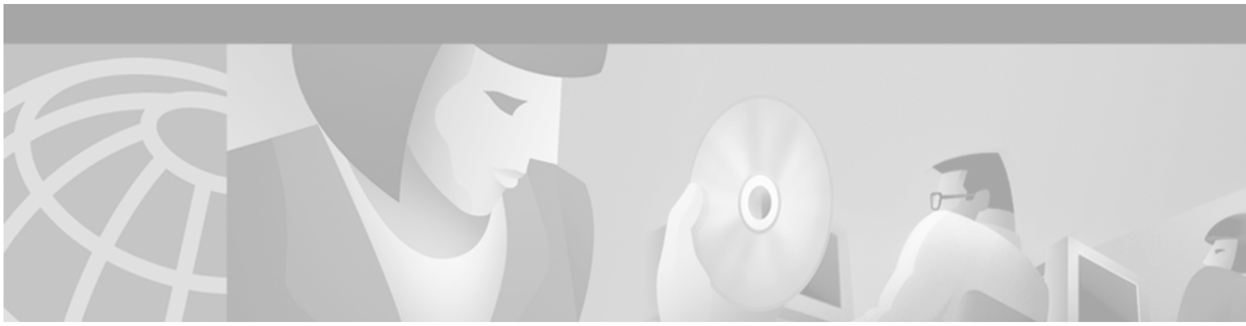


# Configuring IP Multicast Routing

This chapter describes how to configure IP multicast routing. For a complete description of the IP multicast routing commands in this chapter, refer to the "IP Multicast Routing Commands" chapter of the *Cisco IOS IP Command Reference, Volume 3 of 3: Multicast*. To locate documentation of other commands in this chapter, use the command reference master index, or search online.

Traditional IP communication allows a host to send packets to a single host (*unicast transmission*) or to all hosts (*broadcast transmission*). IP multicast provides a third scheme, allowing a host to send packets to a subset of all hosts (*group transmission*). These hosts are known as group members.

Packets delivered to group members are identified by a single multicast group address. Multicast packets are delivered to a group using best-effort reliability, just like IP unicast packets.

The multicast environment consists of senders and receivers. Any host, regardless of whether it is a member of a group, can send to a group. However, only the members of a group receive the message.

A multicast address is chosen for the receivers in a multicast group. Senders use that address as the destination address of a datagram to reach all members of the group.

Membership in a multicast group is dynamic; hosts can join and leave at any time. There is no restriction on the location or number of members in a multicast group. A host can be a member of more than one multicast group at a time.

How active a multicast group is and what members it has can vary from group to group and from time to time. A multicast group can be active for a long time, or it may be very short-lived. Membership in a group can change constantly. A group that has members may have no activity.

Routers executing a multicast routing protocol, such as Protocol Independent Multicast (PIM), maintain forwarding tables to forward multicast datagrams. Routers use the Internet Group Management Protocol (IGMP) to learn whether members of a group are present on their directly attached subnets. Hosts join multicast groups by sending IGMP report messages.

Many multimedia applications involve multiple participants. IP multicast is naturally suitable for this communication paradigm.

To identify the hardware platform or software image information associated with a feature, use the Feature Navigator on Cisco.com to search for information about the feature or refer to the software release notes for a specific release. For more information, see the "Identifying Supported Platforms" section in the "Using Cisco IOS Software" chapter.

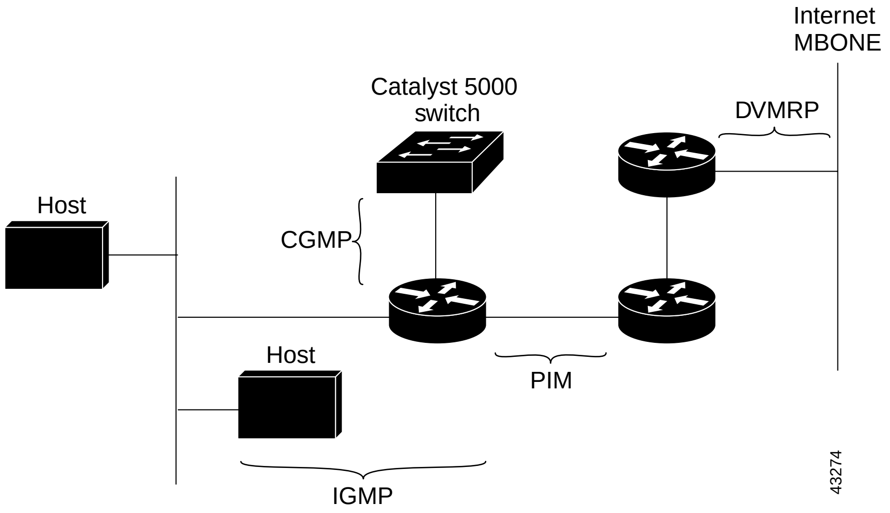
# The Cisco IP Multicast Routing Implementation

The Cisco IOS software supports the following protocols to implement IP multicast routing:

- IGMP is used between hosts on a LAN and the routers on that LAN to track the multicast groups of which hosts are members.
- Protocol Independent Multicast (PIM) is used between routers so that they can track which multicast packets to forward to each other and to their directly connected LANs.
- Distance Vector Multicast Routing Protocol (DVMRP) is used on the MBONE (the multicast backbone of the Internet). The Cisco IOS software supports PIM-to-DVMRP interaction.
- Cisco Group Management Protocol (CGMP) is used on routers connected to Catalyst switches to perform tasks similar to those performed by IGMP.

Figure 66 shows where these protocols operate within the IP multicast environment. The protocols are further described in the sections following the figure.

***Figure 66 IP Multicast Routing Protocols***



## IGMP

To start implementing IP multicast routing in your campus network, you must first define who receives the multicast. IGMP provides a means to automatically control and limit the flow of multicast traffic throughout your network with the use of special multicast queriers and hosts.

- A querier is a network device, such as a router, that sends query messages to discover which network devices are members of a given multicast group.
- A host is a receiver, including routers, that sends report messages (in response to query messages) to inform the querier of a host membership.

A set of queriers and hosts that receive multicast data streams from the same source is called a multicast group. Queries and hosts use IGMP messages to join and leave multicast groups.

IP multicast traffic uses group addresses, which are Class D IP addresses. The high-order four bits of a Class D address are 1110. Therefore, host group addresses can be in the range 224.0.0.0 to 239.255.255.255.

Multicast addresses in the range 224.0.0.0 to 224.0.0.255 are reserved for use by routing protocols and other network control traffic. The address 224.0.0.0 is guaranteed not to be assigned to any group.

IGMP packets are transmitted using IP multicast group addresses as follows:

- IGMP general queries are destined to the address 224.0.0.1 (all systems on a subnet).
- IGMP group-specific queries are destined to the group IP address for which the router is querying.
- IGMP group membership reports are destined to the group IP address for which the router is reporting.
- IGMP Version 2 (IGMPv2) Leave messages are destined to the address 224.0.0.2 (all routers on a subnet).
  - Note that in some old host IP stacks, Leave messages might be destined to the group IP address rather than to the all-routers address.

## IGMP Versions

IGMP messages are used primarily by multicast hosts to signal their interest in joining a specific multicast group and to begin receiving group traffic.

The original IGMP Version 1 Host Membership model defined in RFC 1112 is extended to significantly reduce leave latency and provide control over source multicast traffic by use of Internet Group Management Protocol, Version 2.

- IGMP Version 1

  Provides for the basic Query-Response mechanism that allows the multicast router to determine which multicast groups are active and other processes that enable hosts to join and leave a multicast group. RFC 1112 defines *Host Extensions for IP Multicasting.*

- IGMP Version 2

  Extends IGMP allowing such features as the IGMP leave process, group-specific queries, and an explicit maximum query response time. IGMP Version 2 also adds the capability for routers to elect the IGMP querier without dependence on the multicast protocol to perform this task. RFC 2236 defines *Internet Group Management Protocol, Version 2*.

- IGMP Version 3

  Provides for “source filtering” which enables a multicast receiver host to signal to a router which groups it wants to receive multicast traffic from, and from which sources this traffic is expected.

# PIM

The PIM protocol maintains the current IP multicast service mode of receiver-initiated membership. It is not dependent on a specific unicast routing protocol.

PIM is defined in RFC 2362, *Protocol-Independent Multicast-Sparse Mode (PIM-SM): Protocol Specification*. PIM is defined in the following Internet Engineering Task Force (IETF) Internet drafts:

- *Protocol Independent Multicast (PIM): Motivation and Architecture*
- *Protocol Independent Multicast (PIM), Dense Mode Protocol Specification*
- *Protocol Independent Multicast (PIM), Sparse Mode Protocol Specification*
- draft-ietf-idmr-igmp-v2-06.txt, *Internet Group Management Protocol, Version 2*
- draft-ietf-pim-v2-dm-03.txt, *PIM Version 2 Dense Mode*

PIM can operate in dense mode or sparse mode. It is possible for the router to handle both sparse groups and dense groups at the same time.

In dense mode, a router assumes that all other routers want to forward multicast packets for a group. If a router receives a multicast packet and has no directly connected members or PIM neighbors present, a prune message is sent back to the source. Subsequent multicast packets are not flooded to this router on this pruned branch. PIM builds source-based multicast distribution trees.

In sparse mode, a router assumes that other routers do not want to forward multicast packets for a group, unless there is an explicit request for the traffic. When hosts join a multicast group, the directly connected routers send PIM join messages toward the rendezvous point (RP). The RP keeps track of multicast groups. Hosts that send multicast packets are registered with the RP by the first hop router of that host. The RP then sends join messages toward the source. At this point, packets are forwarded on a shared distribution tree. If the multicast traffic from a specific source is sufficient, the first hop router of the host may send join messages toward the source to build a source-based distribution tree.

## CGMP

CGMP is a protocol used on routers connected to Catalyst switches to perform tasks similar to those performed by IGMP. CGMP is necessary for those Catalyst switches that cannot distinguish between IP multicast data packets and IGMP report messages, both of which are addressed to the same group address at the MAC level.

# Basic IP Multicast Routing Configuration Task List

Basic and advanced IP multicast routing configuration tasks are described in the following sections. The basic tasks in the first two sections are required; the tasks in the remaining sections are optional.

- Enabling IP Multicast Routing (Required)
- Enabling PIM on an Interface (Required)
- Configuring Auto-RP (Optional)
- IGMP Features Configuration Task List (Optional)
- Configuring the TTL Threshold (Optional)
- Disabling Fast Switching of IP Multicast (Optional)
- SAP Listener Support Configuration Task List (Optional)
- Enabling the Functional Address for IP Multicast over Token Ring LANs (Optional)
- Configuring PIM Version 2 (Optional)

# Advanced IP Multicast Routing Configuration Task List

The advanced IP multicast routing tasks described in the following sections are optional:

- Advanced PIM Features Configuration Task List (Optional)
- Configuring an IP Multicast Static Route (Optional)
- Controlling the Transmission Rate to a Multicast Group (Optional)
- Configuring RTP Header Compression (Optional)

- Configuring IP Multicast over ATM Point-to-Multipoint Virtual Circuits (Optional)
- Configuring an IP Multicast Boundary (Optional)
- Configuring an Intermediate IP Multicast Helper (Optional)
- Storing IP Multicast Headers (Optional)
- Enabling CGMP (Optional)
- Configuring Stub IP Multicast Routing (Optional)
- Load Splitting IP Multicast Traffic Across Equal-Cost Paths Configuration Task List (Optional)
- Monitoring and Maintaining IP Multicast Routing Configuration Task List (Optional)

See the "IP Multicast Configuration Examples" later in this chapter for examples of multicast routing configurations.

To see information on IP multicast multilayer switching, refer to the *Cisco IOS Switching Services Configuration Guide* and *Cisco IOS Switching Services Command Reference*.

# Enabling IP Multicast Routing

Enabling IP multicast routing allows the Cisco IOS software to forward multicast packets. To enable IP multicast routing on the router, use the following command in global configuration mode:

| Command | Purpose |
|---|---|
| `Router(config)# ip multicast-routing` | Enables IP multicast routing. |

# Enabling PIM on an Interface

Enabling PIM on an interface also enables IGMP operation on that interface. An interface can be configured to be in dense mode, sparse mode, or sparse-dense mode. The mode determines how the router populates its multicast routing table and how the router forwards multicast packets it receives from its directly connected LANs. You must enable PIM in one of these modes for an interface to perform IP multicast routing.

In populating the multicast routing table, dense mode interfaces are always added to the table. Sparse mode interfaces are added to the table only when periodic join messages are received from downstream routers, or when a directly connected member is on the interface. When forwarding from a LAN, sparse mode operation occurs if an RP is known for the group. If so, the packets are encapsulated and sent toward the RP. When no RP is known, the packet is flooded in a dense mode fashion. If the multicast traffic from a specific source is sufficient, the first hop router of the receiver may send join messages toward the source to build a source-based distribution tree.

There is no default mode setting. By default, multicast routing is disabled on an interface.

## Enabling Dense Mode

To configure PIM on an interface to be in dense mode, use the following command in interface configuration mode:

| Command | Purpose |
|---|---|
| `Router(config-if)# ip pim dense-mode` | Enables PIM dense mode on the interface. |

See the "PIM Dense Mode Example" section later in this chapter for an example of how to configure a PIM interface in dense mode.

## Enabling Sparse Mode

To configure PIM on an interface to be in sparse mode, use the following command in interface configuration mode:

| Command | Purpose |
|---|---|
| `Router(config-if)# ip pim sparse-mode` | Enables PIM sparse mode on the interface. |

See the "PIM Sparse Mode Example" section later in this chapter for an example of how to configure a PIM interface in sparse mode.

## Enabling Sparse-Dense Mode

If you configure either the **ip pim sparse-mode** or **ip pim dense-mode** interface configuration command, then sparseness or denseness is applied to the interface as a whole. However, some environments might require PIM to run in a single region in sparse mode for some groups and in dense mode for other groups.

An alternative to enabling only dense mode or only sparse mode is to enable sparse-dense mode. In this case, the interface is treated as dense mode if the group is in dense mode; the interface is treated in sparse mode if the group is in sparse mode. You must have an RP if the interface is in sparse-dense mode, and you want to treat the group as a sparse group.

If you configure sparse-dense mode, the idea of sparseness or denseness is applied to the group on the router, and the network manager should apply the same concept throughout the network.

Another benefit of sparse-dense mode is that Auto-RP information can be distributed in a dense mode manner; yet, multicast groups for user groups can be used in a sparse mode manner. Thus, there is no need to configure a default RP at the leaf routers.

When an interface is treated in dense mode, it is populated in the outgoing interface list of a multicast routing table when either of the following conditions is true:

- Members or DVMRP neighbors are on the interface.
- There are PIM neighbors and the group has not been pruned.

When an interface is treated in sparse mode, it is populated in the outgoing interface list of a multicast routing table when either of the following conditions is true:

- Members or DVMRP neighbors are on the interface.
- An explicit join message has been received by a PIM neighbor on the interface.

To enable PIM to operate in the same mode as the group, use the following command in interface configuration mode:

| Command | Purpose |
|---|---|
| Router(config-if)# **ip pim sparse-dense-mode** | Enables PIM to operate in sparse or dense mode, depending on the group. |

## Configuring PIM Dense Mode State Refresh

If you have PIM dense mode (PIM-DM) enabled on a router interface, the PIM Dense Mode State Refresh feature is enabled by default.

PIM-DM builds source-based multicast distribution trees that operate on a “flood and prune” principle. Multicast packets from a source are flooded to all areas of a PIM-DM network. PIM routers that receive multicast packets and have no directly connected multicast group members or PIM neighbors send a prune message back up the source-based distribution tree toward the source of the packets. As a result, subsequent multicast packets are not flooded to pruned branches of the distribution tree. However, the pruned state in PIM-DM times out approximately every 3 minutes and the entire PIM-DM network is reflooded with multicast packets and prune messages. This reflooding of unwanted traffic throughout the PIM-DM network consumes network bandwidth.

The PIM Dense Mode State Refresh feature keeps the pruned state in PIM-DM from timing out by periodically forwarding a control message down the source-based distribution tree. The control message refreshes the prune state on the outgoing interfaces of each router in the distribution tree.

This feature also enables PIM routers in a PIM-DM multicast network to recognize topology changes (sources joining or leaving a multicast group) before the default 3-minute state refresh timeout period expires.

By default, all PIM routers that are running a Cisco IOS software release that supports the PIM Dense Mode State Refresh feature automatically process and forward state refresh control messages. To disable the processing and forwarding of state refresh control messages on a PIM router, use the **ip pim state-refresh disable** global configuration command.

