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Introduction to
IP Multicast
Session 2214
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Other Related Presentations

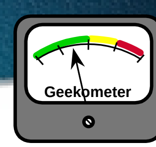
- **Multicast Sessions**

Session #	Title
2214	Introduction to IP Multicast
2215	PIM Multicast Routing
2216	Deploying IP Multicast
2217	Advanced IP Multicast Routing

- **MBGP Related Sessions**

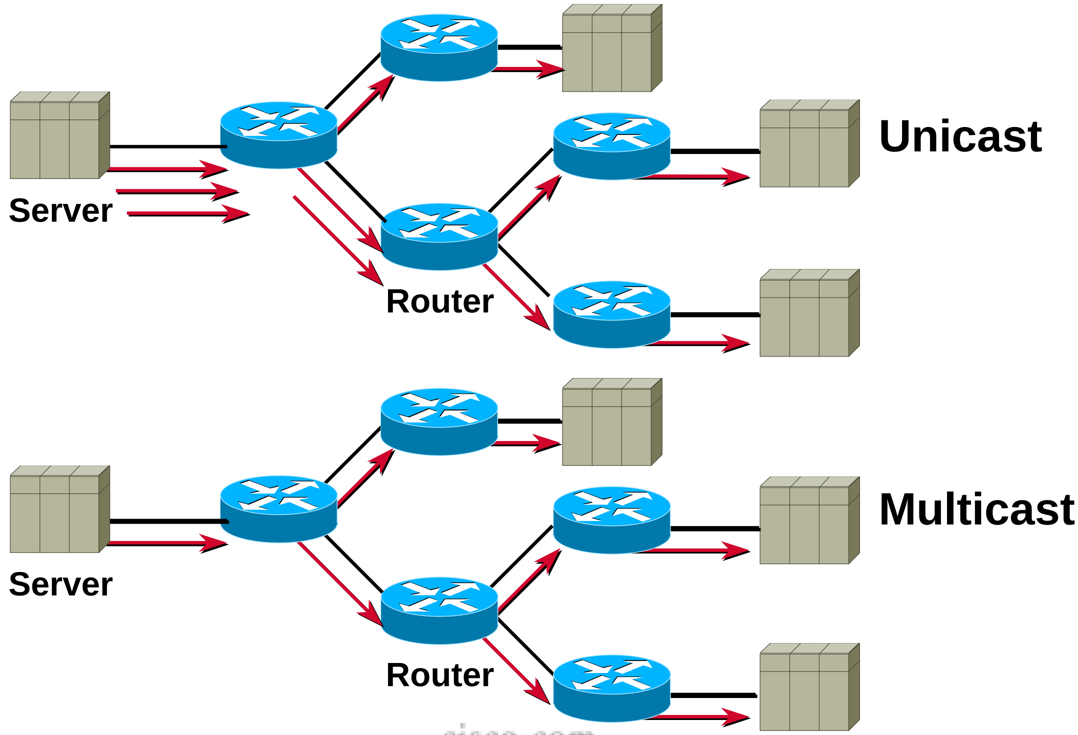
Session #	Title
2209	Deploying BGP

Agenda



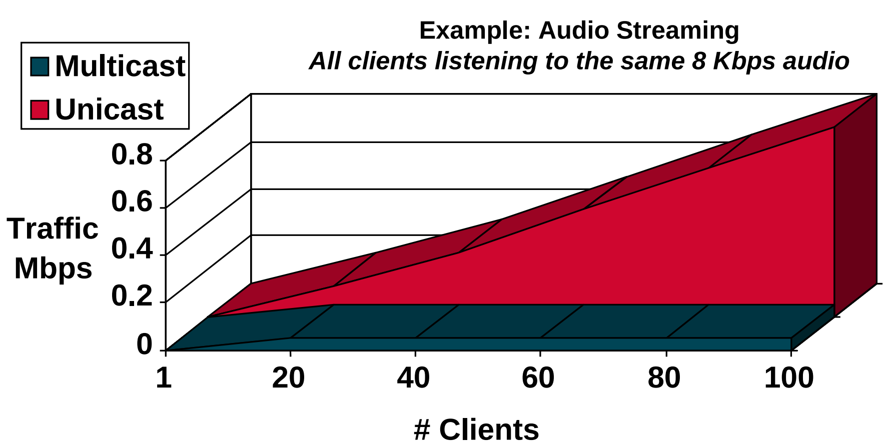
- **Why Multicast?**
- **Multicast Addressing**
- **Host-Router Signaling: IGMP**
- **Multicast Distribution Trees**
- **Multicast Forwarding**
- **Multicast Routing Protocols**

Unicast vs. Multicast



Multicast Advantages

- ***Enhanced Efficiency***: **Controls network traffic and reduces server and CPU loads**
- ***Optimized Performance***: **Eliminates traffic redundancy**
- ***Distributed Applications***: **Makes multipoint applications possible**



Multicast Disadvantages

Multicast Is UDP Based!!!

- ***Best Effort Delivery*: Drops are to be expected. Multicast applications should not expect reliable delivery of data and should be designed accordingly. Reliable Multicast is still an area for much research. Expect to see more developments in this area.**
- ***No Congestion Avoidance*: Lack of TCP windowing and "slow-start" mechanisms can result in network congestion. If possible, Multicast applications should attempt to detect and avoid congestion conditions.**
- ***Duplicates*: Some multicast protocol mechanisms (e.g. Asserts, Registers and SPT Transitions) result in the occasional generation of duplicate packets. Multicast applications should be designed to expect occasional duplicate packets.**
- ***Out of Order Delivery* : Some protocol mechanisms may also result in out of order delivery of packets.**

Apps that Benefit from IP Multicast

- **Multimedia**
  - **Streaming media**
  - **Training, corporate communications**
  - **Conferencing—video/audio**
- **Data warehousing**
- **Financial applications**
- **Any one-to-many data push applications**

Agenda

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Multicast Addressing

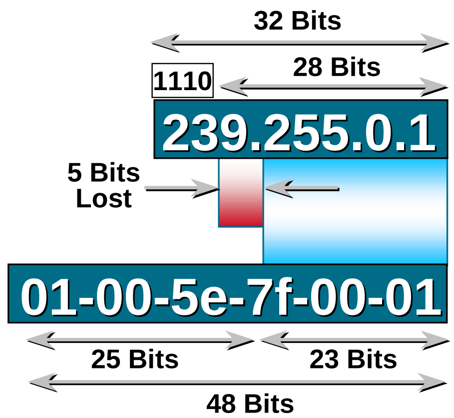
- IP Multicast Group Addresses
  - 224.0.0.0–239.255.255.255
  - Class "D" Address Space
    - High order bits of 1st Octet = "1110"
- Reserved Link-local Addresses
  - 224.0.0.0–224.0.0.255
  - Transmitted with TTL = 1
  - Examples:
    - 224.0.0.1 All systems on this subnet
    - 224.0.0.2 All routers on this subnet
    - 224.0.0.4 DVMRP routers
    - 224.0.0.5 OSPF routers
    - 224.0.0.13 PIMv2 Routers

Multicast Addressing

- Administratively Scoped Addresses
  - 239.0.0.0–239.255.255.255
  - Private address space
    - Similar to RFC1918 unicast addresses
    - Not used for global Internet traffic
    - Used to limit “scope” of multicast traffic
    - Same addresses may be in use at different locations for different multicast sessions
  - Examples
    - Site-local scope: 239.253.0.0/16
    - Organization-local scope: 239.192.0.0/14

Multicast Addressing

IP Multicast MAC Address Mapping
(FDDI and Ethernet)



Multicast Addressing

IP Multicast MAC Address Mapping
(FDDI & Ethernet)

Be Aware of the 32:1 Address Overlap

32 - IP Multicast Addresses

224.1.1.1
224.129.1.1
225.1.1.1
225.129.1.1
.
.
.
238.1.1.1
238.129.1.1
239.1.1.1
239.129.1.1

1 - Multicast MAC Address (FDDI and Ethernet)

0x0100.5E01.0101

Multicast Addressing

IP Multicast MAC Address Mapping
(Token Ring)

A Layer 3 IPmc Address Maps to a single Token Ring Functional Address or the all ones' Broadcast address:

224.x.x.x → c0-00-00-04-00-00

(Shown in Token Ring, non-canonical format)

224.x.x.x → ff-ff-ff-ff-ff-ff

Results in high levels of unwanted interrupts for non-interested Hosts

Multicast Addressing

IP Multicast MAC Address Mapping
(Token Ring)

Be Aware of the 268,435,200:1 Address Overlap

ALL **268,435,200 - IP Multicast Addresses**

224.0.1.0
224.0.1.1
224.0.1.2
224.0.1.3
.
.
.
239.239.255.252
239.255.255.253
239.255.255.254
239.255.255.255

1 - Multicast MAC Address
(Token Ring)

0xFFFF.FFFF.FFFF

RUN AWAY ! ! !

Multicast Addressing

- **Dynamic Group Address Assignment**
  - **Historically accomplished using SDR application**
    - **Sessions/groups announced over well-known multicast groups**
    - **Address collisions detected and resolved at session creation time**
    - **Has problems scaling**
  - **Future dynamic techniques under consideration**
    - **Multicast Address Set-Claim (MASC)**
      - **Hierarchical, dynamic address allocation scheme**
      - **Extremely complex garbage-collection problem.**
      - **Long ways off**
    - **MADCAP**
      - **Similar to DHCP**
      - **Need application and host stack support**

Multicast Addressing

- Static Group Address Assignment (new)
  - Temporary method to meet immediate needs
  - Group range: 233.0.0.0 - 233.255.255.255
    - Your AS number is inserted in middle two octets
    - Remaining low-order octet used for group assignment
  - Defined in IETF draft
    - "draft-ietf-mboned-glop-addressing-00.txt"

Agenda

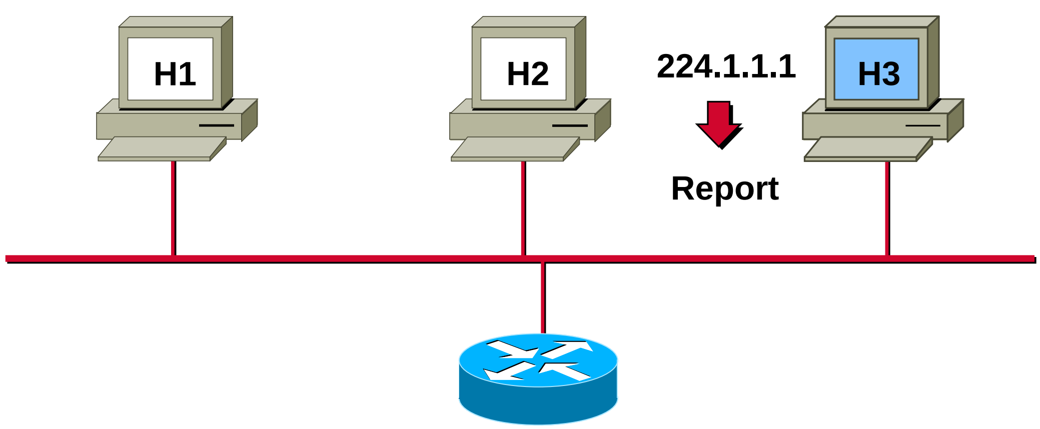
- Why Multicast?
- Multicast Addressing
- **Host-Router Signaling: IGMP**
- Multicast Distribution Trees
- Multicast Forwarding
- Multicast Routing Protocols

Host-Router Signaling: IGMP

- How hosts tell routers about group membership
- Routers solicit group membership from directly connected hosts
- RFC 1112 specifies version 1 of IGMP
  - Supported on Windows 95
- RFC 2236 specifies version 2 of IGMP
  - Supported on latest service pack for Windows and most UNIX systems
- IGMP version 3 is specified in IETF draft
  - draft-ietf-idmr-igmp-v3-03.txt

Host-Router Signaling: IGMP

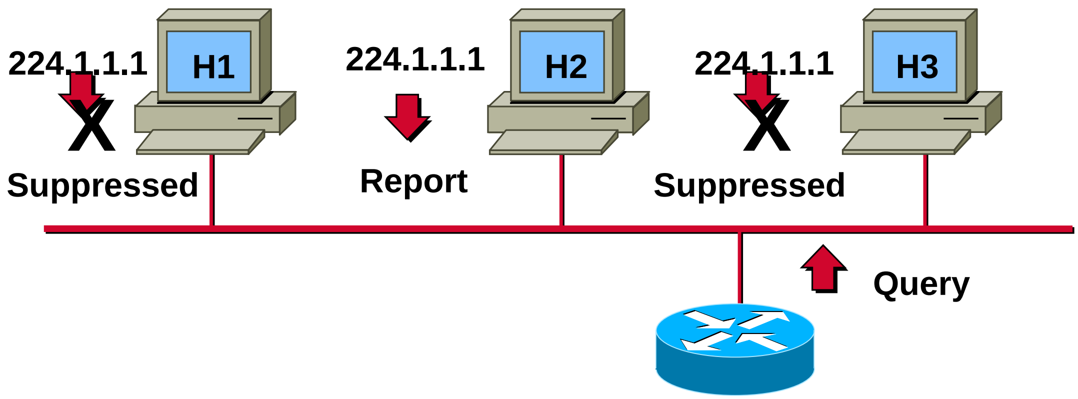
Joining a Group



- Host sends IGMP Report to join group

Host-Router Signaling: IGMP

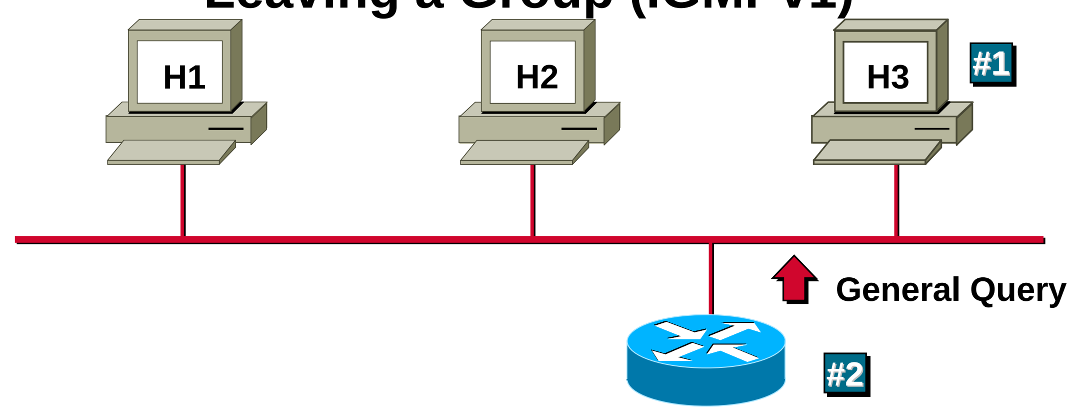
Maintaining a Group



- Router sends periodic Queries to 224.0.0.1
- One member per group per subnet reports
- Other members suppress reports

