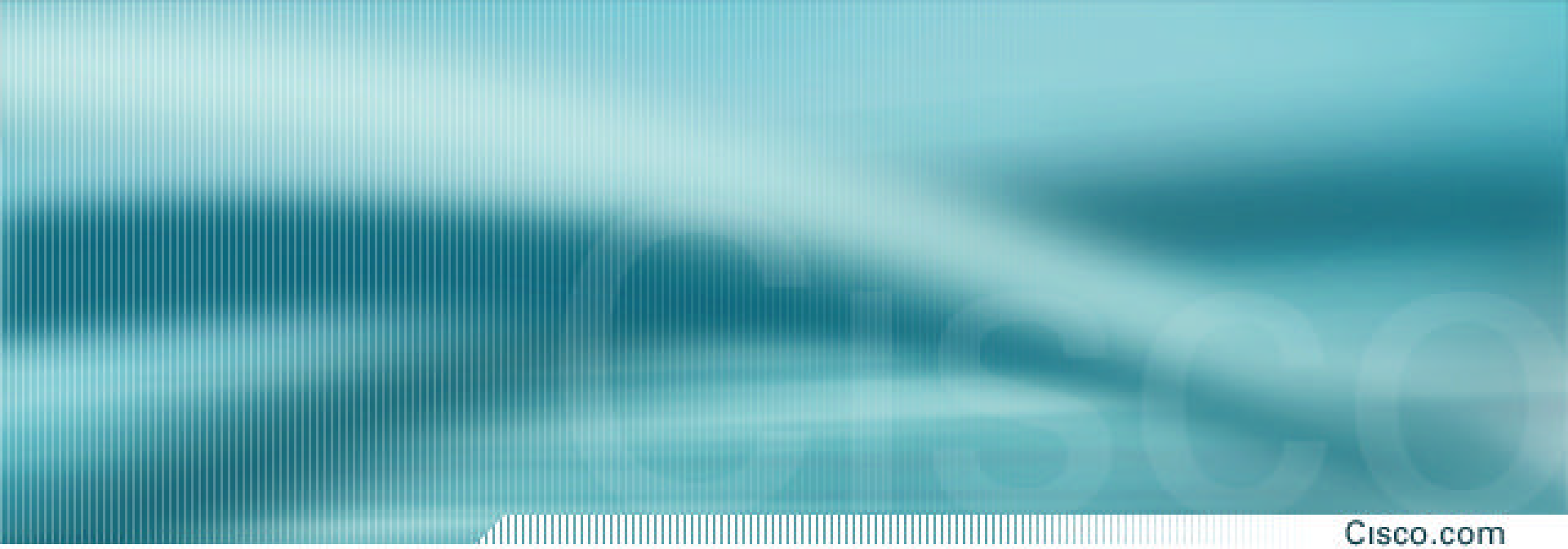

Troubleshooting IP Multicast

RST-360

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Agenda

- What and Why?
- PIM-SM Review
- PIM-SM Protocol Mechanics
- Rendezvous Points
- Tools & Examples

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What & Why?

- PIM SM only
  - Majority of deployments are PIM-SM
  - No DM
  - No Bi-dir
  - No SSM
- Assumes a stable underlying Unicast network!
- Understand the details
  - If you don't know how it should work how do you know where the problem is?
  - Comprehensive analysis of PIM-SM operation
- Know the tools available
  - IOS commands etc

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What & Why?

- Apply the tools
  - See some of the passive tools in action
- Issues know to cause problems
  - What about issues out side of the PIM protocol?
- Review and test!
- Where to find out more
- Next 4hrs should be fun ;)

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Agenda

- What and Why?
- PIM-SM Review
- PIM-SM Protocol Mechanics
- Rendezvous Points
- Tools & Examples

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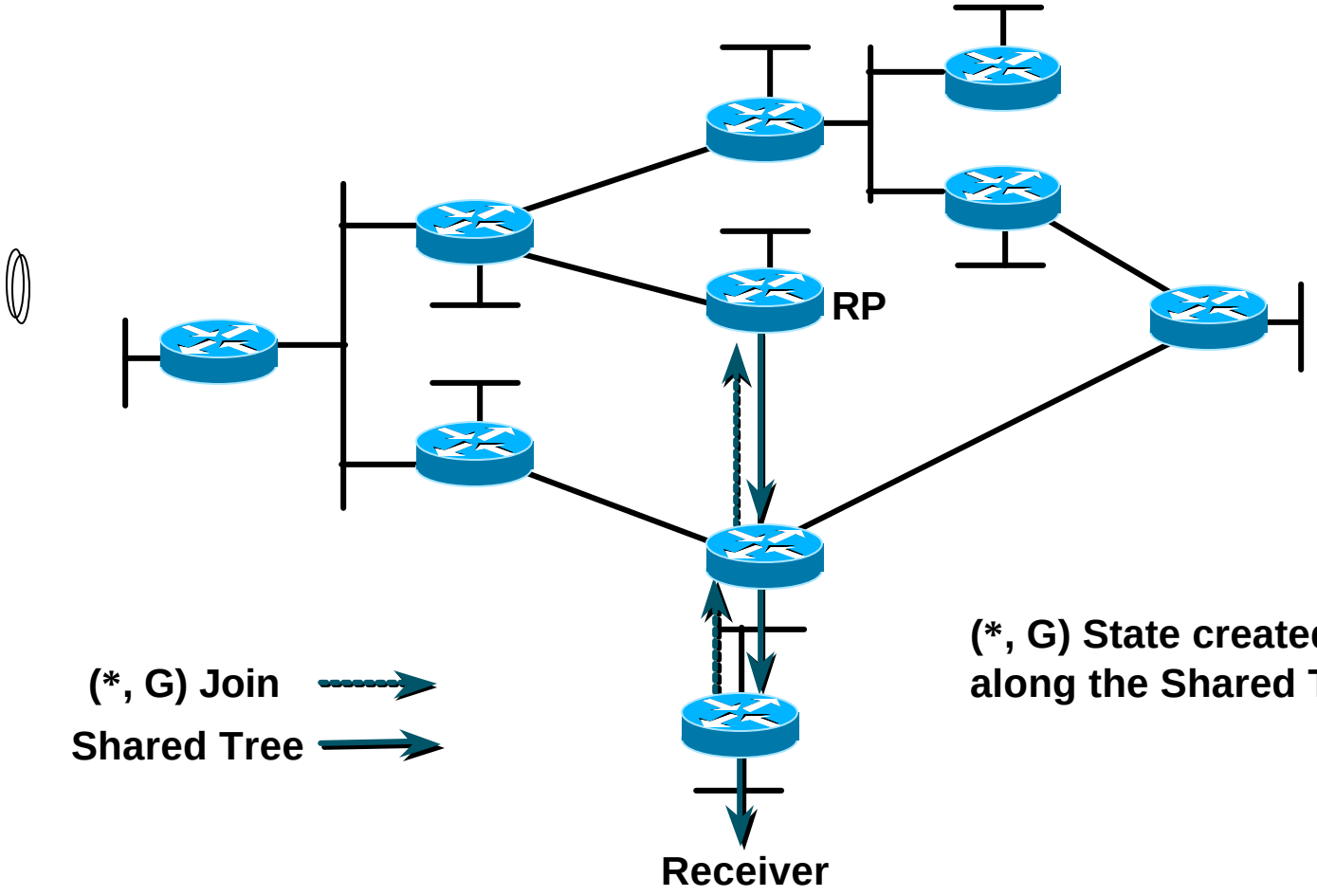
PIM-SM Shared Tree Join



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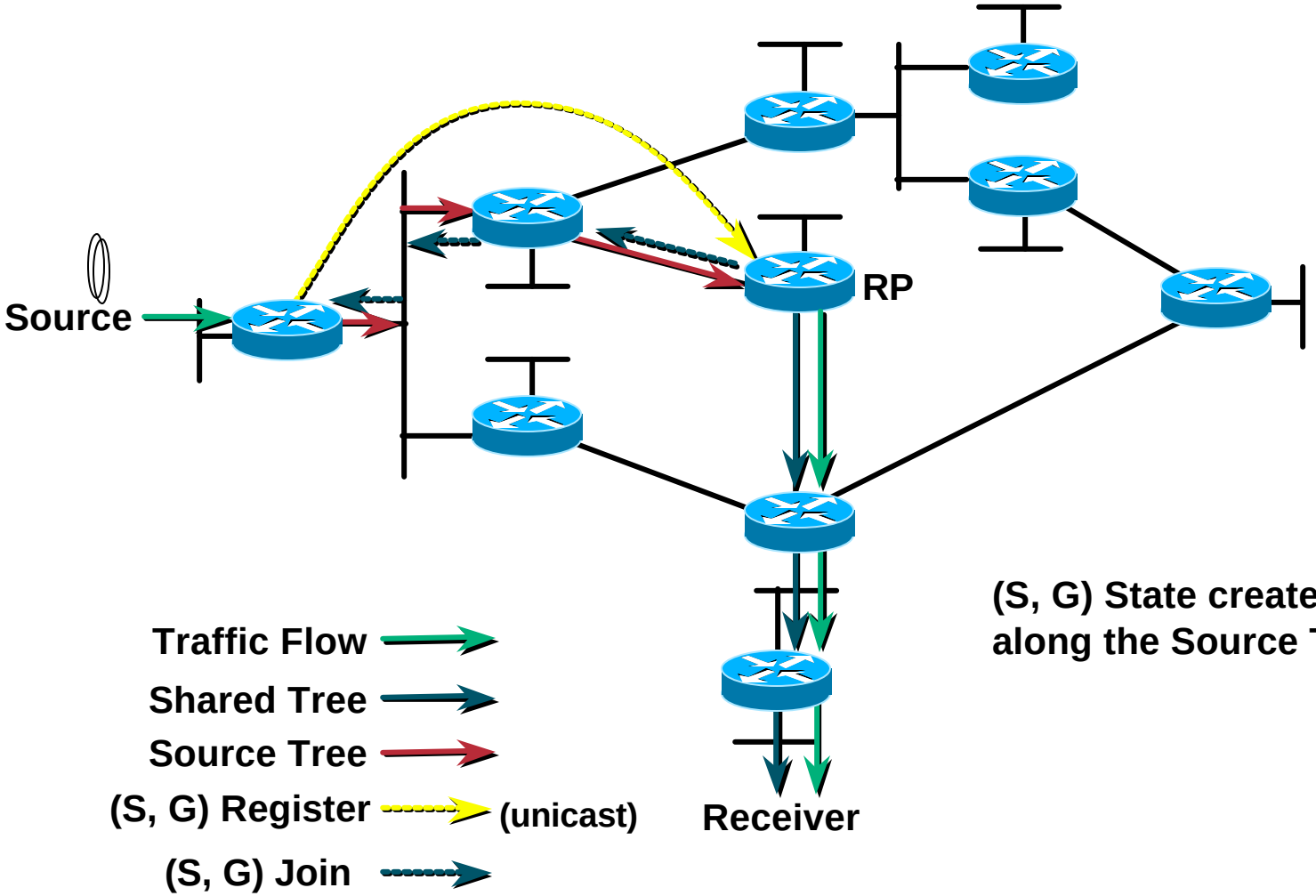
PIM-SM Sender Registration



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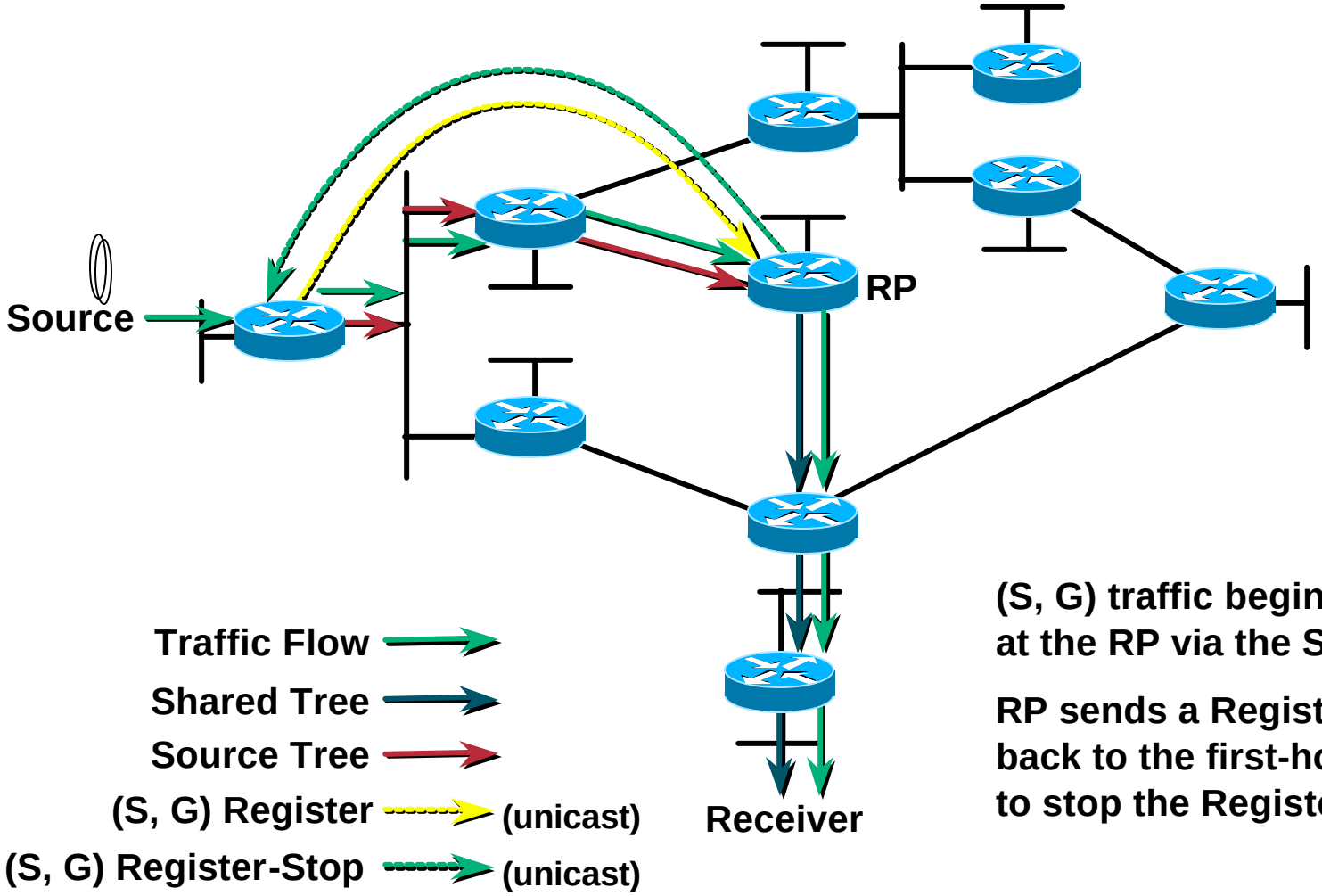
PIM-SM Sender Registration



(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.

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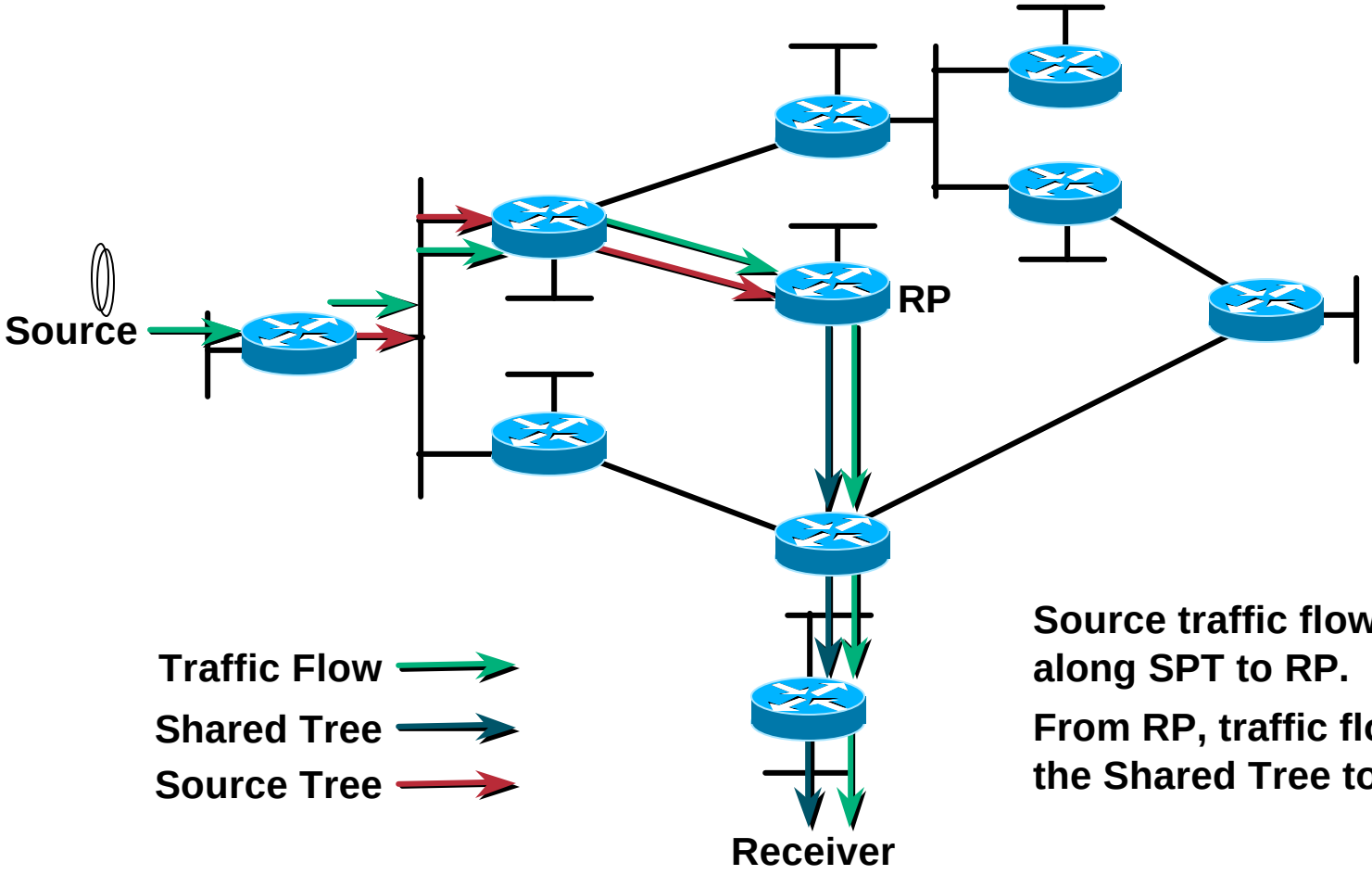
PIM-SM Sender Registration



Source traffic flows natively along SPT to RP.

