Introduction to Multicast Routing View PDF

Michael Gibbs, Riverstone Networks

ABSTRACT

This paper introduces basic multicast routing concepts and theory including the differences between unicast, broadcast and multicast traffic, multicast addressing, IGMP, DVMRP, PIM DM, PIM SM, Shared Trees vs. Shortest Path trees, MSDP, Anycast and the differences between Inter- and Intradomain multicast routing as well as some advice as to when to use particular technologies and sample router configurations.

Introduction

Communications and network technology are becoming increasingly critical in today's business environment. Traditionally data communications has been between individual hosts, (i.e. a sender and receiver). However, with the advent of technologies such as Video over DSL, IP Video Conferencing, Streaming Media and others, there is increasing need for efficient broadcast or one-to-many communications. Multicast data delivery increases network efficiency and decreases server load by eliminating the need for redundant packets when more than one client wishes to access a data stream. Technologies such as these that allow carriers and content providers to maximize the performance and useful work that they can extract from existing server and network infrastructure will become increasingly important and are likely to see widespread adoption in the future. With this in mind, the importance of multicast routing protocols becomes evident.

Definitions

Unicast - Unicast traffic involves traffic going from one host to another. A copy of every packet in the data stream goes to every host that requests it. Unicast applications are very easy to implement as they use well established IP protocols, however they are extremely inefficient when many to many communication is required. Since a copy of every packet in the data stream must be sent to every host requesting access to the data stream this type of transmission is inefficient in terms of both network and server resources and presents fairly obvious scalability issues. See figure 1 for an example of unicast transmission.

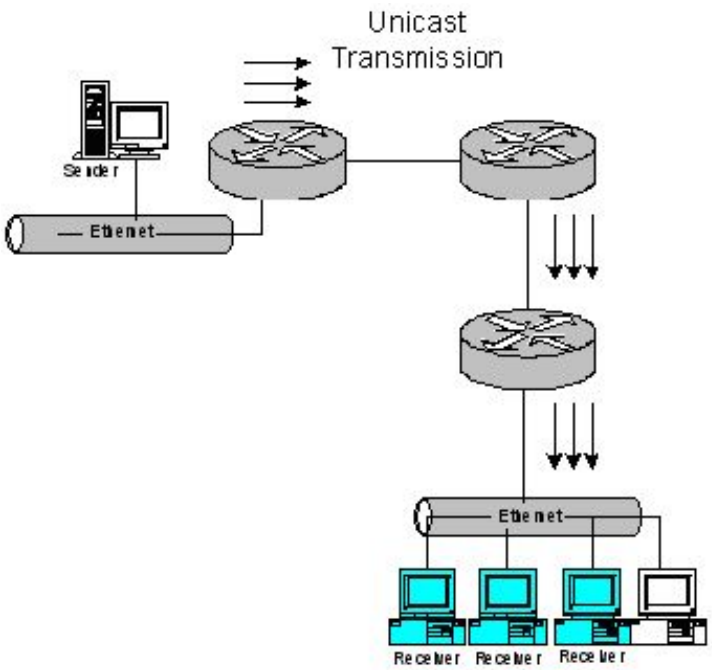

Figure 1 - A Unicast Transmission

Broadcast - Broadcast applications allow one host, typically a server, to send to all receivers on a subnet. The efficiency of a broadcast application increases with the number of hosts that need to receive the broadcast. Most broadcasts, except subnet directed broadcasts, are non-routable and are thus contained to the local subnet, a significant restriction. Another restriction or known issue is that all hosts on the broadcast subnet must process the broadcast packets, regardless of whether or not the user on those hosts is interested in the broadcast. Thus, all hosts on that subnet will see increased CPU usage, which is not efficient for those hosts in the subnet who are not participating in the broadcast. See figure 2.

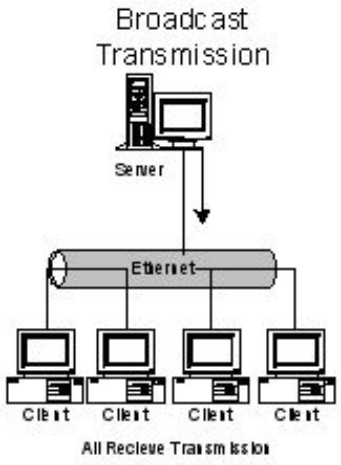

Figure 2 - A Broadcast Transmission

Multicast - a hybrid of unicast and broadcast technologies, multicast allows servers to send single copies of data streams which are then replicated and routed to hosts that signal that they want to receive the data stream. Thus, instead of sending thousands of copies of a streaming sporting event, the server instead streams a single flow that is then directed by routers on the network to the hosts that have indicated that they want to receive the stream. This eliminates the need to send redundant traffic over the network and also tends to eliminate CPU load on systems that are not using the multicast stream, yielding significant enhancements to efficiency for both server and network. See figure 3 for an example of multicasting.

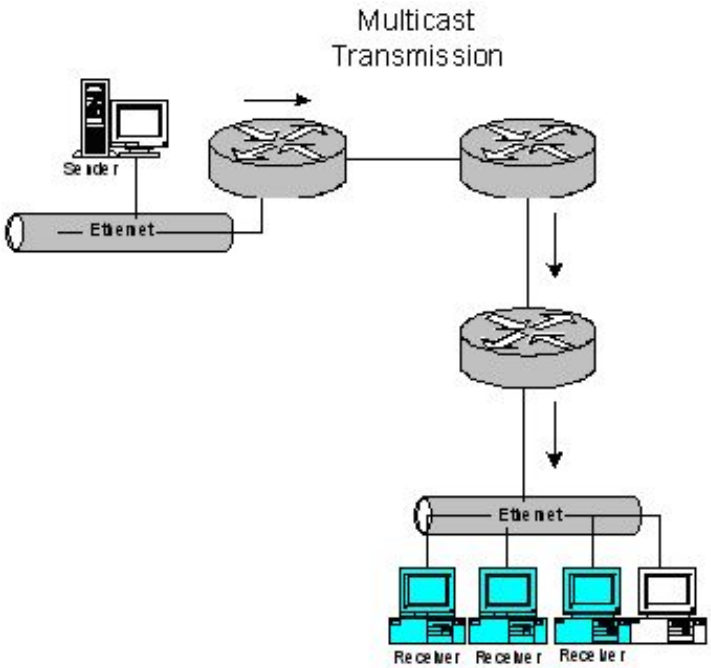

Figure 3 - A Multicast Transmission

Multicast Addressing

Multicasts are delivered to a multicast group, which hosts can join should they want to access the data stream. This is done by routing the data streams to a class D IP address in the address space 224.0.0.0-239.255.255.255. In this space, which is reserved for multicast, there are a number of address ranges reserved for particular applications (see table below). In general, IANA does not reserve multicast address ranges without good cause, an example of which would be stock feeds or some other mission critical stream. Instead of static mappings, it is preferred to use dynamic mappings similar to DHCP for assigning streams to multicast IP addresses. Although an in depth discussion of the various protocols used to achieve this is beyond the scope of this paper, SDR (Session Directory Protocol) was one of the first implemented but proved to have scalability issues. MADCAP (Multicast Address Dynamic Client Allocation Protocol, RFC 2730) is one protocol in use as is MASC (Multicast Address Set-Claim, RFC 2909).

Reserved Block Begin	Reserved Block End	Reserved Block Meaning	Reserved Block Use
224.0.0.0	224.0.0.255	Link local (not forwarded)	Subnet local communication(I.e. routing protocol discovery)
224.0.1.0	224.0.1.255	Non link local reserves	Network protocols or Network applications
232.0.0.0	232.255.255.255	Source Specific Multicast	Source Specific Multicast
233.0.0.0	233.0.0.0	GLOP addressing	Sources with AS's that want public multicast address
239.0.0.0	239.255.255.255	Administratively scoped	Used within a domain for for private multicasting use

Table 1 - Multicast Addressing

The layer 3 multicast group referenced above needs to be converted to a layer 2 MAC address to be used by end stations sending and receiving to the data stream. This layer 2 multicast MAC address can be converted from the layer 3 IP address of the group. There are several caveats to the conversion. The process of conversion from a layer 3 multicast group to a Ethernet MAC address will be covered below. The first four bits of the class D IP address are already reserved by the first four high order bits of the IP address 0X1110 leaving only 28 bits of the 32 bit IP address for the conversion. Of the remaining 28 bits of the IP address the next five bits were lost when IP multicast was created by Dr Steven Deering. These five bits were lost because Dr Deering's organization did not purchase the OUI for all possible MAC addresses in this range. Therefore all multicast addresses are formed from the remaining 23 bits. This will cause overlap of 32 multicast groups. This multicast group overlap can have a performance impact on the receivers of a multicast stream. For example a user requesting information for 224.0.0.1 will also see and process 224.128.0.1 if another user on the same LAN is viewing the later multicast group. The chart below will show an example of the overlapping multicast groups. Please see figure 5 for an example of the overlap.

Multicast Address	MAC Address
224.0.0.1	01-00-5e-00-00-01
224.128.0.1	01-00-5e-00-00-01
225.0.0.1	01-00-5e-00-00-01
225.128.0.1	01-00-5e-00-00-01
226.0.0.1	01-00-5e-00-00-01
226.128.0.1	01-00-5e-00-00-01
227.0.0.1	01-00-5e-00-00-01
227.128.0.1	01-00-5e-00-00-01
228.0.0.1	01-00-5e-00-00-01
228.128.0.1	01-00-5e-00-00-01
229.0.0.1	01-00-5e-00-00-01
229.128.0.1	01-00-5e-00-00-01
……	01-00-5e-00-00-01
……	01-00-5e-00-00-01
……	01-00-5e-00-00-01
……	01-00-5e-00-00-01
……	01-00-5e-00-00-01
239.0.0.1	01-00-5e-00-00-01
239.128.0.1	01-00-5e-00-00-01

Figure 5 - Multicast Addresses vs MAC Addresses

Internet Group Membership Protocol

For multicast to be more useful than broadcast it needs to be contained and distributed to the users that desire to receive the multicast stream. IGMP, the Internet Group Membership Protocol, was created for this purpose. IGMP allows hosts to signal routers that they would like to receive a data stream. Routers in turn use IGMP to determine which interfaces to flood multicast packets to and which multicast groups are on which interfaces. At present the are 3 versions of this protocol with new versions incrementally increasing functionality and efficiency over prior versions.

Internet Group Membership Protocol Version 1

IGMP version 1 was the original IGMP (see Figure 6 for the packet header). An IGMP packet format can be seen below. The key point with IGMP version one is that the packet has no provision for a host to leave a multicast group. A host can signal a router of its desire to join a multicast group. A router floods the requested multicast group out of the interface where the host resides. The router queries the host by multicasting a membership query to the multicast group that the host had requested to join. If any hosts on that subnet desire that multicast feed then they will reply to the query and multicast packets will be sent. Since there is no provision to leave the multicast group the host "notifies" the router of it non-interest by not answering the routers queries. After 3 query intervals 180 seconds (on average) the router deduces there are no receivers and will stop sending packets. This method is bandwidth inefficient and therefore has been replaced in IGMP version 2 or later in most modern operating systems. An IGMP version one packet can be seen below from RFC 1112.

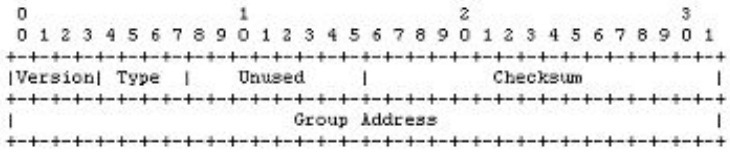

Figure 6 - IGMP Version 1 Packet Header

Internet Group Membership Protocol Version 2

IGMP version 2 improves on IGMP version 1 by allowing hosts to leave a group by sending a leave message to the router. Since the host can voluntarily leave the multicast group the multicast packets will stop flowing from the router when the host or hosts signal the router that they no longer wish to receive the multicast data. The improved leave process works as follows. A host sends an IGMP leave group message to the router. The router sends a group specific query to the multicast group asking if there are still any hosts that want to keep receiving the multicast stream. If no host responds, the flow stops. If one or more hosts respond that they want to keep receiving the flow, then the router continues to forward the multicast packets. An IGMP version 2 packet and can be seen below from RFC 2236.

Figure 7 - IGMP Version 2 Packet Header

Internet Group Membership Protocol Version 3

IGMP version 3 builds upon prior versions by adding provisions for a host to not only specify a group but also specify Include and Exclude lists - lists of IP addresses that it either will or will not accept multicast traffic from. This feature tends to increase security and make Denial of Service attacks considerably more difficult than was the case in prior versions. Because the user can specify the publisher and group it exponentially increases the addresses available for IP multicast. Finally it enables newer multicast protocols and will allow source and group (S,G) requests to move up to the application layer. Although still in draft form, IGMP V3 is currently available in Windows XP and newer Linux distributions and will be supported on the RS in version 10.0. An IGMP version 3 header can be seen below from draft-ietf-idmr-igmp-v3-11.txt.

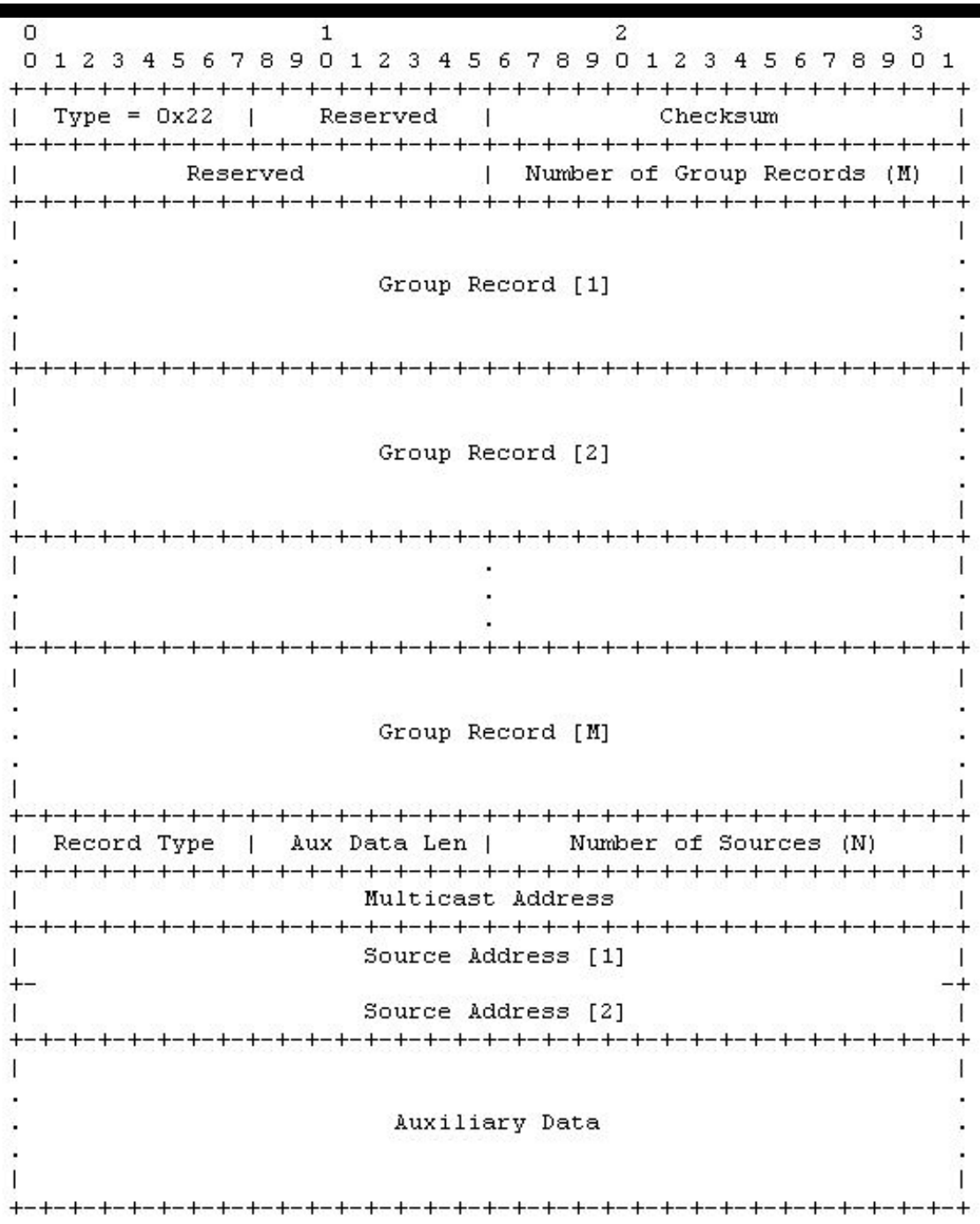

Figure 8 - IGMP Version 3 Packet Header

Internet Group Membership Protocol Snooping

This paper has discussed how a host signals a router that it would like to receive a multicast data stream. It has also been discussed how a layer three multicast address becomes a layer two MAC address. There is however a significant issue to be overcome in order to make multicasting scaleable. Since a layer 3 address will eventually become a layer 2 MAC address (i.e. 01-00-5e-11-11-11) it is important to remember this is the destination of a multicast group and not a host. A switch by default will forward unknown packets out all ports in a broadcast domain except the source port. Since no port will ever have this MAC address the switch can never learn which port to send this frame. Consequently without some other means the switch will always send multicast frames out all ports except the port for which that the frame was received. This flooding is obviously not desirable and consumes a significant degree of network and system resources. In order to get around this problem most modern switches watch the hosts IGMP membership reports and only forward multicast packets for the groups out of the ports for which the switch snooped an IGMP join message. IGMP snooping has enabled efficient LAN multicasting. The RS platform efficiently performs IGMP snooping in hardware. The RS platform's IGMP snooping does not have any of the layer 2 snooping scalability issues seen in older, lower performance LAN switches. The RS platform even has a version of IGMP snooping for ATM links called port aware. This allows the same efficiency of IGMP snooping on LAN interfaces to be ported to NBMA networks.

Multicast Forwarding

Multicast traffic is forwarded in a different manner than unicast traffic is. Unicast traffic is forwarded hop by hop throughout the network using the destination IP network from the source's perspective. In contrast, multicast routing uses reverse path forwarding, commonly known as RPF. RPF generates path metrics based on the origin, not the destination of the traffic. A packet is forwarded by a multicast router only if it is received on an interface that is closer to the source than the other interfaces on the router. If the packet is received on an interface that is not an upstream interface then the packet is dropped.

Refer to figure 9 for an RPF example. Assume all links in the below diagram are equal cost, making the route the same as hop count. From the perspective of router 5 the RPF entry will show that et.1.3 is the interface for which multicast packets for the group 224.1.1.1 are received.

This is because it is the closest upstream interface to source 10.0.0.0/24 in its multicast RIB. If a multicast packet for this destination arrives on any other interface (i.e. et.1.1) it will be dropped as it will not pass the RPF check.

In general there are two global types of intradomain multicast routing protocols, shortest path trees and shared trees. Both of these types of multicast routing protocols have their applications as well as limitations. DVMRP, a shortest path tree protocol and PIM Sparse Mode, a shared tree protocol, are both widely used and also described later in this paper.

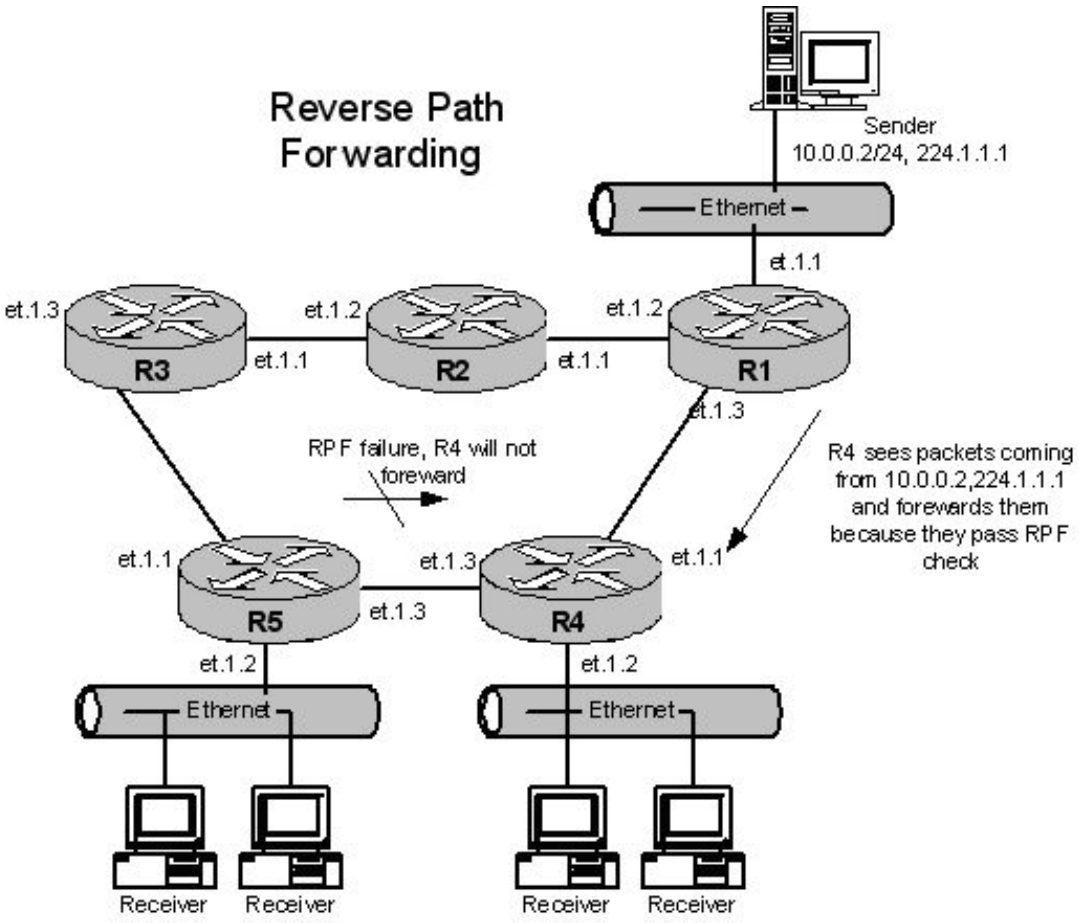

Figure 9 - Reverse Path Forwarding

DVMRP

This section describes DVMRP. DVMRP is the first multicast routing protocol that was developed. It has a long history and has been implemented in some capacity on almost all vendors equipment as well as most Unix servers with mrouted. Since it is so widely supported it allows for almost total interoperability in a multivendor environment.

DVMRP is analogous to a multicast version of RIP. Consequently it shares similar characteristics, it is distance vector based, it broadcasts route updates every 60 seconds, metric based upon hop count, hop count limit and a special implementation of poison reverse. DVMRP computes a shortest path tree to the source. A different shortest path tree is computed for each source sending the multicast data stream. Therefore at any time if the are many senders there will be many shortest path trees. Each shortest path tree requires memory in each router. A shortest path tree is rooted of the source of the multicast. The source periodically pushes multicasts downstream. If there are no receivers downstream then prune

messages will be sent upstream that will tell the upstream routers to stop flooding these multicast streams. Unfortunately, DVMRP prunes are good for only 2 minutes. Therefore after the prune interval these packets will be flooded again down the shortest path trees (SPT). By contrast if a pruned section of the tree receives a join then it will graft the appropriate interfaces back to the SPT tree.