Host-Router Signaling: IGMP

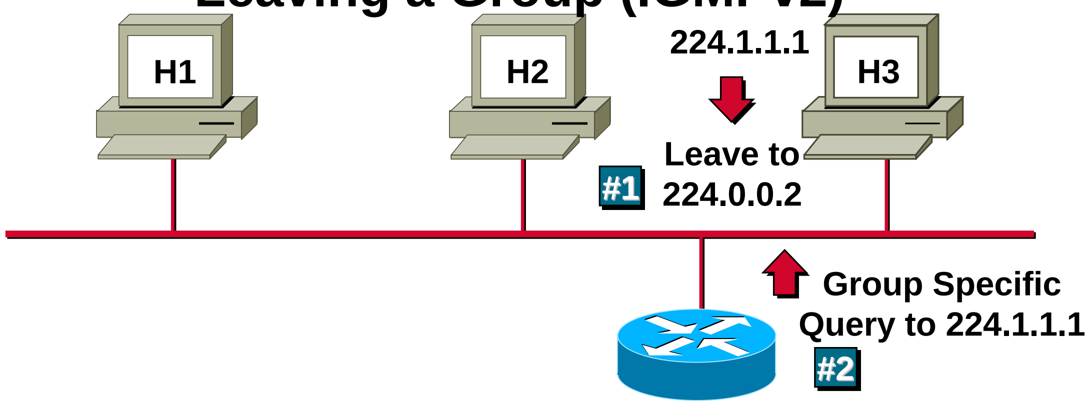
Leaving a Group (IGMPv1)



- Host quietly leaves group
- Router sends 3 General Queries (60 secs apart)
- No IGMP Report for the group is received
- Group times out (Worst case delay ~= 3 minutes)

Host-Router Signaling: IGMP

Leaving a Group (IGMPv2)

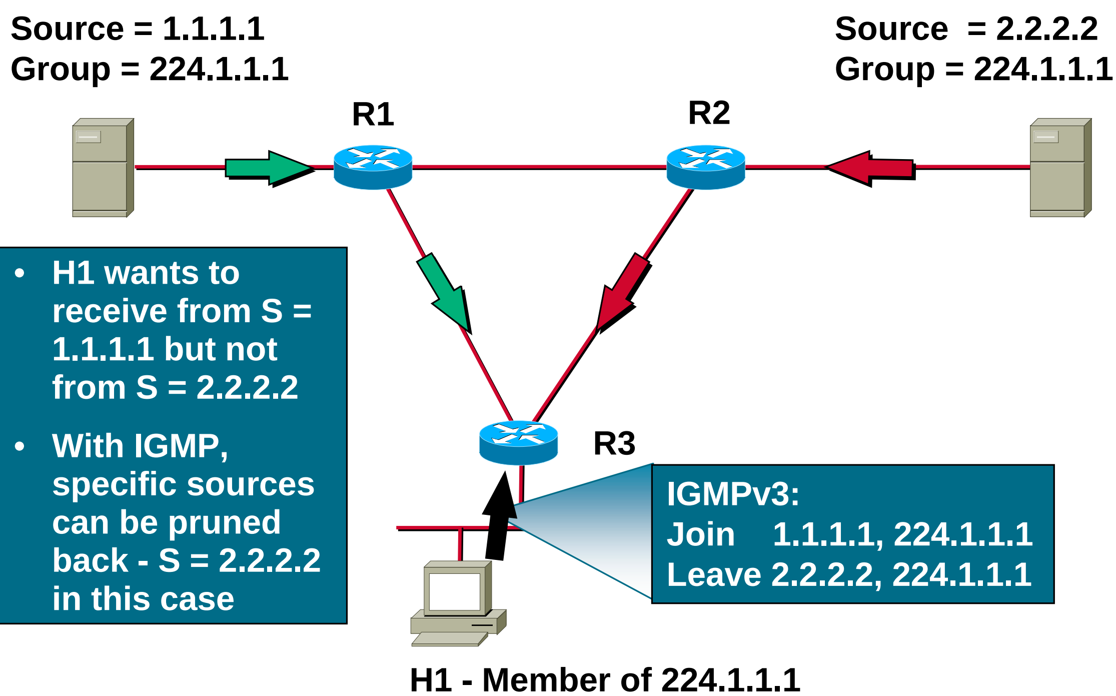


- **Host sends Leave message to 224.0.02**
- **Router sends Group specific query to 224.1.1.1**
- **No IGMP Report is received within ~3 seconds**
- **Group 224.1.1.1 times out**

IGMPv3

- ***draft-ietf-idmr-igmp-v3-??.txt***
- **Early implementations now in beta**
  - **Enables hosts to listen only to a specified subset of the hosts sending to the group**

IGMPv3



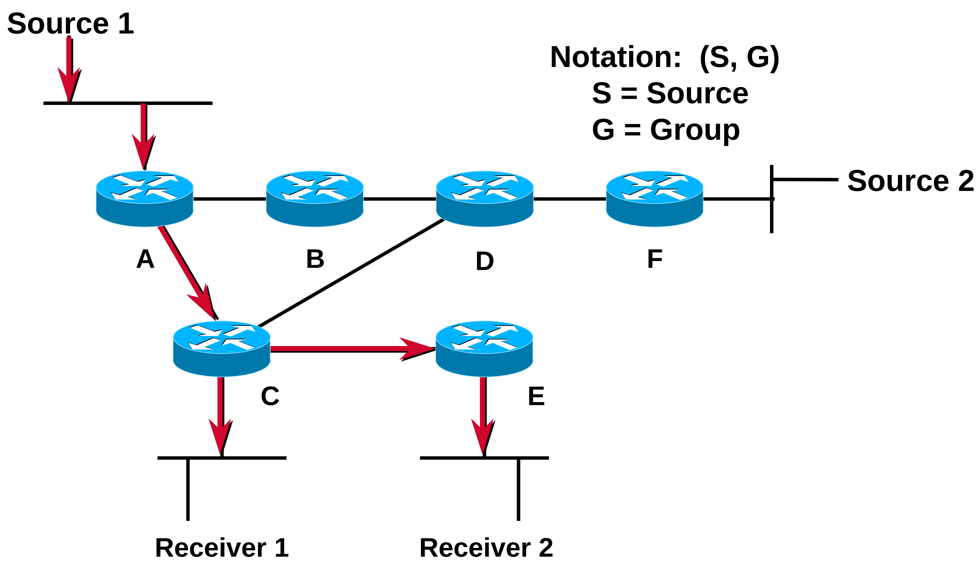
- H1 wants to receive from S = 1.1.1.1 but not from S = 2.2.2.2
- With IGMP, specific sources can be pruned back - S = 2.2.2.2 in this case

Agenda

- Why Multicast?
- Multicast Addressing
- Host-Router Signaling: IGMP
- **Multicast Distribution Trees**
- Multicast Forwarding
- Multicast Routing Protocols

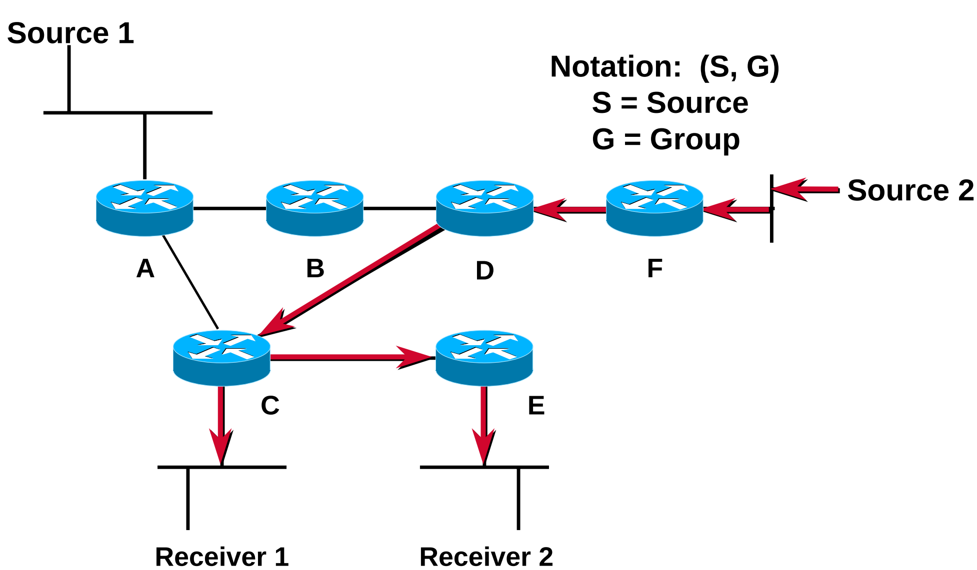
Multicast Distribution Trees

Shortest Path or Source Distribution Tree



Multicast Distribution Trees

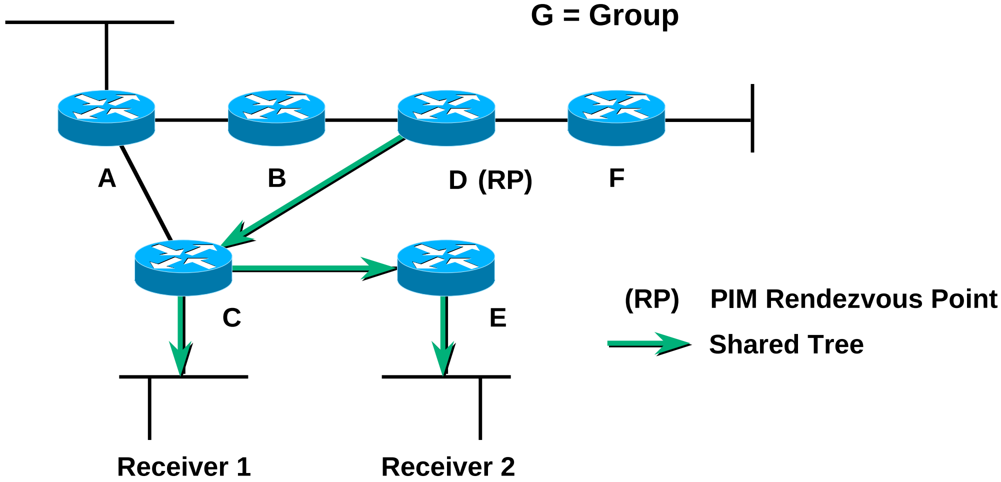
Shortest Path or Source Distribution Tree



Multicast Distribution Trees

Shared Distribution Tree

Notation: (*, G)
* = All Sources
G = Group



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Multicast Distribution Trees

Shared Distribution Tree

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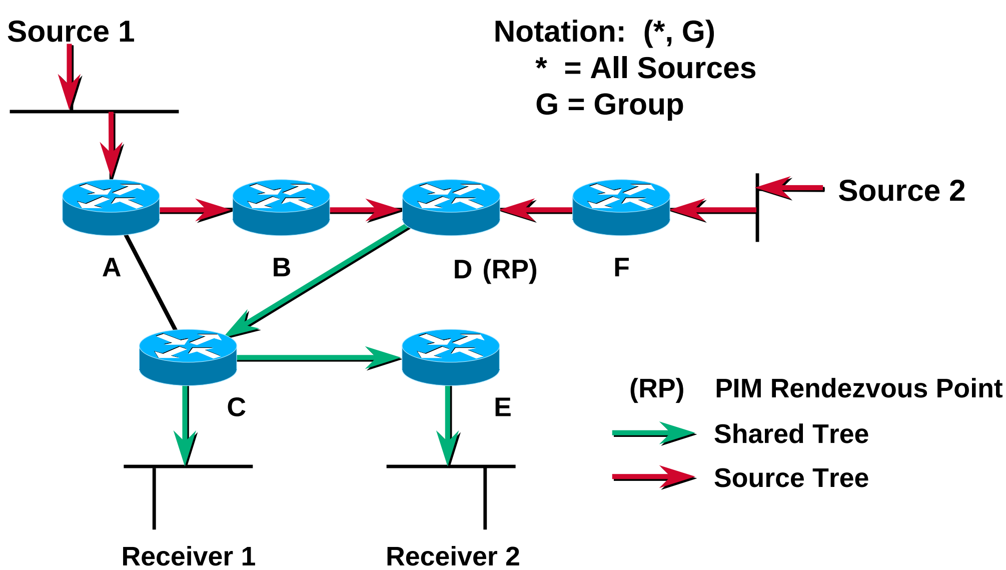

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Multicast Distribution Trees

Characteristics of Distribution Trees

- Source or Shortest Path trees

  Uses more memory O(S x G) but you get optimal paths from source to all receivers; minimizes delay

- Shared trees

  Uses less memory O(G) but you may get sub-optimal paths from source to all receivers; may introduce extra delay

Agenda

- Why Multicast?
- Multicast Addressing
- Host-Router Signaling: IGMP
- Multicast Distribution Trees
- **Multicast Forwarding**
- Multicast Routing Protocols

Multicast Forwarding

- Multicast Routing is backwards from Unicast Routing
  - Unicast Routing is concerned about where the packet is going.
  - Multicast Routing is concerned about where the packet came from.
- Multicast Routing uses “Reverse Path Forwarding”

Multicast Forwarding

Reverse Path Forwarding (RPF)

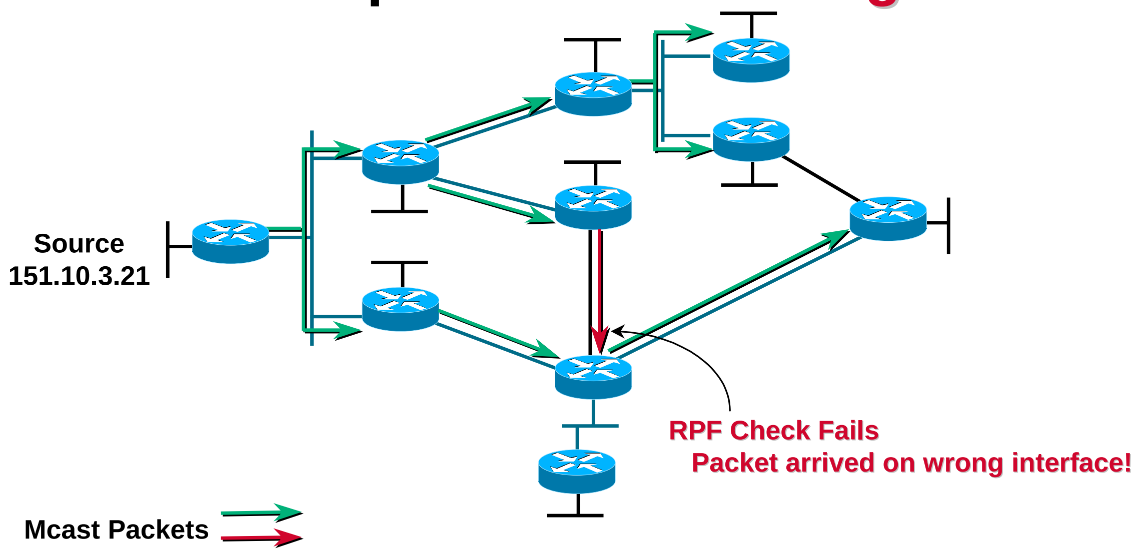
- **What is RPF?**

  A router forwards a multicast datagram only if received on the up stream interface to the source (i.e. it follows the distribution tree).

