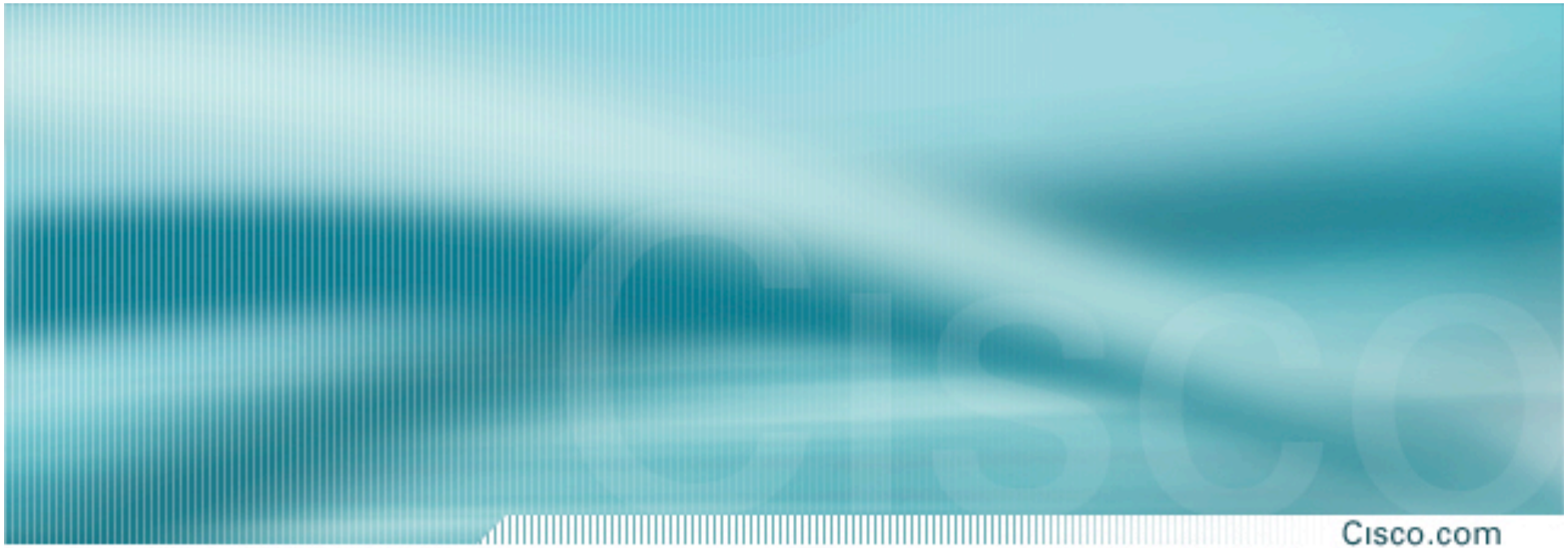
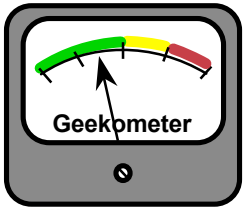


Fundamentals of IP Multicast

Module Objectives

- Recognize when to use IP Multicast
- Identify the fundamental concepts involved in IP Multicasting
- Characterize the differences in various IP Multicast routing protocols

Agenda



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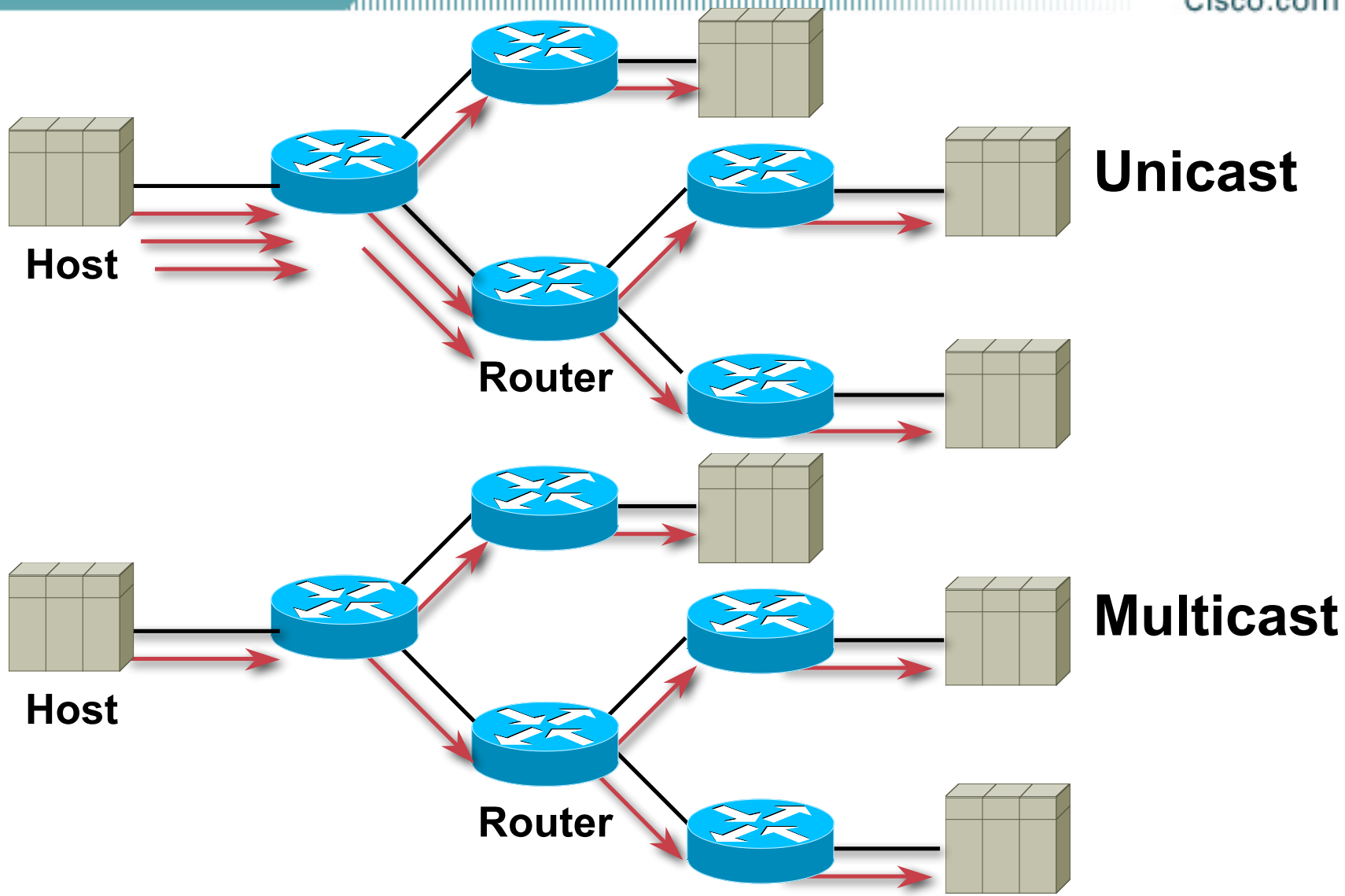
- Why Multicast
- Multicast Applications
- Multicast Service Model
- Multicast Distribution Trees
- Multicast Forwarding
- Multicast Protocol Basics
- Multicast Protocol Review

Why Multicast?

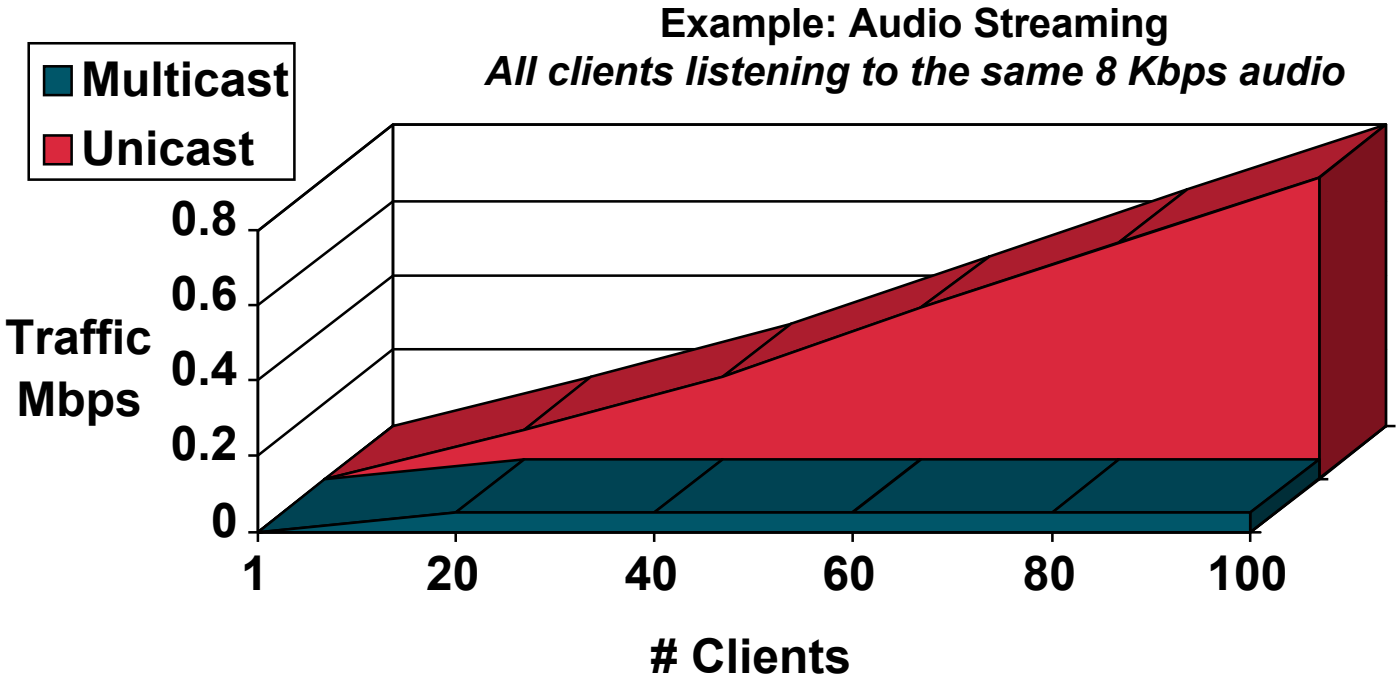
- When sending same data to multiple receivers
- Better bandwidth utilization
- Less host/router processing
- Receivers' addresses unknown

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 Shortest-Path Tree Transitions) result in the occasional generation of duplicate packets. Multicast applications should be designed to expect occasional duplicate packets.**
- ***Out-of-Sequence Packets:* Various network events can result in packets arriving out of sequence. Multicast applications should be designed to handle packets that arrive in some other sequence than they were sent by the source.**

Multicast Applications

Today

- **Finance Applications**
  - –Trading Stocks and Commodities
- **Streaming Multimedia**
  - –E-Learning
  - –Corporate communications
- **Enterprise Resource Applications**
  - –Data warehousing and content synchronization
- **Any one-to-many data push applications**

Tomorrow

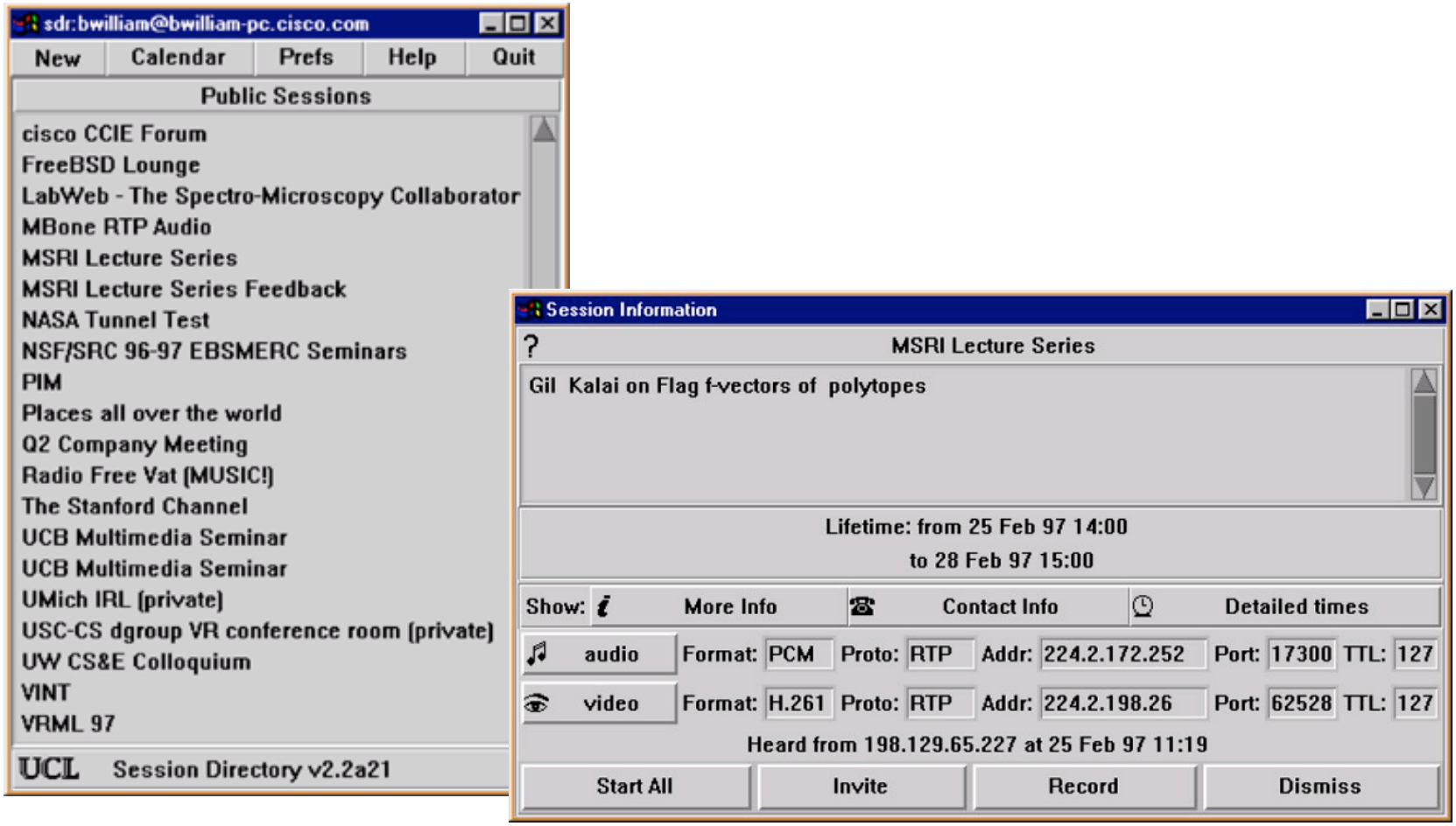
- **Broadband access**
- **Video conferencing**
- **Digital TV**
- **Digital audio**
- **Entertainment**
- **Networked gaming**
- **PDAs and Home appliances**