To configure the origination of the control messages on a PIM router, use the following commands beginning in global configuration mode:

| | Command | Purpose |
|---|---|---|
| **Step 1** | Router(config)# **interface** *type number* | Specifies an interface and places the router in interface configuration mode. |
| **Step 2** | Router(config-if)# **ip pim state-refresh origination-interval** [*interval*] | Configures the origination of the PIM Dense Mode State Refresh control message. Optionally, you can configure the number of seconds between control messages by using the *interval* argument. The default interval is 60 seconds. The interval range is from 4 to 100 seconds. |

**Note** The origination interval for the state refresh control message must be the same for all PIM routers on the same LAN. Specifically, the same origination interval must be configured on each router interface that is directly connected to the LAN.

See the “PIM Dense Mode State Refresh Example” section later in this chapter for an example of how to configure the PIM Dense Mode State Refresh feature.

## Configuring a Rendezvous Point

If you configure PIM to operate in sparse mode, you must also choose one or more routers to be rendezvous points (RPs). You need not configure the routers to be RPs; they learn how to become RPs themselves. RPs are used by senders to a multicast group to announce their existence and by receivers of multicast packets to learn about new senders. The Cisco IOS software can be configured so that packets for a single multicast group can use one or more RPs.

The RP address is used by first hop routers to send PIM register messages on behalf of a host sending a packet to the group. The RP address is also used by last hop routers to send PIM join and prune messages to the RP to inform it about group membership. You must configure the RP address on all routers (including the RP router).

A PIM router can be an RP for more than one group. Only one RP address can be used at a time within a PIM domain. The conditions specified by the access list determine for which groups the router is an RP.

To configure the address of the RP, use the following command on a leaf router in global configuration mode:

| Command | Purpose |
|---|---|
| `Router(config)#` **`ip pim rp-address`** *`rp-address`* `[`*`access-list`*`] [`**`override`**`]` | Configures the address of a PIM RP. |

# Configuring Auto-RP

Auto-RP is a feature that automates the distribution of group-to-RP mappings in a PIM network. This feature has the following benefits:

- The use of multiple RPs within a network to serve different group ranges is easy.
- It allows load splitting among different RPs and arrangement of RPs according to the location of group participants.
- It avoids inconsistent, manual RP configurations that can cause connectivity problems.

Multiple RPs can be used to serve different group ranges or serve as backups of each other. To make Auto-RP work, a router must be designated as an *RP-mapping agent*, which receives the RP-announcement messages from the RPs and arbitrates conflicts. The RP-mapping agent then sends the consistent group-to-RP mappings to all other routers. Thus, all routers automatically discover which RP to use for the groups they support.

**Note** If you configure PIM in sparse mode or sparse-dense mode and do not configure Auto-RP, you must statically configure an RP as described in the section “Assigning an RP to Multicast Groups” later in this chapter.

**Note** If router interfaces are configured in sparse mode, Auto-RP can still be used if all routers are configured with a static RP address for the Auto-RP groups.

## Setting Up Auto-RP in a New Internetwork

If you are setting up Auto-RP in a new internetwork, you do not need a default RP because you configure all the interfaces for sparse-dense mode. Follow the process described in the section "Adding Auto-RP to an Existing Sparse Mode Cloud," except that you should omit the first step of choosing a default RP.

## Adding Auto-RP to an Existing Sparse Mode Cloud

The following sections contain suggestions for the initial deployment of Auto-RP into an existing sparse mode cloud, to minimize disruption of the existing multicast infrastructure.

### Choosing a Default RP

Sparse mode environments need a default RP; sparse-dense mode environments do not. If you have sparse-dense mode configured everywhere, you need not choose a default RP.

Adding Auto-RP to a sparse mode cloud requires a default RP. In an existing PIM sparse mode region, at least one RP is defined across the network that has good connectivity and availability. That is, the **ip pim rp-address** command is already configured on all routers in this network.

Use that RP for the global groups (for example, 224.x.x.x and other global groups). There is no need to reconfigure the group address range that RP serves. RPs discovered dynamically through Auto-RP take precedence over statically configured RPs. Assume it is desirable to use a second RP for the local groups.

### Announcing the RP and the Group Range It Serves

Find another router to serve as the RP for the local groups. The RP-mapping agent can double as an RP itself. Assign the whole range of 239.x.x.x to that RP, or assign a subrange of that (for example, 239.2.x.x).

To designate that a router is the RP, use the following command in global configuration mode:

| Command | Purpose |
|---|---|
| `Router(config)#` **`ip pim send-rp-announce`** *`type number`* **`scope`** *`ttl-value`* `[`**`group-list`** *`access-list`*`]` `[`**`interval`** *`seconds`*`]` | Configures a router to be the RP. |

To change the group ranges this RP optimally will serve in the future, change the announcement setting on the RP. If the change is valid, all other routers automatically will adopt the new group-to-RP mapping.

The following example advertises the IP address of Ethernet interface 0 as the RP for the administratively scoped groups:

```
ip pim send-rp-announce ethernet0 scope 16 group-list 1
access-list 1 permit 239.0.0.0 0.255.255.255
```

### Assigning the RP Mapping Agent

The RP mapping agent is the router that sends the authoritative discovery packets telling other routers which group-to-RP mapping to use. Such a role is necessary in the event of conflicts (such as overlapping group-to-RP ranges).

Find a router whose connectivity is not likely to be interrupted and assign it the role of RP-mapping agent. All routers within time-to-live (TTL) number of hops from the source router receive the Auto-RP discovery messages. To assign the role of RP mapping agent in that router, use the following command in global configuration mode:

| Command | Purpose |
|---|---|
| `Router(config)#` **`ip pim send-rp-discovery scope`** *`ttl-value`* | Assigns the RP mapping agent. |

## Verifying the Group-to-RP Mapping

To learn if the group-to-RP mapping has arrived, use the following command in EXEC mode on the designated routers:

| Command | Purpose |
|---|---|
| `Router#` **`show ip pim rp`** `[`**`mapping`** `|` **`metric`**`]` `[`*`rp-address`*`]` | Displays active RPs that are cached with associated multicast routing entries. Information learned by configuration or Auto-RP. |

## Starting to Use IP Multicast

Use your IP multicast application software to start joining and sending to a group.

## Preventing Join Messages to False RPs

Note the **ip pim accept-rp** global configuration commands previously configured throughout the network. If the **ip pim accept-rp** command is not configured on any router, this problem can be addressed later. In those routers already configured with the **ip pim accept-rp** command, you must specify the command again to accept the newly advertised RP.

To accept all RPs advertised with Auto-RP and reject all other RPs by default, use the **ip pim accept-rp auto-rp** command.

If all interfaces are in sparse mode, a default RP is configured to support the two well-known groups 224.0.1.39 and 224.0.1.40. Auto-RP relies on these two well-known groups to collect and distribute RP-mapping information. When this is the case and the **ip pim accept-rp auto-rp** command is configured, another **ip pim accept-rp** command accepting the default RP must be configured, as follows:

```
ip pim accept-rp <default RP address> 1
access-list 1 permit 224.0.1.39
access-list 1 permit 224.0.1.40
```

# Filtering Incoming RP Announcement Messages

To filter incoming RP announcement messages, use the following command in global configuration mode:

| Command | Purpose |
|---|---|
| `Router(config)#` **`ip pim rp-announce-filter rp-list`** *`access-list`* **`group-list`** *`access-list`* | Filters incoming RP announcement messages. |

# IGMP Features Configuration Task List

To configure IGMP features, perform the tasks described in the following sections. The tasks in the first section are required; the tasks in the remaining sections are optional.

- Configuring a Router to Be a Member of a Group (Required)
- Controlling Access to IP Multicast Groups (Optional)
- Changing the IGMP Version (Optional)
- Modifying the IGMP Host-Query Message and Query Timeout Intervals (Optional)
- Configuring IGMP Version 3 (Optional)
- Changing the Maximum Query Response Time (Optional)
- Configuring the Router as a Statically Connected Member (Optional)
- Configuring IGMP Leave Latency (Optional)

For information about configuring IGMP unidirectional link routing (UDLR), see the chapter "Configuring Unidirectional Link Routing" in this document.

## Configuring a Router to Be a Member of a Group

Cisco routers can be configured to be members of a multicast group. This strategy is useful for determining multicast reachability in a network. If a device is configured to be a group member and supports the protocol that is being sent to the group, it can respond (to the **ping** EXEC command, for example). The device responds to ICMP echo request packets addressed to a group of which it is a member. Another example is the multicast traceroute tools provided in the Cisco IOS software.

To have the router join a multicast group and enable IGMP, use the following command in interface configuration mode:

| Command | Purpose |
|---|---|
| `Router(config-if)#` **`ip igmp join-group`** *`group-address`* | Joins a multicast group. |

## Controlling Access to IP Multicast Groups

Multicast routers send IGMP host query messages to determine which multicast groups have members in the attached local networks of the router. The routers then forward to these group members all packets addressed to the multicast group. You can place a filter on each interface that restricts the multicast groups that hosts on the subnet serviced by the interface can join.

To filter multicast groups allowed on an interface, use the following command in interface configuration mode:

| Command | Purpose |
|---|---|
| `Router(config-if)#` **`ip igmp access-group`** *`access-list`* | Controls the multicast groups that hosts on the subnet serviced by an interface can join. |

# Changing the IGMP Version

By default, the router uses IGMP Version 2 (IGMPv2), which allows such features as the IGMP query timeout and the maximum query response time.

All routers on the subnet must support the same version. The router does not automatically detect Version 1 routers and switch to Version 1 as did earlier releases of the Cisco IOS software. However, a mix of IGMP Version 1 and Version 2 hosts on the subnet is acceptable. IGMP Version 2 routers will always work correctly in the presence of IGMP Version 1 hosts.

To control which version of IGMP the router uses, use the following command in interface configuration mode:

| Command | Purpose |
|---|---|
| `Router(config-if)#` **`ip igmp version`** `{`**`3`** `\|` **`2`** `\|` **`1`**`}` | Selects the IGMP version that the router uses. |

# Modifying the IGMP Host-Query Message and Query Timeout Intervals

Multicast routers send IGMP host-query messages to discover which multicast groups are present on attached networks. These messages are sent to the all-systems group address of 224.0.0.1 with a time-to-live (TTL) of 1.

Multicast routers send host-query messages periodically to refresh their knowledge of memberships present on their networks. If, after some number of queries, the Cisco IOS software discovers that no local hosts are members of a multicast group, the software stops forwarding onto the local network multicast packets from remote origins for that group and sends a prune message upstream toward the source.

## Routers That Run IGMP Version 1

If there are multiple routers on a LAN, a designated router (DR) must be elected to avoid duplicating multicast traffic for connected hosts. PIM routers follow an election process to select a DR. The PIM router with the highest IP address becomes the DR.

The DR is responsible for the following tasks:

- Sending PIM register and PIM join and prune messages toward the RP to inform it about host group membership.
- Sending IGMP host-query messages.

By default, the DR sends host-query messages every 60 seconds in order to keep the IGMP overhead on hosts and networks very low.

To modify this interval, use the following command in interface configuration mode:

| Command | Purpose |
|---|---|
| `Router(config-if)#` **`ip igmp query-interval`** *`seconds`* | Configures the frequency at which the designated router sends IGMP host-query messages. |

### Routers That Run IGMP Version 2

IGMPv2 improved the query messaging capabilities of IGMPv1.

The query and membership report messages in IGMPv2 are identical to the IGMPv1 messages with two exceptions.

1. IGMPv2 query messages are broken into two categories: general queries (identical to IGMPv1 queries) and group-specific queries.
2. IGMPv1 membership reports and IGMPv2 membership reports have different IGMP type codes.

Unlike IGMPv1, in which the DR and the IGMP querier are typically the same router; in IGMPv2, the two functions are decoupled. The DR and the IGMP querier are selected based on different criteria and may be different routers on the same subnet. The DR is the router with the highest IP address on the subnet, whereas the IGMP querier is the router with the lowest IP address.

IP addresses in general query messages are used to elect the IGMP querier and this is the election process:

- When IGMPv2 routers start, they each multicast a general query message to the all-systems group address of 224.0.0.1 with their interface address in the source IP address field of the message.
- When an IGMPv2 router receives a general query message, the router compares the source IP address in the message with its own interface address. The router with the lowest IP address on the subnet is elected the IGMP querier.
- All routers (excluding the querier) start the query timer controlled by the **ip igmp querier-timeout** command that is reset whenever a general query message is received from the IGMP querier. If the query timer expires, it is assumed that the IGMP querier has gone down, and the election process is performed again to elect a new IGMP querier.

By default, the timer is 2 times the query interval controlled by the **ip igmp query-interval** command.

To change the query timeout and to specify the period of time before a new election is performed, use the following command in interface configuration mode:

| Command | Purpose |
|---|---|
| `Router(config-if)#` **`ip igmp querier-timeout`** *`seconds`* | Sets the IGMP query timeout. |

## Configuring IGMP Version 3

IGMP Version 3 (IGMPv3) adds support in Cisco IOS software for “source filtering,” which enables a multicast receiver host to signal to a router which groups it wants to receive multicast traffic from, and from which sources this traffic is expected. This membership information enables Cisco IOS software to forward traffic only from those sources from which receivers requested the traffic.

IGMPv3 supports applications that explicitly signal sources from which they want to receive traffic. With IGMPv3, receivers signal membership to a multicast host group in the following two modes:

- INCLUDE mode—In this mode, the receiver announces membership to a host group and provides a list of IP addresses (the INCLUDE list) from which it wants to receive traffic.
- EXCLUDE mode—In this mode, the receiver announces membership to a host group and provides a list of IP addresses (the EXCLUDE list) from which it does not want to receive traffic. In other words, the host wants to receive traffic only from sources whose IP addresses are not listed in the EXCLUDE list. To receive traffic from all sources, like in the case of the Internet Standard Multicast (ISM) service model, a host expresses EXCLUDE mode membership with an empty EXCLUDE list.

IGMPv3 is the industry-designated standard protocol for hosts to signal channel subscriptions in Source Specific Multicast (SSM). For SSM to rely on IGMPv3, IGMPv3 must be available in last hop routers and host operating system network stacks, and be used by the applications running on those hosts.

In SSM deployment cases where IGMPv3 cannot be used because it is not supported by the receiver host or the receiver applications, two Cisco-developed transition solutions enable the immediate deployment of SSM services: URL Rendezvous Directory (URD) and IGMP Version 3 lite (IGMP v3lite). For more information on URD and IGMP v3lite, see the "Configuring Source Specific Multicast" chapter in this document.

## Restrictions

### Traffic Filtering with Multicast Groups That Are Not Configured in SSM Mode

IGMPv3 membership reports are not utilized by Cisco IOS software to filter or restrict traffic for multicast groups that are not configured in SSM mode. Effectively, Cisco IOS software interprets all IGMPv3 membership reports for groups configured in dense, sparse, or bidirectional mode to be group membership reports and forwards traffic from all active sources onto the network.

### Interoperability with IGMP Snooping

You must be careful when using IGMPv3 with switches that support and are enabled for IGMP snooping, because IGMPv3 messages are different from the messages used in IGMP Version 1 (IGMPv1) and Version 2 (IGMPv2). If a switch does not recognize IGMPv3 messages, then hosts will not correctly receive traffic if IGMPv3 is being used. In this case, either IGMP snooping may be disabled on the switch or the router may be configured for IGMPv2 on the interface (which would remove the ability to use SSM for host applications that cannot resort to URD or IGMP v3lite).

### Interoperability with CGMP

Networks using CGMP will have better group leave behavior if they are configured with IGMPv2 than IGMPv3. If CGMP is used with IGMPv2 and the switch is enabled for the CGMP leave functionality, then traffic to a port joined to a multicast group will be removed from the port shortly after the last member on that port has dropped membership to that group. This fast-leave mechanism is part of IGMPv2 and is specifically supported by the CGMP fast-leave enabled switch.

With IGMPv3, there is currently no CGMP switch support of fast leave. If IGMPv3 is used in a network, CGMP will continue to work, but CGMP fast-leave support is ineffective and the following conditions apply:

- Each time a host on a new port of the CGMP switch joins a multicast group, that port is added to the list of ports to which the traffic of this group is sent.
- If all hosts on a particular port leave the multicast group, but there are still hosts on other ports (in the same virtual LAN) joined to the group, then nothing happens. In other words, the port continues to receive traffic from that multicast group.
- Only when the last host in a virtual LAN (VLAN) has left the multicast group does forwarding of the traffic of this group into the VLAN revert to no ports on the switch forwarding.

This join behavior only applies to multicast groups that actually operate in IGMPv3 mode. If legacy hosts only supporting IGMPv2 are present in the network, then groups will revert to IGMPv2 and fast leave will work for these groups.

If fast leave is needed with CGMP-enabled switches, we recommend that you not enable IGMPv3 but configure IGMPv2 on that interface.