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

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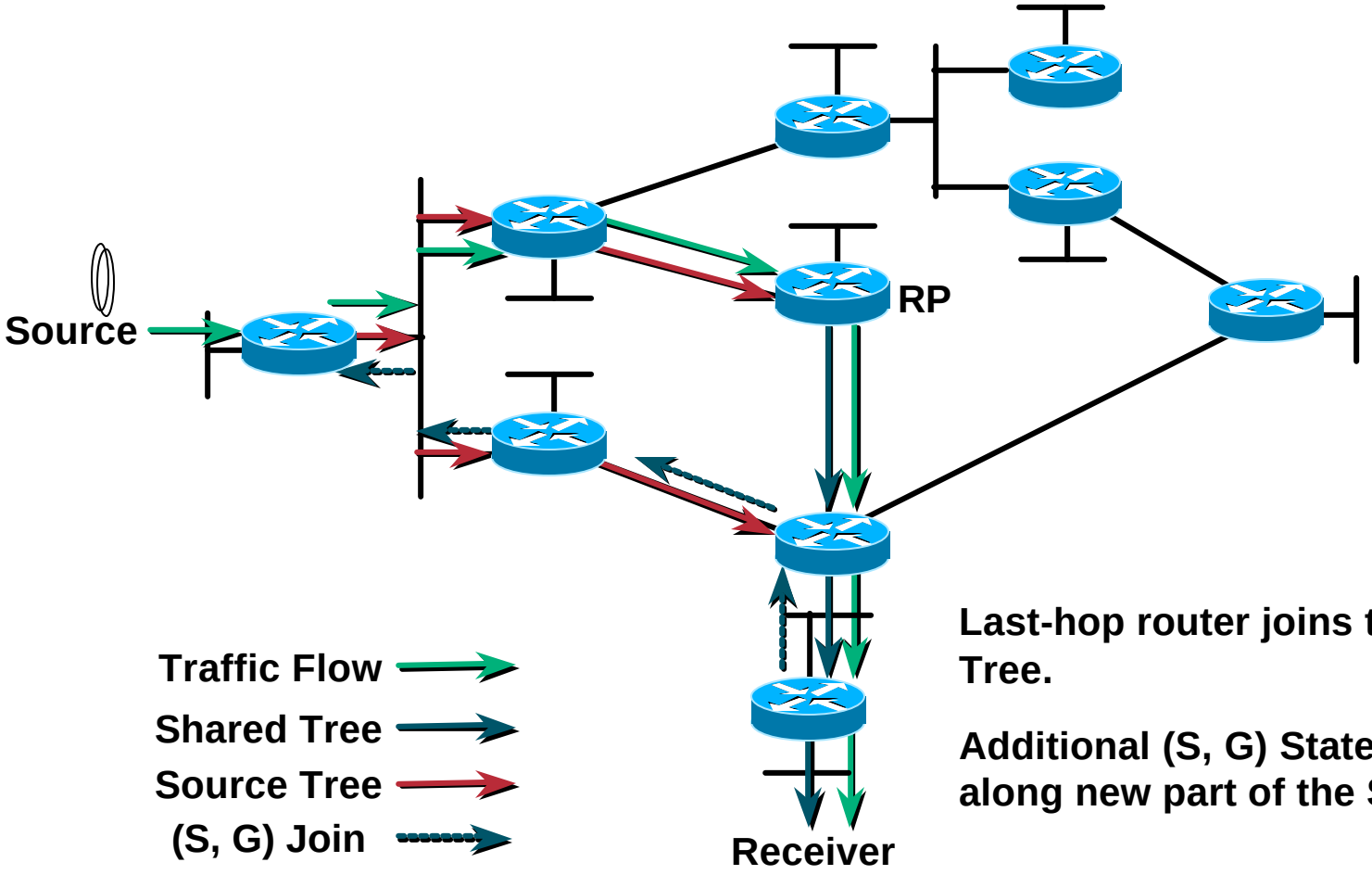
PIM-SM SPT Switchover



Last-hop router joins the Source Tree.

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

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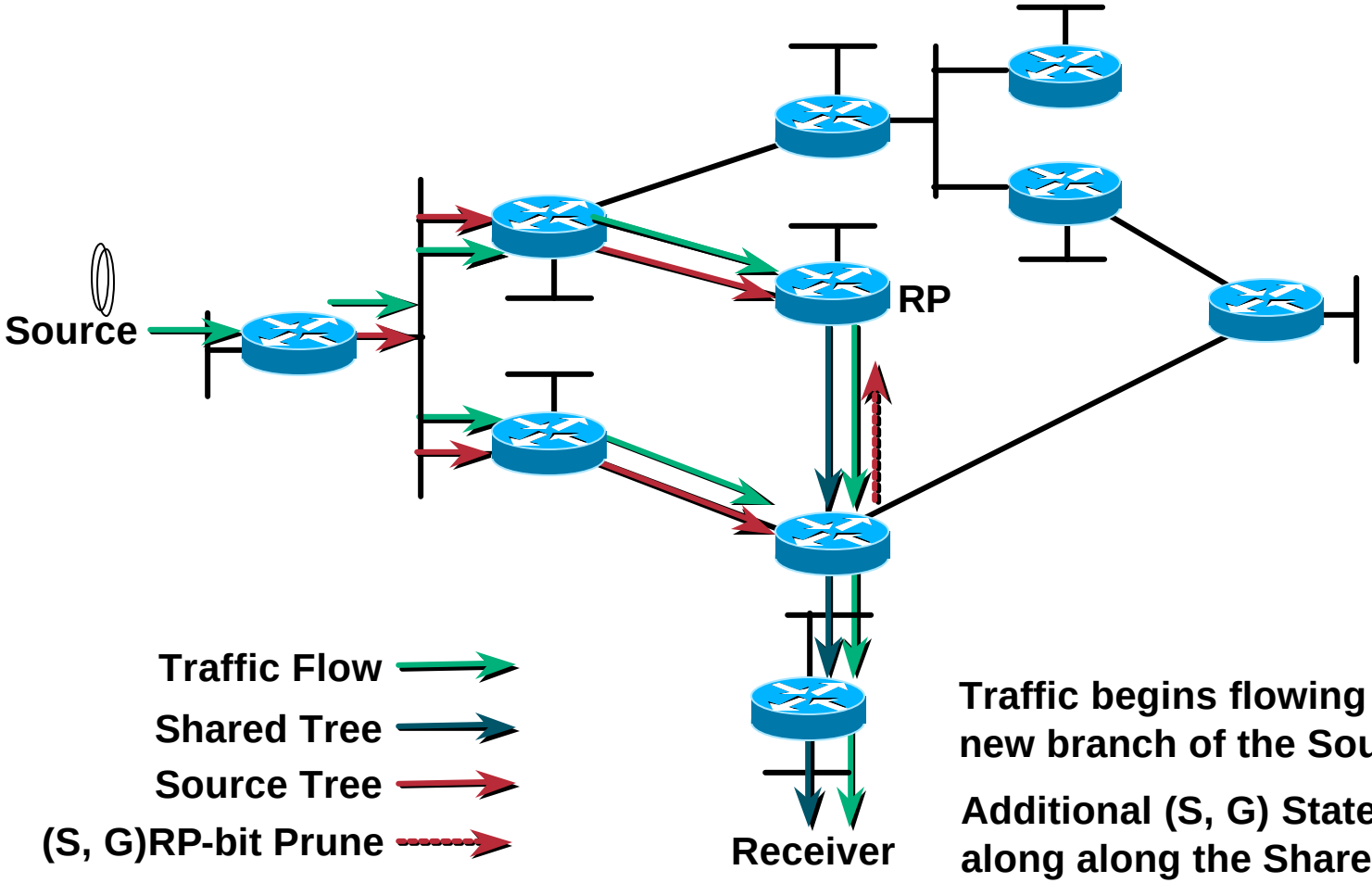
PIM-SM SPT Switchover



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.

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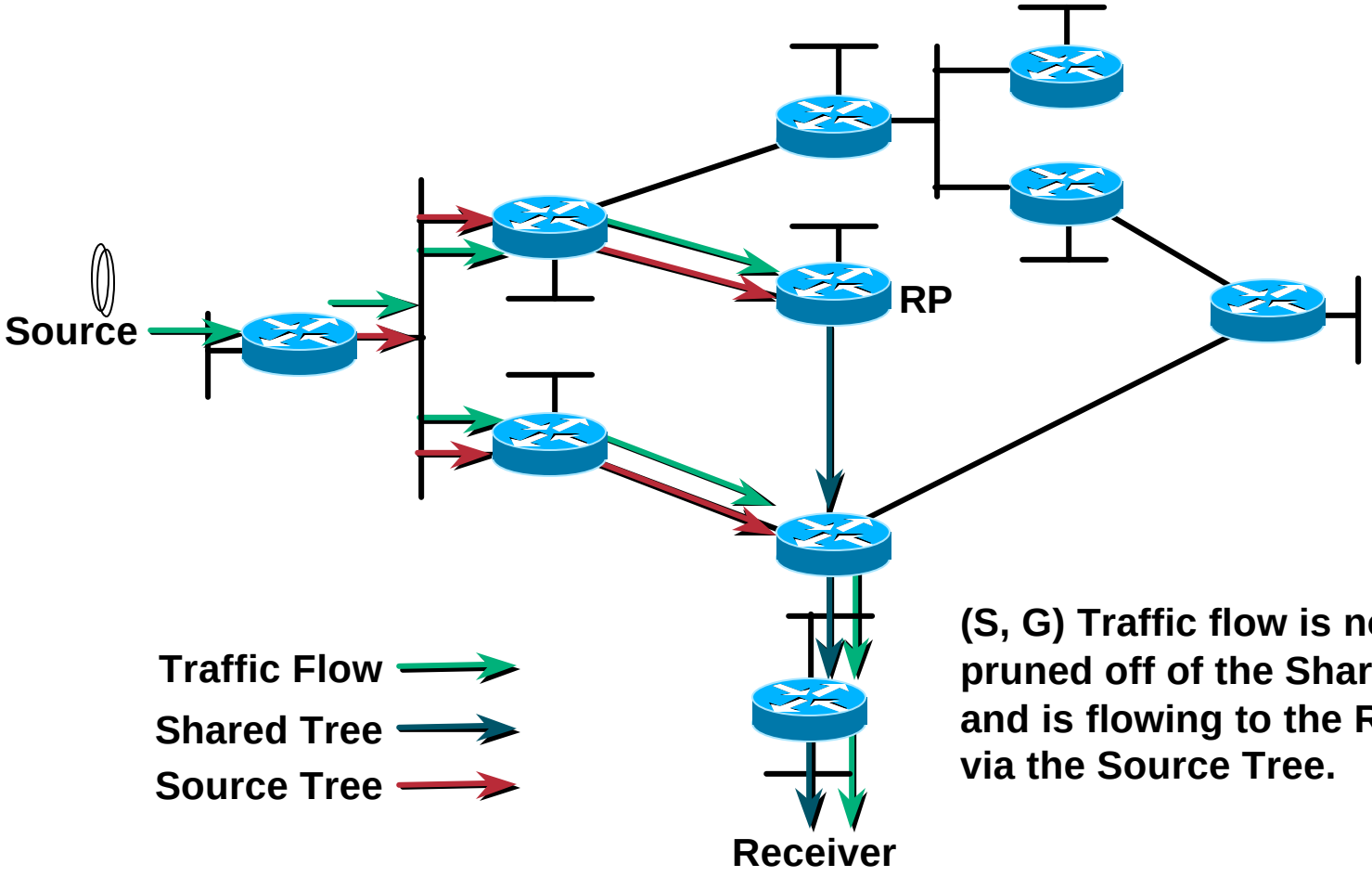
PIM-SM SPT Switchover



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

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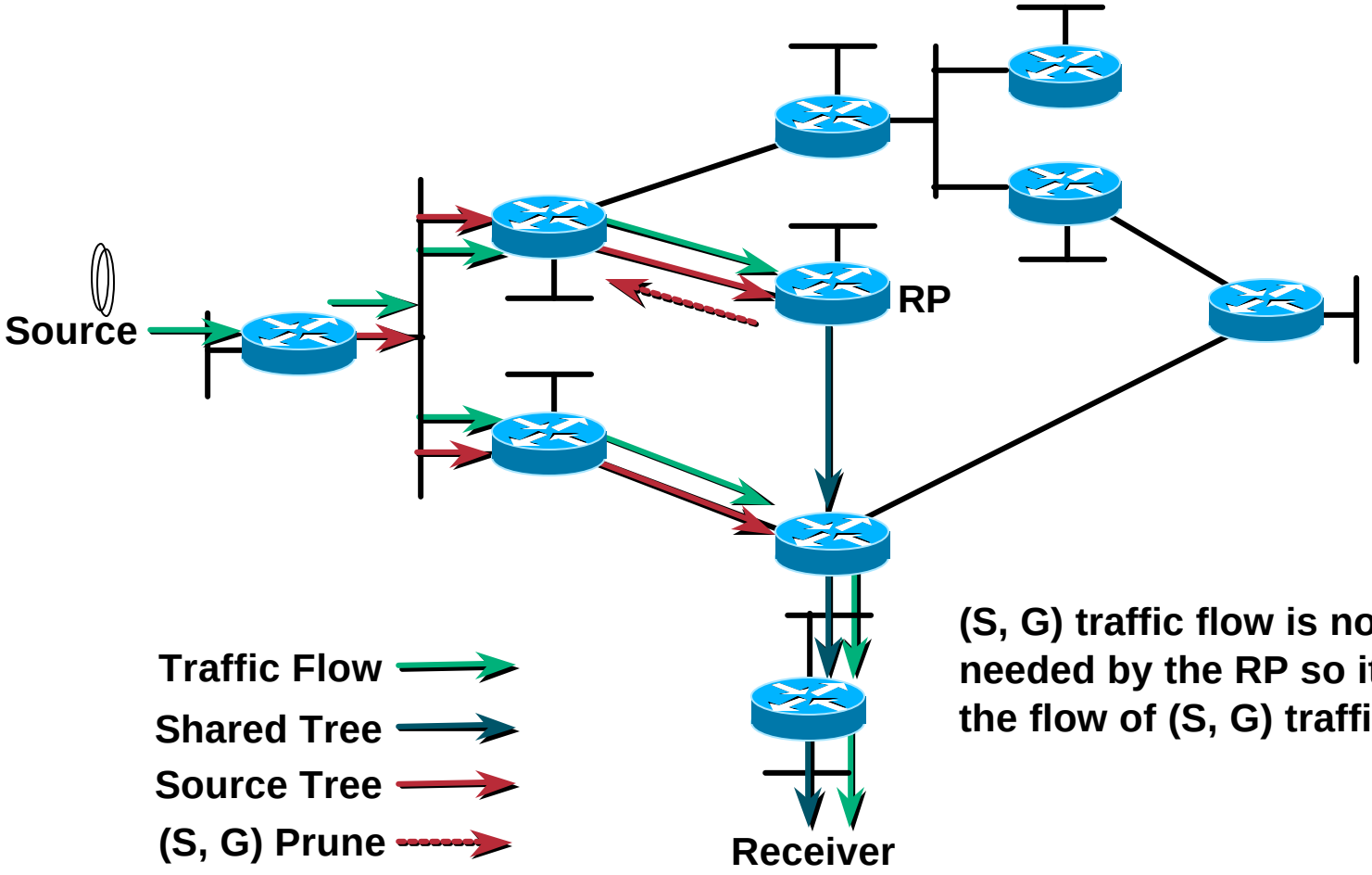
PIM-SM SPT Switchover



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

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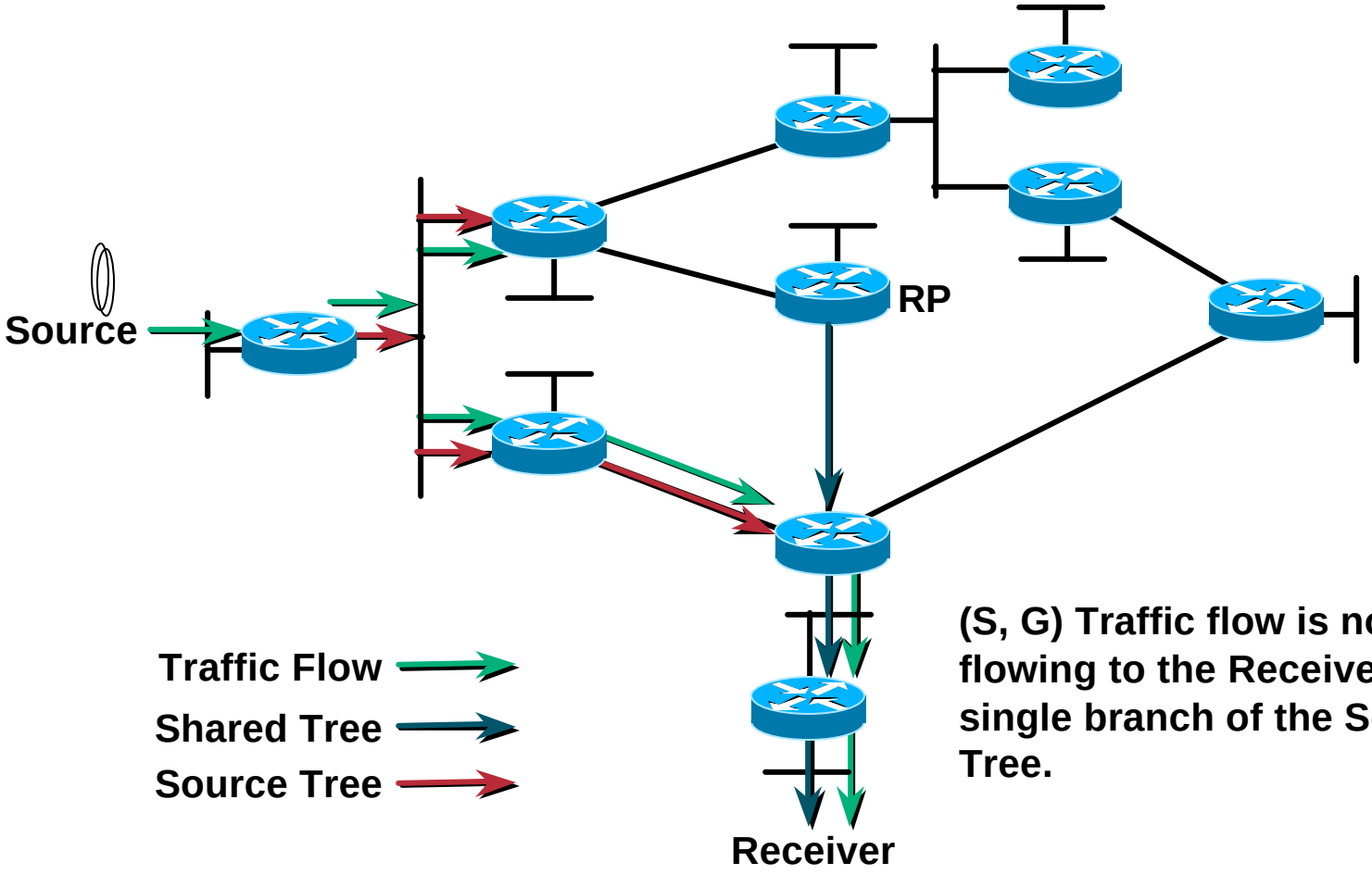
PIM-SM SPT Switchover