First Multicast Applications

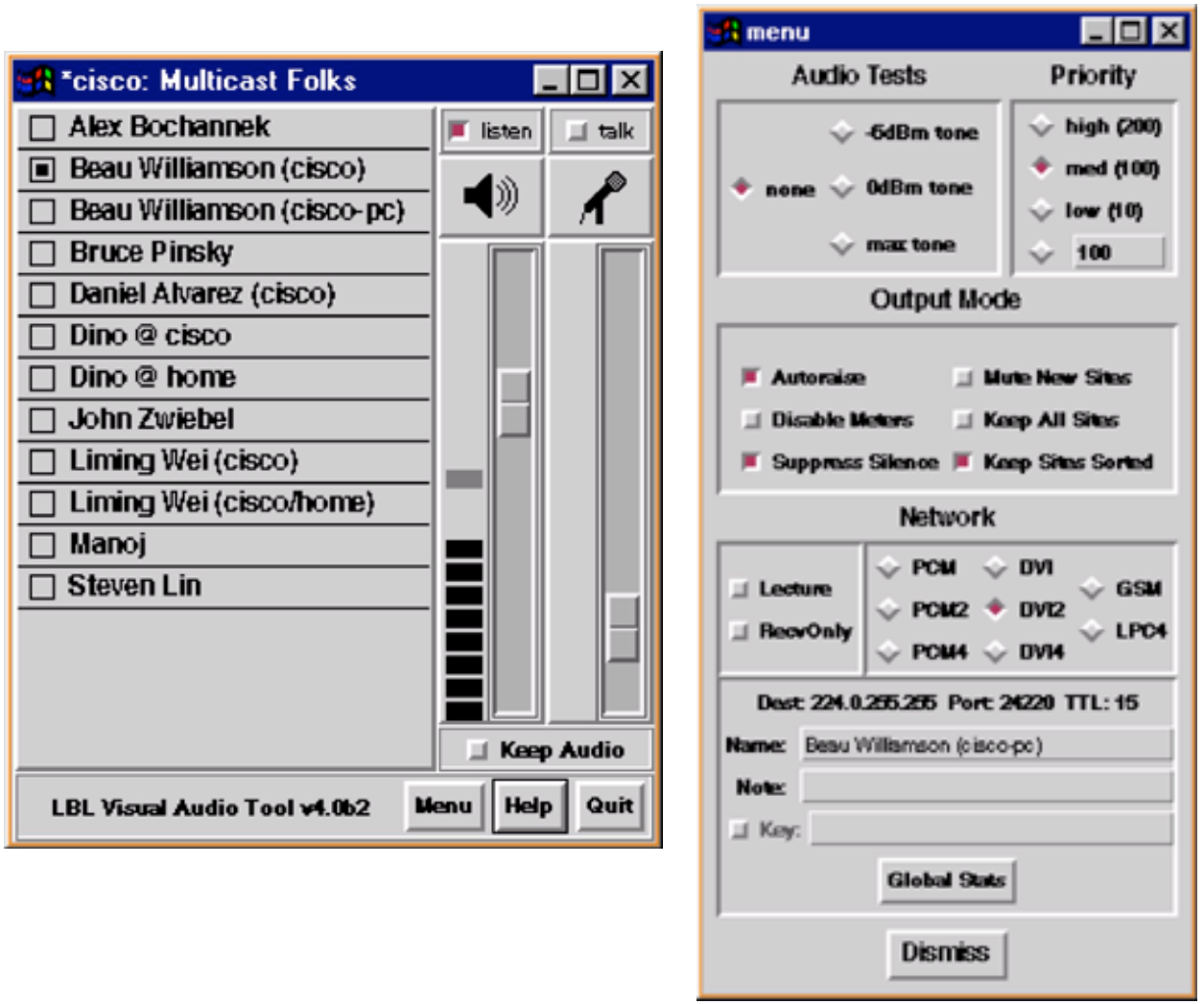
Mbone Multicast Applications

- sdr—session directory
  - Lists advertised sessions
  - Launches multicast application(s)
- rat—audio conferencing
  - PCM, DVI, GSM, and LPC4 compression
- vic—video conferencing
  - H.261 video compression
- wb—white board
  - Shared drawing tool
  - Can import PostScript images
  - Uses Reliable Multicast

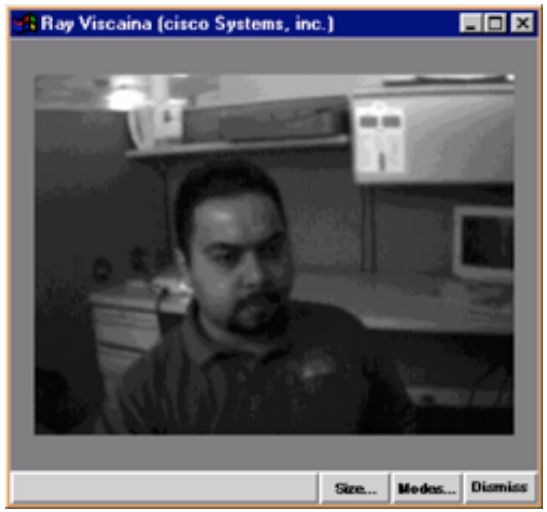
sdr—Session Directory



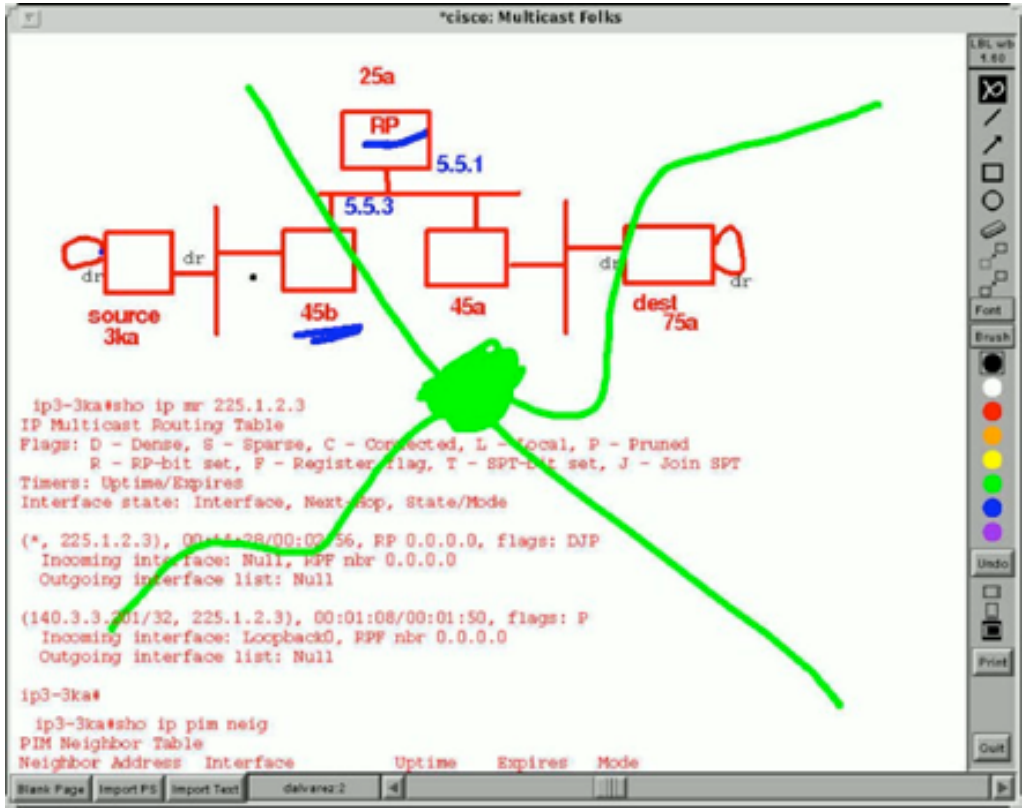
vat—Audio Conferencing



vic—Video Conferencing



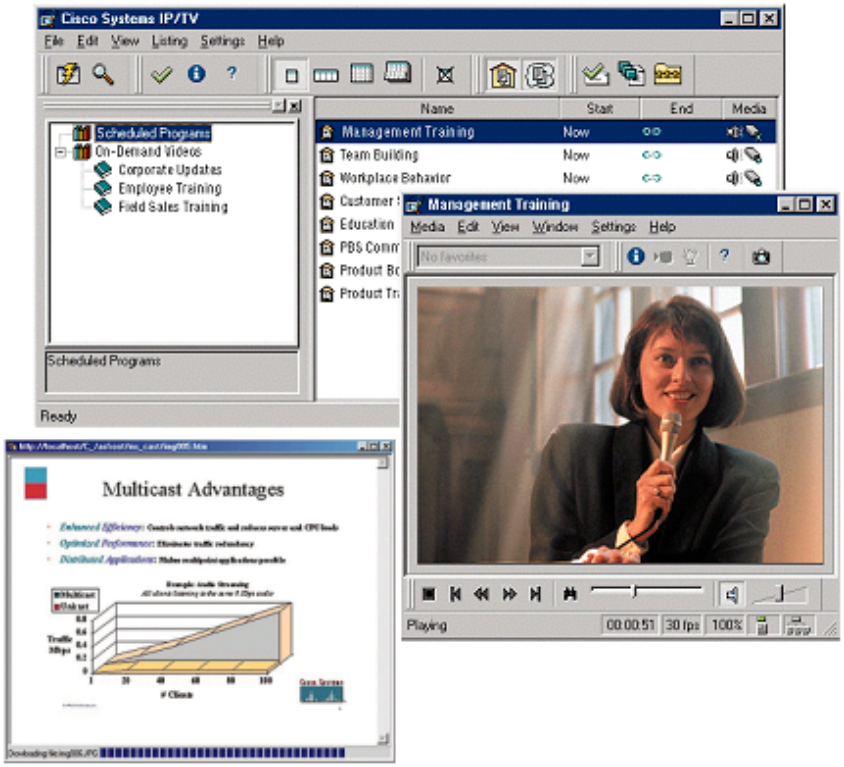
wb—White Board



Popular Multicast Applications

- IP/TV
- Hoot-n-Holler
- VoIP Music-on-Hold
- Tibco Data Distribution

IP/TV

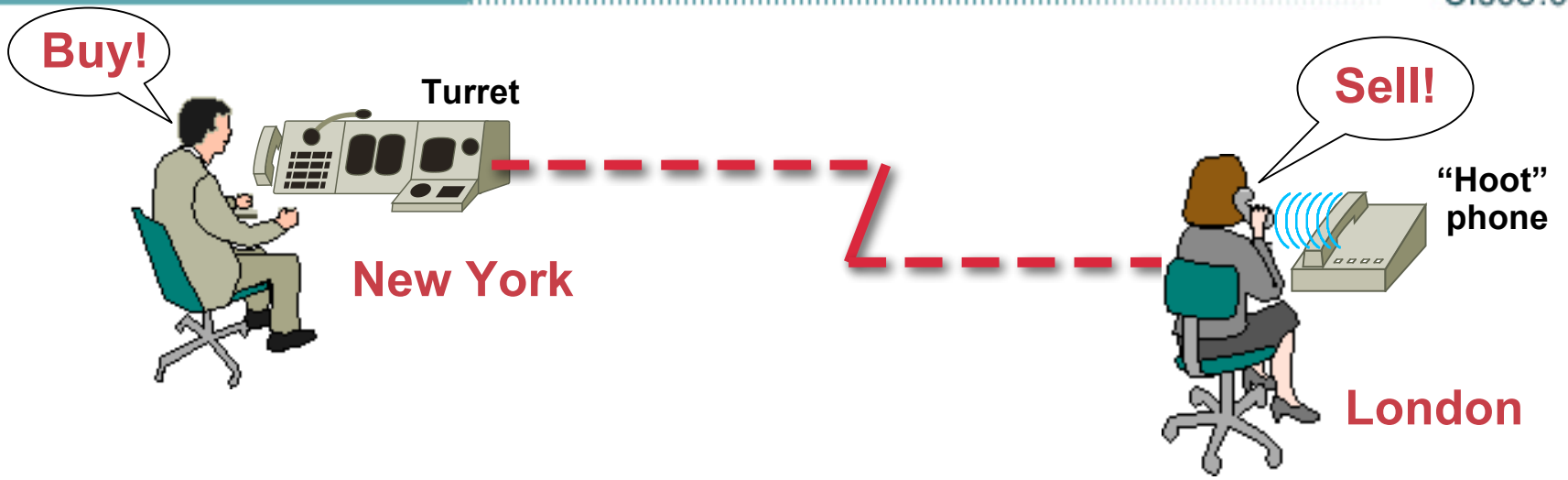


- **One-to-many video multicast**
  - **Live or Rebroadcast Content**
  - **Synchronized Presentations**
  - **Integrated "Question Manager"**
  - **Video-on-Demand (VoD) (Unicast only)**

