bandwidth 64
 ip address 172.16.102.2 255.255.255.248
 no shutdown
!
interface Serial0/0/1
 bandwidth 128
 ip address 172.16.203.2 255.255.255.248
 clock rate 128000
```



```
 no shutdown
!
end
```

R3:

```
!
hostname R3
!
interface Loopback3
 ip address 192.168.3.1 255.255.255.0
!
interface FastEthernet0/0
 ip address 172.16.13.3 255.255.255.0
 no shutdown
!
interface Serial0/0/0
 bandwidth 64
 ip address 172.16.103.3 255.255.255.248
 clock rate 64000
 no shutdown
!
interface Serial0/0/1
 bandwidth 128
 ip address 172.16.203.3 255.255.255.248
 no shutdown
!
end
```

SW1:

```
!
hostname SW1
!
interface FastEthernet0/1
 switchport access vlan 13
 switchport mode access
!
interface FastEthernet0/3
 switchport access vlan 20
 switchport mode access
!
interface FastEthernet0/5
 switchport access vlan 13
 switchport mode access
!
end
```

Use a switched virtual interface (SVI) on SW1 to simulate a multicast source on the VLAN 20 subnet. This will be used to generate a repeated multicast ping to simulate the multicast traffic while you set up the network. Assign the SVI the IP address 172.16.20.4/24 with a default gateway of 172.16.20.2.

```
SW1# conf t
SW1(config)# ip default-gateway 172.16.20.2
SW1(config)# interface vlan 20
SW1(config-if)# ip address 172.16.20.4 255.255.255.0
SW1(config-if)# no shutdown
```

Using IGMP, subscribe each of the loopback interfaces on the three routers to the multicast group 232.32.32.32.


```
R1# conf t
R1(config)# interface loopback 1
R1(config-if)# ip igmp join-group 232.32.32.32

R2# conf t
R2(config)# interface loopback 2
R2(config-if)# ip igmp join-group 232.32.32.32

R3# conf t
R3(config)# interface loopback 3
R3(config-if)# ip igmp join-group 232.32.32.32
```

Verify that each of the interfaces has subscribed to the multicast group using the **show ip igmp groups** command.

```
R1# show ip igmp groups
IGMP Connected Group Membership
Group Address    Interface                Uptime    Expires   Last Reporter
Group Accounted
232.32.32.32     Loopback1                00:02:13  stopped   192.168.1.1

R2# show ip igmp groups
IGMP Connected Group Membership
Group Address    Interface                Uptime    Expires   Last Reporter
Group Accounted
232.32.32.32     Loopback2                00:02:15  stopped   192.168.1.2

R3# show ip igmp groups
IGMP Connected Group Membership
Group Address    Interface                Uptime    Expires   Last Reporter
Group Accounted
232.32.32.32     Loopback3                00:02:17  stopped   192.168.1.3
```

Step 2: Configure EIGRP

Configure EIGRP on each router with the following configuration:

```
router eigrp 1
 network 192.168.0.0 0.0.255.255
 network 172.16.0.0
```

After the EIGRP adjacencies form, run the following TCL script to verify full unicast connectivity:

```
foreach address {
192.168.1.1
172.16.13.1
172.16.102.1
172.16.103.1
192.168.2.1
172.16.20.2
172.16.102.2
172.16.203.2
192.168.3.1
172.16.13.3
172.16.103.3
172.16.203.3
172.16.20.4
} { ping $address }
```


Compare the output you receive with the output in Appendix A (all pings successful). Make sure you have ICMP replies from the host. If your host has a reachable default gateway of R2’s FastEthernet0/0 interface and if all routers have full connectivity between all subnets, you should be able to ping the host and receive all replies.

Step 3: Implement PIM-DM

Ping the 232.32.32.32 multicast address from the VLAN 20 SVI on SW1 discussed in Step 2.

```
SW1# ping 232.32.32.32

Type escape sequence to abort.
Sending 1, 100-byte ICMP Echos to 232.32.32.32, timeout is 2 seconds:

SW1#
```

Did you receive ICMP echo replies from the loopback interfaces subscribed to this group via IGMP?

Why does the host not receive ICMP replies?

List at least three responsibilities of an IP multicast routing protocol.

Routing protocols are primarily useful for “introducing” multicast sources to their receivers, a procedure known as source discovery. In unicast IP networks, a Layer 3 device must know the next downstream hop or interface to route a unicast packet to a destination network. Similarly, an IP multicast router must know the tree along which multicast data from a source should flow to the receivers.

Protocol Independent Multicast (PIM) has two modes: sparse mode (SM) and dense mode (DM). Cisco IOS supports both modes. PIM-DM is designed for networks in which devices on almost every subnet subscribe to the available groups. PIM-DM is useful in lab settings and in situations in which most of the Layer 2 segments involved have subscriptions to the multicast groups. PIM-SM is designed for multicast networks in which multicast groups do not have subscribers on many subnets.

Note: Cisco does not recommend implementing PIM-DM in production networks because of the inefficiency inherent in the push-based model. Though a multicast group does not have subscribers on many subnets in the network, multicast packets are still periodically flooded and pruned throughout the entire multicast network. Also, multicast networks require

PIM-DM creates (S, G) multicast trees rooted at each source that form shortest-cost paths to the receivers throughout the network. Each multicast router uses the unicast IP routing table to track which interfaces are upstream with reference to each multicast source. PIM-DM also analyzes the downstream subscriptions to assign forwarding state to outgoing interfaces. When a PIM router receives a packet for a multicast group, it must determine which interfaces for that group are in a forwarding state before sending the packet.

To enable multicast routing, issue the **ip multicast-routing** command in global configuration mode.