If IGMPv3 is needed to support SSM, then you have two configuration alternatives as follows:

- Configure only the interface for IGMPv2 and use IGMP v3lite and URD.
- Enable IGMPv3 and accept the higher leave latencies through the CGMP switch.

## Changing the IGMP Query Timeout

You can specify the period of time before the router takes over as the querier for the interface, after the previous querier has stopped doing so. By default, the router waits two times the query interval controlled by the **ip igmp query-interval** interface configuration command. After that time, if the router has received no queries, it becomes the querier. This feature requires IGMP Version 2.

To change the query timeout, use the following command in interface configuration mode:

| Command | Purpose |
|---|---|
| `Router(config-if)# ip igmp querier-timeout seconds` | Sets the IGMP query timeout. |

## Changing the Maximum Query Response Time

By default, the maximum query response time advertised in IGMP queries is 10 seconds. If the router is using IGMP Version 2, you can change this value. The maximum query response time allows a router to quickly detect that there are no more directly connected group members on a LAN. Decreasing the value allows the router to *prune* groups faster.

To change the maximum query response time, use the following command in interface configuration mode:

| Command | Purpose |
|---|---|
| `Router(config-if)# ip igmp query-max-response-time seconds` | Sets the maximum query response time advertised in IGMP queries. |

## Configuring the Router as a Statically Connected Member

Sometimes either there is no group member on a network segment or a host cannot report its group membership using IGMP. However, you may want multicast traffic to go to that network segment. The following are two ways to pull multicast traffic down to a network segment:

- Use the **ip igmp join-group** interface configuration command. With this method, the router accepts the multicast packets in addition to forwarding them. Accepting the multicast packets prevents the router from fast switching.
- Use the **ip igmp static-group** interface configuration command. With this method, the router does not accept the packets itself, but only forwards them. Hence, this method allows fast switching. The outgoing interface appears in the IGMP cache, but the router itself is not a member, as evidenced by lack of an “L” (local) flag in the multicast route entry.

To configure the router itself to be a statically connected member of a group (and allow fast switching), use the following command in interface configuration mode:

| Command | Purpose |
|---|---|
| `Router(config-if)# ip igmp static-group group-address` | Configures the router as a statically connected member of a group. |

## Configuring IGMP Leave Latency

In IGMPv2 and IGMPv3, hosts send IGMP messages to indicate that they do not wish to receive a particular group, source, or channel any more. The length of time between the host wanting to leave and the router stopping forwarding is called the IGMP leave latency. IGMP leave latency is only relevant when the last host on a subnet that was a member to a group, source, or channel intends to leave, because as long as there are still other interested members, the router still needs to forward the traffic.

When a router receives such a membership message that indicates a leave, by default, it needs to verify if there are still other members interested in the traffic. To do so, the IGMP querying router sends out a group-specific or group-source-specific query. This query contains the last member query interval (LMQI), which is the time within which other still interested hosts need to send a membership report or else the router will stop forwarding. Because IGMP messages may get lost between router and hosts, the router by default does not immediately stop forwarding after the LMQI has expired, but instead it repeats this process of sending the group or group-source-specific query and waiting for membership reports for a total of times specified by the last member query count (LMQC). Only thereafter will the router stop forwarding.

By default in Cisco IOS software and in the IGMPv2 and IGMPv3 RFCs, the LMQI is 1 second, and the LMQC is 2. Therefore, the default leave latency for individual leaves in Cisco IOS software is 3 seconds.

IGMPv3 explicit tracking allows to reduce the leave latency to approximately 0 for hosts that support IGMPv3. This feature is not available for hosts that support only IGMPv2 because of the protocol limitation.

In IGMPv2, if there is only one IP multicast receiving host connected to a subnet, the **ip igmp immediate-leave group-list** command can be configured so the router immediately stop forwarding traffic for the group, resulting in a leave latency of 0.

To change the values of the LMQI, use the following command in interface configuration mode:

| Command | Purpose |
|---|---|
| `Router(config-if)# ip igmp last-member-query-interval interval` | Configures the interval at which the router sends IGMP group-specific or group-source-specific (with IGMPv3) query messages. |

To change the values of the LMQC, use the following commands in interface configuration mode:

| Command | Purpose |
|---|---|
| `Router(config-if)# ip igmp last-member-query-count lmqc` | Configures the number of times that the router sends IGMP group-specific or group-source-specific (with IGMPv3) query messages. |

# Configuring the TTL Threshold

The TTL value controls whether packets are forwarded out of an interface. You specify the TTL value in hops. Only multicast packets with a TTL greater than the interface TTL threshold are forwarded on the interface. The default value is 0, which means that all multicast packets are forwarded on the interface. To change the default TTL threshold value, use the following command in interface configuration mode:

| Command | Purpose |
|---|---|
| `Router(config-if)# ip multicast ttl-threshold ttl-value` | Configures the TTL threshold of packets being forwarded out an interface. |

# Disabling Fast Switching of IP Multicast

Fast switching of IP multicast packets is enabled by default on all interfaces (including generic routing encapsulation [GRE] and DVMRP tunnels), with one exception: It is disabled and not supported over X.25 encapsulated interfaces. Note the following properties of fast switching:

- If fast switching is disabled on an *incoming* interface for a multicast routing table entry, the packet is sent at process level for all interfaces in the outgoing interface list.
- If fast switching is disabled on an *outgoing* interface for a multicast routing table entry, the packet is process-level switched for that interface, but may be fast switched for other interfaces in the outgoing interface list.

Disable fast switching if you want to log debug messages, because when fast switching is enabled, debug messages are not logged.

To disable fast switching of IP multicast, use the following command in interface configuration mode:

| Command | Purpose |
|---|---|
| `Router(config-if)# no ip mroute-cache` | Disables fast switching of IP multicast. |

# SAP Listener Support Configuration Task List

To configure Session Announcement Protocol (SAP) listener support, perform the tasks described in the following sections. The task in the first section is required; the task in the remaining section is optional.

- Enabling SAP Listener Support (Required)
- Limiting How Long a SAP Cache Entry Exists (Optional)

## Enabling SAP Listener Support

Use session description and announcement protocols and applications to assist the advertisement of multicast multimedia conferences and other multicast sessions and to communicate the relevant session setup information to prospective participants. Sessions are described by the Session Description Protocol (SDP), which is defined in RFC 2327. SDP provides a formatted, textual description of session properties (for example, contact information, session lifetime, and the media) being used in the session (for example, audio, video, and whiteboard) with their specific attributes like TTL scope, group address, and User Datagram Protocol (UDP) port number.

Many multimedia applications rely on SDP for session descriptions. However, they may use different methods to disseminate these session descriptions. For example, IP/TV relies on the Web to disseminate session descriptions to participants. In this example, participants must know of a Web server that provides the session information.

MBONE applications (for example, vic, vat, and wb) and other applications rely on multicast session information sent throughout the network. In these cases, a protocol called Session Announcement Protocol (SAP) is used to transport the SDP session announcements. SAP Version 2 uses the well-known session directory multicast group 224.2.127.254 to disseminate SDP session descriptions for global scope sessions and group 239.255.255.255 for administrative scope sessions.

**Note** The Session Directory (SDR) application is commonly used to send and receive SDP/SAP session announcements.

To enable the Cisco IOS software to listen to Session Directory announcements, use the following command on a multicast-enabled interface in interface configuration mode:

| Command | Purpose |
|---|---|
| `Router(config-if)# ip sap listen` | Enables the Cisco IOS software to listen to Session Directory announcements. |

## Limiting How Long a SAP Cache Entry Exists

By default, entries are deleted 24 hours after they were last received from the network. To limit how long a SAP cache entry stays active in the cache, use the following command in global configuration mode:

| Command | Purpose |
|---|---|
| `Router(config)# ip sap cache-timeout` | Limits how long a SAP cache entry stays active in the cache. |

# Enabling the Functional Address for IP Multicast over Token Ring LANs

By default, IP multicast datagrams on Token Ring LAN segments use the MAC-level broadcast address 0xFFFF.FFFF.FFFF. That default places an unnecessary burden on all devices that do not participate in IP multicast. The IP Multicast over Token Ring LANs feature defines a way to map IP multicast addresses to a single Token Ring MAC address.

This feature defines the Token Ring functional address (0xc000.0004.0000) that should be used over Token Ring. A functional address is a severely restricted form of multicast addressing implemented on Token Ring interfaces. Only 31 functional addresses are available. A bit in the destination MAC address designates it as a functional address.

The implementation used by Cisco complies with RFC 1469, *IP Multicast over Token-Ring Local Area Networks*.

If you configure this feature, IP multicast transmissions over Token Ring interfaces are more efficient than they formerly were. This feature reduces the load on other machines that do not participate in IP multicast because they do not process these packets.

The following restrictions apply to the Token Ring functional address:

- This feature can be configured only on a Token Ring interface.
- Neighboring devices on the Token Ring on which this feature is used should also use the same functional address for IP multicast traffic.
- Because there are a limited number of Token Ring functional addresses, other protocols could be assigned to the Token Ring functional address 0xc000.0004.0000. Therefore, not every frame sent to the functional address is necessarily an IP multicast frame.

To enable the mapping of IP multicast addresses to the Token Ring functional address 0xc000.0004.0000, use the following command in interface configuration mode:

| Command | Purpose |
|---|---|
| `Router(config-if)# ip multicast use-functional` | Enables the mapping of IP multicast addresses to the Token Ring functional address. |

For an example of configuring the functional address, see the section "Functional Address for IP Multicast over Token Ring LAN Example" later in this chapter.

# Configuring PIM Version 2

PIM Version 2 includes the following improvements over PIM Version 1:

- A single, active RP exists per multicast group, with multiple backup RPs. This single RP compares to multiple active RPs for the same group in PIM Version 1.
- A bootstrap router (BSR) provides a fault-tolerant, automated RP discovery and distribution mechanism. Thus, routers dynamically learn the group-to-RP mappings.
- Sparse mode and dense mode are properties of a group, as opposed to an interface. We strongly recommend sparse-dense mode, as opposed to either sparse mode or dense mode only.
- PIM join and prune messages have more flexible encodings for multiple address families.
- A more flexible hello packet format replaces the query packet to encode current and future capability options.
- Register messages to an RP indicate whether they were sent by a border router or a designated router.
- PIM packets are no longer inside IGMP packets; they are standalone packets.

PIM Version 1, together with the Auto-RP feature, can perform the same tasks as the PIM Version 2 BSR. However, Auto-RP is a standalone protocol, separate from PIM Version 1, and is Cisco proprietary. PIM Version 2 is a standards track protocol in the IETF. We recommend that you use PIM Version 2.

**Note** The simultaneous deployment of Auto-RP and BSR is not supported.

Either the BSR or Auto-RP should be chosen for a given range of multicast groups. If there are PIM Version 1 routers in the network, do not use the BSR.

The Cisco PIM Version 2 implementation allows interoperability and transition between Version 1 and Version 2, although there might be some minor problems. You can upgrade to PIM Version 2 incrementally. PIM Versions 1 and 2 can be configured on different routers within one network. Internally, all routers on a shared media network must run the same PIM version. Therefore, if a PIM Version 2 router detects a PIM Version 1 router, the Version 2 router downgrades itself to Version 1 until all Version 1 routers have been shut down or upgraded.

PIM uses the BSR to discover and announce RP-set information for each group prefix to all the routers in a PIM domain. This is the same function accomplished by Auto-RP, but the BSR is part of the PIM Version 2 specification.

To avoid a single point of failure, you can configure several candidate BSRs in a PIM domain. A BSR is elected among the candidate BSRs automatically; they use bootstrap messages to discover which BSR has the highest priority. This router then announces to all PIM routers in the PIM domain that it is the BSR.

Routers that are configured as candidate RPs then unicast to the BSR the group range for which they are responsible. The BSR includes this information in its bootstrap messages and disseminates it to all PIM routers in the domain. Based on this information, all routers will be able to map multicast groups to specific RPs. As long as a router is receiving the bootstrap message, it has a current RP map.

## Prerequisites

- When PIM Version 2 routers interoperate with PIM Version 1 routers, Auto-RP should have already been deployed.-
- Because bootstrap messages are sent hop by hop, a PIM Version1 router will prevent these messages from reaching all routers in your network. Therefore, if your network has a PIM Version 1 router in it, and only Cisco routers, it is best to use Auto-RP rather than the bootstrap mechanism.

## PIM Version 2 Configuration Task List

There are two approaches to using PIM Version 2. You can use Version 2 exclusively in your network, or migrate to Version 2 by employing a mixed PIM version environment. When deploying PIM Version 2 in your network, use the following guidelines:

- If your network is all Cisco routers, you may use either Auto-RP or the bootstrap mechanism (BSR).

**Note** The simultaneous deployment of Auto-RP and BSR is not supported.

- If you have routers other than Cisco in your network, you need to use the bootstrap mechanism.

To configure PIM Version 2, perform the tasks described in the following sections. The tasks in the first section are required; the tasks in the remaining sections are optional.

- Specifying the PIM Version (Required)
- Configuring PIM Version 2 Only (Optional)
- Making the Transition to PIM Version 2 (Optional)
- Monitoring the RP Mapping Information (Optional)

# Specifying the PIM Version

All systems using Cisco IOS Release 11.3(2)T or later start in PIM Version 2 mode by default. To reenable PIM Version 2 or specify PIM Version 1 for some reason, control the PIM version by using the following command in interface configuration mode:

| Command | Purpose |
|---|---|
| `Router(config-if)# ip pim version [1 \| 2]` | Configures the PIM version used. |

# Configuring PIM Version 2 Only

To configure PIM Version 2 exclusively, perform the tasks described in this section. It is assumed that no PIM Version 1 system exists in the PIM domain.

The first task is recommended. If you configure Auto-RP, none of the other tasks is required to run PIM Version 2. To configure Auto-RP, see the section "Configuring Auto-RP" earlier in this chapter.

If you want to configure a BSR, perform the tasks in the following sections. The tasks is the first section are required; the tasks in the remaining sections are optional.

- Configuring PIM Sparse-Dense Mode (Required)
- Defining a PIM Sparse Mode Domain Border Interface (Optional)
- Configuring Candidate BSRs (Optional)
- Configuring Candidate RPs (Optional)

## Configuring PIM Sparse-Dense Mode

To configure PIM sparse-dense mode, use the following commands on all PIM routers inside the PIM domain beginning in global configuration mode:

| | Command | Purpose |
|---|---|---|
| **Step 1** | `Router(config)# ip multicast-routing` | Enables IP multicast routing. |
| **Step 2** | `Router(config)# interface type number` | Configures an interface. |
| **Step 3** | `Router(config-if)# ip pim sparse-dense-mode` | Enables PIM on the interface. The sparse-dense mode is identical to the implicit interface mode in the PIM Version 2 specification. |

Repeat Steps 2 and 3 for each interface on which you want to run PIM.

## Defining a PIM Sparse Mode Domain Border Interface

A border interface in a PIM sparse mode (PIM-SM) domain requires special precautions to avoid exchange of certain traffic with a neighboring domain reachable through that interface, especially if that domain is also running PIM-SM. BSR and Auto-RP messages should not be exchanged between different domains, because routers in one domain may elect RPs in the other domain, resulting in protocol malfunction or loss of isolation between the domains.

To prevent BSR messages from being sent or received through an interface, use the following command in interface configuration mode:

| Command | Purpose |
|---|---|
| `Router(config-if)# ip pim bsr-border` | Prevents BSR messages from being sent or received through an interface. |

To prevent Auto-RP messages from being sent or received through an interface, use the following commands beginning in global configuration mode. The access list denies packets destined for the 224.0.1.39 and 224.0.1.40 multicast groups. These two groups are specifically assigned to carry Auto-RP information.

| | Command | Purpose |
|---|---|---|
| **Step 1** | `Router(config)#` **`access-list`** *`access-list-number`* {**`deny`** \| **`permit`**} *`source`* [*`source-wildcard`*] | Defines an administratively scoped boundary. |
| **Step 2** | `Router(config-if)#` **`ip multicast boundary`** *`access-list`* | Prevents Auto-RP messages (used in PIM Version 1) from being sent or received through an interface. |

## Configuring Candidate BSRs

Configure one or more candidate BSRs. The routers to serve as candidate BSRs should be well connected and be in the backbone portion of the network, as opposed to the dialup portion of the network.

**Note** The Cisco IOS implementation of PIM BSR uses the value 0 as the default priority for candidate RPs and BSRs. This implementation predates the draft-ietf-pim-sm-bsr IETF draft, the first IETF draft to specify 192 as the default priority value. The Cisco IOS implementation, thus, deviates from the IETF draft. To comply with the default priority value specified in the draft, you must explicitly set the priority value to 192.