Hoot-n-Holler

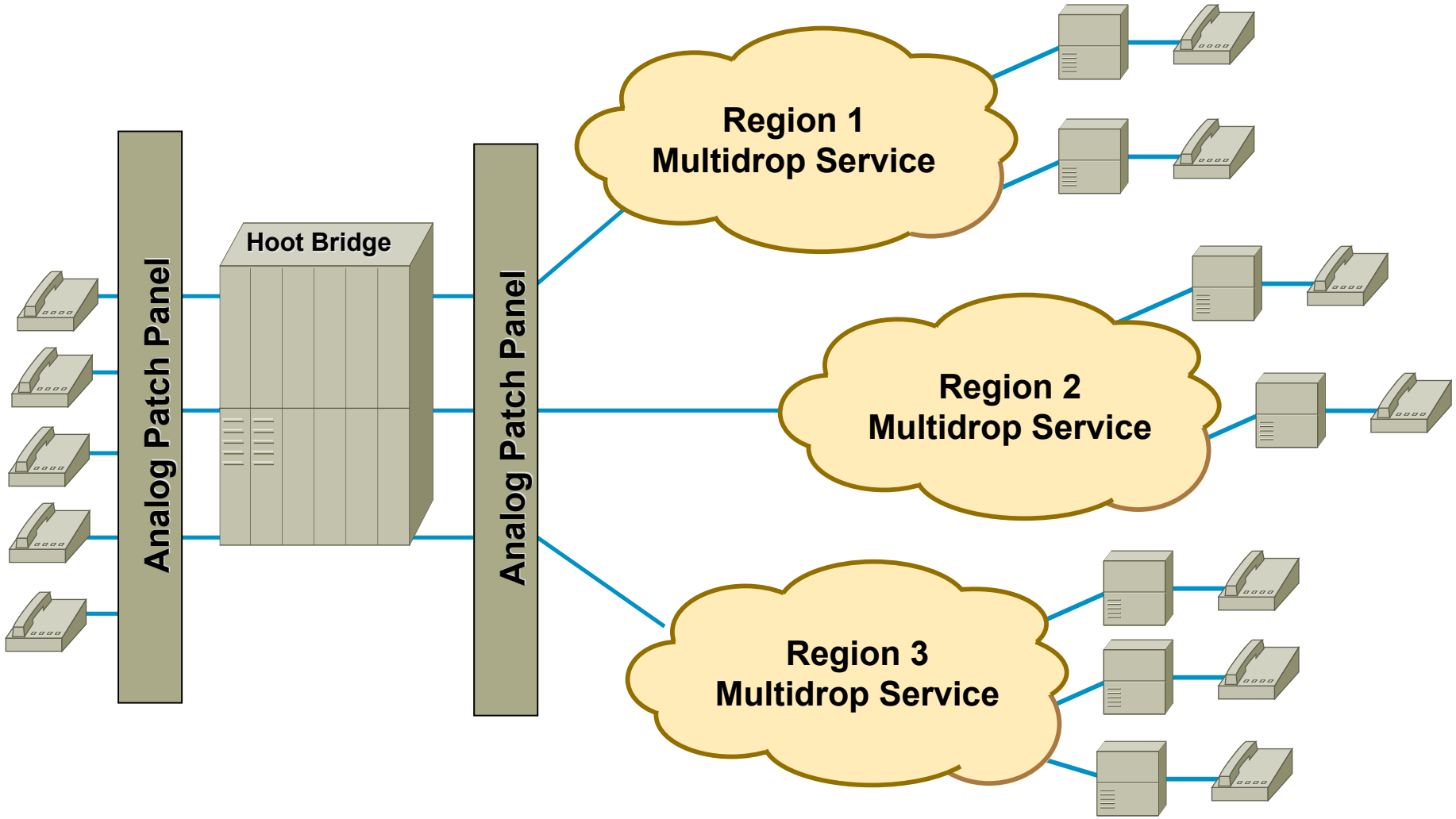
Hoot-n-Holler Turret

Hoot 'n' Holler

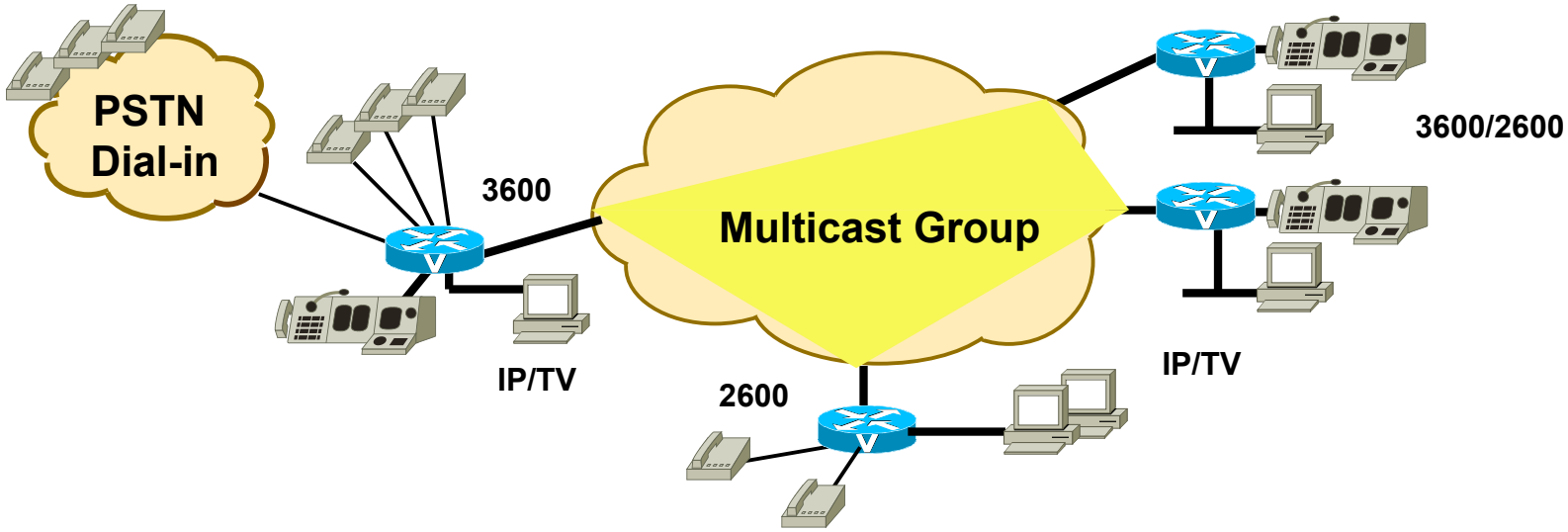


- Broadcast audio network
- Typically point to multipoint
- Uses specialized analog 4-wire phones (Hoot phones) and digital turrets
- Brokerages, utilities, media companies, mass transit, publishing, etc.

Traditional Hoot and Holler Network Design

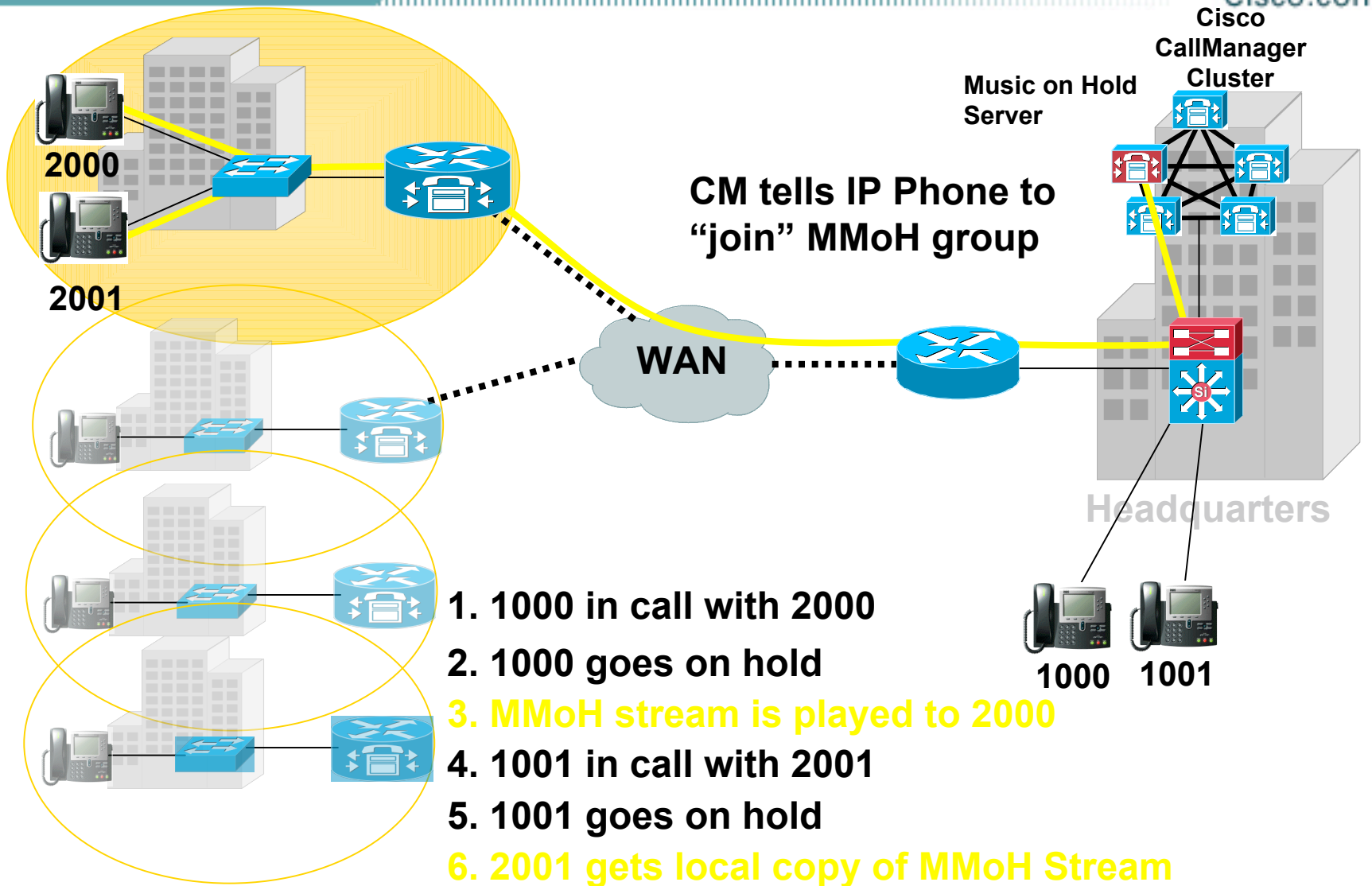


Hoot 'n' Holler over IP Multicast



- Leverages VoIP, IP Multicast (IPmc) & QoS
- Bridging & audio mixing occurs in router voice DSPs
- Dynamic bandwidth sharing & cost savings
- Existing analog end systems & procedures retained

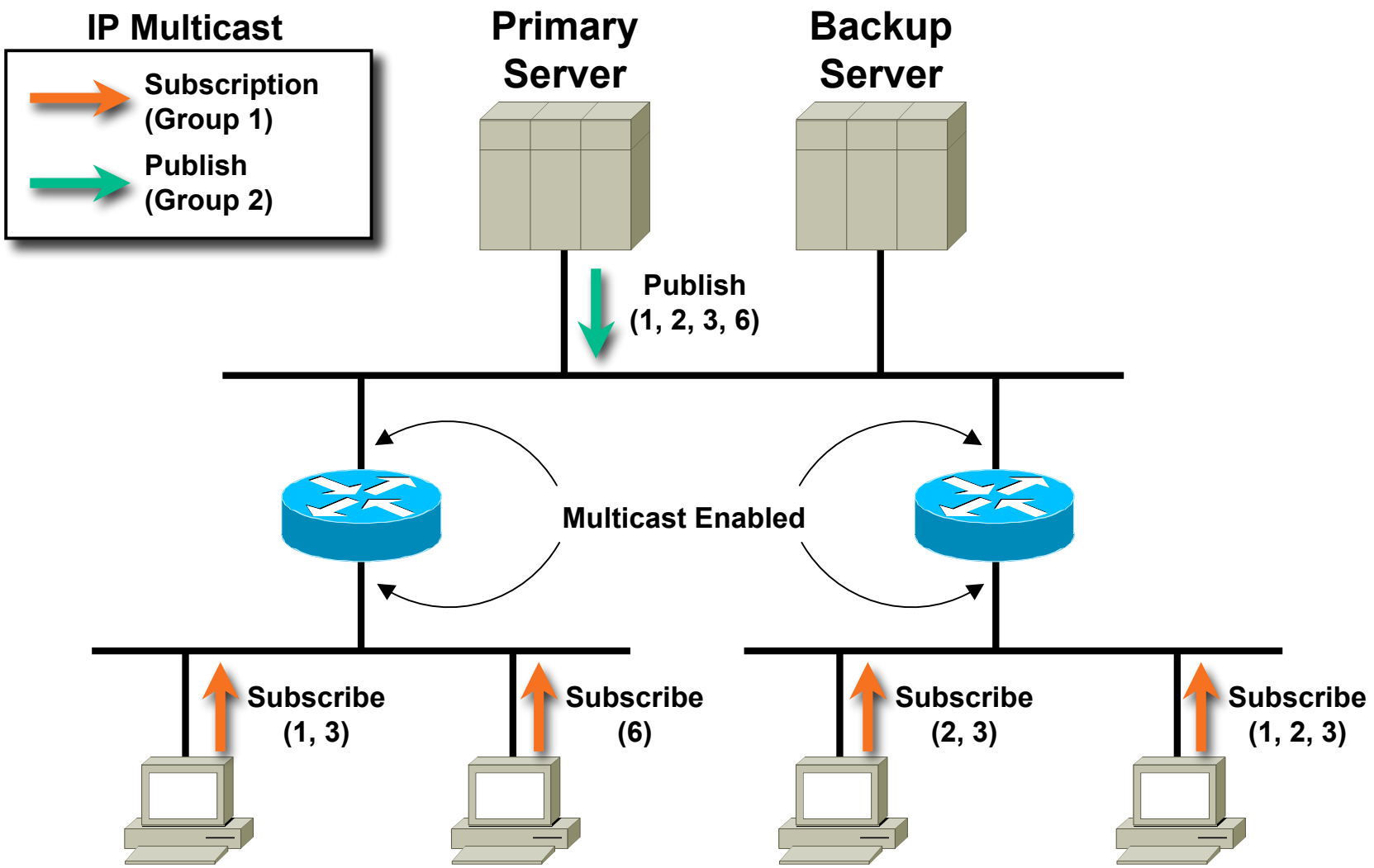
Multicast Music-on-Hold (MMoH)



TIBCO Data Distribution

- Popular with Financial Institutions
  - Used to send Stock Market data to traders
- Uses Subscribe/Publish Model
- Clients multicast Subscriptions messages
  - Specifying data flow(s) they wish to receive
- Servers receive Subscriptions
  - Build list of all requested data flows
  - Primary Server multicast requested flows
  - Backup Server takes over if Primary fails

TIBCO Data Distribution



IP Multicast Service Model

- RFC 1112 (Host Ext. for Multicast Support)
- Each multicast group identified by a class-D IP address
- Members of the group could be present anywhere in the Internet
- Members join and leave the group and indicate this to the routers
- Senders and receivers are distinct:
  i.e., a sender need not be a member
- Routers listen to all multicast addresses and use multicast routing protocols to manage groups