```
R1(config)# ip multicast-routing

R2(config)# ip multicast-routing

R3(config)# ip multicast-routing
```

To enable PIM-DM on the Loopback2 and FastEthernet0/0 interfaces on R2, issue the **ip pim dense-mode** command in interface configuration mode.

```
R2(config)# interface loopback 2
R2(config-if)# ip pim dense-mode
R2(config-if)# interface fastethernet 0/0
R2(config-if)# ip pim dense-mode
```

Recall the behavior of IGMP when PIM-DM was configured on R1’s Fast Ethernet interface in Lab 7.1. Will IGMP queries be sent over VLAN 20?

Now that multicast routing and PIM-DM are enabled on R2, will a ping from SW1 to the 232.32.32.32 group receive any replies? Explain.

Verify your answer by pinging the multicast group from SW1:

```
SW1# ping 232.32.32.32

Type escape sequence to abort.
Sending 1, 100-byte ICMP Echos to 232.32.32.32, timeout is 2 seconds:

Reply to request 0 from 172.16.20.2, 4 ms
```

Why was the first packet dropped?

Why did the host not receive replies from the other loopback interfaces in your topology?

In Lab 7.1, you demonstrated that without IGMP snooping Layer 2 multicast traffic traveling over Ethernet is treated as broadcast traffic. The switch then forwards multicast traffic to all ports that would normally receive a broadcast from the same source. However, at OSI Layer 3, multicast traffic is discarded unless the router receives directives from IGMP to send traffic out certain egress interfaces. If IGMP had registered such messages, the state would be shown in the IP multicast routing table.

Display the multicast routing table to check for egress interfaces to forward multicast traffic to group 232.32.32.32.

```
R2# show ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group
Outgoing interface flags: H - Hardware switched, A - Assert winner
 Timers: Uptime/Expires
 Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 232.32.32.32), 00:25:11/stopped, RP 0.0.0.0, flags: DCL
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Loopback2, Forward/Dense, 00:25:11/00:00:00

(172.16.20.4, 232.32.32.32), 00:00:07/00:02:55, flags: LT
  Incoming interface: FastEthernet0/0, RPF nbr 0.0.0.0
  Outgoing interface list:
    Loopback2, Forward/Dense, 00:00:07/00:00:00
```



```
(*, 224.0.1.40), 00:25:12/00:02:32, RP 0.0.0.0, flags: DCL
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Loopback2, Forward/Dense, 00:25:12/00:00:00
```

Because IGMP only queries interfaces that are running PIM-DM, the subscriptions for the remote loopback interfaces have not been reported to R2 and are, therefore, in a non-forwarding state. Only R2's Loopback2 interface will receive multicast packets destined for 232.32.32.32.

You can resolve this issue by applying the **ip pim dense-mode** command to each remaining interface in the topology.

```
R1(config)# interface loopback 1
R1(config-if)# ip pim dense-mode
R1(config-if)# interface fastethernet 0/0
R1(config-if)# ip pim dense-mode
R1(config-if)# interface serial 0/0/0
R1(config-if)# ip pim dense-mode
R1(config-if)# interface serial 0/0/1
R1(config-if)# ip pim dense-mode

R2(config)# interface serial 0/0/0
R2(config-if)# ip pim dense-mode
R2(config-if)# interface serial 0/0/1
R2(config-if)# ip pim dense-mode

R3(config)# interface loopback 1
R3(config-if)# ip pim dense-mode
R3(config-if)# interface fastethernet 0/0
R3(config-if)# ip pim dense-mode
R3(config-if)# interface serial 0/0/0
R3(config-if)# ip pim dense-mode
R3(config-if)# interface serial 0/0/1
R3(config-if)# ip pim dense-mode
```

Ping the multicast group from SW1 again. You should receive replies from each router. Note that you will not receive replies from the IP address of the interface on which the multicast packet was received but rather from whichever interface on the responding router encapsulated the return packet.

```
SW1# ping 232.32.32.32

Type escape sequence to abort.
Sending 1, 100-byte ICMP Echos to 232.32.32.32, timeout is 2 seconds:

Reply to request 0 from 172.16.20.2, 4 ms
Reply to request 0 from 172.16.102.1, 32 ms
Reply to request 0 from 172.16.203.3, 32 ms
```

Based on your understanding of IP unicast routing, why are the ICMP echo replies sent from the interfaces shown above?

Step 4: Verify PIM Adjacencies

In this step, we explore PIM adjacencies and how PIM functions over various Layer 2 media.

Issue the **show ip pim neighbors** command to display all the routers on the connected Layer 3 subnets.