DVMRP has been deployed in some large networks like the multicast backbone (MBONE). DVMRP has several scalability limitations. The periodic flooding of multicast packets is extremely bandwidth inefficient. DVMRP has a hop count limit of 32 hops which precludes its deployment in extremely large networks. The periodic broadcast of routing updates is bandwidth inefficient in large networks. All routers in a DVMRP network need to maintain a copy of all SPT trees at all times. This is very memory inefficient. Having all of these drawbacks DVMRP is good for LANs where there are high numbers of receivers and a limited number of senders since if users need to receive the multicast on almost all segments then there is really no wasted resources due to any of the above mentioned limitations. Additionally, DVMRP is simple to deploy and is vendor insensitive which at times makes it an excellent choice. DVMRP even has provisions for tunneling updates and packets through non-multicast networks. To assist in clarification please see the figures below. Figures 10-14 show what happens in a DVMRP network.

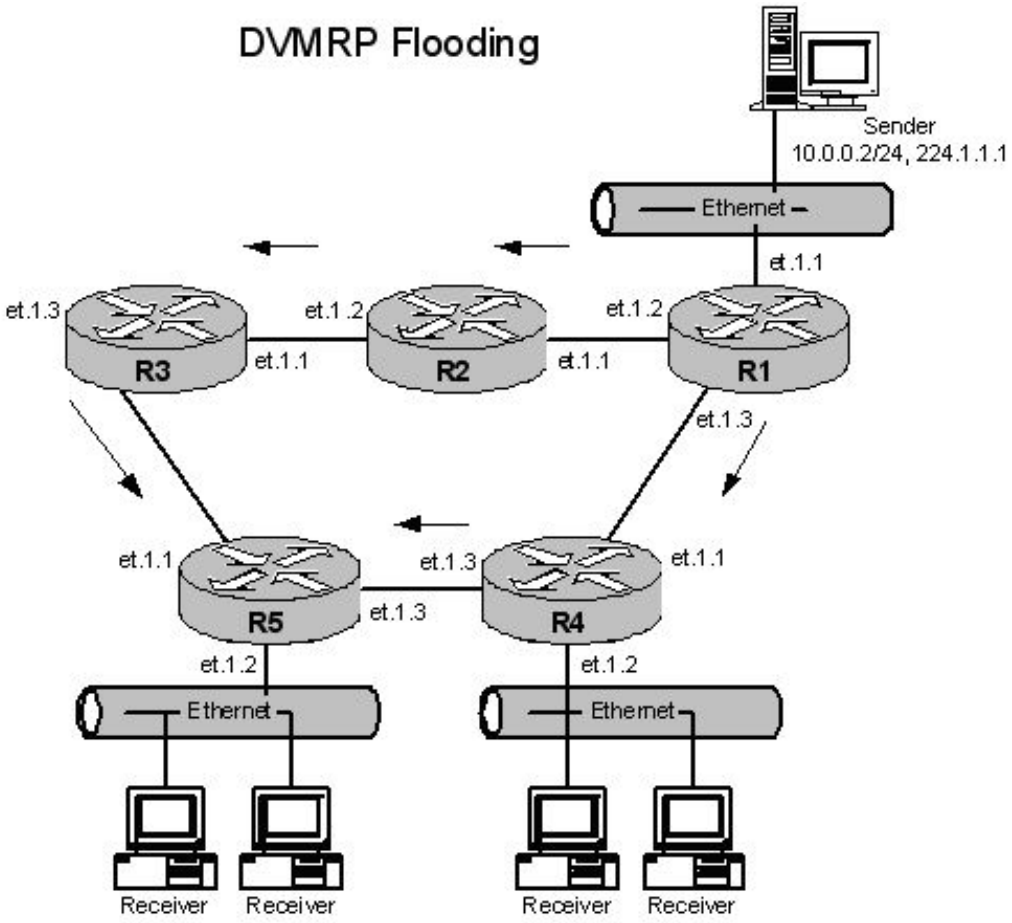

Figure 10 - DVMRP Flooding

In figure 10 source 10.0.0.2 begins publishing to 224.1.1.1. Since router 1 is DVMRP enabled it creates a (S,G) entry and begins flooding multicast packets downstream to all other DVMRP routers. When all other routers receive the multicast traffic they create (S,G) entries and also begin flooding these packets downstream.

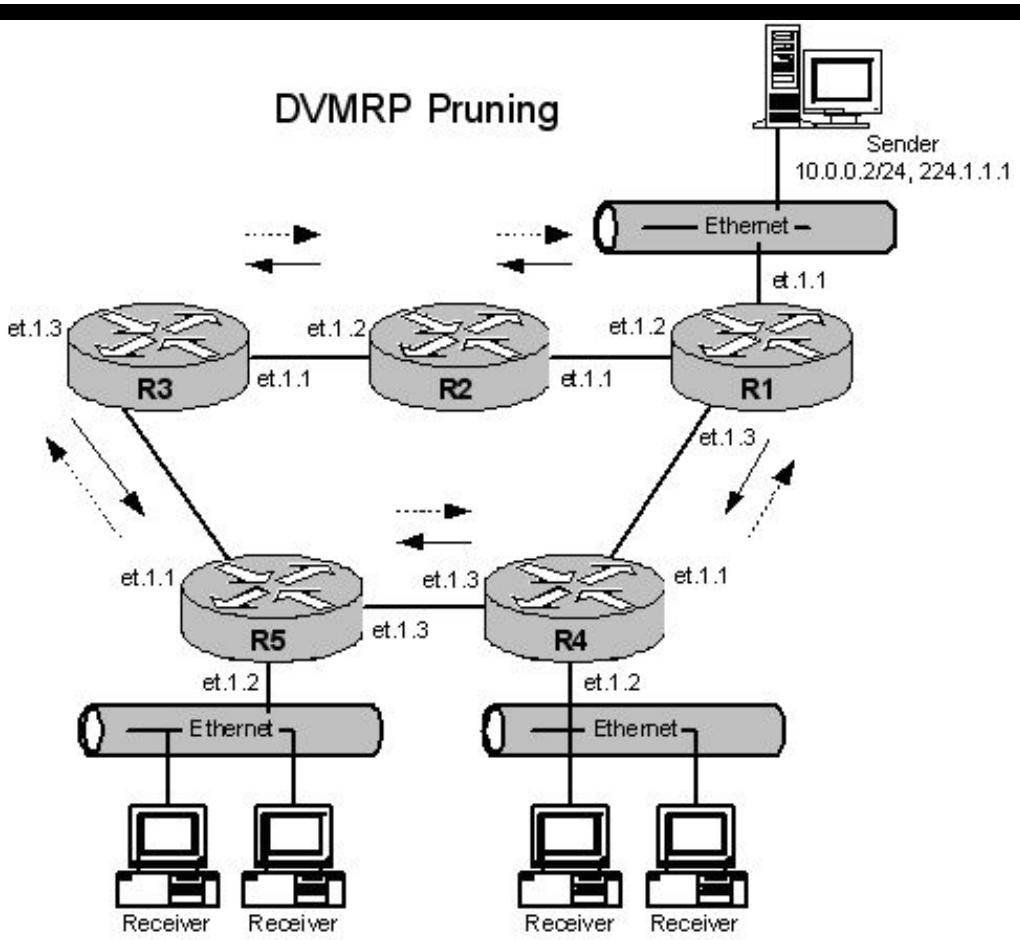

Figure 11 - Multicast Packet Flow Post Pruning

In figure 11 there are no receivers. Since there are no interested receivers R4 and R5 send prune messages upstream to prune off the data flow.

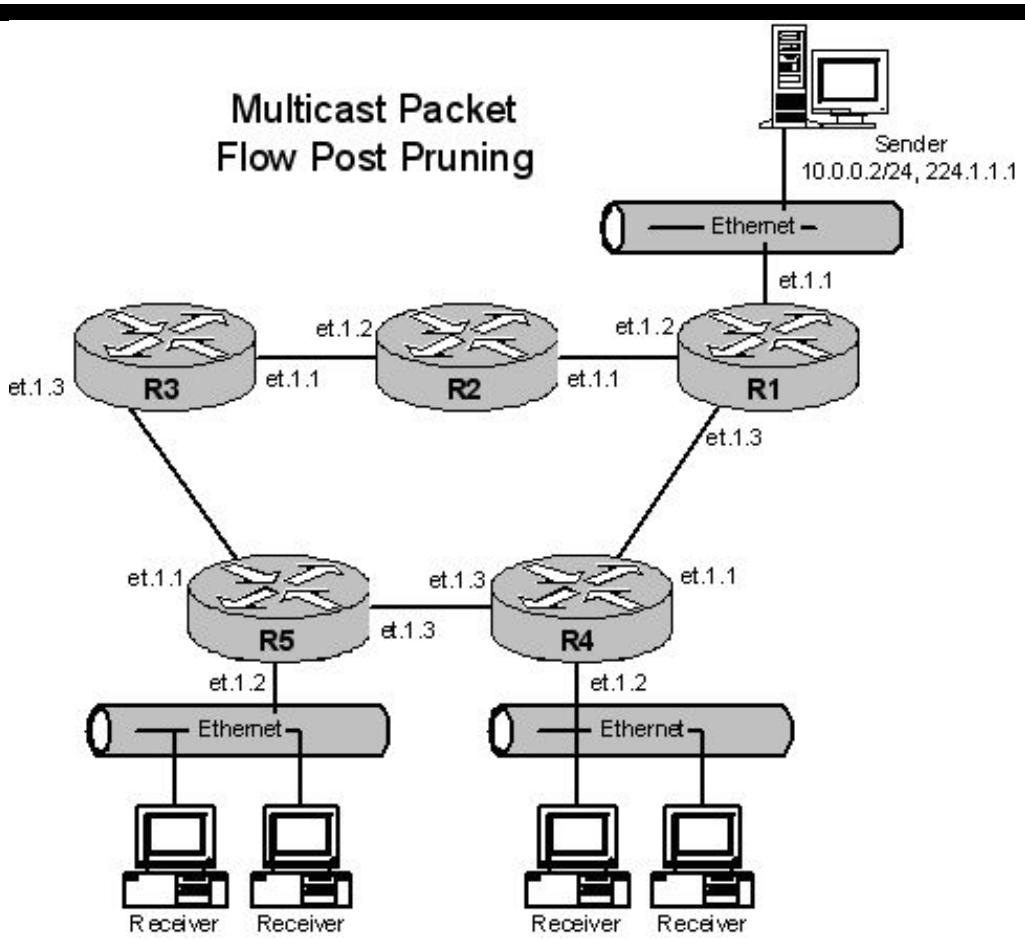

Figure 12 - Multicast Packet Flow Post Pruning

Figure 12 shows the state of the network after pruning. There is no multicast flooding of undesired packets at present. However, all routers have the (S,G) state of all sources.

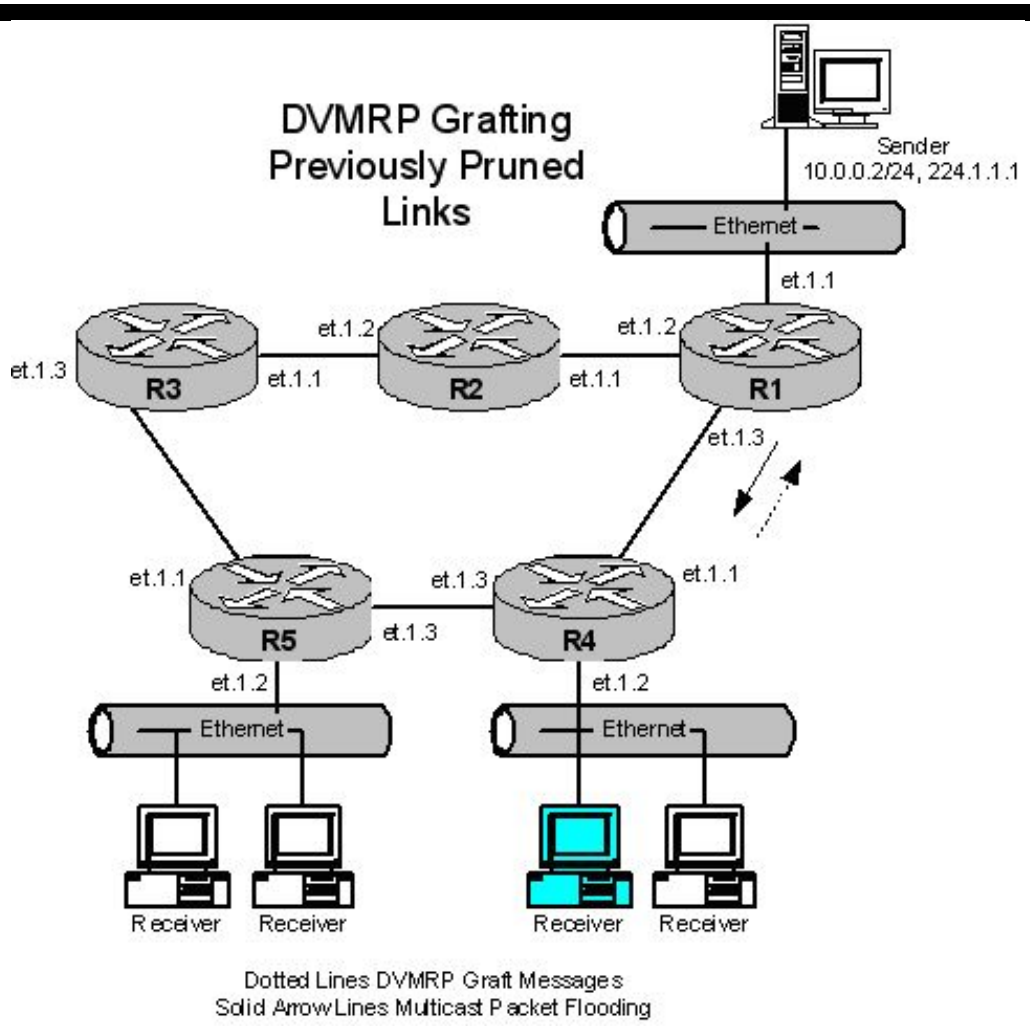

Figure 13 - DVMRP Grafting Previously Pruned Links

In figure 13 receiver blue signals R4 with an IGMP membership report (join) that it desires a multicast feed for group 224.1.1.1. R4 sends a DVMRP graft upstream to R1. R1 then adds et.1.3 to its OIL list and begins flooding packets to R4.

Note the process of DVMRP grafting is reliable. When R4 sends a graft message to R1, R1 replies with an acknowledgement so that R4 knows the grafting is occurring properly. If a graft acknowledgement is not heard by R4 in a specified period of time it will resend a graft message to R1.

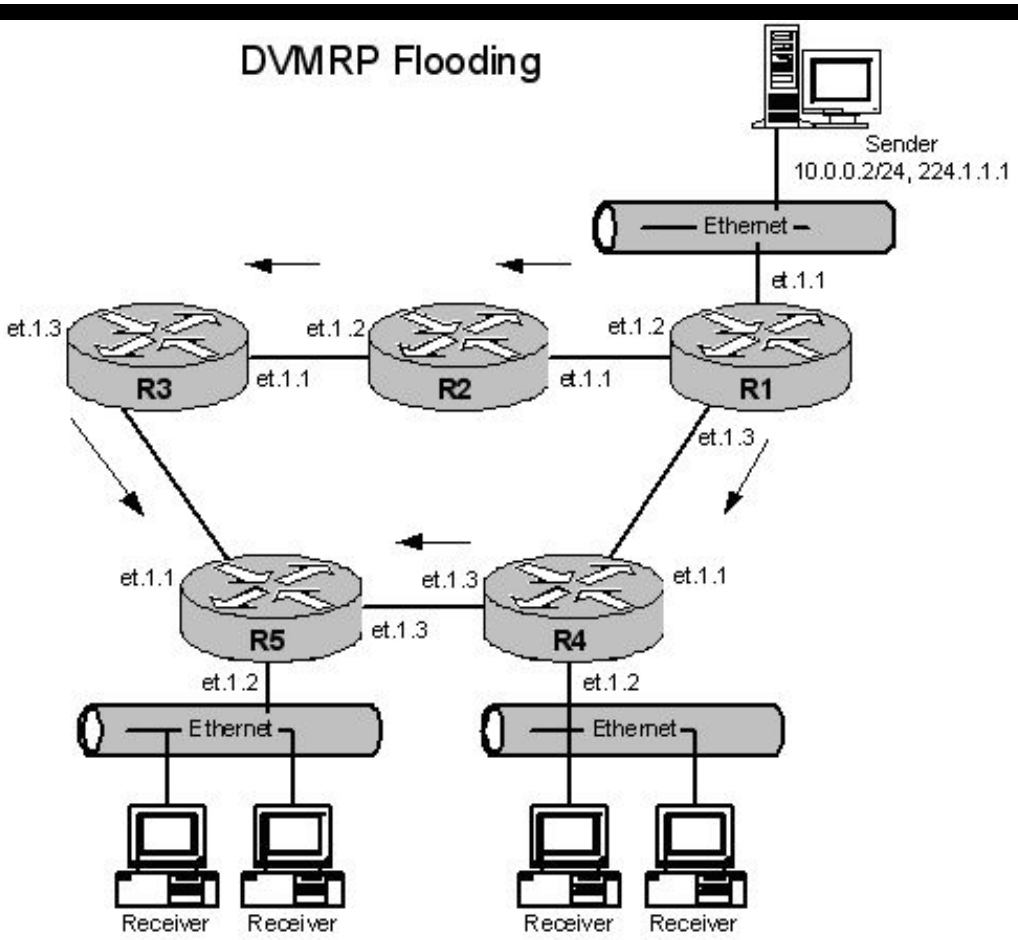

Figure 14 - DVMRP Flooding

Figure 14 shows the network after the two minute prune timer has expired. Multicast packets will begin reflooding downstream to all routers. Again, if this traffic is undesired there will be a prune.

Protocol Independent Multicast (PIM) DM

This section describes PIM DM. PIM DM is not supported on the current RS platform nor has it been widely deployed since most network architects desiring a dense mode protocol use DVMRP due to its vendor interoperability. PIM DM is a dense mode multicast routing protocol, meaning that it uses the implicit join method. Since there is the assumption that all users desire the multicast feed (implicit join) it is sent out all interfaces. Multicast data that is not desired is pruned, with pruning (and flooding) happening by default every 3 minutes. A graphical representation of this prune and flood behavior can be seen in the DVMRP figures 10-14 above

PIM DM computes a shortest path tree to the source using the information in the unicast routing table. No separate protocol is required for RPF lookup, making PIM DM protocol independent. Different shortest path trees are computed for each source sending the multicast data stream, thus if there are many senders there will be many shortest path trees, with each shortest path tree requiring memory in each router. In addition to the memory required in the router, PIM DM must recompute the RPF for all (S,G) entries in the multicast routing table every 5 seconds with default timers. Consequently, memory and CPU requirements will be increased on all multicast enabled PIM DM routers, not just the routers that are actively participating in forwarding multicast traffic. This can seriously tax both memory and cpu resources if there are many broadcast sources.

A significant difference between DVMRP and PIM DM is that PIM DM does not maintain a list of its neighbors like DVMRP and must implement a prune override behavior to prevent prune messages from cutting off traffic destined to routers or hosts downstream that actually wanted the traffic. Assume there are several PIM DM neighbors on a LAN segment. If one of the routers sends a prune message to the upstream router telling that router to prune a multicast feed and another router requires that feed there would be a problem. PIM DM handles this problem with the prune override. A router sends a prune message to 224.0.0.13 (All PIM routers). If another router on that LAN segment still needs to receive that data it sends a prune override telling the upstream router not to shut off the flow for that stream. In order to effectively perform this prune override there is a 3 second delay in the time between a prune message is received and the time the interface is pruned from the sending routers OIL list.

PIM DM also introduces the concept of an assert mechanism. Since it is not good to receive duplicate multicast packets on a given LAN segment, only one router should forward multicast data for a given multicast group per LAN segment. Several multicast forwarders on a LAN segment could result in possible multicast packet looping and multicast storms. PIM accommodates this with an assert mechanism. If there are several PIM routers on a LAN segment and a PIM router receives the same packets it sent out on that same interface then an assert mechanism is triggered to stop the flow coming from one of those routers. This assert message between the routers contains the route preference of the routes to the source

and the metric to the source. In the event of a tie of all of these parameters than the router with the highest address is elected multicast forwarder for that source.

The PIM assert mechanism also applies to PIM SM.

Please see the figures below for an example of Prune overrides and PIM assert messages. Again refer to DVMRP graphics for flood and prune behaviors as they are identical to DVMRP.

In the example below R2 has no receivers so it attempts to prune off the multicast traffic on its incoming LAN interface. It therefore sends a prune message upstream to the address of all PIM routers. Router 3 hears this prune message and signals the upstream routers that it still desires to receive the multicast data flow by sending a prune override. R1 will hear the prune override and continue to send the multicast packets to this LAN segment.

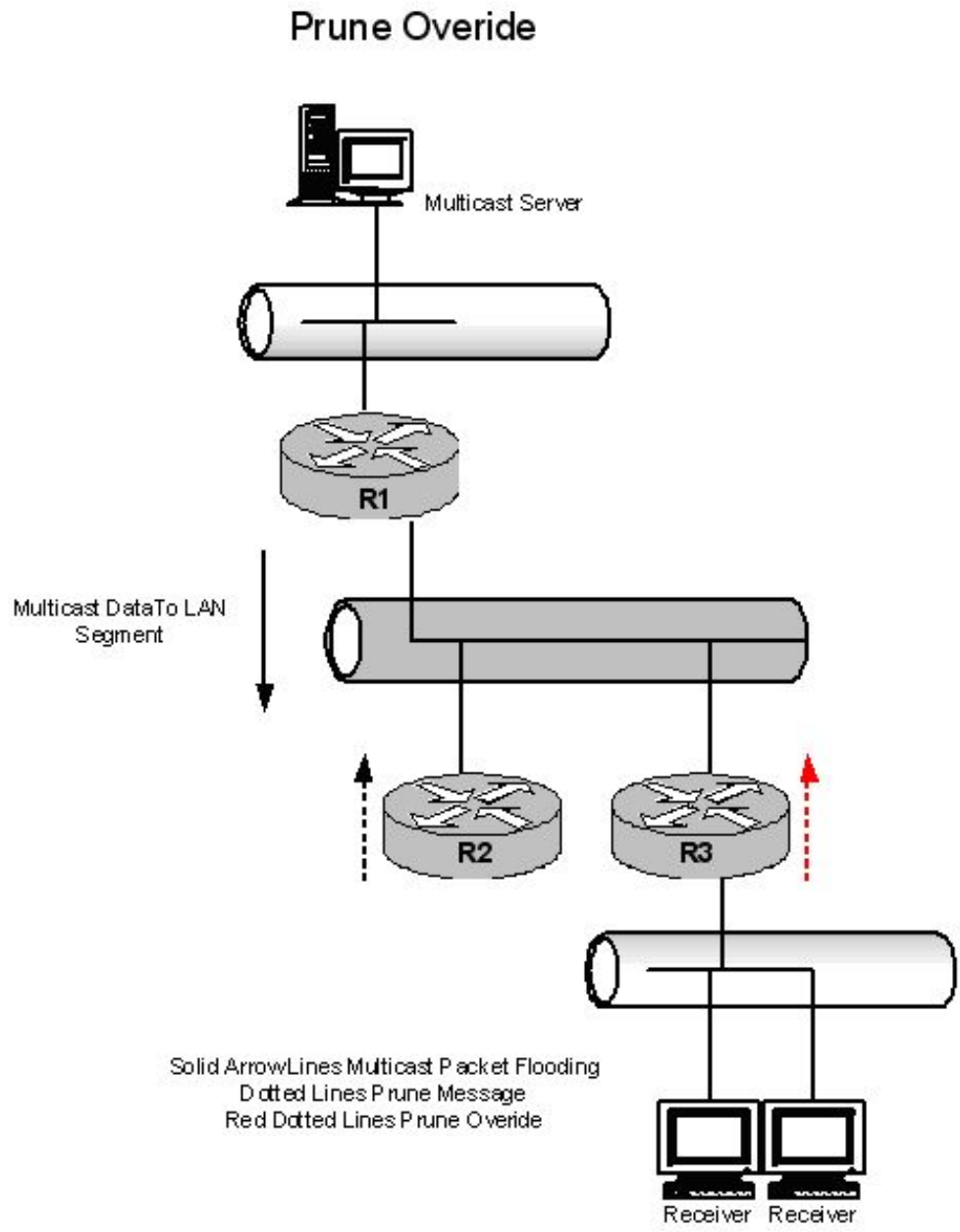

Figure 15 - DVMRP Prune Override

In the example below both routers have received from routers on their OIL list a packet that they sent out on their OIL list. This is bad news, so to break the loop the routers need to determine which router has the better metric to the source and should thus become the elected forwarder. The routers send assert messages, which then triggers the election event.