To configure a router to be a candidate BSR, use the following command in global configuration mode:

| Command | Purpose |
|---|---|
| `Router(config)#` **`ip pim bsr-candidate`** *`type number hash-mask-length`* [*`priority`*] | Configures the router to be a candidate BSR. |

## Configuring Candidate RPs

Configure one or more candidate RPs. Similar to BSRs, the RPs should also be well connected and in the backbone portion of the network. An RP can serve the entire IP multicast address space or a portion of it. Candidate RPs send candidate RP advertisements to the BSR.

**Note** The Cisco IOS implementation of PIM BSR uses the value 0 as the default priority for candidate RPs and BSRs. This implementation predates the draft-ietf-pim-sm-bsr IETF draft, the first IETF draft to specify 192 as the default priority value. The Cisco IOS implementation, thus, deviates from the IETF draft. To comply with the default priority value specified in the draft, you must explicitly set the priority value to 192.

Consider the following scenarios when deciding which routers should be RPs:

- In a network of Cisco routers where only Auto-RP is used, any router can be configured as an RP.
- In a network of routers that includes only Cisco PIM Version 2 routers and routers from other vendors, any router can be used as an RP.
- In a network of Cisco PIM Version 1 routers, Cisco PIM Version 2 routers, and routers from other vendors, only Cisco PIM Version 2 routers should be configured as RPs.

To configure a router to be a candidate RP, use the following command in global configuration mode:

| Command | Purpose |
|---|---|
| `Router(config)#` **`ip pim rp-candidate`** *`type number`* `[`**`group-list`** *`access-list`*`] [`**`priority`** *`value`*`]` | Configures the router to be a candidate RP. |

For examples of configuring PIM Version 2, see the section "PIM Version 2 Examples" later in this chapter.

**Note** The Cisco IOS implementation of PIM BSR selects an RP from a set of candidate RPs using a method that is incompatible with the specification in RFC 2362. Refer to CSCdy56806 using the Cisco Bug Toolkit for more information. See the "RFC 2362 Interoperable Candidate RP Example" section on page 450 for a configuration workaround.

## Making the Transition to PIM Version 2

On each LAN, the Cisco implementation of PIM Version 2 automatically enforces the rule that all PIM messages on a shared LAN are in the same PIM version. To accommodate that rule, if a PIM Version 2 router detects a PIM Version 1 router on the same interface, the Version 2 router downgrades itself to Version 1 until all Version 1 routers have been shut down or upgraded.

## Deciding When to Configure a BSR

If there are only Cisco routers in your network (no routers from other vendors), there is no need to configure a BSR. Configure Auto-RP in the mixed PIM Version 1/Version 2 environment.

**Note** The simultaneous deployment of Auto-RP and BSR is not supported.

## Dense Mode

Dense mode groups in a mixed Version 1/Version 2 region need no special configuration; they will interoperate automatically.

## Sparse Mode

Sparse mode groups in a mixed Version 1/Version 2 region are possible because the Auto-RP feature in Version 1 interoperates with the RP feature of Version 2. Although all PIM Version 2 routers also can use Version 1, we recommend that the RPs be upgraded to Version 2 (or at least upgraded to PIM Version 1 in the Cisco IOS Release 11.3 software).

To ease the transition to PIM Version 2, we also recommend the following configuration:

- Auto-RP be used throughout the region
- Sparse-dense mode be configured throughout the region

If Auto-RP was not already configured in the PIM Version 1 regions, configure Auto-RP. See the section "Configuring Auto-RP" earlier in this chapter.

## Monitoring the RP Mapping Information

To monitor the RP mapping information, use the following commands in EXEC mode as needed:

| Command | Purpose |
|---|---|
| `Router#` **`show ip pim bsr-router`** | Displays information about the currently elected BSR. |
| `Router#` **`show ip pim rp-hash`** `[`*`group-address`*` \| `*`group-name`*`]` | Displays the RP that was selected for the specified group. |
| `Router#` **`show ip pim rp mapping`** `[`*`rp-address`*`]` | Displays how the router learns of the RP (via bootstrap or Auto-RP mechanism). |

# Advanced PIM Features Configuration Task List

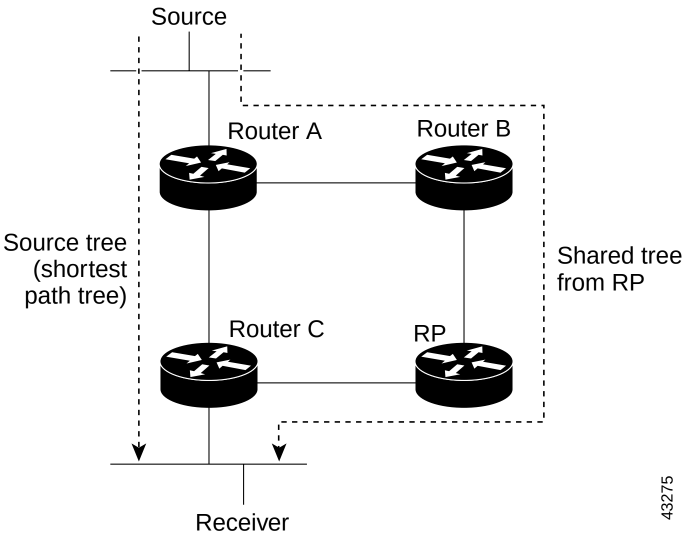
To configure PIM features, perform the optional tasks described in the following sections:

- Delaying the Use of PIM Shortest-Path Tree (Optional)
- Assigning an RP to Multicast Groups (Optional)
- Increasing Control over RPs (Optional)
- Modifying the PIM Router Query Message Interval (Optional)
- Limiting the Rate of PIM Register Messages (Optional)
- Configuring the IP Source Address of Register Messages (Optional)
- Enabling Proxy Registering (Optional)
- Enabling PIM Nonbroadcast Multiaccess Mode (Optional)

# Understanding PIM Shared Tree and Source Tree (Shortest-Path Tree)

By default, members of a group receive data from senders to the group across a single data distribution tree rooted at the RP. This type of distribution tree is called *shared tree*, as shown in Figure 67. Data from senders is delivered to the RP for distribution to group members joined to the shared tree.

*Figure 67 Shared Tree and Source Tree (Shortest-Path Tree)*



If the data rate warrants, leaf routers on the shared tree may initiate a switch to the data distribution tree rooted at the source. This type of distribution tree is called a *shortest-path tree* or *source tree*. By default, the Cisco IOS software switches to a source tree upon receiving the first data packet from a source.

The following process describes the move from shared tree to source tree in more detail:

1. Receiver joins a group; leaf Router C sends a join message toward RP.
2. RP puts link to Router C in its outgoing interface list.
3. Source sends data; Router A encapsulates data in a register message and sends it to RP.
4. RP forwards data down the shared tree to Router C and sends a join message toward Source. At this point, data may arrive twice at Router C, once encapsulated and once natively.
5. When data arrives natively (through multicast) at RP, RP sends a register-stop message to Router A.
6. By default, reception of the first data packet prompts Router C to send a join message toward Source.
7. When Router C receives data on (S, G), it sends a prune message for Source up the shared tree.
8. RP deletes the link to Router C from the outgoing interface of (S, G). RP triggers a prune message toward Source.

Join and prune messages are sent for sources and RPs. They are sent hop-by-hop and are processed by each PIM router along the path to the source or RP. Register and register-stop messages are not sent hop-by-hop. They are sent by the designated router that is directly connected to a source and are received by the RP for the group.

Multiple sources sending to groups used the shared tree.

The network manager can configure the router to stay on the shared tree, as described in the following section, "Delaying the Use of PIM Shortest-Path Tree."

# Understanding Reverse Path Forwarding

Reverse Path Forwarding (RPF) is an algorithm used for forwarding multicast datagrams. It functions as follows:

- If a router receives a datagram on an interface it uses to send unicast packets to the source, the packet has arrived on the RPF interface.
- If the packet arrives on the RPF interface, a router forwards the packet out the interfaces present in the outgoing interface list of a multicast routing table entry.
- If the packet does not arrive on the RPF interface, the packet is silently discarded to prevent loops.

PIM uses both source trees and RP-rooted shared trees to forward datagrams; the RPF check is performed differently for each, as follows:

- If a PIM router has source-tree state (that is, an (S,G) entry is present in the multicast routing table), the router performs the RPF check against the IP address of the source of the multicast packet.
- If a PIM router has shared-tree state (and no explicit source-tree state), it performs the RPF check on the RP address of the RP (which is known when members join the group).

PIM sparse mode uses the RPF lookup function to determine where it needs to send join and prune messages. (S, G) join message (which are source-tree states) are sent toward the source. (*, G) join messages (which are shared-tree states) are sent toward the RP.

DVMRP and PIM dense mode use only source trees and use RPF as described previously.

# Delaying the Use of PIM Shortest-Path Tree

The switch from shared to source tree happens upon the arrival of the first data packet at the last hop router (Router C in Figure 67). This switch occurs because the **ip pim spt-threshold** interface configuration command controls that timing, and its default setting is 0 kbps.

The shortest-path tree requires more memory than the shared tree, but reduces delay. You might want to postpone its use. Instead of allowing the leaf router to move to the shortest-path tree immediately, you can specify that the traffic must first reach a threshold.

You can configure when a PIM leaf router should join the shortest-path tree for a specified group. If a source sends at a rate greater than or equal to the specified kbps rate, the router triggers a PIM join message toward the source to construct a source tree (shortest-path tree). If the **infinity** keyword is specified, all sources for the specified group use the shared tree, never switching to the source tree.

The group list is a standard access list that controls which groups the shortest-path tree threshold applies to. If a value of 0 is specified or the group list is not used, the threshold applies to all groups.

To configure a traffic rate threshold that must be reached before multicast routing is switched from the source tree to the shortest-path tree, use the following command in global configuration mode:

| Command | Purpose |
|---|---|
| `Router(config)#` **`ip pim spt-threshold`** {*kbps* \| **infinity**} [**group-list** *access-list*] | Specifies the threshold that must be reached before moving to shortest-path tree. |

## Assigning an RP to Multicast Groups

If you have configured PIM sparse mode, you must configure a PIM RP for a multicast group. An RP can either be configured statically in each box, or learned through a dynamic mechanism. This section explains how to statically configure an RP. If the RP for a group is learned through a dynamic mechanism (such as Auto-RP), you need not perform this task for that RP. You should use Auto-RP, which is described in the section "Configuring Auto-RP" earlier in this chapter.

PIM designated routers forward data from directly connected multicast sources to the RP for distribution down the shared tree.

Data is forwarded to the RP in one of two ways. It is encapsulated in register packets and unicast directly to the RP, or, if the RP has itself joined the source tree, it is multicast forwarded per the RPF forwarding algorithm described in the preceding section, "Understanding Reverse Path Forwarding." Last hop routers directly connected to receivers may, at their discretion, join themselves to the source tree and prune themselves from the shared tree.

A single RP can be configured for multiple groups defined by an access list. If no RP is configured for a group, the router treats the group as dense using the PIM dense mode techniques.

If a conflict exists between the RP configured with this command and one learned by Auto-RP, the Auto-RP information is used, unless the **override** keyword is configured.

To assign an RP to one or more multicast groups, use the following command in global configuration mode:

| Command | Purpose |
|---|---|
| `Router(config)#` **`ip pim rp-address`** *`rp-address`* `[`*`access-list`*`] [`**`override`**`]` | Assigns an RP to multicast groups. |

## Increasing Control over RPs

You can take a defensive measure to prevent a misconfigured leaf router from interrupting PIM service to the remainder of a network. To do so, configure the local router to accept join messages only if they contain the RP address specified, when the group is in the group range specified by the access list. To configure this feature, use the following command in global configuration mode:

| Command | Purpose |
|---|---|
| `Router(config)#` **`ip pim accept-rp`** `{`*`rp-address`* `\|` **`auto-rp`**`} [`*`access-list`*`]` | Controls which RPs the local router will accept join messages from. |

## Modifying the PIM Router Query Message Interval

Router query messages are used to elect a PIM designated router. The designated router is responsible for sending IGMP host query messages. By default, multicast routers send PIM router query messages every 30 seconds. To modify this interval, use the following command in interface configuration mode:

| Command | Purpose |
|---|---|
| `Router(config-if)#` **`ip pim query-interval`** *`seconds`* | Configures the frequency at which multicast routers send PIM router query messages. |

## Understanding the PIM Registering Process

IP multicast sources do not use a signalling mechanism to announce their presence. Sources just send their data into the attached network, as opposed to receivers that use IGMP to announce their presence. If a source sends traffic to a multicast group configured in PIM-SM, the DR leading toward the source must inform the RP about the presence of this source. If the RP has downstream receivers that want to receive the multicast traffic (natively) from this source and has not joined the shortest path leading toward the source, then the DR must send the traffic from the source to the RP. The PIM registering process, which is individually run for each (S, G) entry, accomplishes these tasks between the DR and RP.

The registering process begins when a DR creates a new (S, G) state. The DR encapsulates all the data packets that match the (S, G) state into PIM register messages and unicasts those register messages to the RP.

If an RP has downstream receivers that want to receive register messages from a new source, the RP can either continue to receive the register messages through the DR or join the shortest path leading toward the source. By default, the RP will join the shortest path, because delivery of native multicast traffic provides the highest throughput. Upon receipt of the first packet that arrives natively through the shortest path, the RP will send a register-stop message back to the DR. When the DR receives this register-stop message, it will stop sending register messages to the RP.

If an RP has no downstream receivers that want to receive register messages from a new source, the RP will not join the shortest path. Instead, the RP will immediately send a register-stop message back to the DR. When the DR receives this register-stop message, it will stop sending register messages to the RP.

Once a routing entry is established for a source, a periodic reregistering takes place between the DR and RP. One minute before the multicast routing table state times out, the DR will send one dataless register message to the RP each second that the source is active until the DR receives a register-stop message from the RP. This action restarts the timeout time of the multicast routing table entry, typically resulting in one reregistering exchange every 2 minutes. Reregistering is necessary to maintain state, to recover from lost state, and to keep track of sources on the RP. It will take place independently of the RP joining the shortest path.

### PIM Version 1 Compatibility

If an RP is running PIM Version 1, it will not understand dataless register messages. In this case, the DR will not send dataless register messages to the RP. Instead, approximately every 3 minutes after receipt of a register-stop message from the RP, the DR encapsulates the incoming data packets from the source into register messages and sends them to the RP. The DR continues to send register messages until it receives another register-stop message from the RP. The same behavior occurs if the DR is running PIM Version 1.

When a DR running PIM Version 1 encapsulates data packets into register messages for a specific (S, G) entry, the entry is process-switched, not fast-switched or hardware-switched. On platforms that support these faster paths, the PIM registering process for an RP or DR running PIM Version 1 may lead to periodic out-of-order packet delivery. For this reason, we recommend upgrading your network from PIM Version 1 to PIM Version 2.

## Limiting the Rate of PIM Register Messages

To set a limit on the maximum number of PIM-SM register messages sent per second for each (S, G) routing entry, use the following global configuration command on the DR:

| Command | Purpose |
|---|---|
| `Router(config)#` **`ip pim register-rate-limit`** *`rate`* | Sets a limit on the maximum number of PIM-SM register messages sent per second for each (S, G) routing entry. |

Dataless register messages are sent at a rate of 1 message per second. Continuous high rates of register messages may occur if a DR is registering bursty sources (sources with high data rates) and if the RP is not running PIM Version 2.

By default, this command is not configured and register messages are sent without limiting their rate. Enabling this command will limit the load on the DR and RP at the expense of dropping those register messages that exceed the set limit. Receivers may experience data packet loss within the first second in which packets are sent from bursty sources.

## Configuring the IP Source Address of Register Messages

Register messages are unicast messages sent by the DR to the RP router when a multicast packet needs to be sent on a rendezvous point tree (RPT). By default, the IP source address of the register message is set to the address of the outgoing interface of the DR leading toward the RP. To configure the IP source address of a register message to an interface address other than the outgoing interface address of the DR leading toward the RP, use the following command in global configuration mode:

| Command | Purpose |
|---|---|
| `Router(config)#` **`ip pim register-source`** *`type number`* | Configures the IP source address of a register message. |

## Enabling Proxy Registering

In a PIM-SM domain, receivers know about sources because the DR connected to the source registers the source with the RP. By default, a DR will only register sources that are connected to it or that are forwarded to the DR from a DVMRP router.

For a router in a PIM-SM domain configured to operate in sparse mode or sparse-dense mode, the **ip pim dense-mode proxy-register** interface configuration command must be configured on the interface leading toward the bordering dense mode region. This configuration will enable the router to register traffic from the dense mode region with the RP in the sparse mode domain.