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

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Agenda

- What and Why?
- PIM-SM Review
- PIM-SM Protocol Mechanics
- Rendezvous Points
- Tools & Examples

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PIM-SM Protocol Mechanics

- **Troubleshooting hints appear in many of the slides in this section.**
  - **Hints appear in red in the lower right corner of certain slides.**
  - **Each hint is assigned a letter which can be cross-referenced to the "Troubleshooting Cheat Sheet".**
  - **The "Troubleshooting Cheat Sheet" will be covered again later in more detail.**
    - **It is offered here as a reference.**

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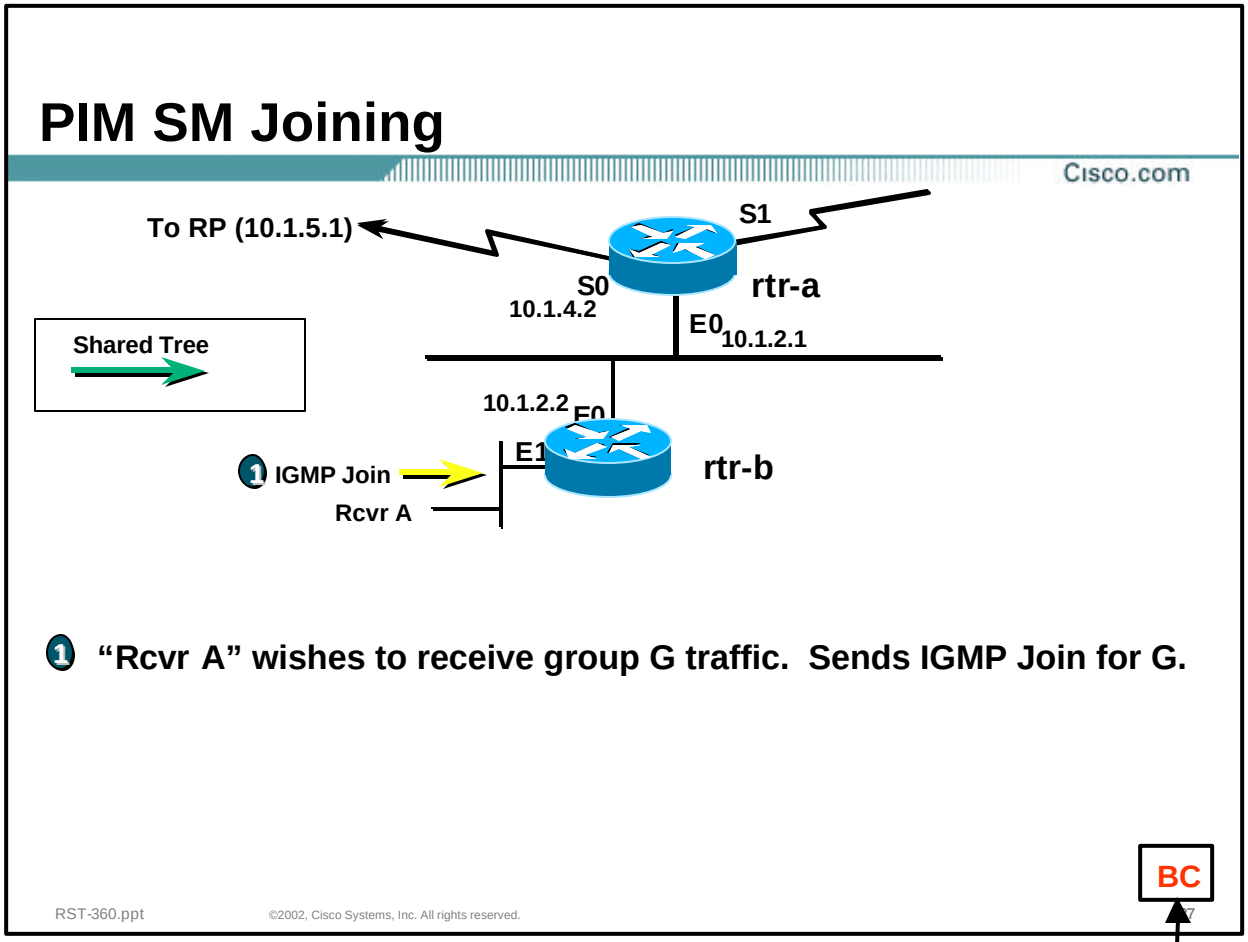
PIM-SM Protocol Mechanics

Cisco.com

Troubleshooting Hints – Example



Troubleshooting Hints

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Troubleshooting Cheat Sheet

A. Make sure you have a source before trying to debug a problem

B. Make sure you have a receiver before trying to debug a problem

- Work backward from the receiver toward the source
  - Check the last-hop has (S,G) state -- if not…
  - Check the last-hop has (*,G) state

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Troubleshooting Cheat Sheet

C. Check IGMP membership on PIM DR on Last Hop LAN
   - If there is no RP, you are trying to forward dense-mode traffic. Is this what you want?

D. Check RP address in (*,G) entry on the DR
   - "show ip rpf <RP>" will point you to the next hop in the (*,G) tree

E. Check RPF interface to RP in (*,G) entry
   - Did the receiver correctly indicate it wants to receive traffic

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Troubleshooting Cheat Sheet

- If the (*,G) information is correct then check the (S,G) information
  - Is the IIF correct
  - Is the OIF correct
- Move up the shortest-path toward the source
  - “show ip rpf <source>” will point you to the next hop
  - Is this the same as the information in the mroute entry
  - Is this what you would expect when looking at the unicast routing table

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Troubleshooting Cheat Sheet

- Is the (S,G) state correct in the RP?

F. What is the RPF router?

G. Is the source sending with an incorrect TTL

  - TTL = 1 is a common problem. Most applications default to this. (S,G) state does not get created anywhere in this case

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Troubleshooting Cheat Sheet

Cisco.com

- What forwarding model are you using?

H. Timers

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PIM Protocol Mechanics

- **PIM Neighbor Discovery**
- **PIM State**
- **PIM SM Joining**
- **PIM SM Registering**
- **PIM SM SPT-Switchover**
- **PIM SM Pruning**

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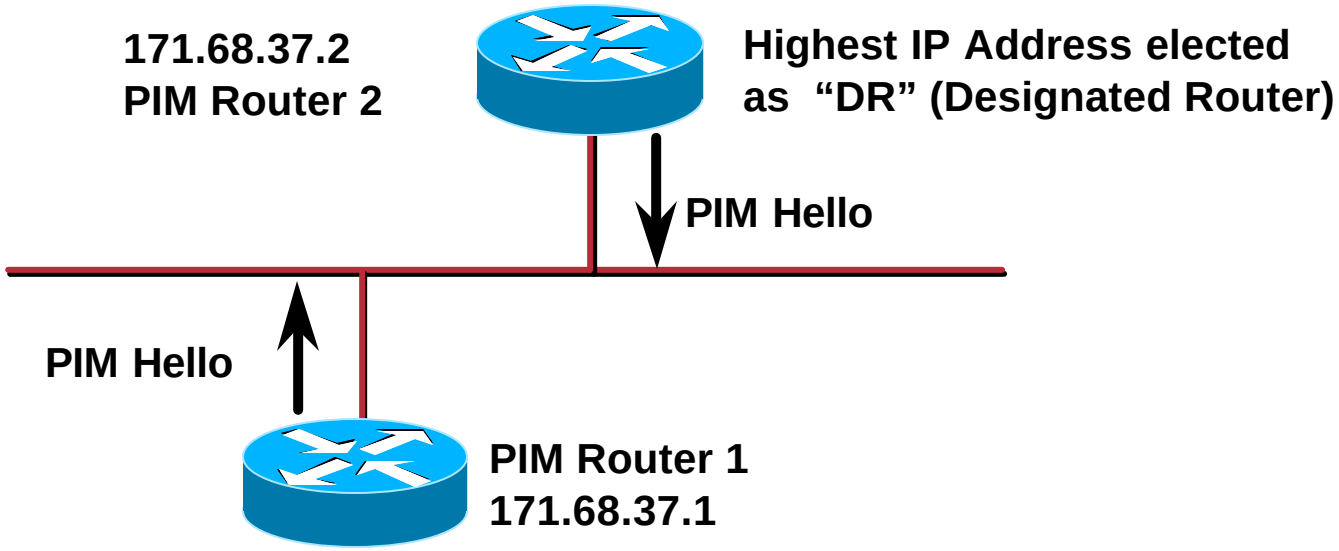
PIM Neighbor Discovery



- PIMv2 Hellos are periodically multicast to the "All-PIM-Routers" (224.0.0.13) group address. (Default = 30 seconds)
  - Note: PIMv1 multicasts PIM Query messages to the "All-Routers" (224.0.0.2) group address.
- If the "DR" times-out, a new "DR" is elected.
- The "DR" is responsible for sending all Joins and Register messages for any receivers or senders on the network.

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PIM Neighbor Discovery

Cisco.com

```
wan-gw8>show ip pim neighbor
PIM Neighbor Table
Neighbor Address  Interface          Uptime    Expires   Mode
171.68.0.70       FastEthernet0      2w1d      00:01:24  Sparse
171.68.0.91       FastEthernet0      2w6d      00:01:01  Sparse (DR)
171.68.0.82       FastEthernet0      7w0d      00:01:14  Sparse
171.68.0.86       FastEthernet0      7w0d      00:01:13  Sparse
171.68.0.80       FastEthernet0      7w0d      00:01:02  Sparse
171.68.28.70      Serial2.31         22:47:11  00:01:16  Sparse
171.68.28.50      Serial2.33         22:47:22  00:01:08  Sparse
171.68.27.74      Serial2.36         22:47:07  00:01:21  Sparse
171.68.28.170     Serial0.70         1d04h     00:01:06  Sparse
171.68.27.2       Serial1.51         1w4d      00:01:25  Sparse
171.68.28.110     Serial3.56         1d04h     00:01:20  Sparse
171.68.28.58      Serial3.102        12:53:25  00:01:03  Sparse
```

D

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Module Agenda

- PIM Neighbor Discovery
- PIM State
- PIM SM Joining
- PIM SM Registering
- PIM SM SPT-Switchover
- PIM SM Pruning

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PIM State

- Describes the “state” of the multicast distribution trees as understood by the router at this point in the network.
- Represented by entries in the multicast routing (mroute) table
  - Used to make multicast traffic forwarding decisions
  - Composed of (*, G) and (S, G) entries
  - Each entry contains RPF information
    - Incoming (i.e. RPF) interface
    - RPF Neighbor (upstream)
  - Each entry contains an Outgoing Interface List (OIL)
    - OIL may be NULL

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PIM-SM State Example


```
sj-mbone> show ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, C - Connected, L - Local, P - Pruned
       R - RP-bit set, F - Register flag, T - SPT-bit set, J - Join SPT
       M - MSDP created entry, X - Proxy Join Timer Running
       A - Advertised via MSDP
Timers: Uptime/Expires
Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 224.1.1.1), 00:13:28/00:02:59, RP 10.1.5.1, flags: SCJ
  Incoming interface: Ethernet0, RPF nbr 10.1.2.1,
  Outgoing interface list:
    Ethernet1, Forward/Sparse, 00:13:28/00:02:32
    Serial0, Forward/Sparse, 00:4:52/00:02:08

(171.68.37.121/32, 224.1.1.1), 00:01:43/00:02:59, flags: CJT
  Incoming interface: Serial0, RPF nbr 192.10.2.1
  Outgoing interface list:
    Ethernet1, Forward/Sparse, 00:01:43/00:02:11
    Ethernet0, forward/Sparse, 00:01:43/00:02:11
```

ABCDEF

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PIM-SM (*,G) State Rules

- (*,G) creation
  - Receipt of a (*,G) Join or IGMP Report
  - Automatically if (S,G) must be created
- (*,G) reflects default group forwarding
  - IIF = RPF interface toward RP
  - OIL = interfaces
    - that received a (*,G) Join or
    - with directly connected members or
    - manually configured
- (*,G) deletion
  - When OIL = NULL and
  - no child (S,G) state exists

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PIM-SM (S,G) State Rules

- (S,G) creation
  - By receipt of (S,G) Join or Prune or
  - By “Register” process
  - Parent (*,G) created (if doesn’t exist)
- (S,G) reflects forwarding of “S” to “G”
  - IIF = RPF Interface normally toward source
    - RPF toward RP if “RP-bit” set
  - OIL = Initially, copy of (*,G) OIL minus IIF
- (S,G) deletion
  - By normal (S,G) entry timeout

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PIM-SM OIL Rules

- Interfaces in OIL added
  - By receipt of Join message
    - Interfaces added to (*,G) are added to all (S,G)'s
- Interfaces in OIL removed
  - By receipt of Prune message
    - Interfaces removed from (*,G) are removed from all (S,G)'s
  - Interface Expire timer counts down to zero
    - Timer reset (to 3 min.) by receipt of periodic Join
      or
    - By IGMP membership report

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PIM-SM OIL Rules

- **Triggering Join/Prune Messages**
  - **(*,G) Joins are triggered when:**
    - **The (*,G) OIL transitions from Null to non-Null**
  - **(*,G) Prunes are triggered when:**
    - **The (*,G) OIL transitions from non-Null to Null**
  - **(S,G) Joins are triggered when:**
    - **The (S,G) OIL transitions from Null to non-Null**
  - **(S,G) Prunes are triggered when:**
    - **The (S,G) OIL transitions from non-Null to Null**
  - **(S,G)RP-bit Prunes are triggered when:**
    - **The (S,G) RPF info != the (*,G) RPF info**

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PIM-SM State Flags

- S = Sparse Mode
- C = Directly Connected Host
- L = Local (Router is member)
- P = Pruned (All intfcs in OIL = Prune)
- T = Forwarding via SPT
  - Indicates at least one packet was forwarded

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PIM-SM State Flags (cont.)

- J = Join SPT
  - In (*, G) entry
    - Indicates SPT-Threshold is being exceeded
    - Next (S,G) received will trigger join of SPT
  - In (S, G) entry
    - Indicates SPT joined due to SPT-Threshold
    - If rate < SPT-Threshold, switch back to Shared Tree
- F = Register/First-Hop
  - In (S,G) entry
    - “S” is a directly connected source
    - Triggers the Register Process
  - In (*, G) entry
    - Set when “F” set in at least one child (S,G)

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PIM-SM State Flags (cont.)

- R = RP bit
  - (S, G) entries only
  - Set by (S,G)RP-bit Prune
  - Indicates info is applicable to Shared Tree
  - Used to prune (S,G) traffic from Shared Tree
    - Initiated by Last-hop router after switch to SPT
  - Modifies (S,G) forwarding behavior
    - IIF = RPF toward RP (I.e. up the Shared Tree)
    - OIL = Pruned accordingly

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PIM Protocol Mechanics

- PIM Neighbor Discovery
- PIM State
- **PIM SM Joining**
- PIM SM Registering
- PIM SM SPT-Switchover
- PIM SM Pruning

BC

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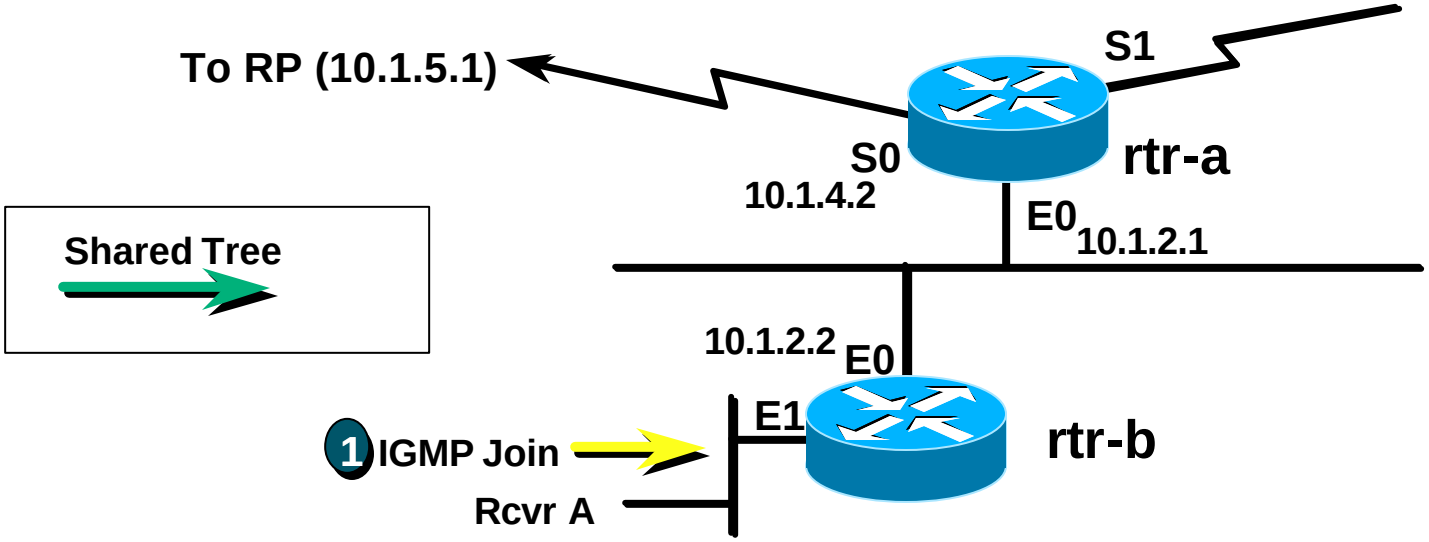
PIM SM Joining



1. "Rcvr A" wishes to receive group G traffic. Sends IGMP Join for G.

