Internet Protocol (IP) multicast is a bandwidth-conserving technology that reduces traffic by simultaneously delivering a single stream of information to thousands of corporate recipients and homes. Applications that take advantage of multicast include videoconferencing, corporate communications, distance learning, and distribution of software, stock quotes, and news.

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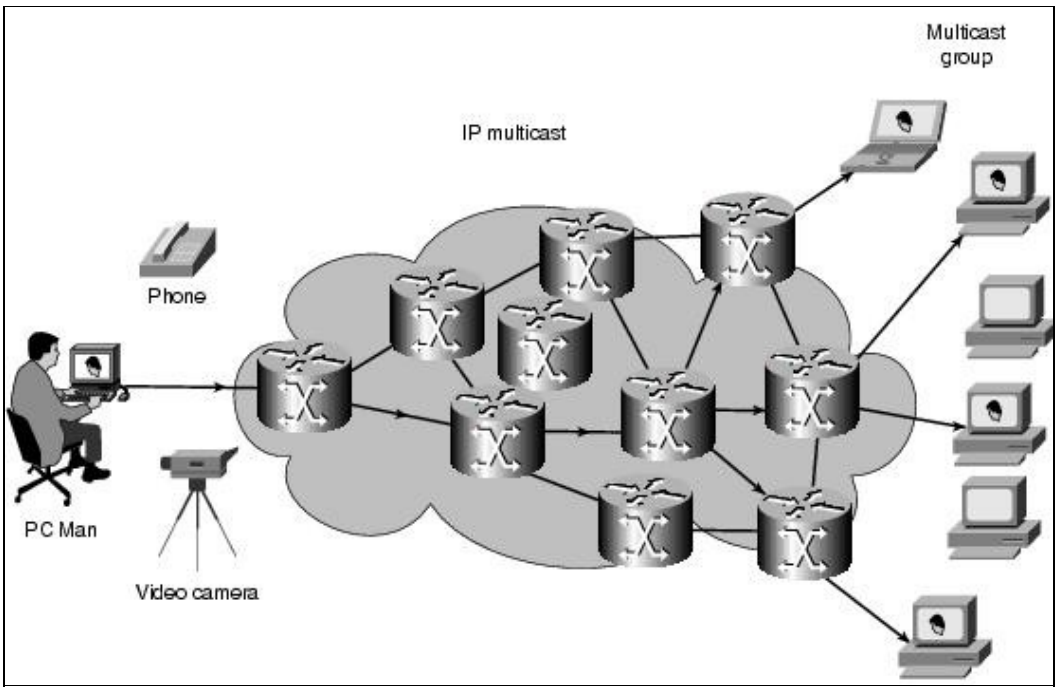
Background

IP Multicast delivers source traffic to multiple receivers without adding any additional burden on the source or the receivers while using the least network bandwidth of any competing technology. Multicast packets are replicated in the network by Cisco routers enabled with Protocol Independent Multicast (PIM) and other supporting multicast protocols resulting in the most efficient delivery of data to multiple receivers possible. All alternatives require the source to send more than one copy of the data. Some even require the source to send an individual copy to each receiver. If there are thousands of receivers, even low-bandwidth applications benefit from using Cisco IP Multicast. High-bandwidth applications, such as MPEG video, may require a large portion of the available network bandwidth for a single stream. In these applications, the only way to send to more than one receiver simultaneously is by using IP Multicast.

Figure: Multicast Transmission Sends a Single Multicast Packet Addressed to All Intended Recipients demonstrates how data from one source is delivered to several interested recipients using IP multicast.

Figure: Multicast Transmission Sends a Single Multicast Packet Addressed to All Intended Recipients



Multicast Group Concept

Multicast is based on the concept of a group. An arbitrary group of receivers expresses an interest in receiving a particular data stream. This group does not have any physical or geographical boundaries-the hosts can be located anywhere on the Internet. Hosts that are interested in receiving data flowing to a particular group must join the group using IGMP. Hosts must be a member of the group to receive the data stream.

IP Multicast Addresses

Multicast addresses specify an arbitrary group of IP hosts that have joined the group and want to receive traffic sent to this group.

IP Class D Addresses

The Internet Assigned Numbers Authority (IANA) controls the assignment of IP multicast addresses. It has assigned the old Class D address space to be used for IP multicast. This means that all IP multicast group addresses will fall in the range of 224.0.0.0 to 239.255.255.255.

Note: This address range is only for the group address or destination address of IP multicast traffic. The source address for multicast datagrams is always the unicast source address.

Reserved Link Local Addresses

The IANA has reserved addresses in the 224.0.0.0 through 224.0.0.255 to be used by network protocols on a local network segment. Packets with these addresses should never be forwarded by a router; they remain local on a particular LAN segment. They are always transmitted with a time-to-live (TTL) of 1.

Figure: Multicast Transmission Sends a Single Multicast Packet Addressed to All Intended Recipients

Network protocols use these addresses for automatic router discovery and to communicate important routing information. For example, OSPF uses 224.0.0.5 and 224.0.0.6 to exchange link state information.

Table: Link Local Addresses lists some of the well-known addresses.

Table: Link Local Addresses

Address	Usage
224.0.0.1	All systems on this subnet
224.0.0.2	All routers on this subnet
224.0.0.5	OSPF routers
224.0.0.6	OSPF designated routers
224.0.0.12	DHCP server/relay agent

Globally Scoped Address

The range of addresses from 224.0.1.0 through 238.255.255.255 are called globally scoped addresses. They can be used to multicast data between organizations and across the Internet.

Some of these addresses have been reserved for use by multicast applications through IANA. For example, 224.0.1.1 has been reserved for Network Time Protocol (NTP).

More information about reserved multicast addresses can be found at http://www.isi.edu/in-notes/iana/assignments/multicast-addresses.

Limited Scope Addresses

The range of addresses from 239.0.0.0 through 239.255.255.255 contains limited scope addresses or administratively scoped addresses. These are defined by RFC 2365 to be constrained to a local group or organization. Routers are typically configured with filters to prevent multicast traffic in this address range from flowing outside an autonomous system (AS) or any user-defined domain. Within an autonomous system or domain, the limited scope address range can be further subdivided so those local multicast boundaries can be defined. This also allows for address reuse among these smaller domains.

