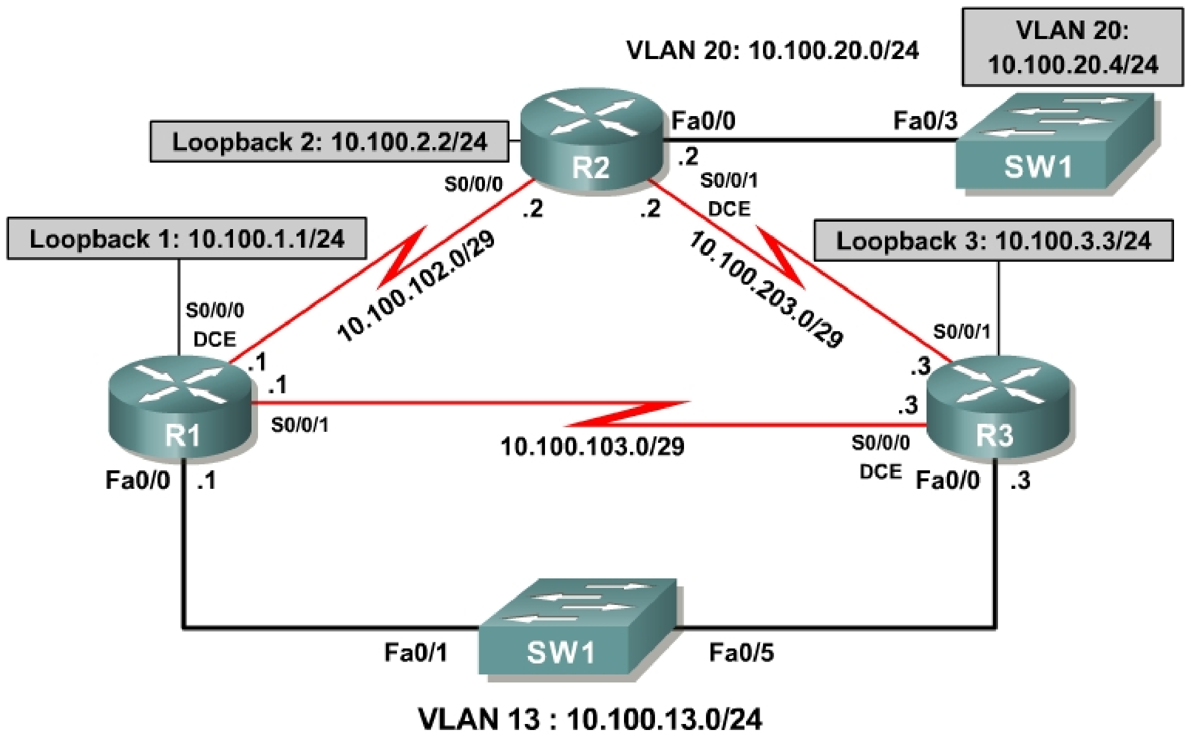
Lab 7-4 Routing IP Multicast with PIM Sparse-Dense Mode

Learning Objectives

- Configure multiple multicast sources and groups via IGMP
- Configure and verify PIM sparse-dense mode operation and adjacencies
- Configure and verify automatic rendezvous points and mapping agents
- Force PIM sparse-dense mode to fail over to dense mode operation

Topology Diagram



Scenario

After the incredible community response to CrushASodaCan.com TV spots, a skeptical citizen began questioning the usefulness of crushing aluminum cans before recycling them. After conducting a thorough case study, he founded the organization JustRecycleTheCan.org, and began producing TV announcements encouraging citizens to recycle but informing them that it is unnecessary to crush cans before committing them to the safe care of a recycle bin.

The founder of JustRecycleTheCan.org has contracted you to implement multicast on his network so that he can also preview TV spots before releasing them to the public. However, he requests that you implement PIM in a more redundant, scalable manner than you did for CrushASodaCan.com.

Fully configure multicast routing on his network according to the requests of the founder of the organization. Verify that if the route to the rendezvous point (RP) is lost, multicast receivers on remote networks can still receive multicast streams.

Step 1: Configure Addressing and Implement IGMP

Paste in the following initial configurations:

R1:

```
!
hostname R1
!
interface Loopback1
 ip address 10.100.1.1 255.255.255.0
!
interface FastEthernet0/0
 ip address 10.100.13.1 255.255.255.0
 no shutdown
!
interface Serial0/0/0
 bandwidth 64
 ip address 10.100.102.1 255.255.255.248
 clock rate 64000
 no shutdown
!
interface Serial0/0/1
 bandwidth 64
 ip address 10.100.103.1 255.255.255.248
 no shutdown
!
end
```

R2:

```
!
hostname R2
!
interface Loopback2
 ip address 10.100.2.2 255.255.255.0
!
interface FastEthernet0/0
 ip address 10.100.20.2 255.255.255.0
 no shutdown
!
interface Serial0/0/0
 bandwidth 64
 ip address 10.100.102.2 255.255.255.248
 no shutdown
!
interface Serial0/0/1
 bandwidth 128
 ip address 10.100.203.2 255.255.255.248
 clock rate 128000
 no shutdown
!
end
```


R3:

```
!
hostname R3
!
interface Loopback3
 ip address 10.100.3.3 255.255.255.0
!
interface FastEthernet0/0
 ip address 10.100.13.3 255.255.255.0
 no shutdown
!
interface Serial0/0/0
 bandwidth 64
 ip address 10.100.103.3 255.255.255.248
 clock rate 64000
 no shutdown
!
interface Serial0/0/1
 bandwidth 128
 ip address 10.100.203.3 255.255.255.248
 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. Use this SVI to send a repeated multicast ping that simulates multicast traffic while you set up the network. Assign the SVI the IP address 10.100.20.4/24 with a default gateway of 10.100.20.2.

```
SW1# conf t
SW1(config)# ip default-gateway 10.100.20.2
SW1(config)# interface vlan 20
SW1(config-if)# ip address 10.100.20.4 255.255.255.0
SW1(config-if)# no shutdown
```

Using IGMP, subscribe each of the loopback interfaces on the three routers to the multicast groups 225.25.25.25. Subscribe R1 and R3 loopbacks to 226.26.26.26 as well.