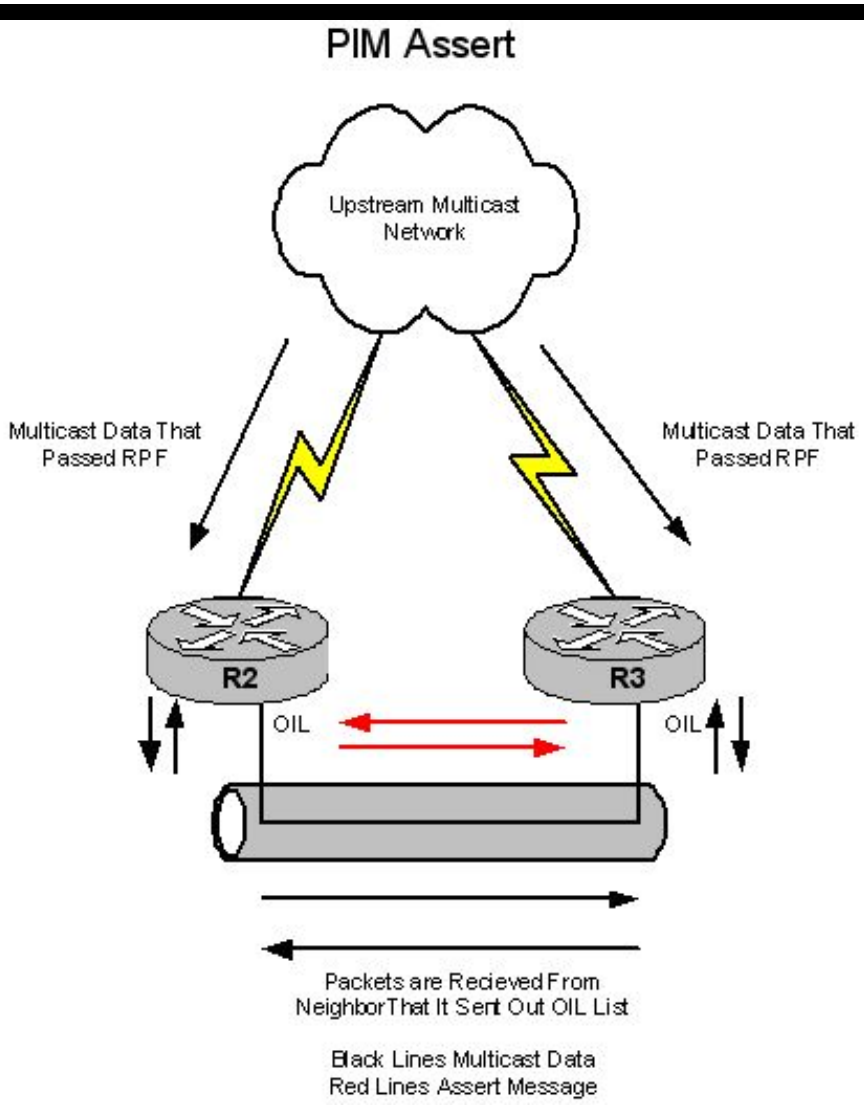

Figure 16 - PIM Assert

In the example below there is a representation of the information contained in the assert messages and the results of the election.

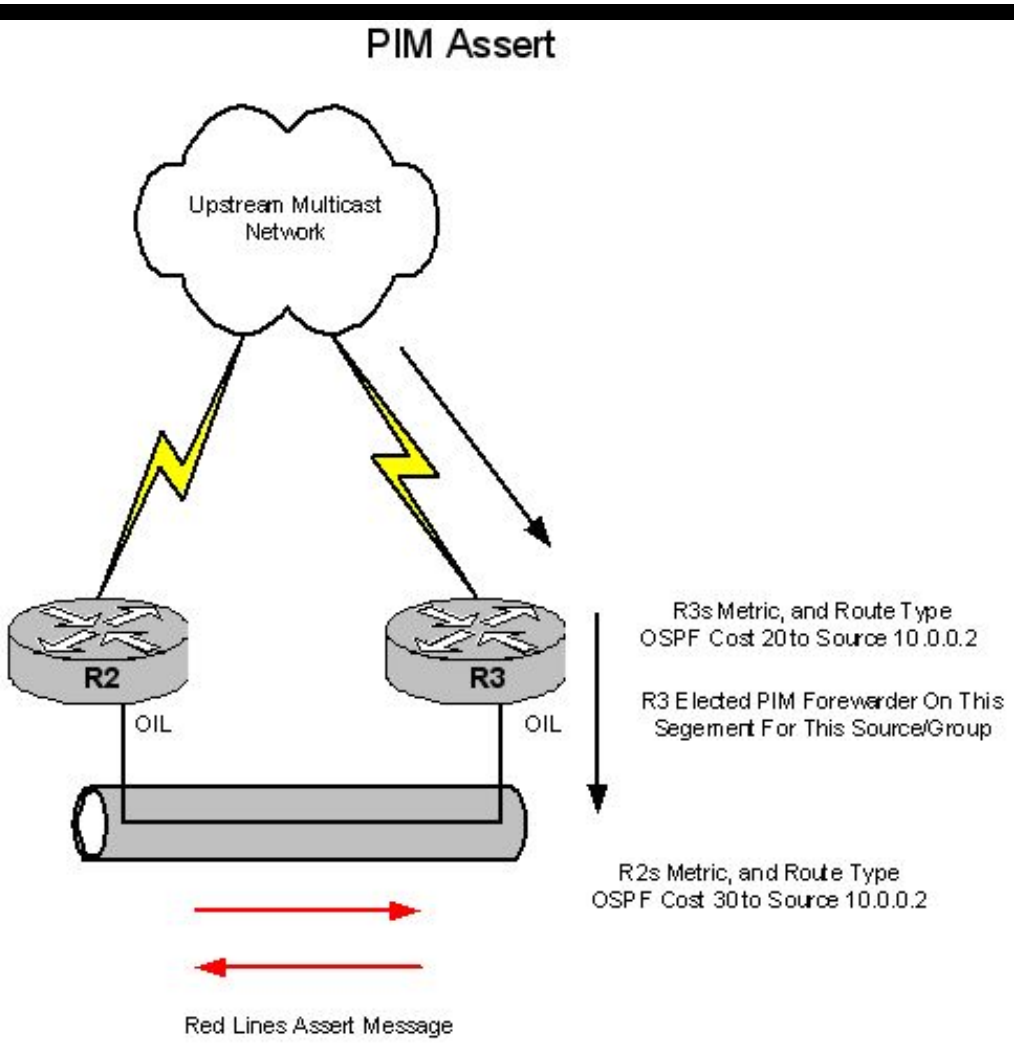

Figure 17 - PIM Election Event

Protocol Independent Multicast (PIM) Sparse Mode

The next major multicast routing protocol is PIM-Sparse Mode. PIM-Sparse Mode is the generally recommended for almost all new multicast deployments. PIM-SM is also protocol independent, which means that the multicast RIB can be populated from whatever protocol is used to populate the unicast RIB. Thus special routing protocols used just for reverse path lookup are not need, unlike the situation with DVMRP.

PIM sparse mode centers around a shared tree, with a Rendezvous Point (RP) serving as the root of the tree in this environment . A shared tree prevents each router from maintaining source and group (S,G) state for every multicast source. In order to receive a multicast stream, routers explicitly join the stream by sending join (*.G) messages to the RP. This (*,G) join message is analogous to a unicast router following a default route to a destination. Effectively the function of the RP is a place for multicast sources and receivers to meet. Since the RP is the center of the multicast universe in PIM-SM then somehow the RP needs to be aware of the multicast sources. This is accomplished by the PIM designated router on the LAN sourcing the multicast sending source register messages to the RP. The source registration process occurs via unicast source register messages. When the RP receives these source registration messages it learns of the necessary S,G information as well as receives multicast data to forward down the shared tree. A detailed description of all of the possibilities of source registration is beyond the scope of this paper. Refer to the PIM SM spec for greater detail if desired. Assuming that the RP already has receivers for a source that it has learned about by the source registration process it creates a SPT (Shortest Path Tree) to the source.

PIM SM is extremely memory and CPU efficient. Since the only thing that most routers need to know is how to reach the RP, memory requirements are greatly reduced. There are several methods for routers in a PIM SM domain to learn where to find the RP. Probably the simplest mechanism is statically configuring all routers to reach the RP. Unfortunately if the routers are statically configured to an RP and the RP dies then the multicast network is no longer functional. Additionally, a statically configured network does not allow for easy changes as all routers will need to be touched in order to change RPs, not a big deal in a small network but a significant issue in very large networks. Effectively static RPs have all of the limitations of static routes. The only exception to this rule is Anycast RP to be covered in a section below. Alternatively, the RP can be learned dynamically via the PIM SM bootstrap mechanism. Since this bootstrap mechanism is dynamic it allows for network changes and redundancy. The PIM SM bootstrap mechanism is generally the recommended approach for simplicity and redundancy.

PIM routers discover neighbors by sending multicast hellos. PIM routers maintain their adjacencies by continuing to send hellos. When a router

receives an IGMP join (IGMP membership report) from a host it sends a message to add forwarding of the requested group to the next upstream router closer to the RP. Since the shared tree may not be exactly the "most efficient" path there are provisions in PIM-SM to switchover to a SPT. The Riverstone Networks (RS) platform will automatically switch from a shared tree to a shortest path tree upon receipt of the first few multicast data packets. This gives the optimization of SPT trees with the memory and bandwidth efficiency of source based trees. After the receiver is no longer is interested in receiving the data stream the SPT is effectively cancelled by routers sending prune messages. Since PIM-SM is routing protocol independent it has the capability to scale to reasonably large sizes since the hierarchy is already implemented in the unicast routing protocol and network design. To assist in clarification please see the figures below.

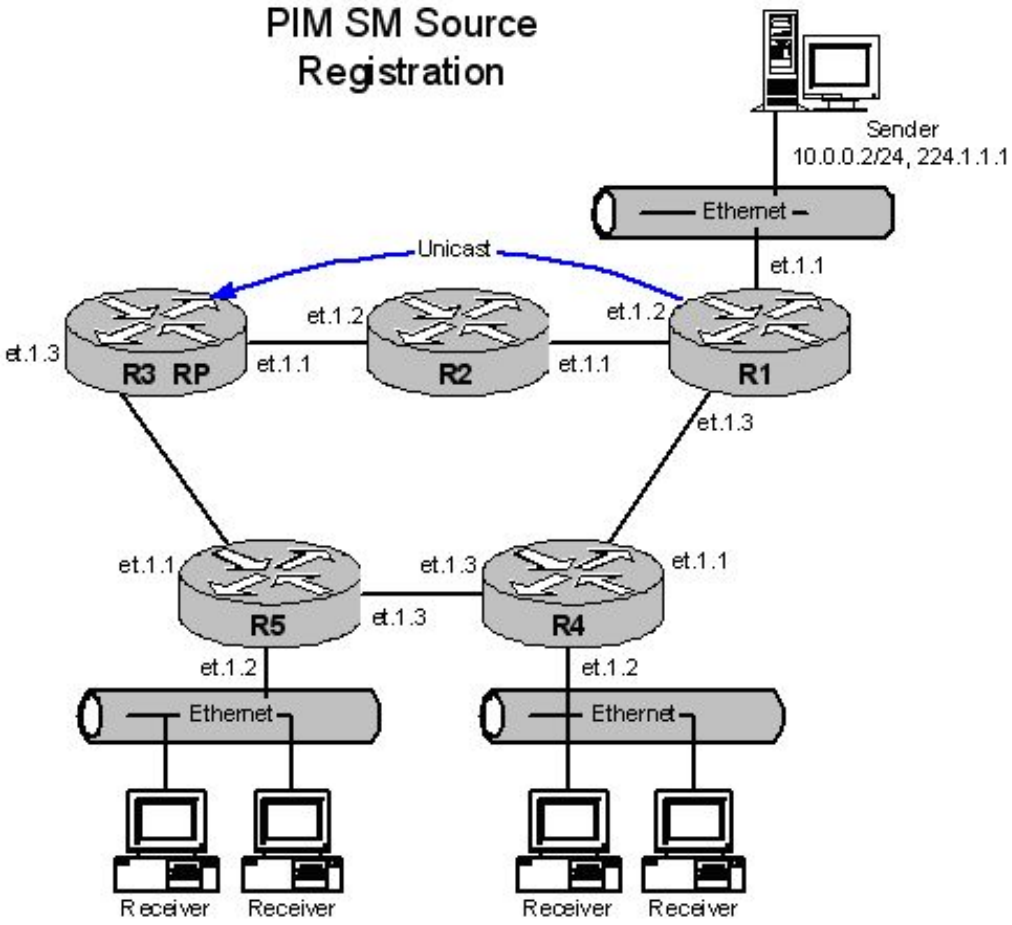

Figure 18 PIM SM Source Registration

In this diagram a source begins publishing data. The PIM designated router on this LAN segment hears these packets and informs the RP. This process gives the RP source and group knowledge of multicast sources. Additionally, this process actually gets the multicast data to the RP. This process is performed in software so it is CPU intensive. This process only occurs for several milliseconds.

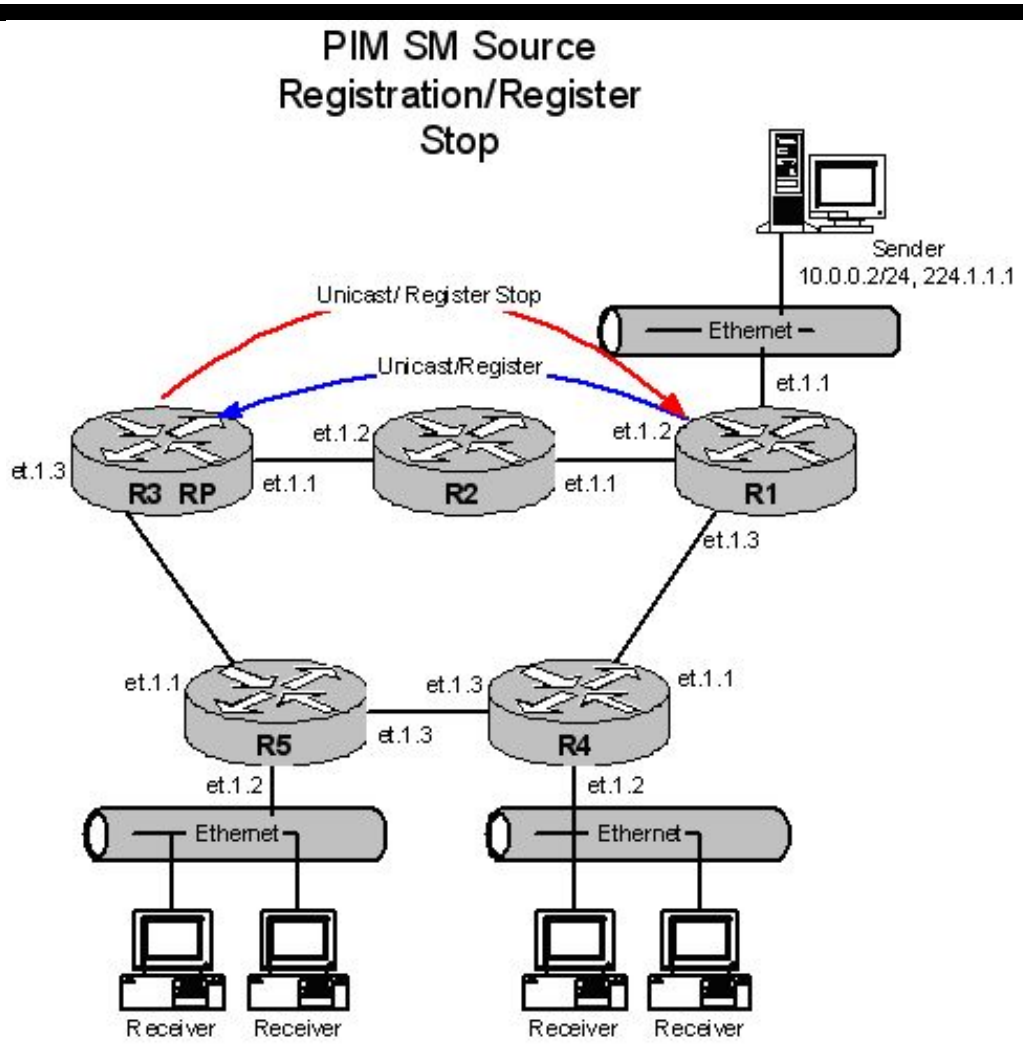

Figure 19 - PIM SM Source Registration/Register Stop

If the RP has no receivers then it will send a register stop message to sender of the register messages. This will tell then sending router to stop sending these unicast encapsulated register messages. The RP will however create (S,G) and (*,G) states for this multicast source. If there were receivers here the RP would send the decapsulated multicast packets down the shared tree and send an (S,G)join to the source router. After the RP sends an (S,G) join upstream towards the sending router and it receives the data by native multicast then it would send a register stop to the sending router. If the RP is not receiving data from the sending router via the SPT then periodically (typically every 3 minutes) the sending router will send these register packets to the RP and the RP will again send register stop messages back to the RP.

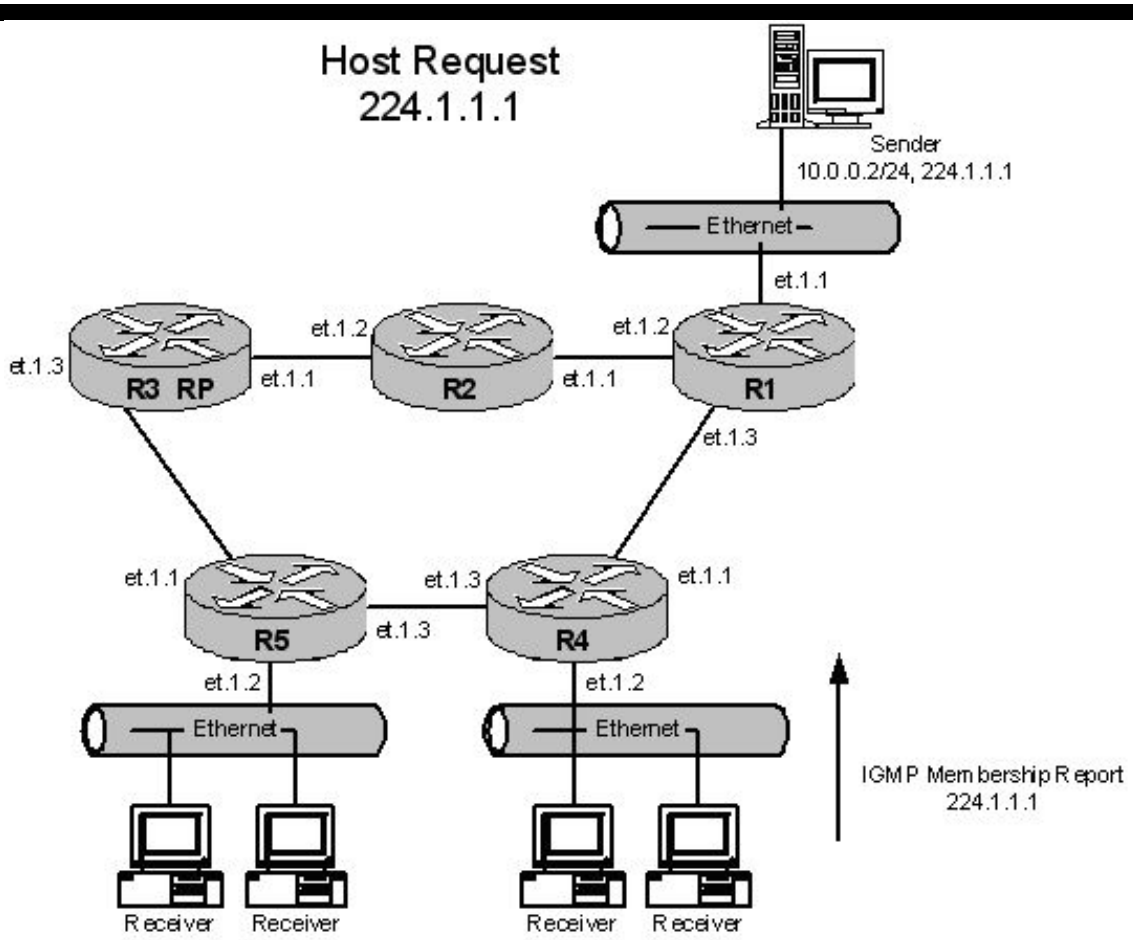

Figure 20 PIM SM Explicit Join Model

PIM SM works by the explicit join model. In order to receive multicast data a host needs to send an IGMP membership report (commonly called an IGMP join) to the IGMP designated forwarder on the LAN. Upon receipt of an IGMP membership report PIM begins creating the shared tree.

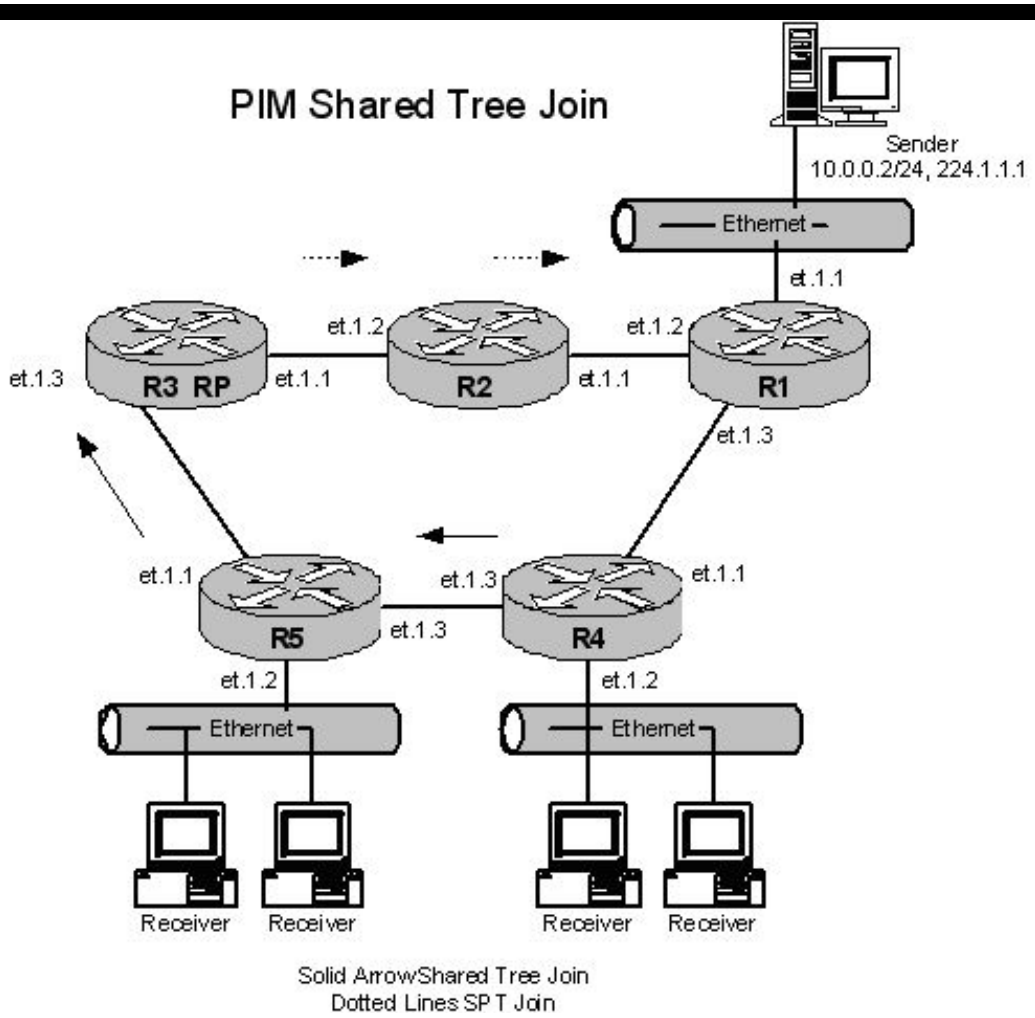

Figure 21 - PIM Shared Tree Join

PIM SM creates a shared tree upon the receipt of a IGMP join. When a host informs its local router of its desire to receive a multicast data stream the local router adds that interface to its outgoing interface list (OIL). It then sends a (*,G) shared tree join to the next router towards the RP. Upon the receipt of a (*,G) join the next upstream router adds the interface where the (*,G) join was received to its OIL list and sends a (*.G) join to the next upstream router. This process is repeated all the way to the RP. The RP will send (S,G) joins to the routers on the path to the source.