IP Multicast Service Model

- IP group addresses
  - Class D address—high-order 3 bits are set (224.0.0.0)
  - Range from 224.0.0.0 through 239.255.255.255
- Well known addresses designated by IANA
  - Reserved use: 224.0.0.0 through 224.0.0.255
    - 224.0.0.1—all multicast systems on subnet
    - 224.0.0.2—all routers on subnet
    - See “ftp://ftp.isi.edu/in-notes/iana/assignments/multicast-addresses”
- Transient addresses, assigned and reclaimed dynamically
  - Global scope: 224.0.1.0-238.255.255.255
  - Limited Scope: 239.0.0.0-239.255.255.255
    - Site-local scope: 239.253.0.0/16
    - Organization-local scope: 239.192.0.0/14

IP Multicast Addressing

- Dynamic Address Assignment
  - Session Directory Tool (SDR)
    - Historically used to announce session/group information on a well-known multicast group
    - Has problems scaling
  - Multicast Address Dynamic Client Allocation Protocol (MADCAP) - RFC 2730
    - Similar to DHCP
    - Server and Client API shipped in W2K
    - Applications need to support to support MADCAP
  - Multicast Address Set-Claim (MASC) - RFC 2909
    - Hierarchical, dynamic address allocation scheme
    - Top of hierarchy is at an Internet exchange
    - Children request addresses from parent
    - Complex garbage-collection problem
    - Long ways off

IP Multicast Addressing

- **Static Global Group Address Assignment**
  - **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 RFC 2770**
    - **“GLOP Addressing in 233/8”**
- **Manual Address Allocation by the Admin !!**
  - **Is still the most common practice in Enterprises**

Multicast Protocol Basics

- Multicast Distribution Trees
- Multicast Forwarding
- Types of Multicast Protocols
  - Dense Mode Protocols
  - Sparse Mode Protocols

Multicast Distribution Trees

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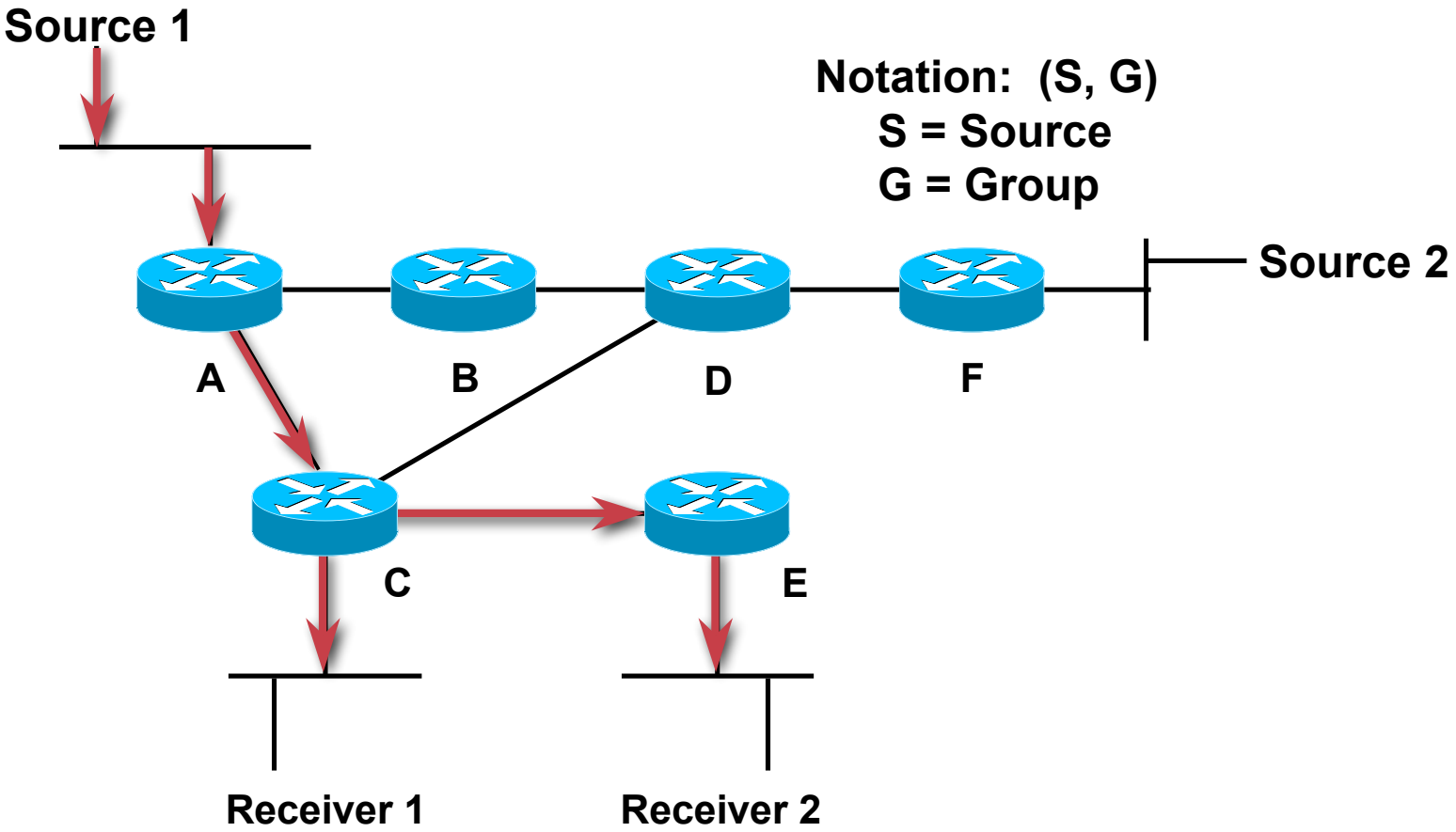
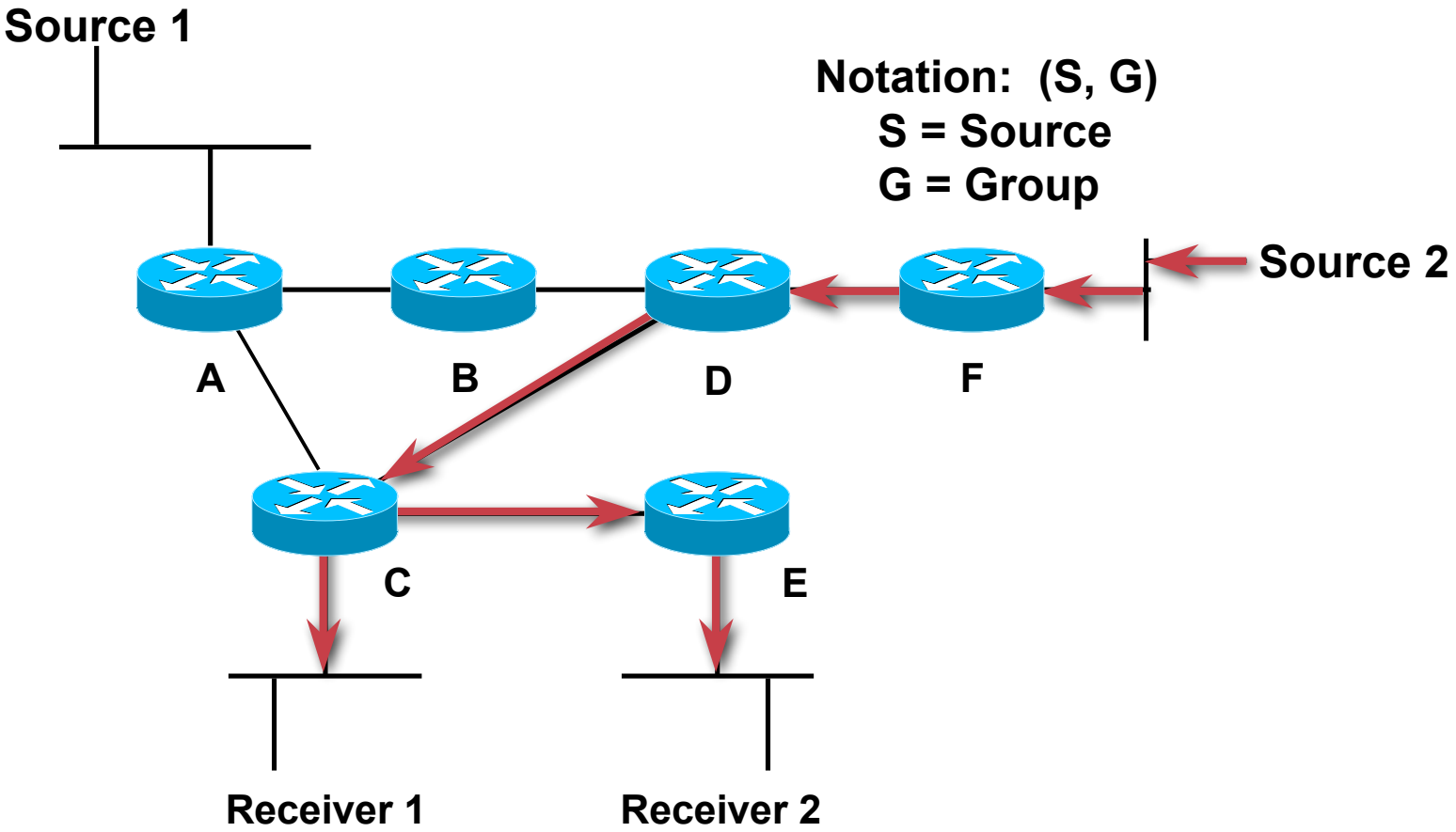
Shortest Path or Source Distribution Tree