Glop Addressing

RFC 2770 proposes that the 233.0.0.0/8 address range be reserved for statically defined addresses by organizations that already have an AS number reserved. The AS number of the domain is embedded into the second and third octets of the 233.0.0.0/8 range.

For example, the AS 62010 is written in hex as F23A. Separating out the two octets F2 and 3A, we get 242 and 58 in decimal. This would give us a subnet of 233.242.58.0 that would be globally reserved for AS 62010 to use.

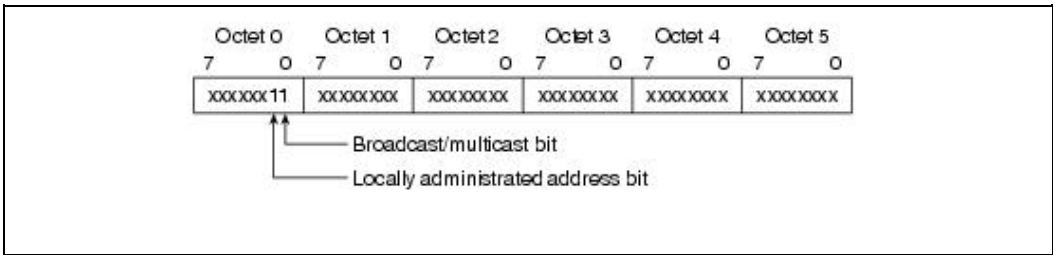
Layer 2 Multicast Addresses

Normally, network interface cards (NICs) on a LAN segment will receive only packets destined for their burned-in MAC address or the broadcast MAC address. Some means had to be devised so that multiple hosts could receive the same packet and still be capable of differentiating among multicast groups.

Fortunately, the IEEE LAN specifications made provisions for the transmission of broadcast and/or multicast packets. In the 802.3 standard, bit 0 of the first octet is used to indicate a broadcast and/or multicast frame.

Figure: IEEE 802.3 MAC Address Format shows the location of the broadcast/multicast bit in an Ethernet frame.

Figure: IEEE 802.3 MAC Address Format



This bit indicates that the frame is destined for an arbitrary group of hosts or all hosts on the network (in the case of the broadcast address, 0xFFFF.FFFF.FFFF).

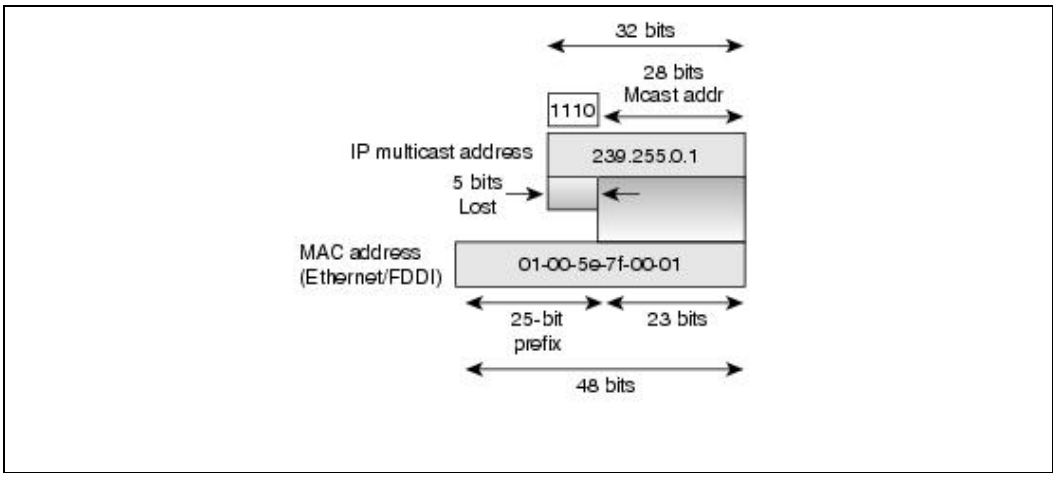
IP multicast makes use of this capability to transmit IP packets to a group of hosts on a LAN segment.

Ethernet MAC Address Mapping

The IANA owns a block of Ethernet MAC addresses that start with 01:00:5E in hexadecimal. Half of this block is allocated for multicast addresses. This creates the range of available Ethernet MAC addresses to be 0100.5e00.0000 through 0100.5e7f.ffff.

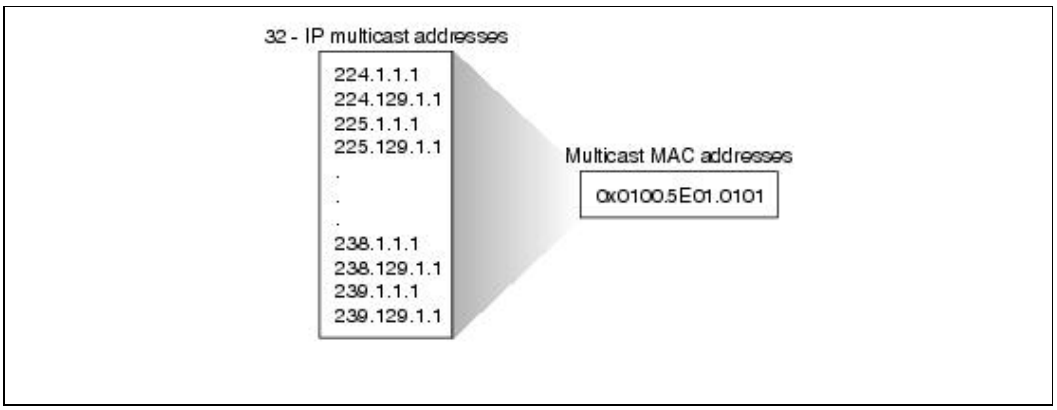
This allocation allows for 23 bits in the Ethernet address to correspond to the IP multicast group address. The mapping places the lower 23 bits of the IP multicast group address into these available 23 bits in the Ethernet address (shown in Figure: Mapping of IP Multicast to Ethernet/FDDI MAC Address).