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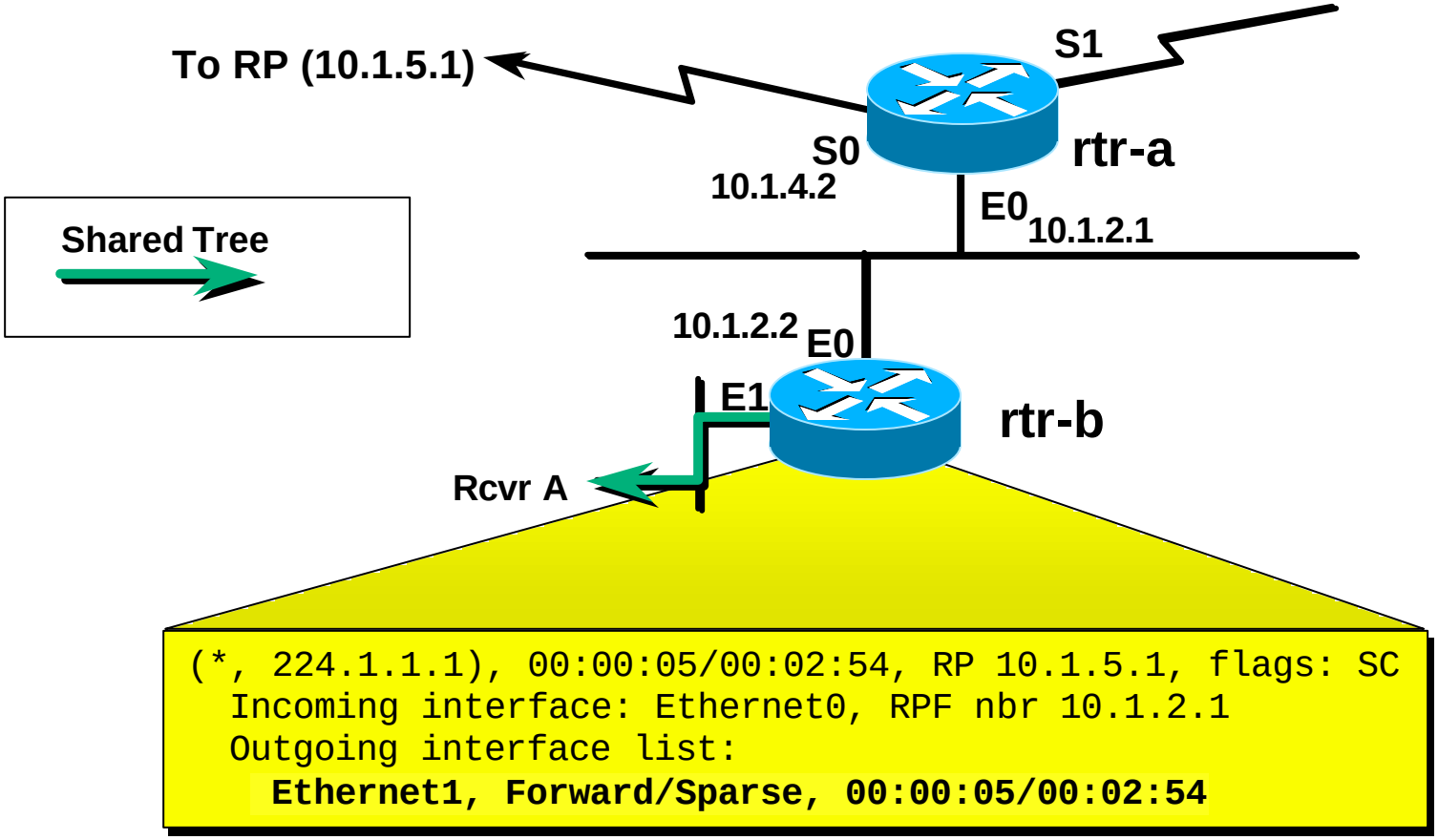
PIM SM Joining



"rtr-b" creates (*, 224.1.1.1) state

BC

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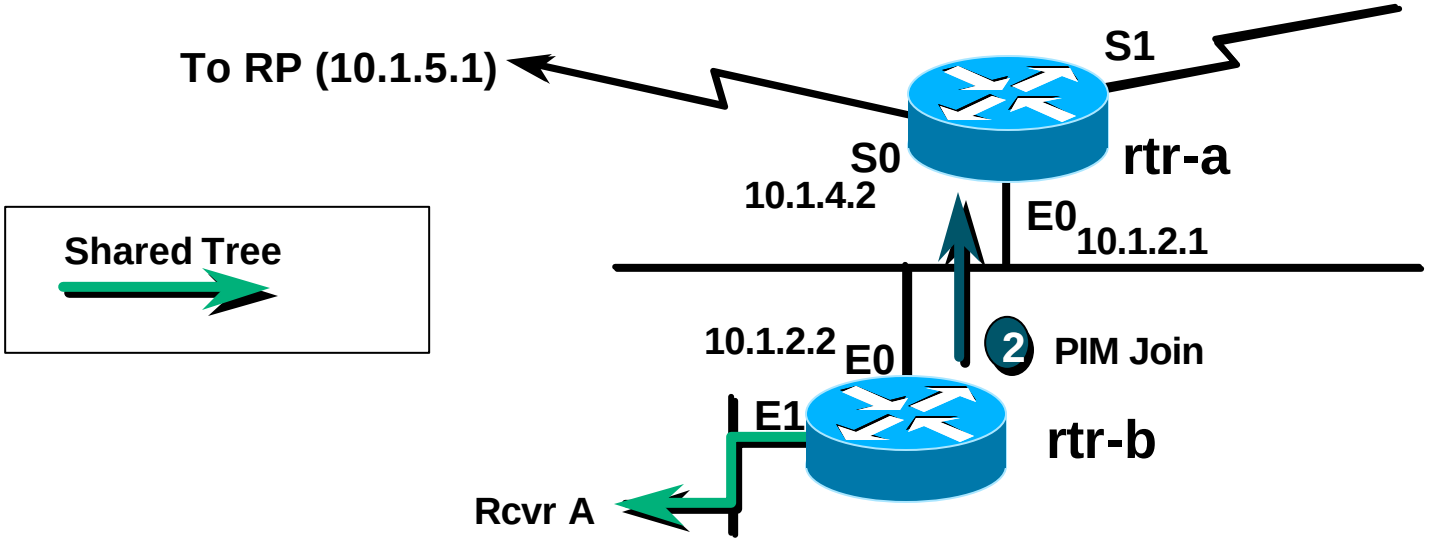
PIM SM Joining



1. "Rcvr A" wishes to receive group G traffic. Sends IGMP Join for G.
2. "rtr-b" sends (*,G) Join towards RP.

BC

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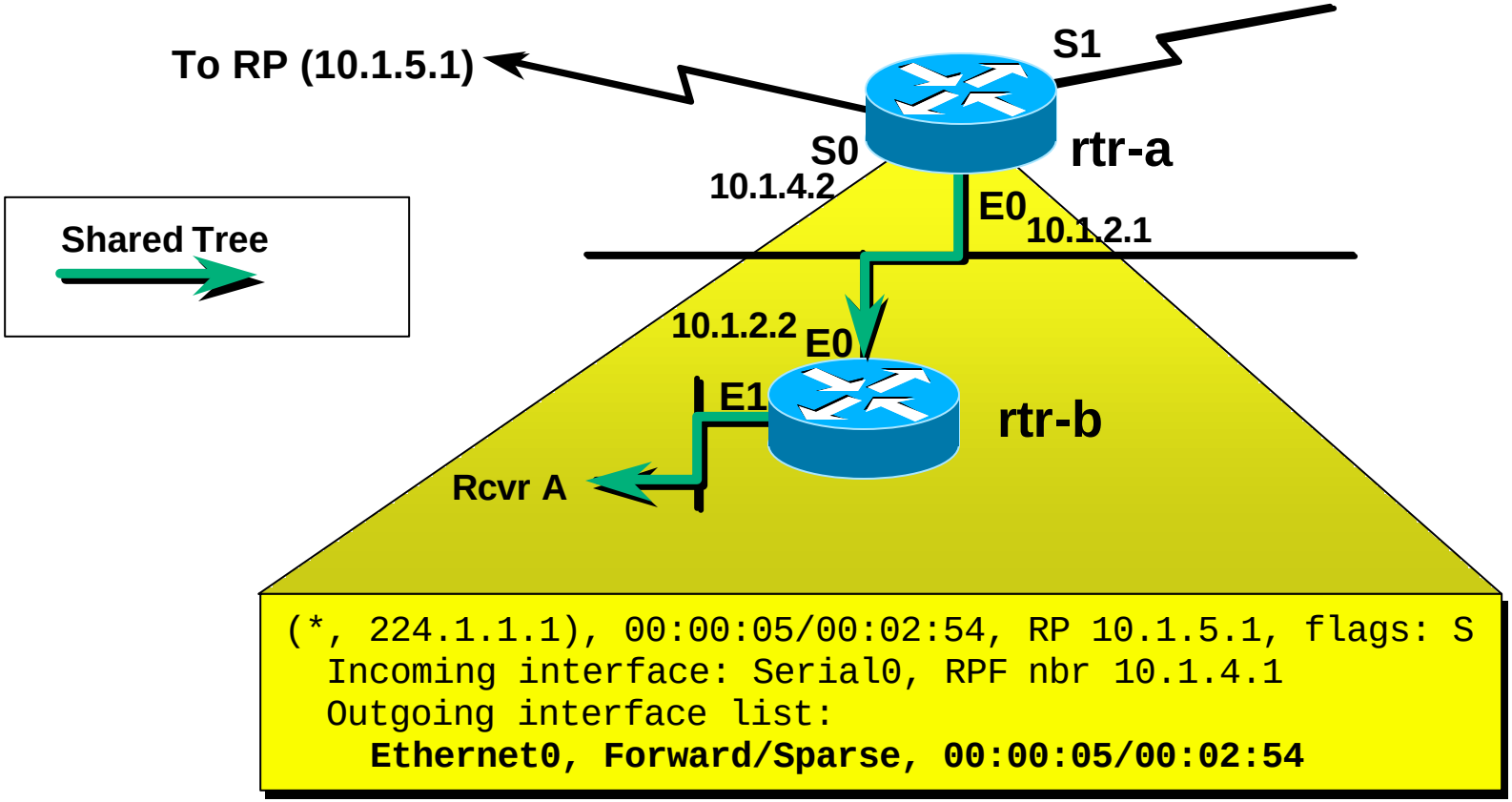
PIM SM Joining



“rtr-a” creates (*, 224.1.1.1) state.

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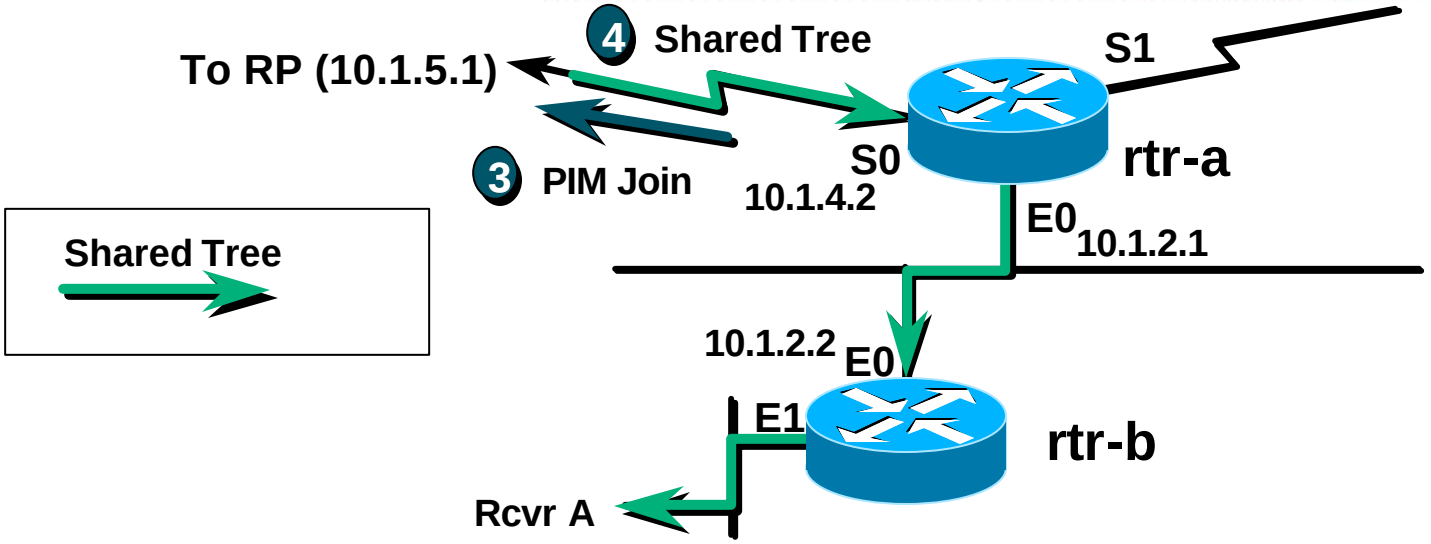
PIM SM Joining



1. "Rcvr A" wishes to receive group G traffic. Sends IGMP Join for G.
2. "rtr-b" sends (*,G) Join towards RP.
3. "rtr-a" sends (*,G) Join towards RP.
4. Shared tree is built all the way back to the RP.

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PIM Protocol Mechanics

- PIM Neighbor Discovery
- PIM State
- PIM SM Joining
- PIM SM Registering
- PIM SM SPT-Switchover
- PIM SM Pruning

AB

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PIM SM Register Examples

- **Receivers Join Group First**
- **Source Registers First**
- **Receivers along the SPT**

AB

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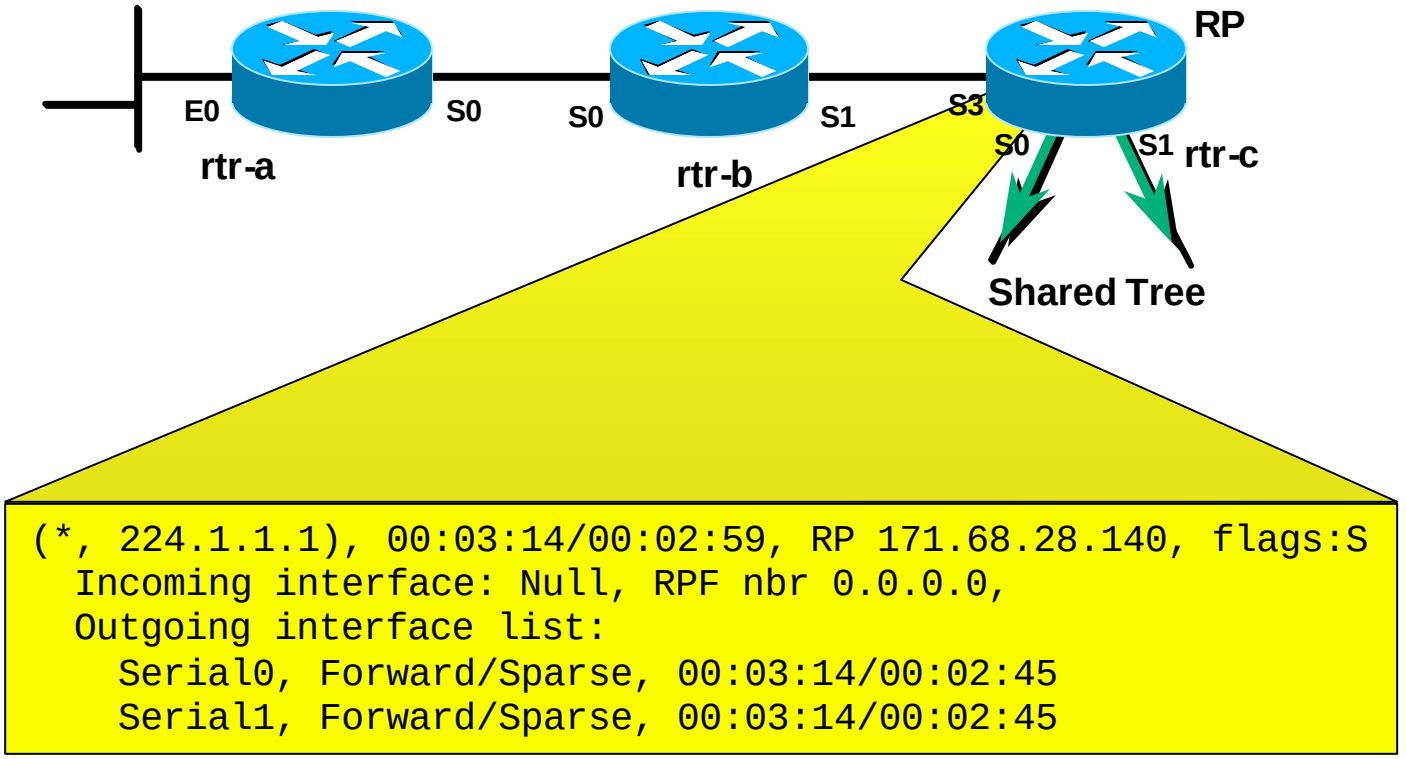
PIM SM Registering
Receiver Joins Group First



State in "RP" before any source registers
(with receivers on Shared Tree)