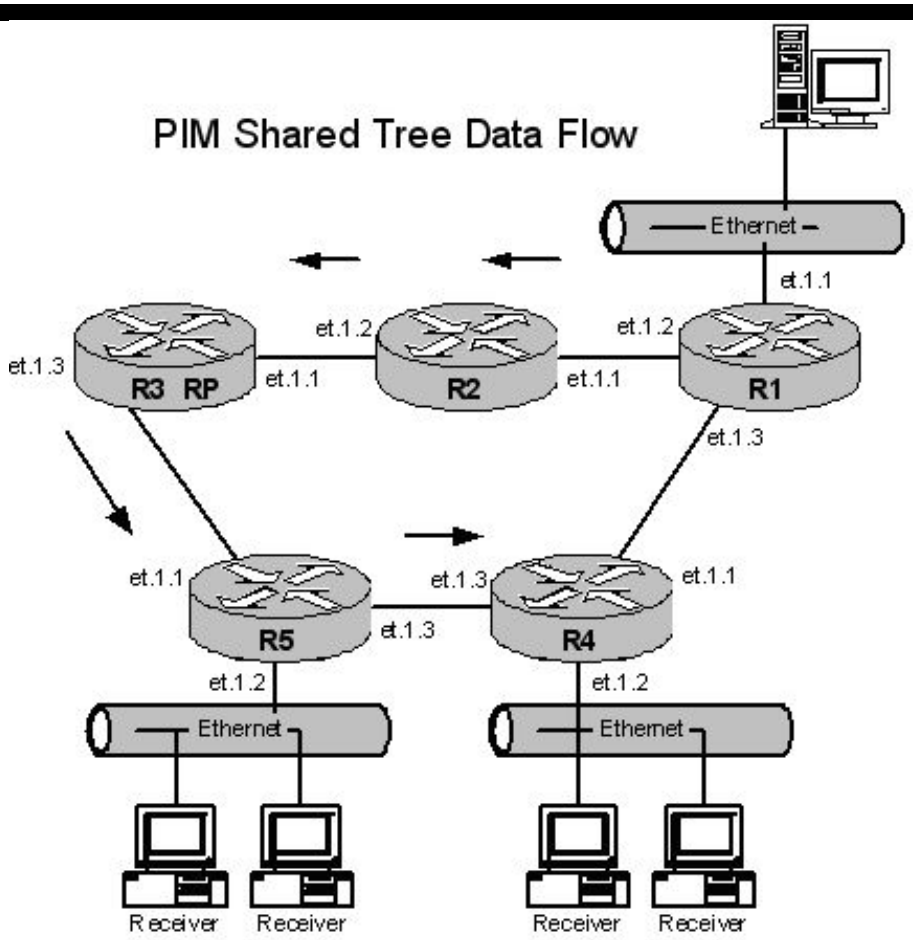

Figure 22- PIM Shared Tree Data Flow

After the RP sends a (S,G) join to the source router and has received data it will forward this multicast data down the shared tree.

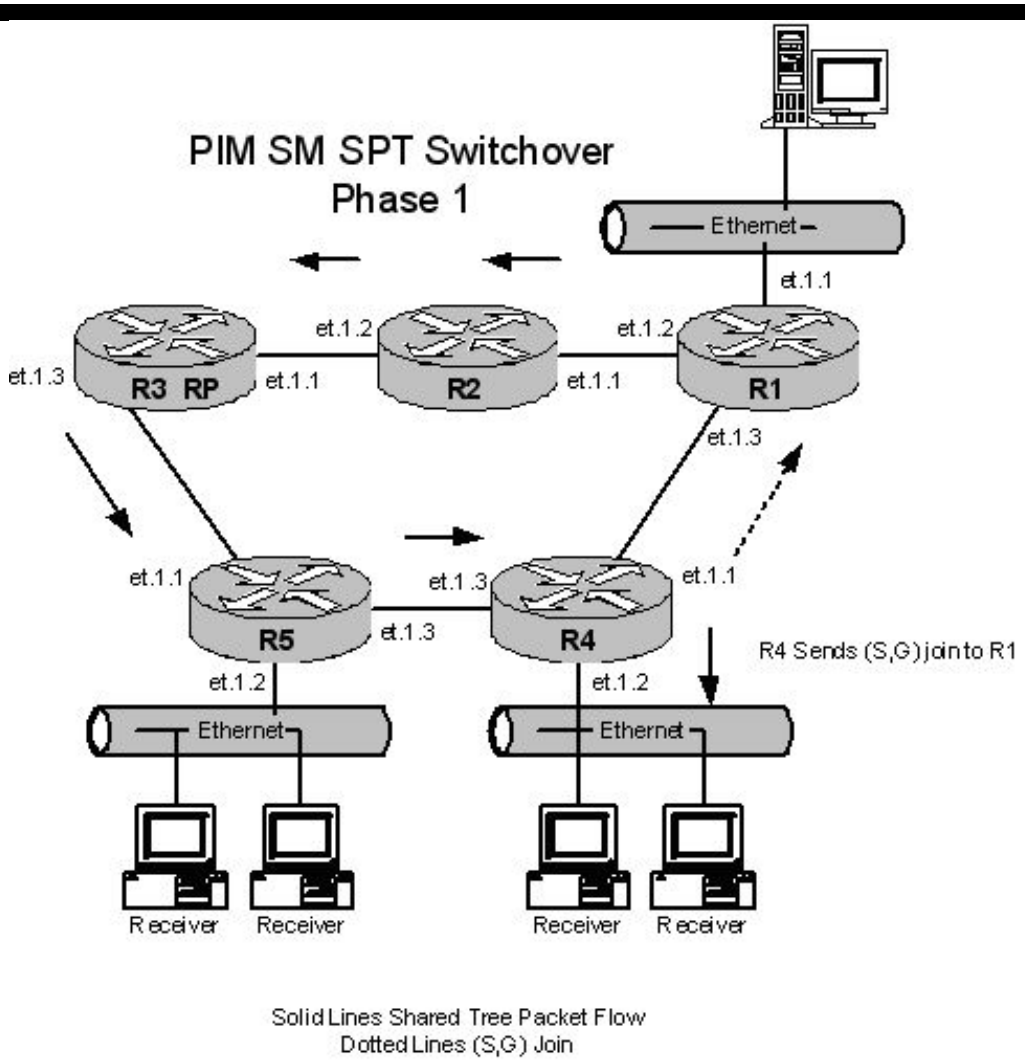

Figure 23 - PIM SM SPT Switchover Phase 1

The router that is the bifurcation point for the SPT and shared tree will switchover to a SPT upon exceeding a certain threshold of multicast traffic. This SPT switchover gives the benefit of optimal routing. The threshold for SPT switchover for the RS is zero. This means upon receipt of the first packet from the shared tree an (S,G) join is sent up the SPT tree. The (S,G) join can be performed at this point as this router knows the source of the multicast data stream as it is receiving multicast packets. This SPT switchover threshold can be changed if desired.

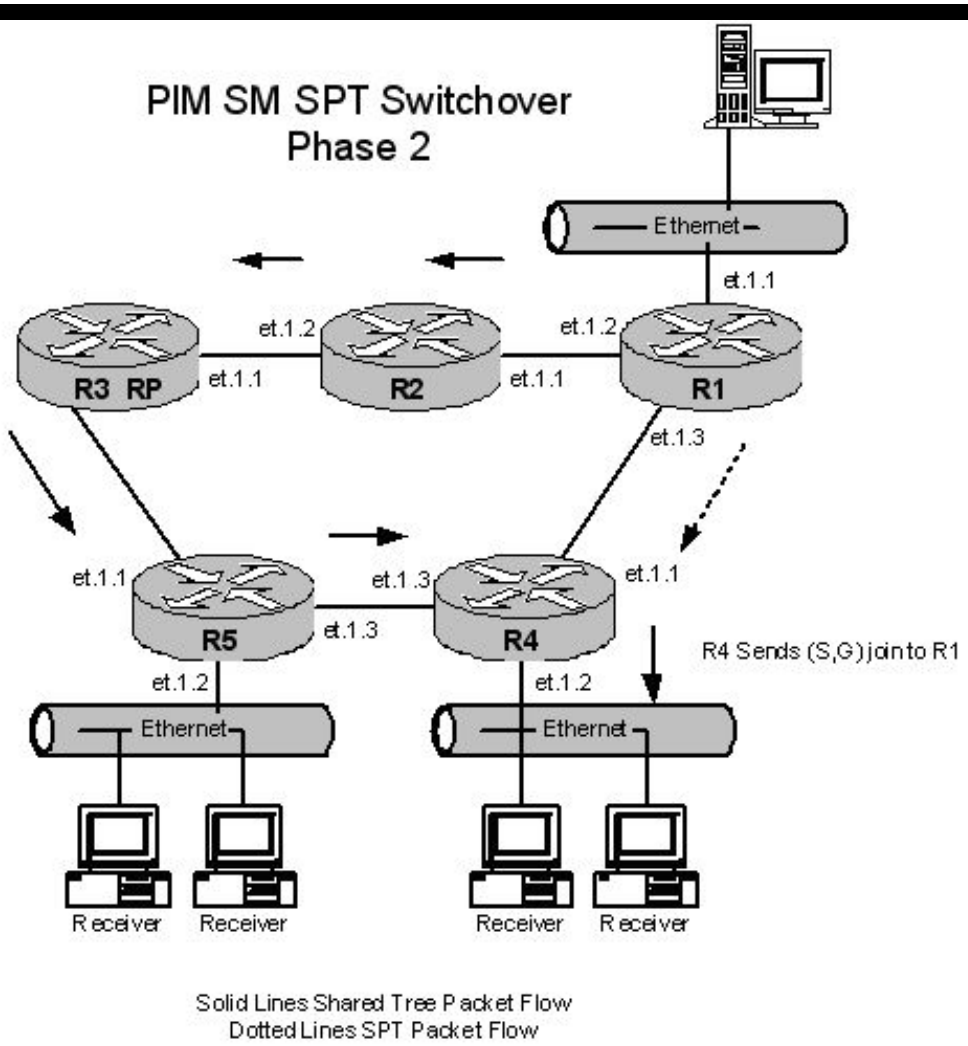

Figure 24 - PIM SM SPT Switchover Phase 2

After the router at the bifurcation point (R4) sends an (S,G) join it soon starts to receive multicast packets down the shared and SPT trees.

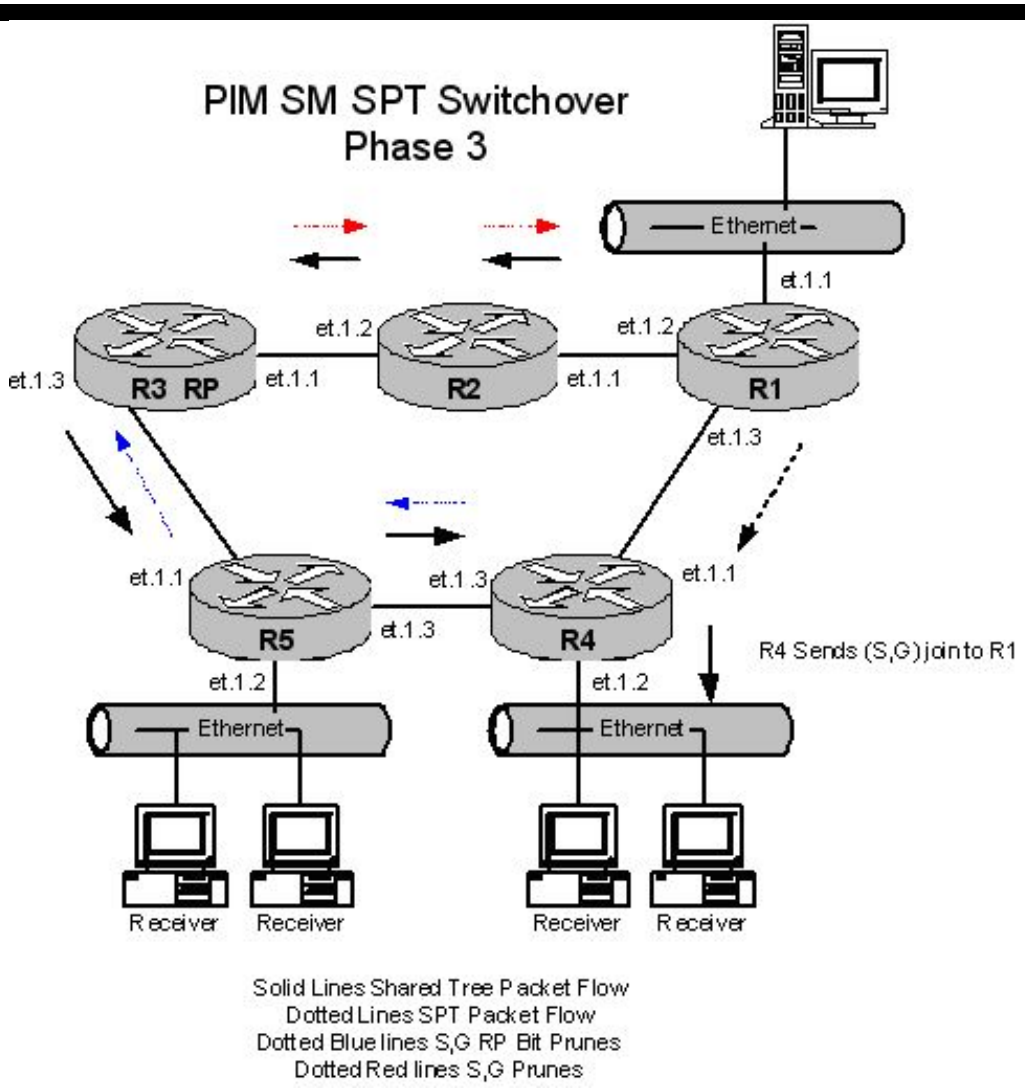

Figure 25 - PIM SM SPT Switchover Phase 3

After R4 begins receiving data from the shared tree and the SPT simultaneously it sends an (S,G) RP bit prune up the shared tree to tell the RP to stop sending data down that path.

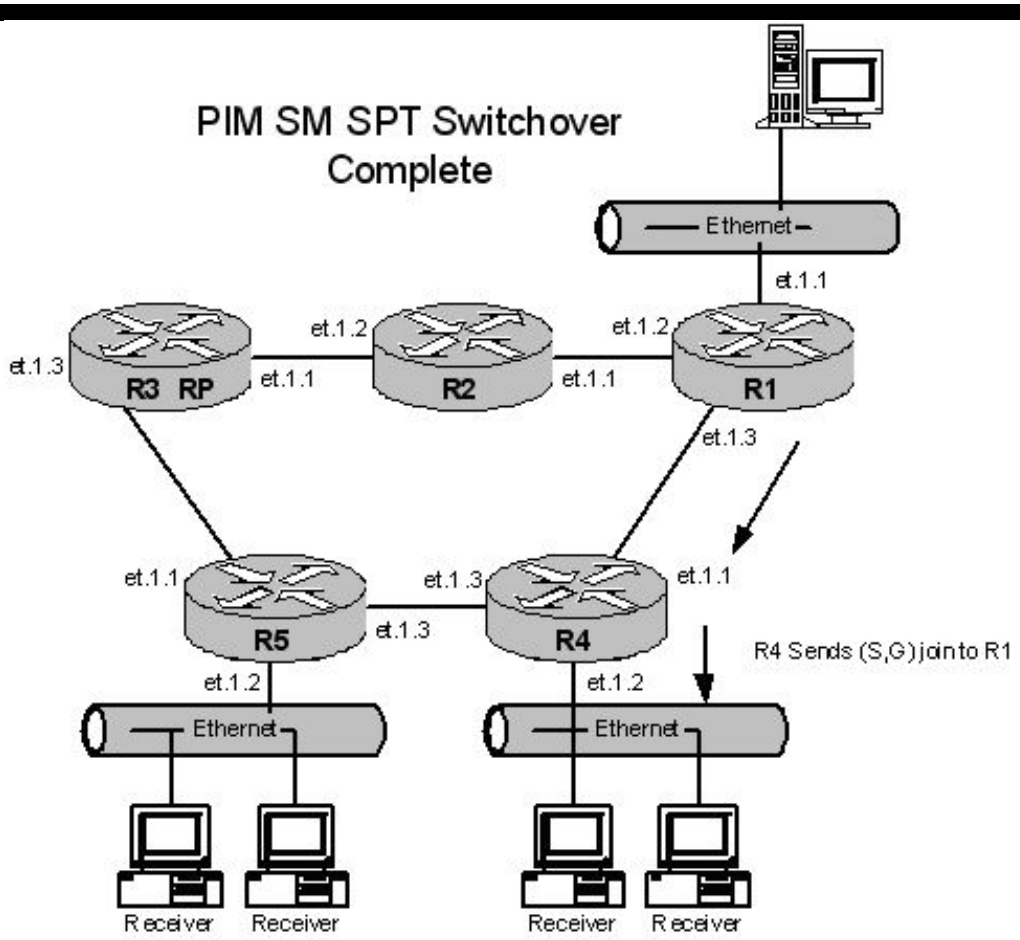

Figure 26 - PIM SM SPT Switchover Complete

After pruning the shared tree the network is left with an efficient SPT.

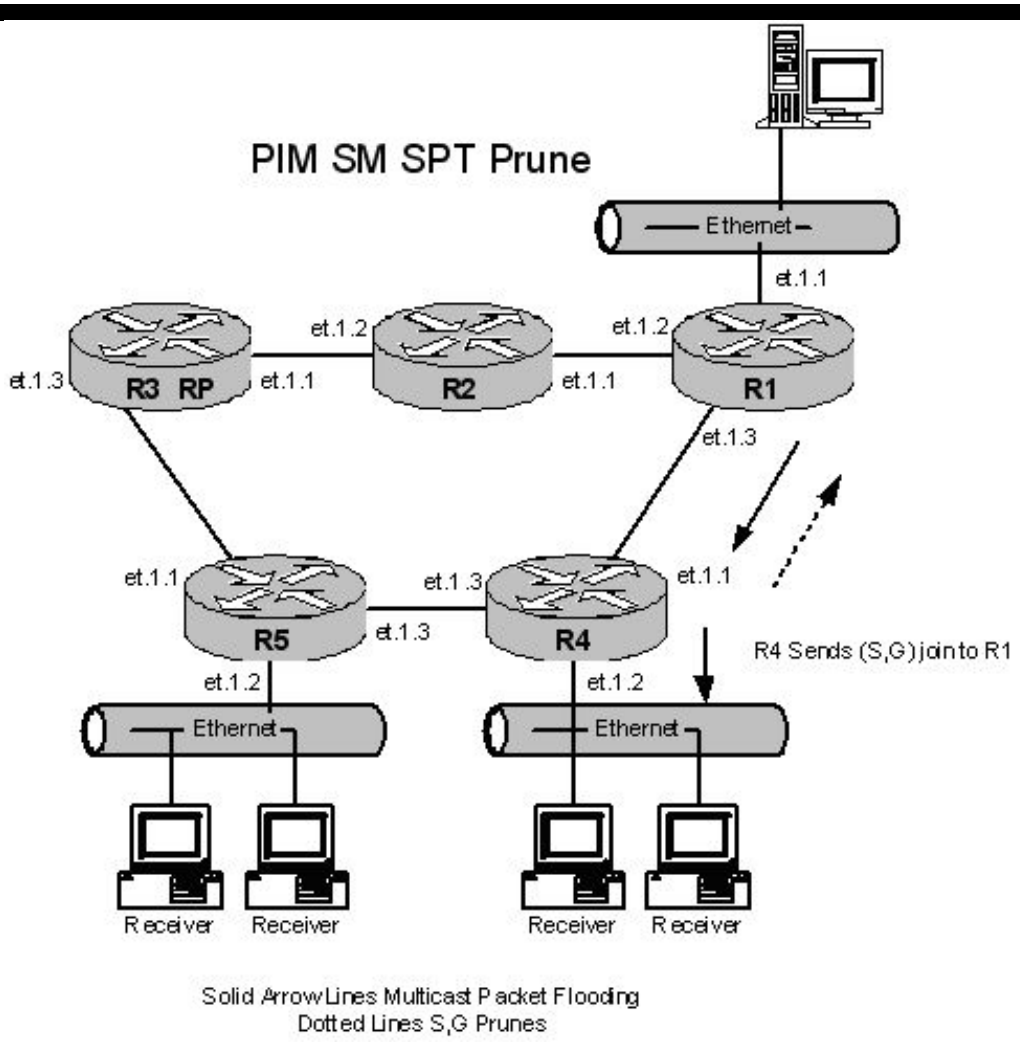

Figure 27 - PIM SM SPT Prune

When the data flow is no longer desired, prune messages are sent up the SPT. After the pruning of the SPT is complete there is no multicast flow for this group until it is requested again.