- **The RPF Check**
  - The routing table used for multicasting is checked against the “source” IP address in the packet.
  - If the datagram arrived on the interface specified in the routing table for the source address; then the RPF check succeeds.
  - Otherwise, the RPF Check fails.

Multicast Forwarding

Example: RPF Checking



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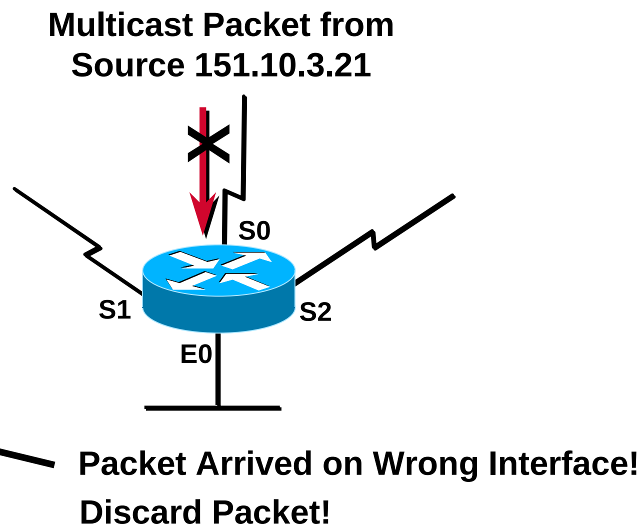
Multicast Forwarding

A closer look: RPF Check Fails



RPF Check Fails!

Unicast Route Table	
Network	Interface
151.10.0.0/16	S1
198.14.32.0/24	S0
204.1.16.0/24	E0

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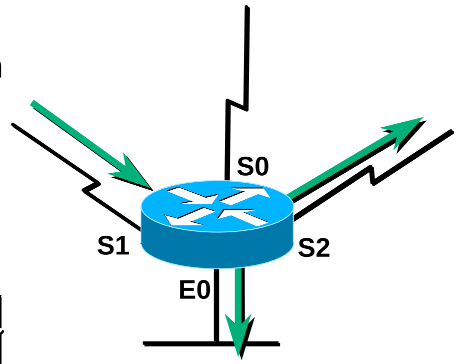
Multicast Forwarding

A closer look: RPF Check Succeeds

Multicast Packet from Source 151.10.3.21



RPF Check Succeeds!

Unicast Route Table	
Network	**Interface**
151.10.0.0/16	S1
198.14.32.0/24	S0
204.1.16.0/24	E0

Packet Arrived on Correct Interface!

Forward out all outgoing interfaces.
(i. e. down the distribution tree)

Agenda

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Multicast vs. Unicast Routing

Multicast Routing is not unicast routing. You have to think of it differently. It is not like OSPF. It is not like RIP. It is not like anything you may be familiar with.

Types of Multicast Protocols

- **Dense-mode**
  - Uses "Push" Model
  - Traffic Flooded throughout network
  - Pruned back where it is unwanted
  - Flood & Prune behavior (typically every 3 minutes)
- **Sparse-mode**
  - Uses "Pull" Model
  - Traffic sent only to where it is requested
  - Explicit Join behavior

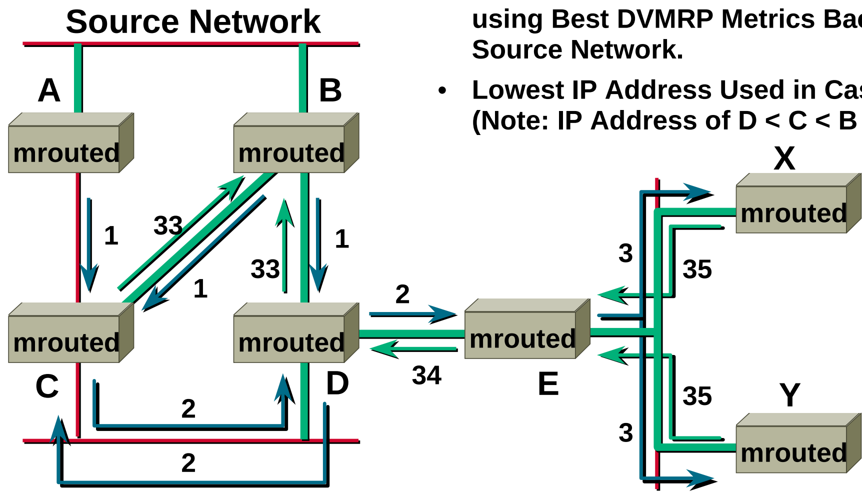
Multicast Protocol Overview

- Currently, there are four multicast routing protocols:
  - DVMRPv3 (Internet-draft)
    - DVMRPv1 (RFC 1075) is obsolete and unused. A variant is currently implemented
  - MOSPF (RFC 1584)
  - PIM-DM (Internet-draft)
  - PIM-SM (RFC 2362- v2)
  - Others (CBT, OCBT, QOSMIC, SM, etc.)

DVMRP Overview

- Dense Mode Protocol
  - Distance vector-based
    - Similar to RIP
    - Infinity = 32 hops
    - Subnet masks in route advertisements
  - DVMRP Routes used:
    - For RPF Check
    - To build Truncated Broadcast Trees (TBTs)
      - Uses special “Poison-Reverse” mechanism
  - Uses Flood and Prune operation
    - Traffic initially flooded down TBT’s
    - TBT branches are pruned where traffic is unwanted.
    - Prunes periodically time-out causing reflooding.

DVMRP—Source Trees



- Truncated Broadcast Trees Are Built using Best DVMRP Metrics Back to Source Network.
- Lowest IP Address Used in Case of a Tie. (Note: IP Address of D < C < B < A)

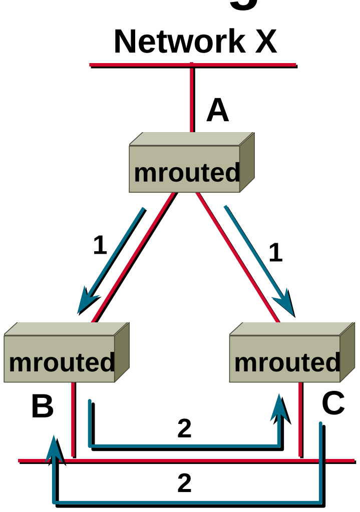
n — Route for source network of metric “n”

m — Poison reverse (metric + infinity) sent to upstream “parent” router. Router depends on “parent” to receive traffic for this source.

Resulting Truncated Broadcast Tree for Source Network

DVMRP—Source Trees

Forwarding onto Multi-access Networks

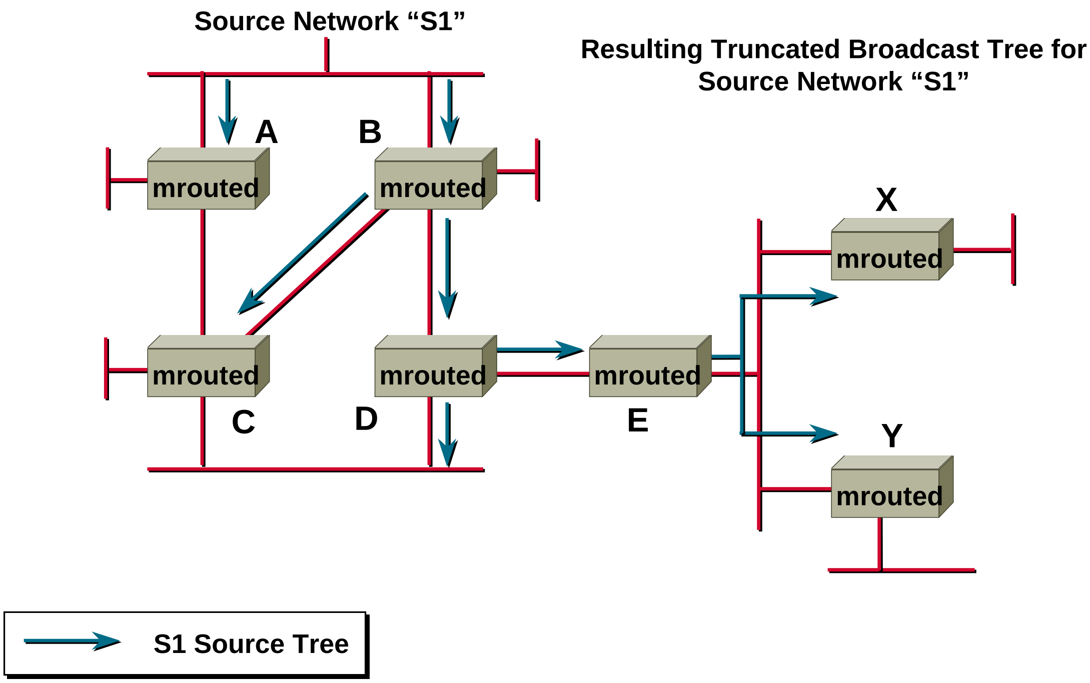


(Note: IP Address of C < B)

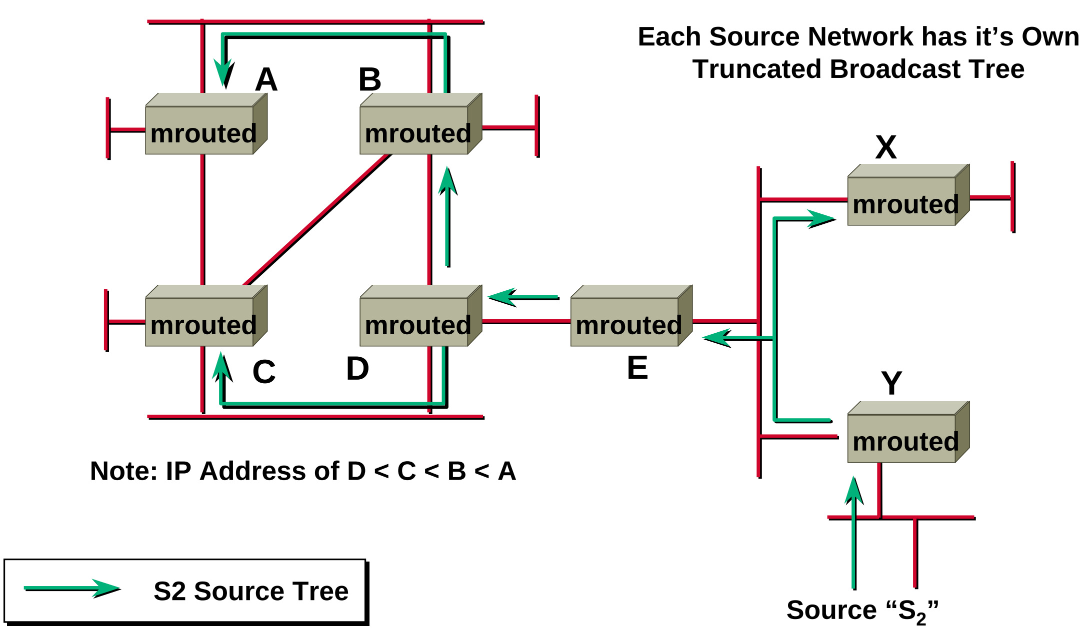
- Both B and C have routes to network X.
- To avoid duplicates, only one router can be “Designated Forwarder” for network X.
- Router with best metric is elected as the “Designated Forwarder”.
- Lowest IP address used as tie-breaker.
- Router C wins in this example.

n — Route advertisement for network X of metric “n”

DVMRP—Source Trees

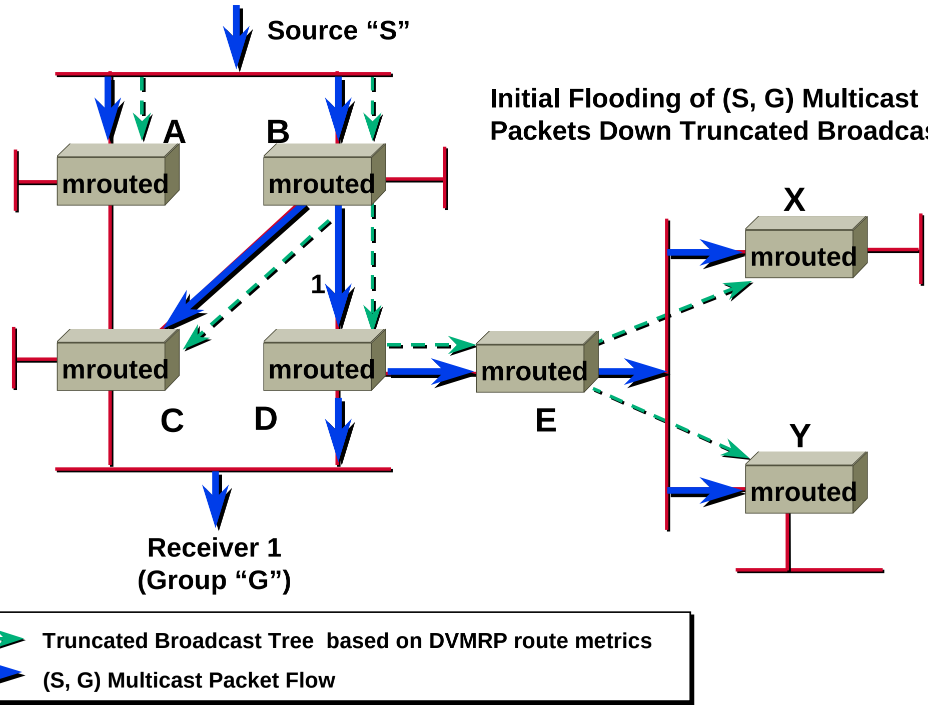


DVMRP—Source Trees



DVMRP—Flood & Prune

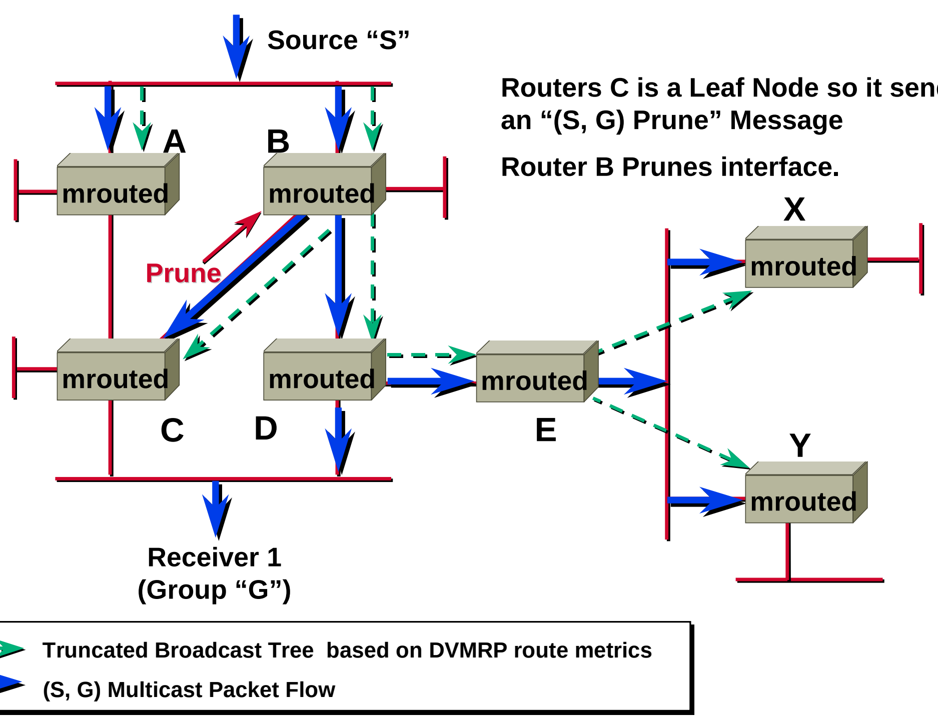
Initial Flooding of (S, G) Multicast Packets Down Truncated Broadcast Tree