```
R1# show ip pim neighbor
PIM Neighbor Table
Mode: B - Bidir Capable, DR - Designated Router, N - Default DR Priority,
      S - State Refresh Capable
Neighbor          Interface                Uptime/Expires    Ver   DR
Address                                                            Prio/Mode
172.16.13.3       FastEthernet0/0          00:02:29/00:01:42 v2    1 / DR S
172.16.102.2      Serial0/0/0              00:02:30/00:01:40 v2    1 / S
172.16.103.3      Serial0/0/1              00:02:29/00:01:43 v2    1 / S

R2# show ip pim neighbor
PIM Neighbor Table
Mode: B - Bidir Capable, DR - Designated Router, N - Default DR Priority,
      S - State Refresh Capable
Neighbor          Interface                Uptime/Expires    Ver   DR
Address                                                            Prio/Mode
172.16.102.1      Serial0/0/0              00:03:16/00:01:25 v2    1 / S
172.16.203.3      Serial0/0/1              00:03:18/00:01:24 v2    1 / S

R3# show ip pim neighbor
PIM Neighbor Table
Mode: B - Bidir Capable, DR - Designated Router, N - Default DR Priority,
      S - State Refresh Capable
Neighbor          Interface                Uptime/Expires    Ver   DR
Address                                                            Prio/Mode
172.16.13.1       FastEthernet0/0          00:03:00/00:01:42 v2    1 / S
172.16.103.1      Serial0/0/0              00:03:31/00:01:41 v2    1 / S
172.16.203.2      Serial0/0/1              00:03:03/00:01:38 v2    1 / S
```

Consider the adjacency between R1 and R3 on VLAN 13. If more than one multicast router exists on a multi-access VLAN, is it necessary for both devices to query for IGMP subscriptions on the VLAN?

Recall the idea of a designated router (DR) in OSPF or a designated intermediate system (DIS) in IS-IS. These link-state protocols allow Layer 3 devices running those protocols to become adjacent only with the master device for that multi-access Layer 2 medium. This behavior decreases network control traffic and provides an authoritative source for routing information on that network segment.

A similar situation exists for IGMP control traffic on multi-access media, such as Ethernet. Rather than have each multicast router on a subnet running its own IGMP queries, PIM-DM elects one router to handle the IGMP querying for the entire network segment. PIM elects a DR for that subnet by selecting the PIM-DM router with the highest IP address.

From a practical perspective, do you need a DR on a point-to-point medium? Explain.

Display detailed information about PIM-enabled interfaces with the **show ip pim interface detail** command on R1.

```
R1# show ip pim interface detail
Loopback1 is up, line protocol is up
  Internet address is 192.168.1.1/24
  Multicast switching: fast
  Multicast packets in/out: 919/0
  Multicast TTL threshold: 0
  PIM: enabled
    PIM version: 2, mode: dense
    PIM DR: 192.168.1.1 (this system)
    PIM neighbor count: 0
    PIM Hello/Query interval: 30 seconds
    PIM Hello packets in/out: 77/78
    PIM State-Refresh processing: enabled
    PIM State-Refresh origination: disabled
    PIM NBMA mode: disabled
    PIM ATM multipoint signalling: disabled
    PIM domain border: disabled
  Multicast Tagswitching: disabled
Serial0/0/0 is up, line protocol is up
  Internet address is 172.16.102.1/29
  Multicast switching: fast
  Multicast packets in/out: 917/0
  Multicast TTL threshold: 0
  PIM: enabled
    PIM version: 2, mode: dense
    PIM DR: 0.0.0.0
    PIM neighbor count: 1
    PIM Hello/Query interval: 30 seconds
    PIM Hello packets in/out: 77/78
    PIM State-Refresh processing: enabled
    PIM State-Refresh origination: disabled
    PIM NBMA mode: disabled
    PIM ATM multipoint signalling: disabled
    PIM domain border: disabled
  Multicast Tagswitching: disabled
Serial0/0/1 is up, line protocol is up
  Internet address is 172.16.103.1/29
  Multicast switching: fast
  Multicast packets in/out: 920/0
  Multicast TTL threshold: 0
  PIM: enabled
    PIM version: 2, mode: dense
    PIM DR: 0.0.0.0
    PIM neighbor count: 1
    PIM Hello/Query interval: 30 seconds
    PIM Hello packets in/out: 77/78
    PIM State-Refresh processing: enabled
```



```
    PIM State-Refresh origination: disabled
    PIM NBMA mode: disabled
    PIM ATM multipoint signalling: disabled
    PIM domain border: disabled
  Multicast Tagswitching: disabled
FastEthernet0/0 is up, line protocol is up
  Internet address is 172.16.13.1/24
  Multicast switching: fast
  Multicast packets in/out: 918/0
  Multicast TTL threshold: 0
  PIM: enabled
    PIM version: 2, mode: dense
    PIM DR: 172.16.13.3
    PIM neighbor count: 1
    PIM Hello/Query interval: 30 seconds
    PIM Hello packets in/out: 76/77
    PIM State-Refresh processing: enabled
    PIM State-Refresh origination: disabled
    PIM NBMA mode: disabled
    PIM ATM multipoint signalling: disabled
    PIM domain border: disabled
  Multicast Tagswitching: disabled
```

Notice that the two serial interfaces use the default DR address 0.0.0.0 as the DR for the interface. Because a multicast packet is received by either 0 or 1 remote routers on a serial segment, PIM does not need to set up a complex neighbor relationship.

Step 5: Verify Multicast Routing Operation

On each router, use the **mrinfo** command to view information about the connected multicast-enabled routers.