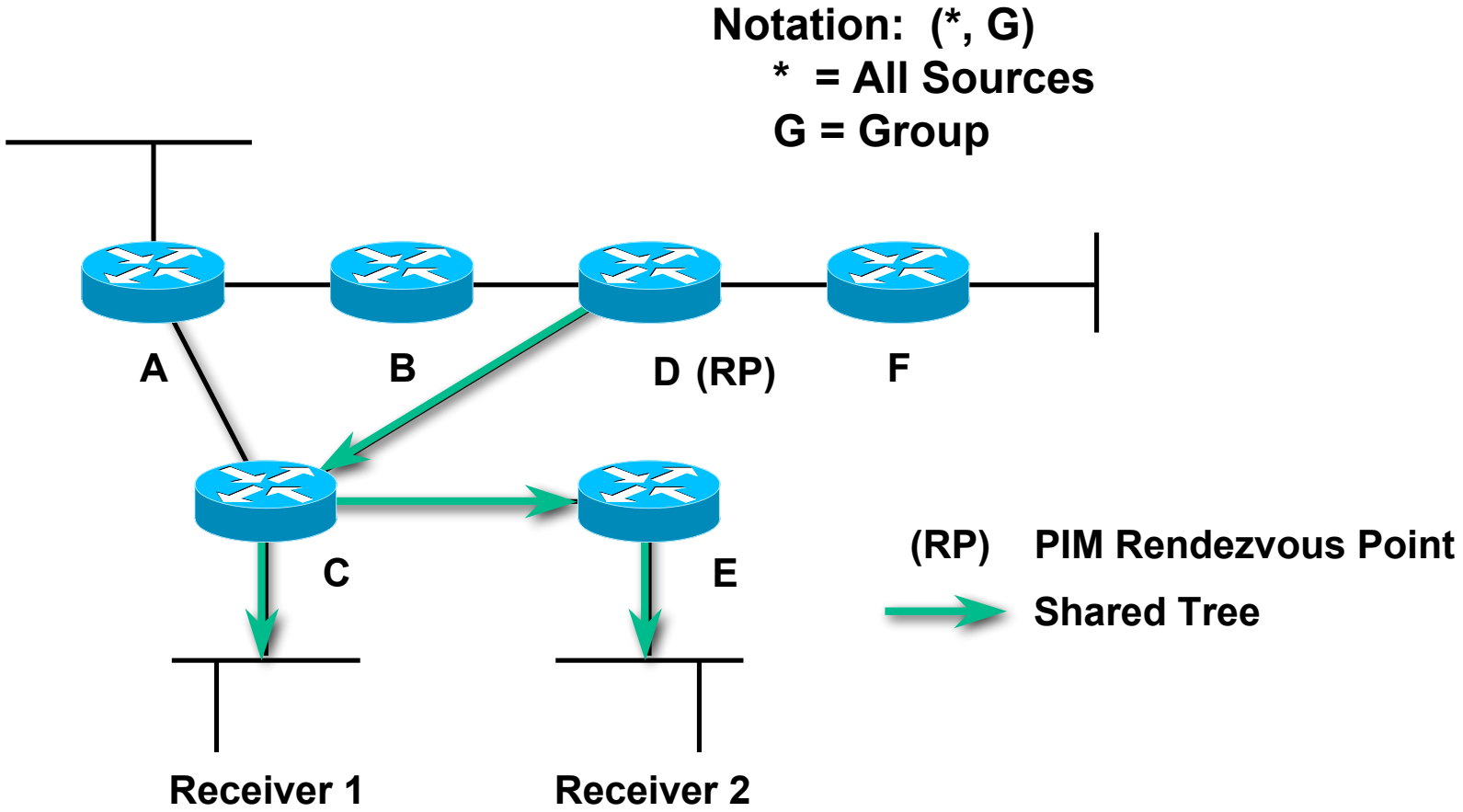
Multicast Distribution Trees

Shortest Path or Source Distribution Tree



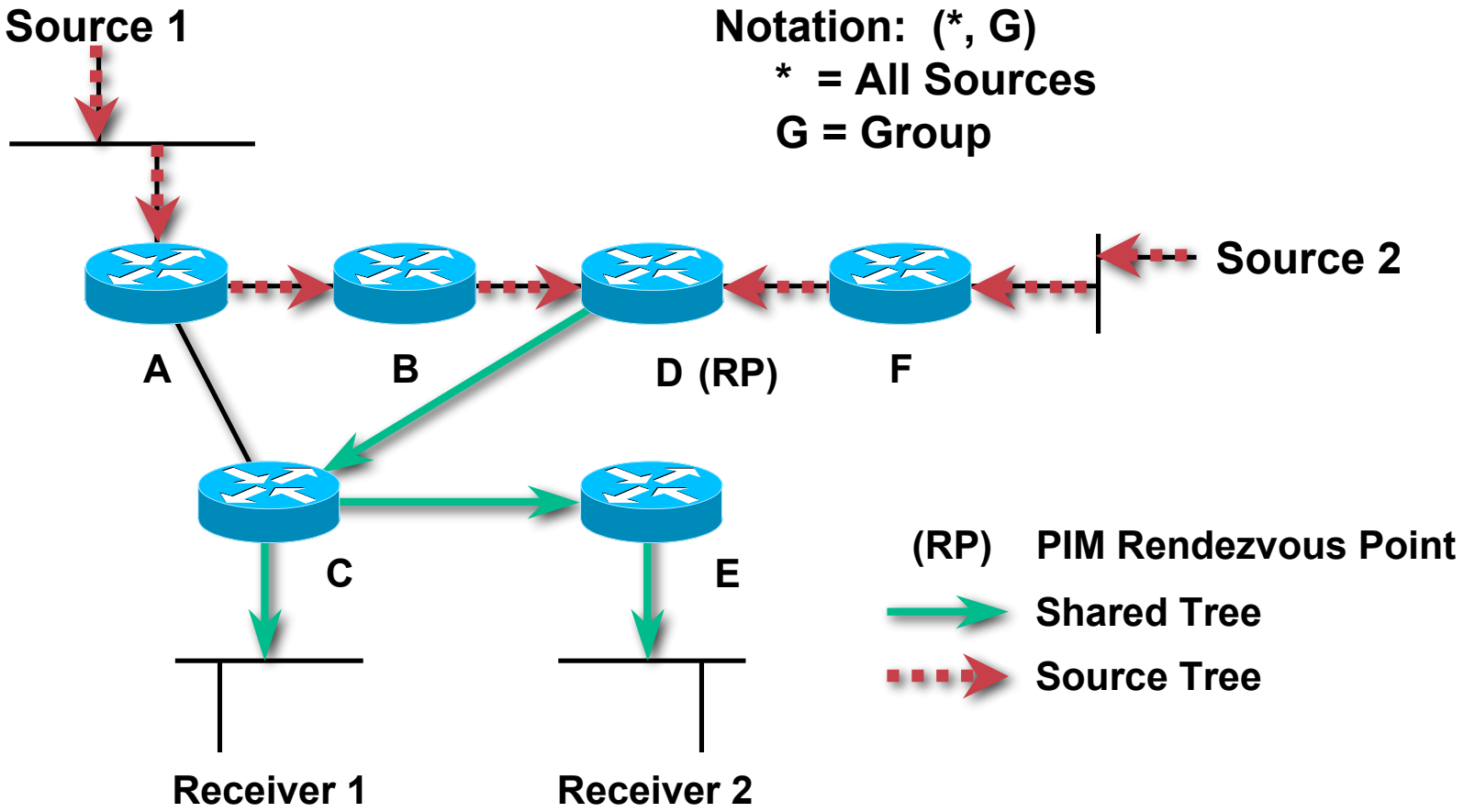
Multicast Distribution Trees

Shared Distribution Tree



Multicast Distribution Trees

Shared Distribution Tree



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

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”

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).

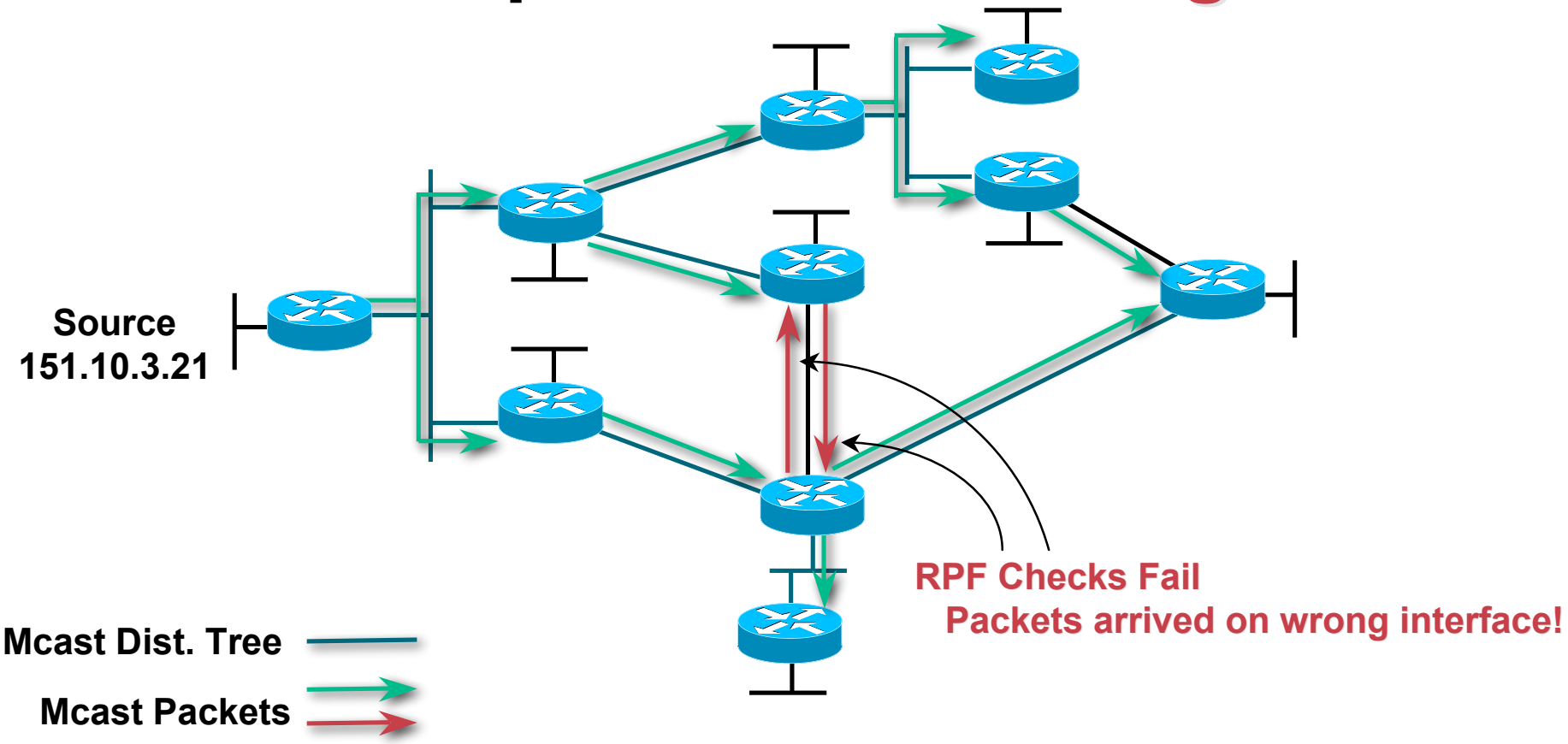
- **The RPF Check**
  - **The routing table used for multicasting is checked against the "source" address in the multicast datagram.**
  - **If the datagram arrived on the interface specified in the routing table for the source address; then the RPF check succeeds.**
  - **Otherwise, the RPF Check fails.**

Reverse Path Forwarding (RPF)

- If the RPF check succeeds, the datagram is forwarded
- If the RPF check fails, the datagram is typically silently discarded
- When a datagram is forwarded, it is sent out each interface in the outgoing interface list
- Packet is never forwarded back out the RPF interface!

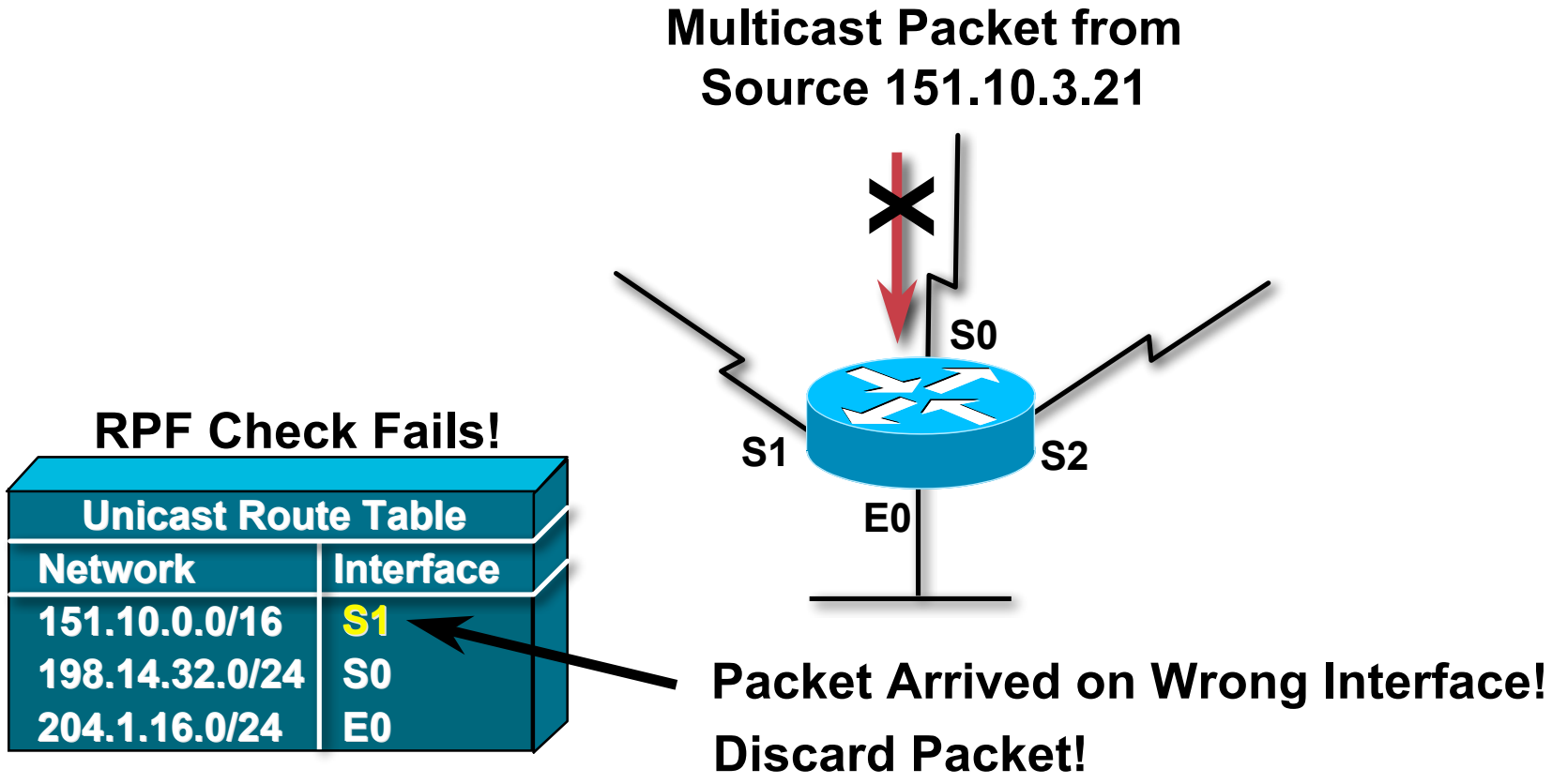
Reverse Path Forwarding (RPF)

Example: RPF Checking



Reverse Path Forwarding (RPF)

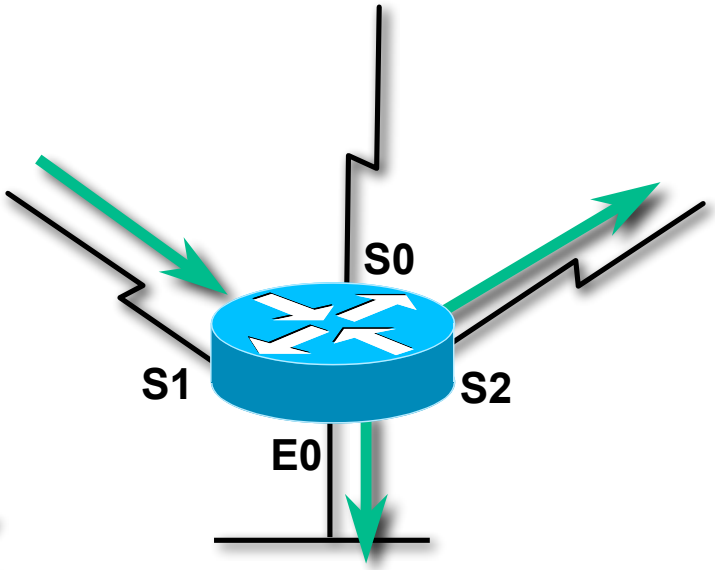
A closer look: RPF Check Fails



Reverse Path Forwarding (RPF)

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)

TTL Thresholds

- **What is a TTL Threshold?**

  A "TTL Threshold" may be set on a multicast router interface to limit the forwarding of multicast traffic to outgoing packets with TTLs greater than the Threshold.

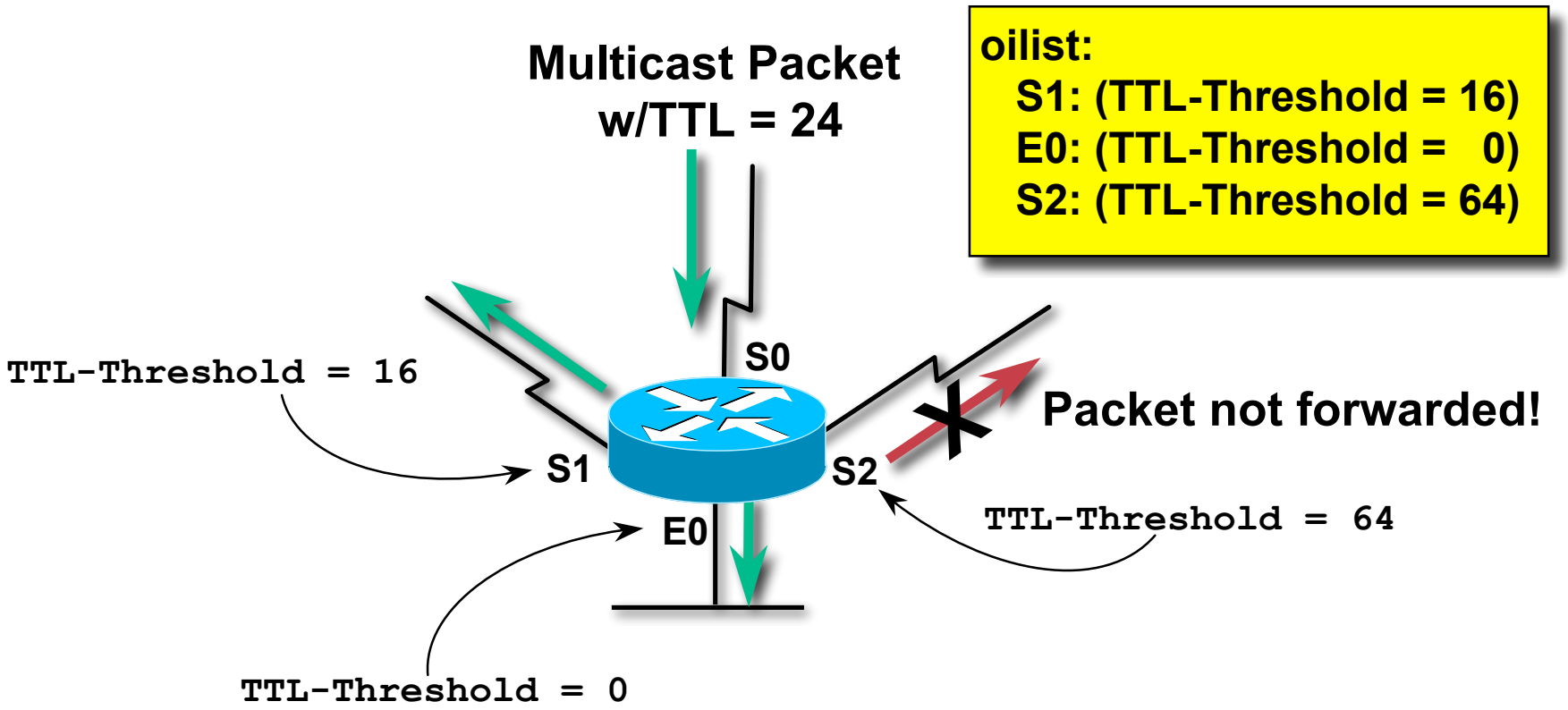
- **The TTL Threshold Check**

  1) All incoming IP packets first have their TTL decremented byone. If <= Zero, they are dropped.