```
R1# conf t
R1(config)# interface loopback 1
R1(config-if)# ip igmp join-group 225.25.25.25
```



```
R1(config-if)# ip igmp join-group 226.26.26.26

R2# conf t
R2(config)# interface loopback 2
R2(config-if)# ip igmp join-group 225.25.25.25

R3# conf t
R3(config)# interface loopback 3
R3(config-if)# ip igmp join-group 225.25.25.25
R3(config-if)# ip igmp join-group 226.26.26.26
```

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
226.26.26.26    Loopback1   00:01:51  00:02:03  10.100.1.1
225.25.25.25    Loopback1   00:01:51  00:02:03  10.100.1.1
R2# show ip igmp groups
IGMP Connected Group Membership
Group Address   Interface   Uptime    Expires   Last Reporter   Group Accounted
225.25.25.25    Loopback2   00:01:51  00:02:03  10.100.2.2

R3# show ip igmp groups
IGMP Connected Group Membership
Group Address   Interface   Uptime    Expires   Last Reporter   Group Accounted
226.26.26.26    Loopback3   00:01:51  00:02:03  10.100.3.3
225.25.25.25    Loopback3   00:01:51  00:02:03  10.100.3.3
```

Step 2: Configure Single-Area OSPF

Configure single-area OSPF on each router with the following configuration:

```
router ospf 1
 network 10.0.0.0 0.255.255.255 area 0
```

After you apply this configuration and the OSPF adjacencies form, run the following TCL script to verify full unicast connectivity:

```
foreach address {
10.100.1.1
10.100.13.1
10.100.102.1
10.100.103.1
10.100.2.2
10.100.20.2
10.100.102.2
10.100.203.2
10.100.3.3
10.100.13.3
10.100.103.3
10.100.203.3
10.100.20.4
} { ping $address }
```

Compare the output you receive with the output found in Appendix A (all pings successful). Make sure that you have ICMP replies from the SVI interface on SW1. If SW1 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 SVI address and receive all replies.

Step 3: Implement PIM Sparse-Dense Mode

First, enable your routers to accumulate and maintain multicast state using the **ip multicast-routing** command in global configuration mode.

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

R2(config)# ip multicast-routing

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

Next, enable PIM sparse-dense mode on all interfaces using the **ip pim sparse-dense-mode** command in interface configuration mode.

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

R2(config)# interface loopback 2
R2(config-if)# ip pim sparse-dense-mode
R2(config-if)# interface fastethernet 0/0
R2(config-if)# ip pim sparse-dense-mode
R2(config-if)# interface serial 0/0/0
R2(config-if)# ip pim sparse-dense-mode
R2(config-if)# interface serial 0/0/1
R2(config-if)# ip pim sparse-dense-mode

R3(config)# interface loopback 3
R3(config-if)# ip pim sparse-dense-mode
R3(config-if)# interface fastethernet 0/0
R3(config-if)# ip pim sparse-dense-mode
R3(config-if)# interface serial 0/0/0
R3(config-if)# ip pim sparse-dense-mode
R3(config-if)# interface serial 0/0/1
R3(config-if)# ip pim sparse-dense-mode
```

After completing the previous two labs, you should have an idea of how PIM-SM operates. The following questions test your understanding of the concepts.

What is the purpose of the PIM-SM rendezvous point?

If no rendezvous points are reachable in an PIM-SM network, what functionality is lost? (Hint: Will PIMv2 Register messages be sent?)

If you implement PIM-SM with a static RP as in Lab 7.3, which routers identify the RP? Which routers identify the group-to-RP mappings?

Other than configuring a static RP globally for a network or on a per-group basis, which other ways can you configure an RP in sparse mode or sparse-dense mode? Why are other methods useful?

As shown in the last lab, it is important to locate RPs in locations that are reachable via a unicast routing protocol when available. In this lab, you will configure two RP candidates for the 225.25.25.25 multicast group. Allow only R1 to be elected as the RP for the 226.26.26.26 group, but discover all RP candidates dynamically. Use PIM sparse-dense mode and Auto-RP to achieve this functionality.

PIM sparse-dense mode manages multicast groups dynamically between sparse mode and dense mode. Sparse-dense mode applies sparse mode processes and algorithms to any multicast groups for which it can discover an RP via static configuration, Auto-RP, or the more advanced Bootstrap Router (BSR) process. All multicast groups for which a sparse-dense mode router cannot discover an RP run in PIM-DM. This applies to PIM-SM networks as well. This process is referred to as dense mode fallback and can be disabled with the **no ip pim dm-fallback** command in global configuration mode.

Without additional configuration, will the multicast groups 225.25.25.25 and 226.26.26.26 effectively operate in sparse mode or dense mode? Explain.

Will a ping from SW1 to the 225.25.25.25 group receive any replies? Explain.

Issue a stream of multicast pings from the SVI on SW1 to generate the (S, G) state on your routers.

```
SW1# ping
Protocol [ip]:
Target IP address: 225.25.25.25
Repeat count [1]: 1
Datagram size [100]:
Timeout in seconds [2]:
Extended commands [n]:
Sweep range of sizes [n]:
Type escape sequence to abort.
Sending 1, 100-byte ICMP Echos to 225.25.25.25, timeout is 2 seconds:

Reply to request 0 from 10.100.20.2, 8 ms
Reply to request 0 from 10.100.13.1, 32 ms
Reply to request 0 from 10.100.203.3, 20 ms
```

Display the multicast routing table on each router with the **show ip mroute** command.

```
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

(*, 226.26.26.26), 00:49:00/00:02:48, RP 0.0.0.0, flags: DCL
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Serial0/0/0, Forward/Sparse-Dense, 00:47:56/00:00:00
    Serial0/0/1, Forward/Sparse-Dense, 00:48:30/00:00:00
    FastEthernet0/0, Forward/Sparse-Dense, 00:48:38/00:00:00
    Loopback1, Forward/Sparse-Dense, 00:49:00/00:00:00

(*, 225.25.25.25), 00:50:35/stopped, RP 0.0.0.0, flags: DCL
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Serial0/0/0, Forward/Sparse-Dense, 00:47:57/00:00:00
    Serial0/0/1, Forward/Sparse-Dense, 00:48:31/00:00:00
    FastEthernet0/0, Forward/Sparse-Dense, 00:48:39/00:00:00
    Loopback1, Forward/Sparse-Dense, 00:50:35/00:00:00

(10.100.20.4, 225.25.25.25), 00:00:43/00:02:58, flags: LT
  Incoming interface: FastEthernet0/0, RPF nbr 10.100.13.3
  Outgoing interface list:
    Loopback1, Forward/Sparse-Dense, 00:00:51/00:00:00
    Serial0/0/1, Prune/Sparse-Dense, 00:00:51/00:02:11
    Serial0/0/0, Prune/Sparse-Dense, 00:00:51/00:02:11

(*, 224.0.1.40), 00:50:43/00:02:47, RP 0.0.0.0, flags: DCL
  Incoming interface: Null, RPF nbr 0.0.0.0
```



```
  Outgoing interface list:
    Serial0/0/0, Forward/Sparse-Dense, 00:48:05/00:00:00
    Serial0/0/1, Forward/Sparse-Dense, 00:48:39/00:00:00
    FastEthernet0/0, Forward/Sparse-Dense, 00:48:47/00:00:00
    Loopback1, Forward/Sparse-Dense, 00:50:43/00:00:00

R2# show ip mroute
<output omitted>

(*, 225.25.25.25), 00:00:45/stopped, RP 0.0.0.0, flags: DL
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Serial0/0/1, Forward/Sparse-Dense, 00:00:45/00:00:00
    Serial0/0/0, Forward/Sparse-Dense, 00:00:45/00:00:00