```
R1# mrinfo
172.16.13.1 [version  12.4] [flags: PMA]:
  192.168.1.1 -> 0.0.0.0 [1/0/pim/querier/leaf]
  172.16.13.1 -> 172.16.13.3 [1/0/pim]
  172.16.102.1 -> 172.16.102.2 [1/0/pim]
  172.16.103.1 -> 172.16.103.3 [1/0/pim]

R2# mrinfo
172.16.20.2 [version  12.4] [flags: PMA]:
  192.168.2.1 -> 0.0.0.0 [1/0/pim/querier/leaf]
  172.16.20.2 -> 0.0.0.0 [1/0/pim/querier/leaf]
  172.16.102.2 -> 172.16.102.1 [1/0/pim]
  172.16.203.2 -> 172.16.203.3 [1/0/pim]

R3# mrinfo
172.16.13.3 [version  12.4] [flags: PMA]:
  192.168.3.1 -> 0.0.0.0 [1/0/pim/querier/leaf]
  172.16.13.3 -> 172.16.13.1 [1/0/pim/querier]
  172.16.103.3 -> 172.16.103.1 [1/0/pim]
  172.16.203.3 -> 172.16.203.2 [1/0/pim]
```

Each router realizes that the loopback interfaces are topological leaves in which PIM will never establish an adjacency with any other routers. These routers also record the neighboring multicast router addresses and the multicast routing protocols they utilize.

Use the **show ip multicast interface** command to display statistics about the multicast traffic passing through the router. You should receive similar output on each router.

```
R1# show ip multicast interface
Loopback1 is up, line protocol is up
  Internet address is 192.168.1.1/24
  Multicast routing: enabled
  Multicast switching: fast
  Multicast packets in/out: 512/0
  Multicast TTL threshold: 0
  Multicast Tagswitching: disabled
FastEthernet0/0 is up, line protocol is up
  Internet address is 172.16.13.1/24
  Multicast routing: enabled
  Multicast switching: fast
  Multicast packets in/out: 524/6
  Multicast TTL threshold: 0
  Multicast Tagswitching: disabled
Serial0/0/0 is up, line protocol is up
  Internet address is 172.16.102.1/29
  Multicast routing: enabled
  Multicast switching: fast
  Multicast packets in/out: 519/0
  Multicast TTL threshold: 0
  Multicast Tagswitching: disabled
Serial0/0/1 is up, line protocol is up
  Internet address is 172.16.103.1/29
  Multicast routing: enabled
  Multicast switching: fast
  Multicast packets in/out: 516/6
  Multicast TTL threshold: 0
  Multicast Tagswitching: disabled
```

Based on the above output and your knowledge of PIM-DM and this topology, which interfaces appear to be forwarding multicasts to 232.32.32.32 on R1?

Generate a stream of multicast data to the group by issuing an extended ping from SW1 with a repeat count of 100.

```
SW1# ping
Protocol [ip]:
Target IP address: 232.32.32.32
Repeat count [1]: 100
Datagram size [100]:
Timeout in seconds [2]:
Extended commands [n]:
Sweep range of sizes [n]:
Type escape sequence to abort.
Sending 100, 100-byte ICMP Echos to 232.32.32.32, timeout is 2 seconds:

Reply to request 0 from 172.16.20.2, 8 ms
Reply to request 0 from 172.16.102.1, 36 ms
Reply to request 0 from 172.16.203.3, 36 ms
Reply to request 1 from 172.16.20.2, 4 ms
```



```
Reply to request 1 from 172.16.102.1, 28 ms
Reply to request 1 from 172.16.203.3, 28 ms
Reply to request 2 from 172.16.20.2, 8 ms
Reply to request 2 from 172.16.102.1, 32 ms
Reply to request 2 from 172.16.203.3, 32 ms
...
```

On each of the routers, you should see that PIM and IGMP have communicated to install the 232.32.32.32 multicast group in the multicast routing table. Verify this with the **show ip mroute** command on each router.

```
R1# show ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group
Outgoing interface flags: H - Hardware switched, A - Assert winner
 Timers: Uptime/Expires
 Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 232.32.32.32), 02:34:00/stopped, RP 0.0.0.0, flags: DCL
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Serial0/0/0, Forward/Dense, 00:31:23/00:00:00
    FastEthernet0/0, Forward/Dense, 02:33:31/00:00:00
    Serial0/0/1, Forward/Dense, 02:33:31/00:00:00
    Loopback1, Forward/Dense, 02:34:00/00:00:00

(172.16.20.4, 232.32.32.32), 00:00:09/00:03:00, flags: LT
  Incoming interface: Serial0/0/0, RPF nbr 172.16.102.2
  Outgoing interface list:
    Loopback1, Forward/Dense, 00:00:09/00:00:00
    Serial0/0/1, Prune/Dense, 00:00:09/00:02:52
    FastEthernet0/0, Prune/Dense, 00:00:09/00:02:49

(*, 224.0.1.40), 02:34:01/00:02:43, RP 0.0.0.0, flags: DCL
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Serial0/0/0, Forward/Dense, 00:31:24/00:00:00
    FastEthernet0/0, Forward/Dense, 02:33:33/00:00:00
    Serial0/0/1, Forward/Dense, 02:33:33/00:00:00
    Loopback1, Forward/Dense, 02:34:02/00:00:00