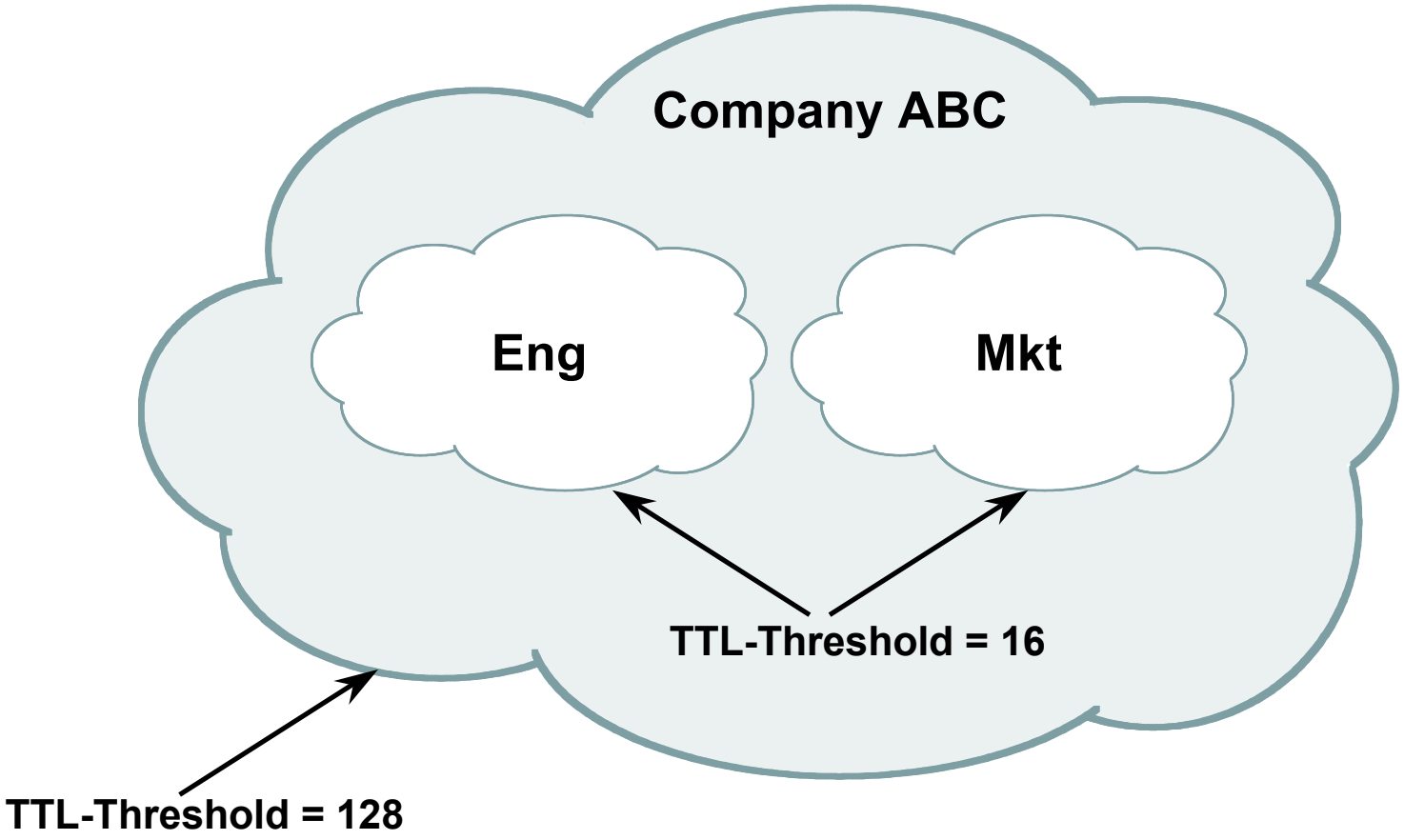
  2) If a multicast packet is to be forwarded out an interface with a non-zero TTL Threshold; then it's TTL is checked against the TTL Threshold. If the packet's TTL is < the specified threshold, it is not forwarded out the interface.

TTL Thresholds

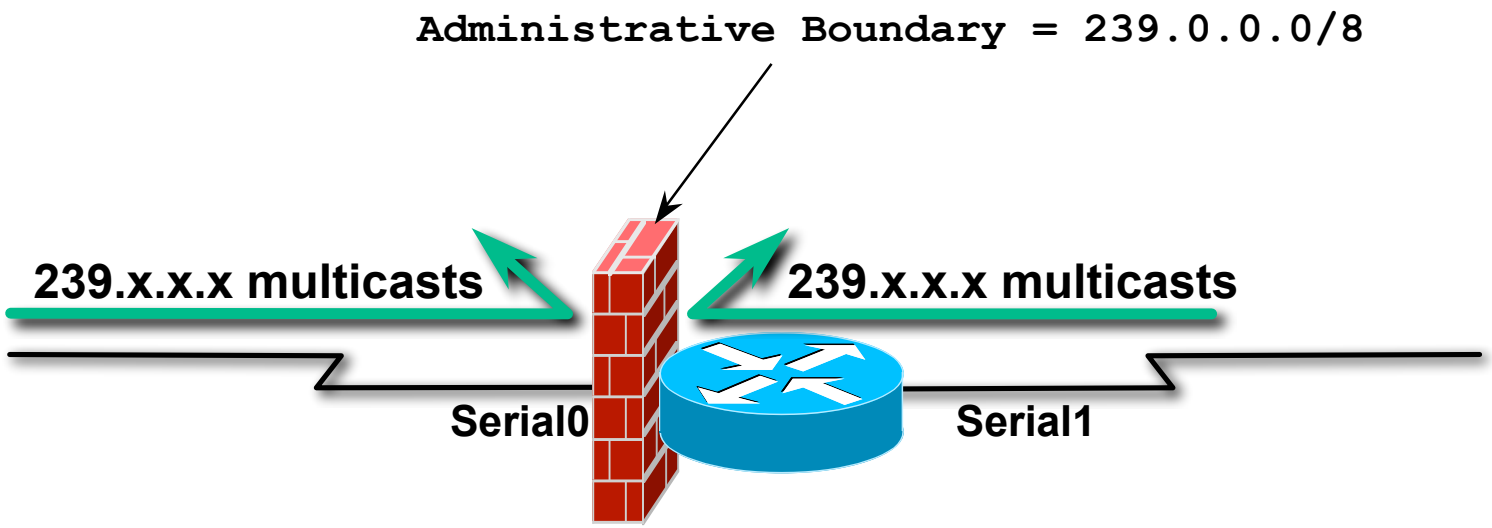
A closer look: TTL-Thresholds



TTL Threshold Boundaries

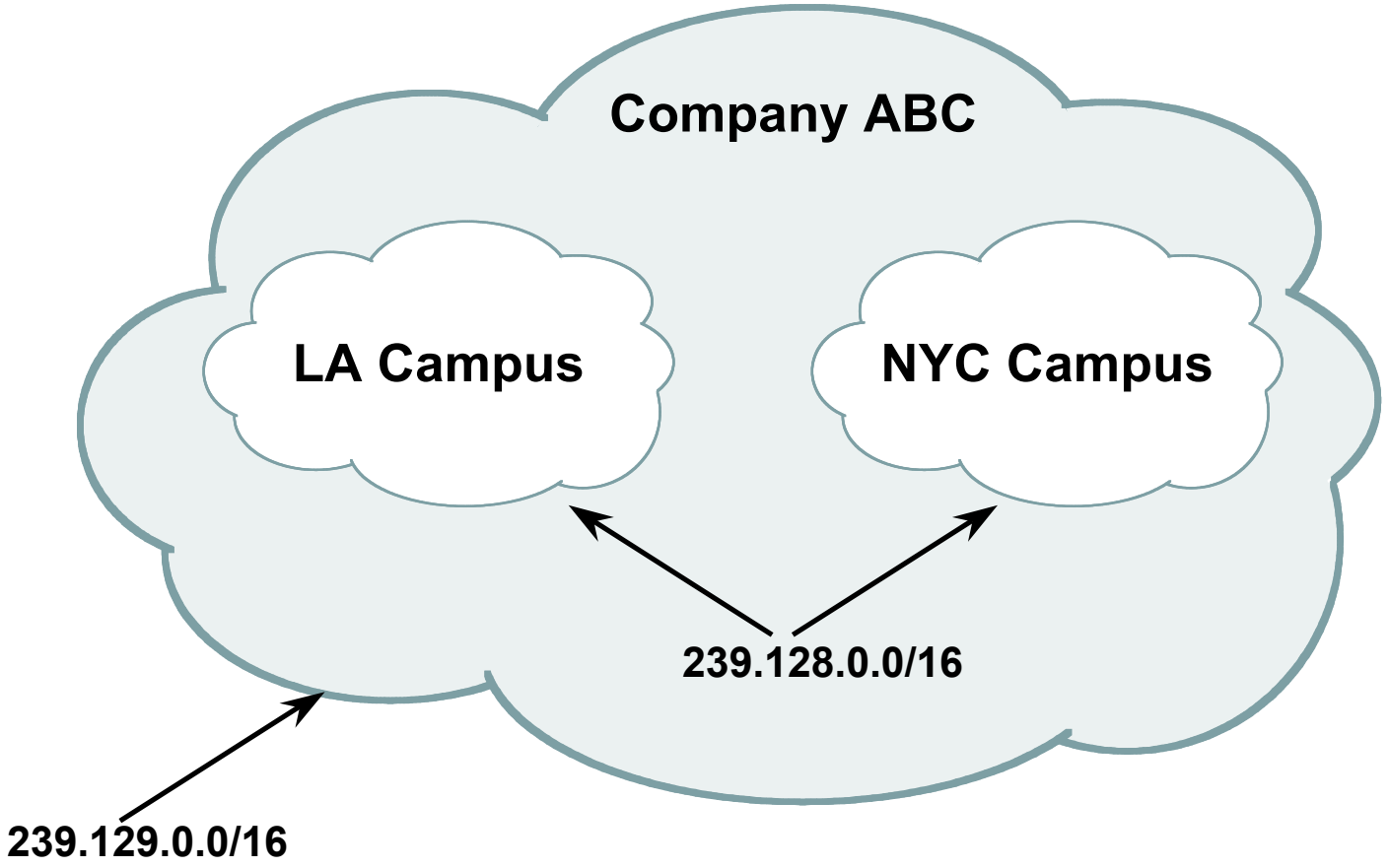


Administrative Boundaries



- Configured using the '`ip multicast boundary <acl>`' interface command

Administrative Boundaries



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

Legacy Protocols

- DVMRP – Distance Vector Multicast Routing Protocol
- MOSPF – Multicast OSPF

Legacy Protocol Summary

CONCLUSION

"DVMRP and MOSPF are legacy protocols that do not scale in today's networks"

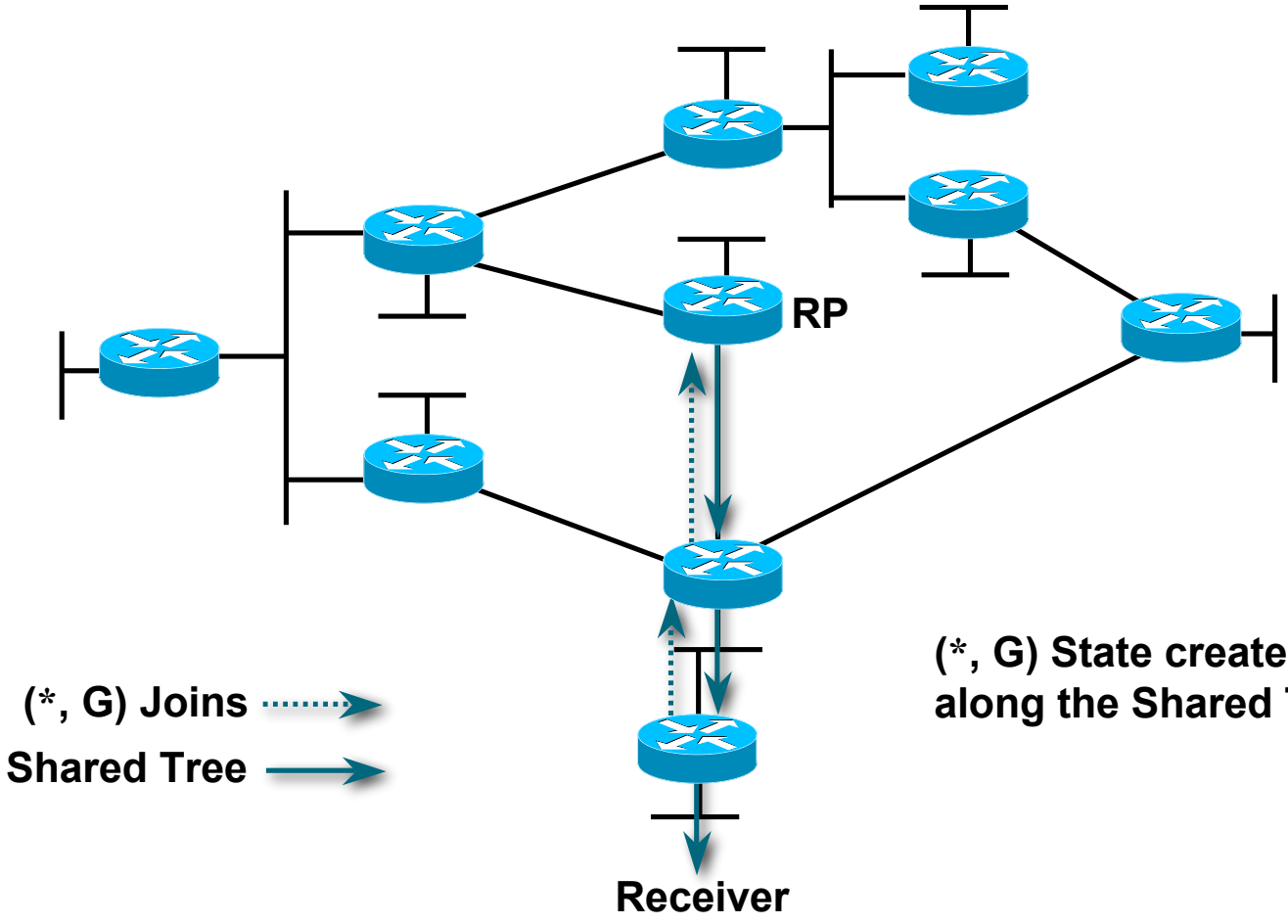
PIM – Protocol Independent Multicast

- PIM-DM (Dense Mode)
  - Another “legacy” protocol
  - Very limited applicability today
- PIM-SM (Sparse Mode)