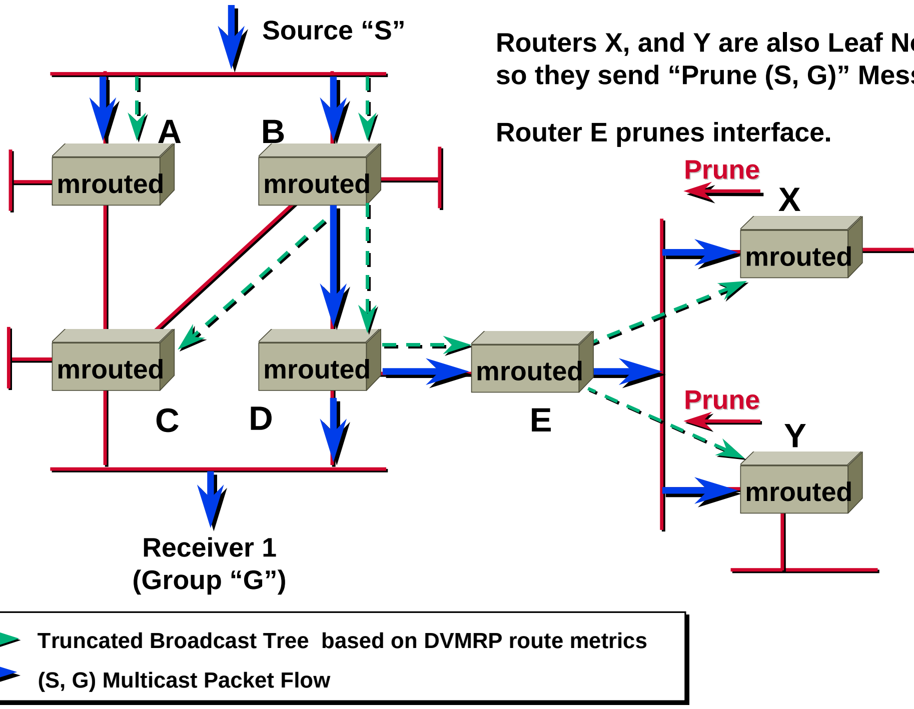
DVMRP—Flood & Prune

Routers C is a Leaf Node so it sends an "(S, G) Prune" Message

Router B Prunes interface.



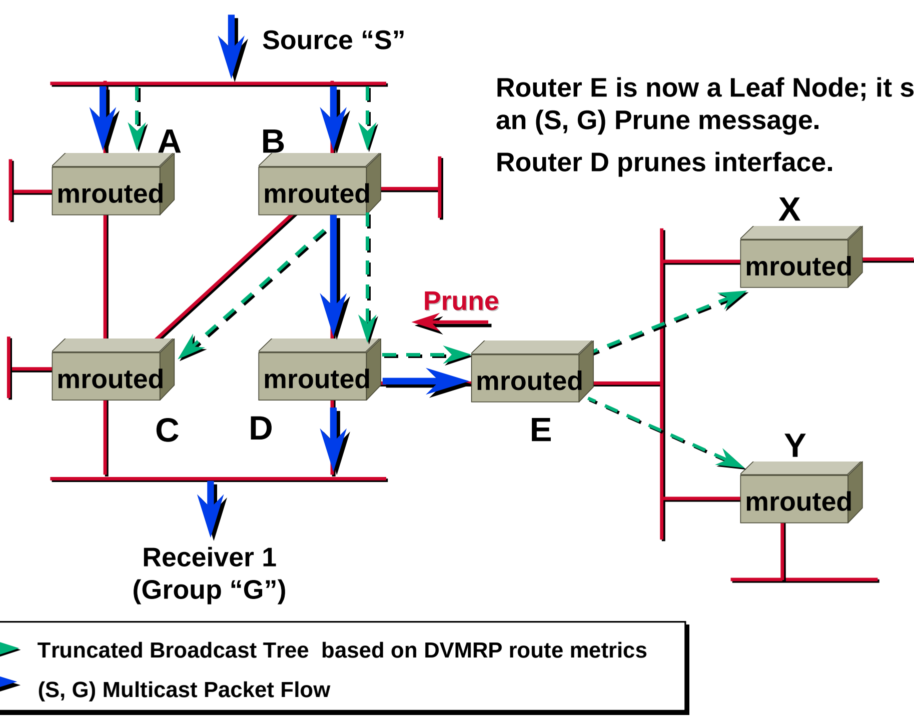
DVMRP—Flood & Prune



Routers X, and Y are also Leaf Nodes so they send "Prune (S, G)" Messages

Router E prunes interface.

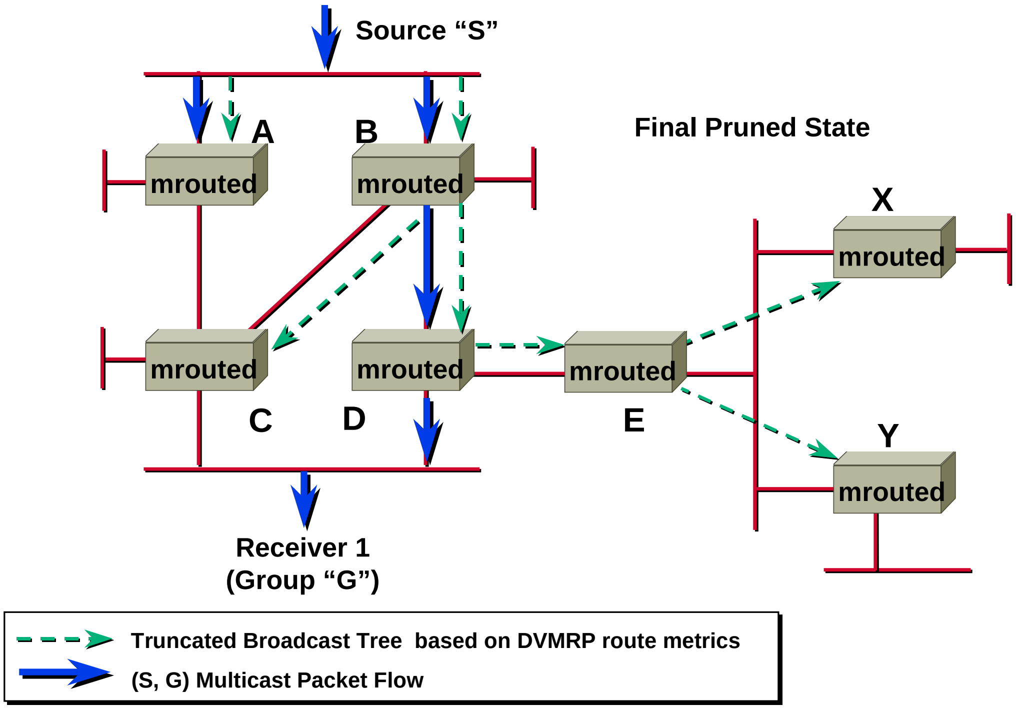
DVMRP—Flood & Prune



Router E is now a Leaf Node; it sends an (S, G) Prune message.

Router D prunes interface.

DVMRP—Flood & Prune



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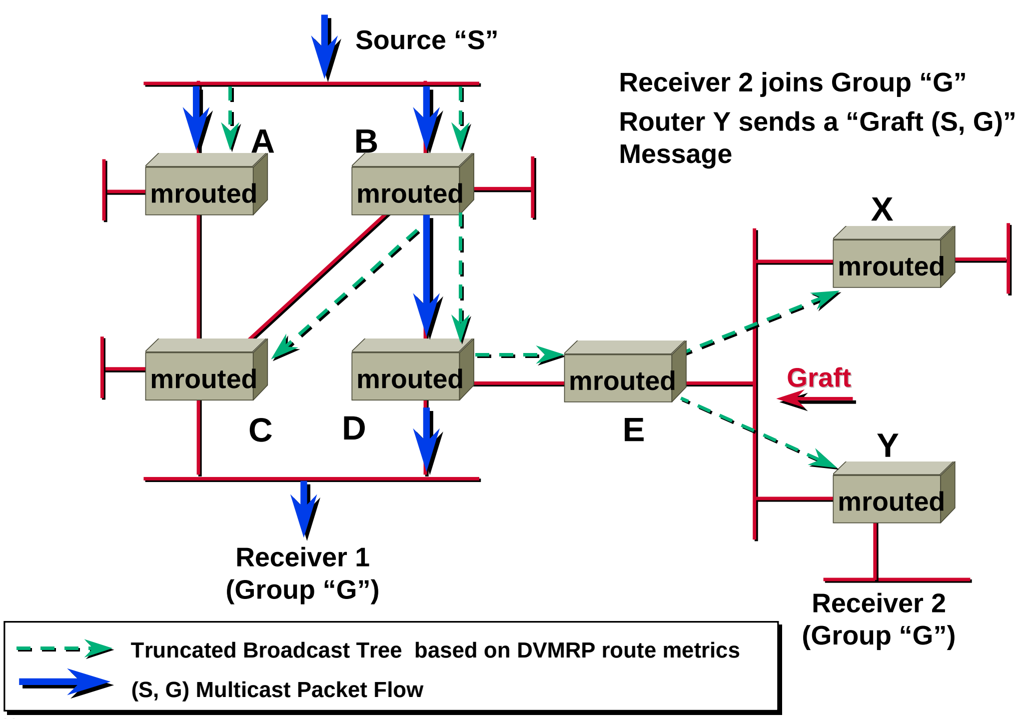
DVMRP—Grafting



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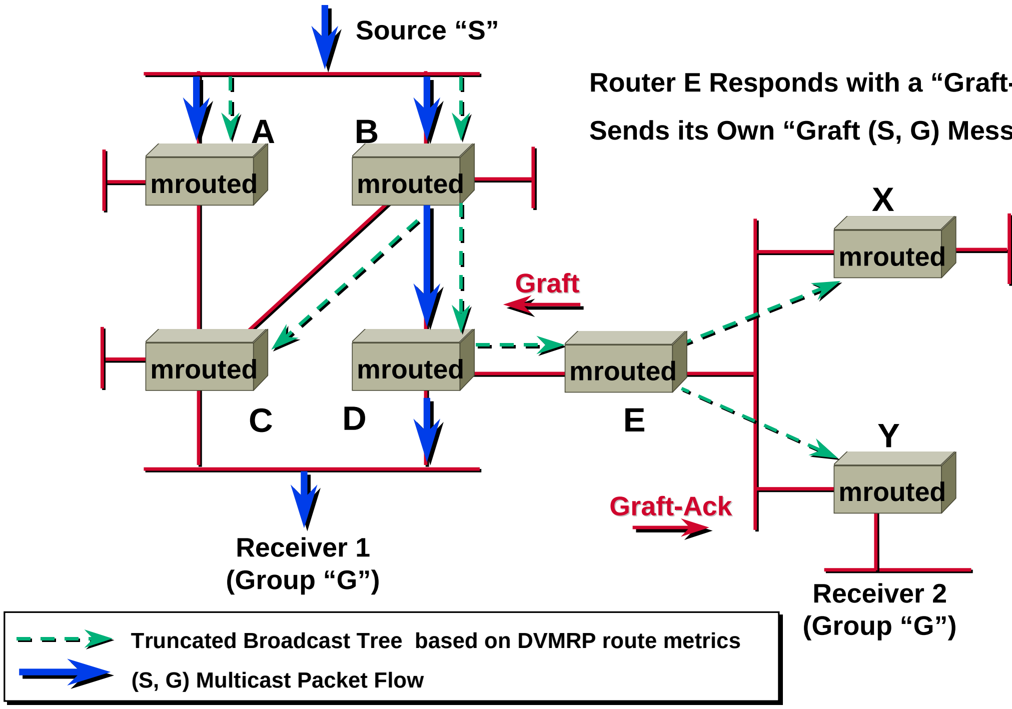
DVMRP—Grafting

Router E Responds with a “Graft-Ack”