To enable proxy registering, use the following command in interface configuration mode:

| Command | Purpose |
|---|---|
| `Router(config-if)#` **`ip pim dense-mode`** `[`**`proxy-register`** `{`**`list`** *`access-list`* `\|` **`route-map`** *`map-name`*`}]` | Enables proxy registering on the interface of a DR (leading toward the bordering dense mode region) for multicast traffic from sources not connected to the DR. |

For traffic from DVMRP neighbors, proxy registering is always active and cannot be influenced by the **ip pim dense-mode proxy-register** interface configuration command. For dense mode or DVMRP regions, proxy registering allows for limited interoperability between a dense mode region and a sparse mode domain. This limitation is referred to as “receiver must also be sender.” The “receiver must also be sender” limit exists because there is no mechanism in dense mode protocols to convey the existence of receiver-only hosts to a border router, and the flooding (and pruning) of all multicast traffic originated in the dense mode domain inhibits the purpose of a sparse mode domain. The behavior of participating hosts in the dense mode region is as follows:

- A host in the dense mode region is only guaranteed to receive traffic from sources in the sparse mode domain through the proxy registering border router if at least one host is in the dense mode region that is a sender for the multicast group. This host is typically the receiving host itself.
- A sender in the dense mode region will trigger proxy registering in the border router, which in turn will cause the border router to join the multicast group and forward traffic from sources in the sparse mode domain toward the dense mode region.
- If no sender is in the dense mode region for a multicast group, then no traffic will be forwarded into the dense mode region.

## Enabling PIM Nonbroadcast Multiaccess Mode

PIM nonbroadcast multiaccess (NBMA) mode allows the Cisco IOS software to replicate packets for each neighbor on the NBMA network. Traditionally, the software replicates multicast and broadcast packets to all “broadcast” configured neighbors. This action might be inefficient when not all neighbors want packets for certain multicast groups. NBMA mode enables you to reduce bandwidth on links leading into the NBMA network, and to reduce the number of CPU cycles in switches and attached neighbors.

Configure this feature on ATM, Frame Relay, Switched Multimegabit Data Service (SMDS), PRI ISDN, or X.25 networks only, especially when these media do not have native multicast available. Do not use this feature on multicast-capable LANs (such as Ethernet or FDDI).

You should use PIM sparse mode with this feature. Therefore, when each join message is received from NBMA neighbors, PIM stores each neighbor IP address and interface in the outgoing interface list for the group. When a packet is destined for the group, the software replicates the packet and unicasts (data-link unicasts) it to each neighbor that has joined the group.

To enable PIM NBMA mode on your serial link, use the following command in interface configuration mode:

| Command | Purpose |
|---|---|
| `Router(config-if)# ip pim nbma-mode` | Enables PIM NBMA mode. |

Consider the following two factors before enabling PIM NBMA mode:

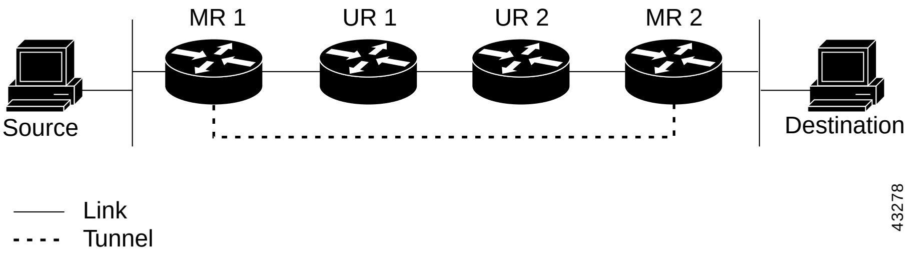
- If the number of neighbors grows, the outgoing interface list gets large, which costs memory and replication time.
- If the network (Frame Relay, SMDS, or ATM) supports multicast natively, you should use it so that replication is performed at optimal points in the network.

# Configuring an IP Multicast Static Route

IP multicast static routes (mroutes) allow you to have multicast paths diverge from the unicast paths. When using PIM, the router expects to receive packets on the same interface where it sends unicast packets back to the source. This expectation is beneficial if your multicast and unicast topologies are congruent. However, you might want unicast packets to take one path and multicast packets to take another.

The most common reason for using separate unicast and multicast paths is tunneling. When a path between a source and a destination does not support multicast routing, a solution is to configure two routers with a GRE tunnel between them. In Figure 68, each unicast router (UR) supports unicast packets only; each multicast router (MR) supports multicast packets.

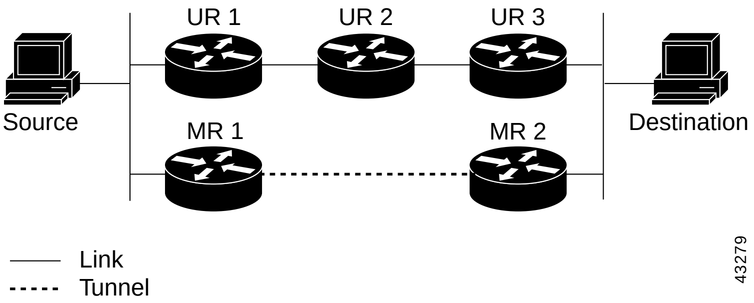
***Figure 68 Tunnel for Multicast Packets***



In Figure 68, Source delivers multicast packets to Destination by using MR 1 and MR 2. MR 2 accepts the multicast packet only if it believes it can reach Source over the tunnel. If this situation is true, when Destination sends unicast packets to Source, MR 2 sends them over the tunnel. Sending the packet over the tunnel could be slower than natively sending the it through UR 2, UR 1, and MR 1.

Prior to multicast static routes, the configuration in Figure 69 was used to overcome the problem of both unicasts and multicasts using the tunnel. In this figure, MR 1 and MR 2 are used as multicast routers only. When Destination sends unicast packets to Source, it uses the (UR 3, UR 2, UR 1) path. When Destination sends multicast packets, the UR routers do not understand or forward them. However, the MR routers forward the packets.

***Figure 69 Separate Paths for Unicast and Multicast Packets***



To make the configuration in Figure 69 work, MR 1 and MR 2 must run another routing protocol (typically a different instantiation of the same protocol running in the UR routers), so that paths from sources are learned dynamically.

A multicast static route allows you to use the configuration in Figure 68 by configuring a static multicast source. The Cisco IOS software uses the configuration information instead of the unicast routing table. Therefore, multicast packets can use the tunnel without having unicast packets use the tunnel. Static mroutes are local to the router they are configured on and not advertised or redistributed in any way to any other router.

To configure a multicast static route, use the following command in global configuration mode:

| Command | Purpose |
|---|---|
| `Router(config)#` **`ip mroute`** *`source-address mask`* `[`*`protocol as-number`*`] {`*`rpf-address`* `\|` *`type number`*`} [`*`distance`*`]` | Configures an IP multicast static route. |

# Controlling the Transmission Rate to a Multicast Group

By default, there is no limit as to how fast a sender can send packets to a multicast group. To control the rate that the sender from the source list can send to a multicast group in the group list, use the following command in interface configuration mode:

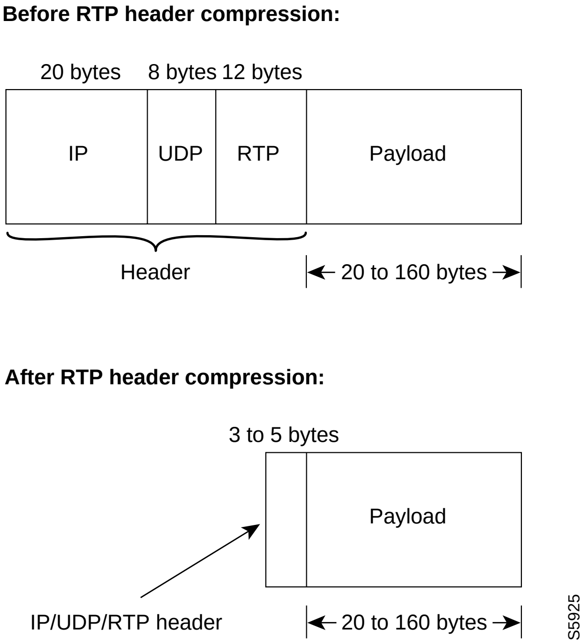
| Command | Purpose |
|---|---|
| `Router(config-if)#` **`ip multicast rate-limit`** `{`**`in`** `\|` **`out`**`} [`**`video`** `\|` **`whiteboard`**`] [`**`group-list`** *`access-list`*`] [`**`source-list`** *`access-list`*`]` *`kbps`* | Controls transmission rate to a multicast group. |

# Configuring RTP Header Compression

Real-Time Transport Protocol (RTP) is a protocol used for carrying packetized audio and video traffic over an IP network. RTP, described in RFC 1889, is not intended for data traffic, which uses TCP or UDP. RTP provides end-to-end network transport functions intended for applications with real-time requirements (such as audio, video, or simulation data over multicast or unicast network services).

The minimal 12 bytes of the RTP header, combined with 20 bytes of IP header and 8 bytes of UDP header, create a 40-byte IP/UDP/RTP header, as shown in Figure 70. The RTP packet has a payload of approximately 20 to 150 bytes for audio applications that use compressed payloads. It is very inefficient to send the IP/UDP/RTP header without compressing it.

*Figure 70 RTP Header Compression*



The RTP header compression feature compresses the IP/UDP/RTP header in an RTP data packet from 40 bytes to approximately 2 to 5 bytes, as shown in Figure 70. It is a hop-by-hop compression scheme similar to RFC 1144 for TCP/IP header compression. Using RTP header compression can benefit both telephony voice and MBONE applications running over slow links.

RTP header compression is supported on serial lines using Frame Relay, High-Level Data Link Control (HDLC), or PPP encapsulation. It is also supported over ISDN interfaces.

Enabling compression on both ends of a low-bandwidth serial link can greatly reduce the network overhead if substantial amounts of RTP traffic are on that slow link. This compression is beneficial especially when the RTP payload size is small (for example, compressed audio payloads of 20 to 50 bytes). Although the MBONE-style RTP traffic has higher payload sizes, compact encodings such as code excited linear prediction (CELP) compression can also help considerably.

Before you can enable RTP header compression, you must have configured a serial line that uses either Frame Relay, HDLC, or PPP encapsulation, or an ISDN interface. To configure RTP header compression, perform the tasks described in the following sections. Either one of the first two tasks is required.

- Enabling RTP Header Compression on a Serial Interface
- Enabling RTP Header Compression with Frame Relay Encapsulation
- Changing the Number of Header Compression Connections

You can compress the IP/UDP/RTP headers of RTP traffic to reduce the size of your packets, making audio or video communication more efficient. You must enable compression on both ends of a serial connection.

RTP header compression occurs in either the fast-switched or CEF-switched path, depending on whether certain prerequisites are met. Otherwise, it occurs in the process-switched path. For more information about where RTP header compression occurs, see the section “Enabling Express RTP Header Compression” later in this document.

# Enabling RTP Header Compression on a Serial Interface

To enable RTP header compression for serial encapsulation HDLC or PPP, use the following command in interface configuration mode:

| Command | Purpose |
|---|---|
| Router(config-if)# **ip rtp header-compression** [**passive**] | Enables RTP header compression. |

If you include the **passive** keyword, the software compresses outgoing RTP packets only if incoming RTP packets on the same interface are compressed. If you use the command without the **passive** keyword, the software compresses all RTP traffic.

See the "RTP Header Compression Examples" section later in this chapter for an example of how to enable RTP header compression on a serial interface.

# Enabling RTP Header Compression with Frame Relay Encapsulation

To enable RTP header compression with Frame Relay encapsulation, use the following commands in interface configuration mode as needed:

| Command | Purpose |
|---|---|
| Router(config-if)# **frame-relay ip rtp header-compression** [**passive**] | Enables RTP header compression on the physical interface, and all the interface maps inherit it. Subsequently, all maps will perform RTP/IP header compression. |
| Router(config-if)# **frame-relay map ip** *ip-address dlci* [**broadcast**] **rtp header-compression** [**active** \| **passive**] [**connections** *number*] | Enables RTP header compression only on the particular map specified. |
| Router(config-if)# **frame-relay map ip** *ip-address dlci* [**broadcast**] **compress** [**active** \| **passive**] [**connections** *number*] | Enables both RTP and TCP header compression on this link. |

See the "RTP Header Compression Examples" section later in this chapter for an example of how to enable RTP header compression with Frame Relay encapsulation.

To disable RTP and TCP header compression with Frame Relay encapsulation, use the following command in interface configuration mode:

| Command | Purpose |
|---|---|
| Router(config-if)# **frame-relay map ip** *ip-address dlci* [**broadcast**] **nocompress** | Disables both RTP and TCP header compression on this link. |

# Changing the Number of Header Compression Connections

For Frame Relay encapsulation, the software does not specify a maximum number of RTP header compression connections. You can configure from 3 to 256 RTP header compression connections on an interface.

By default, for PPP or HDLC encapsulation, the software allows 32 RTP header compression connections (16 calls). This default can be increased to a maximum of 1000 RTP header compression connections on an interface.

To change the number of compression connections supported, use the following command in interface configuration mode:

| Command | Purpose |
|---|---|
| `Router(config-if)#` **`frame-relay ip rtp compression-connections`** *`number`* | Specifies the maximum number of RTP header compression connections supported on the Frame Relay interface. |
| `Router(config-if)#` **`ip rtp compression-connections`** *`number`* | Specifies the total number of RTP header compression connections supported on the PPP or HDLC interface. |

See the "RTP Header Compression Examples" section later in this chapter for an example of how to change the number of header compression connections.

# Enabling Express RTP Header Compression

Before Cisco IOS Release 12.0(7)T, if compression of TCP or RTP headers was enabled, compression was performed in the process-switching path, which meant that packets traversing interfaces that had TCP or RTP header compression enabled were queued and passed up to the process to be switched. This procedure slowed down transmission of the packet, and therefore some users preferred to fast switch uncompressed TCP and RTP packets.

With Release 12.1 and later releases, if TCP or RTP header compression is enabled, it occurs by default in the fast-switched path or the Cisco Express Forwarding-switched (CEF-switched) path, depending on which switching method is enabled on the interface.

If neither fast switching nor CEF switching is enabled, if enabled, RTP header compression will occur in the process-switched path as before.

For examples of RTP header compression, see the sections "Express RTP Header Compression with PPP Encapsulation Example" and "Express RTP Header Compression with Frame Relay Encapsulation Example."

The Express RTP and TCP Header Compression feature has the following benefits:

- It reduces network overhead.
- It speeds up transmission of TCP and RTP packets. The faster speed provides a greater benefit on slower links than faster links.

One restriction affects Multilink PPP (MLP) interfaces that have link fragment and interleave (LFI). In this case, if RTP header compression is configured, RTP packets originating on or destined to the router will be process switched. Transit traffic will be fast switched.

The CEF and fast-switching aspects of this feature are related to these documents:

- *Cisco IOS Switching Services Configuration Guide*
- *Cisco IOS Switching Services Command Reference*

In order for the Express RTP Header Compression feature to work, the following conditions must exist:

- CEF switching or fast switching must be enabled on the interface.
- HDLC, PPP, or Frame Relay encapsulation must be configured.
- RTP header compression must be enabled.

The Express RTP Header Compression feature supports the following RFCs:

- RFC 1144, *Compressing TCP/IP Headers for Low-Speed Serial Links*
- RFC 2507, *IP Header Compression*
- RFC 2508, *Compressing IP/UDP/RTP Headers for Low-Speed Serial Links*

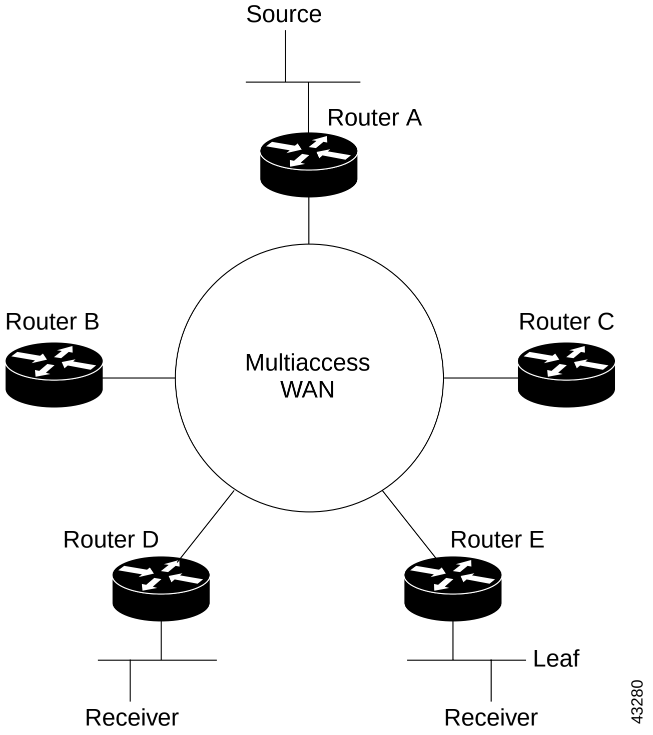
# Configuring IP Multicast over ATM Point-to-Multipoint Virtual Circuits

IP multicast over ATM point-to-multipoint virtual circuits (VCs) is a feature that dynamically creates ATM point-to-multipoint switched virtual circuits (SVCs) to handle IP multicast traffic more efficiently.