AB

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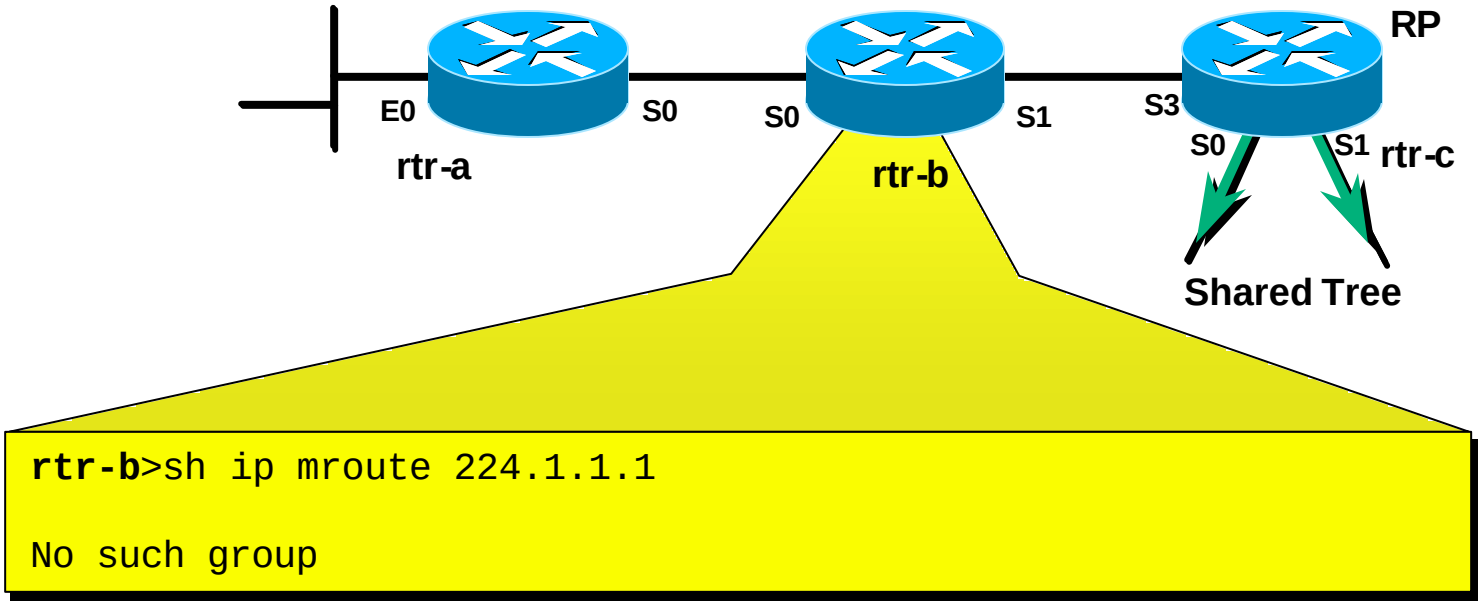
PIM SM Registering
Receiver Joins Group First



State in “rtr-b” before any source registers
(with receivers on Shared Tree)

AB

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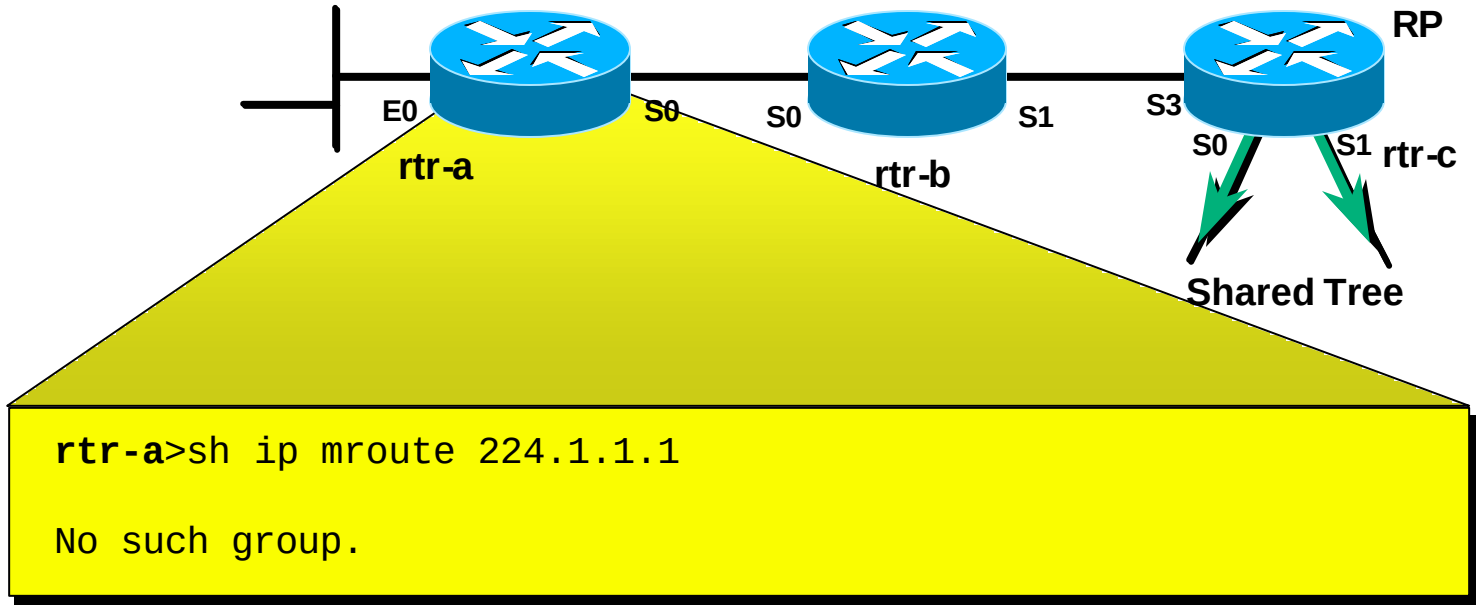
PIM SM Registering
Receiver Joins Group First



State in "rtr-a" before any source registers
(with receivers on Shared Tree)

AB

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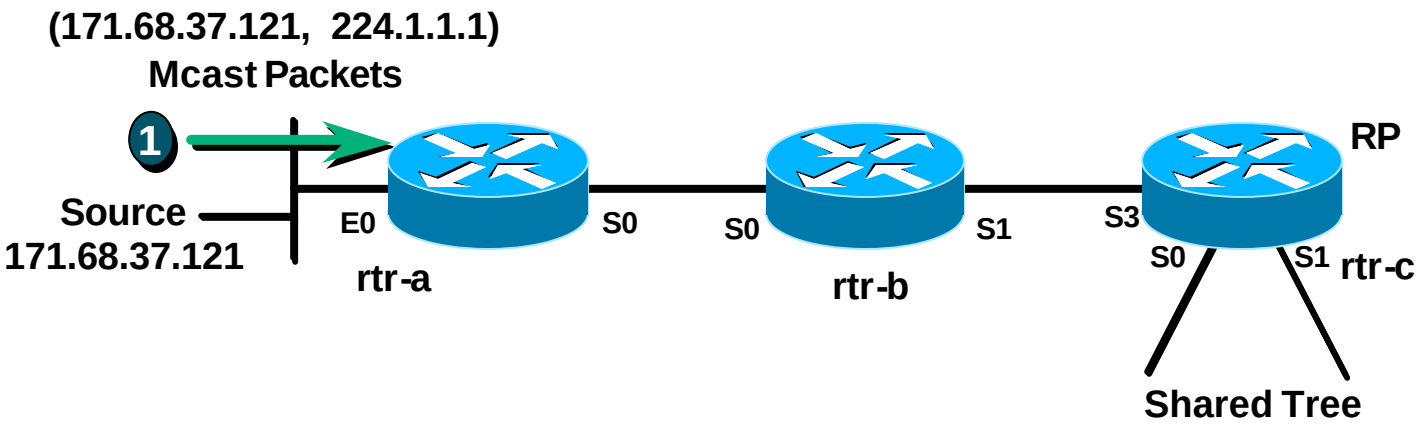
PIM SM Registering

Receiver Joins Group First



1. “Source” begins sending group G traffic.

A

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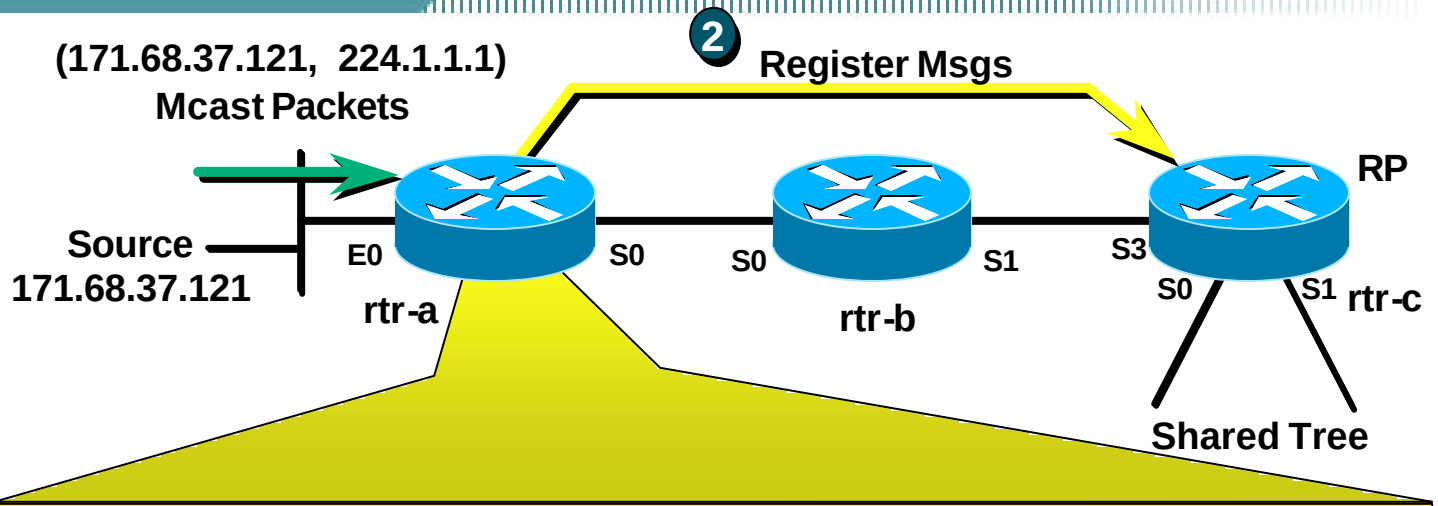
PIM SM Registering

Receiver Joins Group First




```
(*, 224.1.1.1), 00:00:03/00:02:56, RP 171.68.28.140, flags: SP
  Incoming interface: Serial0, RPF nbr 171.68.28.191,
  Outgoing interface list: Null

(171.68.37.121/32, 224.1.1.1), 00:00:03/00:02:56, flags: FPT
  Incoming interface: Ethernet0, RPF nbr 0.0.0.0, Registering
  Outgoing interface list: Null
```

"rtr-a" creates (S, G) state for source

(After automatically creating a (*, G) entry)

1. **"Source" begins sending group G traffic.**
2. **"rtr-a" encapsulates packets in Registers; unicasts to RP.**

A

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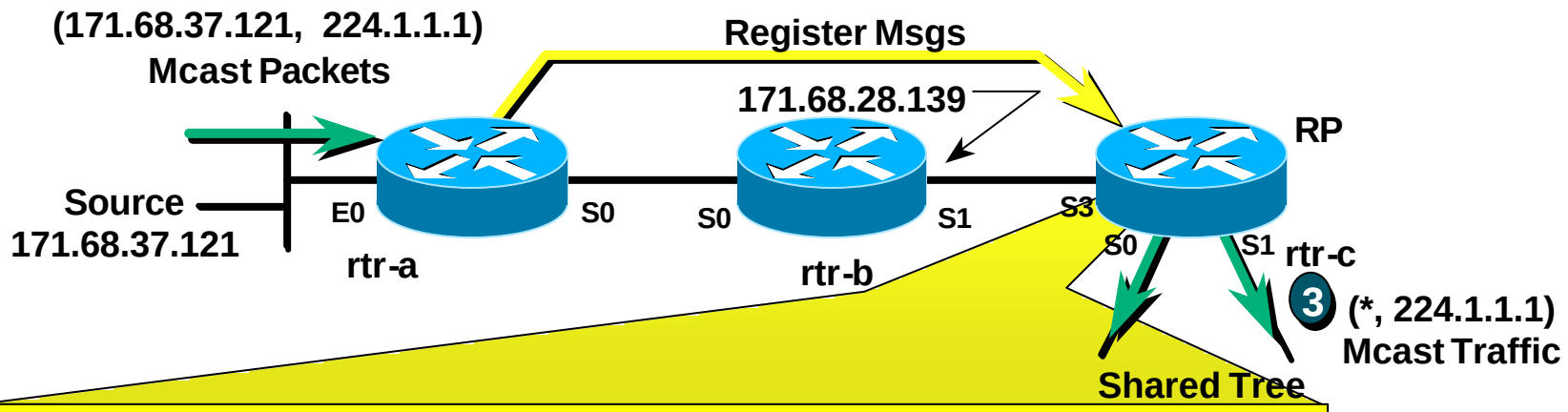
PIM SM Registering
Receiver Joins Group First




```
(*, 224.1.1.1), 00:09:21/00:02:38, RP 171.68.28.140, flags: S
  Incoming interface: Null, RPF nbr 0.0.0.0,
  Outgoing interface list:
    Serial0, Forward/Sparse, 00:09:21/00:02:38
    Serial1, Forward/Sparse, 00:03:14/00:02:46

(171.68.37.121, 224.1.1.1, 00:01:15/00:02:46, flags:
  Incoming interface: Serial3, RPF nbr 171.68.28.139,
  Outgoing interface list:
    Serial0, Forward/Sparse, 00:00:49/00:02:11
    Serial1, Forward/Sparse, 00:00:49/00:02:11
```

"RP" processes Register; creates (S, G) state

3 "rtr-c" (RP) de-encapsulates packets; forwards down Shared tree.

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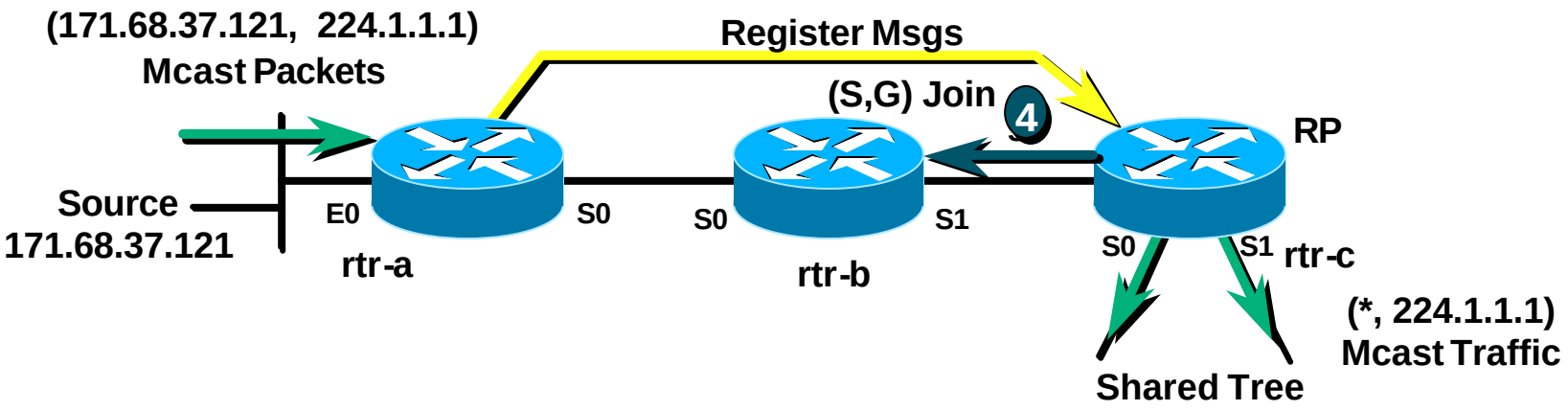
PIM SM Registering

Receiver Joins Group First



4 **RP sends (S,G) Join toward Source to build SPT.**

A

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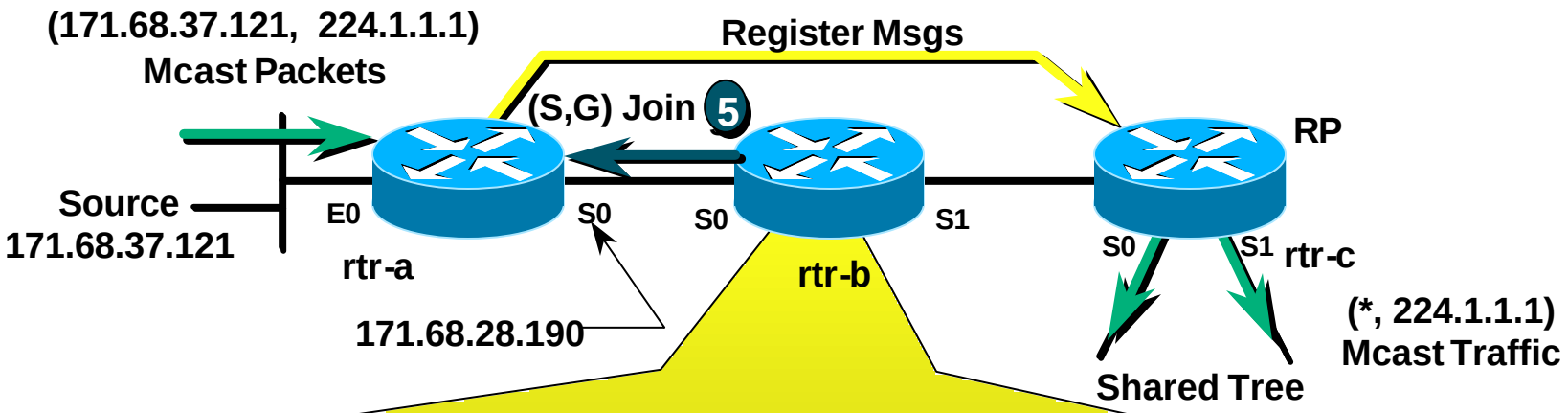
PIM SM Registering

Receiver Joins Group First




```
(*, 224.1.1.1), 00:04:28/00:01:32, RP 171.68.28.140, flags: SP
  Incoming interface: Serial1, RPF nbr 171.68.28.140,
  Outgoing interface list: Null

(171.68.37.121/32, 224.1.1.1), 00:04:28/00:01:32, flags:
  Incoming interface: Serial0, RPF nbr 171.68.28.190
  Outgoing interface list:
    Serial1, Forward/Sparse, 00:04:28/00:01:32
```

"rtr-b" processes Join, creates (S, G) state

(After automatically creating the (*, G) entry)