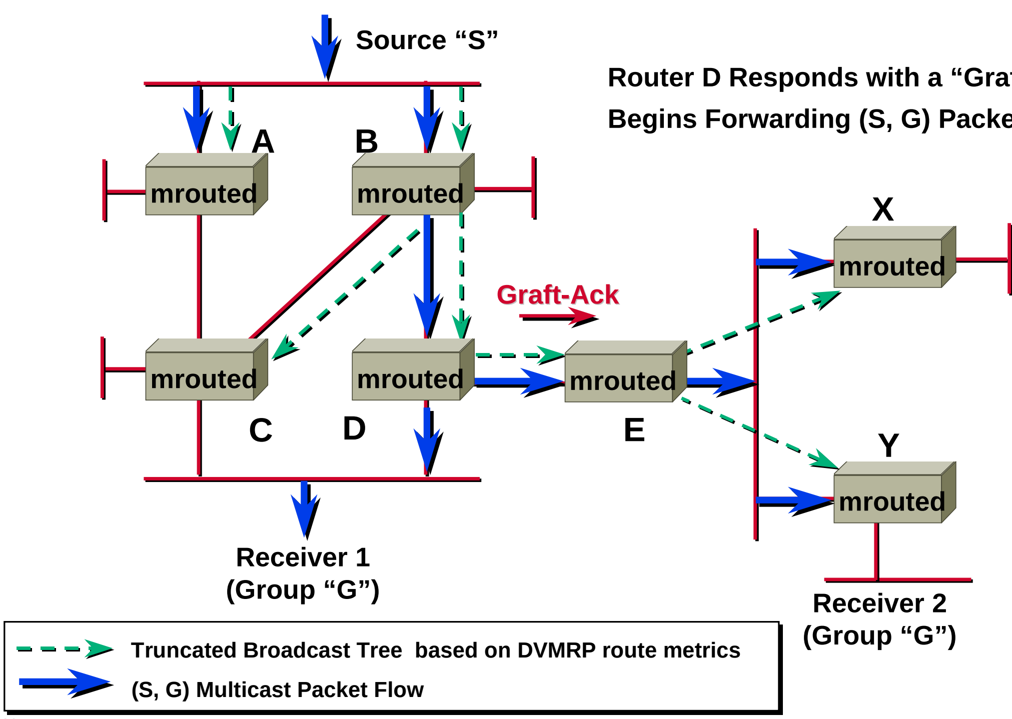
Sends its Own “Graft (S, G) Message



DVMRP—Grafting

Router D Responds with a “Graft-Ack”

Begins Forwarding (S, G) Packets



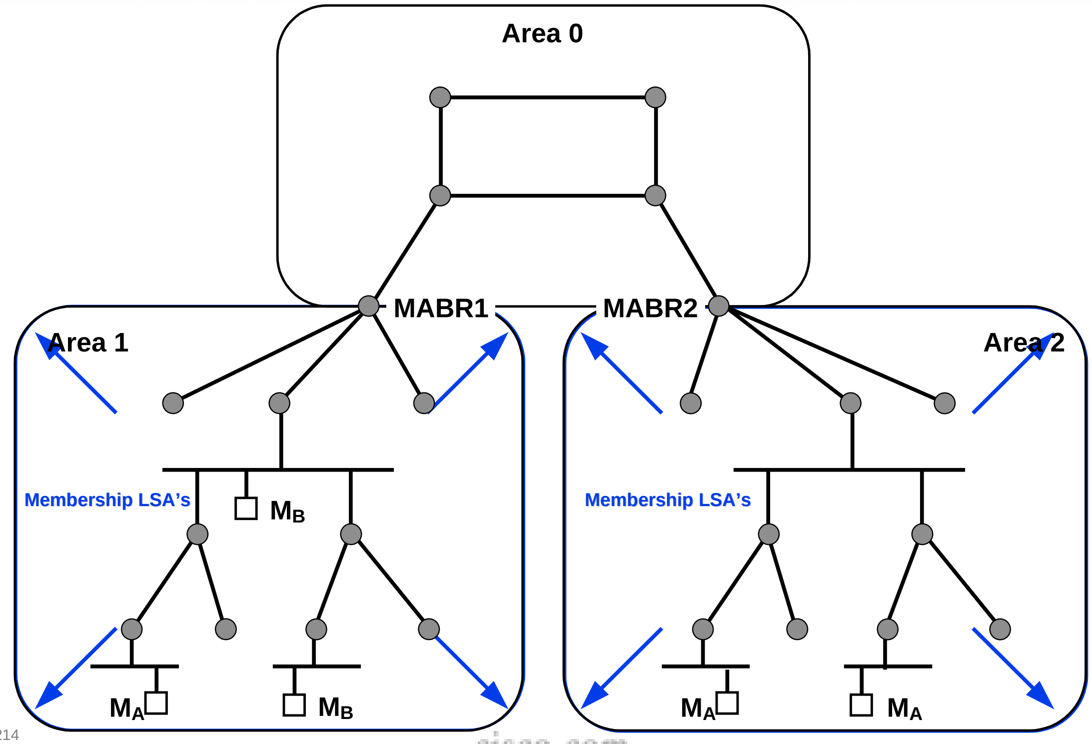
DVMRP—Evaluation

- Widely used on the MBONE (being phased out)
- Significant scaling problems
  - Slow Convergence—RIP-like behavior
  - Significant amount of multicast routing state information stored in routers—(S,G) everywhere
  - No support for shared trees
  - Maximum number of hops < 32
- Not appropriate for large scale production networks
  - Due to flood and prune behavior
  - Due to its poor scalability

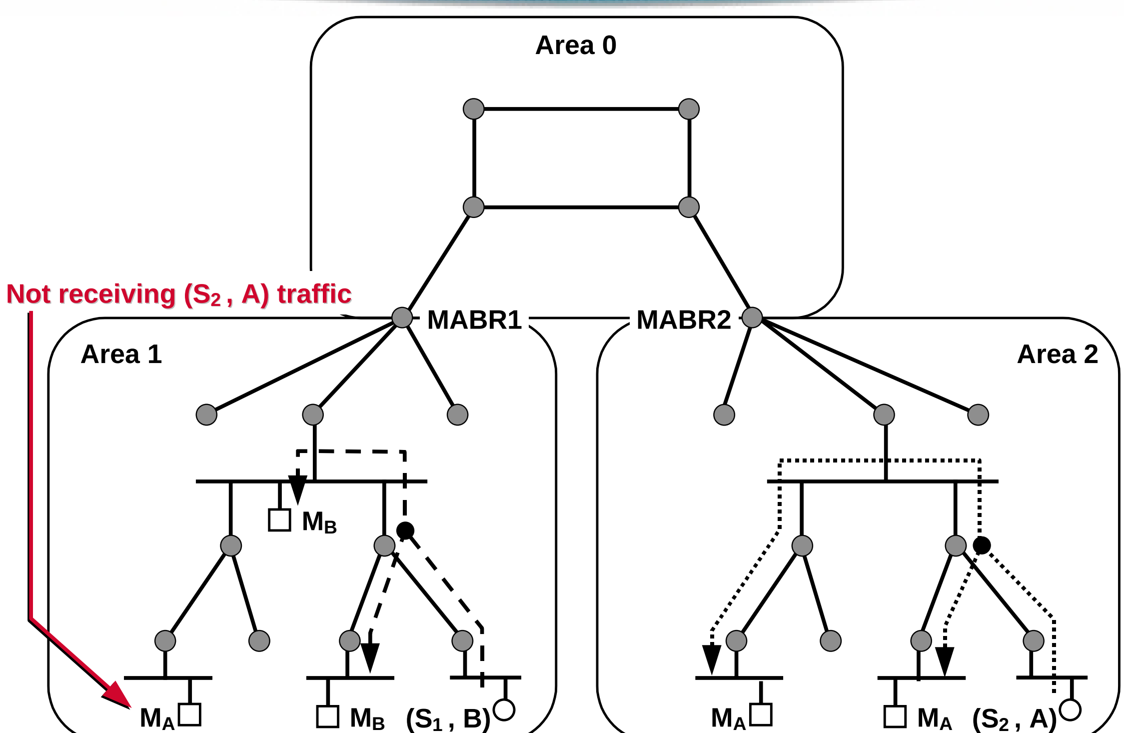
MOSPF (RFC 1584)

- Extension to OSPF unicast routing protocol
  - OSPF: Routers use link state advertisements to understand all available links in the network (route messages along least-cost paths)
  - MOSPF: Includes multicast information in OSPF link state advertisements to construct multicast distribution trees (each router maintains an up-to-date image of the topology of the entire network)
- Group membership LSAs are flooded throughout the OSPF routing domain so MOSPF routers can compute outgoing interface lists
- Uses Dijkstra algorithm to compute shortest-path tree
  - Separate calculation is required for each (S_{Net}, G) pair

MOSPF Membership LSA's

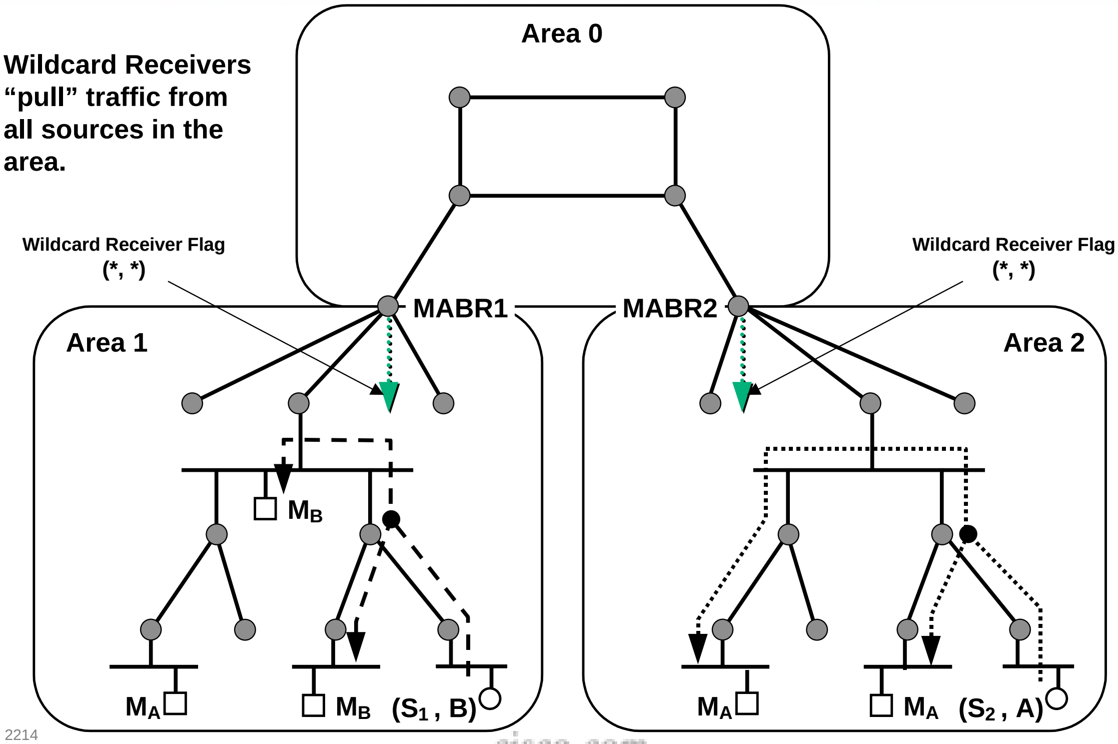


MOSPF Intra-Area Traffic

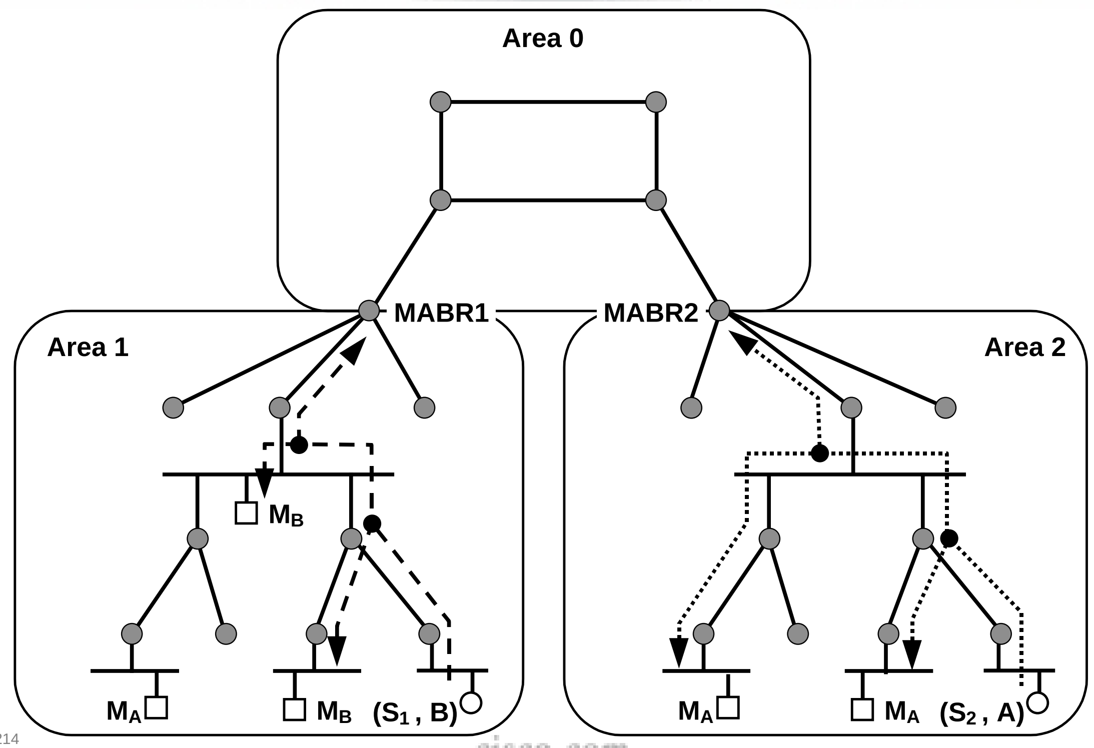


MOSPF Inter-Area Traffic

Wildcard Receivers "pull" traffic from all sources in the area.