R2# show ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group
Outgoing interface flags: H - Hardware switched, A - Assert winner
 Timers: Uptime/Expires
 Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 232.32.32.32), 00:32:01/stopped, RP 0.0.0.0, flags: DCL
  Incoming interface: Null, RPF nbr 0.0.0.0
```



```
  Outgoing interface list:
    Serial0/0/0, Forward/Dense, 00:31:33/00:00:00
    Serial0/0/1, Forward/Dense, 00:31:33/00:00:00
    Loopback2, Forward/Dense, 00:32:01/00:00:00

(172.16.20.4, 232.32.32.32), 00:00:48/00:02:58, flags: LT
  Incoming interface: FastEthernet0/0, RPF nbr 0.0.0.0
  Outgoing interface list:
    Loopback2, Forward/Dense, 00:00:50/00:00:00
    Serial0/0/1, Forward/Dense, 00:00:50/00:00:00
    Serial0/0/0, Prune/Dense, 00:00:50/00:00:00

(*, 224.0.1.40), 00:32:03/00:02:47, RP 0.0.0.0, flags: DCL
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Serial0/0/0, Forward/Dense, 00:31:34/00:00:00
    Serial0/0/1, Forward/Dense, 00:31:34/00:00:00
    Loopback2, Forward/Dense, 00:32:23/00:00:00

R3# show ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group
Outgoing interface flags: H - Hardware switched, A - Assert winner
 Timers: Uptime/Expires
 Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 232.32.32.32), 02:34:45/stopped, RP 0.0.0.0, flags: DCL
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Serial0/0/1, Forward/Dense, 00:32:05/00:00:00
    FastEthernet0/0, Forward/Dense, 02:34:13/00:00:00
    Serial0/0/0, Forward/Dense, 02:34:43/00:00:00
    Loopback3, Forward/Dense, 02:34:45/00:00:00

(172.16.20.4, 232.32.32.32), 00:00:52/00:02:59, flags: LT
  Incoming interface: Serial0/0/1, RPF nbr 172.16.203.2
  Outgoing interface list:
    Loopback3, Forward/Dense, 00:00:52/00:00:00
    Serial0/0/0, Prune/Dense, 00:00:51/00:02:11, A
    FastEthernet0/0, Forward/Dense, 00:00:48/00:02:11, A

(*, 224.0.1.40), 02:34:46/00:02:58, RP 0.0.0.0, flags: DCL
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Serial0/0/1, Forward/Dense, 00:32:06/00:00:00
    FastEthernet0/0, Forward/Dense, 02:34:15/00:00:00
    Serial0/0/0, Forward/Dense, 02:34:46/00:00:00
    Loopback3, Forward/Dense, 02:34:47/00:00:00
```

The two timers shown on the first line of the (S, G) entry on each router indicate the time since the first multicast to that group and the time when the entry expires. All the expiration timers for (172.16.20.4, 232.32.32.32) state display as roughly three minutes while SW1 sends the multicast pings. Thus, each time the router receives a multicast packet matching the (S, G) entry (172.16.20.4, 232.32.32.32), IGMP resets the expiration timer to three minutes.

By default, IGMP sends a general query every 60 seconds on each PIM interface. A general query requests any devices running IGMP on that subnet to report any groups to which they subscribe to the querying router. If no membership reports are heard for a particular group on that interface over three times the query interval, the multicast router declares that there is no active member of the group on the interface. The router stops sending multicasts to that group on that egress interface. If a router does not receive multicasts from an (S, G) pair for three minutes, the multicast routing table deletes the (S, G) entry.

The IP multicast routing table also indicates whether the PIM interfaces negotiated to flood multicast data to that group out an interface or pruned (S, G) multicast traffic from being sent out that interface.

Based on the IP multicast routing tables shown above, which PIM interfaces on each router are forwarding traffic from 172.16.20.4 to 232.32.32.32?

Step 6: Verify PIM-DM Flood-and-Prune Behavior

To view the flood-and-prune behavior of PIM-DM, wait for the multicast stream from 172.16.20.4 to complete and for the (S, G) state in the multicast routing tables to expire. Then issue the **debug ip igmp** and **debug ip pim** commands on all routers.

PIM relies on the unicast IP routing table to construct shortest-path trees from the sources to the multicast subscribers. PIM neighbors send control messages to determine which neighbor is closer to the source in terms of the unicast routing information on each neighbor. PIM neighbors on the subnet elect a particular router as the forwarder for that (S, G) pair using Assert messages. Each Assert message carries the best administrative distance and metric that the advertising router has to the source. The PIM router with the best administrative distance and metric is elected as the forwarder for that (S, G) or (*, G) entry. The forwarder then prunes that (S, G) pair from being forwarded by any other routers on the subnet.

Do not confuse the DR with the forwarder. Although both are elected on multi-access networks, the role of DR does not include the responsibility to forward multicast traffic. As defined by IGMPv1, a DR is elected based on highest IP address to control the IGMP querying. Thus, a DR exists to identify which receivers exist on a subnet by polling for listeners to any group. There can only be one DR on a subnet at a time.

In contrast, every multi-access subnet elects forwarders individually for each (S, G) and (*, G) pair. The forwarder is elected based on best administrative distance and metric to the source. The forwarder is the metrically closest router on the subnet to the source.

Display the unicast routing table entry for 172.16.20.4 on each router.