(10.100.20.4, 225.25.25.25), 00:00:45/00:03:01, flags: LT
  Incoming interface: FastEthernet0/0, RPF nbr 0.0.0.0
  Outgoing interface list:
    Serial0/0/0, Prune/Sparse-Dense, 00:00:45/00:02:17, A
    Serial0/0/1, Forward/Sparse-Dense, 00:00:46/00:00:00

(*, 224.0.1.40), 00:48:03/00:02:48, RP 0.0.0.0, flags: DCL
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Serial0/0/1, Forward/Sparse-Dense, 00:47:56/00:00:00
    Serial0/0/0, Forward/Sparse-Dense, 00:48:00/00:00:00
    FastEthernet0/0, Forward/Sparse-Dense, 00:48:03/00:00:00

R3# show ip mroute
<output omitted>

(*, 226.26.26.26), 00:00:03/00:02:58, RP 0.0.0.0, flags: DCL
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Serial0/0/1, Forward/Sparse-Dense, 00:00:03/00:00:00
    Serial0/0/0, Forward/Sparse-Dense, 00:00:03/00:00:00
    FastEthernet0/0, Forward/Sparse-Dense, 00:00:03/00:00:00
    Loopback3, Forward/Sparse-Dense, 00:00:03/00:00:00

(*, 225.25.25.25), 00:00:05/00:02:55, RP 0.0.0.0, flags: DCL
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Serial0/0/1, Forward/Sparse-Dense, 00:00:05/00:00:00
    Serial0/0/0, Forward/Sparse-Dense, 00:00:05/00:00:00
    FastEthernet0/0, Forward/Sparse-Dense, 00:00:05/00:00:00
    Loopback3, Forward/Sparse-Dense, 00:00:05/00:00:00

(10.100.20.4, 225.25.25.25), 00:03:26/00:02:56, flags: LT
  Incoming interface: Serial0/0/1, RPF nbr 10.100.203.2
  Outgoing interface list:
    FastEthernet0/0, Forward/Sparse-Dense, 00:03:27/00:00:00
    Serial0/0/0, Prune/Sparse-Dense, 00:00:22/00:02:40, A

(*, 224.0.1.40), 00:51:23/00:02:05, RP 0.0.0.0, flags: DCL
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Serial0/0/1, Forward/Sparse-Dense, 00:50:37/00:00:00
    Serial0/0/0, Forward/Sparse-Dense, 00:51:15/00:00:00
    FastEthernet0/0, Forward/Sparse-Dense, 00:51:23/00:00:00
```

Referring to the output above, in which mode is PIM operating if it is not relying on the shared tree to connect it with receivers?

How is this indicated in the multicast routing tables?

If your output differs from that shown above, verify that you have configured PIM sparse-dense mode correctly on all interfaces by using the **show ip pim interface** command. Make sure that all PIM adjacencies are active by using the **show ip pim neighbor** command.

Step 4: Configure PIM Auto-RP

PIM now operates successfully, but you can configure the routers to use bandwidth more efficiently by forcing multicast groups to use PIM-SM.

PIM-SM rendezvous points introduce multicast sources by acting as a network receptionist that knows the location of all multicast sources for specific groups. PIM-SM creates shared distribution trees for multicast groups represented by (*, G) in each multicast routing table. This shared tree is calculated using the RPF upstream interface to the RP for that group. Thus, the shared tree is essentially a shortest-path tree to the RP address.

When you configured the interfaces in sparse-dense mode, every router implicitly subscribed to the RP Discovery group 224.0.1.40. Use the **show ip igmp groups** command to verify this. Each router applies the information it receives about group-to-RP mappings via the RP Discovery group to its multicast routing table entries.

```
R1# show ip igmp groups
IGMP Connected Group Membership
Group Address    Interface                Uptime    Expires   Last Reporter
Group Accounted
226.26.26.26     Loopback1                00:42:38  00:02:14  10.100.1.1
225.25.25.25     Loopback1                00:42:38  00:02:09  10.100.1.1
224.0.1.40       FastEthernet0/0          00:41:44  00:02:10  10.100.13.3
224.0.1.40       Loopback1                00:42:38  00:02:13  10.100.1.1
```

When configuring interfaces running only PIM-SM, you also need to apply the **ip pim autorp listener** command to each sparse mode interface. This command allows RP mapping messages to be read by multicast routers and propagated throughout the network in dense mode fashion. Because sparse-dense mode acts in a PIM-DM fashion without an RP for the group, you achieve the same functionality without applying the command.

By default, sparse-dense mode also enables the installation of RP mapping information into the multicast routing table. Verify this with the **show ip pim autorp** command.

```
R1# show ip pim autorp
AutoRP Information:
  AutoRP is enabled.

PIM AutoRP Statistics: Sent/Received
  RP Announce: 0/0, RP Discovery: 0/0
```

Enable the advertisement of Auto-RP information for the specified groups on R1 and R3. Configure R1 to candidate as an RP for both groups. Allow R3 to only apply as a candidate for the 226.26.26.26 group. Configure access lists to control the groups for which Auto-RP information is sent. Finally, apply these access lists with the **ip pim send-rp-announce** {*interface-type interface-number* **|** *ip-address*} **scope** *ttl-value* [**group-list** *access-list*] command. The RP candidates should be the loopback interfaces on R1 and R3. Use a time-to-live (TTL) value of 3 so that RP announcements are not discarded anywhere in your existing network. The scope determines the number of times a multicast packet is routed at Layer 3 before being discarded because the TTL has reached 0.

```
R1(config)# access-list 1 permit 225.25.25.25
R1(config)# access-list 1 permit 226.26.26.26
R1(config)# ip pim send-rp-announce Loopback 1 scope 3 group-list 1

R3(config)# access-list 3 permit 226.26.26.26
R3(config)# ip pim send-rp-announce Loopback 3 scope 3 group-list 3
```

Enable PIM Auto-RP debugging with the **debug ip pim auto-rp** command on R1 and R3. The following excerpt shows that Auto-RP announcements are sent periodically, indicating that the announcements are being flooded from the local router.

```
R1# debug ip pim auto-rp
*Nov  7 16:08:05.803: Auto-RP(0): Build RP-Announce for 10.100.1.1, PIMv2/v1,
ttl 3, ht 181
*Nov  7 16:08:05.803: Auto-RP(0):  Build announce entry for (225.25.25.25/32)
*Nov  7 16:08:05.803: Auto-RP(0):  Build announce entry for (226.26.26.26/32)
*Nov  7 16:08:05.803: Auto-RP(0): Send RP-Announce packet on FastEthernet0/0
*Nov  7 16:08:05.803: Auto-RP(0): Send RP-Announce packet on Serial0/0/0
*Nov  7 16:08:05.803: Auto-RP(0): Send RP-Announce packet on Serial0/0/1
*Nov  7 16:08:05.803: Auto-RP: Send RP-Announce packet on Loopback1
```

Continue debugging Auto-RP messages while you configure the mapping agent.

PIM-SM networks using Auto-RP also need one or more mapping agents to inform routers that are listening to the Auto-RP group of the group-to-RP mappings. Configure R1 as the mapping agent for this network using the **ip pim send-rp-discovery** [*interface-type interface-number*] **scope** *ttl-value* command to generate group-to-RP mapping messages from R1.