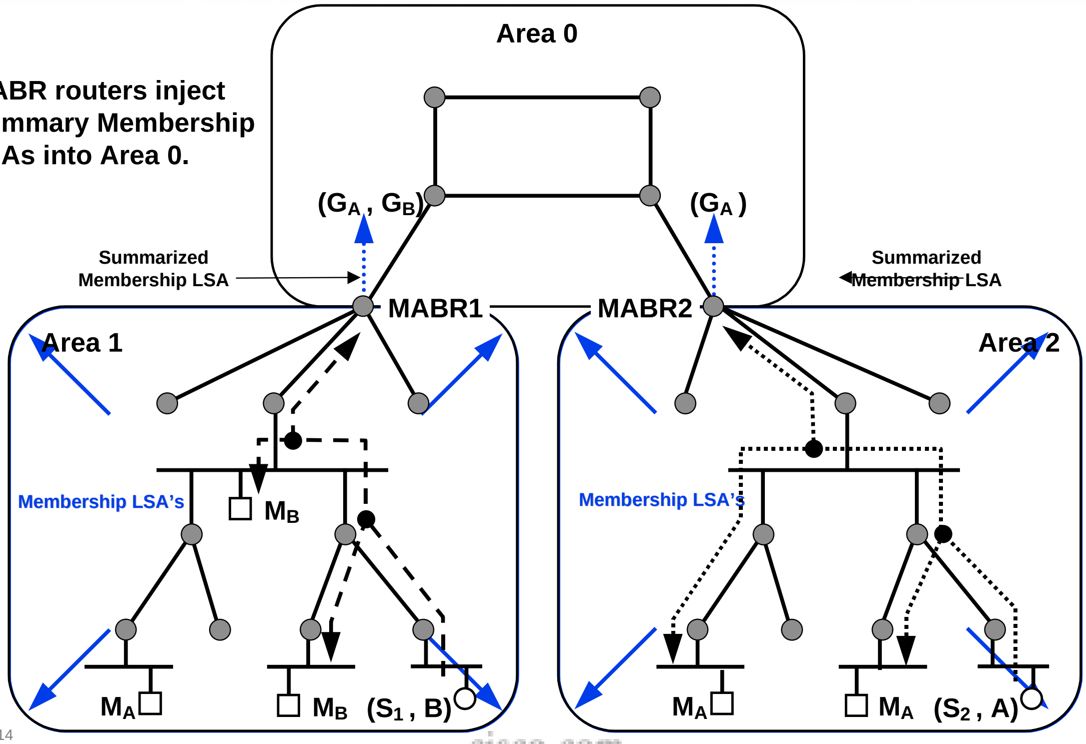


MOSPF Inter-Area Traffic

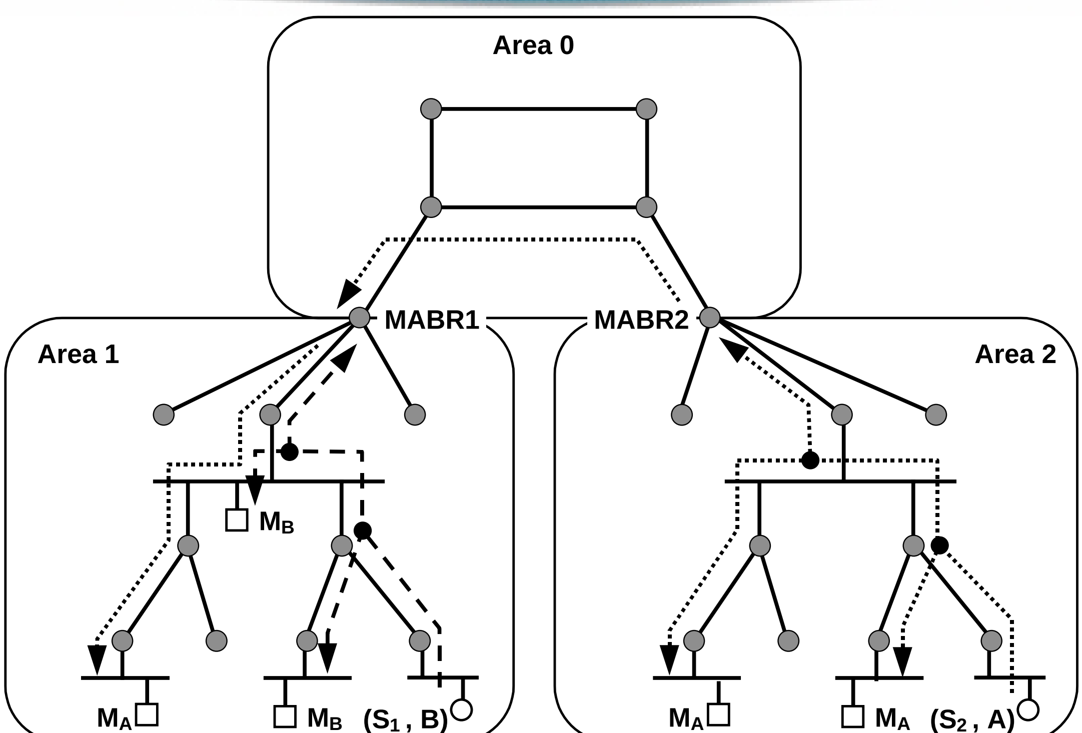


MOSPF Inter-Area Traffic

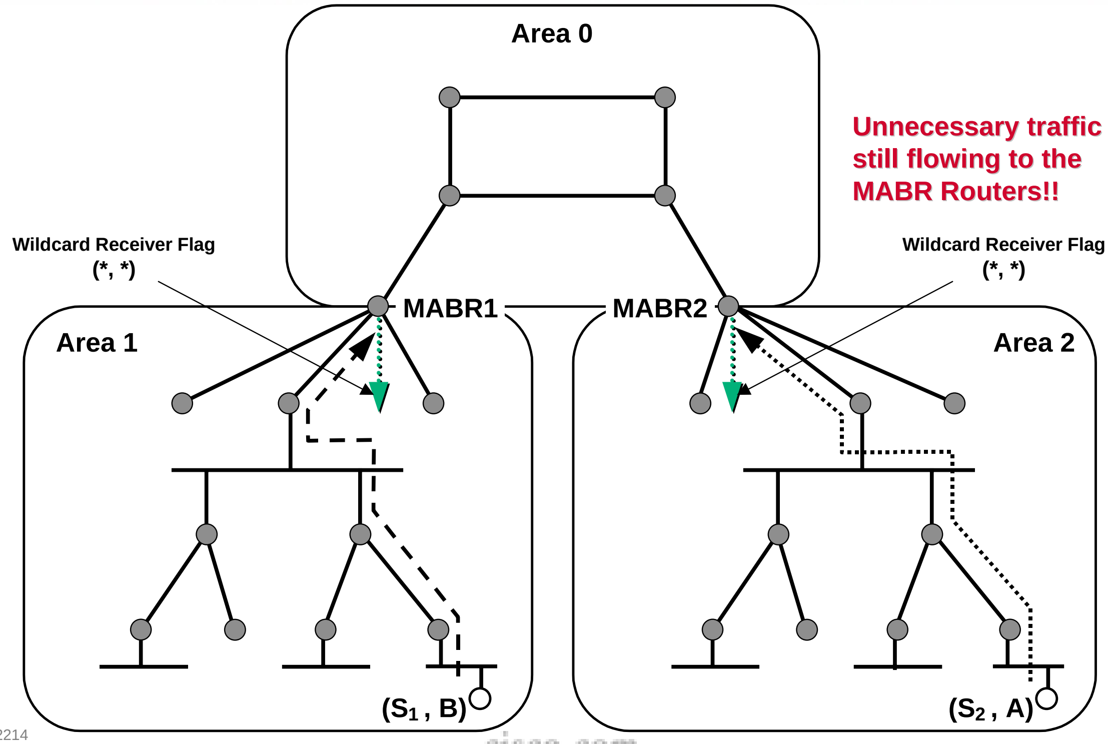
MABR routers inject Summary Membership LSAs into Area 0.



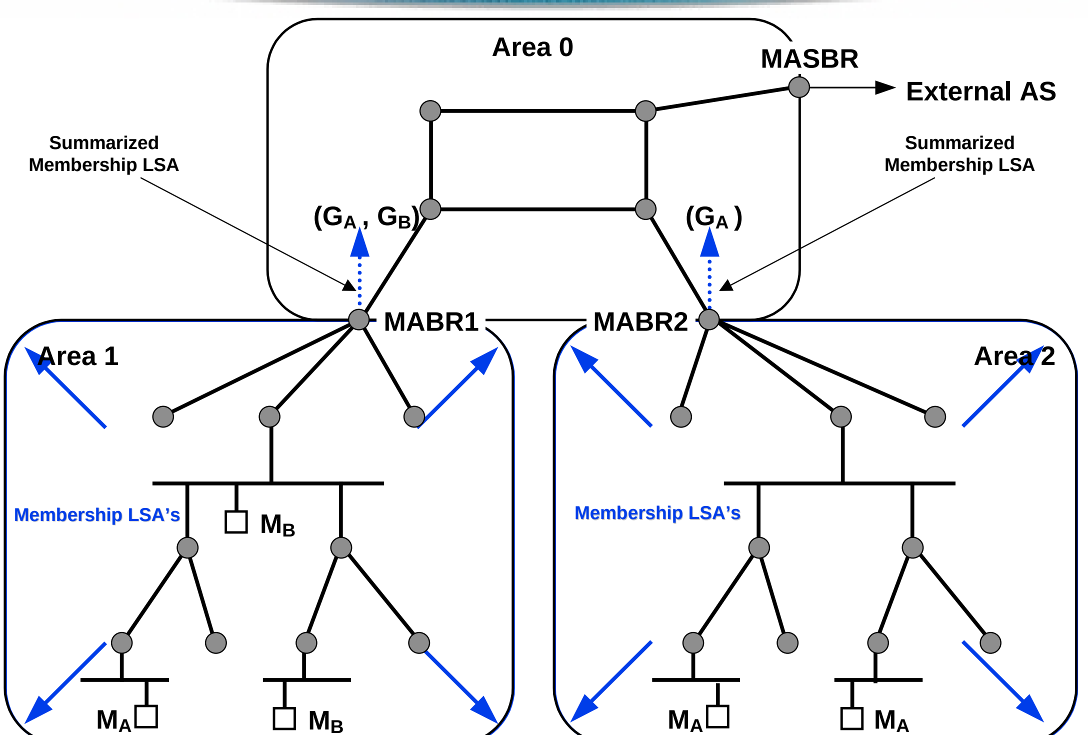
MOSPF Inter-Area Traffic



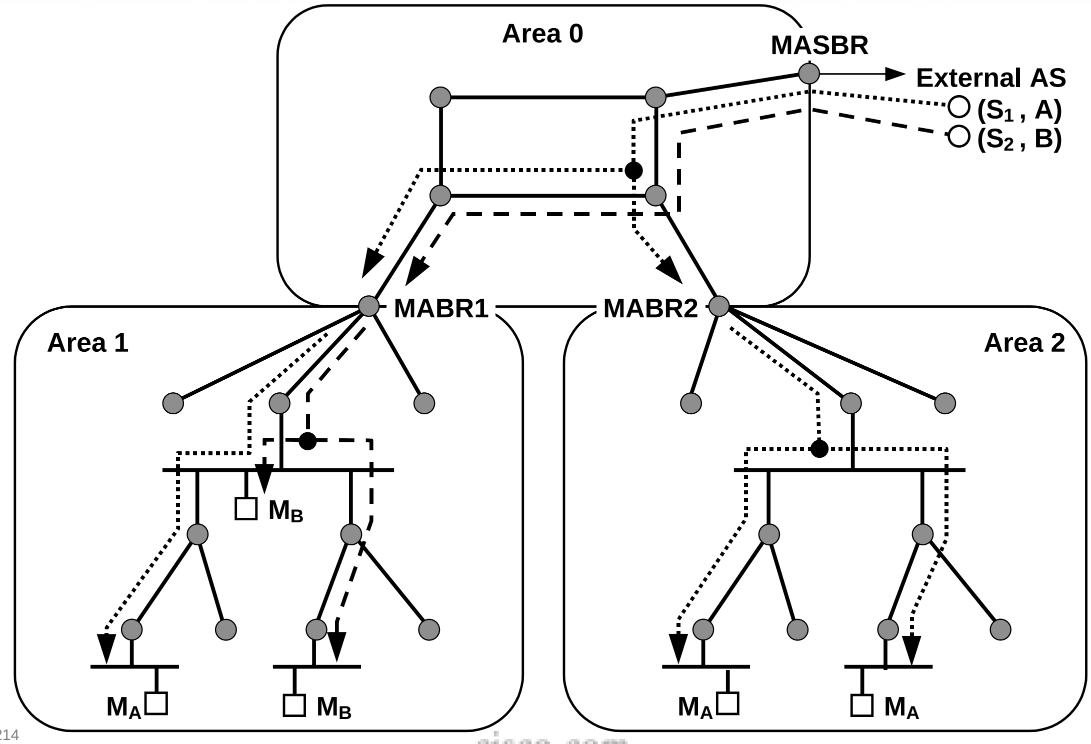
MOSPF Inter-Area Traffic



MOSPF Inter-Domain Traffic

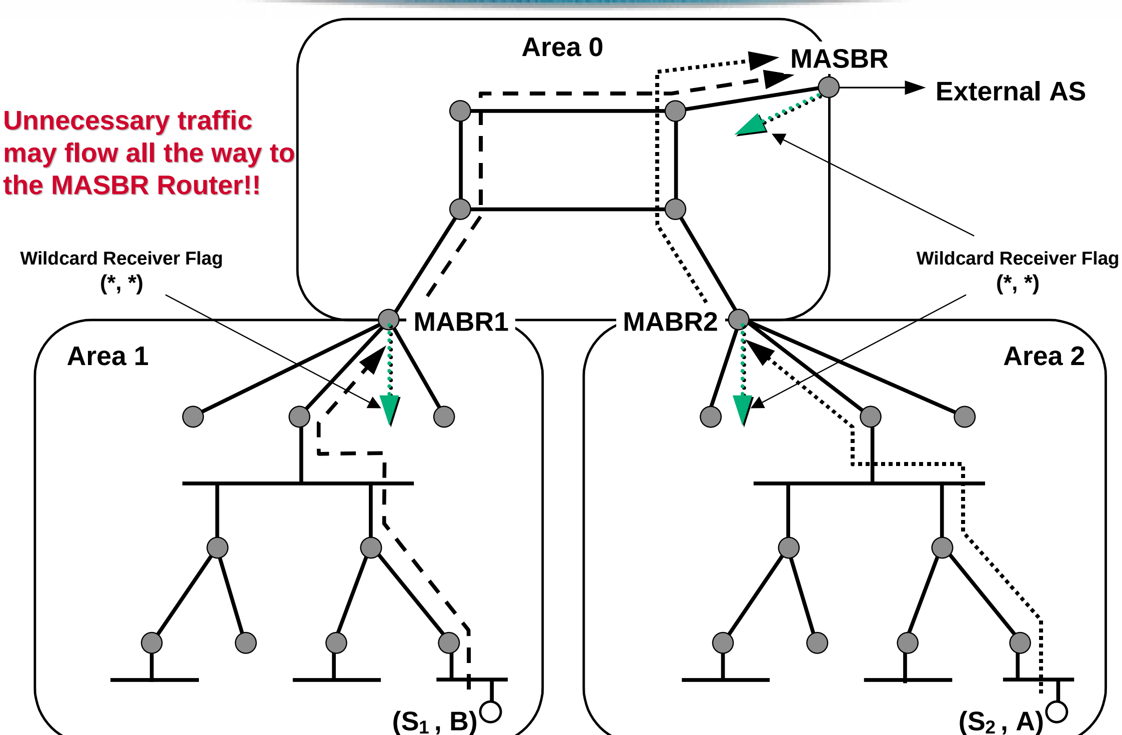


MOSPF Inter-Domain Traffic



MOSPF Inter-Domain Traffic

Unnecessary traffic may flow all the way to the MASBR Router!!