The feature can enhance router performance and link utilization because packets are not replicated and sent multiple times over the ATM interface.

Traditionally, over NBMA networks, Cisco routers would perform a pseudobroadcast to get broadcast or multicast packets to all neighbors on a multiaccess network. For example, assume in Figure 71 that routers A, B, C, D, and E were running the Open Shortest Path First (OSPF) protocol. Router A must deliver to Routers D and E. When Router A sends an OSPF hello packet, the data link layer replicates the hello packet and sends one to each neighbor (this procedure is known as *pseudobroadcast*), which results in four copies being sent over the link from Router A to the multiaccess WAN.

*Figure 71 Environment for IP Multicast over ATM Point-to-Multipoint VCs*



With the advent of IP multicast, where high-rate multicast traffic can occur, that approach does not scale. Furthermore, in the preceding example, routers B and C would get data traffic they do not need. To handle this problem, PIM can be configured in NBMA mode using the **ip pim nbma-mode** interface configuration command. PIM in NBMA mode works only for sparse mode groups. Configuring PIM in NBMA mode would allow only routers D and E to get the traffic without distributing to routers B and C. However, two copies are still delivered over the link from Router A to the multiaccess WAN.

If the underlying network supported multicast capability, the routers could handle this situation more efficiently. If the multiaccess WAN were an ATM network, IP multicast could use multipoint VCs.

To configure IP multicast using multipoint VCs, routers A, B, C, D, and E in Figure 71 must run PIM sparse mode. If the Receiver directly connected to Router D joins a group and A is the PIM RP, the following sequence of events occur:

1. Router D will send a PIM join message to Router A.
2. When Router A receives the PIM join, it sets up a multipoint VC for the multicast group.
3. Later, when the Receiver directly connected to Router E joins the same group, E will send a PIM join message to Router A.
4. Router A will see there is a multipoint VC already associated with the group, and will add Router E to the existing multipoint VC.
5. When the Source sends a data packet, Router A can send a single packet over its link that gets to both Router D and Router E. The replication occurs in the ATM switches at the topological diverging point from Router A to Router D and Router E.

If a host sends an IGMP report over an ATM interface to a router, the router adds the host to the multipoint VC for the group.

This feature can also be used over ATM subinterfaces.

You must have ATM configured for multipoint signalling. Refer to the "Configuring ATM" chapter in the *Cisco IOS Wide-Area Networking Configuration Guide* for more information on how to configure ATM for point-to-multipoint signalling.

You also must have IP multicast routing and PIM sparse mode configured. This feature does not work with PIM dense mode.

To configure IP multicast over ATM point-to-multipoint VCs, perform the tasks described in the following sections. The task in the first section is required; the task in the remaining section is optional.

- Enabling IP Multicast over ATM Point-to-Multipoint VCs (Required)
- Limiting the Number of VCs (Optional)

## Enabling IP Multicast over ATM Point-to-Multipoint VCs

To enable PIM to open ATM point-to-multipoint VCs for each multicast group that a receiver joins, use the following commands in interface configuration mode on the ATM interface:

| | Command | Purpose |
|---|---|---|
| **Step 1** | `Router(config-if)# ip pim multipoint-signalling` | Enables IP multicast over ATM point-to-multipoint VCs. |
| **Step 2** | `Router(config-if)# atm multipoint-signalling` | Enables point-to-multipoint signaling to the ATM switch. |

The **atm multipoint-signaling** interface configuration command is required so that static map multipoint VCs can be opened. The router uses existing static map entries that include the **broadcast** keyword to establish multipoint calls. You must have the map list to act like a static ARP table.

Use the **show ip pim vc** EXEC command to display ATM VC status information for multipoint VCs opened by PIM.

See the "IP Multicast over ATM Point-to-Multipoint VC Example" section later in this chapter for an example of how to enable IP multicast over ATM point-to-multipoint VCs.

## Limiting the Number of VCs

By default, PIM can open a maximum of 200 VCs. When the router reaches this number, it deletes inactive VCs so it can open VCs for new groups that might have activity. To change the maximum number of VCs that PIM can open, use the following command in interface configuration mode:

| Command | Purpose |
|---|---|
| `Router(config-if)# ip pim vc-count` *`number`* | Changes the maximum number of VCs that PIM can open. |

## Idling Policy

An idling policy uses the **ip pim vc-count** *number* interface configuration command to limit the number of VCs created by PIM. When the router stays at or below this *number* value, no idling policy is in effect. When the next VC to be opened will exceed the *number* value, an idling policy is exercised. An idled VC does not mean that the multicast traffic is not forwarded; the traffic is switched to VC 0. The VC 0 is the broadcast VC that is open to all neighbors listed in the map list. The name "VC 0" is unique to PIM and the mrouting table.

## How the Idling Policy Works

The idling policy works as follows:

- The only VCs eligible for idling are those with a current 1-second activity rate less than or equal to the value configured by the **ip pim minimum-vc-rate** interface configuration command on the ATM interface. Activity level is measured in packets per second (pps).
- The VC with the least amount of activity below the configured **ip pim minimum-vc-rate** *pps* rate is idled.
- If the **ip pim minimum-vc-rate** command is not configured, all VCs are eligible for idling.
- If other VCs are at the same activity level, the VC with the highest fanout (number of leaf routers on the multipoint VC) is idled.
- The activity level is rounded to three orders of magnitude (less than 10 pps, 10 to 100 pps, and 100 to 1000 pps). Therefore, a VC that has 40 pps activity and another that has 60 pps activity are considered to have the same rate, and the fanout count determines which one is idled. If the first VC has a fanout of 5 and the second has a fanout of 3, the first one is idled.
- Idling a VC means releasing the multipoint VC that is dedicated for the multicast group. The traffic of the group continues to be sent; it is moved to the static map VC. Packets will flow over a shared multipoint VC that delivers packets to all PIM neighbors.
- If all VCs have a 1-minute rate greater than the *pps* value, the new group (that exceeded the **ip pim vc-count** *number*) will use the shared multipoint VC.

## Keeping VCs from Idling

You can configure the minimum rate required to keep VCs from being idled. By default, all VCs are eligible for idling. To configure a minimum rate, use the following command in interface configuration mode:

| Command | Purpose |
|---|---|
| `Router(config-if)#` **`ip pim minimum-vc-rate`** *`pps`* | Sets the minimum activity rate required to keep VCs from being idled. |

# Configuring an IP Multicast Boundary

You can set up an administratively scoped boundary on an interface for multicast group addresses. A standard access list defines the range of addresses affected. When a boundary is set up, no multicast data packets are allowed to flow across the boundary from either direction. The boundary allows the same multicast group address to be reused in different administrative domains.

The Internet Assigned Numbers Authority (IANA) has designated the multicast address range 239.0.0.0 to 239.255.255.255 as the administratively scoped addresses. This range of addresses can be reused in domains administered by different organizations. They would be considered local, not globally unique.

You can configure the **filter-autorp** keyword to examine and filter Auto-RP discovery and announcement messages at the administratively scoped boundary. Any Auto-RP group range announcements from the Auto-RP packets that are denied by the boundary access control list (ACL) are removed. An Auto-RP group range announcement is permitted and passed by the boundary only if all addresses in the Auto-RP group range are permitted by the boundary ACL. If any address is not permitted, the entire group range is filtered and removed from the Auto-RP message before the Auto-RP message is forwarded.

To set up an administratively scoped boundary, use the following commands beginning in global configuration mode:

| | Command | Purpose |
|---|---|---|
| **Step 1** | Router(config)# **access-list** *access-list-number* {**deny** \| **permit**} *source* [*source-wildcard*] | Creates a standard access list, repeating the command as many times as necessary.<br>**Note** An access-list entry that uses the **deny** keyword creates a multicast boundary for packets that match that entry. |
| **Step 2** | Router(config)# **interface** *type number* | Configures an interface. |
| **Step 3** | Router(config-if)# **ip multicast boundary** *access-list* [**filter-autorp**] | Configures the boundary, specifying the access list you created in Step 1. Optionally configures Auto-RP message filtering. |

See the section "Administratively Scoped Boundary Example" later in this chapter for an example of configuring a boundary.

# Configuring an Intermediate IP Multicast Helper

When a multicast-capable internetwork is between two subnets with broadcast-only-capable hosts, you can convert broadcast traffic to multicast at the first hop router, and convert it back to broadcast at the last hop router to deliver the packets to the broadcast clients. Thus, you can take advantage of the multicast capability of the intermediate multicast internetwork. Configuring an intermediate IP multicast helper prevents unnecessary replication at the intermediate routers and can take advantage of multicast fast switching in the multicast internetwork.

See Figure 73 and the example of this feature in the section "IP Multicast Helper Example" later in this chapter.

An extended IP access list controls which broadcast packets are translated, based on the UDP port number.

To configure an intermediate IP multicast helper, the first hop router and the last hop router must be configured. To configure the first hop router, use the following commands beginning in global configuration mode:

| | Command | Purpose |
|---|---|---|
| **Step 1** | `Router(config)#` **`interface`** *`type number`* | Specifies an interface. |
| **Step 2** | `Router(config-if)#` **`ip multicast helper-map broadcast`** *`multicast-address access-list`* | Configures a first hop router to convert broadcast traffic to multicast traffic. |
| **Step 3** | `Router(config)#` **`access-list`** *`access-list-number`* {**`deny`** \| **`permit`**} **`udp`** *`source source-wildcard destination destination-wildcard port`* | Configures an access list. |
| **Step 4** | `Router(config)#` **`ip forward-protocol udp`** [*`port`*] | Configures IP to forward the protocol you are using. |

After configuring the first hop router, use the following commands on the last hop router beginning in global configuration mode:

| | Command | Purpose |
|---|---|---|
| **Step 1** | `Router(config)#` **`interface`** *`type number`* | Specifies an interface. |
| **Step 2** | `Router(config-if)#` **`ip directed-broadcast`** | Configures directed broadcasts. |
| **Step 3** | `Router(config-if)#` **`ip multicast helper-map`** *`group-address broadcast-address extended-access-list-number`* | Configures a last hop router to convert multicast traffic to broadcast traffic. |
| **Step 4** | `Router(config)#` **`access-list`** *`access-list-number`* {**`deny`** \| **`permit`**} **`udp`** *`source source-wildcard destination destination-wildcard port`* | Configures an access list. |
| **Step 5** | `Router(config)#` **`ip forward-protocol udp`** [*`port`*] | Configures IP to forward the protocol you are using. |

# Storing IP Multicast Headers

You can store IP multicast packet headers in a cache and then display them to determine any of the following information:

- Who is sending IP multicast packets to what groups
- Interpacket delay
- Duplicate IP multicast packets (if any)
- Multicast forwarding loops in your network (if any)
- Scope of the group
- UDP port numbers
- Packet length

To allocate a circular buffer to store IP multicast packet headers that the router receives, use the following command in global configuration mode:

| Command | Purpose |
|---|---|
| `Router(config)#` **`ip multicast cache-headers`** | Allocates a buffer to store IP multicast packet headers. |

**Note** The **ip multicast cache-headers** global configuration command allocates a circular buffer of approximately 32 KB.

Use the **show ip mpacket** EXEC command to display the buffer.

# Enabling CGMP

CGMP is a protocol used on routers connected to Catalyst switches to perform tasks similar to those performed by IGMP. CGMP is necessary because the Catalyst switch cannot distinguish between IP multicast data packets and IGMP report messages, which are both at the MAC level and are addressed to the same group address.

Enabling CGMP triggers a CGMP join message. CGMP should be enabled only on 802 or ATM media, or LAN emulation (LANE) over ATM. CGMP should be enabled only on routers connected to Catalyst switches.

To enable CGMP for IP multicast on a LAN, use the following command in interface configuration mode:

| Command | Purpose |
|---|---|
| `Router(config-if)# ip cgmp [proxy]` | Enables CGMP. |

When the **proxy** keyword is specified, the CGMP proxy function is enabled. That is, any router that is not CGMP-capable will be advertised by the proxy router. The proxy router advertises the existence of other non-CGMP-capable routers by sending a CGMP join message with the MAC address of the non-CGMP-capable router and group address of 0000.0000.0000.

# Configuring Stub IP Multicast Routing

When you use PIM in a large network, there are often stub regions over which the administrator has limited control. To reduce the configuration and administration burden, you can configure a subset of PIM functionality that provides the stub region with connectivity, but does not allow it to participate in or potentially complicate any routing decisions.

Stub IP multicast routing allows simple multicast connectivity and configuration at stub networks. It eliminates periodic flood-and-prune behavior across slow-speed links (ISDN and below) using dense mode. It eliminates that behavior by using forwarded IGMP reports as a type of join message and using selective PIM message filtering.

Stub IP multicast routing allows stub sites to be configured quickly and easily for basic multicast connectivity, without the flooding of multicast packets and subsequent group pruning that occurs in dense mode, and without excessive administrative burden at the central site.

Before configuring stub IP multicast routing, you must have IP multicast routing configured on both the stub router and the central router. You must also have PIM dense mode configured on both the incoming and outgoing interfaces of the stub router.

Two steps are required to enable stub IP multicast routing. One task is performed on the stub router, and the other is performed on a central router one hop away from the stub router. By definition, a stub region is marked by a leaf router. That is, the stub router (leaf router) is the last stop before any hosts receiving multicast packets or the first stop for anyone sending multicast packets.

The first step is to configure the stub router to forward all IGMP host reports and leave messages received on the interface to an IP address. The reports are re-sent out the next hop interface toward the IP address, with the source address of that interface. This action enables a sort of "dense mode" join message, allowing stub sites not participating in PIM to indicate membership in multicast groups.

To configure the stub router to forward IGMP host reports and leave messages, use the following command in interface configuration mode. Specify the IP address of an interface on the central router. When the central router receives IGMP host report and leave messages, it appropriately adds or removes the interface from its outgoing list for that group.

| Command | Purpose |
|---|---|
| `Router(config-if)#` **`ip igmp helper-address`** *`ip-address`* | On the stub router, forwards all IGMP host reports and leave messages to the specified IP address on a central router. |

The second step is to configure an access list on the central router to filter all PIM control messages from the stub router. Thus, the central router does not by default add the stub router to its outgoing interface list for any multicast groups. This task has the side benefit of preventing a misconfigured PIM neighbor from participating in PIM.

To filter PIM control messages, use the following command in interface configuration mode:

| Command | Purpose |
|---|---|
| `Router(config-if)#` **`ip pim neighbor-filter`** *`access-list`* | On the central router, filters all PIM control messages based on the specified access list. |

For an example of stub IP multicast routing, see the section "Stub IP Multicast Example" later in this chapter.

# Load Splitting IP Multicast Traffic Across Equal-Cost Paths Configuration Task List

To configure load splitting of IP multicast traffic across equal-cost paths, perform the optional tasks described in either of the following sections:

- Enabling Native Load Splitting (Optional)
- Enabling Load Splitting Across Tunnels (Optional)

## Enabling Native Load Splitting

If two or more equal-cost paths from a source are available, unicast traffic will be load split across those paths. However, by default multicast traffic will not be load split across multiple equal-cost paths. In general, multicast traffic will flow down from the RPF neighbor. According to PIM specifications, this neighbor must have the highest IP address if more than one neighbor has the same metric (refer to RFC 2362 for PIM sparse mode information).

To enable load splitting of IP multicast traffic across multiple equal-cost paths, use the following command in global configuration mode:

| Command | Purpose |
|---|---|
| `Router(config)# ip multicast multipath` | Enables load splitting of IP multicast traffic across multiple equal-cost paths. |

When the **ip multicast multipath** global configuration command is configured and multiple equal-cost paths exist, the path in which multicast traffic will travel is selected based on the source IP address. Multicast traffic from different sources will be load split across the different equal-cost paths. Load splitting will not occur across equal-cost paths for multicast traffic from the same source sent to different multicast groups.

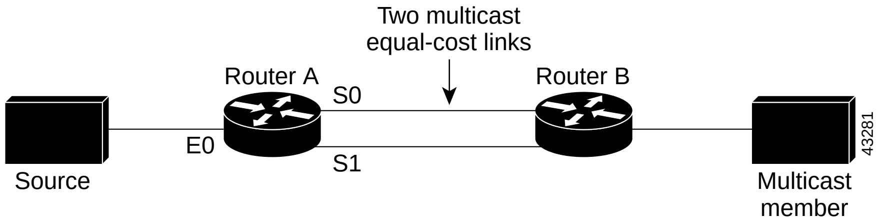
**Note** The **ip multicast multipath** global configuration command load splits the traffic and does not load balance the traffic. Traffic from a source will use only one path, even if the traffic far outweighs traffic from other sources.