```
R1# show ip route 172.16.20.4
Routing entry for 172.16.20.0/24
  Known via "eigrp 1", distance 90, metric 20517120, type internal
  Redistributing via eigrp 1
  Last update from 172.16.13.3 on FastEthernet0/0, 00:42:57 ago
  Routing Descriptor Blocks:
  * 172.16.13.3, from 172.16.13.3, 00:42:57 ago, via FastEthernet0/0
      Route metric is 20517120, traffic share count is 1
      Total delay is 20200 microseconds, minimum bandwidth is 128 Kbit
      Reliability 255/255, minimum MTU 1500 bytes
      Loading 1/255, Hops 2

R2# show ip route 172.16.20.4
Routing entry for 172.16.20.0/24
  Known via "connected", distance 0, metric 0 (connected, via interface)
  Redistributing via eigrp 1
  Routing Descriptor Blocks:
  * directly connected, via FastEthernet0/0
      Route metric is 0, traffic share count is 1

R3# show ip route 172.16.20.4
Routing entry for 172.16.20.0/24
  Known via "eigrp 1", distance 90, metric 20514560, type internal
  Redistributing via eigrp 1
  Last update from 172.16.203.2 on Serial0/0/1, 00:43:31 ago
  Routing Descriptor Blocks:
  * 172.16.203.2, from 172.16.203.2, 00:43:31 ago, via Serial0/0/1
      Route metric is 20514560, traffic share count is 1
      Total delay is 20100 microseconds, minimum bandwidth is 128 Kbit
      Reliability 255/255, minimum MTU 1500 bytes
      Loading 1/255, Hops 1
```

Begin the same extended ping on SW1 to the multicast group. Examine the debugging messages shown on each router.

```
R1# debug ip pim
*Nov  6 00:43:28.731: PIM(0): Send v2 Assert on Serial0/0/0 for 232.32.32.32,
source 172.16.20.4, metric [90/20517120]
*Nov  6 00:43:28.735: PIM(0): Assert metric to source 172.16.20.4 is
[90/20517120]
*Nov  6 00:43:28.735: PIM(0): We win, our metric [90/20517120]
*Nov  6 00:43:28.735: PIM(0): Prune Serial0/0/0/232.32.32.32 from
(172.16.20.4/32, 232.32.32.32)
*Nov  6 00:43:28.735: PIM(0): Pruning immediately Serial0/0/0 (p2p)
*Nov  6 00:43:28.743: PIM(0): Send v2 Assert on Serial0/0/1 for 232.32.32.32,
source 172.16.20.4, metric [90/20517120]
*Nov  6 00:43:28.743: PIM(0): Assert metric to source 172.16.20.4 is
[90/20517120]
*Nov  6 00:43:28.743: PIM(0): We win, our metric [90/20517120]
*Nov  6 00:43:28.743: PIM(0): Prune Serial0/0/1/232.32.32.32 from
(172.16.20.4/32, 232.32.32.32)
*Nov  6 00:43:28.743: PIM(0): Pruning immediately Serial0/0/1 (p2p)

... continues below ...
```


Because R1 has not yet received any PIMv2 assert messages from its neighbors on either Serial0/0/0 or Serial0/0/1, it has elected itself as the forwarder for (172.16.20.4/32, 232.32.32.32) on both interfaces and pruned other traffic flows.

On a point-to-point link, a PIM-DM router must assert itself as being the forwarder on the subnet for the group, unless another router sends an assert message with a lower metric to the source. This behavior allows PIM-DM to succeed in the simple case of a single multicast router on a subnet. In this case, the router cannot wait for other multicast routers to respond to the assert message before flooding multicast data; it must simply begin sending data until another router with a lower metric to the source prunes it.

Notice that the metrics used for route calculation are the EIGRP and composite metrics for the unicast IP routes to those source networks from the unicast routing table.

```
... continued from above ...

*Nov  6 00:43:28.751: PIM(0): Received v2 Assert on Serial0/0/1 from
172.16.103.3
*Nov  6 00:43:28.751: PIM(0): Assert metric to source 172.16.20.4 is
[90/20514560]
*Nov  6 00:43:28.751: PIM(0): We lose, our metric [90/20517120]
*Nov  6 00:43:28.751: PIM(0): (172.16.20.4/32, 232.32.32.32) oif Serial0/0/1
in Prune state
*Nov  6 00:43:28.751: PIM(0): Received v2 Assert on Serial0/0/0 from
172.16.102.2
*Nov  6 00:43:28.751: PIM(0): Assert metric to source 172.16.20.4 is [0/0]
*Nov  6 00:43:28.751: PIM(0): We lose, our metric [90/20517120]
*Nov  6 00:43:28.751: PIM(0): (172.16.20.4/32, 232.32.32.32) oif Serial0/0/0
in Prune state
*Nov  6 00:43:29.663: PIM(0): Received v2 Assert on Serial0/0/0 from
172.16.102.2
*Nov  6 00:43:29.663: PIM(0): Assert metric to source 172.16.20.4 is [0/0]
*Nov  6 00:43:29.663: PIM(0): We lose, our metric [90/20517120]
*Nov  6 00:43:29.663: PIM(0): (172.16.20.4/32, 232.32.32.32) oif Serial0/0/0
in Prune state
*Nov  6 00:43:29.751: PIM(0): Received v2 Assert on Serial0/0/1 from
172.16.103.3
*Nov  6 00:43:29.751: PIM(0): Assert metric to source 172.16.20.4 is
[90/20514560]
*Nov  6 00:43:29.751: PIM(0): We lose, our metric [90/20517120]
*Nov  6 00:43:29.751: PIM(0): (172.16.20.4/32, 232.32.32.32) oif Serial0/0/1
in Prune state
```

PIM selects the router with the lowest administrative distance to be the designated forwarder for the subnet for the (S, G) pair. In the case of a tie, PIM prefers the router with the lowest metric.

Step 7: Explore the Multicast Routing Table

Verify the state you predicted at the end of Step 5 about forwarding and pruning interfaces against the following output of the **show ip mroute** *source_address group_address* command:


```
R1# show ip mroute 172.16.20.4 232.32.32.32
<output omitted>

(172.16.20.4, 232.32.32.32), 00:01:07/00:02:58, flags: LT
  Incoming interface: FastEthernet0/0, RPF nbr 172.16.13.3
  Outgoing interface list:
    Loopback1, Forward/Dense, 00:01:07/00:00:00
    Serial0/0/1, Prune/Dense, 00:01:07/00:01:55
    Serial0/0/0, Prune/Dense, 00:01:07/00:01:55

R2# show ip mroute 172.16.20.4 232.32.32.32
<output omitted>

(172.16.20.4, 232.32.32.32), 00:01:21/00:02:58, flags: LT
  Incoming interface: FastEthernet0/0, RPF nbr 0.0.0.0
  Outgoing interface list:
    Loopback2, Forward/Dense, 00:01:21/00:00:00
    Serial0/0/0, Prune/Dense, 00:01:20/00:01:42, A
    Serial0/0/1, Forward/Dense, 00:01:21/00:00:00

R3# show ip mroute 172.16.20.4 232.32.32.32
<output omitted>

(172.16.20.4, 232.32.32.32), 00:01:22/00:02:59, flags: LT
  Incoming interface: Serial0/0/1, RPF nbr 172.16.203.2
  Outgoing interface list:
    Loopback3, Forward/Dense, 00:01:22/00:00:00
    Serial0/0/0, Prune/Dense, 00:01:22/00:01:40, A
    FastEthernet0/0, Forward/Dense, 00:01:22/00:00:00
```

How does PIM decide which incoming interface to use for each group?

Because PIM does not use its own topological algorithm to locate multicast sources, it must have a way of determining which interface faces the upstream neighbor of the tree stemming from the multicast source. PIM uses the reverse-path forwarding (RPF) check to find the interface closest to the source in terms of destination-based unicast routing.

Cisco IOS allows you to run RPF checks for specific sources with the **show ip rpf** *source_address* command. Use this command on R1 to find the incoming interface for the (172.16.20.4, 232.32.32.32) pair.

```
R1# show ip rpf 172.16.20.4
RPF information for ? (172.16.20.4)
  RPF interface: FastEthernet0/0
  RPF neighbor: ? (172.16.13.3)
  RPF route/mask: 172.16.20.0/24
  RPF type: unicast (eigrp 1)
  RPF recursion count: 0
  Doing distance-preferred lookups across tables
```

Although the multicast routing table includes RPF information, the **show ip rpf** command can be useful when debugging hidden multicast issues.

Use this output from R1 to answer the following questions:

```
R1# show ip mroute 172.16.20.4 232.32.32.32
<output omitted>

(172.16.20.4, 232.32.32.32), 00:01:07/00:02:58, flags: LT
  Incoming interface: FastEthernet0/0, RPF nbr 172.16.13.3
  Outgoing interface list:
    Loopback1, Forward/Dense, 00:01:07/00:00:00
    Serial0/0/1, Prune/Dense, 00:01:07/00:01:55
    Serial0/0/0, Prune/Dense, 00:01:07/00:01:55
```

What is the incoming interface for the (S, G) pair (172.16.20.4, 232.32.32.32)?

How does Cisco IOS assign this interface as the incoming interface?

Which neighboring router appears to R1 as being the next hop upstream toward the multicast source 172.16.20.4?

Challenge

If your simulation of the (S, G) pair (172.16.20.4, 232.32.32.32) correctly models the CEO's presentation to be shown later this week, do you think the presentation will be available on the loopback interfaces at all three sites?

Why does Cisco not recommend using PIM-DM in production networks?

Appendix A: TCL Script Output – Unicast

```
R1# tclsh
R1(tcl)#foreach address {
+>(tcl)#192.168.1.1
+>(tcl)#172.16.13.1
+>(tcl)#172.16.102.1
+>(tcl)#172.16.103.1
+>(tcl)#192.168.2.1
+>(tcl)#172.16.20.2
+>(tcl)#172.16.102.2
+>(tcl)#172.16.203.2
+>(tcl)#192.168.3.1
+>(tcl)#172.16.13.3
+>(tcl)#172.16.103.3
+>(tcl)#172.16.203.3
+>(tcl)#172.16.20.4
+>(tcl)#} { ping $address }