Figure: Mapping of IP Multicast to Ethernet/FDDI MAC Address



Because the upper 5 bits of the IP multicast address are dropped in this mapping, the resulting address is not unique. In fact, 32 different multicast group IDs all map to the same Ethernet address (see Figure: MAC Address Ambiguities).

Figure: MAC Address Ambiguities



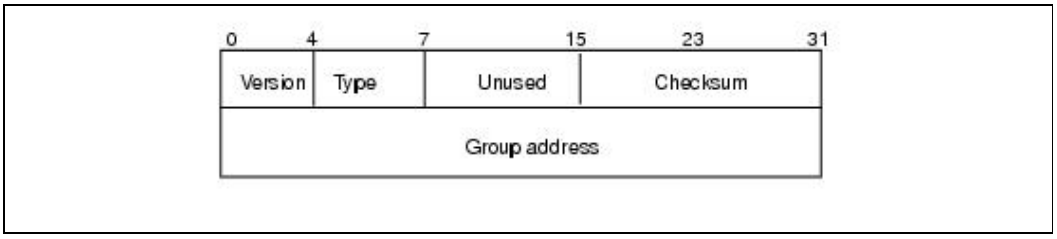
Internet Group Management Protocol

IGMP is used to dynamically register individual hosts in a multicast group on a particular LAN. Hosts identify group memberships by sending IGMP messages to their local multicast router. Under IGMP, routers listen to IGMP messages and periodically send out queries to discover which groups are active or inactive on a particular subnet.

IGMP Version 1

RFC 1112 defines the specification for IGMP Version 1. A diagram of the packet format is found in Figure: IGMP Version 1 Packet Format.

Figure: IGMP Version 1 Packet Format



In Version 1, there are just two different types of IGMP messages:

- Membership query
- Membership report

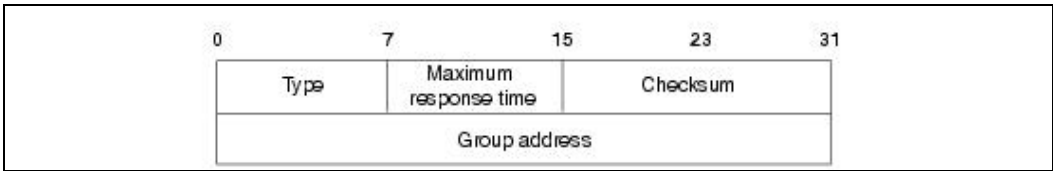
Hosts send out IGMP membership reports corresponding to a particular multicast group to indicate that they are interested in joining that group. The router periodically sends out an IGMP membership query to verify that at least one host on the subnet is still interested in receiving traffic directed to that group. When there is no reply to three consecutive IGMP membership queries, the router times out the group and stops forwarding traffic directed toward that group.

IGMP Version 2

RFC 2236 defines the specification for IGMP Version 2.

A diagram of the packet format follows in the following figure.

Figure: IGMPv2 Message Format



In Version 2, there are four types of IGMP messages:

- Membership query
- Version 1 membership report
- Version 2 membership report
- Leave group

IGMP Version 2 works basically the same as Version 1. The main difference is that there is a leave group message. The hosts now can actively communicate to the local multicast router their intention to leave the group. The router then sends out a group-specific query and determines whether there are any remaining hosts interested in receiving the traffic. If there are no replies, the router times out the group and stops forwarding the traffic. This can greatly reduce the leave latency compared to IGMP Version 1. Unwanted and unnecessary traffic can be stopped much sooner.

Multicast in the Layer 2 Switching Environment

The default behavior for a Layer 2 switch is to forward all multicast traffic to every port that belongs to the destination LAN on the switch. This would defeat the purpose of the switch, which is to limit traffic to the ports that need to receive the data.

Two methods exist by which to deal with multicast in a Layer 2 switching environment efficiently-Cisco Group Management Protocol (CGMP) and IGMP snooping.

Cisco Group Management Protocol

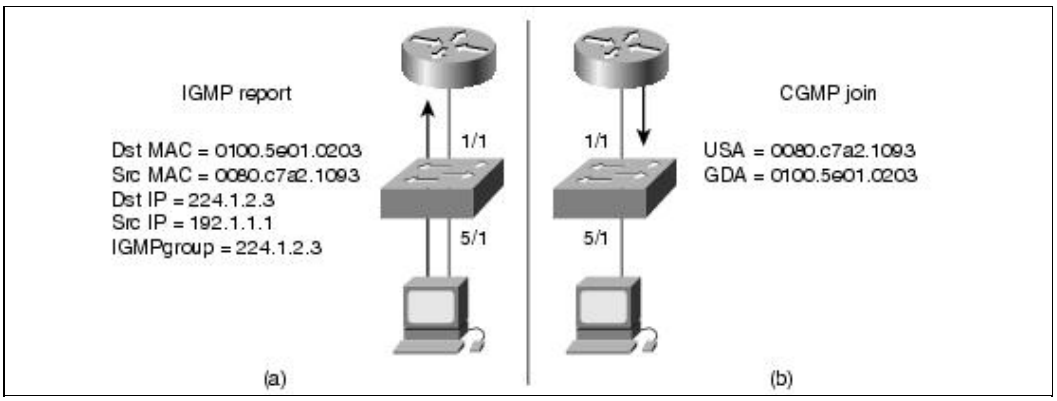
CGMP is a Cisco-developed protocol that allows Catalyst switches to leverage IGMP information on Cisco routers to make Layer 2 forwarding decisions. CGMP must be configured both on the multicast routers and on the Layer 2 switches. The net result is that with CGMP, IP multicast traffic is delivered only to those Catalyst switch ports that are interested in the traffic. All other ports that have not explicitly requested the traffic will not receive it.