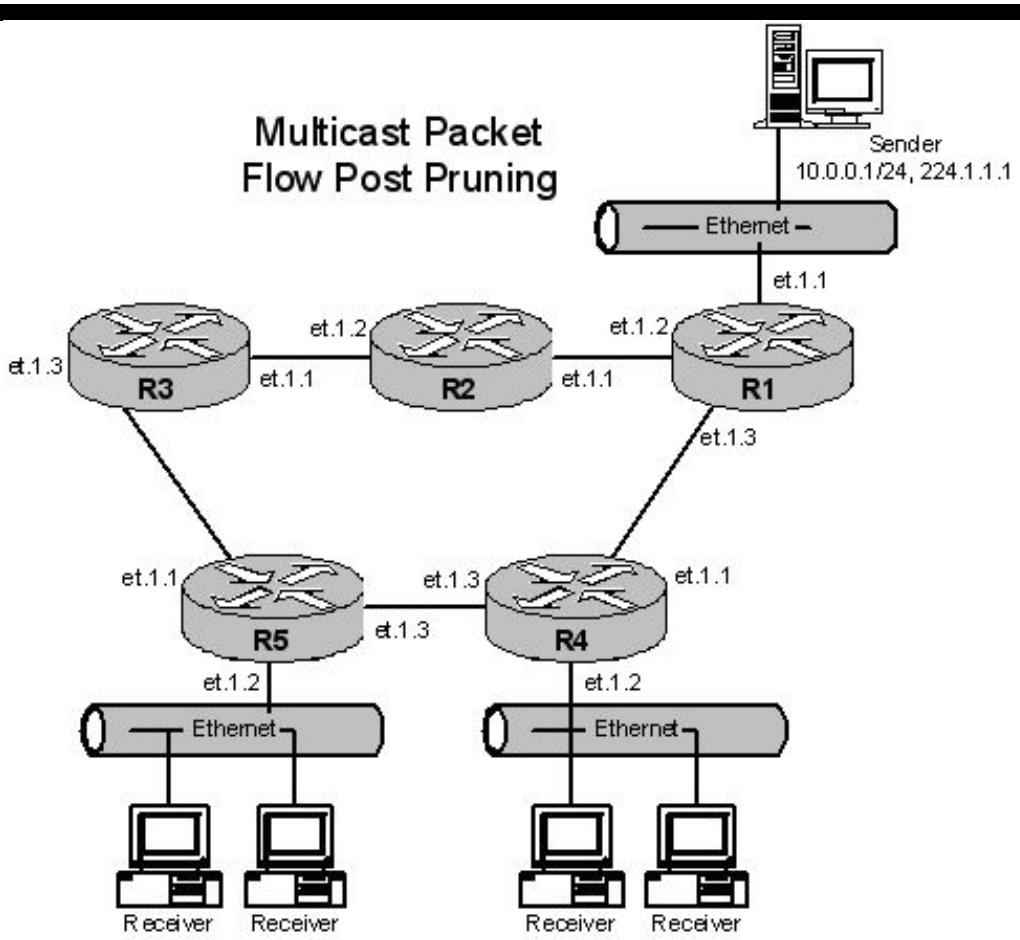

Figure 28 - Multicast Packet Flow Post Pruning

When all the pruning is complete, there is no more multicast traffic on the network. Also, (S,G) state exists only in the RP and the router that received the multicast on the local LAN, in this case R1.

In the example below the bootstrap mechanism tells all routers in the PIM SM domain that R3 is the RP for 224.0.0.0/4. In this example R3 is both the Candidate RP (C-RP) and the Candidate Bootstrap Router (C-BSR). If they had been separate routers then the Candidate RP would have unicast its C-RP availability to the C-BSR mapping agent. Then the C-BSR would multicast these messages to all PIM routers in a hop by hop manner. In small networks they are typically configured as the same router just like in our example in the configuration lab in Appendix A.

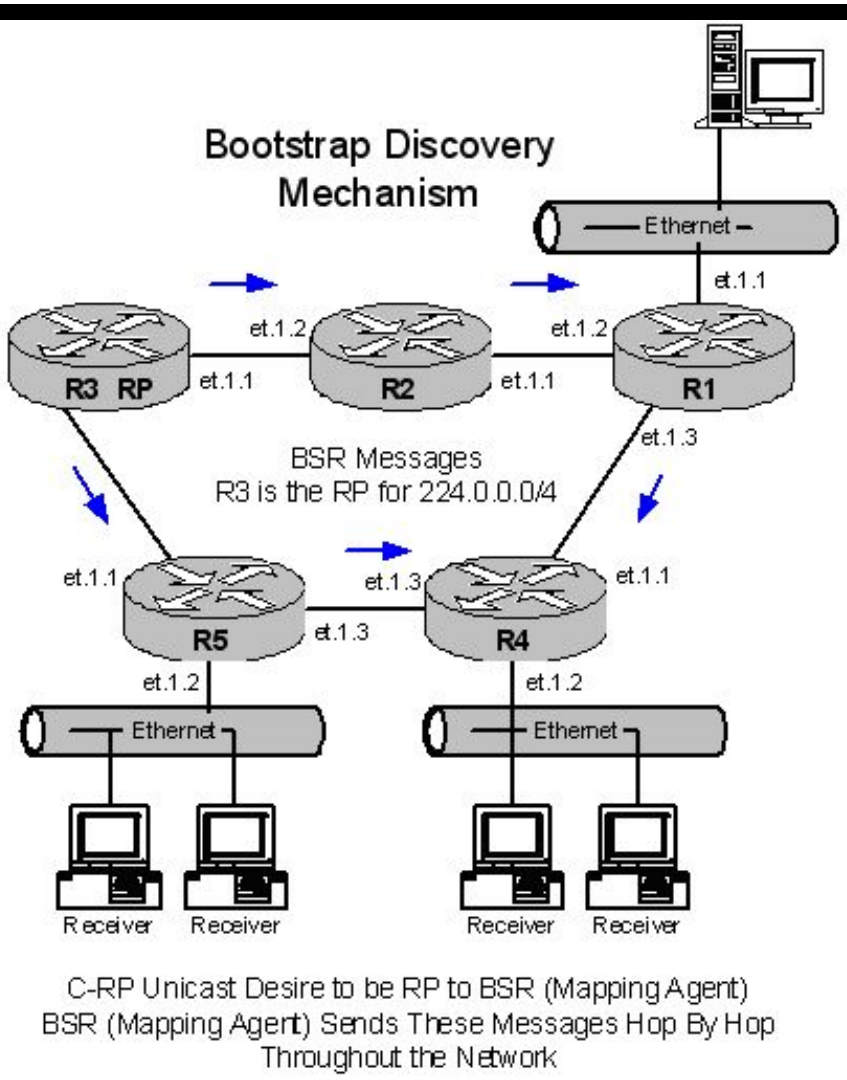

Figure 29 - Bootscrap Discovery Mechanism

Intradomain Verses Interdomain Multicast

DVMP and PIM-SM are both intradomain routing protocols. Just like an IGP is meant to be run inside an AS these protocols are designed for multicast routing inside the AS. In order for multicasts to scale through the global Internet an entire new set of multicast protocols needs to be developed. PIM-SM is considered the defacto Internet multicast routing protocol. Since PIM-SM is so widely deployed, all interdomain multicast routing protocols will need to interoperate with PIM-SM. Protocols that pertain to interdomain multicasting are BGP, MP-BGP, and MSDP.

PIM-SM is protocol independent and thus uses any available routing protocol for reverse path lookup. Consequently, BGP will function very effectively for the reverse path lookup part of interdomain multicasting. However, in interdomain multicasting there is often a desire to have unicast and multicast traffic utilize different links at peering points. Since BGP does not provide for multiple traffic patterns for unicast and multicast traffic MP-BGP can be used in these situations. MP-BGP for multicast uses the address family "IPV4 multicast" for multicast reverse path forwarding, adding two new messages MP_REACH_NLRI and MP_UNREACH_NLRI. For clarity an MP-BGP message has been taken from RFC 2283 for figure 30.

Realistically BGP alone could provide for RPF information for PIM SM. However, since most peering points require that multicast traffic be sent over a different physical connection then unicast traffic MP-BGP is required. Consequently, most service providers require customers to advertise multicast routes through MP-BGP.

```
+-------------------------------------------------------+
| Address Family Identifier (2 octets)                  |
+-------------------------------------------------------+
| Subsequent Address Family Identifier (1 octet)        |
+-------------------------------------------------------+
| Withdrawn Routes (variable)                           |
+-------------------------------------------------------+
```

Figure 30

Multicast Source Discovery Protocol

BGP and MP-BGP provide the RPF information for multicast forwarding. However, there is still a need for the RP (S,G) information to be advertised throughout the internet. A new protocol, Multicast Source Discovery Protocol (MSDP), has been developed for dynamic interdomain source to RP mapping. Even better, MSDP is generally thought to be both simple and elegant.

MSDP operates over TCP, allowing reliable multicast source information to travel throughout the network. MSDP works with PIM SM in the following manner. A source registers with the RP in PIM SM. The RP is also an MSDP peer and sends Source Active (SA) messages to all other MSDP peers of the new multicast source that it learned. This source active message is propagated to all MSDP peers. The MSDP peers now have the full (S,G) mappings in other domains. MSDP utilizes the BGP next hop for RPF and loop prevention. Consequently, MSDP generally requires BGP or MP-BGP to be run concurrently. This allows PIM SM to work by allowing the RP to be knowledgeable of all sources both intradomain and interdomain. Please see below figure 31 for some clarification on the interoperability between MBGP and MSDP.

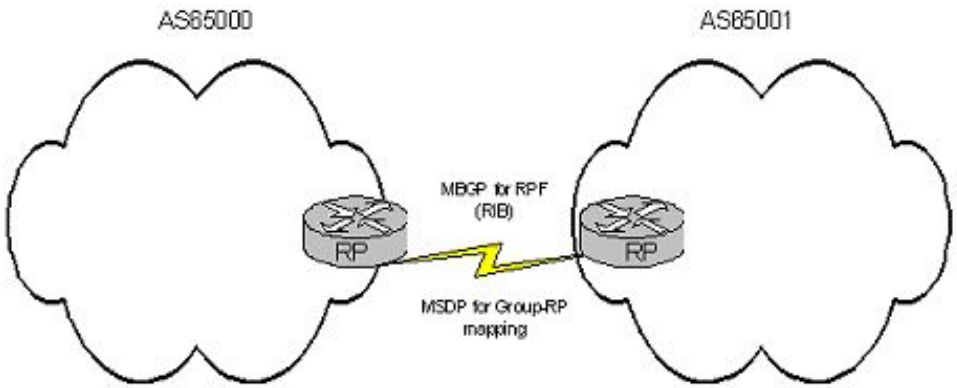

Figure 31 - MBGP and MSDP Interoperability

Anycast RP

The next new and exciting multicast protocol is Anycast RP. The RP is critical component of PIM-SM. Since there can only be a single RP for each multicast group this lends itself to sub optimal multicast routing in a shared tree environment. Additionally, fail over times are slow when the RP fails as a new RP needs to be elected and this needs to propagate thought the network. In addition the RP becomes a potential bottleneck. Anycast RP enables multiple routers to effectively share the same IP address providing redundancy and load sharing. Anycast RP uses MDSP which is what enables this "duplicate" IP address to work. The RPs are MSDP peers so they have information of all active sources via MSDP SA messages. All routers that are not RPs are statically configured with an IP address of the Anycast address. The IGP will naturally provide the user with the optimal RP based upon IGP cost. In the event of a failure of an RP another RP will be used when the IGP converges as it has the same address that is already statically configured on the routers. If the RP fails, data is not lost since traffic switches over to a SPT with the RP being used only as a meeting place for the multicast routers on the network. Please see Figure 22 below for clarification.

Note: Anycast RP is not currently supported on the RS platform. It is currently under review and probable development.

In the example below R3 and R1 are both configured as MSDP peers. They are both configured with a logical address of 7.7.7.7 that is advertised

into the IGP. MSDP peering routers use unique addresses for peering with each other and all SA information is propagated via MSDP. All routers are statically configured with the address of 7.7.7.7 (Anycast RP). Given the below topology if link cost is the same on all links R5 will choose R3 as the closest path to 7.7.7.7 while R4 will chose R1 as the closest path to 7.7.7.7. If either R3 or R1 fails than the IGP will converge and all routers will point to the other 7.7.7.7.

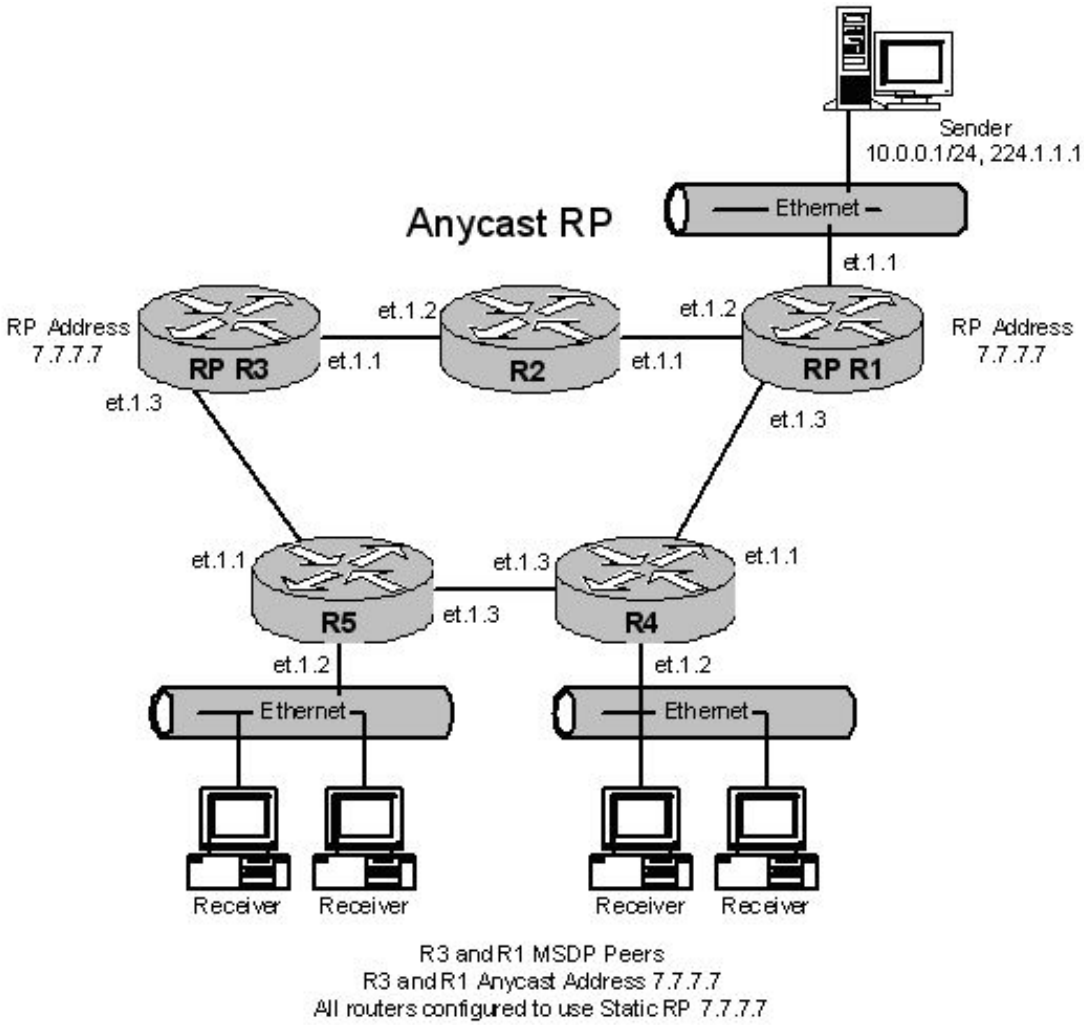

Figure 32 - Anycast RP

Summary

The advent of new technologies such as Video over DSL, distance learning, video conferencing, remote collaboration and others calls out for mechanisms that are more efficient than unicasting. Multicasting provides the technological infrastructure that can make these and other new bandwidth intensive applications workable in large production networks. Both intra- and interdomain multicasting require new forwarding mechanisms that differ from existing unicast forwarding mechanisms. PIM SM is considered the de facto standard for intradomain multicast while MSDP and MP-BGP are more commonly used for interdomain multicast. For intradomain multicast, protocols typically use either shortest path trees or shared trees. Although shortest path trees can work well in smaller environments where there are very few senders and most hosts are receivers, shared trees are considered to be more scalable and are recommended for most multicast networks.

Appendix A

This section has configurations for the routers in the above scenarios which can be used as a reference point. Where applicable specific commands are highlighted for explanation. For lab simplicity R4 and R5 have static multicast joins, which may or may not be applicable in a real world environment.

Configurations and Command Line Output

```
r1# show running-config
Running system configuration:
     !
     ! Last modified from Telnet (192.168.1.101) on 2002-07-24 16:53:41
     !
 1 : vlan create mserver port-based id 2
 2 : vlan add ports et.1.1 to mserver
     !
 3 : interface create ip tortr2 address-netmask 10.0.12.1/24 port et.1.2
 4 : interface create ip MSERVER address-netmask 10.0.0.1/24 vlan mserver
 5 : interface create ip tortr4 address-netmask 10.0.14.1/24 port et.1.3
 6 : interface add ip en0 address-netmask 192.168.1.151/24
 7 : interface add ip lo0 address-netmask 1.1.1.1/24
     !
 8 : ip-router global set router-id 1.1.1.1
     !
 9 : ospf create area backbone
10 : ospf add interface all to-area backbone
11 : ospf add stub-host 1.1.1.1 to-area backbone cost 10
12 : ospf set rib multicast  (Tells routers to use ospf routes for MRIB)
13 : ospf start
     !
14 : igmp add interface MSERVER  (Turns on IGMP on MSERVER interface)
15 : igmp start
     !
16 : pim sparse add interface  (Turns on PIM SM on all interfaces. PIM SM should be
enabled on all interfaces.)
all
17 : pim sparse start
     !
18 : system set name r1
r1# pim show routes

PIM Multicast Routing Table
Flags: S - Sparse, C - Directly connected host, L - Local, P - Pruned
       R - RP-bit set, T - SPT-bit set
       J - Join SPT, F - Directly connected source, E - External join
Timers: Uptime/Expires
Interface state: Interface, Timers, Output Ports

 (0.0.0.0/0, 239.1.1.1/32), 00:04:57/never, RP 3.3.3.3, flags: SC  (*,G)  Created
automatically when S,G state is created
  Incoming interface: tortr2, RPF nbr 10.0.12.2,
  Outgoing interface list:
     MSERVER (10.0.0.1), 00:04:57/never, ,


 (10.0.0.2/32, 239.1.1.1/32), (S,G) 00:05:25/00:01:34, flags: STRF
See above description
  Total packet/byte count: 27874/38437791, Rate: n/a
  Incoming interface: MSERVER, RPF nbr 10.0.0.2,
  Outgoing interface list:
```

```
     Tortr4 (10.0.14.1), 00:04:40/00:02:50, et.1.3,


 (0.0.0.0/0, 239.255.255.250/32), 00:04:53/never, RP 3.3.3.3, flags: SC
  Incoming interface: tortr2, RPF nbr 10.0.12.2,
  Outgoing interface
list:
     MSERVER (10.0.0.1), 00:04:53/never, ,


 (10.0.0.2/32, 239.255.255.250/32), 00:05:30/00:01:34, flags: STRF
  Total packet/byte count: 2/322, Rate: n/a
  Incoming interface: MSERVER, RPF nbr 10.0.0.2,
  Outgoing interface list:
     register (127.0.0.2), 00:03:51/unknown, ,




r1#


r2# show running-config
Running system configuration:
     !
     ! Last modified from Telnet (192.168.1.101) on 2002-07-24 16:52:14
     !
 1 : interface create ip tortr3 address-netmask 10.0.23.2/24 port et.1.2
 2 : interface create ip tortr2 address-netmask 10.0.12.2/24 port et.1.1
 3 : interface add ip en0 address-netmask 192.168.1.152/24
 4 : interface add ip lo0 address-netmask 2.2.2.2/24
     !
 5 : ip-router global set router-id 2.2.2.2
     !
 6 : ospf create area backbone
 7 : ospf add interface all to-area backbone
 8 : ospf add stub-host 2.2.2.2 to-area backbone cost 10
 9 : ospf set rib multicast
10 : ospf start
     !
11 : pim sparse add interface all
12 : pim sparse start
     !
13 : system set name r2
r2# pim show routes

PIM Multicast Routing Table
Flags: S - Sparse, C - Directly connected host, L - Local, P - Pruned
       R - RP-bit set, T - SPT-bit set
       J - Join SPT, F - Directly connected source, E - External join
Timers: Uptime/Expires
Interface state: Interface, Timers, Output Ports
```

```
 (0.0.0.0/0, 239.1.1.1/32), 00:05:48/never, RP 3.3.3.3, flags: S
  Incoming interface: tortr3, RPF nbr 10.0.23.3,
  Outgoing interface list:
     tortr2 (10.0.12.2), 00:05:48/00:02:42, et.1.1,


 (10.0.0.2/32, 239.1.1.1/32), 00:06:11/00:01:02, flags: SPR
  Total packet/byte count: NA/NA, Rate: NA
  Incoming interface: tortr3, RPF nbr 10.0.23.3,
  Outgoing interface list: n/a


 (0.0.0.0/0, 239.255.255.250/32), 00:05:44/never, RP 3.3.3.3, flags: S
  Incoming interface: tortr3, RPF nbr 10.0.23.3,
  Outgoing interface list:
     tortr2 (10.0.12.2), 00:05:44/00:02:46,
et.1.1,


 (10.0.0.2/32, 239.255.255.250/32), 00:05:44/00:01:02, flags: SPR
  Total packet/byte count: NA/NA, Rate: NA
  Incoming interface: tortr3, RPF nbr 10.0.23.3,
  Outgoing interface list: n/a



r2#

R3# show running-config
Running system configuration:
     !
     ! Last modified from Telnet (192.168.1.101) on 2002-07-24 19:06:52
     !
 1 : interface create ip tortr5 address-netmask 10.0.35.3/24 port et.1.3
 2 : interface create ip tortr2 address-netmask 10.0.23.3/24 port et.1.1
 3 : interface add ip en0 address-netmask 192.168.1.153/24
 4 : interface add ip lo0 address-netmask 3.3.3.3/24
     !
 5 : ip-router global set router-id 3.3.3.3
     !
 6 : ospf create area backbone
 7 : ospf add interface all to-area backbone
 8 : ospf add stub-host 3.3.3.3 to-area backbone cost 10
 9 : ospf set rib multicast
10 : ospf start
     !
11 : pim sparse add interface all
12 : pim sparse crp address 3.3.3.3 priority 100  (PIM telling BSRs its intention to
be a RP)
13 : pim sparse cbsr address 3.3.3.3 priority 100  (PIM telling all PIM SM routers
its intention to be BSR)
14 : pim sparse start
```

```
     !
15 : system set name R3

R3# pim show routes

PIM Multicast Routing Table
Flags: S - Sparse, C - Directly connected host, L - Local, P - Pruned
       R - RP-bit set, T - SPT-bit set
       J - Join SPT, F - Directly connected source, E - External join
Timers: Uptime/Expires
Interface state: Interface, Timers, Output Ports

 (0.0.0.0/0, 239.1.1.1/32), 00:08:27/never, RP 3.3.3.3, flags: S
  Incoming interface: register, RPF nbr (null),
  Outgoing interface list:
     tortr2 (10.0.23.3), 00:06:48/00:02:41, et.1.1,
     tortr5 (10.0.35.3), 00:08:27/00:03:03, et.1.3,


 (10.0.0.2/32, 239.1.1.1/32), 00:07:15/00:02:12, flags: SPR
  Total packet/byte count: NA/NA, Rate: NA
  Incoming interface: register, RPF nbr (null),
  Outgoing interface list: n/a


 (0.0.0.0/0, 239.255.255.250/32), 00:06:44/never, RP 3.3.3.3, flags: S
  Incoming interface: register, RPF nbr (null),
  Outgoing interface
list:
     tortr2 (10.0.23.3), 00:06:44/00:02:45, et.1.1,


 (10.0.0.2/32, 239.255.255.250/32), 00:06:42/00:02:12, flags: SPR
  Total packet/byte count: NA/NA, Rate: NA
  Incoming interface: register, RPF nbr (null),
  Outgoing interface list: n/a




R3#

R4# show running-config
Running system configuration:
     !
     ! Last modified from Telnet (192.168.1.101) on 2002-07-24 14:00:16
     !
 1 : vlan create mcastrec port-based id 5
 2 : vlan add ports et.2.2 to mcastrec
     !
 3 : interface create ip tortr5 address-netmask 10.0.45.4/24 port et.2.3
 4 : interface create ip tortr1 address-netmask 10.0.14.4/24 port et.2.1
 5 : interface create ip MCASTREC address-netmask 10.0.4.1/24 vlan mcastrec
 6 : interface add ip en0 address-netmask 192.168.1.154/24
```

```
 7 : interface add ip lo0 address-netmask 4.4.4.4/24
     !
 8 : ip-router global set router-id 4.4.4.4
     !
 9 : ospf create area backbone
10 : ospf add interface all to-area backbone
11 : ospf add stub-host 4.4.4.4 to-area backbone cost 10
12 : ospf set rib multicast
13 : ospf start
     !
14 : igmp add interface MCASTREC
15 : igmp join group 239.1.1.1 interface MCASTREC
16 : igmp start

!
17 : pim sparse add interface all
18 : pim sparse start
     !
19 : system set name R4

R4# pim show
routes

PIM Multicast Routing Table
Flags: S - Sparse, C - Directly connected host, L - Local, P - Pruned
       R - RP-bit set, T - SPT-bit set
       J - Join SPT, F - Directly connected source, E - External join
Timers: Uptime/Expires
Interface state: Interface, Timers, Output Ports

 (0.0.0.0/0, 239.1.1.1/32), 00:24:58/never, RP 3.3.3.3, flags: SEC
  Incoming interface: tortr5, RPF nbr 10.0.45.5,
  Outgoing interface list:
     MCASTREC (10.0.4.1), 00:07:56/never, et.2.2,


 (10.0.0.2/32, 239.1.1.1/32), 00:10:56/00:02:29, flags: STR
  Total packet/byte count: 74856/103226109, Rate: 202621 bytes/sec
  Incoming interface: tortr1, RPF nbr 10.0.14.1,
  Outgoing interface list:
     MCASTREC (10.0.4.1), 00:07:56/never, et.2.2,
     tortr5 (10.0.45.4), 00:00:07/00:03:23, et.2.3,


 (0.0.0.0/0, 239.255.255.250/32), 00:01:16/never, RP 3.3.3.3, flags: SC
  Incoming interface: tortr5, RPF nbr
10.0.45.5,
  Outgoing interface list:
     MCASTREC (10.0.4.1), 00:01:16/never, et.2.2,
```

```
R4#


R5# show running-config
Running system configuration:
     !
     ! Last modified from Telnet (192.168.1.103) on 2002-07-24 20:24:58
     !
 1 : interface create ip tortr4 address-netmask 10.0.45.5/24 port et.1.3
 2 : interface create ip tortr3 address-netmask 10.0.35.5/24 port et.1.1
 3 : interface create ip toreciever address-netmask 10.0.55.5/24 port et.1.2
 4 : interface add ip en0 address-netmask 192.168.1.155/24
 5 : interface add ip lo0 address-netmask 5.5.5.5/24
     !
 6 : ip-router global set router-id 5.5.5.5
     !
 7 : ospf create area backbone
 8 : ospf add interface all to-area backbone
 9 : ospf add stub-host 5.5.5.5 to-area backbone cost 10
10 : ospf set rib multicast
11 : ospf start
     !
12 : igmp add interface toreciever
13 : igmp join group 239.1.1.1 interface toreciever
14 : igmp join group 239.255.255.250 interface toreciever
15 : igmp start
     !
16 : pim sparse add interface all
17 : pim sparse
start
     !
18 : system set name R5
R5#
R5# pim show routes

PIM Multicast Routing Table
Flags: S - Sparse, C - Directly connected host, L - Local, P - Pruned
       R - RP-bit set, T - SPT-bit set
       J - Join SPT, F - Directly connected source, E - External join
Timers: Uptime/Expires
Interface state: Interface, Timers, Output Ports

 (0.0.0.0/0, 239.1.1.1/32), 00:13:08/never, RP 3.3.3.3, flags: SC
  Incoming interface: tortr3, RPF nbr 10.0.35.3,
  Outgoing interface list:
     Tortr4 (10.0.45.5), 00:13:08/00:03:21, et.1.3,
     toreciever (10.0.55.5), 00:01:07/never, et.1.2,


 (10.0.0.2/32, 239.1.1.1/32), 00:11:55/00:02:38, flags: STR
  Total packet/byte count: NA/NA, Rate: NA
  Incoming interface: tortr4, RPF nbr 10.0.45.4,
```

```
  Outgoing interface list:
     toreciever (10.0.55.5), 00:01:07/never, et.1.2,


 (0.0.0.0/0, 239.255.255.250/32), 00:02:15/never, RP 3.3.3.3, flags: SC
  Incoming interface: tortr3, RPF nbr
10.0.35.3,
  Outgoing interface list:
     Tortr4 (10.0.45.5), 00:02:15/00:03:15, et.1.3,
     toreciever (10.0.55.5), 00:01:07/never, et.1.2,

R5#
```