5 **"rtr-b" sends (S,G) Join toward Source to continue building SPT.**A

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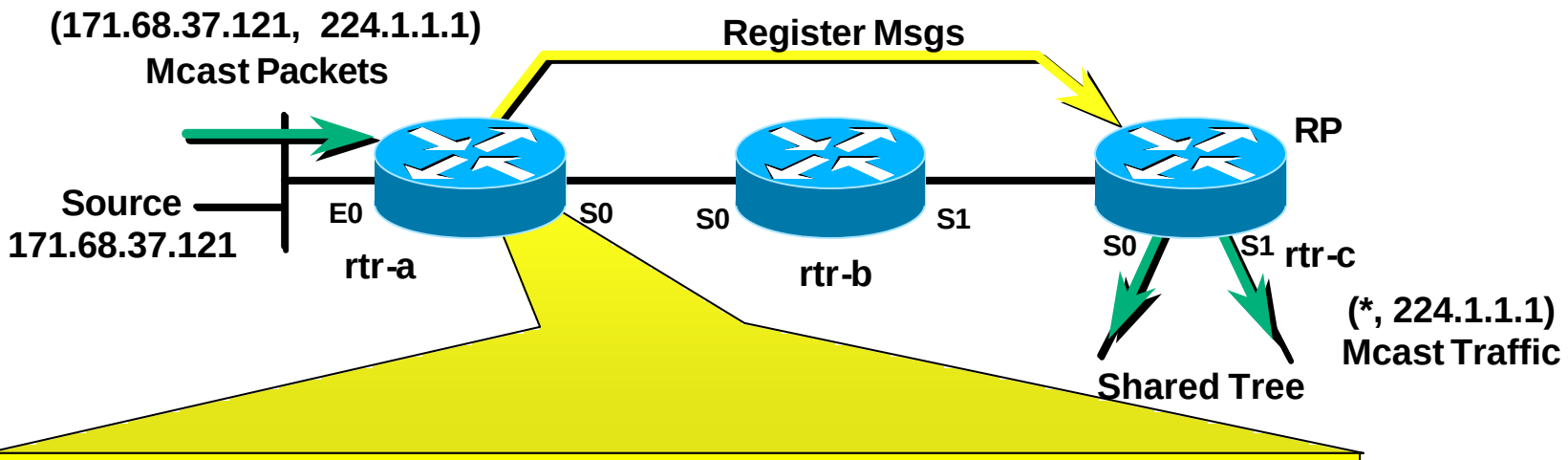
PIM SM Registering

Receiver Joins Group First




```
(*, 224.1.1.1), 00:04:28/00:01:32, RP 171.68.28.140, flags: SP
  Incoming interface: Serial0, RPF nbr 171.68.28.191,
  Outgoing interface list: Null

(171.68.37.121/32, 224.1.1.1), 00:04:28/00:01:32, flags: FT
  Incoming interface: Ethernet0, RPF nbr 0.0.0.0, Registering
  Outgoing interface list:
    Serial0, Forward/Sparse, 00:04:28/00:01:32
```

“rtr-a” processes the (S, G) Join; adds Serial 0 to OIL

A

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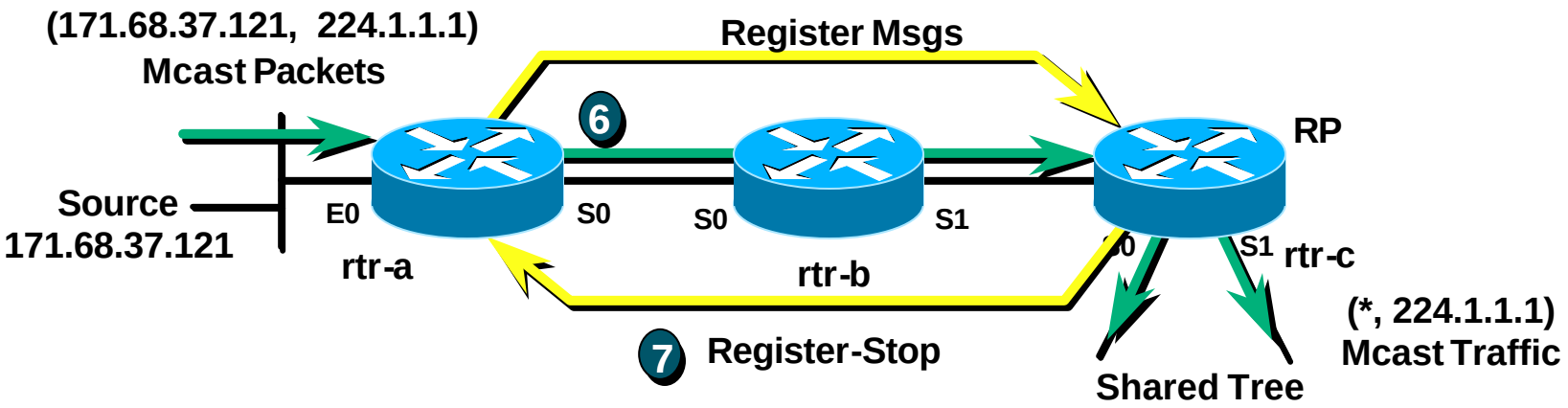
PIM SM Registering
Receiver Joins Group First



6. RP begins receiving (S,G) traffic down SPT.
7. RP sends “Register-Stop” to “rtr-a”.

A

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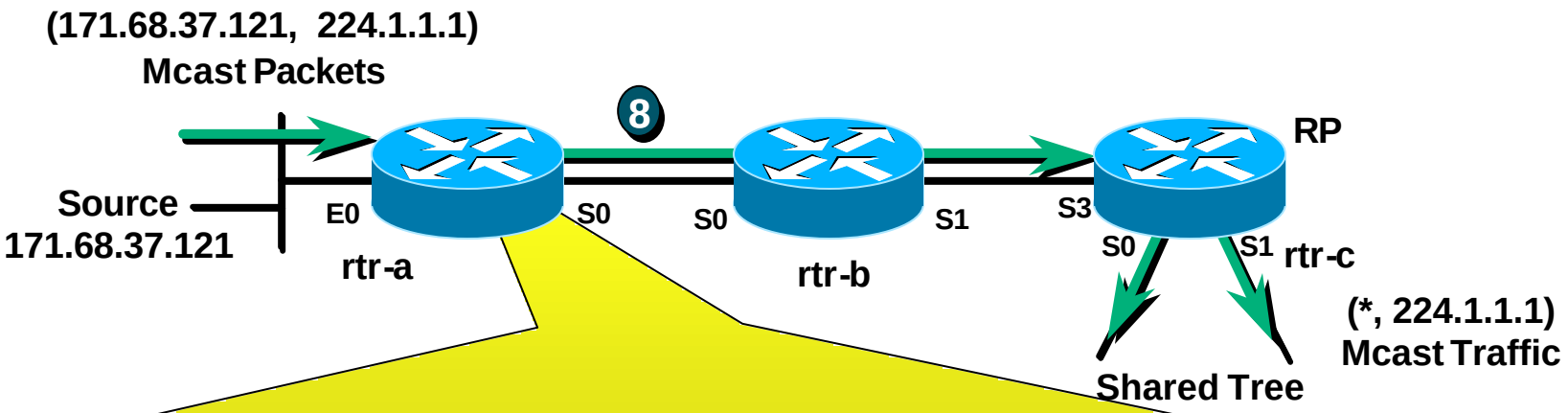
PIM SM Registering

Receiver Joins Group First




```
(*, 224.1.1.1), 00:04:28/00:01:32, RP 171.68.28.140, flags: SP
  Incoming interface: Serial0, RPF nbr 171.68.28.191,
  Outgoing interface list: Null

(171.68.37.121/32, 224.1.1.1), 00:04:28/00:01:32, flags: FT
  Incoming interface: Ethernet0, RPF nbr 0.0.0.0,
  Outgoing interface list:
     Serial0, Forward/Sparse, 00:04:28/00:01:32
```

“rtr-a” stops sending Register messages

(Final State in “rtr-a”)

8 **(S,G) Traffic now flowing down a single path (SPT) to RP.**

A

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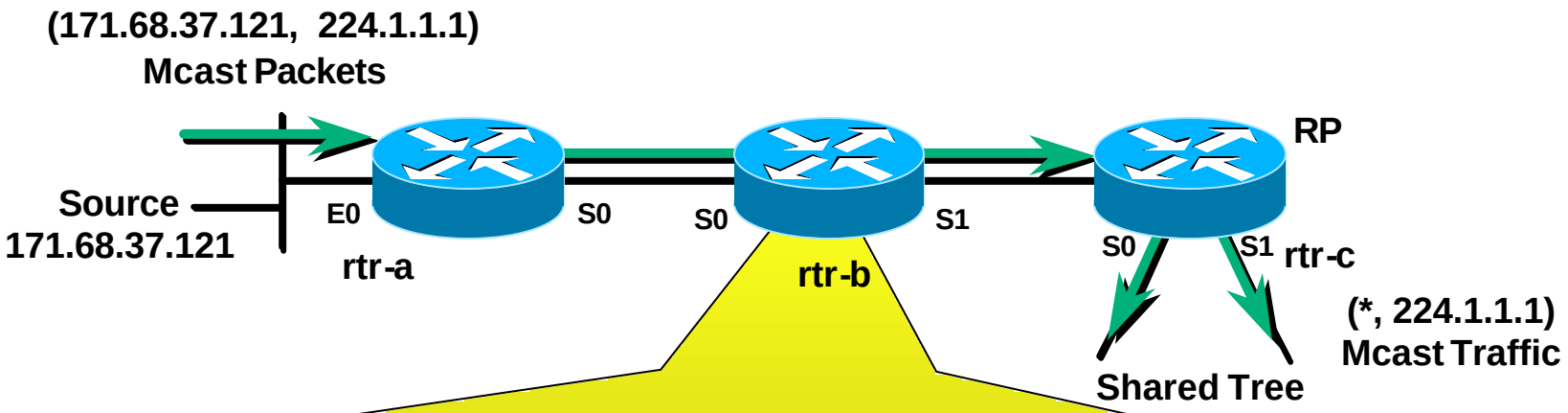
PIM SM Registering
Receiver Joins Group First




```
(*, 224.1.1.1), 00:04:28/00:01:32, RP 171.68.28.140, flags: SP
  Incoming interface: Serial1, RPF nbr 171.68.28.140,
  Outgoing interface list: Null

(171.68.37.121/32, 224.1.1.1), 00:04:28/00:01:32, flags: T
  Incoming interface: Serial0, RPF nbr 171.68.28.190
  Outgoing interface list:
    Serial1, Forward/Sparse, 00:04:28/00:01:32
```

Final state in “rtr-b”

A

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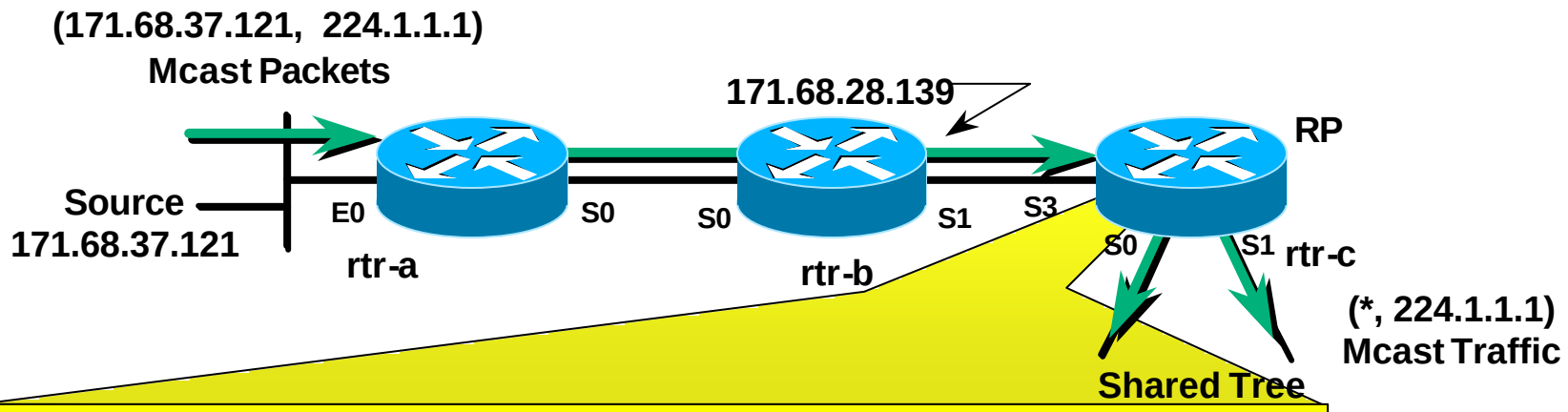
PIM SM Registering

Receiver Joins Group First




```
(*, 224.1.1.1), 00:09:21/00:02:38, RP 171.68.28.140, flags: S
  Incoming interface: Null, RPF nbr 0.0.0.0,
  Outgoing interface list:
    Serial0, Forward/Sparse, 00:09:21/00:02:38
    Serial1, Forward/Sparse, 00:03:14/00:02:46

(171.68.37.121, 224.1.1.1, 00:01:15/00:02:46, flags: T
  Incoming interface: Serial3, RPF nbr 171.68.28.139,
  Outgoing interface list:
    Serial0, Forward/Sparse, 00:00:49/00:02:11
    Serial1, Forward/Sparse, 00:00:49/00:02:11
```

Final state in the “RP”

(with receivers on Shared Tree)

A

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PIM SM Register Examples

- Receivers Join Group First
- Source Registers First
- Receivers along the SPT

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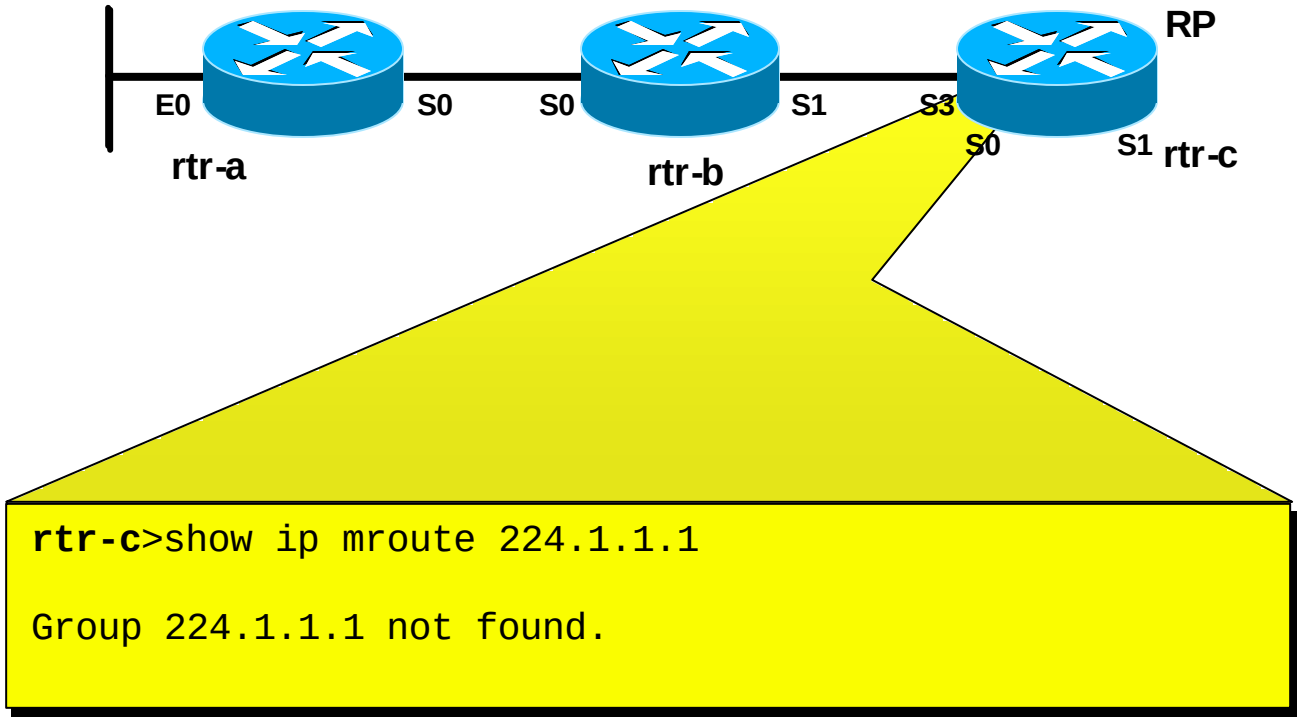
PIM SM Registering
Source Registers First



State in "RP" before Registering
(without receivers on Shared Tree)

A

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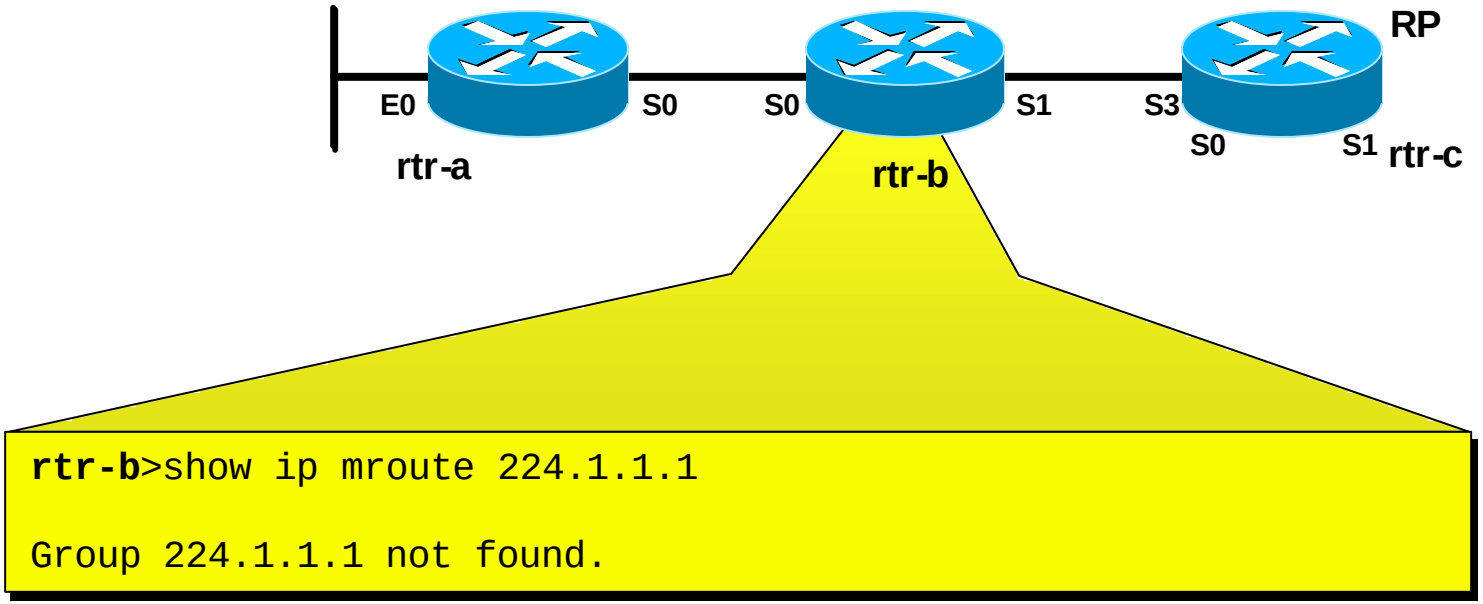
PIM SM Registering
Source Registers First