When a host joins a multicast group (part A), it multicasts an unsolicited IGMP membership report message to the target group (224.1.2.3, in this example). The IGMP report is passed through the switch to the router for the normal IGMP processing. The router (which must have CGMP enabled on this interface) receives this IGMP report and processes it as it normally would, but in addition it creates a CGMP join message and sends it to the switch.

The switch receives this CGMP join message and then adds the port to its content addressable memory (CAM) table for that multicast group. Subsequent traffic directed to this multicast group will be forwarded out the port for that host. The router port is also added to the entry for the multicast group. Multicast routers must listen to all multicast traffic for every group because the IGMP control messages are also sent as multicast traffic. With CGMP, the switch must listen only to CGMP join and CGMP leave messages from the router. The rest of the multicast traffic is forwarded using its CAM table exactly the way the switch was designed.

The basic concept of CGMP is shown in Figure: Basic CGMP Operation.

Figure: Basic CGMP Operation



IGMP Snooping

IGMP snooping requires the LAN switch to examine, or snoop, some Layer 3 information in the IGMP packets sent between the hosts and the router. When the switch hears the IGMP host report from a host for a particular multicast group, the switch adds the host's port number to the associated multicast table entry. When the switch hears the IGMP leave group message from a host, it removes the host's port from the table entry.

Because IGMP control messages are transmitted as multicast packets, they are indistinguishable from multicast data at Layer 2. A switch running IGMP snooping examine every multicast data packet to check whether it contains any pertinent IGMP must control information. If IGMP snooping has been implemented on a low-end switch with a slow CPU, this could have a severe performance impact when data is transmitted at high rates. The solution is to implement IGMP snooping on high-end switches with special ASICs that can perform the IGMP checks in hardware. CGMP is ideal for low-end switches without special hardware.

Multicast Distribution Trees

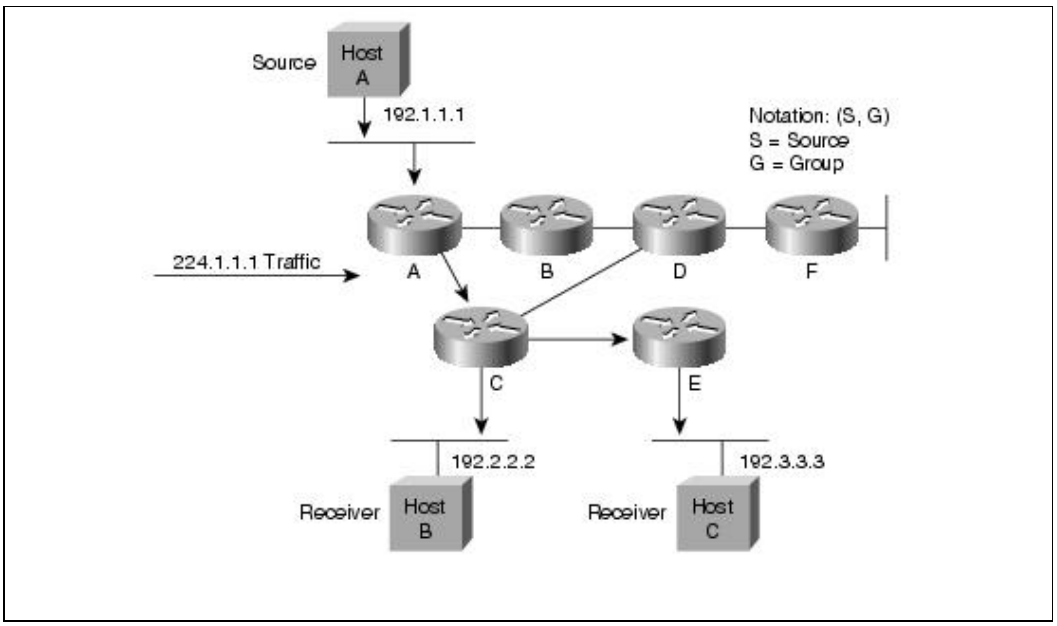
Multicast-capable routers create distribution trees that control the path that IP multicast traffic takes through the network to deliver traffic to all receivers. The two basic types of multicast distribution trees are source trees and shared trees.

Source Trees

The simplest form of a multicast distribution tree is a source tree whose root is the source of the multicast tree and whose branches form a spanning tree through the network to the receivers. Because this tree uses the shortest path through the network, it is also referred to as a shortest path tree (SPT).

Figure: Host A Shortest Path Tree shows an example of an SPT for group 224.1.1.1 rooted at the source, Host A, and connecting two receivers, hosts B and C.

Figure: Host A Shortest Path Tree



The special notation of (S,G), pronounced "S comma G," enumerates an SPT in which S is the IP address of the source and G is the multicast group address. Using this notation, the SPT for the example in Figure 43-7 would be (192.1.1.1, 224.1.1.1).

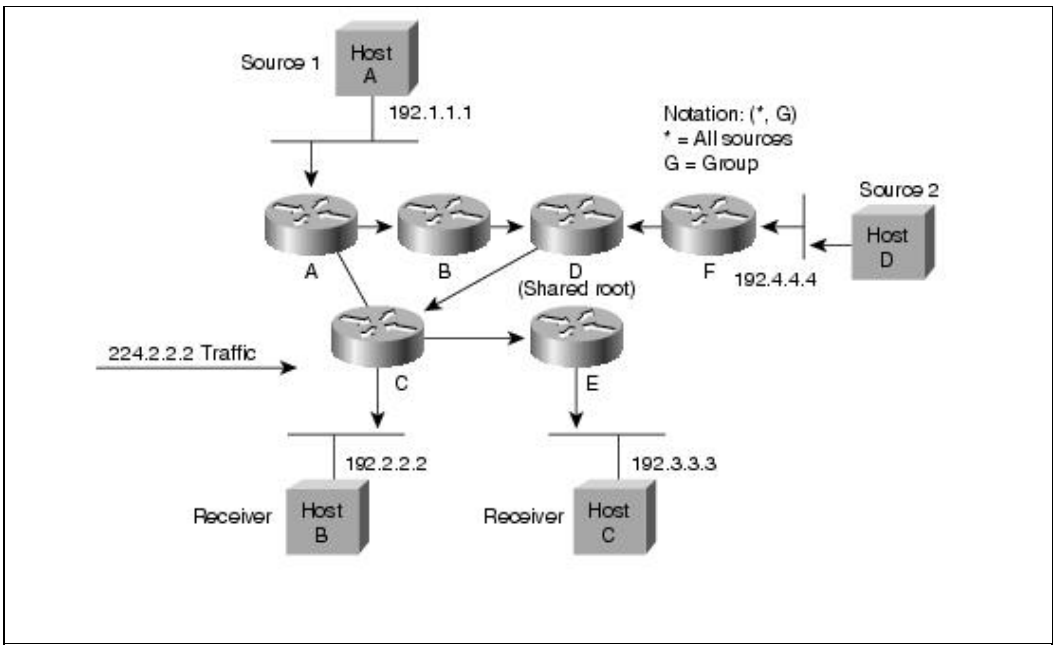
The (S,G) notation implies that a separate SPT exists for each individual source sending to each group, which is correct. For example, if Host B is also sending traffic to group 224.1.1.1 and hosts A and C are receivers, then a separate (S,G) SPT would exist with a notation of (192.2.2.2,224.1.1.1).