DVMRP configurations

```
r1# show running-config
Running system configuration:
     !
     ! Last modified from Telnet (192.168.1.100) on 2002-07-25 07:46:27
     !
 1 : vlan create mserver port-based id 2
 2 : vlan add ports et.1.1 to mserver
     !
 3 : interface create ip tortr2 address-netmask 10.0.12.1/24 port et.1.2
 4 : interface create ip MSERVER address-netmask 10.0.0.1/24 vlan mserver
 5 : interface create ip tortr4 address-netmask 10.0.14.1/24 port et.1.3
 6 : interface add ip en0 address-netmask 192.168.1.151/24
 7 : interface add ip lo0 address-netmask 1.1.1.1/24
     !
 8 : ip-router global set router-id 1.1.1.1
     !
 9 : ospf create area backbone
10 : ospf add interface all to-area backbone
11 : ospf add stub-host 1.1.1.1 to-area backbone cost 10
12 : ospf start
     !
13 : igmp add interface MSERVER  (Turns on IGMP on MSERVER interface)
14 : igmp start
     !
15 : dvmrp add interface all  (Turns on DVMRP  on all interfaces. DVMRP should be
enabled on all interfaces that could possibly forward multicast traffic.)
16 : dvmrp start
     !
17 : system set name r1
18 : system set idle-timeout serial 0 telnet 0 ssh 0

r1# dvmrp show routes   (Note these are unicast routes for RPF)
```

```
Proto       Route/Mask   NextHop         Holddown Age  Metric
----- ----------------- --------------- -------- ---- ------
DVMRP         2.2.2.2/32 10.0.12.2       0        10   2
DVMRP         3.3.3.3/32 10.0.12.2       0        10   3
DVMRP         4.4.4.4/32 10.0.14.4       0        52   2
DVMRP         5.5.5.5/32 10.0.14.4       0        52   3
DVMRP          10.0.4/24 10.0.14.4       0        52   2
DVMRP        10.0.23/24 10.0.12.2       0        10   2
DVMRP        10.0.35/24 10.0.12.2       0        10   3
DVMRP        10.0.45/24 10.0.14.4       0        52   2
DVMRP        10.0.55/24 10.0.14.4       0        52   3
r1# ip-router show mrt

Multicast Routing Table
Flags: C - Cached, N - Negative cache, P - Pending, D - Delete, R - Reject

Source Address   Group Address    Flags     Incoming I/f     Outgoing I/f
--------------  --------------  --------  ---------------  ---------------
10.0.0.2         239.1.1.1        C         10.0.0.1         10.0.14.1

r1#

r2# show running-config
Running system configuration:
     !
     ! Last modified from Telnet (192.168.1.100) on 2002-07-25 07:48:01
     !
 1 : interface create ip tortr3 address-netmask 10.0.23.2/24 port et.1.2
 2 : interface create ip tortr2 address-netmask 10.0.12.2/24 port et.1.1
 3 : interface add ip en0 address-netmask 192.168.1.152/24
 4 : interface add ip lo0 address-netmask 2.2.2.2/24
     !
 5 : ip-router global set router-id 2.2.2.2
     !
 6 : ospf create area backbone
 7 : ospf add interface all to-area backbone
 8 : ospf add stub-host 2.2.2.2 to-area backbone cost 10
 9 : ospf start
     !
10 : dvmrp add interface all
11 : dvmrp start
     !
12 : system set name r2
13 : system set idle-timeout serial 0 telnet 0 ssh 0
r2# dvmrp show routes
Proto       Route/Mask   NextHop         Holddown Age  Metric
----- ----------------- --------------- -------- ---- ------
DVMRP         1.1.1.1/32 10.0.12.1       0        39   2
DVMRP         3.3.3.3/32 10.0.23.3       0        57   2
DVMRP         4.4.4.4/32 10.0.12.1       0        39   3
DVMRP         5.5.5.5/32 10.0.23.3       0        57   3
```

```
DVMRP              10/24 10.0.12.1       0        39   2
DVMRP           10.0.4/24 10.0.12.1       0        39   3
DVMRP          10.0.14/24 10.0.12.1       0        39   2
DVMRP          10.0.35/24 10.0.23.3       0        57   2
DVMRP          10.0.45/24 10.0.12.1       0        39   3
DVMRP          10.0.55/24 10.0.23.3       0        57   3
r2# ip-router show mrt

Multicast Routing Table
Flags: C - Cached, N - Negative cache, P - Pending, D - Delete, R - Reject

Source Address   Group Address    Flags     Incoming I/f     Outgoing I/f
--------------  --------------  --------  --------------  --------------

Note:  Pruned Entries (S,G) are still in the box.  They do not show up under the
generic ip-router show mrt.  They can only be viewed from diag mode.

r2

R3# show running-config
Running system configuration:
     !
     ! Last modified from Telnet (192.168.1.100) on 2002-07-25 09:49:23
     !
 1 : interface create ip tortr5 address-netmask 10.0.35.3/24 port et.1.3
 2 : interface create ip tortr2 address-netmask 10.0.23.3/24 port et.1.1
 3 : interface add ip en0 address-netmask 192.168.1.153/24
 4 : interface add ip lo0 address-netmask 3.3.3.3/24
     !
 5 : ip-router global set router-id 3.3.3.3
     !
 6 : ospf create area backbone
 7 : ospf add interface all to-area backbone
 8 : ospf add stub-host 3.3.3.3 to-area backbone cost 10
 9 : ospf start
     !
10 : dvmrp add interface all
11 : dvmrp start
     !
12 : system set name R3
13 : system set idle-timeout serial 0 telnet 0 ssh 0
R3# dvmrp show routes
Proto       Route/Mask   NextHop         Holddown Age  Metric
----- ----------------- --------------- -------- ---- ------
DVMRP         1.1.1.1/32 10.0.23.2       0        28   3
DVMRP         2.2.2.2/32 10.0.23.2       0        28   2
DVMRP         4.4.4.4/32 10.0.35.5       0        55   3
DVMRP         5.5.5.5/32 10.0.35.5       0        55   2
DVMRP              10/24 10.0.23.2       0        28   3
DVMRP           10.0.4/24 10.0.35.5       0        55   3
DVMRP          10.0.12/24 10.0.23.2       0        28   2
DVMRP          10.0.14/24 10.0.23.2       0        28   3
```

```
DVMRP         10.0.45/24 10.0.35.5       0        55   2
DVMRP         10.0.55/24 10.0.35.5       0        55   2
R3# ip-router show mrt

Multicast Routing Table
Flags: C - Cached, N - Negative cache, P - Pending, D - Delete, R - Reject

Source Address   Group Address    Flags     Incoming I/f     Outgoing I/f
--------------  --------------  --------  --------------  --------------

R3#

R4# show running-config
Running system configuration:
     !
     ! Last modified from Telnet (192.168.1.100) on 2002-07-25 05:05:22
     !
 1 : vlan create mcastrec port-based id 5
 2 : vlan add ports et.2.2 to mcastrec
     !
 3 : interface create ip tortr5 address-netmask 10.0.45.4/24 port et.2.3
 4 : interface create ip tortr1 address-netmask 10.0.14.4/24 port et.2.1
 5 : interface create ip MCASTREC address-netmask 10.0.4.1/24 vlan mcastrec
 6 : interface add ip en0 address-netmask 192.168.1.154/24
 7 : interface add ip lo0 address-netmask 4.4.4.4/24
     !
 8 : ip-router global set router-id 4.4.4.4
     !
 9 : ospf create area backbone
10 : ospf add interface all to-area backbone
11 : ospf add stub-host 4.4.4.4 to-area backbone cost 10
12 : ospf start
     !
13 : igmp add interface MCASTREC
14 : igmp join group 239.1.1.1 interface MCASTREC
15 : igmp start
     !
16 : dvmrp add interface all
17 : dvmrp start
     !
18 : system set name R4
19 : system set idle-timeout serial 0 telnet 0 ssh 0
R4# dvmrp show routes
Proto       Route/Mask   NextHop         Holddown Age  Metric
----- ----------------- -------------- -------- ---- ------
DVMRP         1.1.1.1/32 10.0.14.1       0        11   2
DVMRP         2.2.2.2/32 10.0.14.1       0        11   3
DVMRP         3.3.3.3/32 10.0.45.5       0        35   3
DVMRP         5.5.5.5/32 10.0.45.5       0        35   2
DVMRP              10/24 10.0.14.1       0        11   2
DVMRP         10.0.12/24 10.0.14.1       0        11   2
DVMRP         10.0.23/24 10.0.14.1       0        11   3
```

```
DVMRP         10.0.35/24 10.0.45.5       0        35   2
DVMRP         10.0.55/24 10.0.45.5       0        35   2
R4# ip-router show mrt

Multicast Routing Table
Flags: C - Cached, N - Negative cache, P - Pending, D - Delete, R - Reject

Source Address   Group Address    Flags     Incoming I/f     Outgoing I/f
--------------   --------------   -------   --------------   --------------
10.0.0.2         239.1.1.1        C         10.0.14.4        10.0.4.1

R4#

R5# show running-config
Running system configuration:
     !
     ! Last modified from Telnet (192.168.1.100) on 2002-07-25 11:05:30
     !
 1 : interface create ip tortr4 address-netmask 10.0.45.5/24 port et.1.3
 2 : interface create ip tortr3 address-netmask 10.0.35.5/24 port et.1.1
 3 : interface create ip toreciever address-netmask 10.0.55.5/24 port et.1.2
 4 : interface add ip en0 address-netmask 192.168.1.155/24
 5 : interface add ip lo0 address-netmask 5.5.5.5/24
     !
 6 : ip-router global set router-id 5.5.5.5
     !
 7 : ospf create area backbone
 8 : ospf add interface all to-area backbone
 9 : ospf add stub-host 5.5.5.5 to-area backbone cost 10
10 : ospf start
     !
11 : igmp join group 239.1.1.1 interface toreciever
     !
12 : dvmrp add interface all
13 : dvmrp start
     !
14 : system set name R5
15 : system set idle-timeout serial 0 telnet 0 ssh 0
R5# dvmrp show routes
Proto       Route/Mask   NextHop         Holddown Age  Metric
----- ----------------- -------------- -------- ---- ------
DVMRP         1.1.1.1/32 10.0.45.4       0        29   3
DVMRP         2.2.2.2/32 10.0.35.3       0        9    3
DVMRP         3.3.3.3/32 10.0.35.3       0        9    2
DVMRP         4.4.4.4/32 10.0.45.4       0        29   2
DVMRP              10/24 10.0.45.4       0        29   3
DVMRP          10.0.4/24 10.0.45.4       0        29   2
DVMRP         10.0.12/24 10.0.35.3       0        9    3
DVMRP         10.0.14/24 10.0.45.4       0        29   2
DVMRP         10.0.23/24 10.0.35.3       0        9    2
R5# ip-router show mrt
```

```
Multicast Routing Table
Flags: C - Cached, N - Negative cache, P - Pending, D - Delete, R - Reject

Source Address   Group Address    Flags     Incoming I/f     Outgoing I/f
--------------   --------------   --------  --------------   --------------

R5#
```