State in “rtr-b” before any source registers
(with receivers on Shared Tree)

A

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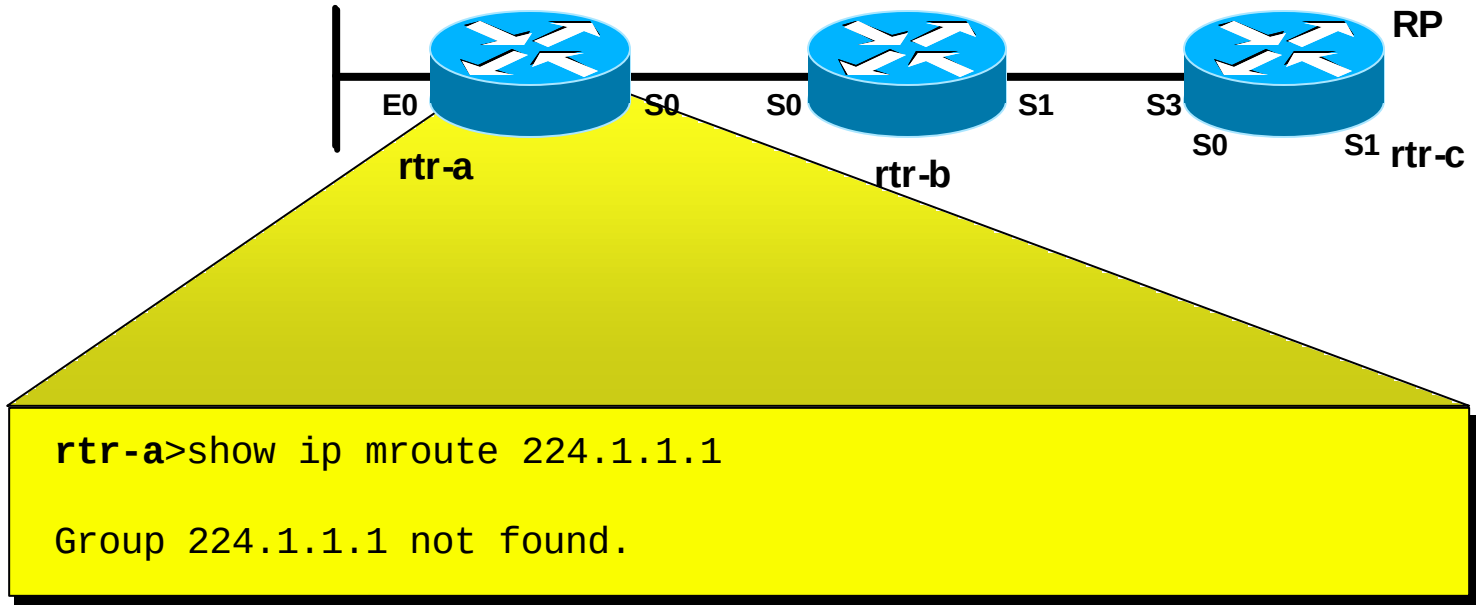
PIM SM Registering
Source Registers First



State in "rtr-a" before any source registers
(with receivers on Shared Tree)

A

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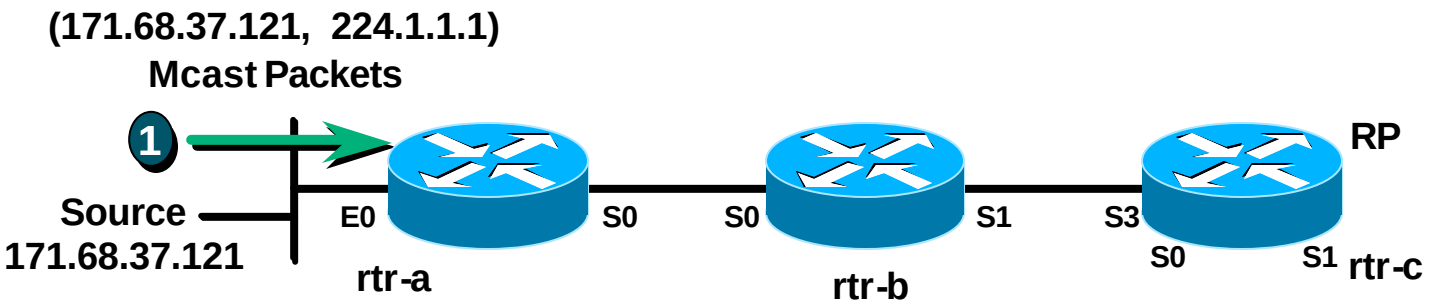
PIM SM Registering

Source Registers First



1. “Source” begins sending group G traffic.

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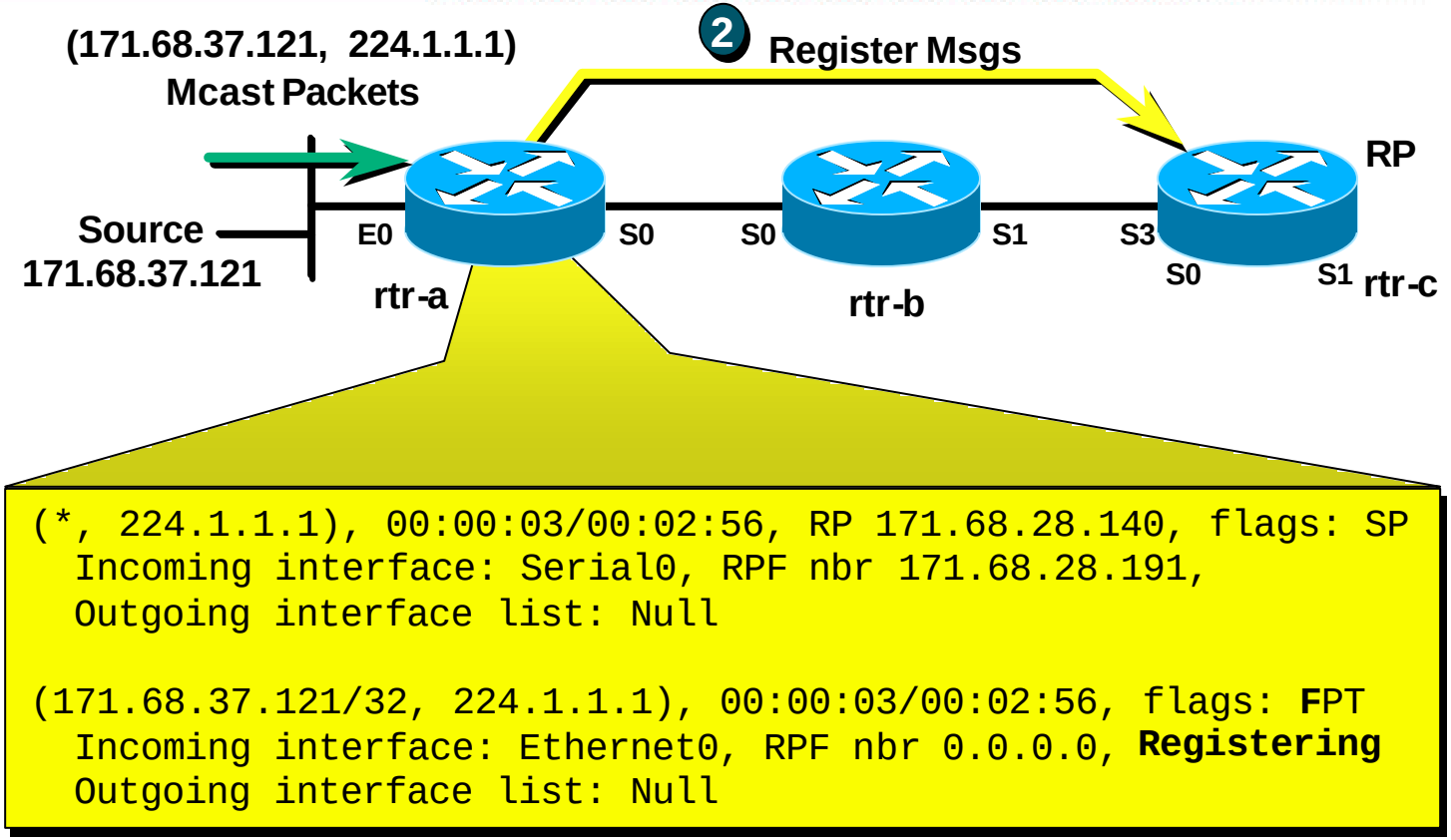
PIM SM Registering

Source Registers First



"rtr-a" creates (S, G) state for source

(After automatically creating a (*, G) entry)

1. **"Source" begins sending group G traffic.**
2. **"rtr-a" encapsulates packets in Registers; unicasts to RP.**

A

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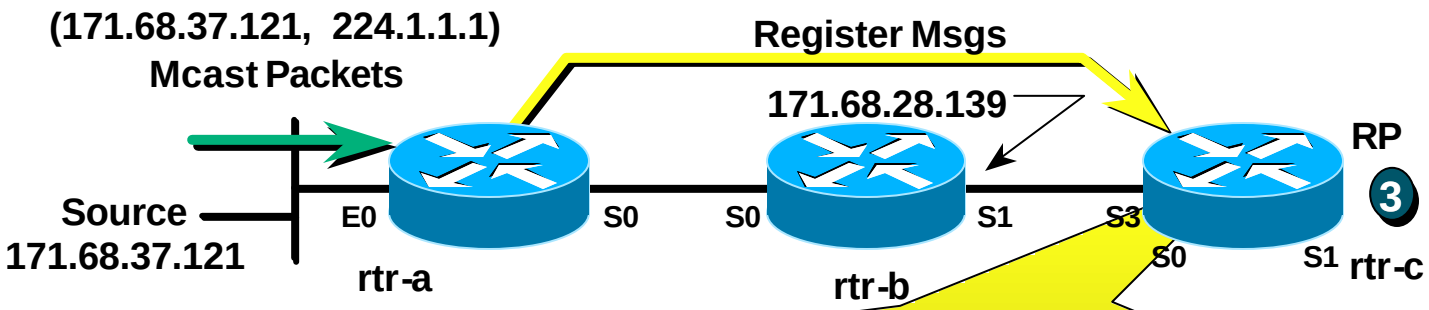
PIM SM Registering
Source Registers First




```
(*, 224.1.1.1), 00:01:15/00:01:45, RP 171.68.28.140, flags: SP
  Incoming interface: Null, RPF nbr 0.0.0.0,
  Outgoing interface list: Null

(171.68.37.121, 224.1.1.1), 00:01:15/00:01:45, flags: P
  Incoming interface: Serial3, RPF nbr 171.68.28.139,
  Outgoing interface list: Null
```

"RP" processes Register; creates (S, G) state

(After automatically creating the (*, G) entry)

3 **"rtr-c" (RP) has no receivers on Shared Tree; discards packet.**

A

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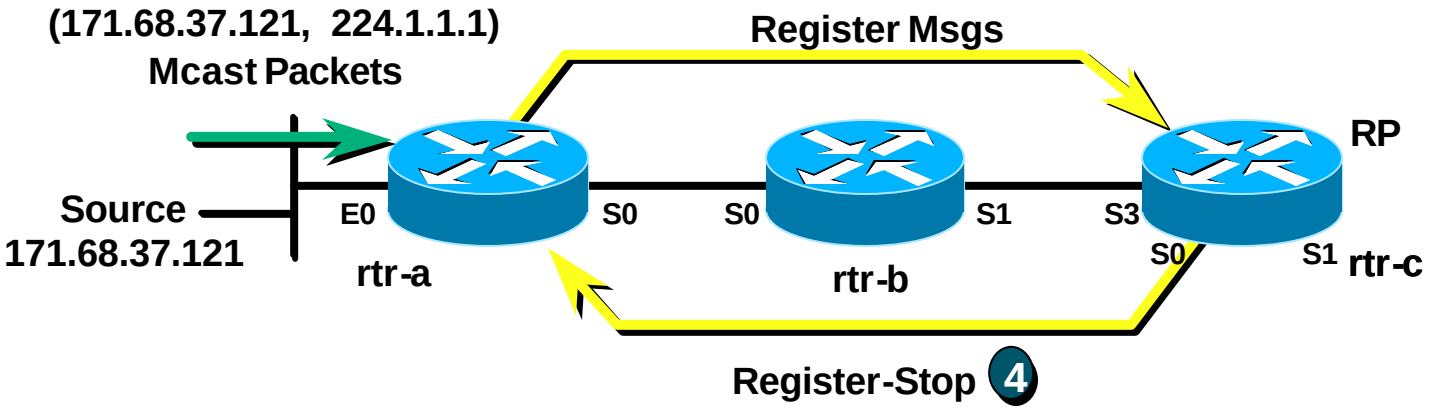
PIM SM Registering
Source Registers First



4. RP sends “Register-Stop” to “rtr-a”.

A

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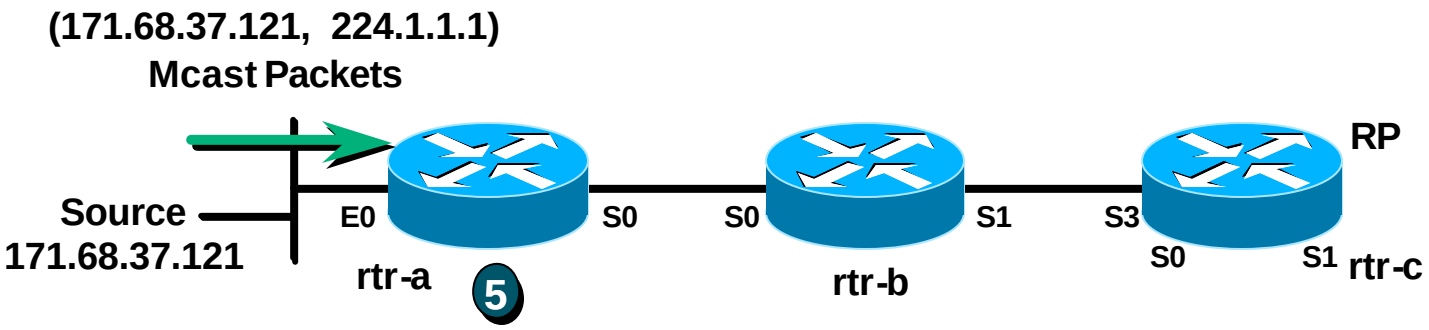
PIM SM Registering

Source Registers First



5 “rtr-a” stops encapsulating traffic in Register Messages; drops packets from Source.

A

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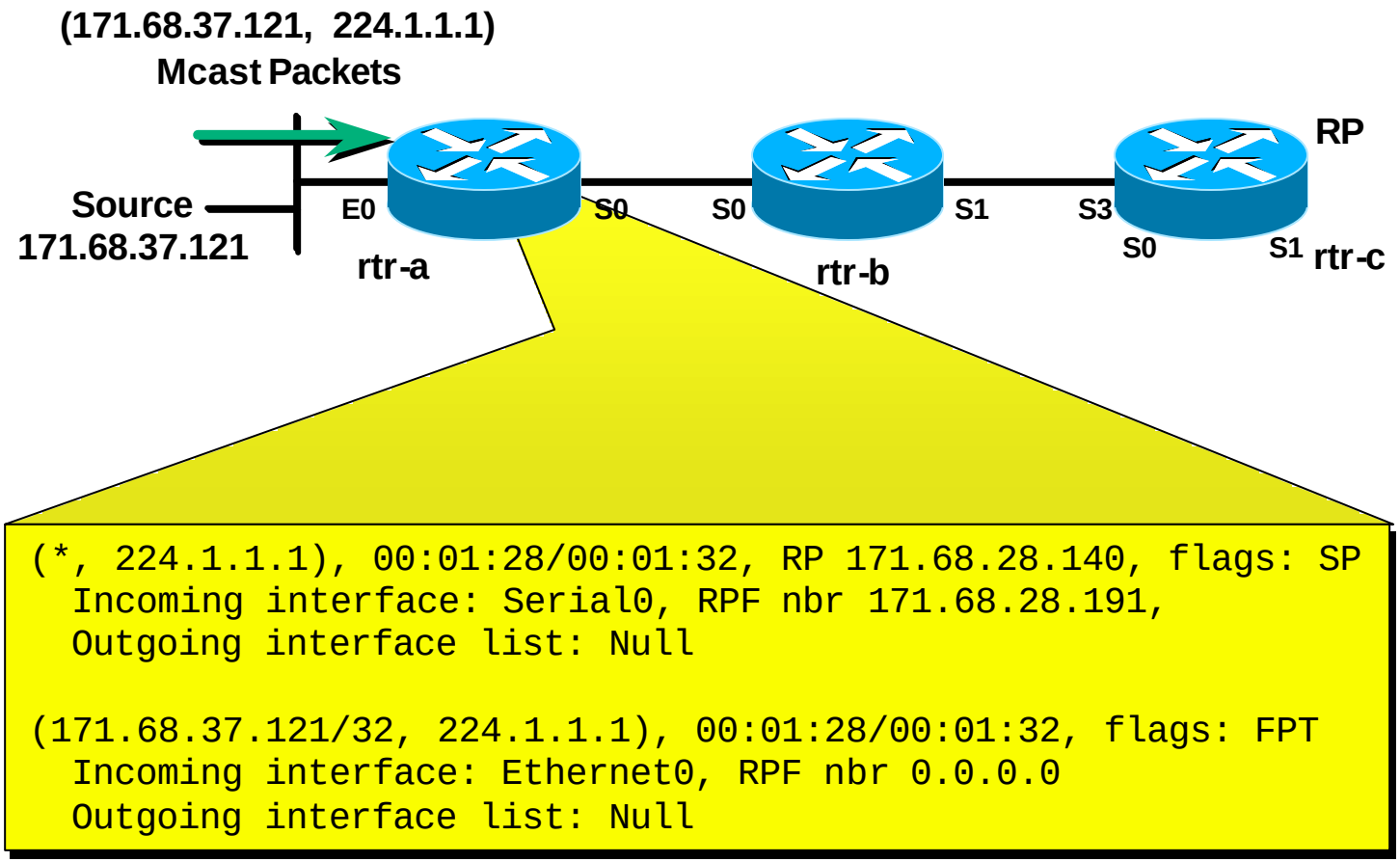
PIM SM Registering