Shared Trees

Unlike source trees that have their root at the source, shared trees use a single common root placed at some chosen point in the network. This shared root is called the rendezvous point (RP).

Figure: Shared Distribution Tree shows a shared tree for the group 224.2.2.2 with the root located at Router D. When using a shared tree, sources must send their traffic to the root, and then the traffic is forwarded down the shared tree to reach all receivers.

Figure: Shared Distribution Tree



In this example, multicast traffic from the source hosts A and D travels to the root (Router D) and then down the shared tree to the two receivers, hosts B and C. Because all sources in the multicast group use a common shared tree, a wildcard notation written as (*, G), pronounced "star comma G," represents the tree. In this case, * means all sources, and the G represents the multicast group. Therefore, the shared tree shown in the figure would be written as (*, 224.2.2.2).

Both SPT and shared trees are loop-free. Messages are replicated only where the tree branches.

Members of multicast groups can join or leave at any time, so the distribution trees must be dynamically updated. When all the active receivers on a particular branch stop requesting the traffic for a particular multicast group, the routers prune that branch from the distribution tree and stop forwarding traffic down that branch. If one receiver on that branch becomes active and requests the multicast traffic, the router dynamically modifies the distribution tree and starts forwarding traffic again.

Shortest path trees have the advantage of creating the optimal path between the source and the receivers. This guarantees the minimum amount of network latency for forwarding multicast traffic. This optimization does come with a price, though: The routers must maintain path information for each source. In a network that has thousands of sources and thousands of groups, this can quickly become a resource issue on the routers. Memory consumption from the size of the multicast routing table is a factor that network designers must take into consideration.

Shared trees have the advantage of requiring the minimum amount of state in each router. This lowers the overall memory requirements for a network that allows only shared trees. The disadvantage of shared trees is that, under certain circumstances, the paths between the source and receivers might not be the optimal paths-which might introduce some latency in packet delivery. Network designers must carefully consider the placement of the RP when implementing an environment with only shared trees.

Multicast Forwarding

In unicast routing, traffic is routed through the network along a single path from the source to the destination host. A unicast router does not really care about the source address-it only cares about the destination address and how to forward the traffic towards that destination. The router scans through its routing table and then forwards a single copy of the unicast packet out the correct interface in the direction of the destination.

Figure: Shared Distribution Tree

In multicast routing, the source is sending traffic to an arbitrary group of hosts represented by a multicast group address. The multicast router must determine which direction is upstream (toward the source) and which direction (or directions) is downstream. If there are multiple downstream paths, the router replicates the packet and forwards the traffic down the appropriate downstream paths-which is not necessarily all paths. This concept of forwarding multicast traffic away from the source, rather than to the receiver, is called reverse path forwarding.

Reverse Path Forwarding

Reverse path forwarding (RPF) is a fundamental concept in multicast routing that enables routers to correctly forward multicast traffic down the distribution tree. RPF makes use of the existing unicast routing table to determine the upstream and downstream neighbors. A router forwards a multicast packet only if it is received on the upstream interface. This RPF check helps to guarantee that the distribution tree will be loop-free.

RPF Check

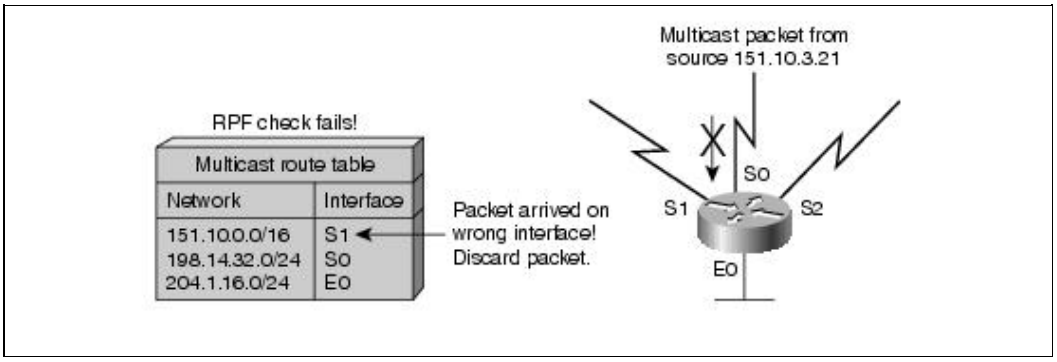
When a multicast packet arrives at a router, the router performs an RPF check on the packet. If the RPF check is successful, the packet is forwarded. Otherwise, it is dropped.

For traffic flowing down a source tree, the RPF check procedure works as follows:

1. Router looks up the source address in the unicast routing table to determine whether it has arrived on the interface that is on the reverse path back to the source.
2. If packet has arrived on the interface leading back to the source, the RPF check is successful and the packet is forwarded.
3. If the RPF check in Step 2 fails, the packet is dropped.

Figure: RPF Check Fails shows an example of an unsuccessful RPF check.