```
R1(config)# ip pim send-rp-discovery Loopback 1 scope 3
```


You should see the following debug output on R1:

```
R1#
*Nov  7 16:26:08.803: Auto-RP(0): Build RP-Announce for 10.100.1.1, PIMv2/v1,
ttl 3, ht 181
*Nov  7 16:26:08.803: Auto-RP(0):  Build announce entry for (225.25.25.25/32)
*Nov  7 16:26:08.803: Auto-RP(0):  Build announce entry for (226.26.26.26/32)
*Nov  7 16:26:08.803: Auto-RP(0): Send RP-Announce packet on FastEthernet0/0
*Nov  7 16:26:08.803: Auto-RP(0): Send RP-Announce packet on Serial0/0/0
*Nov  7 16:26:08.803: Auto-RP(0): Send RP-Announce packet on Serial0/0/1
*Nov  7 16:26:08.803: Auto-RP: Send RP-Announce packet on Loopback1
  ... continued below ...
```

Because you previously configured R1 as an RP candidate, it advertises itself as an RP for the 225.25.25.25 and 226.26.26.26 groups. However, no router will select R1 as the confirmed RP for those groups until it hears from the mapping agent. R1 continues to multicast its announcements of RP candidacy out all interfaces.

```
  ... continued from above ...
R1#
*Nov  7 16:26:08.803: Auto-RP(0): Received RP-announce, from 10.100.1.1,
RP_cnt 1, ht 181
*Nov  7 16:26:08.803: Auto-RP(0): Added with (225.25.25.25/32, RP:10.100.1.1),
PIMv2 v1
*Nov  7 16:26:08.803: Auto-RP(0): Added with (226.26.26.26/32, RP:10.100.1.1),
PIMv2 v1
*Nov  7 16:26:08.807: Auto-RP(0): Build RP-Discovery packet
*Nov  7 16:26:08.807: Auto-RP:  Build mapping (225.25.25.25/32,
RP:10.100.1.1), PIMv2 v1,
*Nov  7 16:26:08.807: Auto-RP:  Build mapping (226.26.26.26/32,
RP:10.100.1.1), PIMv2 v1.
*Nov  7 16:26:08.811: Auto-RP(0): Send RP-discovery packet on FastEthernet0/0
(1 RP entries)
*Nov  7 16:26:08.811: Auto-RP(0): Send RP-discovery packet on Serial0/0/0 (1
RP entries)
*Nov  7 16:26:08.811: Auto-RP(0): Send RP-discovery packet on Serial0/0/1 (1
RP entries)
*Nov  7 16:26:08.811: Auto-RP: Send RP-discovery packet on Loopback1 (1 RP
entries)
```

The router acting as a mapping agent, which in this case is also R1, receives the candidacy announcement that the Auto-RP process on R1 just sent to the 224.0.1.39 Auto-RP announcement group.

R1, acting as an RP mapping agent, elects R1 as the RP for both groups because it has not received any other RP announcements with higher source IP addresses. The mapping agent sends the two group-to-RP mappings via multicast to all Auto-RP listeners in the network. The mappings are sent to the Auto-RP discovery group 224.0.1.40.

```
  ... continued from above ...
R1#
*Nov  7 16:26:08.819: Auto-RP(0): Received RP-announce, from 10.100.1.1,
RP_cnt 1, ht 181
*Nov  7 16:26:08.819: Auto-RP(0): Update (225.25.25.25/32, RP:10.100.1.1),
PIMv2 v1
```



```
*Nov  7 16:26:08.819: Auto-RP(0): Update (226.26.26.26/32, RP:10.100.1.1),
PIMv2 v1
*Nov  7 16:26:08.819: Auto-RP(0): Received RP-announce, from 10.100.1.1,
RP_cnt 1, ht 181
*Nov  7 16:26:08.819: Auto-RP(0): Update (225.25.25.25/32, RP:10.100.1.1),
PIMv2 v1
*Nov  7 16:26:08.823: Auto-RP(0): Update (226.26.26.26/32, RP:10.100.1.1),
PIMv2 v1
  ... continued below ...
```

The Auto-RP messages that R1 sent previously are received back again on different interfaces because of the dense-mode flooding throughout the network. R1 simply installs the group-to-RP mappings in its table again.

```
  ... continued from above ...
R1#
*Nov  7 16:26:36.911: Auto-RP(0): Received RP-announce, from 10.100.3.3,
RP_cnt 1, ht 181
*Nov  7 16:26:36.911: Auto-RP(0): Added with (226.26.26.26/32, RP:10.100.3.3),
PIMv2 v1
*Nov  7 16:26:36.915: Auto-RP(0): Build RP-Discovery packet
*Nov  7 16:26:36.915: Auto-RP:  Build mapping (225.25.25.25/32,
RP:10.100.1.1), PIMv2 v1,
*Nov  7 16:26:36.915: Auto-RP:  Build mapping (226.26.26.26/32,
RP:10.100.3.3), PIMv2 v1.
*Nov  7 16:26:36.915: Auto-RP(0): Send RP-discovery packet on FastEthernet0/0
(2 RP entries)
*Nov  7 16:26:36.915: Auto-RP(0): Send RP-discovery packet on Serial0/0/0 (2
RP entries)
R1#
*Nov  7 16:26:36.915: Auto-RP(0): Send RP-discovery packet on Serial0/0/1 (2
RP entries)
*Nov  7 16:26:36.915: Auto-RP: Send RP-discovery packet on Loopback1 (2 RP
entries)
```

Within a short amount of time, R3 sends its candidacy announcement for the 226.26.26.26 multicast group. R1 receives this packet and, acting as the RP mapping agent, evaluates it against the existing RP. Since the IP address of 10.100.3.3 is higher than 10.100.1.1, the mapping agent elects R3 as the RP for 226.26.26.26. R1 remains the RP for the 225.25.25.25 group.

R1 sends notification of the winners of the group-to-RP elections to the 224.0.1.40 RP Discovery group. All multicast routers running PIM-SM or sparse-dense mode have been implicitly subscribed to this group and install this information in their multicast routing tables.

During this time, the PIM protocol running on R3 has logged the following output. Analyze the Auto-RP election from R3’s perspective.