MOSPF—Evaluation

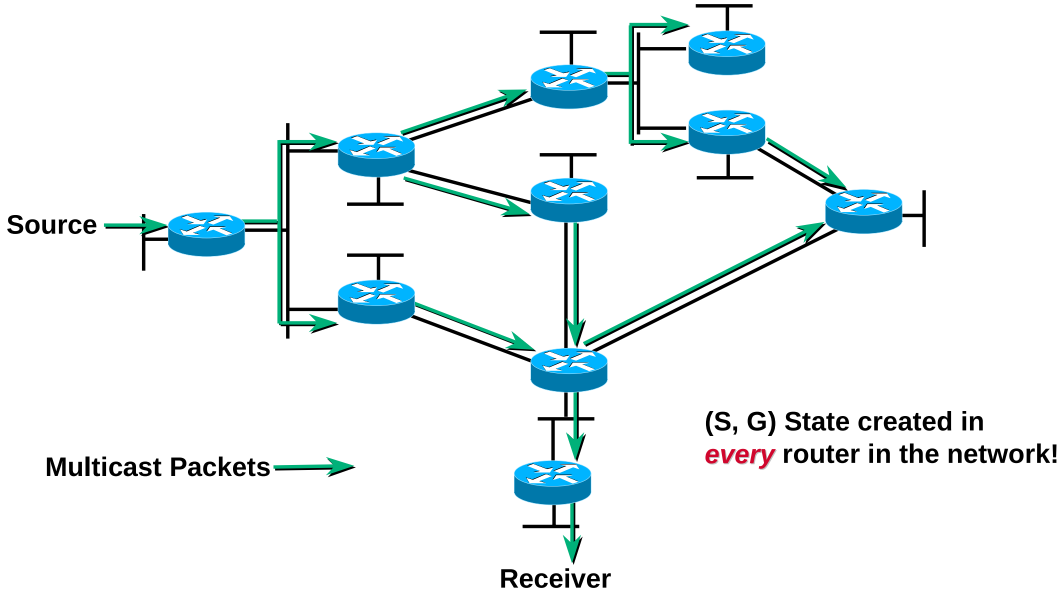
- Does not flood multicast traffic everywhere to create state, Uses LSAs and the link-state database
- Protocol dependent—works only in OSPF-based networks
- Significant scaling problems
  - Dijkstra algorithm run for EVERY multicast (S_{Net}, G) pair!
  - Dijkstra algorithm rerun when:
    - Group Membership changes
    - Line-flaps
  - Does not support shared-trees
- Not appropriate for…
  - General purpose multicast networks where the number of senders may be quite large.
    - IP/TV—(Every IP/TV client is a multicast source)

PIM-DM

- Protocol Independent
  - Supports all underlying unicast routing protocols including: static, RIP, IGRP, EIGRP, IS-IS, BGP, and OSPF
- Uses reverse path forwarding
  - Floods network and prunes back based on multicast group membership
  - Assert mechanism used to prune off redundant flows
- Appropriate for...
  - Smaller implementations and pilot networks

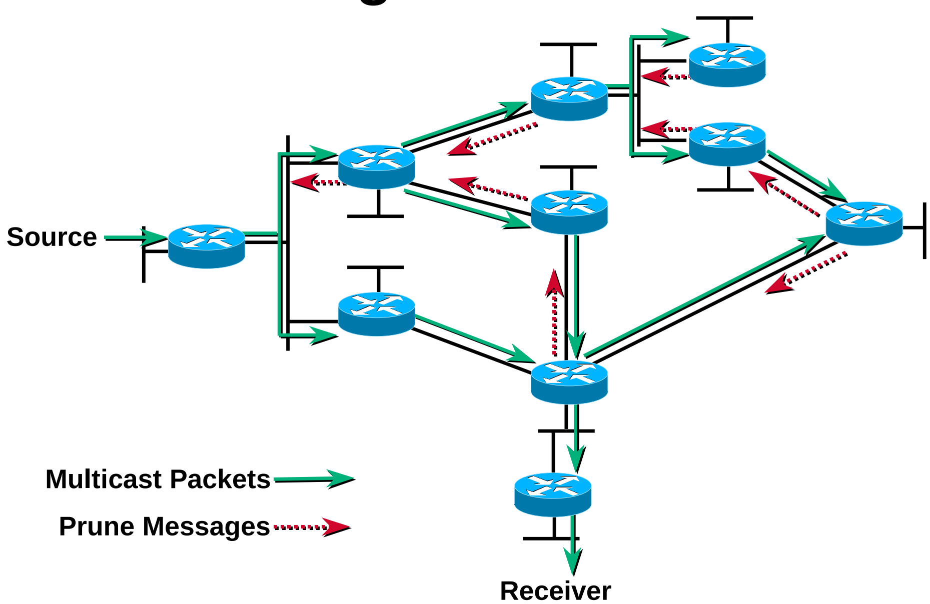
PIM-DM Flood & Prune

Initial Flooding



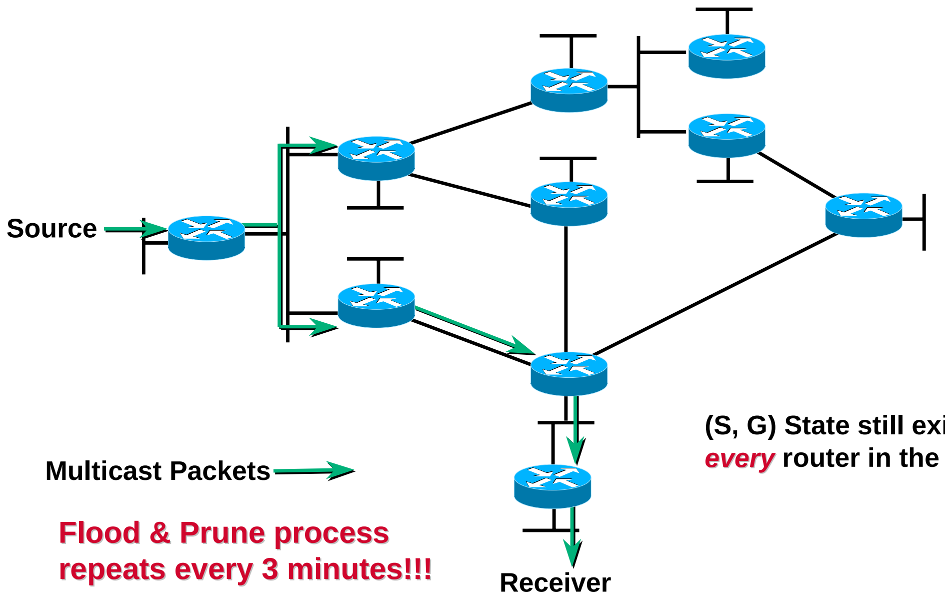
PIM-DM Flood & Prune

Pruning Unwanted Traffic



PIM-DM Flood & Prune

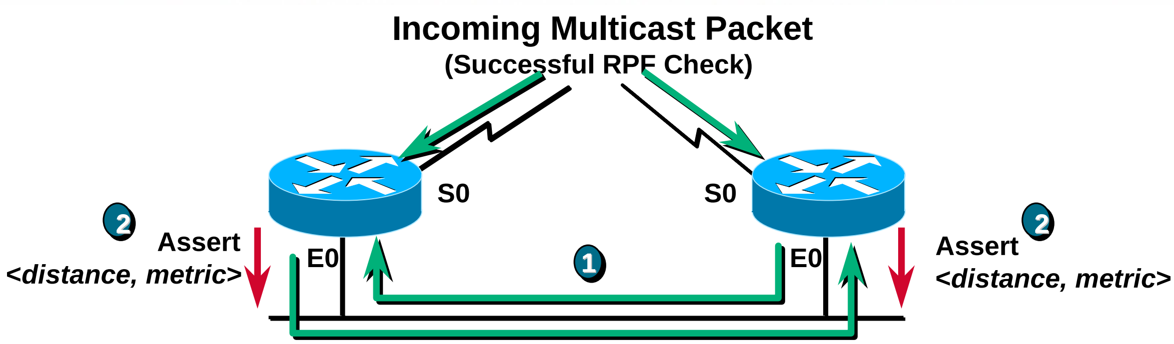
Results After Pruning



(S, G) State still exists in *every* router in the network!

Flood & Prune process repeats every 3 minutes!!!

PIM-DM Assert Mechanism



1. Routers *receive* packet on an interface in their "*oilist*"!!
   – Only one router should continue sending to avoid duplicate packets.
2. Routers send "PIM Assert" messages
   – Compare *distance* and *metric* values
   – Router with best route to source wins
   – If *metric* & *distance* equal, highest IP adr wins
   – Losing router stops sending (prunes interface)

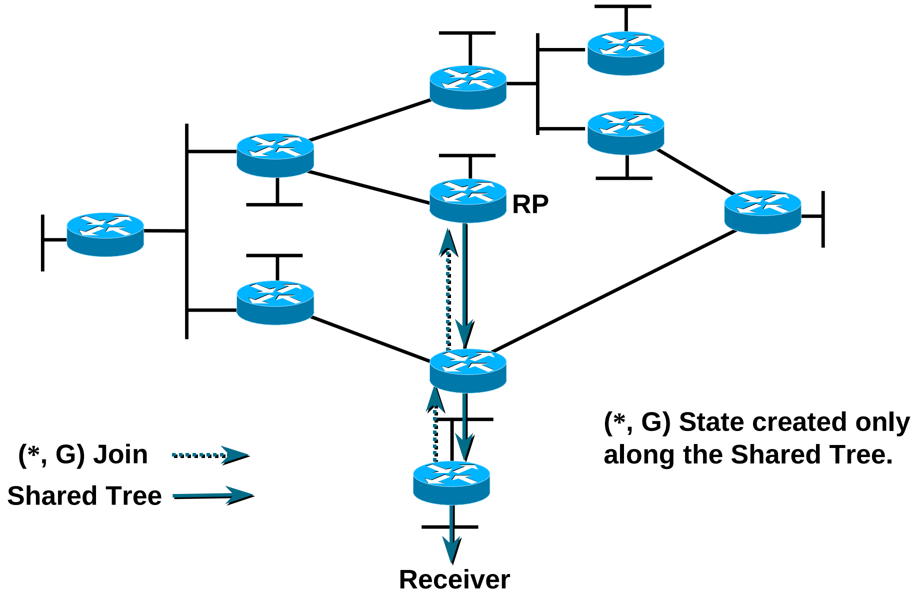
PIM-DM — Evaluation

- Most effective for small pilot networks
- Advantages:
  - Easy to configure—two commands
  - Simple flood and prune mechanism
- Potential issues...
  - Inefficient flood and prune behavior
  - Complex Assert mechanism
  - Mixed control and data planes
    - Results in (S, G) state in every router in the network
    - Can result in non-deterministic topological behaviors
  - No support for shared trees

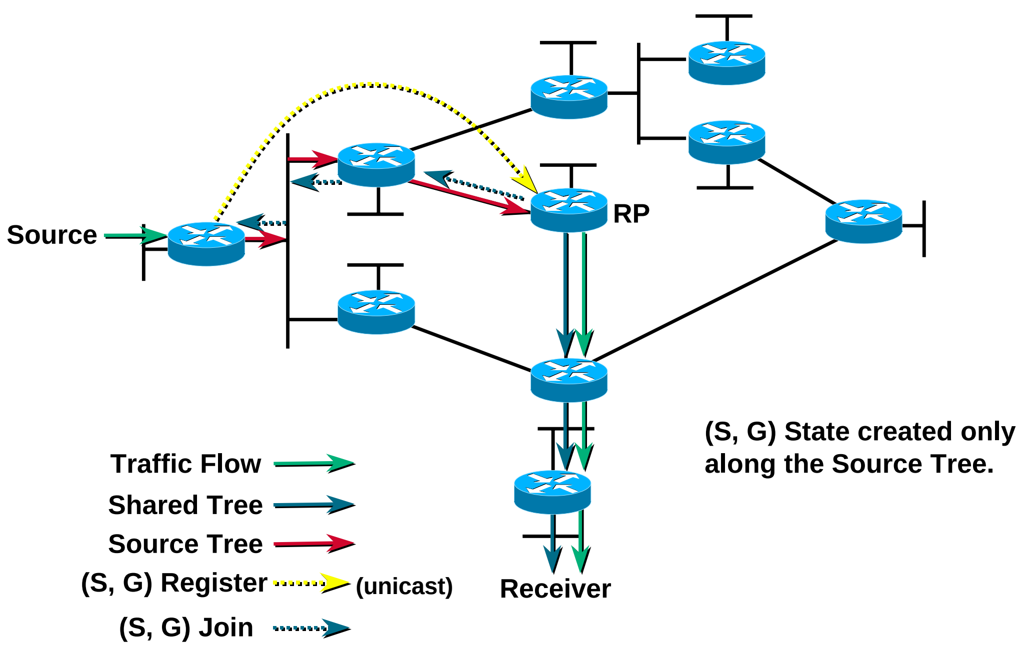
PIM-SM (RFC 2362)

- Supports both source and shared trees
  - Assumes no hosts want multicast traffic unless they specifically ask for it
- Uses a Rendezvous Point (RP)
  - Senders and Receivers "rendezvous" at this point to learn of each others existence.
    - Senders are "registered" with RP by their first-hop router.
    - Receivers are "joined" to the Shared Tree (rooted at the RP) by their local Designated Router (DR).
- Appropriate for…
  - Wide scale deployment for *both* densely and sparsely populated groups in the enterprise
  - Optimal choice for all production networks regardless of size and membership density.