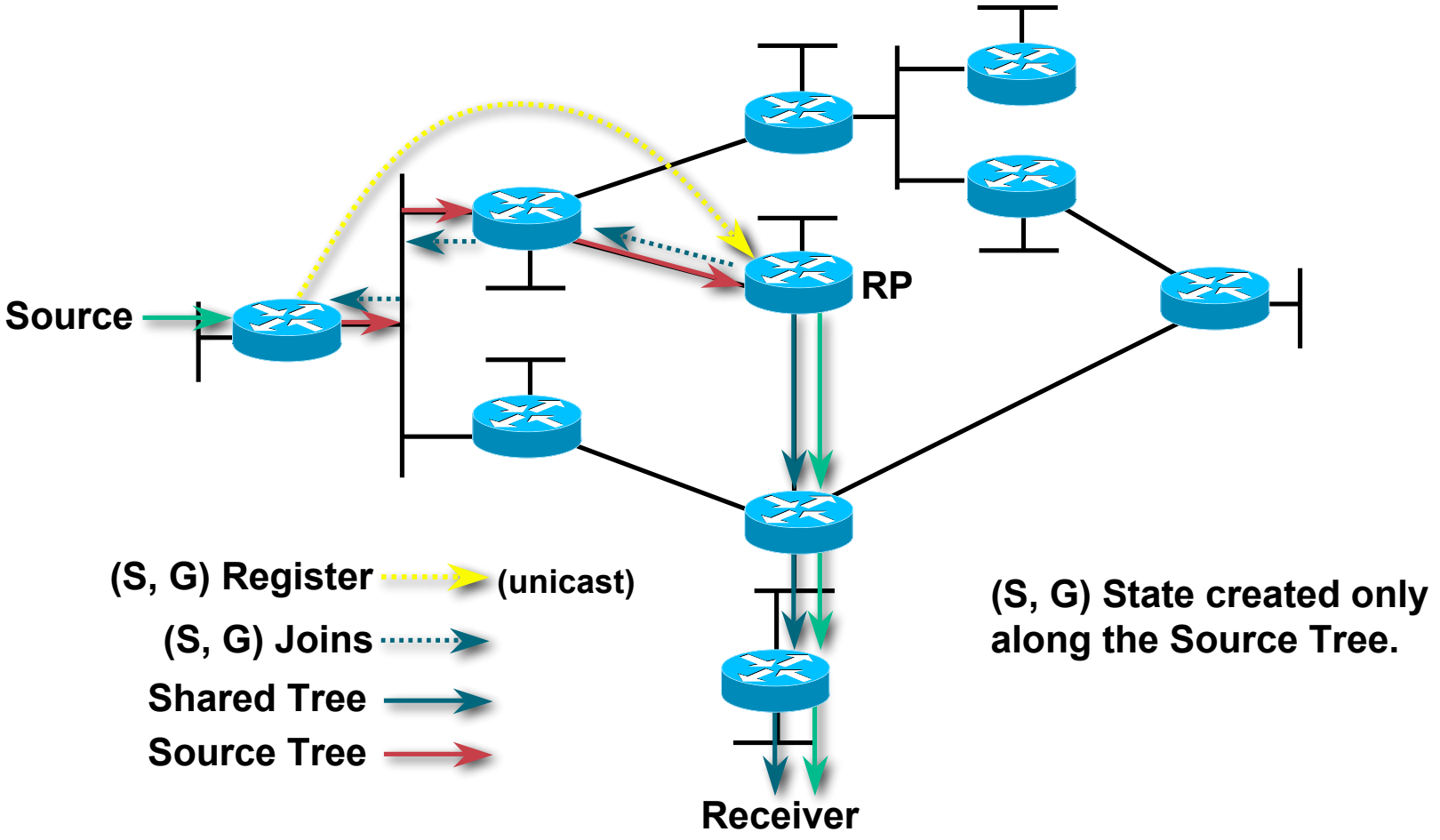
PIM-SM (RFC 2362)

- 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.