The **ip multicast multipath** command does not support configurations in which the same PIM neighbor IP address is reachable through multiple equal-cost paths. This situation typically occurs if unnumbered interfaces are used. We recommend using different IP addresses for all interfaces when configuring the **ip multicast multipath** command.

## Enabling Load Splitting Across Tunnels

Load splitting of IP multicast traffic can be achieved by consolidating multiple parallel links into a single tunnel over which the multicast traffic is then routed. Figure 72 shows an example of a topology in which this method can be used. Router A and Router B are connected with two equal-cost links.

*Figure 72 Two Multicast Links Without Load Splitting*



If a tunnel is configured between Router A and Router B, and multicast traffic is made to reverse path forward over the tunnel, then the multicast packets are sent encapsulated into the tunnel as unicast packets between Router A and Router B. The underlying unicast mechanism will then perform load splitting across the equal-cost links.

To configure load splitting across tunnels, perform the tasks described in the following sections. The tasks in the first three sections are required; the task in the remaining section is optional.

- Configuring the Access Router (Required)
- Configuring the Router at the Opposite End of the Tunnel (Required)
- Configuring Both Routers to RPF (Required)
- Verifying the Load Splitting (Optional)

## Configuring the Access Router

To configure the access router end of the tunnel (the end of the tunnel near the source), use the following commands beginning in global configuration mode. The tunnel mode is GRE IP by default.

| | Command | Purpose |
|---|---|---|
| **Step 1** | Router(config)# **interface tunnel** *number* | Configures a tunnel interface. |
| **Step 2** | Router(config-if)# **ip unnumbered** *type number* | Enables IP processing without assigning an IP address to the interface. |
| **Step 3** | Router(config-if)# **ip pim** {**dense-mode** \| **sparse-mode** \| **sparse-dense-mode**} | Enables PIM on the tunnel interface. |
| **Step 4** | Router(config-if)# **tunnel source** {*ip-address* \| *type number*} | Configures the tunnel source. |
| **Step 5** | Router(config-if)# **tunnel destination** {*hostname* \| *ip-address*} | Configures the tunnel destination. |

## Configuring the Router at the Opposite End of the Tunnel

After configuring the access router end of the tunnel, use the following commands on the router at the opposite end of the tunnel beginning in global configuration mode:

| | Command | Purpose |
|---|---|---|
| **Step 1** | Router(config)# **interface tunnel** *number* | Configures a tunnel interface. |
| **Step 2** | Router(config-if)# **ip unnumbered** *type number* | Enables IP processing without assigning an IP address to the interface. |
| **Step 3** | Router(config-if)# **ip pim** {**dense-mode** \| **sparse-mode** \| **sparse-dense-mode**} | Enables PIM on the tunnel interface. |
| **Step 4** | Router(config-if)# **tunnel source** {*ip-address* \| *type number*} | Configures the tunnel source. This configuration matches the tunnel destination at the opposite end of the tunnel. |
| **Step 5** | Router(config-if)# **tunnel destination** {*hostname* \| *ip-address*} | Configures the tunnel destination. This configuration matches the tunnel source at the opposite end of the tunnel. |

## Configuring Both Routers to RPF

Because the use of the tunnel makes the multicast topology incongruent with the unicast topology, and only multicast traffic traverses the tunnel, you must configure the routers to reverse path forward correctly over the tunnel. The following sections describe two ways to configure the routers to reverse path forward multicast traffic over the tunnel, depending on your topology:

- Load Splitting to a Stub Network
- Load Splitting to the Middle of a Network

### Load Splitting to a Stub Network

To load split to a stub network using a static multicast router, use the following command on the stub router in global configuration mode:

| Command | Purpose |
|---|---|
| `Router(config)# ip mroute 0.0.0.0 0.0.0.0 tunnel number` | Configures a static multicast route over which to reverse path forward from the stub router to the other end of the tunnel. |

After configuring a static multicast route, use the following commands on the router at the opposite end of the tunnel from the stub router in global configuration mode:

| | Command | Purpose |
|---|---|---|
| **Step 1** | `Router(config)# ip mroute source-address mask tunnel number` | Configures a static route over which to reverse path forward from the access router to the other end of the tunnel. Configure the *source-address* argument to be the network address of the network connected to the stub router. |
| **Step 2** | `Router(config)# ip mroute source-address mask tunnel number` | Repeat Step 1 for each network connected to the stub router. |

### Load Splitting to the Middle of a Network

You can also use static mroutes to load split to the middle of a network, but you must make sure that Router A would reverse path forward to the tunnel for source networks behind Router B, and Router B would reverse path forward to the tunnel for source networks behind Router A.

Another option is to run a separate unicast routing protocol with a better administrative distance to provide the RPF. You must make sure that your multicast routers do not advertise the tunnel to your real network. For details, refer to the "Configuring an IP Multicast Static Route" section in this chapter.

If you are using a DVMRP routing table for RPF information within your network, you could configure the **ip dvmrp unicast-routing** interface configuration command on your tunnel interfaces to make the routers reverse path forward correctly over the tunnel.

## Verifying the Load Splitting

Load splitting works for both fast switching and process switching, but splitting the traffic among the physical interfaces is performed differently for each case. Fast switching occurs if both the incoming and outgoing interfaces are configured with the **ip mroute-cache** interface configuration command. IP multicast fast switching is enabled by default. Note the following properties of load splitting:

- With process switching, load splitting occurs on a per-packet basis by round robin on the equal-cost links. To verify that load splitting is working, look at the interface statistics using the **show interfaces accounting** EXEC command, and verify that the packet count is about equal for the underlying interfaces that provide the equal-cost paths.
- With fast switching, load splitting occurs on a per-flow basis. A flow is a set of traffic with the same source and destination. Once the cache is populated for the (S, G) pair, that flow is pinned to the physical interface assigned on the cache (the outgoing interface used by the first packet of the flow). If the cached interface goes down, the cache entry for the (S, G) pair is torn down and the flow is automatically switched to a different physical interface.

In the case of fast switching, you can verify that load splitting is occurring by viewing the multicast fast-switched cache by using the **show ip mcache** EXEC command. The flows should be split among the underlying interfaces, as shown in the following example:

```
Router# show ip mcache

IP Multicast Fast-Switching Cache
(100.1.1.6/32, 224.1.1.1), Ethernet0, Last used: 00:00:00
 Tunnel0         MAC Header: 0F000800 (Serial1)
(100.1.1.6/32, 224.1.1.2), Ethernet0, Last used: 00:00:00
 Tunnel0         MAC Header: 0F000800 (Serial1)
(100.1.1.5/32, 224.1.1.3), Ethernet0, Last used: 00:00:00
 Tunnel0         MAC Header: 0F000800 (Serial0)
(100.1.1.5/32, 224.1.1.4), Ethernet0, Last used: 00:00:00
 Tunnel0         MAC Header: 0F000800 (Serial0)
```

For an example of load splitting IP multicast traffic across equal-cost paths, see the section "Load Splitting IP Multicast Traffic Across Equal-Cost Paths Example" later in this chapter.

# Monitoring and Maintaining IP Multicast Routing Configuration Task List

To monitor and maintain IP multicast routing, perform the optional tasks described in the following sections.

- Clearing Caches, Tables, and Databases (Optional)
- Displaying System and Network Statistics (Optional)
- Using IP Multicast Heartbeat (Optional)

**Note** For information about Multicast Routing Monitor (MRM) and commands that monitor IP multicast information, see the chapter "Using IP Multicast Tools."

## Clearing Caches, Tables, and Databases

You can remove all contents of a particular cache, table, or database. Clearing a cache, table, or database can become necessary when the contents of the particular structure have become, or are suspected to be, invalid.

To clear IP multicast caches, tables, and databases, use the following commands in EXEC mode as needed:

| Command | Purpose |
|---|---|
| Router# **clear ip cgmp** | Clears all group entries the Catalyst switches have cached. |
| Router# **clear ip igmp group** [*group-name* \| *group-address* \| *type number*] | Deletes entries from the IGMP cache. |
| Router# **clear ip mroute** {***** \| *group-name* [*source-name* \| *source-address*] \| *group-address* [*source-name* \| *source-address*]} | Deletes entries from the IP multicast routing table. |
| Router# **clear ip pim auto-rp** *rp-address* | Clears the Auto-RP cache. |
| Router# **clear ip rtp header-compression** [*type number*] | Clears RTP header compression structures and statistics. |
| Router# **clear ip sap** [*group-address* \| **"***session-name***"**] | Deletes the SAP cache or a SAP cache entry. The session name is enclosed in quotation marks (**" "**) that the user must enter. |

## Displaying System and Network Statistics

You can display specific statistics such as the contents of IP routing tables, caches, and databases. Information provided can be used to determine resource utilization and solve network problems. You can also display information about node reachability and discover the routing path the packets of your device are taking through the network.

To display various routing statistics, use the following commands in EXEC mode, as needed:

| Command | Purpose |
|---|---|
| Router# **ping** [*group-name* \| *group-address*] | Sends an ICMP echo request message to a multicast group address. |
| Router# **show frame-relay ip rtp header-compression** [**interface** *type number*] | Displays Frame Relay RTP header compression statistics. |
| Router# **show ip igmp groups** [*group-name* \| *group-address* \| *type number*] [**detail**] | Displays the multicast groups that are directly connected to the router and that were learned via IGMP. |
| Router# **show ip igmp interface** [*type number*] | Displays multicast-related information about an interface. |
| Router# **show ip mcache** [*group-address* \| *group-name*] [*source-address* \| *source-name*] | Displays the contents of the IP fast-switching cache. |
| Router# **show ip mpacket** [*group-address* \| *group-name*] [*source-address* \| *source-name*] [**detail**] | Displays the contents of the circular cache header buffer. |
| Router# **show ip mroute** [*group-address* \| *group-name*] [*source-address* \| *source-name*] [*type number*] [**summary**] [**count**] [**active** *kbps*] | Displays the contents of the IP multicast routing table. |
| Router# **show ip pim interface** [*type number*] [**df** \| **count**] [*rp-address*] [**detail**] | Displays information about interfaces configured for PIM. |

| Command | Purpose |
|---|---|
| `Router# show ip pim neighbor [type number]` | Lists the PIM neighbors discovered by the router. |
| `Router# show ip pim rp [mapping \| metric] [rp-address]` | Displays the RP routers associated with a sparse mode multicast group. |
| `Router# show ip pim vc [group-address \| name] [type number]` | Displays ATM VC status information for multipoint VCs opened by PIM. |
| `Router# show ip rpf {source-address \| source-name} [metric]` | Displays how the router is doing RPF (that is, from the unicast routing table, DVMRP routing table, or static mroutes). Also displays the unicast routing metric. |
| `Router# show ip rtp header-compression [type number] [detail]` | Displays RTP header compression statistics. |
| `Router# show ip sap [group \| "session-name" \| detail]` | Displays the SAP cache. |

# Using IP Multicast Heartbeat

The IP multicast heartbeat feature enables you to monitor the delivery of IP multicast packets and to be alerted if the delivery fails to meet certain parameters.

Although you can also use MRM to monitor IP multicast, you can perform the following tasks with IP multicast heartbeat that you cannot do with MRM:

- Generate an SNMP trap
- Monitor a production multicast stream

When IP multicast heartbeat is enabled, the router monitors IP multicast packets destined for a particular multicast group at a particular interval. If the number of packets observed is less than a configured minimum amount, the router sends an Simple Network Management Protocol (SNMP) trap to a specified network management station to indicate a loss of heartbeat exception.

To configure IP multicast heartbeat, use the following commands in global configuration mode:

| | Command | Purpose |
|---|---|---|
| **Step 1** | `Router(config)# ip multicast-routing` | Enables IP multicast routing. |
| **Step 2** | `Router(config)# snmp-server host host traps community-string` | Specifies the recipient of an SNMP notification operation. |
| **Step 3** | `Router(config)# snmp-server enable traps ipmulticast` | Enables the router to send IP multicast traps. |
| **Step 4** | `Router(config)# ip multicast heartbeat group-address minimum-number window-size interval` | Enables the monitoring of the IP multicast packet delivery. |

See the "IP Multicast Heartbeat Example" section later in this chapter for an example of how to configure IP multicast heartbeat.

For more information on the information contained in IP multicast SNMP notifications, refer to the *Cisco IOS Configuration Fundamentals Command Reference*.

# IP Multicast Configuration Examples

This section provides the following IP multicast routing configuration examples:

- PIM Dense Mode Example
- PIM Sparse Mode Example
- PIM Dense Mode State Refresh Example
- Functional Address for IP Multicast over Token Ring LAN Example
- PIM Version 2 Examples
- RTP Header Compression Examples
- IP Multicast over ATM Point-to-Multipoint VC Example
- Administratively Scoped Boundary Example
- IP Multicast Helper Example
- Stub IP Multicast Example
- Load Splitting IP Multicast Traffic Across Equal-Cost Paths Example
- IP Multicast Heartbeat Example

## PIM Dense Mode Example

The following example configures PIM dense mode on Fast Ethernet interface 0/1 of the router:

```
ip multicast-routing

interface FastEthernet0/1
ip address 172.16.8.1 255.255.255.0
 ip pim dense-mode
```

## PIM Sparse Mode Example

The following example configures the Cisco IOS software to operate in PIM sparse mode. The RP router is the router whose address is 10.8.0.20.

```
ip multicast-routing
 ip pim rp-address 10.8.0.20 1
interface ethernet 1
 ip pim sparse-mode
```

# PIM Dense Mode State Refresh Example

The following example shows a PIM router that is originating, processing, and forwarding PIM Dense Mode State Refresh control messages on Fast Ethernet interface 0/1 every 60 seconds:

```
ip multicast-routing

interface FastEthernet0/1
 ip address 172.16.8.1 255.255.255.0
 ip pim state-refresh origination-interval 60
 ip pim dense-mode
```

The following example shows a PIM router that is processing and forwarding PIM Dense Mode State Refresh control messages and not originating messages on Fast Ethernet interface 1/1:

```
ip multicast-routing

interface FastEthernet1/1
 ip address 172.16.7.3 255.255.255.0
 ip pim dense-mode
```

# Functional Address for IP Multicast over Token Ring LAN Example

In the following example, any IP multicast packets going out Token Ring interface 0 are mapped to MAC address 0xc000.0004.0000:

```
interface token 0
 ip address 1.1.1.1 255.255.255.0
 ip pim dense-mode
 ip multicast use-functional
```

# PIM Version 2 Examples

This section provides examples in the following sections:

- BSR Configuration Example
- Border Router Configuration Example
- RFC 2362 Interoperable Candidate RP Example

## BSR Configuration Example

The following example is a configuration for a candidate BSR, which also happens to be a candidate RP:

```
version 11.3
!
ip multicast-routing
!
interface Ethernet0
 ip address 171.69.62.35 255.255.255.240
!
interface Ethernet1
 ip address 172.21.24.18 255.255.255.248
 ip pim sparse-dense-mode
!
interface Ethernet2
 ip address 172.21.24.12 255.255.255.248
 ip pim sparse-dense-mode
!
router ospf 1
 network 172.21.24.8 0.0.0.7 area 1
 network 172.21.24.16 0.0.0.7 area 1
!
ip pim bsr-candidate Ethernet2 30 10
ip pim rp-candidate Ethernet2 group-list 5
access-list 5 permit 239.255.2.0 0.0.0.255
```

## Border Router Configuration Example

The following example shows how to configure a border router in a PIM-SM domain on Ethernet interface 1. The **ip pim bsr-border** interface configuration command will prevent BSR messages from being sent or received through the interface. The **ip multicast boundary** interface configuration command and access list 1 will prevent Auto-RP messages from being sent or received through the interface.

```
version 12.0
!
ip multicast-routing
!
interface Ethernet0
ip address 171.69.62.35 255.255.255.240

!
interface Ethernet1
ip address 172.21.24.18 255.255.255.248
ip pim sparse-dense-mode
ip pim bsr-border
ip multicast boundary 1
!
! Access list to deny Auto-RP (224.0.1.39, 224.0.1.40) and
! all administrately scoped multicast groups (239.X.X.X)
access-list 1 deny 239.0.0.0 0.255.255.255
access-list 1 deny 224.0.1.39
access-list 1 deny 224.0.1.40
access-list 1 permit 224.0.0.0 15.255.255.255
```

## RFC 2362 Interoperable Candidate RP Example

When Cisco and non-Cisco routers are being operated in a single PIM domain with PIM Version 2 BSR, care must be taken when configuring candidate RPs because the Cisco IOS implementation of the BSR RP selection is not fully compatible with RFC 2362.