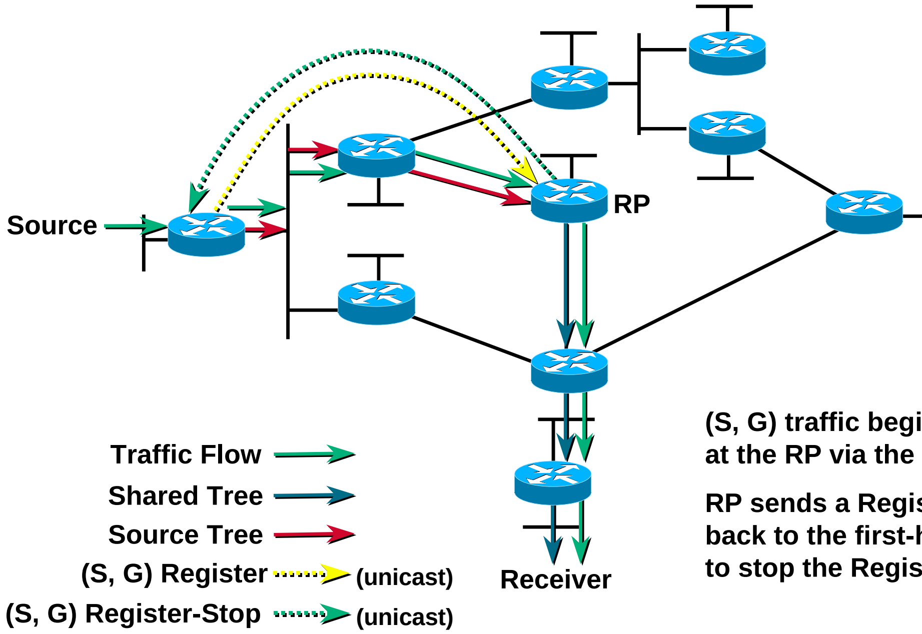
PIM-SM Shared Tree Join



PIM-SM Sender Registration



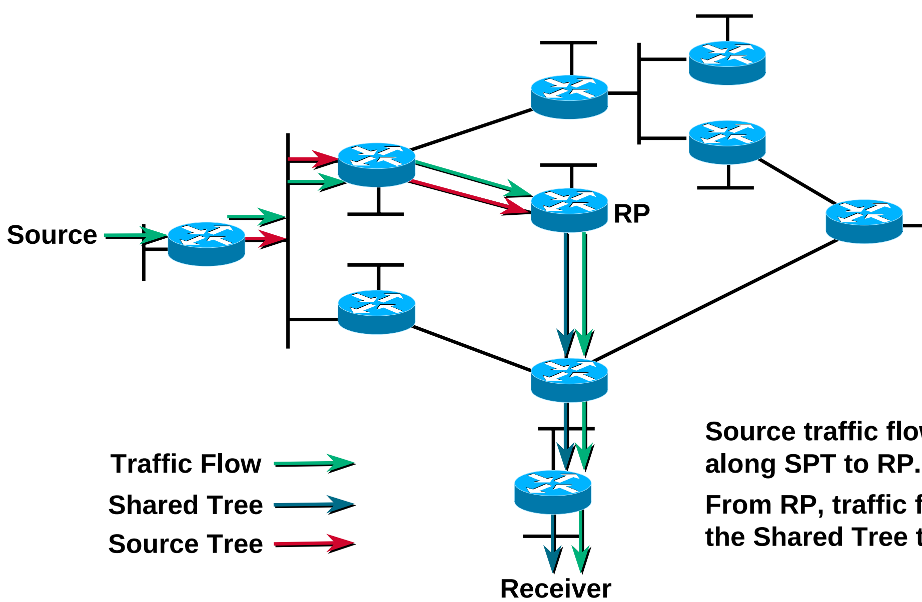
PIM-SM Sender Registration



(S, G) traffic begins arriving at the RP via the Source tree.

RP sends a Register-Stop back to the first-hop router to stop the Register process.

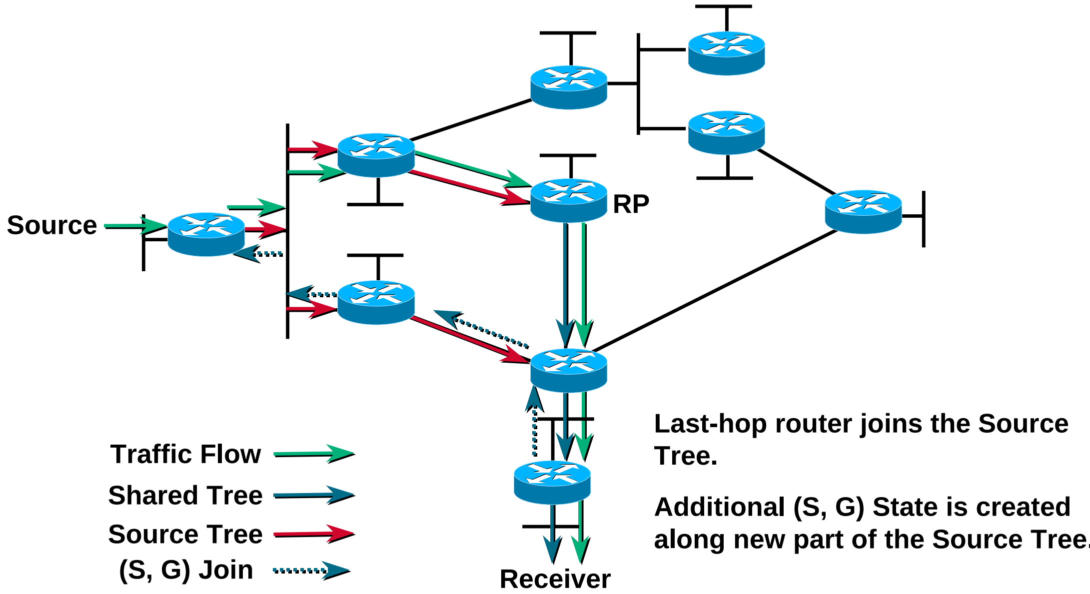
PIM-SM Sender Registration



Source traffic flows natively along SPT to RP.

From RP, traffic flows down the Shared Tree to Receivers.

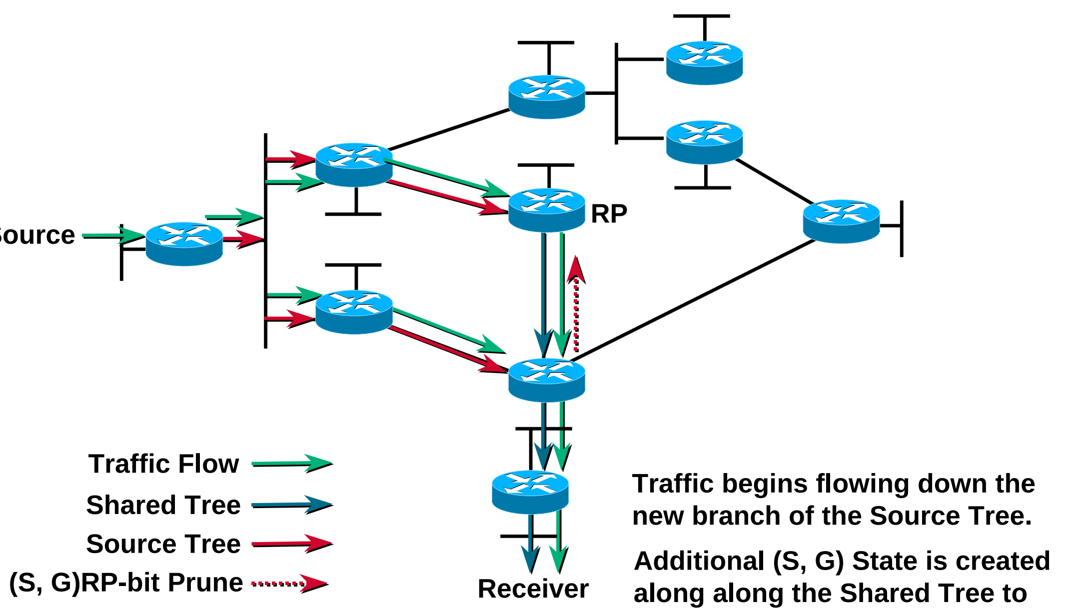
PIM-SM SPT Switchover



Last-hop router joins the Source Tree.

Additional (S, G) State is created along new part of the Source Tree.

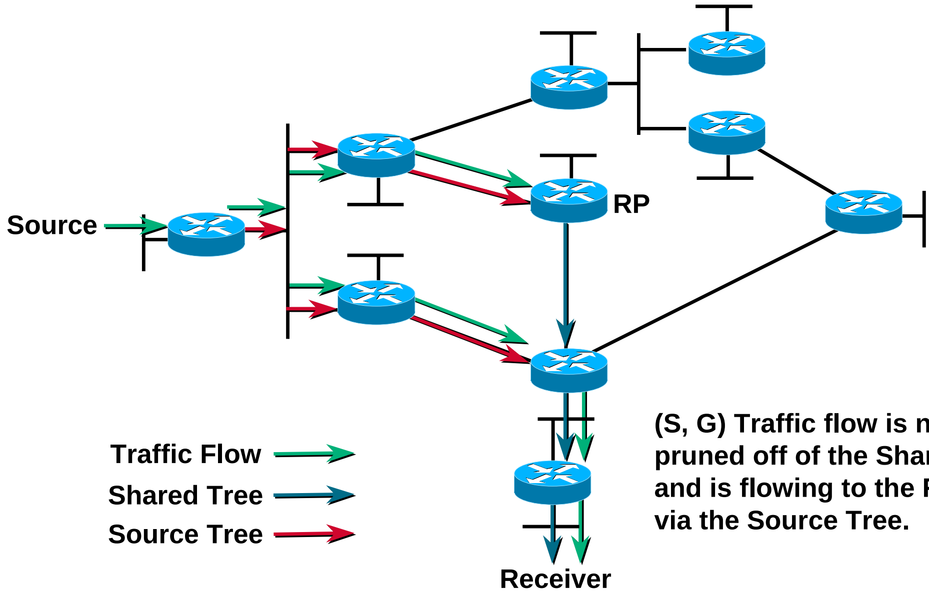
PIM-SM SPT Switchover



Traffic begins flowing down the new branch of the Source Tree.

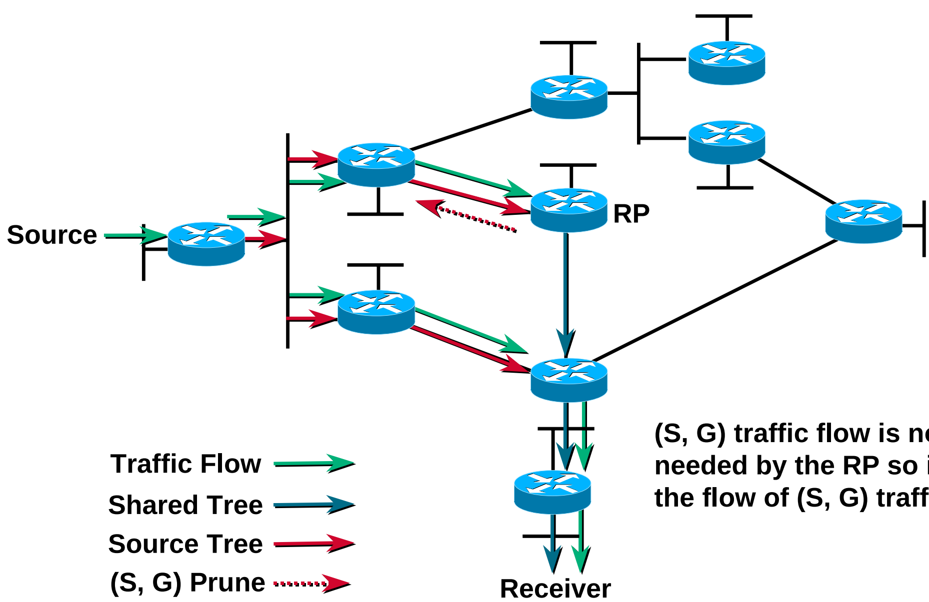
Additional (S, G) State is created along along the Shared Tree to prune off (S, G) traffic.

PIM-SM SPT Switchover



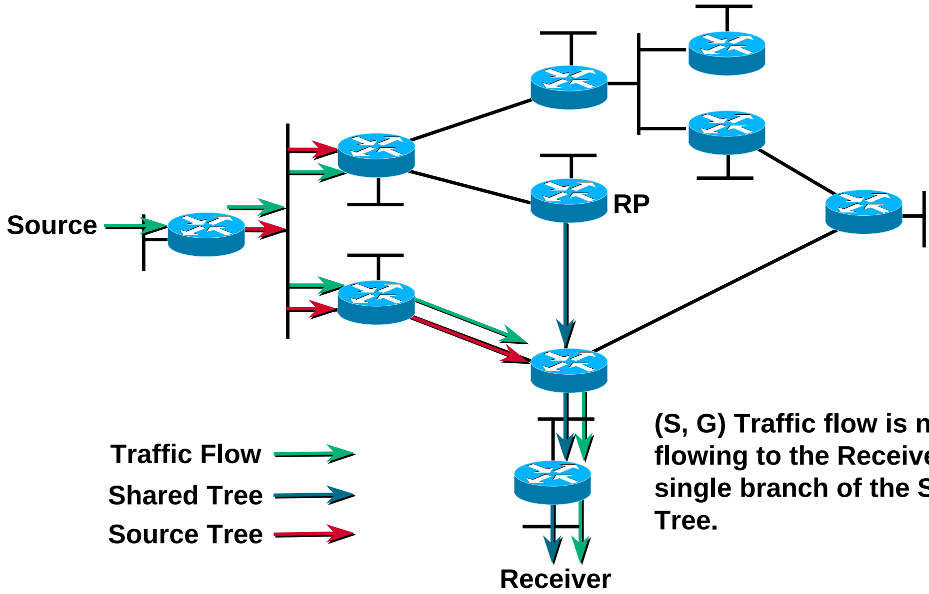
(S, G) Traffic flow is now pruned off of the Shared Tree and is flowing to the Receiver via the Source Tree.

PIM-SM SPT Switchover



(S, G) traffic flow is no longer needed by the RP so it Prunes the flow of (S, G) traffic.

PIM-SM SPT Switchover



(S, G) Traffic flow is now only flowing to the Receiver via a single branch of the Source Tree.

PIM-SM FFF

PIM-SM Frequently Forgotten Fact

The *default* behavior of PIM-SM in Cisco IOS is that routers with directly connected members will join the Shortest Path Tree as soon as they detect a new multicast source.

PIM-SM—Evaluation

- Effective for sparse or dense distribution of multicast receivers
- Advantages:
  - Traffic only sent down “joined” branches
  - Can switch to optimal source-trees for high traffic sources dynamically
  - Unicast routing protocol-independent
  - Basis for inter-domain multicast routing
    - When used with MBGP and MSDP

Other Multicast Protocols

- Academic works-in-progress
- Run primarily on MS Power Point

Documentation and Contact Info

- **EFT/Beta Site Web Page:**

  ftp://ftpeng.cisco.com/ipmulticast.html

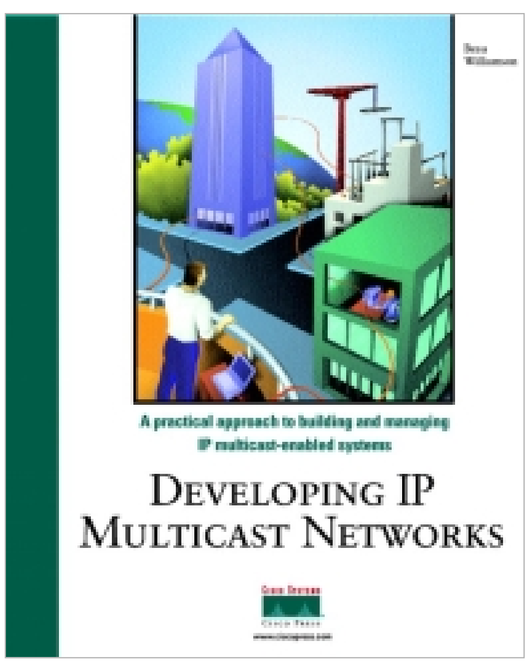
- **TAC Support Mailing List:**

  tac@cisco.com

- **Customer Support Mailing List:**

  cs-ipmulticast@cisco.com

If All Else Fails—RTFB[1]



[1] **Read this fine book**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