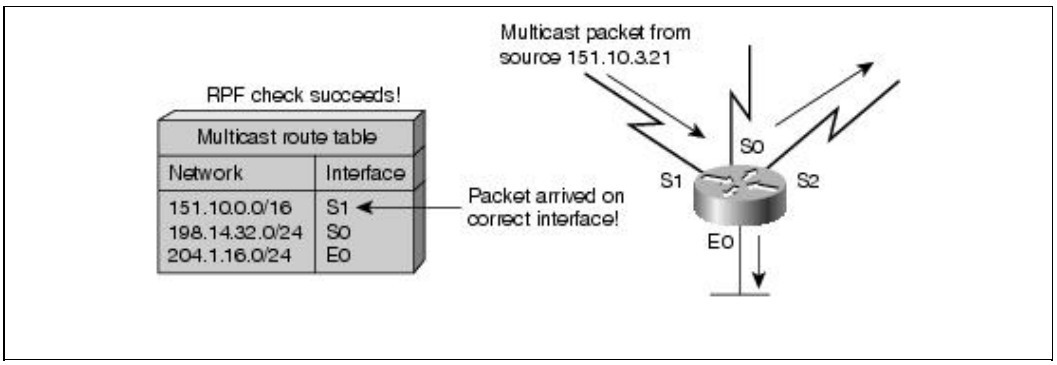
Figure: RPF Check Fails



A multicast packet from source 151.10.3.21 is received on interface S0. A check of the unicast route table shows that the interface that this router would use to forward unicast data to 151.10.3.21 is S1. Because the packet has arrived on S0, the packet will be discarded.

Figure: RPF Check Succeeds shows an example of a successful RPF check.

Figure: RPF Check Succeeds



This time the multicast packet has arrived on S1. The router checks the unicast routing table and finds that S1 is the correct interface. The RPF check passes and the packet is forwarded.

Protocol-Independent Multicast

Protocol-independent multicast (PIM) gets its name from the fact that it is IP routing protocol-independent. PIM can leverage whichever unicast routing protocols are used to populate the unicast routing table, including EIGRP, OSPF, BGP, or static routes. PIM uses this unicast routing information to perform the multicast forwarding function, so it is IP protocol-independent. Although PIM is called a multicast routing protocol, it actually uses the unicast routing table to perform the reverse path forwarding (RPF) check function instead of building up a completely independent multicast routing table. PIM does not send and receive multicast routing updates between routers like other routing protocols do.

PIM Dense Mode

PIM Dense Mode (PIM-DM) uses a push model to flood multicast traffic to every corner of the network. This is a brute-force method for delivering data to the receivers, but in certain applications, this might be an efficient mechanism if there are active receivers on every subnet in the network.

PIM-DM initially floods multicast traffic throughout the network. Routers that do not have any downstream neighbors prune back the unwanted traffic. This process repeats every 3 minutes.

The flood and prune mechanism is how the routers accumulate their state information-by receiving the data stream. These data streams contain the source and group information so that downstream routers can build up their multicast forwarding tables. PIM-DM can support only source trees-(S,G) entries. It cannot be used to build a shared distribution tree.

PIM Sparse Mode

PIM Sparse Mode (PIM-SM) uses a pull model to deliver multicast traffic. Only networks that have active receivers that have explicitly requested the data will be forwarded the traffic. PIM-SM is defined in RFC 2362.

PIM-SM uses a shared tree to distribute the information about active sources. Depending on the configuration options, the traffic can remain on the shared tree or switch over to an optimized source distribution tree. The latter is the default behavior for PIM-SM on Cisco routers. The traffic starts to flow down the shared tree, and then routers along the path determine whether there is a better path to the source. If a better, more direct path exists, the designated router (the router closest to the receiver) will send a join message toward the source and then reroute the traffic along this path.

Figure: RPF Check Succeeds

PIM-SM has the concept of an RP, since it uses shared trees-at least initially. The RP must be administratively configured in the network. Sources register with the RP, and then data is forwarded down the shared tree to the receivers. If the shared tree is not an optimal path between the source and the receiver, the routers dynamically create a source tree and stop traffic from flowing down the shared tree. This is the default behavior in IOS. Network administrators can force traffic to stay on the shared tree by using a configuration option (lp pim spt-threshold infinity).

PIM-SM scales well to a network of any size, including those with WAN links. The explicit join mechanism prevents unwanted traffic from flooding the WAN links.

Sparse-Dense Mode

Cisco has implemented an alternative to choosing just dense mode or just sparse mode on a router interface new IP. This was necessitated by a change in the paradigm for forwarding multicast traffic via PIM that became apparent during its development. It turned out that it was more efficient to choose sparse or dense on a per group basis rather than a per router interface basis. Sparse-dense mode facilitates this ability.

Network administrators can also configure sparse-dense mode. This configuration option allows individual groups to be run in either sparse or dense mode, depending on whether RP information is available for that group. If the router learns RP information for a particular group, it will be treated as sparse mode; otherwise, that group will be treated as dense mode.

Multiprotocol Border Gateway Protocol

Multiprotocol Border Gateway Protocol (MBGP) gives a method for providers to distinguish which route prefixes they will use for performing multicast RPF checks. The RPF check is the fundamental mechanism that routers use to determine the paths that multicast forwarding trees will follow and successfully deliver multicast content from sources to receivers.

MBGP is described in RFC 2283, Multiprotocol Extensions for BGP-4. Since MBGP is an extension of BGP, it brings along all the administrative machinery that providers and customers like in their interdomain routing environment. Including all the inter-AS tools to filter and control routing (e.g., route maps). Therefore, by using MBGP, any network utilizing internal or external BGP can apply the multiple policy control knobs familiar in BGP to specify routing (and thereby forwarding) policy for multicast.

Two path attributes, MP_REACH_NLRI and MP_UNREACH_NLRI have been introduced in BGP4+. These new attributes create a simple way to carry two sets of routing information-one for unicast routing and one for multicast routing. The routes associated with multicast routing are used to build the multicast distribution trees.