MSDP and MP-BGP Configuration Lab

See new topology

```
r1# show running-config
Running system configuration:
     !
     ! Last modified from Telnet (10.33.33.3) on 2002-08-19 09:02:12
     !
 1 : vlan create mserver port-based id 2
 2 : vlan add ports et.1.1 to mserver
     !
 3 : interface create ip tortr2 address-netmask 10.0.12.1/24 port et.1.2
 4 : interface create ip MSERVER address-netmask 10.0.0.1/24 vlan mserver
 5 : interface create ip tortr4 address-netmask 10.0.14.1/24 port et.1.3
 6 : interface add ip en0 address-netmask 192.168.1.151/24
 7 : interface add ip lo0 address-netmask 1.1.1.1/24
     !
 8 : ip-router global set router-id 1.1.1.1
 9 : ip-router global set autonomous-system 65000
     !
10 : ip add route default blackhole
     !
11 : ip-router policy redistribute from-proto static to-proto ospf metric 10
     !
12 : ospf create area backbone
13 : ospf add stub-host 1.1.1.1 to-area backbone cost 10
14 : ospf add interface MSERVER to-area backbone
15 : ospf add interface tortr4 to-area backbone
16 : ospf add interface tortr2 to-area backbone
17 : ospf set rib multicast
18 : ospf set interface tortr2 passive
19 : ospf start
     !
20 : bgp create peer-group external autonomous-system 65001
21 : bgp add peer-host 10.0.12.2 group external
22 : bgp set peer-group external multicast-rib
23 : bgp start
```

```
(MPBGP for multicast RPF checks)
     !
24 : igmp add interface MSERVER
25 : igmp start
     !
26 : msdp add peer local-addr 1.1.1.1 remote-addr 3.3.3.3
27 : msdp start

(MSDP for multicast sources in other domains)
     !
28 : pim sparse add interface all
29 : pim sparse static-rp address 1.1.1.1
30 : pim sparse start
     !
31 : system set name r1
32 : system set idle-timeout telnet 0 ssh 0 serial 0
     !
33 : bgp advertise network 1.1.1.0/24
34 : bgp advertise network 10.0.0.0/24
35 : bgp advertise network 10.0.4.0/24
36 : bgp advertise network 10.0.14.0/24
37 : bgp advertise network 4.4.4.0/24
r1# pim show routes

PIM Multicast Routing Table
Flags: S - Sparse, C - Directly connected host, L - Local, P - Pruned
       R - RP-bit set, T - SPT-bit set
       J - Join SPT, F - Directly connected source, E - External join
Timers: Uptime/Expires
Interface state: Interface, Timers, Output Ports

 (0.0.0.0/0, 238.1.1.1/32), 00:14:46/never, RP 1.1.1.1, flags: SC
  Incoming interface: register, RPF nbr (null),
  Outgoing interface list:
     MSERVER (10.0.0.1), 00:14:46/never, et.1.1,
     tortr4 (10.0.14.1), 00:14:37/00:02:53, et.1.3,


 (10.0.0.2/32, 238.1.1.1/32), 00:14:45/00:00:23, flags: STF
  Total packet/byte count: 190054/262084081, Rate: 384235 bytes/sec
  Incoming interface: MSERVER, RPF nbr 10.0.0.2,
  Outgoing interface list:
     tortr4 (10.0.14.1), 00:14:37/00:02:53, et.1.3,


 (0.0.0.0/0, 238.1.1.2/32), 00:14:46/never, RP 1.1.1.1, flags: SC
  Incoming interface: register, RPF nbr (null),
  Outgoing interface list:
     MSERVER (10.0.0.1), 00:14:46/never, et.1.1,
     tortr4 (10.0.14.1), 00:14:37/00:02:53, et.1.3,


 (10.0.0.2/32, 238.1.1.2/32), 00:14:45/00:00:23, flags: STF
```

```
 Total packet/byte count: 190053/262082702, Rate: 384235 bytes/sec
 Incoming interface: MSERVER, RPF nbr 10.0.0.2,
 Outgoing interface list:
    tortr4 (10.0.14.1), 00:14:37/00:02:53, et.1.3,


(0.0.0.0/0, 238.1.1.3/32), 00:14:46/never, RP 1.1.1.1, flags: SC
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    MSERVER (10.0.0.1), 00:14:46/never, et.1.1,
    tortr4 (10.0.14.1), 00:14:37/00:02:53, et.1.3,


(10.0.0.2/32, 238.1.1.3/32), 00:14:45/00:00:23, flags: STF
 Total packet/byte count: 190053/262082702, Rate: 384235 bytes/sec
 Incoming interface: MSERVER, RPF nbr 10.0.0.2,
 Outgoing interface list:
    tortr4 (10.0.14.1), 00:14:37/00:02:53, et.1.3,


(0.0.0.0/0, 238.1.1.4/32), 00:14:46/never, RP 1.1.1.1, flags: SC
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    MSERVER (10.0.0.1), 00:14:46/never, et.1.1,
    tortr4 (10.0.14.1), 00:14:37/00:02:53, et.1.3,


(10.0.0.2/32, 238.1.1.4/32), 00:14:45/00:00:23, flags: STF
 Total packet/byte count: 190052/262081323, Rate: 384228 bytes/sec
 Incoming interface: MSERVER, RPF nbr 10.0.0.2,
 Outgoing interface list:
    tortr4 (10.0.14.1), 00:14:37/00:02:53, et.1.3,


(0.0.0.0/0, 238.1.1.5/32), 00:14:46/never, RP 1.1.1.1, flags: SC
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    MSERVER (10.0.0.1), 00:14:46/never, et.1.1,
    tortr4 (10.0.14.1), 00:14:37/00:02:53, et.1.3,


(10.0.0.2/32, 238.1.1.5/32), 00:14:45/00:00:23, flags: STF
 Total packet/byte count: 190052/262081323, Rate: 384228 bytes/sec
 Incoming interface: MSERVER, RPF nbr 10.0.0.2,
 Outgoing interface list:
    tortr4 (10.0.14.1), 00:14:37/00:02:53, et.1.3,


(0.0.0.0/0, 238.1.1.6/32), 00:14:46/never, RP 1.1.1.1, flags: SC
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    MSERVER (10.0.0.1), 00:14:46/never, et.1.1,
    tortr4 (10.0.14.1), 00:14:37/00:02:53, et.1.3,
```

```
(10.0.0.2/32, 238.1.1.6/32), 00:14:45/00:00:23, flags: STF
 Total packet/byte count: 190051/262079944, Rate: 384228 bytes/sec
 Incoming interface: MSERVER, RPF nbr 10.0.0.2,
 Outgoing interface list:
    tortr4 (10.0.14.1), 00:14:37/00:02:53, et.1.3,


(0.0.0.0/0, 238.1.1.7/32), 00:14:46/never, RP 1.1.1.1, flags: SC
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    MSERVER (10.0.0.1), 00:14:46/never, et.1.1,
    tortr4 (10.0.14.1), 00:14:37/00:02:53, et.1.3,


(10.0.0.2/32, 238.1.1.7/32), 00:14:45/00:00:23, flags: STF
 Total packet/byte count: 190050/262078565, Rate: 384228 bytes/sec
 Incoming interface: MSERVER, RPF nbr 10.0.0.2,
 Outgoing interface list:
    tortr4 (10.0.14.1), 00:14:37/00:02:53, et.1.3,


(0.0.0.0/0, 238.1.1.8/32), 00:14:46/never, RP 1.1.1.1, flags: SC
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    MSERVER (10.0.0.1), 00:14:46/never, et.1.1,
    tortr4 (10.0.14.1), 00:14:37/00:02:53, et.1.3,


(10.0.0.2/32, 238.1.1.8/32), 00:14:45/00:00:23, flags: STF
 Total packet/byte count: 190048/262075807, Rate: 384228 bytes/sec
 Incoming interface: MSERVER, RPF nbr 10.0.0.2,
 Outgoing interface list:
    tortr4 (10.0.14.1), 00:14:37/00:02:53, et.1.3,


(0.0.0.0/0, 238.1.1.9/32), 00:14:46/never, RP 1.1.1.1, flags: SC
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    MSERVER (10.0.0.1), 00:14:46/never, et.1.1,
    tortr4 (10.0.14.1), 00:14:37/00:02:53, et.1.3,


(10.0.0.2/32, 238.1.1.9/32), 00:14:45/00:00:23, flags: STF
 Total packet/byte count: 190047/262074428, Rate: 384228 bytes/sec
 Incoming interface: MSERVER, RPF nbr 10.0.0.2,
 Outgoing interface list:
    tortr4 (10.0.14.1), 00:14:37/00:02:53, et.1.3,


(0.0.0.0/0, 238.1.1.10/32), 00:14:46/never, RP 1.1.1.1, flags: SC
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    MSERVER (10.0.0.1), 00:14:46/never, et.1.1,
```

```
    tortr4 (10.0.14.1), 00:14:37/00:02:53, et.1.3,


(10.0.0.2/32, 238.1.1.10/32), 00:14:45/00:00:23, flags: STF
 Total packet/byte count: 190047/262074428, Rate: 384228 bytes/sec
 Incoming interface: MSERVER, RPF nbr 10.0.0.2,
 Outgoing interface list:
    tortr4 (10.0.14.1), 00:14:37/00:02:53, et.1.3,


(0.0.0.0/0, 239.1.1.1/32), 00:14:37/never, RP 1.1.1.1, flags: S
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr4 (10.0.14.1), 00:14:37/00:02:53, et.1.3,


(10.33.33.3/32, 239.1.1.1/32), 00:14:37/00:00:23, flags: S
 Total packet/byte count: NA/NA, Rate: NA
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr4 (10.0.14.1), 00:14:37/never, et.1.3,


(0.0.0.0/0, 239.1.1.2/32), 00:14:37/never, RP 1.1.1.1, flags: S
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr4 (10.0.14.1), 00:14:37/00:02:53, et.1.3,


(10.33.33.3/32, 239.1.1.2/32), 00:14:37/00:00:23, flags: S
 Total packet/byte count: NA/NA, Rate: NA
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr4 (10.0.14.1), 00:14:37/never, et.1.3,


(0.0.0.0/0, 239.1.1.3/32), 00:14:37/never, RP 1.1.1.1, flags: S
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr4 (10.0.14.1), 00:14:37/00:02:53, et.1.3,


(10.33.33.3/32, 239.1.1.3/32), 00:14:37/00:00:23, flags: S
 Total packet/byte count: NA/NA, Rate: NA
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr4 (10.0.14.1), 00:14:37/never, et.1.3,


(0.0.0.0/0, 239.1.1.4/32), 00:14:37/never, RP 1.1.1.1, flags: S
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr4 (10.0.14.1), 00:14:37/00:02:53, et.1.3,
```

```
(10.33.33.3/32, 239.1.1.4/32), 00:14:37/00:00:23, flags: S
 Total packet/byte count: NA/NA, Rate: NA
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr4 (10.0.14.1), 00:14:37/never, et.1.3,


(0.0.0.0/0, 239.1.1.5/32), 00:14:37/never, RP 1.1.1.1, flags: S
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr4 (10.0.14.1), 00:14:37/00:02:53, et.1.3,


(10.33.33.3/32, 239.1.1.5/32), 00:14:37/00:00:23, flags: S
 Total packet/byte count: NA/NA, Rate: NA
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr4 (10.0.14.1), 00:14:37/never, et.1.3,


(0.0.0.0/0, 239.1.1.6/32), 00:14:37/never, RP 1.1.1.1, flags: S
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr4 (10.0.14.1), 00:14:37/00:02:53, et.1.3,


(10.33.33.3/32, 239.1.1.6/32), 00:14:37/00:00:23, flags: S
 Total packet/byte count: NA/NA, Rate: NA
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr4 (10.0.14.1), 00:14:37/never, et.1.3,


(0.0.0.0/0, 239.1.1.7/32), 00:14:37/never, RP 1.1.1.1, flags: S
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr4 (10.0.14.1), 00:14:37/00:02:53, et.1.3,


(10.33.33.3/32, 239.1.1.7/32), 00:14:37/00:00:23, flags: S
 Total packet/byte count: NA/NA, Rate: NA
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr4 (10.0.14.1), 00:14:37/never, et.1.3,


(0.0.0.0/0, 239.1.1.8/32), 00:14:37/never, RP 1.1.1.1, flags: S
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr4 (10.0.14.1), 00:14:37/00:02:53, et.1.3,


(10.33.33.3/32, 239.1.1.8/32), 00:14:37/00:00:23, flags: S
```

```
 Total packet/byte count: NA/NA, Rate: NA
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr4 (10.0.14.1), 00:14:37/never, et.1.3,


(0.0.0.0/0, 239.1.1.9/32), 00:14:37/never, RP 1.1.1.1, flags: S
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr4 (10.0.14.1), 00:14:37/00:02:53, et.1.3,


(10.33.33.3/32, 239.1.1.9/32), 00:14:37/00:00:23, flags: S
 Total packet/byte count: NA/NA, Rate: NA
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr4 (10.0.14.1), 00:14:37/never, et.1.3,


(0.0.0.0/0, 239.1.1.10/32), 00:14:37/never, RP 1.1.1.1, flags: S
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr4 (10.0.14.1), 00:14:37/00:02:53, et.1.3,


(10.33.33.3/32, 239.1.1.10/32), 00:14:37/00:00:23, flags: S
 Total packet/byte count: NA/NA, Rate: NA
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr4 (10.0.14.1), 00:14:37/never, et.1.3,


(0.0.0.0/0, 239.255.255.250/32), 00:15:52/never, RP 1.1.1.1, flags: SC
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    MSERVER (10.0.0.1), 00:15:52/never, et.1.1,
    tortr4 (10.0.14.1), 00:14:37/00:02:53, et.1.3,


(10.33.33.3/32, 239.255.255.250/32), 00:15:52/00:00:23, flags: SJ
 Total packet/byte count: NA/NA, Rate: NA
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    MSERVER (10.0.0.1), 00:15:52/unknown, et.1.1,
    tortr4 (10.0.14.1), 00:14:37/never, et.1.3,


(192.168.1.100/32, 239.255.255.250/32), 00:15:52/00:00:23, flags: S
 Total packet/byte count: NA/NA, Rate: NA
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    MSERVER (10.0.0.1), 00:15:52/unknown, et.1.1,
    tortr4 (10.0.14.1), 00:14:37/never, et.1.3,
```

```
r1# msdp show sa-cache
Comp: msdp0
        1.1.1.1 (10.0.0.2/32, 238.1.1.5/32)
        1.1.1.1 (10.0.0.2/32, 238.1.1.6/32)
        1.1.1.1 (10.0.0.2/32, 238.1.1.7/32)
        1.1.1.1 (10.0.0.2/32, 238.1.1.8/32)
        1.1.1.1 (10.0.0.2/32, 238.1.1.10/32)
        1.1.1.1 (10.0.0.2/32, 238.1.1.9/32)
        1.1.1.1 (10.0.0.2/32, 238.1.1.2/32)
        1.1.1.1 (192.168.1.100/32, 239.255.255.250/32)
        1.1.1.1 (10.0.0.2/32, 238.1.1.3/32)
        1.1.1.1 (10.0.0.2/32, 238.1.1.1/32)
        1.1.1.1 (10.0.0.2/32, 238.1.1.4/32)
        3.3.3.3 (10.33.33.3/32, 239.1.1.7/32)
        3.3.3.3 (10.33.33.3/32, 239.1.1.6/32)
        3.3.3.3 (10.33.33.3/32, 239.1.1.9/32)
        3.3.3.3 (10.33.33.3/32, 239.1.1.10/32)
        3.3.3.3 (10.33.33.3/32, 239.255.255.250/32)
        3.3.3.3 (10.33.33.3/32, 239.1.1.8/32)
        3.3.3.3 (10.33.33.3/32, 239.1.1.3/32)
        3.3.3.3 (10.33.33.3/32, 239.1.1.1/32)
        3.3.3.3 (10.33.33.3/32, 239.1.1.2/32)
        3.3.3.3 (10.33.33.3/32, 239.1.1.5/32)
        3.3.3.3 (10.33.33.3/32, 239.1.1.4/32)

(Interdomain MSDP SA messages-  Populates above PIM SM mroute table)
r1#


R4# show running-config
Running system configuration:
     !
     ! Last modified from Console on 2002-08-19 06:06:19
     !
 1 : vlan create mcastrec port-based id 5
 2 : vlan add ports et.2.2 to mcastrec
     !
 3 : interface create ip tortr1 address-netmask 10.0.14.4/24 port et.2.1
 4 : interface create ip MCASTREC address-netmask 10.0.4.1/24 vlan mcastrec
 5 : interface add ip en0 address-netmask 192.168.1.154/24
 6 : interface add ip lo0 address-netmask 4.4.4.4/24
     !
 7 : ip-router global set router-id 4.4.4.4
 8 : ip-router global set autonomous-system 65000
     !
 9 : ospf create area backbone
10 : ospf add interface all to-area backbone
11 : ospf add stub-host 4.4.4.4 to-area backbone cost 10
12 : ospf set rib multicast
```

```
13 : ospf start
     !
14 : igmp add interface MCASTREC
15 : igmp join group 239.1.1.1 interface MCASTREC
16 : igmp join group 239.255.255.250 interface MCASTREC
17 : igmp join group 239.1.1.2 interface MCASTREC
18 : igmp join group 239.1.1.3 interface MCASTREC
19 : igmp join group 239.1.1.4 interface MCASTREC
20 : igmp join group 239.1.1.5 interface MCASTREC
21 : igmp join group 239.1.1.6 interface MCASTREC
22 : igmp join group 239.1.1.7 interface MCASTREC
23 : igmp join group 239.1.1.8 interface MCASTREC
24 : igmp join group 239.1.1.9 interface MCASTREC
25 : igmp join group 239.1.1.10 interface MCASTREC
26 : igmp join group 238.1.1.1 interface MCASTREC
27 : igmp join group 238.1.1.2 interface MCASTREC
28 : igmp join group 238.1.1.3 interface MCASTREC
29 : igmp join group 238.1.1.5 interface MCASTREC
30 : igmp join group 238.1.1.6 interface MCASTREC
31 : igmp join group 238.1.1.7 interface MCASTREC
32 : igmp join group 238.1.1.8 interface MCASTREC
33 : igmp join group 238.1.1.9 interface MCASTREC
34 : igmp join group 238.1.1.10 interface MCASTREC
35 : igmp join group 238.1.1.4 interface MCASTREC
36 : igmp start
     !
37 : pim sparse add interface all
38 : pim sparse static-rp address 1.1.1.1
39 : pim sparse start
     !
40 : system set name R4
41 : system set idle-timeout telnet 0 ssh 0 serial 0
R4#  pim show routes

PIM Multicast Routing Table
Flags: S - Sparse, C - Directly connected host, L - Local, P - Pruned
       R - RP-bit set, T - SPT-bit set
       J - Join SPT, F - Directly connected source, E - External join
Timers: Uptime/Expires
Interface state: Interface, Timers, Output Ports

 (0.0.0.0/0, 238.1.1.1/32), 00:16:12/never, RP 1.1.1.1, flags: SC
  Incoming interface: tortr1, RPF nbr 10.0.14.1,
  Outgoing interface list:
     MCASTREC (10.0.4.1), 00:16:12/never, et.2.2,


 (10.0.0.2/32, 238.1.1.1/32), 00:15:18/00:02:18, flags: ST
  Total packet/byte count: 231686/319494889, Rate: 383854 bytes/sec
  Incoming interface: tortr1, RPF nbr 10.0.14.1,
  Outgoing interface list:
     MCASTREC (10.0.4.1), 00:16:12/never, et.2.2,
```

```
(0.0.0.0/0, 238.1.1.2/32), 00:16:12/never, RP 1.1.1.1, flags: SC
 Incoming interface: tortr1, RPF nbr 10.0.14.1,
 Outgoing interface list:
    MCASTREC (10.0.4.1), 00:16:12/never, et.2.2,


(10.0.0.2/32, 238.1.1.2/32), 00:15:18/00:02:18, flags: ST
 Total packet/byte count: 231686/319494889, Rate: 383854 bytes/sec
 Incoming interface: tortr1, RPF nbr 10.0.14.1,
 Outgoing interface list:
    MCASTREC (10.0.4.1), 00:16:12/never, et.2.2,


(0.0.0.0/0, 238.1.1.3/32), 00:16:12/never, RP 1.1.1.1, flags: SC
 Incoming interface: tortr1, RPF nbr 10.0.14.1,
 Outgoing interface list:
    MCASTREC (10.0.4.1), 00:16:12/never, et.2.2,


(10.0.0.2/32, 238.1.1.3/32), 00:15:18/00:02:18, flags: ST
 Total packet/byte count: 231686/319494889, Rate: 383854 bytes/sec
 Incoming interface: tortr1, RPF nbr 10.0.14.1,
 Outgoing interface list:
    MCASTREC (10.0.4.1), 00:16:12/never, et.2.2,


(0.0.0.0/0, 238.1.1.4/32), 00:16:12/never, RP 1.1.1.1, flags: SC
 Incoming interface: tortr1, RPF nbr 10.0.14.1,
 Outgoing interface list:
    MCASTREC (10.0.4.1), 00:16:12/never, et.2.2,


(10.0.0.2/32, 238.1.1.4/32), 00:15:18/00:02:18, flags: ST
 Total packet/byte count: 231682/319489373, Rate: 383854 bytes/sec
 Incoming interface: tortr1, RPF nbr 10.0.14.1,
 Outgoing interface list:
    MCASTREC (10.0.4.1), 00:16:12/never, et.2.2,


(0.0.0.0/0, 238.1.1.5/32), 00:16:12/never, RP 1.1.1.1, flags: SC
 Incoming interface: tortr1, RPF nbr 10.0.14.1,
 Outgoing interface list:
    MCASTREC (10.0.4.1), 00:16:12/never, et.2.2,


(10.0.0.2/32, 238.1.1.5/32), 00:15:18/00:02:18, flags: ST
 Total packet/byte count: 231680/319486615, Rate: 383854 bytes/sec
 Incoming interface: tortr1, RPF nbr 10.0.14.1,
 Outgoing interface list:
    MCASTREC (10.0.4.1), 00:16:12/never, et.2.2,
```

```
(0.0.0.0/0, 238.1.1.6/32), 00:16:12/never, RP 1.1.1.1, flags: SC
 Incoming interface: tortr1, RPF nbr 10.0.14.1,
 Outgoing interface list:
    MCASTREC (10.0.4.1), 00:16:12/never, et.2.2,


(10.0.0.2/32, 238.1.1.6/32), 00:15:18/00:02:18, flags: ST
 Total packet/byte count: 231677/319482478, Rate: 383854 bytes/sec
 Incoming interface: tortr1, RPF nbr 10.0.14.1,
 Outgoing interface list:
    MCASTREC (10.0.4.1), 00:16:12/never, et.2.2,


(0.0.0.0/0, 238.1.1.7/32), 00:16:12/never, RP 1.1.1.1, flags: SC
 Incoming interface: tortr1, RPF nbr 10.0.14.1,
 Outgoing interface list:
    MCASTREC (10.0.4.1), 00:16:12/never, et.2.2,


(10.0.0.2/32, 238.1.1.7/32), 00:15:18/00:02:18, flags: ST
 Total packet/byte count: 231679/319485026, Rate: 383854 bytes/sec
 Incoming interface: tortr1, RPF nbr 10.0.14.1,
 Outgoing interface list:
    MCASTREC (10.0.4.1), 00:16:12/never, et.2.2,


(0.0.0.0/0, 238.1.1.8/32), 00:16:12/never, RP 1.1.1.1, flags: SC
 Incoming interface: tortr1, RPF nbr 10.0.14.1,
 Outgoing interface list:
    MCASTREC (10.0.4.1), 00:16:12/never, et.2.2,


(10.0.0.2/32, 238.1.1.8/32), 00:15:18/00:02:18, flags: ST
 Total packet/byte count: 231679/319485026, Rate: 383854 bytes/sec
 Incoming interface: tortr1, RPF nbr 10.0.14.1,
 Outgoing interface list:
    MCASTREC (10.0.4.1), 00:16:12/never, et.2.2,


(0.0.0.0/0, 238.1.1.9/32), 00:16:12/never, RP 1.1.1.1, flags: SC
 Incoming interface: tortr1, RPF nbr 10.0.14.1,
 Outgoing interface list:
    MCASTREC (10.0.4.1), 00:16:12/never, et.2.2,


(10.0.0.2/32, 238.1.1.9/32), 00:15:18/00:02:18, flags: ST
 Total packet/byte count: 231674/319478131, Rate: 383854 bytes/sec
 Incoming interface: tortr1, RPF nbr 10.0.14.1,
 Outgoing interface list:
    MCASTREC (10.0.4.1), 00:16:12/never, et.2.2,


(0.0.0.0/0, 238.1.1.10/32), 00:16:12/never, RP 1.1.1.1, flags: SC
 Incoming interface: tortr1, RPF nbr 10.0.14.1,
```

```
 Outgoing interface list:
    MCASTREC (10.0.4.1), 00:16:12/never, et.2.2,


(10.0.0.2/32, 238.1.1.10/32), 00:15:18/00:02:18, flags: ST
 Total packet/byte count: 231670/319472615, Rate: 383854 bytes/sec
 Incoming interface: tortr1, RPF nbr 10.0.14.1,
 Outgoing interface list:
    MCASTREC (10.0.4.1), 00:16:12/never, et.2.2,


(0.0.0.0/0, 239.1.1.1/32), 00:16:12/never, RP 1.1.1.1, flags: SC
 Incoming interface: tortr1, RPF nbr 10.0.14.1,
 Outgoing interface list:
    MCASTREC (10.0.4.1), 00:16:12/never, et.2.2,


(0.0.0.0/0, 239.1.1.2/32), 00:16:12/never, RP 1.1.1.1, flags: SC
 Incoming interface: tortr1, RPF nbr 10.0.14.1,
 Outgoing interface list:
    MCASTREC (10.0.4.1), 00:16:12/never, et.2.2,


(0.0.0.0/0, 239.1.1.3/32), 00:16:12/never, RP 1.1.1.1, flags: SC
 Incoming interface: tortr1, RPF nbr 10.0.14.1,
 Outgoing interface list:
    MCASTREC (10.0.4.1), 00:16:12/never, et.2.2,


(0.0.0.0/0, 239.1.1.4/32), 00:16:12/never, RP 1.1.1.1, flags: SC
 Incoming interface: tortr1, RPF nbr 10.0.14.1,
 Outgoing interface list:
    MCASTREC (10.0.4.1), 00:16:12/never, et.2.2,


(0.0.0.0/0, 239.1.1.5/32), 00:16:12/never, RP 1.1.1.1, flags: SC
 Incoming interface: tortr1, RPF nbr 10.0.14.1,
 Outgoing interface list:
    MCASTREC (10.0.4.1), 00:16:12/never, et.2.2,


(0.0.0.0/0, 239.1.1.6/32), 00:16:12/never, RP 1.1.1.1, flags: SC
 Incoming interface: tortr1, RPF nbr 10.0.14.1,
 Outgoing interface list:
    MCASTREC (10.0.4.1), 00:16:12/never, et.2.2,


(0.0.0.0/0, 239.1.1.7/32), 00:16:12/never, RP 1.1.1.1, flags: SC
 Incoming interface: tortr1, RPF nbr 10.0.14.1,
 Outgoing interface list:
    MCASTREC (10.0.4.1), 00:16:12/never, et.2.2,


(0.0.0.0/0, 239.1.1.8/32), 00:16:12/never, RP 1.1.1.1, flags: SC
```

```
 Incoming interface: tortr1, RPF nbr 10.0.14.1,
 Outgoing interface list:
    MCASTREC (10.0.4.1), 00:16:12/never, et.2.2,


(0.0.0.0/0, 239.1.1.9/32), 00:16:12/never, RP 1.1.1.1, flags: SC
 Incoming interface: tortr1, RPF nbr 10.0.14.1,
 Outgoing interface list:
    MCASTREC (10.0.4.1), 00:16:12/never, et.2.2,


(0.0.0.0/0, 239.1.1.10/32), 00:16:12/never, RP 1.1.1.1, flags: SC
 Incoming interface: tortr1, RPF nbr 10.0.14.1,
 Outgoing interface list:
    MCASTREC (10.0.4.1), 00:16:12/never, et.2.2,


(0.0.0.0/0, 239.255.255.250/32), 00:16:12/never, RP 1.1.1.1, flags: SC
 Incoming interface: tortr1, RPF nbr 10.0.14.1,
 Outgoing interface list:
    MCASTREC (10.0.4.1), 00:16:12/never, et.2.2,



R4#


r2# show running-config
Running system configuration:
     !
     ! Last modified from Telnet (192.168.1.254) on 2002-08-19 08:24:33
     !
 1 : interface create ip tortr3 address-netmask 10.0.23.2/24 port et.1.2
 2 : interface create ip tortr1 address-netmask 10.0.12.2/24 port et.1.1
 3 : interface add ip en0 address-netmask 192.168.1.152/24