```
R3#
*Nov  7 16:26:48.763: Auto-RP(0): Received RP-discovery, from 10.100.1.1,
RP_cnt 1, ht 181
*Nov  7 16:26:48.763: Auto-RP(0): Added with (225.25.25.25/32, RP:10.100.1.1),
PIMv2 v1
*Nov  7 16:26:48.763: Auto-RP(0): Added with (226.26.26.26/32, RP:10.100.1.1),
PIMv2 v1
R3#
```



```
*Nov  7 16:27:16.863: Auto-RP(0): Build RP-Announce for 10.100.3.3, PIMv2/v1,
ttl 3, ht 181
*Nov  7 16:27:16.863: Auto-RP(0):  Build announce entry for (226.26.26.26/32)
*Nov  7 16:27:16.863: Auto-RP(0): Send RP-Announce packet on FastEthernet0/0
*Nov  7 16:27:16.863: Auto-RP(0): Send RP-Announce packet on Serial0/0/0
*Nov  7 16:27:16.863: Auto-RP(0): Send RP-Announce packet on Serial0/0/1
*Nov  7 16:27:16.863: Auto-RP: Send RP-Announce packet on Loopback3
*Nov  7 16:27:16.871: Auto-RP(0): Received RP-discovery, from 10.100.1.1,
RP_cnt 2, ht 181
*Nov  7 16:27:16.871: Auto-RP(0): Update (225.25.25.25/32, RP:10.100.1.1),
PIMv2 v1
*Nov  7 16:27:16.871: Auto-RP(0): Added with (226.26.26.26/32, RP:10.100.3.3),
PIMv2 v1
```

Notice that when R1 floods the first RP discovery packet, the mapping agent has not yet received an Auto-RP announcement packet from R3. After R3 sends the announcement, the mapping agent compares the IP addresses of the two candidates for the 226.26.26.26 network and elects R3 as the RP. R1 then floods the new group-to-RP mappings to all routers within its scope via multicast.

Issue the **undebug all** command on R1 and R3 to stop debugging PIM Auto-RP events.

```
R1# undebug all
```

```
R3# undebug all
```

Step 5: Verify the RP Mappings

Use the **show ip pim rp** command on the Auto-RP routers to view group-to-RP mappings.

```
R1# show ip pim rp
Group: 226.26.26.26, RP: 10.100.3.3, v2, v1, uptime 00:53:51, expires 00:02:03
Group: 225.25.25.25, RP: 10.100.1.1, v2, v1, next RP-reachable in 00:01:10
```

```
R3# show ip pim rp
Group: 226.26.26.26, RP: 10.100.3.3, v2, v1, next RP-reachable in 00:01:17
Group: 225.25.25.25, RP: 10.100.1.1, v2, v1, uptime 00:54:40, expires 00:02:23
```

For a full view of the group-to-RP mappings, issue the **show ip pim rp mapping** command on all routers. This command discloses how the RP was elected and which router performed the mapping. It is extremely useful in debugging Auto-RP elections.

```
R1# show ip pim rp mapping
PIM Group-to-RP Mappings
This system is an RP (Auto-RP)
This system is an RP-mapping agent (Loopback1)

Group(s) 225.25.25.25/32
  RP 10.100.1.1 (?), v2v1
    Info source: 10.100.1.1 (?), elected via Auto-RP
         Uptime: 00:54:25, expires: 00:02:34
Group(s) 226.26.26.26/32
  RP 10.100.3.3 (?), v2v1
```



```
    Info source: 10.100.3.3 (?), elected via Auto-RP
         Uptime: 00:53:57, expires: 00:01:58
  RP 10.100.1.1 (?), v2v1
    Info source: 10.100.1.1 (?), via Auto-RP
         Uptime: 00:54:25, expires: 00:02:32

R2# show ip pim rp mapping
PIM Group-to-RP Mappings

Group(s) 225.25.25.25/32
  RP 10.100.1.1 (?), v2v1
    Info source: 10.100.1.1 (?), elected via Auto-RP
         Uptime: 00:58:36, expires: 00:02:24
Group(s) 226.26.26.26/32
  RP 10.100.3.3 (?), v2v1
    Info source: 10.100.1.1 (?), elected via Auto-RP
         Uptime: 00:54:06, expires: 00:02:27

R3# show ip pim rp mapping
PIM Group-to-RP Mappings
This system is an RP (Auto-RP)

Group(s) 225.25.25.25/32
  RP 10.100.1.1 (?), v2v1
    Info source: 10.100.1.1 (?), elected via Auto-RP
         Uptime: 00:54:44, expires: 00:02:20
Group(s) 226.26.26.26/32
  RP 10.100.3.3 (?), v2v1
    Info source: 10.100.1.1 (?), elected via Auto-RP
         Uptime: 00:54:16, expires: 00:02:15
```

How did each router learn these mappings?

Because you configured R1 as a mapping agent, PIM routers that are not elected as the Auto-RP track the number of RP discovery messages received. Verify this with the **show ip pim autorp** command on R2.

```
R2# show ip pim autorp
AutoRP Information:
  AutoRP is enabled.

PIM AutoRP Statistics: Sent/Received
  RP Announce: 0/0, RP Discovery: 0/96
```

Step 6: Verify Multicast Operation

Issue multicast pings to generate the (S, G) state in the multicast network. Use a repeat count of 100 to generate a stream of multicast packets flowing through the network.

```
SW1# ping
Protocol [ip]:
Target IP address: 225.25.25.25
Repeat count [1]: 1
```



```
Datagram size [100]:
Timeout in seconds [2]:
Extended commands [n]:
Sweep range of sizes [n]:
Type escape sequence to abort.
Sending 1, 100-byte ICMP Echos to 225.25.25.25, timeout is 2 seconds:

Reply to request 0 from 10.100.20.2, 8 ms
Reply to request 0 from 10.100.13.1, 32 ms
Reply to request 0 from 10.100.203.3, 20 ms
Reply to request 0 from 10.100.20.2, 8 ms
Reply to request 0 from 10.100.13.1, 32 ms
Reply to request 0 from 10.100.203.3, 20 ms
Reply to request 0 from 10.100.20.2, 8 ms
Reply to request 0 from 10.100.13.1, 32 ms
Reply to request 0 from 10.100.203.3, 20 ms
 ...
```

Display the multicast routing entry for 225.25.25.25 on each router with the **show ip mroute** *group-address* command.

```
R1# show ip mroute 225.25.25.25
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

(*, 225.25.25.25), 02:39:52/00:03:20, RP 10.100.1.1, flags: SJCL
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    FastEthernet0/0, Forward/Sparse-Dense, 00:18:52/00:03:20
    Loopback1, Forward/Sparse-Dense, 02:39:52/00:02:15

(10.100.20.4, 225.25.25.25), 00:03:14/00:02:59, flags: LT
  Incoming interface: FastEthernet0/0, RPF nbr 10.100.13.3
  Outgoing interface list:
    Loopback1, Forward/Sparse-Dense, 00:03:15/00:02:14

R2# show ip mroute 225.25.25.25
<output omitted>

(*, 225.25.25.25), 00:02:36/stopped, RP 10.100.1.1, flags: SJPLF
  Incoming interface: Serial0/0/1, RPF nbr 10.100.203.3
  Outgoing interface list: Null

(10.100.20.4, 225.25.25.25), 00:02:36/00:03:28, flags: LFT
  Incoming interface: FastEthernet0/0, RPF nbr 0.0.0.0
  Outgoing interface list:
    Serial0/0/1, Forward/Sparse-Dense, 00:02:36/00:02:52

R3# show ip mroute 225.25.25.25
<output omitted>

(*, 225.25.25.25), 00:19:07/00:02:59, RP 10.100.1.1, flags: SJCL
  Incoming interface: FastEthernet0/0, RPF nbr 10.100.13.1
```



```
  Outgoing interface list:
    Serial0/0/1, Forward/Sparse-Dense, 00:02:29/00:02:59
    Loopback3, Forward/Sparse-Dense, 00:19:05/00:02:02

(10.100.20.4, 225.25.25.25), 00:03:27/00:03:27, flags: LT
  Incoming interface: Serial0/0/1, RPF nbr 10.100.203.2
  Outgoing interface list:
    FastEthernet0/0, Forward/Sparse-Dense, 00:03:28/00:03:11
    Loopback3, Forward/Sparse-Dense, 00:03:28/00:02:01
```

Which PIM mode is the 225.25.25.25 group using on the routers based on the flags in the output shown above and why?

To which router will R2 send PIMv2 Register messages for the 225.25.25.25 group?

To which router will R2 send PIMv2 Register messages for the 226.26.26.26 group?

Step 7: Explore Auto-RP Operation with Sparse-Dense Mode

Enable Auto-RP debugging on R1 with the **debug ip pim auto-rp** command. Shut down the Loopback3 interface on R3.