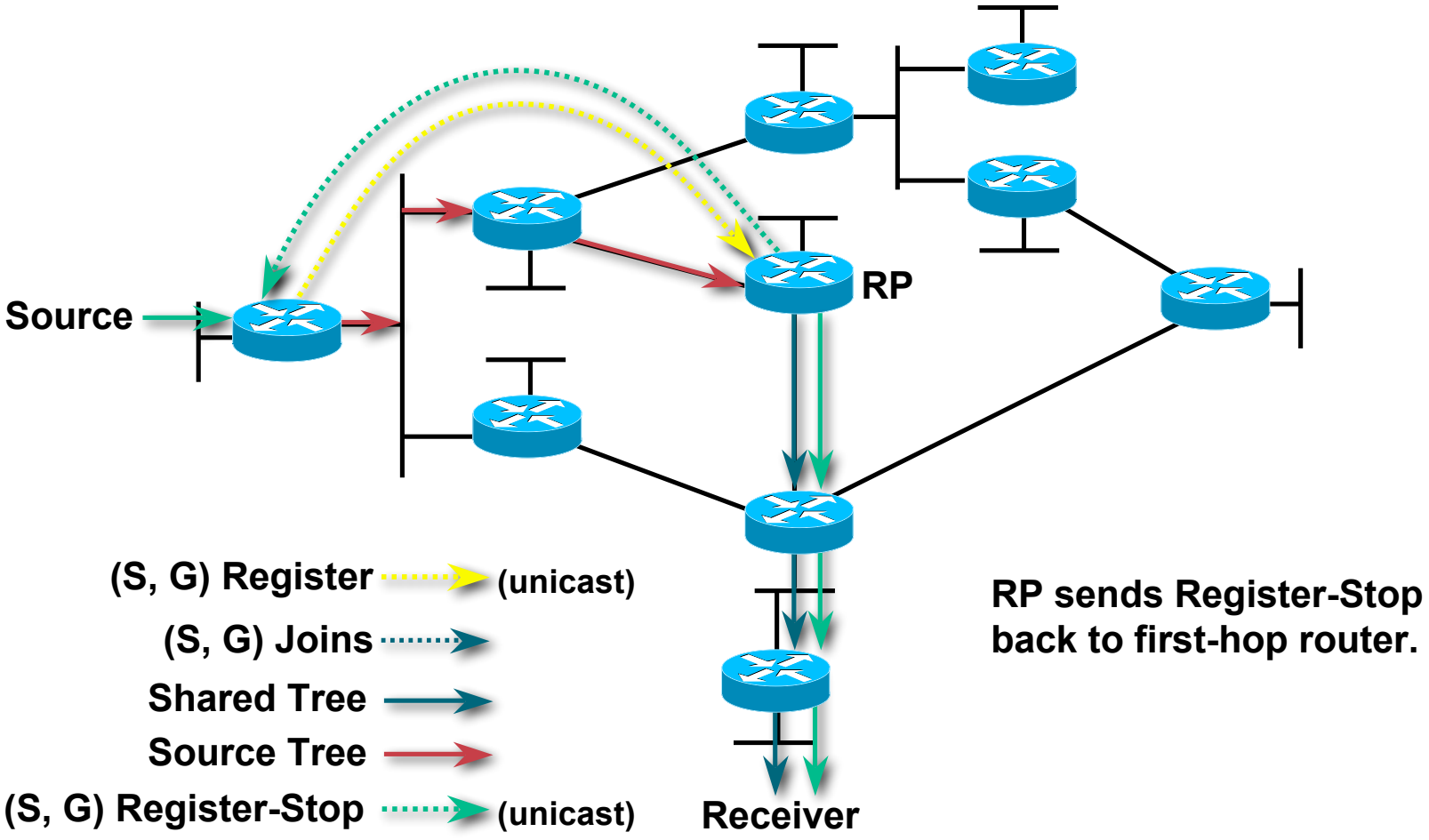
PIM-SM Shared Tree Joins



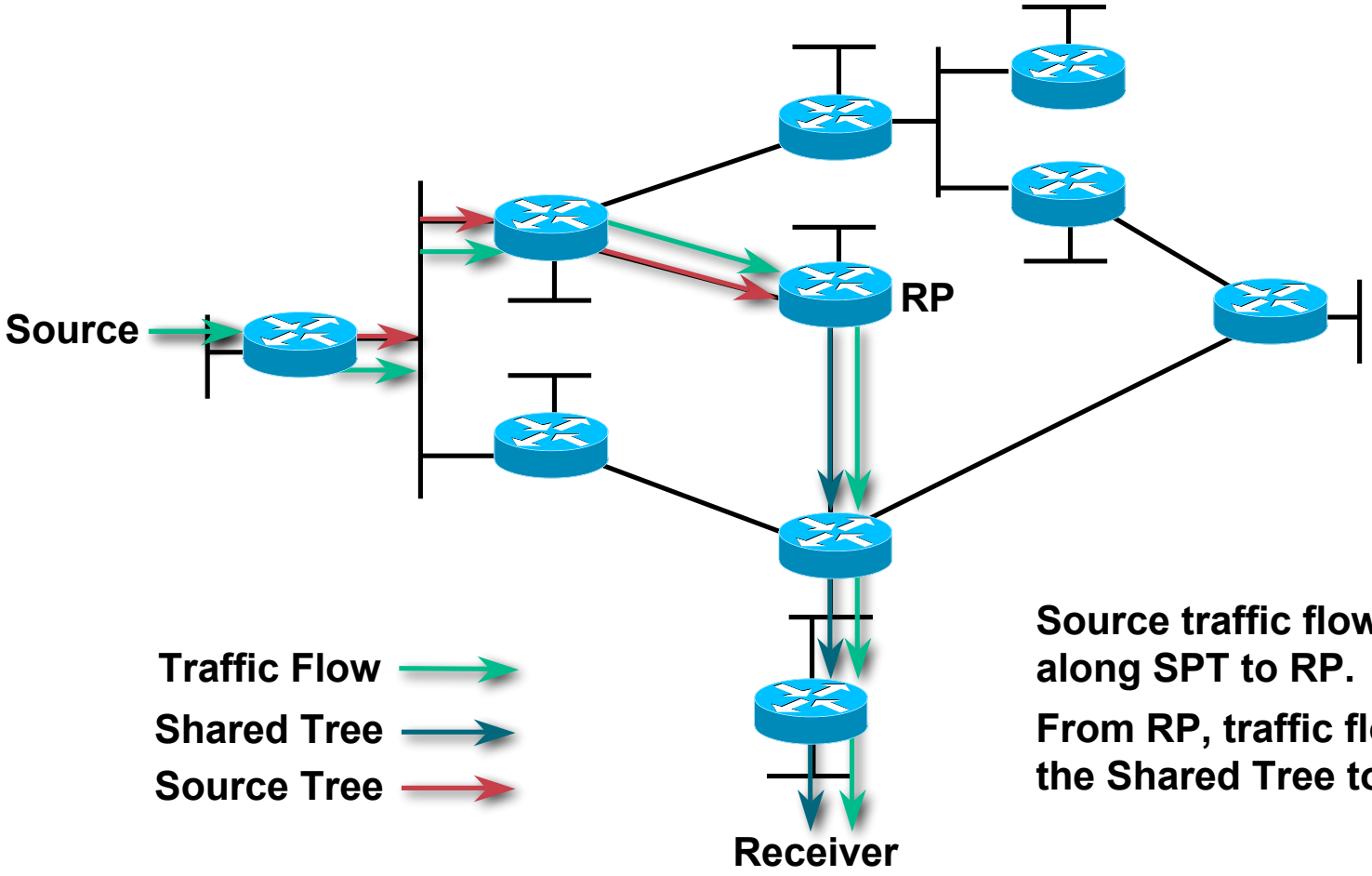
PIM-SM Sender Registration



PIM-SM Sender Registration



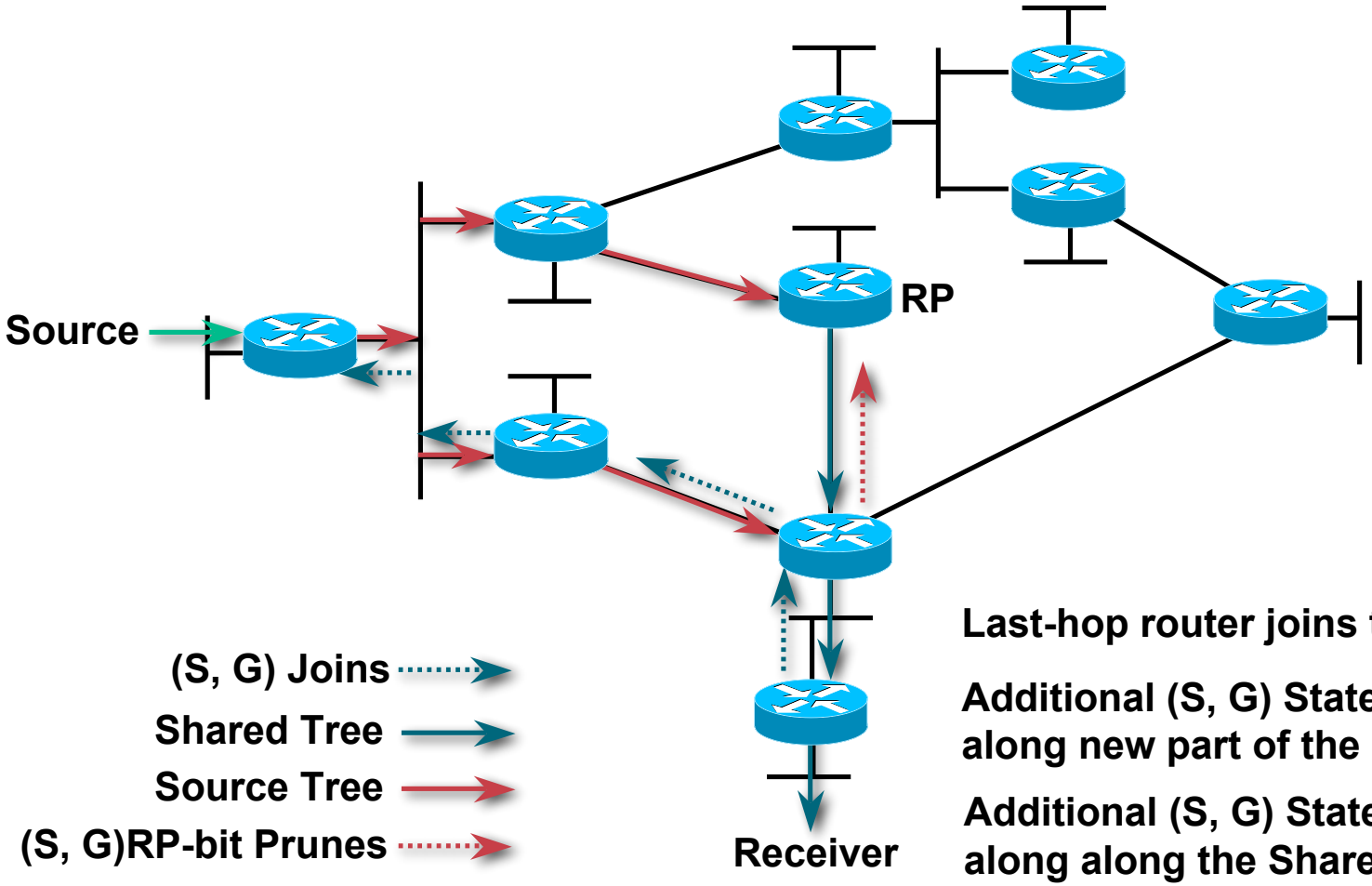
PIM-SM Sender Registration



Source traffic flows natively along SPT to RP.

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

PIM-SM SPT Switchover

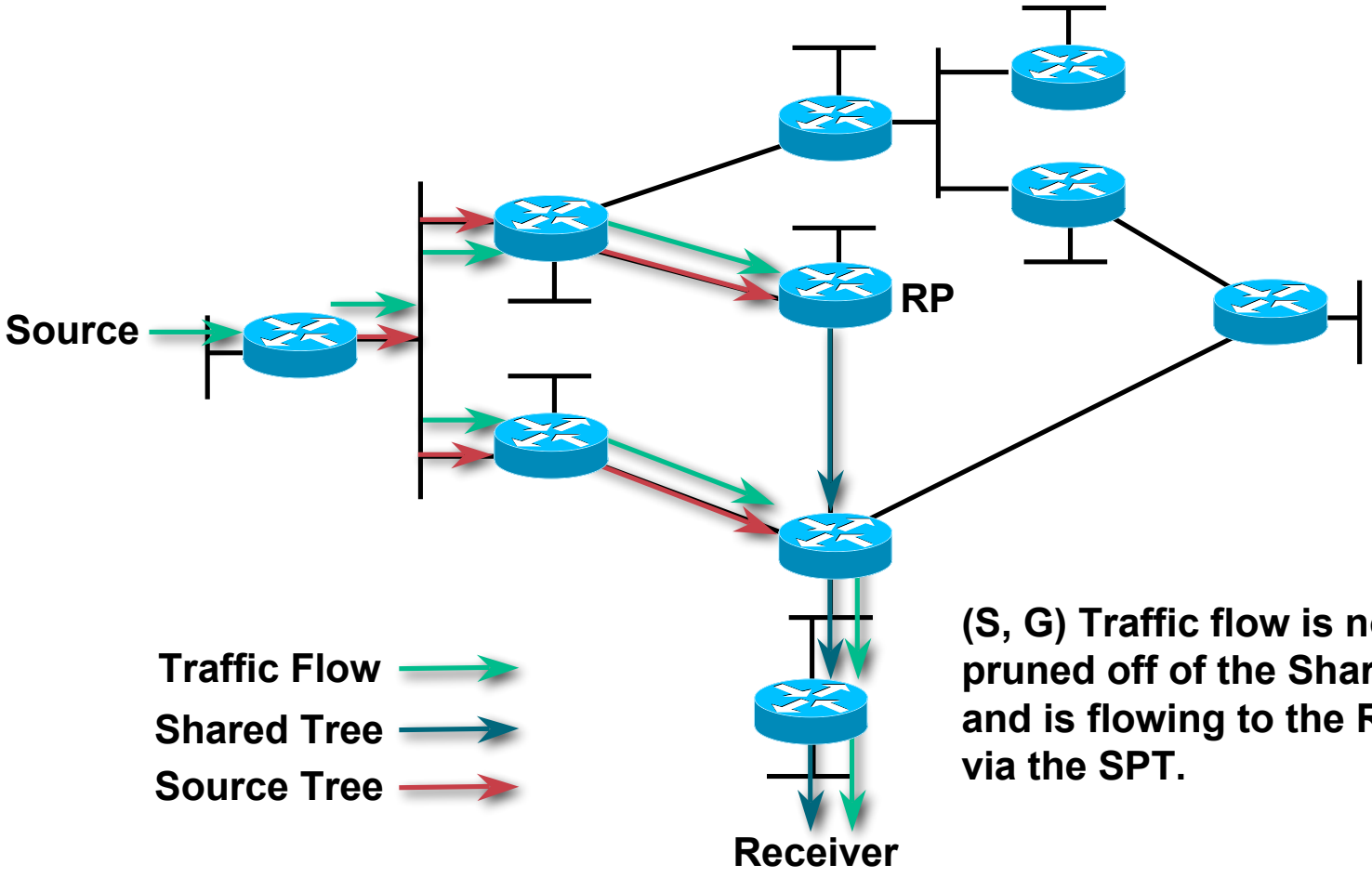


Last-hop router joins the SPT.

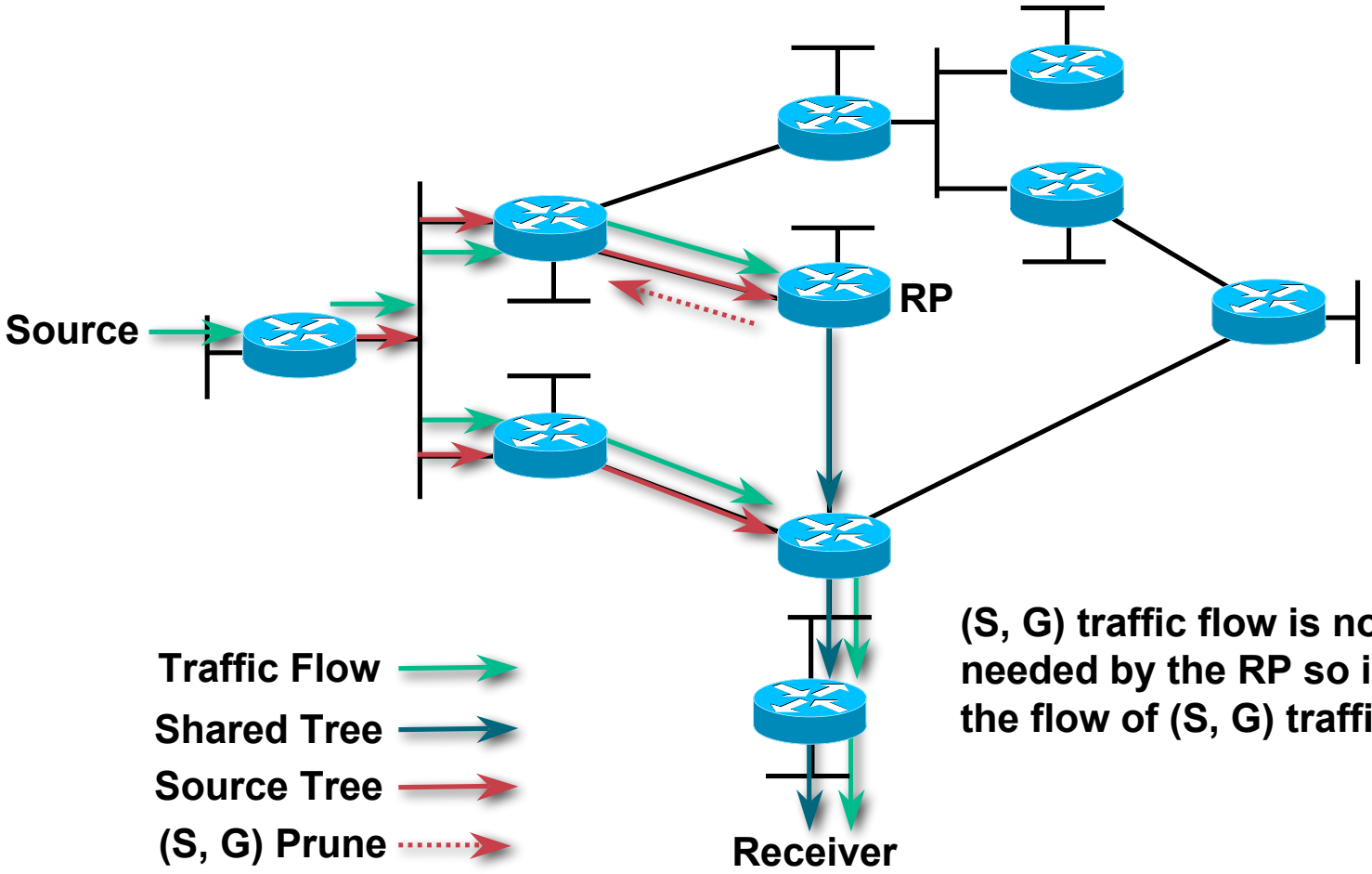
Additional (S, G) State is created along new part of the Source Tree.

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

PIM-SM SPT Switchover

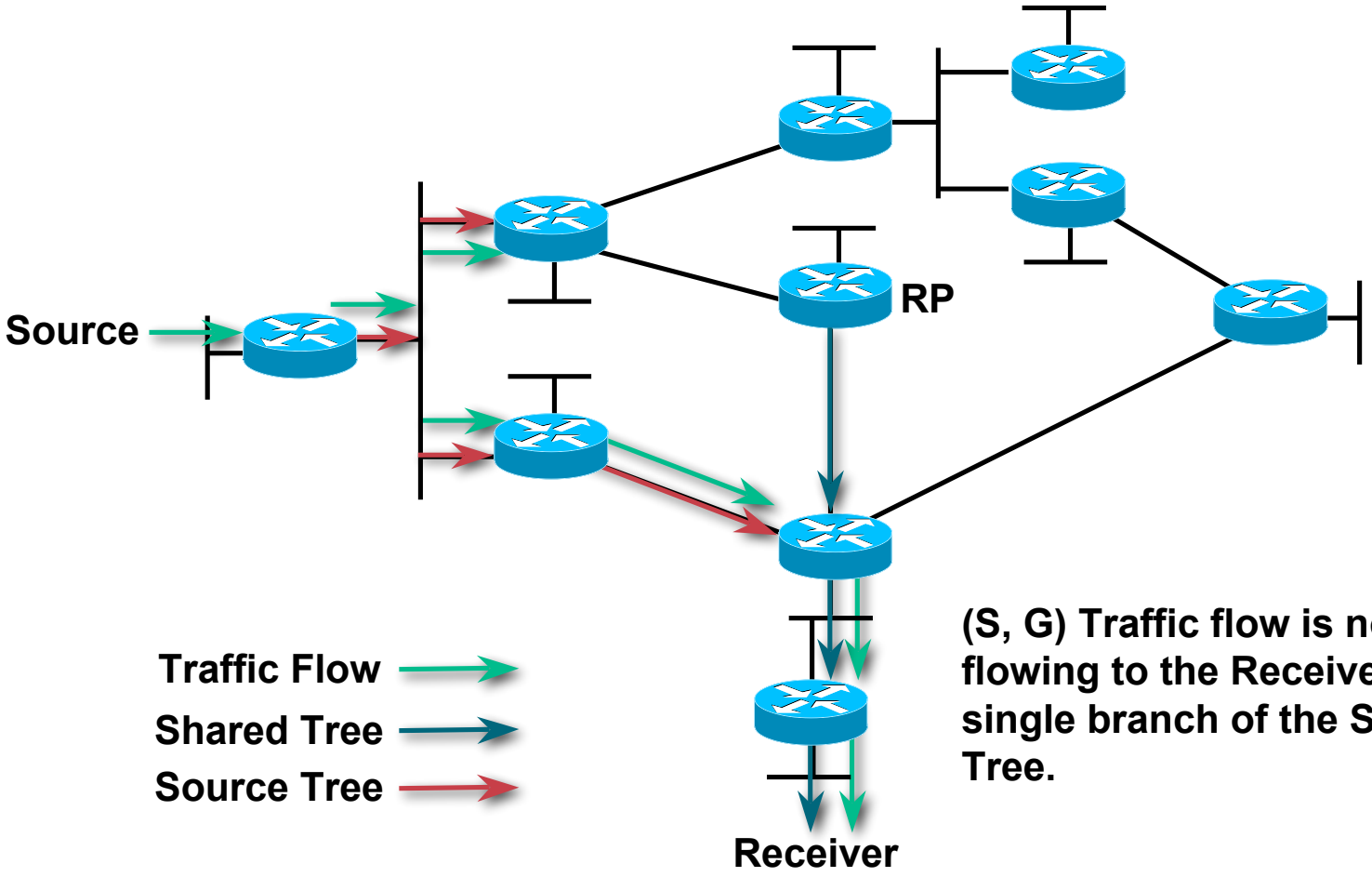


PIM-SM SPT Switchover



(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 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

PIM Protocol Summary

CONCLUSION

"Sparse mode Good! Dense mode Bad!"

Source: ***"The Caveman's Guide to IP Multicast", ©2000, R. Davis***