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.1.1, 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 172.16.13.1, 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 172.16.102.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 56/56/60 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.103.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 56/56/60 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.2.1, 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 172.16.20.2, 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 172.16.102.2, 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 172.16.203.2, 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 192.168.3.1, 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 172.16.13.3, 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 172.16.103.3, 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 172.16.203.3, 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 172.16.20.4, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/28/32 ms
R1(tcl)# tclquit

R2# tclsh
R2(tcl)#foreach address {
+>(tcl)#192.168.1.1
+>(tcl)#172.16.13.1
+>(tcl)#172.16.102.1
+>(tcl)#172.16.103.1
+>(tcl)#192.168.2.1
+>(tcl)#172.16.20.2
+>(tcl)#172.16.102.2
+>(tcl)#172.16.203.2
+>(tcl)#192.168.3.1
+>(tcl)#172.16.13.3
+>(tcl)#172.16.103.3
+>(tcl)#172.16.203.3
+>(tcl)#172.16.20.4
+>(tcl)#} { ping $address }

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.1.1, 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 172.16.13.1, 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 172.16.102.1, 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 172.16.103.1, 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 192.168.2.1, 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 172.16.20.2, 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 172.16.102.2, 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 172.16.203.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 56/58/68 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.3.1, 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 172.16.13.3, 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 172.16.103.3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 40/42/44 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.203.3, 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 172.16.20.4, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/4 ms
R2(tcl)# tclquit

R3# tclsh
R3(tcl)#foreach address {
+>(tcl)#192.168.1.1
+>(tcl)#172.16.13.1
+>(tcl)#172.16.102.1
+>(tcl)#172.16.103.1
+>(tcl)#192.168.2.1
+>(tcl)#172.16.20.2
+>(tcl)#172.16.102.2
+>(tcl)#172.16.203.2
+>(tcl)#192.168.3.1
+>(tcl)#172.16.13.3
+>(tcl)#172.16.103.3
+>(tcl)#172.16.203.3
+>(tcl)#172.16.20.4
+>(tcl)#} { ping $address }

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.1.1, 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 172.16.13.1, 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 172.16.102.1, 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 172.16.103.1, 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 192.168.2.1, 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 172.16.20.2, 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 172.16.102.2, 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 172.16.203.2, 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 192.168.3.1, 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 172.16.13.3, 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 172.16.103.3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 56/56/60 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.203.3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 56/58/64 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.20.4, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/28/32 ms
R3(tcl)# tclquit
```

Final Configurations

```
R1# show run
!
hostname R1
!
interface Loopback1
 ip address 192.168.1.1 255.255.255.0
 ip pim dense-mode
 ip igmp join-group 232.32.32.32
!
interface FastEthernet0/0
 ip address 172.16.13.1 255.255.255.0
 ip pim dense-mode
 no shutdown
!
interface Serial0/0/0
 bandwidth 64
 ip address 172.16.102.1 255.255.255.248
 ip pim dense-mode
 clock rate 64000
 no shutdown
!
interface Serial0/0/1
 bandwidth 64
 ip address 172.16.103.1 255.255.255.248
 ip pim dense-mode
 no shutdown
!
router eigrp 1
 network 172.16.0.0
 network 192.168.0.0 0.0.255.255
 auto-summary
!
end
```



```
R2# show run
!
hostname R2
!
interface Loopback2
 ip address 192.168.2.1 255.255.255.0
 ip pim dense-mode
 ip igmp join-group 232.32.32.32
!
interface FastEthernet0/0
 ip address 172.16.20.2 255.255.255.0
 ip pim dense-mode
 no shutdown
!
interface Serial0/0/0
 bandwidth 64
 ip address 172.16.102.2 255.255.255.248
 ip pim dense-mode
 no shutdown
!
interface Serial0/0/1
 bandwidth 128
 ip address 172.16.203.2 255.255.255.248
 ip pim dense-mode
 clock rate 128000
 no shutdown
!
router eigrp 1
 network 172.16.0.0
 network 192.168.0.0 0.0.255.255
 auto-summary
@
end
```

```
R3# show run
!
hostname R3
!
interface Loopback3
 ip address 192.168.3.1 255.255.255.0
 ip pim dense-mode
 ip igmp join-group 232.32.32.32
!
interface FastEthernet0/0
 ip address 172.16.13.3 255.255.255.0
 ip pim dense-mode
 no shutdown
!
interface Serial0/0/0
 bandwidth 64
 ip address 172.16.103.3 255.255.255.248
 ip pim dense-mode
 clock rate 64000
 no shutdown
!
interface Serial0/0/1
 bandwidth 128
 ip address 172.16.203.3 255.255.255.248
 ip pim dense-mode
 no shutdown
!
router eigrp 1
 network 172.16.0.0
```



```
 network 192.168.0.0 0.0.255.255
 auto-summary
!
emd


SW1# show run
!
hostname SW1
!
interface FastEthernet0/1
 switchport access vlan 13
 switchport mode access
!
interface FastEthernet0/3
 switchport access vlan 20
 switchport mode access
!
interface FastEthernet0/5
 switchport access vlan 13
 switchport mode access
!
interface Vlan20
 ip address 172.16.20.4 255.255.255.0
 no shutdown
!
ip default-gateway 172.16.20.2
!
end
```