```
R1# debug ip pim auto-rp

R3(config)# interface loopback 3
R3(config-if)# shutdown
```

How will this affect the Auto-RP election?

Issue the repeated multicast ping to generate (S, G) state on your routers before R1 takes over as the RP for the 226.26.26.26 group.

```
SW1# ping
Protocol [ip]:
Target IP address: 226.26.26.26
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 226.26.26.26, timeout is 2 seconds:
............................................................
Reply to request 60 from 10.100.13.1, 48 ms
Reply to request 61 from 10.100.13.1, 48 ms
Reply to request 62 from 10.100.13.1, 28 ms
Reply to request 63 from 10.100.13.1, 28 ms
Reply to request 64 from 10.100.13.1, 28 ms
Reply to request 65 from 10.100.13.1, 32 ms
Reply to request 66 from 10.100.13.1, 28 ms
Reply to request 67 from 10.100.13.1, 28 ms
Reply to request 68 from 10.100.13.1, 28 ms
Reply to request 69 from 10.100.13.1, 28 ms
  ... continues through request 99 ...
```

Why were so many pings dropped before reaching the IGMP-subscribed loopback interfaces on R1 and R3?

How does this affect multicast routing?

If Auto-RP debugging were enabled, you would see the following output on the mapping agent after three minutes:

```
*Nov  7 18:35:34.839: Auto-RP(0): Mapping (226.26.26.26/32, RP:10.100.3.3)
expired,
*Nov  7 18:35:34.843: Auto-RP(0): Build RP-Discovery packet
*Nov  7 18:35:34.843: Auto-RP:  Build mapping (225.25.25.25/32,
RP:10.100.1.1), PIMv2 v1,
*Nov  7 18:35:34.843: Auto-RP:  Build mapping (226.26.26.26/32,
RP:10.100.1.1), PIMv2 v1.
*Nov  7 18:35:34.843: Auto-RP(0): Send RP-discovery packet on FastEthernet0/0
(1 RP entries)
*Nov  7 18:35:34.843: Auto-RP(0): Send RP-discovery packet on Serial0/0/0 (1
RP entries)
*Nov  7 18:35:34.843: Auto-RP(0): Send RP-discovery packet on Serial0/0/1 (1
RP entries)
*Nov  7 18:35:34.843: Auto-RP: Send RP-discovery packet on Loopback1 (1 RP
entries)
```

Explain the preceding output.

You can check the resulting group-to-RP mappings by using the **show ip pim rp mapping** command.

```
R1# show ip pim rp mapping
PIM Group-to-RP Mappings
This system is an RP (Auto-RP)
This system is an RP-mapping agent (Loopback1)

Group(s) 225.25.25.25/32
  RP 10.100.1.1 (?), v2v1
    Info source: 10.100.1.1 (?), elected via Auto-RP
         Uptime: 02:53:45, expires: 00:02:12
Group(s) 226.26.26.26/32
  RP 10.100.1.1 (?), v2v1
    Info source: 10.100.1.1 (?), elected via Auto-RP
         Uptime: 02:53:45, expires: 00:02:12
```

Auto-RP allows you to configure backup RPs in a sparse mode or sparse-dense mode network. If you configured a static RP and later it became unreachable, receivers would no longer be able to use the shared tree to receive data. Auto-RP provides a layer of redundancy in sparse mode networks by using mapping agents to delegate RP roles to RP candidates.

Step 8: Verify the Operation of Dense-Mode Fallback

How will the status of the RPs in the network change if you shut down the Loopback1 interface on R1?

Will the PIM mappings in the network change their behavior immediately or after a short time? Which mode is PIM now operating in for the active groups?

Verify your answers with the **show ip pim rp mapping** and **show ip mroute summary** commands on R2 after the mappings expire.

```
R1# conf t
R1(config)# interface loopback 1
R1(config-if)# shutdown

R2# show ip pim rp mapping
PIM Group-to-RP Mappings

Group(s) 225.25.25.25/32
  RP 10.100.1.1 (?), v2v1
    Info source: 10.100.1.1 (?), elected via Auto-RP
         Uptime: 03:06:13, expires: 00:00:18
Group(s) 226.26.26.26/32
  RP 10.100.1.1 (?), v2v1
```



```
    Info source: 10.100.1.1 (?), elected via Auto-RP
         Uptime: 00:08:38, expires: 00:00:18

SW1# ping
Protocol [ip]:
Target IP address: 225.25.25.25
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 225.25.25.25, timeout is 2 seconds:
.............................................................
Reply to request 61 from 10.100.20.2, 8 ms
Reply to request 62 from 10.100.20.2, 4 ms
Reply to request 63 from 10.100.20.2, 4 ms
Reply to request 64 from 10.100.20.2, 4 ms
Reply to request 65 from 10.100.20.2, 4 ms
Reply to request 66 from 10.100.20.2, 4 ms
Reply to request 67 from 10.100.20.2, 4 ms
  ... continues through request 99 ...

R2# show ip pim rp mapping
PIM Group-to-RP Mappings

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

(*, 225.25.25.25), 00:05:09/stopped, RP 0.0.0.0, flags: DL
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Serial0/0/1, Forward/Sparse-Dense, 00:05:09/00:00:00
    Serial0/0/0, Forward/Sparse-Dense, 00:05:09/00:00:00

(10.100.20.4, 225.25.25.25), 00:00:06/00:02:57, flags: PLT
  Incoming interface: FastEthernet0/0, RPF nbr 0.0.0.0
  Outgoing interface list:
    Serial0/0/0, Prune/Sparse-Dense, 00:00:07/00:02:55, A
    Serial0/0/1, Prune/Sparse-Dense, 00:00:06/00:02:53

(*, 224.0.1.40), 00:16:56/00:02:38, RP 0.0.0.0, flags: DCL
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Serial0/0/1, Forward/Sparse-Dense, 00:16:56/00:00:00
    Serial0/0/0, Forward/Sparse-Dense, 00:16:56/00:00:00
    FastEthernet0/0, Forward/Sparse-Dense, 00:16:56/00:00:00
```

When the group-to-RP mappings expire on R2, PIM realizes that there is no longer an RP for the 225.25.25.25 and 226.26.26.26 groups and converts those groups to use dense mode operation. When this occurs, PIM floods multicast data out all interfaces and then prunes back to R2 because there are no other receivers of the 225.25.25.25 group.

Ping from SW1 again and then enable the loopback interfaces you shut down on R1 and R3.