 4 : interface add ip lo0 address-netmask 2.2.2.2/24
     !
 5 : ip-router global set router-id 2.2.2.2
 6 : ip-router global set autonomous-system 65001
     !
 7 : ospf create area backbone
 8 : ospf add stub-host 2.2.2.2 to-area backbone cost 10
 9 : ospf add interface tortr3 to-area backbone
10 : ospf add interface tortr1 to-area backbone
11 : ospf set rib multicast
12 : ospf set interface tortr3 passive
13 : ospf set interface tortr1 passive
14 : ospf start
     !
15 : bgp create peer-group external autonomous-system 65000
16 : bgp create peer-group external1 autonomous-system 65002
17 : bgp add peer-host 10.0.12.1 group external
```

```
18 : bgp add peer-host 10.0.23.3 group external1
19 : bgp set peer-group external multicast-rib
20 : bgp set peer-group external1 multicast-rib
21 : bgp start
     !
22 : pim sparse add interface all
23 : pim sparse static-rp address 1.1.1.1
24 : pim sparse start
     !
25 : system set name r2
     !
26 : bgp advertise network 10.0.23.0/24
27 : bgp advertise network 2.2.2.0/24
28 : bgp advertise network 10.0.12.0/24
r2#  pim show routes

PIM Multicast Routing Table
Flags: S - Sparse, C - Directly connected host, L - Local, P - Pruned
       R - RP-bit set, T - SPT-bit set
       J - Join SPT, F - Directly connected source, E - External join
Timers: Uptime/Expires
Interface state: Interface, Timers, Output Ports

 (10.33.33.3/32, 239.255.255.250/32), 00:17:11/00:02:48, flags: ST
  Total packet/byte count: NA/NA, Rate: NA
  Incoming interface: tortr3, RPF nbr 10.0.23.3,
  Outgoing interface list:
     tortr1 (10.0.12.2), 00:17:11/00:03:19, et.1.1,




r2# exit


R3# show running-config
Running system configuration:
     !
     ! Last modified from Telnet (192.168.1.100) on 2002-08-19 10:45:30
     !
 1 : vlan create mserver port-based
 2 : vlan add ports et.2.16 to mserver
     !
 3 : interface create ip tortr5 address-netmask 10.0.35.3/24 port et.1.3
 4 : interface create ip tortr2 address-netmask 10.0.23.3/24 port et.1.1
 5 : interface create ip MSERVER vlan mserver address-netmask 10.33.33.1/24
 6 : interface add ip en0 address-netmask 192.168.1.153/24
 7 : interface add ip lo0 address-netmask 3.3.3.3/24
     !
 8 : ip-router global set router-id 3.3.3.3
 9 : ip-router global set autonomous-system 65002
     !
10 : ip add route default blackhole
```

```
     !
11 : ip-router policy redistribute from-proto static to-proto ospf metric 10
     !
12 : ospf create area backbone
13 : ospf add stub-host 3.3.3.3 to-area backbone cost 10
14 : ospf add interface tortr5 to-area backbone
15 : ospf add interface tortr2 to-area backbone
16 : ospf add interface MSERVER to-area backbone
17 : ospf set rib multicast
18 : ospf set interface tortr2 passive
19 : ospf start
     !
20 : bgp create peer-group external autonomous-system 65001
21 : bgp add peer-host 10.0.23.2 group external
22 : bgp set peer-group external multicast-rib
23 : bgp start
     !
24 : msdp add peer local-addr 3.3.3.3 remote-addr 1.1.1.1
25 : msdp start
     !
26 : pim sparse add interface all
27 : pim sparse crp address 3.3.3.3 priority 100
28 : pim sparse cbsr address 3.3.3.3 priority 100
29 : pim sparse start
     !
30 : system set name R3
     !
31 : bgp advertise network 10.0.55.0/24
32 : bgp advertise network 5.5.5.0/24
33 : bgp advertise network 3.3.3.0/24
34 : bgp advertise network 10.0.23.0/24
35 : bgp advertise network 10.0.35.0/24
36 : bgp advertise network 10.33.33.0/24
R3# pim show routes

PIM Multicast Routing Table
Flags: S - Sparse, C - Directly connected host, L - Local, P - Pruned
       R - RP-bit set, T - SPT-bit set
       J - Join SPT, F - Directly connected source, E - External join
Timers: Uptime/Expires
Interface state: Interface, Timers, Output Ports

 (0.0.0.0/0, 238.1.1.1/32), 00:09:50/never, RP 3.3.3.3, flags: S
  Incoming interface: register, RPF nbr (null),
  Outgoing interface list:
     tortr5 (10.0.35.3), 00:09:50/00:02:40, et.1.3,


 (10.0.0.2/32, 238.1.1.1/32), 00:09:50/00:03:36, flags: S
  Total packet/byte count: NA/NA, Rate: NA
  Incoming interface: register, RPF nbr (null),
  Outgoing interface list:
```

```
    tortr5 (10.0.35.3), 00:09:50/never, et.1.3,


(0.0.0.0/0, 238.1.1.2/32), 00:09:50/never, RP 3.3.3.3, flags: S
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/00:02:40, et.1.3,


(10.0.0.2/32, 238.1.1.2/32), 00:09:50/00:03:36, flags: S
 Total packet/byte count: NA/NA, Rate: NA
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/never, et.1.3,


(0.0.0.0/0, 238.1.1.3/32), 00:09:50/never, RP 3.3.3.3, flags: S
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/00:02:40, et.1.3,


(10.0.0.2/32, 238.1.1.3/32), 00:09:50/00:03:36, flags: S
 Total packet/byte count: NA/NA, Rate: NA
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/never, et.1.3,


(0.0.0.0/0, 238.1.1.4/32), 00:09:50/never, RP 3.3.3.3, flags: S
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/00:02:40, et.1.3,


(10.0.0.2/32, 238.1.1.4/32), 00:09:50/00:03:36, flags: S
 Total packet/byte count: NA/NA, Rate: NA
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/never, et.1.3,


(0.0.0.0/0, 238.1.1.5/32), 00:09:50/never, RP 3.3.3.3, flags: S
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/00:02:40, et.1.3,


(10.0.0.2/32, 238.1.1.5/32), 00:09:50/00:03:36, flags: S
 Total packet/byte count: NA/NA, Rate: NA
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/never, et.1.3,
```

```
(0.0.0.0/0, 238.1.1.6/32), 00:09:50/never, RP 3.3.3.3, flags: S
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/00:02:40, et.1.3,


(10.0.0.2/32, 238.1.1.6/32), 00:09:50/00:03:36, flags: S
 Total packet/byte count: NA/NA, Rate: NA
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/never, et.1.3,


(0.0.0.0/0, 238.1.1.7/32), 00:09:50/never, RP 3.3.3.3, flags: S
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/00:02:40, et.1.3,


(10.0.0.2/32, 238.1.1.7/32), 00:09:50/00:03:36, flags: S
 Total packet/byte count: NA/NA, Rate: NA
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/never, et.1.3,


(0.0.0.0/0, 238.1.1.8/32), 00:09:50/never, RP 3.3.3.3, flags: S
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/00:02:40, et.1.3,


(10.0.0.2/32, 238.1.1.8/32), 00:09:50/00:03:36, flags: S
 Total packet/byte count: NA/NA, Rate: NA
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/never, et.1.3,


(0.0.0.0/0, 238.1.1.9/32), 00:09:50/never, RP 3.3.3.3, flags: S
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/00:02:40, et.1.3,


(10.0.0.2/32, 238.1.1.9/32), 00:09:50/00:03:36, flags: S
 Total packet/byte count: NA/NA, Rate: NA
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/never, et.1.3,


(0.0.0.0/0, 238.1.1.10/32), 00:09:50/never, RP 3.3.3.3, flags: S
```

```
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/00:02:40, et.1.3,


(10.0.0.2/32, 238.1.1.10/32), 00:09:50/00:03:36, flags: S
 Total packet/byte count: NA/NA, Rate: NA
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/never, et.1.3,


(0.0.0.0/0, 239.1.1.1/32), 00:09:50/never, RP 3.3.3.3, flags: S
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/00:02:40, et.1.3,


(10.33.33.3/32, 239.1.1.1/32), 00:28:31/00:03:36, flags: STF
 Total packet/byte count: 474032/653690023, Rate: 371581 bytes/sec
 Incoming interface: MSERVER, RPF nbr 10.33.33.3,
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/00:02:40, et.1.3,


(0.0.0.0/0, 239.1.1.2/32), 00:09:50/never, RP 3.3.3.3, flags: S
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/00:02:40, et.1.3,


(10.33.33.3/32, 239.1.1.2/32), 00:28:31/00:03:36, flags: STF
 Total packet/byte count: 474032/653690023, Rate: 371581 bytes/sec
 Incoming interface: MSERVER, RPF nbr 10.33.33.3,
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/00:02:40, et.1.3,


(0.0.0.0/0, 239.1.1.3/32), 00:09:50/never, RP 3.3.3.3, flags: S
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/00:02:40, et.1.3,


(10.33.33.3/32, 239.1.1.3/32), 00:28:31/00:03:36, flags: STF
 Total packet/byte count: 474032/653690023, Rate: 371581 bytes/sec
 Incoming interface: MSERVER, RPF nbr 10.33.33.3,
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/00:02:40, et.1.3,


(0.0.0.0/0, 239.1.1.4/32), 00:09:50/never, RP 3.3.3.3, flags: S
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
```

```
    tortr5 (10.0.35.3), 00:09:50/00:02:40, et.1.3,


(10.33.33.3/32, 239.1.1.4/32), 00:28:31/00:03:36, flags: STF
 Total packet/byte count: 474032/653690023, Rate: 371587 bytes/sec
 Incoming interface: MSERVER, RPF nbr 10.33.33.3,
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/00:02:40, et.1.3,


(0.0.0.0/0, 239.1.1.5/32), 00:09:50/never, RP 3.3.3.3, flags: S
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/00:02:40, et.1.3,


(10.33.33.3/32, 239.1.1.5/32), 00:28:31/00:03:36, flags: STF
 Total packet/byte count: 474032/653690023, Rate: 371587 bytes/sec
 Incoming interface: MSERVER, RPF nbr 10.33.33.3,
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/00:02:40, et.1.3,


(0.0.0.0/0, 239.1.1.6/32), 00:09:50/never, RP 3.3.3.3, flags: S
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/00:02:40, et.1.3,


(10.33.33.3/32, 239.1.1.6/32), 00:28:31/00:03:36, flags: STF
 Total packet/byte count: 474032/653690023, Rate: 371587 bytes/sec
 Incoming interface: MSERVER, RPF nbr 10.33.33.3,
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/00:02:40, et.1.3,


(0.0.0.0/0, 239.1.1.7/32), 00:09:50/never, RP 3.3.3.3, flags: S
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/00:02:40, et.1.3,


(10.33.33.3/32, 239.1.1.7/32), 00:28:31/00:03:36, flags: STF
 Total packet/byte count: 474032/653690023, Rate: 371587 bytes/sec
 Incoming interface: MSERVER, RPF nbr 10.33.33.3,
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/00:02:40, et.1.3,


(0.0.0.0/0, 239.1.1.8/32), 00:09:50/never, RP 3.3.3.3, flags: S
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/00:02:40, et.1.3,
```

```
(10.33.33.3/32, 239.1.1.8/32), 00:28:31/00:03:36, flags: STF
 Total packet/byte count: 474032/653690023, Rate: 371587 bytes/sec
 Incoming interface: MSERVER, RPF nbr 10.33.33.3,
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/00:02:40, et.1.3,


(0.0.0.0/0, 239.1.1.9/32), 00:09:50/never, RP 3.3.3.3, flags: S
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/00:02:40, et.1.3,


(10.33.33.3/32, 239.1.1.9/32), 00:28:31/00:03:36, flags: STF
 Total packet/byte count: 474032/653690023, Rate: 371587 bytes/sec
 Incoming interface: MSERVER, RPF nbr 10.33.33.3,
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/00:02:40, et.1.3,


(0.0.0.0/0, 239.1.1.10/32), 00:09:50/never, RP 3.3.3.3, flags: S
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/00:02:40, et.1.3,


(10.33.33.3/32, 239.1.1.10/32), 00:28:31/00:03:36, flags: STF
 Total packet/byte count: 474032/653690023, Rate: 371587 bytes/sec
 Incoming interface: MSERVER, RPF nbr 10.33.33.3,
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/00:02:40, et.1.3,


(0.0.0.0/0, 239.255.255.250/32), 00:09:50/never, RP 3.3.3.3, flags: S
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/00:02:40, et.1.3,


(10.0.0.2/32, 239.255.255.250/32), 00:09:50/00:03:36, flags: S
 Total packet/byte count: NA/NA, Rate: NA
 Incoming interface: register, RPF nbr (null),
 Outgoing interface list:
    tortr5 (10.0.35.3), 00:09:50/never, et.1.3,


(10.33.33.3/32, 239.255.255.250/32), 00:29:22/00:03:36, flags: STF
 Total packet/byte count: 2/322, Rate: 0 bytes/sec
 Incoming interface: MSERVER, RPF nbr 10.33.33.3,
 Outgoing interface list:
    tortr2 (10.0.23.3), 00:17:48/00:02:42, et.1.1,
    tortr5 (10.0.35.3), 00:09:50/never, et.1.3,
```

```
 (192.168.1.100/32, 239.255.255.250/32), 00:09:50/00:03:36, flags: S
  Total packet/byte count: NA/NA, Rate: NA
  Incoming interface: register, RPF nbr (null),
  Outgoing interface list:
     tortr5 (10.0.35.3), 00:09:50/never, et.1.3,



R3#  msdp show sa-cache
Comp: msdp0
        1.1.1.1 (10.0.0.2/32, 238.1.1.5/32)
        1.1.1.1 (10.0.0.2/32, 238.1.1.6/32)
        1.1.1.1 (10.0.0.2/32, 239.255.255.250/32)
        1.1.1.1 (10.0.0.2/32, 238.1.1.7/32)
        1.1.1.1 (10.0.0.2/32, 238.1.1.8/32)
        1.1.1.1 (10.0.0.2/32, 238.1.1.10/32)
        1.1.1.1 (10.0.0.2/32, 238.1.1.9/32)
        1.1.1.1 (10.0.0.2/32, 238.1.1.2/32)
        1.1.1.1 (192.168.1.100/32, 239.255.255.250/32)
        1.1.1.1 (10.0.0.2/32, 238.1.1.3/32)
        1.1.1.1 (10.0.0.2/32, 238.1.1.1/32)
        1.1.1.1 (10.0.0.2/32, 238.1.1.4/32)
        3.3.3.3 (10.33.33.3/32, 239.1.1.7/32)
        3.3.3.3 (10.33.33.3/32, 239.1.1.6/32)
        3.3.3.3 (10.33.33.3/32, 239.1.1.9/32)
        3.3.3.3 (10.33.33.3/32, 239.1.1.10/32)
        3.3.3.3 (10.33.33.3/32, 239.255.255.250/32)
        3.3.3.3 (10.33.33.3/32, 239.1.1.8/32)
        3.3.3.3 (10.33.33.3/32, 239.1.1.3/32)
        3.3.3.3 (10.33.33.3/32, 239.1.1.1/32)
        3.3.3.3 (10.33.33.3/32, 239.1.1.2/32)
        3.3.3.3 (10.33.33.3/32, 239.1.1.5/32)
        3.3.3.3 (10.33.33.3/32, 239.1.1.4/32)
R3#


R5# show running-config
Running system configuration:
     !
     ! Last modified from Console on 2002-08-19 12:13:02
     !
 1 : interface create ip toreciever address-netmask 10.0.55.5/24 port et.1.2
 2 : interface create ip tortr3 address-netmask 10.0.35.5/24 port et.1.1
 3 : interface add ip en0 address-netmask 192.168.1.155/24
 4 : interface add ip lo0 address-netmask 5.5.5.5/24
     !
 5 : ip-router global set router-id 5.5.5.5
     !
 6 : ospf create area backbone
 7 : ospf add interface all to-area backbone
 8 : ospf add stub-host 5.5.5.5 to-area backbone cost 10
```

```
 9 : ospf set rib multicast
10 : ospf start
     !
11 : igmp add interface toreciever
12 : igmp join group 239.1.1.1 interface toreciever
13 : igmp join group 239.255.255.250 interface toreciever
14 : igmp join group 239.1.1.2 interface toreciever
15 : igmp join group 239.1.1.3 interface toreciever
16 : igmp join group 239.1.1.4 interface toreciever
17 : igmp join group 239.1.1.5 interface toreciever
18 : igmp join group 239.1.1.6 interface toreciever
19 : igmp join group 239.1.1.7 interface toreciever
20 : igmp join group 239.1.1.8 interface toreciever
21 : igmp join group 239.1.1.9 interface toreciever
22 : igmp join group 239.1.1.10 interface toreciever
23 : igmp join group 238.1.1.1 interface toreciever
24 : igmp join group 238.1.1.2 interface toreciever
25 : igmp join group 238.1.1.3 interface toreciever
26 : igmp join group 238.1.1.5 interface toreciever
27 : igmp join group 238.1.1.6 interface toreciever
28 : igmp join group 238.1.1.7 interface toreciever
29 : igmp join group 238.1.1.8 interface toreciever
30 : igmp join group 238.1.1.9 interface toreciever
31 : igmp join group 238.1.1.10 interface toreciever
32 : igmp join group 238.1.1.4 interface toreciever
33 : igmp start
     !
34 : pim sparse add interface all
35 : pim sparse static-rp address 3.3.3.3
36 : pim sparse start
     !
37 : system set name R5
R5#   pim show routes

PIM Multicast Routing Table
Flags: S - Sparse, C - Directly connected host, L - Local, P - Pruned
       R - RP-bit set, T - SPT-bit set
       J - Join SPT, F - Directly connected source, E - External join
Timers: Uptime/Expires
Interface state: Interface, Timers, Output Ports

 (0.0.0.0/0, 238.1.1.1/32), 00:11:12/never, RP 3.3.3.3, flags: SC
  Incoming interface: tortr3, RPF nbr 10.0.35.3,
  Outgoing interface list:
     toreciever (10.0.55.5), 00:11:12/never, et.1.2,


 (0.0.0.0/0, 238.1.1.2/32), 00:11:12/never, RP 3.3.3.3, flags: SC
  Incoming interface: tortr3, RPF nbr 10.0.35.3,
  Outgoing interface list:
     toreciever (10.0.55.5), 00:11:12/never, et.1.2,
```

```
(0.0.0.0/0, 238.1.1.3/32), 00:11:12/never, RP 3.3.3.3, flags: SC
 Incoming interface: tortr3, RPF nbr 10.0.35.3,
 Outgoing interface list:
    toreciever (10.0.55.5), 00:11:12/never, et.1.2,


(0.0.0.0/0, 238.1.1.4/32), 00:11:12/never, RP 3.3.3.3, flags: SC
 Incoming interface: tortr3, RPF nbr 10.0.35.3,
 Outgoing interface list:
    toreciever (10.0.55.5), 00:11:12/never, et.1.2,


(0.0.0.0/0, 238.1.1.5/32), 00:11:12/never, RP 3.3.3.3, flags: SC
 Incoming interface: tortr3, RPF nbr 10.0.35.3,
 Outgoing interface list:
    toreciever (10.0.55.5), 00:11:12/never, et.1.2,


(0.0.0.0/0, 238.1.1.6/32), 00:11:12/never, RP 3.3.3.3, flags: SC
 Incoming interface: tortr3, RPF nbr 10.0.35.3,
 Outgoing interface list:
    toreciever (10.0.55.5), 00:11:12/never, et.1.2,


(0.0.0.0/0, 238.1.1.7/32), 00:11:12/never, RP 3.3.3.3, flags: SC
 Incoming interface: tortr3, RPF nbr 10.0.35.3,
 Outgoing interface list:
    toreciever (10.0.55.5), 00:11:12/never, et.1.2,


(0.0.0.0/0, 238.1.1.8/32), 00:11:12/never, RP 3.3.3.3, flags: SC
 Incoming interface: tortr3, RPF nbr 10.0.35.3,
 Outgoing interface list:
    toreciever (10.0.55.5), 00:11:12/never, et.1.2,


(0.0.0.0/0, 238.1.1.9/32), 00:11:12/never, RP 3.3.3.3, flags: SC
 Incoming interface: tortr3, RPF nbr 10.0.35.3,
 Outgoing interface list:
    toreciever (10.0.55.5), 00:11:12/never, et.1.2,


(0.0.0.0/0, 238.1.1.10/32), 00:11:12/never, RP 3.3.3.3, flags: SC
 Incoming interface: tortr3, RPF nbr 10.0.35.3,
 Outgoing interface list:
    toreciever (10.0.55.5), 00:11:12/never, et.1.2,


(0.0.0.0/0, 239.1.1.1/32), 00:11:12/never, RP 3.3.3.3, flags: SC
 Incoming interface: tortr3, RPF nbr 10.0.35.3,
 Outgoing interface list:
    toreciever (10.0.55.5), 00:11:12/never, et.1.2,
```

```
(10.33.33.3/32, 239.1.1.1/32), 00:10:17/00:00:17, flags: ST
 Total packet/byte count: 114571/157993304, Rate: 385548 bytes/sec
 Incoming interface: tortr3, RPF nbr 10.0.35.3,
 Outgoing interface list:
    toreciever (10.0.55.5), 00:11:12/never, et.1.2,


(0.0.0.0/0, 239.1.1.2/32), 00:11:12/never, RP 3.3.3.3, flags: SC
 Incoming interface: tortr3, RPF nbr 10.0.35.3,
 Outgoing interface list:
    toreciever (10.0.55.5), 00:11:12/never, et.1.2,


(10.33.33.3/32, 239.1.1.2/32), 00:10:17/00:00:17, flags: ST
 Total packet/byte count: 114566/157986409, Rate: 385548 bytes/sec
 Incoming interface: tortr3, RPF nbr 10.0.35.3,
 Outgoing interface list:
    toreciever (10.0.55.5), 00:11:12/never, et.1.2,


(0.0.0.0/0, 239.1.1.3/32), 00:11:12/never, RP 3.3.3.3, flags: SC
 Incoming interface: tortr3, RPF nbr 10.0.35.3,
 Outgoing interface list:
    toreciever (10.0.55.5), 00:11:12/never, et.1.2,


(10.33.33.3/32, 239.1.1.3/32), 00:10:17/00:00:17, flags: ST
 Total packet/byte count: 114565/157985030, Rate: 385548 bytes/sec
 Incoming interface: tortr3, RPF nbr 10.0.35.3,
 Outgoing interface list:
    toreciever (10.0.55.5), 00:11:12/never, et.1.2,


(0.0.0.0/0, 239.1.1.4/32), 00:11:12/never, RP 3.3.3.3, flags: SC
 Incoming interface: tortr3, RPF nbr 10.0.35.3,
 Outgoing interface list:
    toreciever (10.0.55.5), 00:11:12/never, et.1.2,


(10.33.33.3/32, 239.1.1.4/32), 00:10:17/00:00:17, flags: ST
 Total packet/byte count: 114563/157982272, Rate: 385548 bytes/sec
 Incoming interface: tortr3, RPF nbr 10.0.35.3,
 Outgoing interface list:
    toreciever (10.0.55.5), 00:11:12/never, et.1.2,


(0.0.0.0/0, 239.1.1.5/32), 00:11:12/never, RP 3.3.3.3, flags: SC
 Incoming interface: tortr3, RPF nbr 10.0.35.3,
 Outgoing interface list:
    toreciever (10.0.55.5), 00:11:12/never, et.1.2,


(10.33.33.3/32, 239.1.1.5/32), 00:10:17/00:00:17, flags: ST
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 Total packet/byte count: 114562/157980893, Rate: 385548 bytes/sec
 Incoming interface: tortr3, RPF nbr 10.0.35.3,
 Outgoing interface list:
    toreciever (10.0.55.5), 00:11:12/never, et.1.2,


(0.0.0.0/0, 239.1.1.6/32), 00:11:12/never, RP 3.3.3.3, flags: SC
 Incoming interface: tortr3, RPF nbr 10.0.35.3,
 Outgoing interface list:
    toreciever (10.0.55.5), 00:11:12/never, et.1.2,


(10.33.33.3/32, 239.1.1.6/32), 00:10:17/00:00:17, flags: ST
 Total packet/byte count: 114561/157979374, Rate: 385548 bytes/sec
 Incoming interface: tortr3, RPF nbr 10.0.35.3,
 Outgoing interface list:
    toreciever (10.0.55.5), 00:11:12/never, et.1.2,


(0.0.0.0/0, 239.1.1.7/32), 00:11:12/never, RP 3.3.3.3, flags: SC
 Incoming interface: tortr3, RPF nbr 10.0.35.3,
 Outgoing interface list:
    toreciever (10.0.55.5), 00:11:12/never, et.1.2,


(10.33.33.3/32, 239.1.1.7/32), 00:10:17/00:00:17, flags: ST
 Total packet/byte count: 114561/157979374, Rate: 385548 bytes/sec
 Incoming interface: tortr3, RPF nbr 10.0.35.3,
 Outgoing interface list:
    toreciever (10.0.55.5), 00:11:12/never, et.1.2,


(0.0.0.0/0, 239.1.1.8/32), 00:11:12/never, RP 3.3.3.3, flags: SC
 Incoming interface: tortr3, RPF nbr 10.0.35.3,
 Outgoing interface list:
    toreciever (10.0.55.5), 00:11:12/never, et.1.2,


(10.33.33.3/32, 239.1.1.8/32), 00:10:17/00:00:17, flags: ST
 Total packet/byte count: 114555/157971100, Rate: 385548 bytes/sec
 Incoming interface: tortr3, RPF nbr 10.0.35.3,
 Outgoing interface list:
    toreciever (10.0.55.5), 00:11:12/never, et.1.2,


(0.0.0.0/0, 239.1.1.9/32), 00:11:12/never, RP 3.3.3.3, flags: SC
 Incoming interface: tortr3, RPF nbr 10.0.35.3,
 Outgoing interface list:
    toreciever (10.0.55.5), 00:11:12/never, et.1.2,


(10.33.33.3/32, 239.1.1.9/32), 00:10:17/00:00:17, flags: ST
 Total packet/byte count: 114546/157958689, Rate: 385548 bytes/sec
 Incoming interface: tortr3, RPF nbr 10.0.35.3,
```

```
 Outgoing interface list:
    toreciever (10.0.55.5), 00:11:12/never, et.1.2,


(0.0.0.0/0, 239.1.1.10/32), 00:11:12/never, RP 3.3.3.3, flags: SC
 Incoming interface: tortr3, RPF nbr 10.0.35.3,
 Outgoing interface list:
    toreciever (10.0.55.5), 00:11:12/never, et.1.2,


(10.33.33.3/32, 239.1.1.10/32), 00:10:17/00:00:17, flags: ST
 Total packet/byte count: 114541/157951794, Rate: 385548 bytes/sec
 Incoming interface: tortr3, RPF nbr 10.0.35.3,
 Outgoing interface list:
    toreciever (10.0.55.5), 00:11:12/never, et.1.2,


(0.0.0.0/0, 239.255.255.250/32), 00:11:12/never, RP 3.3.3.3, flags: SC
 Incoming interface: tortr3, RPF nbr 10.0.35.3,
 Outgoing interface list:
    toreciever (10.0.55.5), 00:11:12/never, et.1.2,
```