The main advantage of MBGP is that an internet can support noncongruent unicast and multicast topologies. When the unicast and multicast topologies are congruent, MBGP can support different policies for each. MBGP provides a scalable policy based interdomain routing protocol.

Multicast Source Discovery Protocol

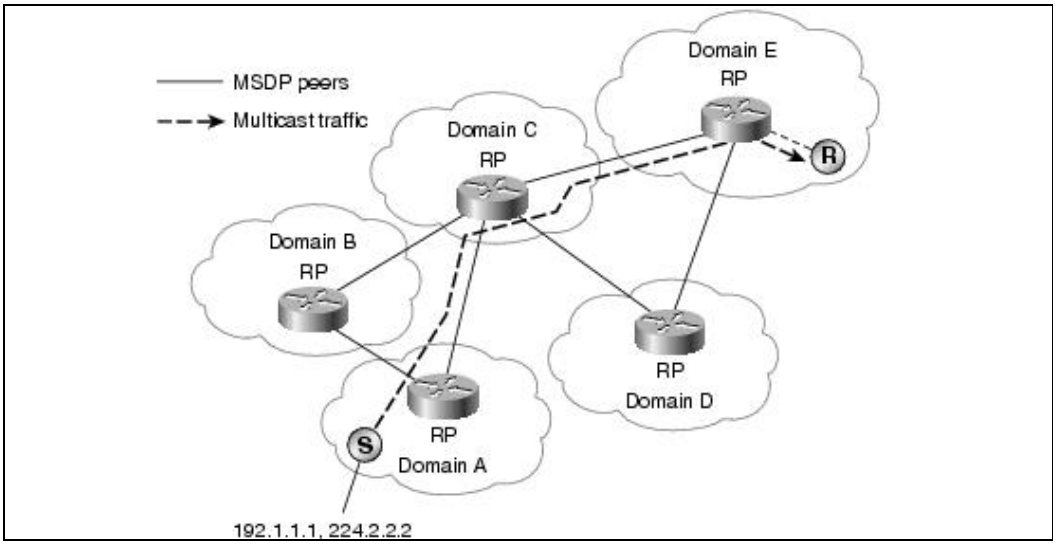
In the PIM Sparse mode model, multicast sources and receivers must register with their local Rendezvous Point (RP). Actually, the closest router to the sources or receivers registers with the RP but the point is that the RP knows about all the sources and receivers for any particular group. RPs in other domains have no way of knowing about sources located in other domains. MSDP is an elegant way to solve this problem. MSDP is a mechanism that connects PIM-SM domains and allows RPs to share information about active sources. When RPs in remote domains know about active sources they can pass on that information to their local

receivers and multicast data can be forwarded between the domains. A nice feature of MSDP is that it allows each domain to maintain an independent RP which does not rely on other domains, but it does enable RPs to forward traffic between domains.

The RP in each domain establishes an MSDP peering session using a TCP connection with the RPs in other domains or with border routers leading to the other domains. When the RP learns about a new multicast source within its own domain (through the normal PIM register mechanism), the RP encapsulates the first data packet in a Source Active (SA) message and sends the SA to all MSDP peers. The SA is forwarded by each receiving peer using a modified RPF check, until it reaches every MSDP router in the interconnected networks-theoretically the entire multicast internet. If the receiving MSDP peer is an RP, and the RP has a (*,G) entry for the group in the SA (there is an interested receiver), the RP will create (S,G) state for the source and join to the shortest path tree for the state of the source. The encapsulated data is decapsulated and forwarded down that RP's shared tree. When the packet is received by a receiver's last hop router, the last-hop may also join the shortest path tree to the source. The source's RP periodically sends SAs, which include all sources within that RP's own domain.

Figure: MSDP Example shows how data would flow between a source in domain A to a receiver in domain E.

Figure: MSDP Example



MDSP was developed for peering between Internet Service Providers (ISPs). ISPs did not want to rely on an RP maintained by a competing ISP to service their customers. MSDP allows each ISP to have their own local RP and still forward and receive multicast traffic to the Internet.

Anycast RP-Logical RP

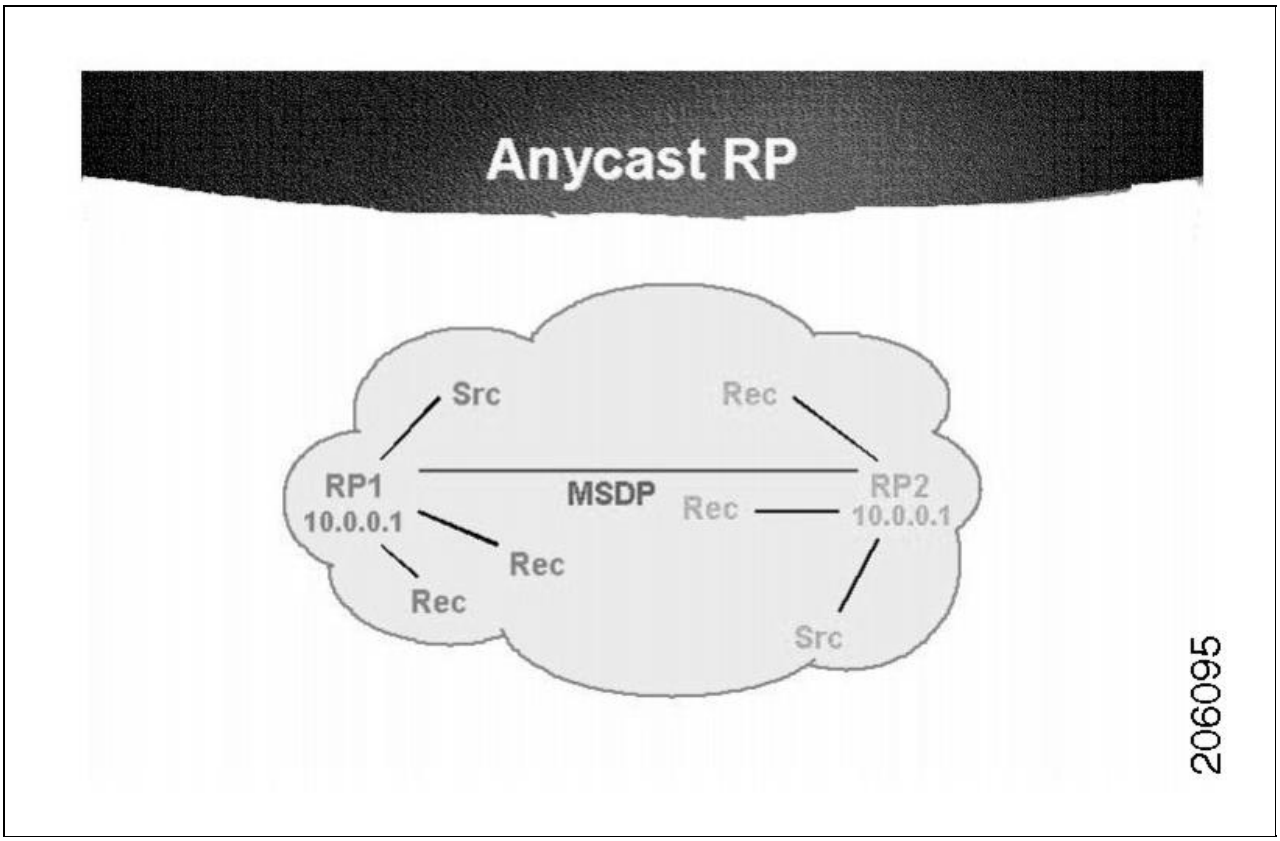
A very useful application of MSDP is called anycast RP. This is a technique for configuring a multicast sparse-mode network to provide for fault tolerance and load sharing within a single multicast domain.