```
SW1# ping
Protocol [ip]:
Target IP address: 225.25.25.25
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 225.25.25.25, timeout is 2 seconds:

Reply to request 0 from 10.100.20.2, 8 ms
Reply to request 1 from 10.100.20.2, 4 ms
Reply to request 2 from 10.100.20.2, 4 ms
Reply to request 3 from 10.100.20.2, 8 ms
Reply to request 4 from 10.100.20.2, 8 ms
Reply to request 5 from 10.100.20.2, 4 ms
Reply to request 6 from 10.100.20.2, 4 ms
Reply to request 7 from 10.100.20.2, 4 ms
Reply to request 8 from 10.100.20.2, 4 ms
Reply to request 9 from 10.100.20.2, 4 ms
Reply to request 10 from 10.100.20.2, 4 ms
Reply to request 11 from 10.100.20.2, 4 ms
Reply to request 12 from 10.100.20.2, 8 ms
Reply to request 12 from 10.100.13.1, 32 ms
Reply to request 13 from 10.100.20.2, 12 ms
Reply to request 13 from 10.100.13.1, 28 ms
Reply to request 14 from 10.100.20.2, 4 ms
Reply to request 14 from 10.100.13.1, 28 ms
Reply to request 15 from 10.100.20.2, 4 ms
Reply to request 15 from 10.100.13.1, 28 ms
Reply to request 16 from 10.100.20.2, 4 ms
Reply to request 16 from 10.100.13.1, 44 ms
Reply to request 16 from 10.100.203.3, 28 ms
 ... continued below ...
```

Over the period highlighted, both loopback interfaces were opened and PIM-DM flooded traffic to them. No RPs for these groups were sent to R2 by the mapping agent, so it continues to employ PIM-DM flood-and-prune behavior.

```
 ... continued from above ...
Reply to request 17 from 10.100.20.2, 4 ms
Reply to request 17 from 10.100.13.1, 44 ms
Reply to request 17 from 10.100.203.3, 28 ms
Reply to request 18 from 10.100.20.2, 8 ms
Reply to request 18 from 10.100.13.1, 44 ms
Reply to request 18 from 10.100.203.3, 28 ms
Reply to request 19 from 10.100.20.2, 8 ms
Reply to request 19 from 10.100.13.1, 44 ms
Reply to request 19 from 10.100.203.3, 32 ms
Reply to request 20 from 10.100.20.2, 8 ms
Reply to request 20 from 10.100.13.1, 44 ms
Reply to request 20 from 10.100.203.3, 32 ms
Reply to request 21 from 10.100.20.2, 8 ms
```



```
Reply to request 21 from 10.100.13.1, 44 ms
Reply to request 21 from 10.100.203.3, 32 ms
Reply to request 22 from 10.100.20.2, 8 ms
Reply to request 22 from 10.100.13.1, 44 ms
Reply to request 22 from 10.100.203.3, 28 ms
Reply to request 23 from 10.100.20.2, 8 ms
Reply to request 23 from 10.100.13.1, 48 ms
Reply to request 23 from 10.100.203.3, 32 ms
Reply to request 24 from 10.100.20.2, 4 ms
Reply to request 24 from 10.100.13.1, 44 ms
Reply to request 24 from 10.100.203.3, 28 ms
Reply to request 25 from 10.100.20.2, 4 ms
Reply to request 25 from 10.100.13.1, 44 ms
Reply to request 25 from 10.100.203.3, 28 ms
Reply to request 26 from 10.100.20.2, 8 ms
Reply to request 26 from 10.100.13.1, 44 ms
Reply to request 26 from 10.100.203.3, 28 ms
Reply to request 27 from 10.100.20.2, 4 ms
Reply to request 27 from 10.100.13.1, 44 ms
Reply to request 27 from 10.100.203.3, 28 ms
Reply to request 28 from 10.100.20.2, 4 ms
Reply to request 28 from 10.100.13.1, 44 ms
Reply to request 28 from 10.100.203.3, 28 ms
Reply to request 29 from 10.100.20.2, 4 ms
Reply to request 29 from 10.100.13.1, 44 ms
Reply to request 29 from 10.100.203.3, 32 ms
Reply to request 30 from 10.100.20.2, 4 ms
Reply to request 31 from 10.100.20.2, 8 ms
Reply to request 32 from 10.100.20.2, 4 ms
Reply to request 33 from 10.100.20.2, 4 ms
Reply to request 34 from 10.100.20.2, 4 ms
 ... continued below ...
```

R2 hears R1's Auto-RP announcement to the 224.0.1.240 group. Because there are now RPs in the network, R2 converts the 225.25.25.25 and 226.26.26.26 state to use PIM-SM. R2 does not begin forwarding data to the RP because the mapping agent has not yet elected an RP for the 225.25.25.25 group. R2 waits to receive the RP address from the mapping agent before it begins encapsulating multicast data as unicasts to R1, the RP.

```
 ... continued from above ...
Reply to request 35 from 10.100.20.2, 4 ms
Reply to request 36 from 10.100.20.2, 8 ms
Reply to request 37 from 10.100.20.2, 4 ms
Reply to request 38 from 10.100.20.2, 4 ms
Reply to request 39 from 10.100.20.2, 4 ms
Reply to request 40 from 10.100.20.2, 4 ms
Reply to request 41 from 10.100.20.2, 8 ms
Reply to request 42 from 10.100.20.2, 4 ms
Reply to request 43 from 10.100.20.2, 4 ms
Reply to request 44 from 10.100.20.2, 8 ms
Reply to request 45 from 10.100.20.2, 8 ms
Reply to request 46 from 10.100.20.2, 8 ms
Reply to request 47 from 10.100.20.2, 8 ms
Reply to request 48 from 10.100.20.2, 4 ms
Reply to request 49 from 10.100.20.2, 4 ms
Reply to request 50 from 10.100.20.2, 4 ms
Reply to request 51 from 10.100.20.2, 8 ms
Reply to request 52 from 10.100.20.2, 4 ms
Reply to request 53 from 10.100.20.2, 4 ms
Reply to request 54 from 10.100.20.2, 4 ms
```