RFC 2362 specifies that the BSR RP be selected as follows (RFC 2362, 3.7):

**Step 1** Select the candidate RP with the highest priority (lowest configured priority value).

**Step 2** If there is a tie in the priority level, select the candidate RP with the highest hash function value.

**Step 3** If there is a tie in the hash function value, select the candidate RP with the highest IP address.

Cisco routers always select the candidate RP based on the longest match on the announced group address prefix before selecting an RP based on priority, hash function, or IP address.

Inconsistent candidate RP selection between Cisco and non-Cisco RFC 2362-compliant routers in the same domain if multiple candidate RPs with partially overlapping group address ranges are configured can occur. Inconsistent candidate RP selection can lead to disconnectivity between sources and receivers in the PIM domain. A source may register with one candidate RP and a receiver may connect to a different candidate RP even though it is in the same group.

The following example shows a configuration that can cause inconsistent RP selection between a Cisco and a non-Cisco router in a single PIM domain with PIM Version 2 BSR:

```
access-list 10 permit 224.0.0.0  7.255.255.255
ip pim rp-candidate ethernet1 group-list 10 priority 20

access-list 20 permit 224.0.0.0 15.255.255.255
ip pim rp-candidate ethernet2 group-list 20 priority 10
```

In this example, a candidate RP on Ethernet interface 1 announces a longer group prefix of 224.0.0.0/5 with a lower priority of 20. The candidate RP on Ethernet interface 2 announces a shorter group prefix of 224.0.0.0/4 with a higher priority of 10. For all groups that match both ranges a Cisco router will always select the candidate RP on Ethernet interface 1 because it has the longer announced group prefix. A non-Cisco fully RFC 2362-compliant router will always select the candidate RP on Ethernet interface 2 because it is configured with a higher priority.

To avoid this interoperability issue, do not configure different candidate RPs to announce partially overlapping group address prefixes. Configure any group prefixes that you want to announce from more than one candidate RP with the same group prefix length.

The following example shows how to configure the previous example so that there is no incompatibility between a Cisco router and a non-Cisco router in a single PIM domain with PIM Version 2 BSR:

```
access-list 10 permit 224.0.0.0  7.255.255.255
ip pim rp-candidate ethernet1 group-list 10 priority 20

access-list 20 permit 224.0.0.0  7.255.255.255
access-list 20 permit 232.0.0.0  7.255.255.255
ip pim rp-candidate ethernet2 group-list 20 priority 10
```

In this configuration the candidate RP on Ethernet interface 2 announces group address 224.0.0.0/5 and 232.0.0.0/5 which equal 224.0.0.0/4, but gives the interface the same group prefix length (5) as the candidate RP on Ethernet 1. As a result, both a Cisco router and an RFC 2362-compliant router will select the RP Ethernet interface 2.

## RTP Header Compression Examples

The following example enables RTP header compression for a serial, ISDN, or asynchronous interface. For ISDN, you also need a broadcast dialer map.

```
interface serial 0 :or interface bri 0
 ip rtp header-compression
 encapsulation ppp
 ip rtp compression-connections 25
```

The following Frame Relay encapsulation example shows how to enable RTP header compression on the specified map.

```
interface serial 0
 ip address 1.0.0.2 255.0.0.0
 encapsulation frame-relay
 no keepalive
 clockrate 64000
 frame-relay map ip 1.0.0.1 17 broadcast rtp header-compression connections 64
 frame-relay ip rtp header-compression
 frame-relay ip rtp compression-connections 32
```

## Express RTP Header Compression with PPP Encapsulation Example

The following example shows how to configure a Cisco 7200 router with the Express RTP Header Compression and PPP encapsulation:

```
version 12.0
no service pad
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
hostname abc-1234
!
enable password lab
!
ip subnet-zero
no ip domain-lookup
ip host xy-tftp 172.17.249.2
clock timezone GMT 1
clock summer-time GMT recurring
ip routing
ip cef
!
!
controller E1 3/0
!
controller E1 3/1
!
!
interface Ethernet2/0
 ip address 9.1.72.104 255.255.255.0
 no ip directed-broadcast
 no ip route-cache
!
interface Ethernet2/1
 ip address 15.1.1.1 255.255.255.0
 no ip directed-broadcast
 ip route-cache
 no shutdown
!
interface Serial4/0
 ip address 15.3.0.1 255.255.255.0
 no ip directed-broadcast
 encapsulation ppp
 ip rtp header-compression iphc-format
 ip tcp header-compression iphc-format
 ip rtp compression-connections 1000
 no ip mroute-cache
 clockrate 2015232
 bandwidth 2000
 ip route-cache
 no shutdown
!
interface Serial4/1
 no ip address
 no ip directed-broadcast
 no ip route-cache
 shutdown
 clockrate 2015232
!
ip default-gateway 9.1.72.1
ip classless
ip route 0.0.0.0 0.0.0.0 9.1.72.1
!
router igrp 1
 network 15.0.0.0
!
line con 0
 exec-timeout 0 0
 transport input none
line aux 0
line vty 0 4
 password lab
 login
!
no scheduler max-task-time
end
```

## Express RTP Header Compression with Frame Relay Encapsulation Example

The following example shows how to configure a Cisco 7200 router with the Express RTP Header Compression feature and Frame Relay encapsulation:

```
version 12.0
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
hostname ed1-72a
!
enable password lab
!
ip subnet-zero
no ip domain-lookup
ip host xy-tftp 172.17.249.2
clock timezone GMT 1
clock summer-time GMT recurring
ip routing
ip cef
!
!
controller E1 3/0
!
controller E1 3/1
!
interface Ethernet2/0
 ip address 9.1.72.104 255.255.255.0
 no ip directed-broadcast
 no ip route-cache
 no ip mroute-cache
 ntp broadcast client
!
interface Ethernet2/1
 ip address 15.1.1.1 255.255.255.0
 no ip directed-broadcast
 ip route-cache
 no ip mroute-cache
 no shutdown
```

```
!
interface Serial4/0
 ip address 15.3.0.1 255.255.255.0
 encapsulation frame-relay
 frame-relay map ip 15.3.0.2 100 broadcast compress connections 16
 frame-relay ip rtp header-compression
 frame-relay ip tcp header-compression
 frame-relay ip rtp compression-connections 32
no ip mroute-cache
 ip route-cache
 bandwidth 2000
 no keepalive
 no shutdown
!
interface Serial4/1
 no ip address
 no ip directed-broadcast
 no ip route-cache
 no ip mroute-cache
 shutdown
 no fair-queue
!
router igrp 1
 network 15.0.0.0
!
!
ip default-gateway 9.1.72.1
ip classless
!
map-class frame-relay frag
 frame-relay cir 64000
 frame-relay bc 1000
 frame-relay be 0
 frame-relay mincir 64000
 frame-relay adaptive-shaping becn
 frame-relay fair-queue
 frame-relay fragment 70
!
dialer-list 1 protocol ip permit
dialer-list 1 protocol ipx permit
!
line con 0
 exec-timeout 0 0
 transport input none
line aux 0
line vty 0 4
 password lab
 login
!
!
ntp clock-period 17179866
end
```

# IP Multicast over ATM Point-to-Multipoint VC Example

The following example shows how to enable IP multicast over ATM point-to-multipoint VCs:

```
interface ATM2/0
 ip address 171.69.214.43 255.255.255.248
 ip pim sparse-mode
 ip pim multipoint-signalling
 ip ospf network broadcast
 atm nsap-address 47.00918100000000410B0A1981.333333333333.00
 atm pvc 1 0 5 qsaal
 atm pvc 2 0 16 ilmi
 atm multipoint-signalling
 map-group mpvc
router ospf 9
 network 171.69.214.0 0.0.0.255 area 0
!
ip classless
 ip pim rp-address 171.69.10.13 98
!
map-list mpvc
 ip 171.69.214.41 atm-nsap 47.00918100000000410B0A1981.111111111111.00 broadcast
 ip 171.69.214.42 atm-nsap 47.00918100000000410B0A1981.222222222222.00 broadcast
 ip 171.69.214.43 atm-nsap 47.00918100000000410B0A1981.333333333333.00 broadcast
```

# Administratively Scoped Boundary Example

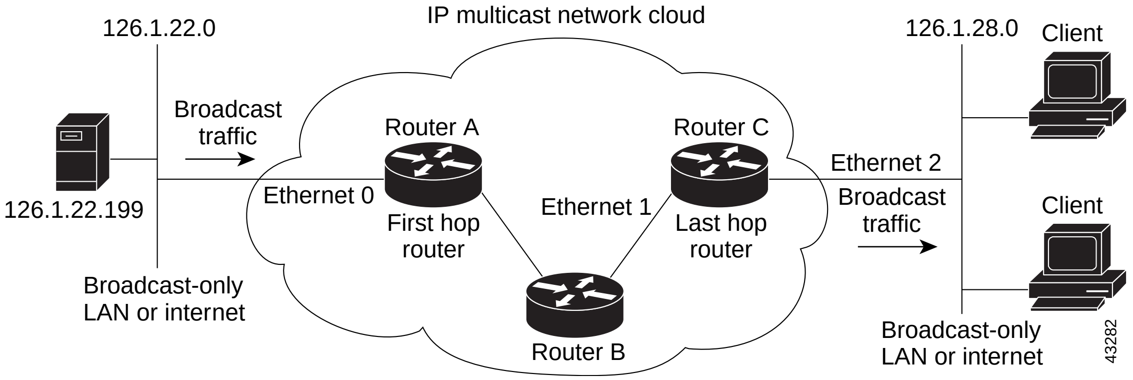
The following example shows how to set up a boundary for all administratively scoped addresses:

```
access-list 1 deny 239.0.0.0 0.255.255.255
access-list 1 permit 224.0.0.0 15.255.255.255
interface ethernet 0
 ip multicast boundary 1
```

# IP Multicast Helper Example

Figure 73 illustrates how a helper address on two routers converts traffic from broadcast to multicast and back to broadcast.

***Figure 73 IP Multicast Helper Scenario***



In this example, a server on the LAN connected to Ethernet interface 0 of Router A is sending a UDP broadcast stream with a source address of 126.1.22.199 and a destination address of 126.1.22.255:4000. The configuration on the first hop router converts the broadcast stream arriving at incoming Ethernet interface 0 destined for UDP port 4000 to a multicast stream. The access list permits traffic being sent from the server at 126.1.22.199 being sent to 126.1.22.255:4000. The traffic is sent to group address 239.254.2.5. The **ip forward-protocol** command specifies the forwarding of broadcast messages destined for UDP port 4000.

**Note** This example only displays the configuration related to configuring an IGMP intermediate helper. PIM-SM is used in this example. PIM-SM requires the use of a rendezvous point (RP). For more information about configuring RPs, see the "Configuring Basic IP Multicast" chapter in the *Cisco IOS IP Multicast Configuration Guide*, Release 12.4.

The second configuration on the last hop router converts the multicast stream arriving at incoming Ethernet interface 1 back to broadcast at outgoing Ethernet interface 2. Again, not all multicast traffic emerging from the multicast cloud should be converted from multicast to broadcast, only the traffic destined for 126.1.22.255:4000.

The configurations for Router A and Router C are as follows:

### Router A—First Hop Router Configuration

```
interface ethernet 0
 ip address 126.1.22.1 255.255.255.0
 ip pim sparse-mode
 ip multicast helper-map broadcast 239.254.2.5 105
access-list 105 permit udp host 126.1.22.199 host 126.1.22.255 eq 4000
ip forward-protocol udp 4000
```

### Router C—Last Hop Router Configuration

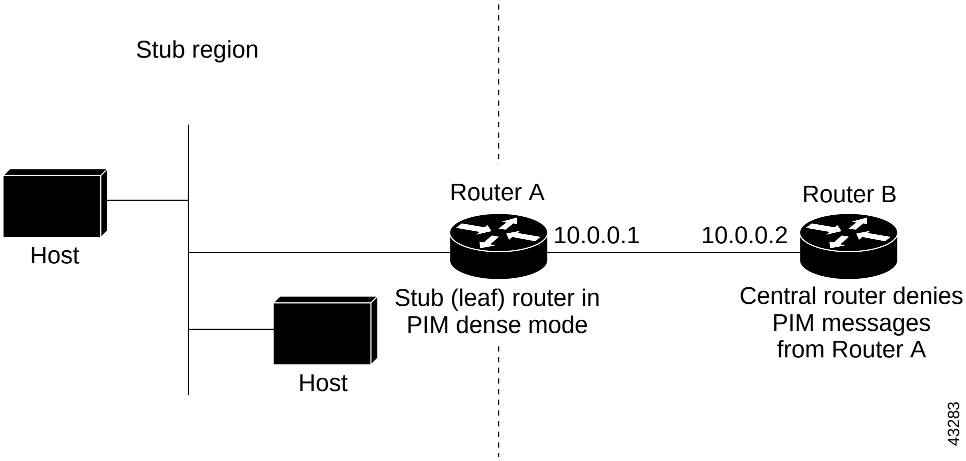
```
interface ethernet 1
 ip address 126.1.26.1 255.255.255.0
 ip pim sparse-mode
 ip multicast helper-map 239.254.2.5 126.1.28.255 105

interface ethernet 2
 ip address 126.1.28.1 255.255.255.0
 ip directed-broadcast
access-list 105 permit udp host 126.1.22.199 any eq 4000
ip forward-protocol udp 4000
```

## Stub IP Multicast Example

The following example shows how to configure stub IP multicast routing for Router A. Figure 74 illustrates the example. On stub Router A, the interfaces must be configured for PIM dense mode. The helper address is configured on the host interfaces. Central site Router B can be configured for either PIM sparse mode or dense mode. The access list on Router B denies any PIM messages from Router A.

*Figure 74 Stub IP Multicast Routing Scenario*



The configurations for Router A and Router B are as follows:

### Router A Configuration

```
ip multicast-routing
 ip pim dense-mode
 ip igmp helper-address 10.0.0.2
```

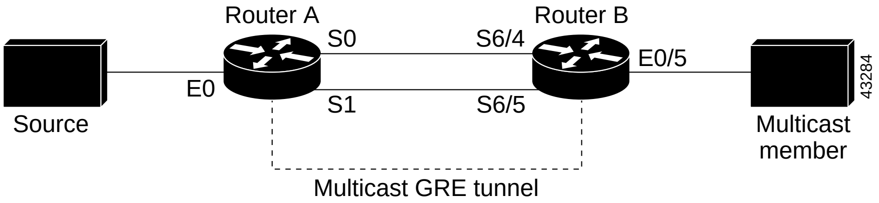
### Router B Configuration

```
ip multicast-routing
 ip pim dense-mode : or ip pim sparse-mode
 ip pim neighbor-filter 1
access-list 1 deny 10.0.0.1
```

## Load Splitting IP Multicast Traffic Across Equal-Cost Paths Example

The following example shows how to configure a GRE tunnel between Router A and Router B. Figure 75 illustrates the tunneled topology. The configurations follow the figure.

*Figure 75 IP Multicast Load Splitting Across Equal-Cost Paths*



### Router A Configuration

```
interface tunnel 0
 ip unnumbered Ethernet0
 ip pim dense-mode : or sparse-mode or sparse-dense-mode
 tunnel source 100.1.1.1
 tunnel destination 100.1.5.3
!
interface ethernet 0
 ip address 100.1.1.1 255.255.255.0
 ip pim dense-mode : or sparse-mode or sparse-dense-mode
!
interface Serial0
 ip address 100.1.2.1 255.255.255.0
 bandwidth 125
 clock rate 125000
!
interface Serial1
 ip address 100.1.3.1 255.255.255.0
 bandwidth 125
```

### Router B Configuration

```
interface tunnel 0
 ip unnumbered ethernet 0/5
 ip pim dense-mode : or sparse-mode or sparse-dense-mode
 tunnel source 100.1.5.3
 tunnel destination 100.1.1.1
!
interface ethernet 0/5
 ip address 100.1.5.3 255.255.255.0
 ip pim dense-mode : or sparse-mode or sparse-dense-mode
!
interface serial 6/4
 ip address 100.1.2.3 255.255.255.0
 bandwidth 125
!
interface Serial6/5
 ip address 100.1.3.3 255.255.255.0
 bandwidth 125
 clock rate 125000
```

## IP Multicast Heartbeat Example

The following example shows how to monitor IP multicast packets forwarded through this router to group address 244.1.1.1. If no packet for this group is received in a 10-second interval, an SNMP trap will be sent to the SNMP management station with the IP address of 224.1.0.1.

```
!
ip multicast-routing
!
snmp-server host 224.1.0.1 traps public
snmp-server enable traps ipmulticast
ip multicast heartbeat ethernet0 224.1.1.1 1 1 10
```