Two or more RPs are configured with the same IP address on loopback interfaces-say, 10.0.0.1, for example (refer to Figure: Anycast RP). The loopback address should be configured as a 32 bit address. All the downstream routers are configured so that they know that their local RP's address is 10.0.0.1. IP routing automatically selects the topologically closest RP for each source and receiver. Because some sources might end up using one RP and some receivers a different RP, there needs to be some way for the RPs to exchange information about active sources. This is done with MSDP. All the RPs are configured to be MSDP peers of each other. Each RP will know about the active sources in the other RP's area. If any of the RPs fail, IP

routing will converge and one of the RPs will become the active RP in both areas.

Note: The Anycast RP example above uses IP addresses from RFC 1918. These IP addresses are normally blocked at interdomain borders and therefore are not accessible to other ISPs. You must use valid IP addresses if you want the RPs to be reachable from other domains.

Figure: Anycast RP



Note: The RPs are used only to set up the initial connection between sources and receivers. After the last-hop routers join the shortest path tree, the RP is no longer necessary.

Multicast Address Dynamic Client Allocation Protocol

The Multicast Address Dynamic Client Allocation Protocol (MADCAP) is defined in RFC 2730 as a protocol that allows hosts to request a multicast address allocation dynamically from a MADCAP server. The concept is very similar to the way DHCP works today and is built on a client/server model.

Multicast-Scope Zone Announcement Protocol

Multicast-Scope Zone Announcement Protocol (MZAP) is defined in RFC 2776 as a protocol that allows networks to automatically discover administratively scoped zones relative to a particular location.

Reliable Multicast-Pragmatic General Multicast

Pragmatic General Multicast (PGM) is a reliable multicast transport protocol for applications that require ordered, duplicate-free, multicast data delivery from multiple sources to multiple receivers. PGM guarantees that a receiver in a multicast group either receives all data packets from transmissions and retransmissions, or can detect unrecoverable data packet loss.

The PGM Reliable Transport Protocol itself is implemented on the sources and the receivers. The source maintains a transmit window of outgoing data packets and retransmits individual packets when it receives a negative acknowledgment (NAK). The network elements (routers) assist in suppressing an implosion of NAKs (when a failure does occur) and aids in efficient forwarding of the retransmitted data just to the networks that need it.

PGM is intended as a solution for multicast applications with basic reliability requirements. The specification for PGM is network layer-independent. The Cisco implementation of PGM Router Assist supports PGM over IP.

Today, the specification for PGM is an Internet draft that can be found on the IETF web site (http://www.ietf.org) under the name "PGM Reliable Transport Protocol."

Review Questions

Q - *What is the range of available IP multicast addresses?*

A - 224.0.0.0 to 239.255.255.255.

Q - *What is the purpose of IGMP?*

A - IGMP is used between the hosts and their local multicast router to join and leave multicast groups.

Q - *What is an advantage of IGMPv2 over IGMPv1?*

A - IGMPv2 has a leave group message that can greatly reduce the latency of unwanted traffic on a LAN.

Q - *What is a potential disadvantage of IGMP snooping over CGMP on a low-end Layer 2 switch?*

A - IGMP snooping requires the switch to examine every multicast packet for an IGMP control message. On a low-end switch, this might have a severe performance impact.

Q - *What is an advantage of shortest path (or source) trees compared to shared trees?*

A - Source trees guarantee an optimal path between each source and each receiver, which will minimize network latency.

Q - *What is an advantage of using shared trees?*

A - Shared trees require very little state to be kept in the routers, which requires less memory.

Q - *What information does the router use to do an RPF check?*

A - The unicast routing table.

Q - *Why is protocol-independent multicast called "independent"?*

A - PIM works with any underlying IP unicast routing protocol-RIP, EIGRP, OSPF, BGP or static routes.

Q - *What is the main advantage of MBGP?*

A - Providers can have noncongruent unicast and multicast routing topologies.

Q - *How do RPs learn about sources from other RPs with MSDP?*

A - RPs are configured to be MSDP peers with other RPs. Each RP forwards source active (SA) messages to each other.

Q - *What is the purpose of the anycast RP?*

A - Load balancing and fault tolerance.

For More Information

Williamson, Beau. *Developing IP Multicast Networks.* Indianapolis: Cisco Press, 2000.

Multicast Quick Start Configuration Guide (http://www.cisco.com/warp/customer/105/48.html)