```
Reply to request 55 from 10.100.20.2, 4 ms
Reply to request 56 from 10.100.20.2, 8 ms
Reply to request 57 from 10.100.20.2, 4 ms
Reply to request 58 from 10.100.20.2, 4 ms
Reply to request 59 from 10.100.20.2, 8 ms
Reply to request 59 from 10.100.13.1, 44 ms
Reply to request 59 from 10.100.203.3, 32 ms
Reply to request 60 from 10.100.20.2, 8 ms
Reply to request 60 from 10.100.13.1, 44 ms
Reply to request 60 from 10.100.203.3, 32 ms
```

Request 59 is the first packet that R2 encapsulates in a unicast packet and sends to the RP. R1, the RP, forwards the multicast traffic down the shared tree to any subscribers of the 225.25.25.25 group.

When R2 converts a group to a different mode, multicast packets are inevitably dropped before reaching receivers. Although sparse-dense mode brings a high level of resiliency compared to sparse mode, packets are still lost during the transition to and recovery from dense-mode fallback.

This lab demonstrates two basic features of resiliency available on Cisco routers; however, there are more advanced ways to deploy high-availability solutions in a multicast network.

The first three labs on multicast provided the foundation to understand sparse-dense mode. Explain how the concepts in those first three labs lead to an in-depth understanding of PIM sparse-dense mode.

Appendix A: TCL Script Output

```
R1# tclsh
R1(tcl)#foreach address {
+>(tcl)#10.100.1.1
+>(tcl)#10.100.13.1
+>(tcl)#10.100.102.1
+>(tcl)#10.100.103.1
+>(tcl)#10.100.2.2
+>(tcl)#10.100.20.2
+>(tcl)#10.100.102.2
+>(tcl)#10.100.203.2
+>(tcl)#10.100.3.3
+>(tcl)#10.100.13.3
+>(tcl)#10.100.103.3
+>(tcl)#10.100.203.3
+>(tcl)#10.100.20.4
+>(tcl)#} { ping $address }

Type escape sequence to abort.
```



```
Sending 5, 100-byte ICMP Echos to 10.100.1.1, 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 10.100.13.1, 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 10.100.102.1, 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 10.100.103.1, 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 10.100.2.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 12/15/16 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.100.20.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 12/15/16 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.100.102.2, 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 10.100.203.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 12/14/16 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.100.3.3, 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 10.100.13.3, 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 10.100.103.3, 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 10.100.203.3, 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 10.100.20.4, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 16/16/20 ms
R1(tcl)# tclquit

R2# tclsh
R2(tcl)#foreach address {
+>(tcl)#10.100.1.1
+>(tcl)#10.100.13.1
+>(tcl)#10.100.102.1
+>(tcl)#10.100.103.1
+>(tcl)#10.100.2.2
+>(tcl)#10.100.20.2
+>(tcl)#10.100.102.2
+>(tcl)#10.100.203.2
```



```
+>(tcl)#10.100.3.3
+>(tcl)#10.100.13.3
+>(tcl)#10.100.103.3
+>(tcl)#10.100.203.3
+>(tcl)#10.100.20.4
+>(tcl)#} { ping $address }

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.100.1.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 12/15/16 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.100.13.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 12/15/16 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.100.102.1, 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 10.100.103.1, 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 10.100.2.2, 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 10.100.20.2, 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 10.100.102.2, 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 10.100.203.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/29/36 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.100.3.3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 12/14/16 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.100.13.3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 12/14/16 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.100.103.3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 12/15/16 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.100.203.3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 12/15/16 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.100.20.4, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/4 ms
R2(tcl)# tclquit

R3# tclsh
R3(tcl)#foreach address {
```



```
+>(tcl)#10.100.1.1
+>(tcl)#10.100.13.1
+>(tcl)#10.100.102.1
+>(tcl)#10.100.103.1
+>(tcl)#10.100.2.2
+>(tcl)#10.100.20.2
+>(tcl)#10.100.102.2
+>(tcl)#10.100.203.2
+>(tcl)#10.100.3.3
+>(tcl)#10.100.13.3
+>(tcl)#10.100.103.3
+>(tcl)#10.100.203.3
+>(tcl)#10.100.20.4
+>(tcl)#} { ping $address }

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.100.1.1, 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 10.100.13.1, 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 10.100.102.1, 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 10.100.103.1, 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 10.100.2.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 12/15/16 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.100.20.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 12/15/16 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.100.102.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 20/20/24 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.100.203.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 12/13/16 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.100.3.3, 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 10.100.13.3, 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 10.100.103.3, 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 10.100.203.3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/29/36 ms
```



```
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.100.20.4, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 16/16/16 ms
R3(tcl)# tclquit
```

Final Configurations

```
R1# show run
!
hostname R1
!
ip multicast-routing
!
interface Loopback1
 ip address 10.100.1.1 255.255.255.0
 ip pim sparse-dense-mode
 ip igmp join-group 225.25.25.25
 ip igmp join-group 226.26.26.26
!
interface FastEthernet0/0
 ip address 10.100.13.1 255.255.255.0
 ip pim sparse-dense-mode
 no shutdown
!
interface Serial0/0/0
 bandwidth 64
 ip address 10.100.102.1 255.255.255.248
 ip pim sparse-dense-mode
 clock rate 64000
 no shutdown
!
interface Serial0/0/1
 bandwidth 64
 ip address 10.100.103.1 255.255.255.248
 ip pim sparse-dense-mode
 no shutdown
!
router ospf 1
 network 10.0.0.0 0.255.255.255 area 0
!
ip pim send-rp-announce Loopback1 scope 3 group-list 1
ip pim send-rp-discovery Loopback1 scope 3
!
access-list 1 permit 225.25.25.25
access-list 1 permit 226.26.26.26
!
end

R2# show run
!
hostname R2
!
ip multicast-routing
!
interface Loopback2
 ip address 10.100.2.2 255.255.255.0
 ip igmp join-group 225.25.25.25
!
interface FastEthernet0/0
 ip address 10.100.20.2 255.255.255.0
 ip pim sparse-dense-mode
 no shutdown
```



```
!
interface Serial0/0/0
 bandwidth 64
 ip address 10.100.102.2 255.255.255.248
 ip pim sparse-dense-mode
 no shutdown
!
interface Serial0/0/1
 bandwidth 128
 ip address 10.100.203.2 255.255.255.248
 ip pim sparse-dense-mode
 clock rate 64000
 no shutdown
!
router ospf 1
 network 10.0.0.0 0.255.255.255 area 0
!
end
```

```
R3# show run
!
hostname R3
!
ip multicast-routing
!
interface Loopback3
 ip address 10.100.3.3 255.255.255.0
 ip pim sparse-dense-mode
 ip igmp join-group 225.25.25.25
 ip igmp join-group 226.26.26.26
!
interface FastEthernet0/0
 ip address 10.100.13.3 255.255.255.0
 ip pim sparse-dense-mode
 no shutdown
!
interface Serial0/0/0
 bandwidth 64
 ip address 10.100.103.3 255.255.255.248
 ip pim sparse-dense-mode
 clock rate 64000
 no shutdown
!
interface Serial0/0/1
 bandwidth 128
 ip address 10.100.203.3 255.255.255.248
 ip pim sparse-dense-mode
 no shutdown
!
router ospf 1
 network 10.0.0.0 0.255.255.255 area 0
!
ip pim send-rp-announce Loopback3 scope 3 group-list 3
!
access-list 3 permit 226.26.26.26
!
end
```

```
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 10.100.20.4 255.255.255.0
 no shutdown
!
ip default-gateway 10.100.20.2
!
end
```