Source Registers First



State in "rtr-a" after Registering

(without receivers on Shared Tree)

A

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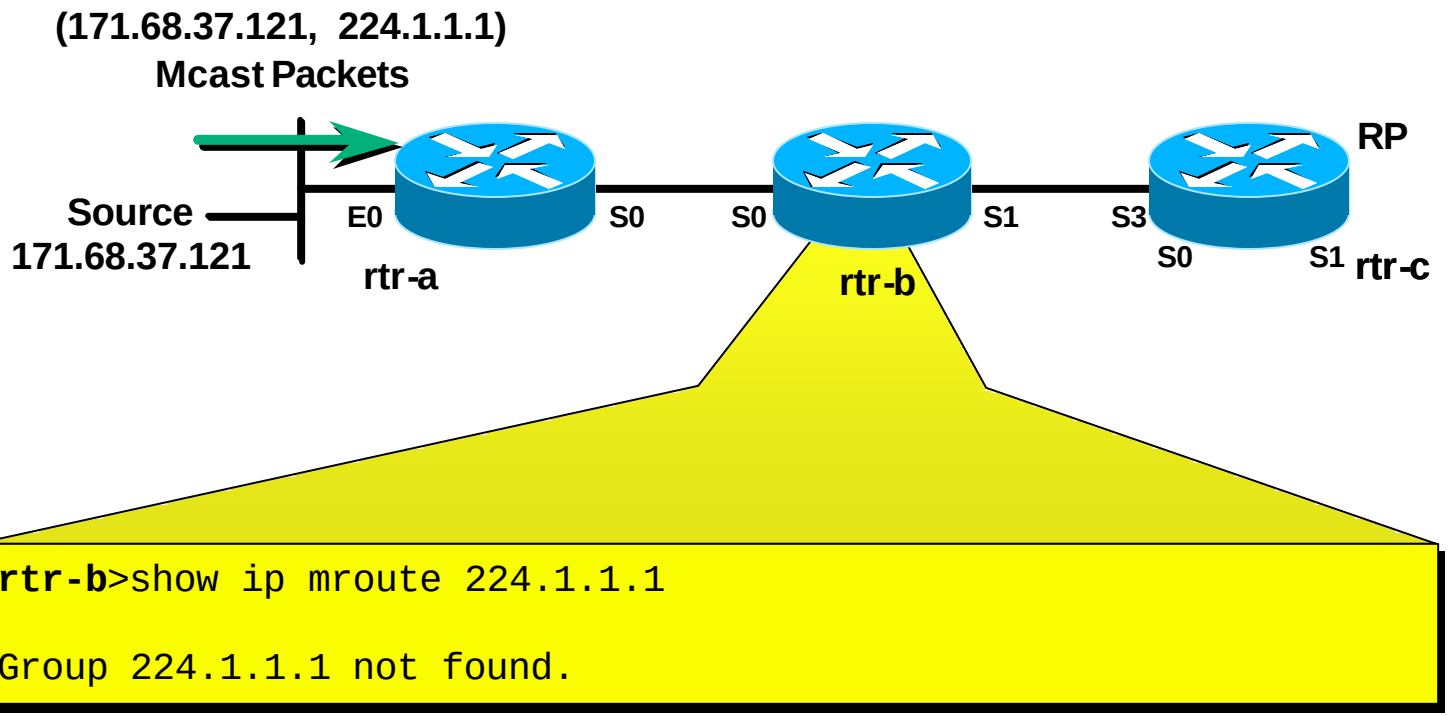
PIM SM Registering

Source Registers First



State in "rtr-b" after "rtr-a" Registers

(without receivers on Shared Tree)

A

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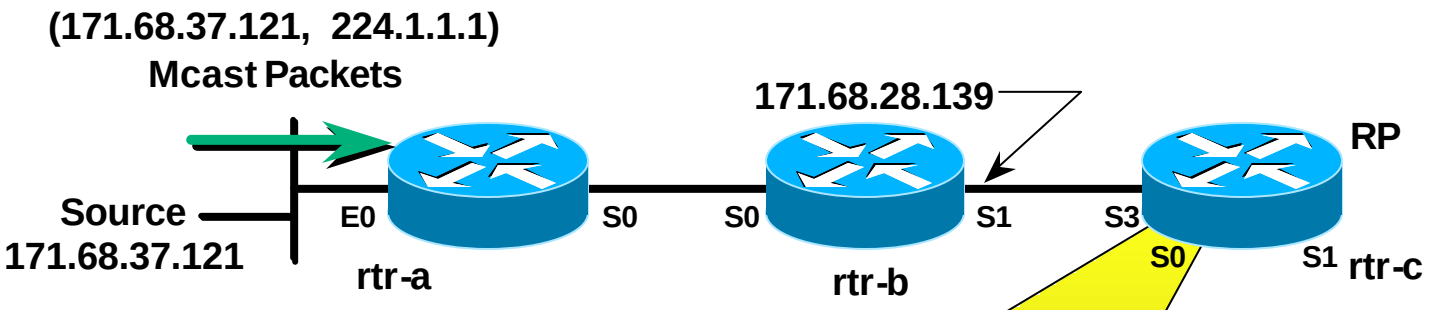
PIM SM Registering

Source Registers First




```
(*, 224.1.1.1), 00:01:15/00:01:45, RP 171.68.28.140, flags: SP
  Incoming interface: Null, RPF nbr 0.0.0.0,
  Outgoing interface list: Null

(171.68.37.121, 224.1.1.1), 00:01:15/00:01:45, flags: P
  Incoming interface: Serial3, RPF nbr 171.68.28.139,
  Outgoing interface list: Null
```

State in “RP” after “rtr-a” Registers
(without receivers on Shared Tree)

A

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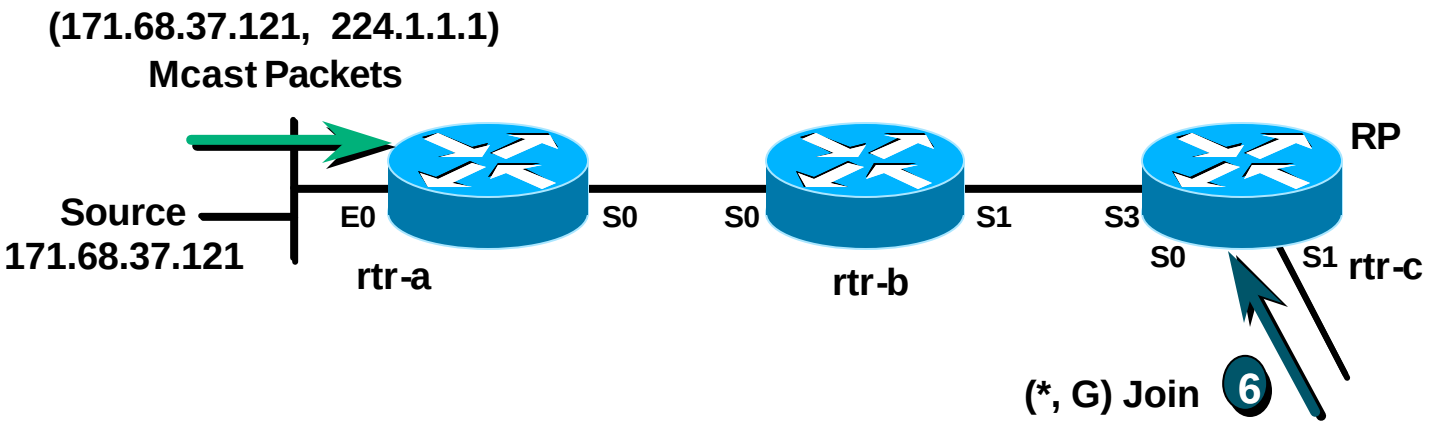
PIM SM Registering

Source Registers First



Receivers begin joining the Shared Tree

6 **RP (“rtr-c”) receives (*, G) Join from a receiver on Shared Tree.**

A

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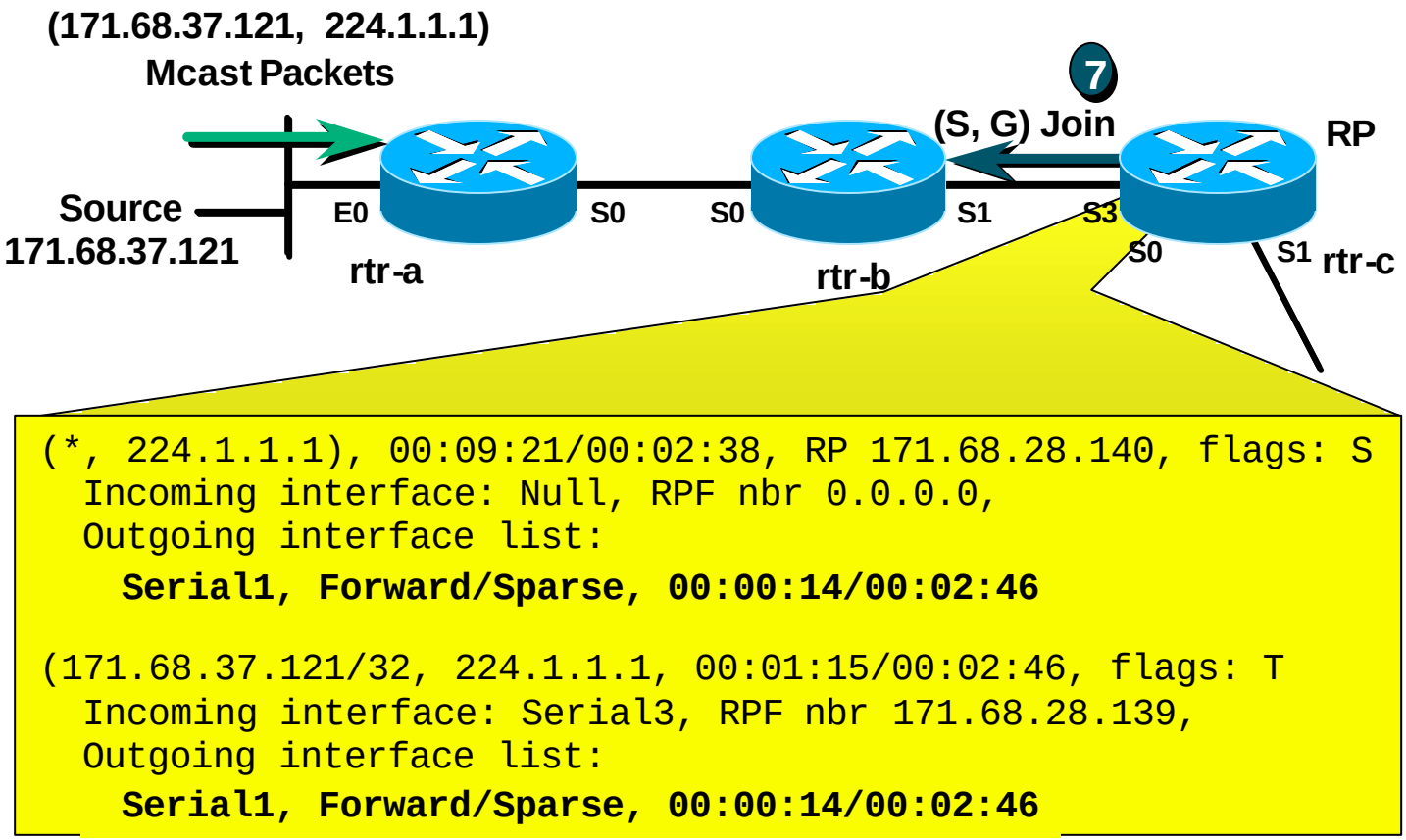
PIM SM Registering
Source Registers First



"RP" processes (*,G) Join

(Adds Serial1 to Outgoing Interface Lists)

7 **RP sends (S,G) Joins for all known Sources in Group.**

A

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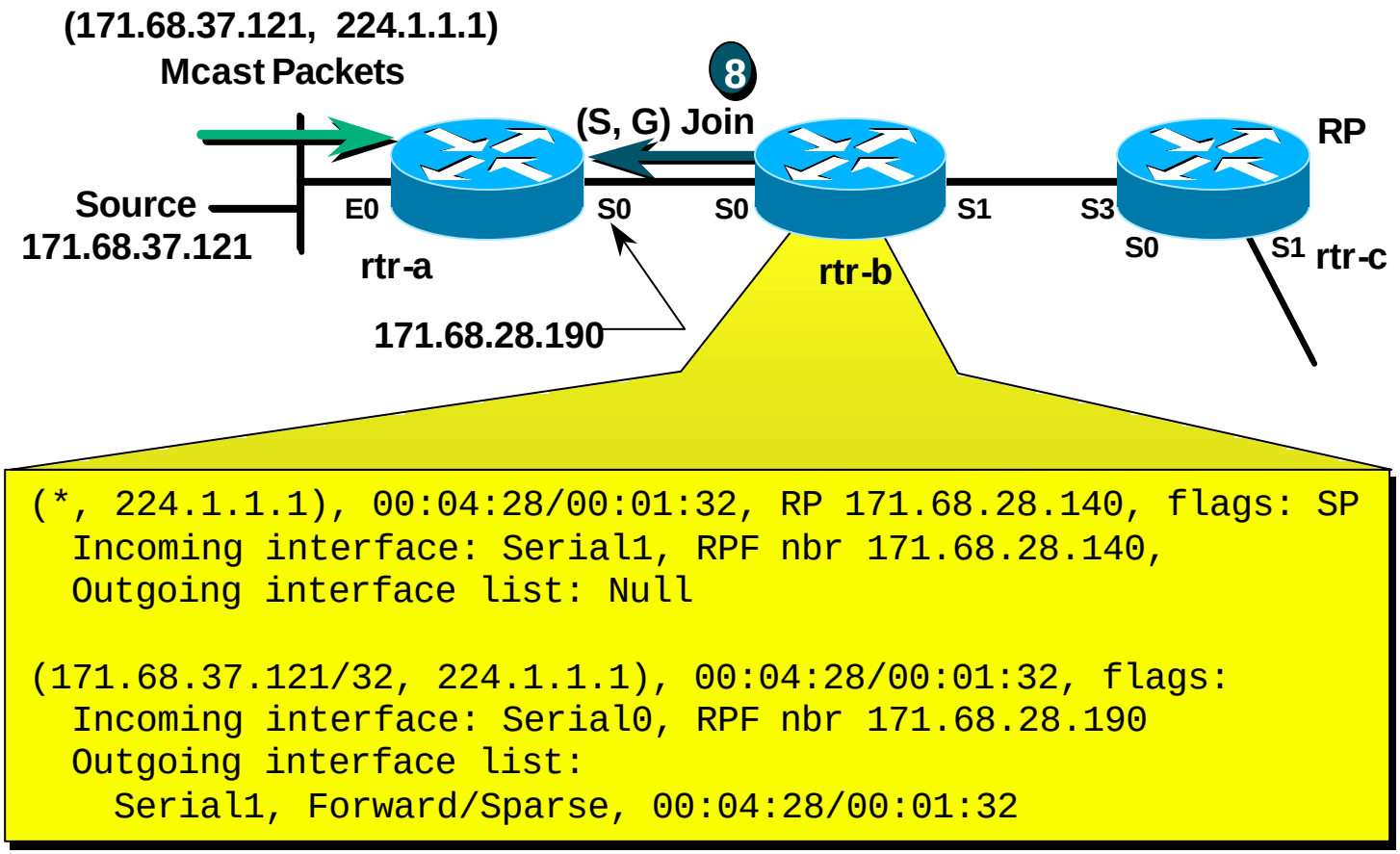
PIM SM Registering

Source Registers First



"rtr-b" processes Join, creates (S, G) state

(After automatically creating the (*, G) entry)

8 **"rtr-b" sends (S,G) Join toward Source to continue building SPT.**A

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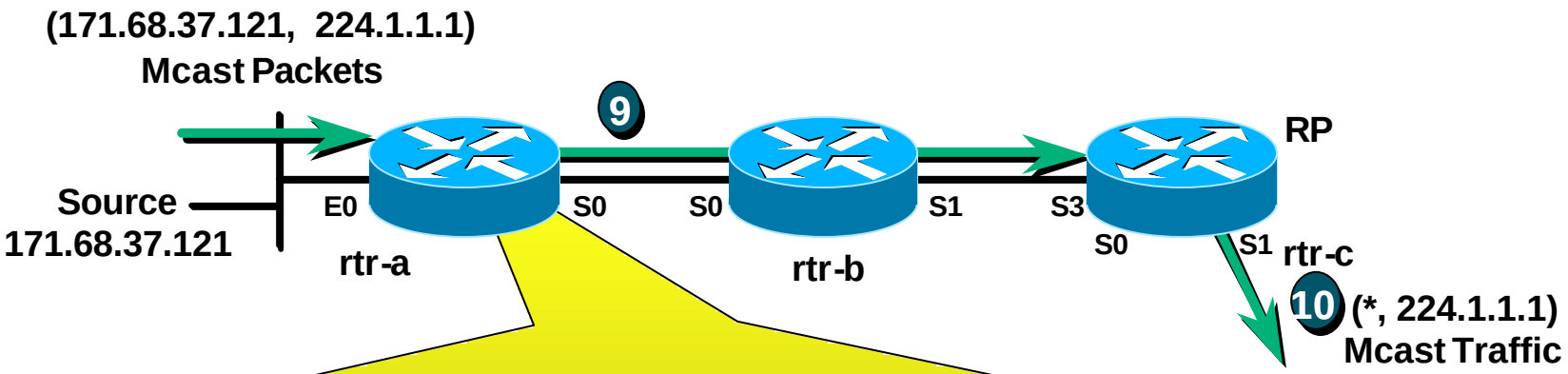
PIM SM Registering

Source Registers First




```
(*, 224.1.1.1), 00:04:28/00:01:32, RP 171.68.28.140, flags: SP
  Incoming interface: Serial0, RPF nbr 171.68.28.191,
  Outgoing interface list: Null

(171.68.37.121/32, 224.1.1.1), 00:04:28/00:01:32, flags: FT
  Incoming interface: Ethernet0, RPF nbr 0.0.0.0,
  Outgoing interface list:
    Serial0, Forward/Sparse, 00:04:28/00:01:32
```

"rtr-a" processes the (S, G) Join; adds Serial0 to OIL

9 **RP begins receiving (S,G) traffic down SPT.**

10 **RP forwards (S,G) traffic down Shared Tree to receivers.**

A

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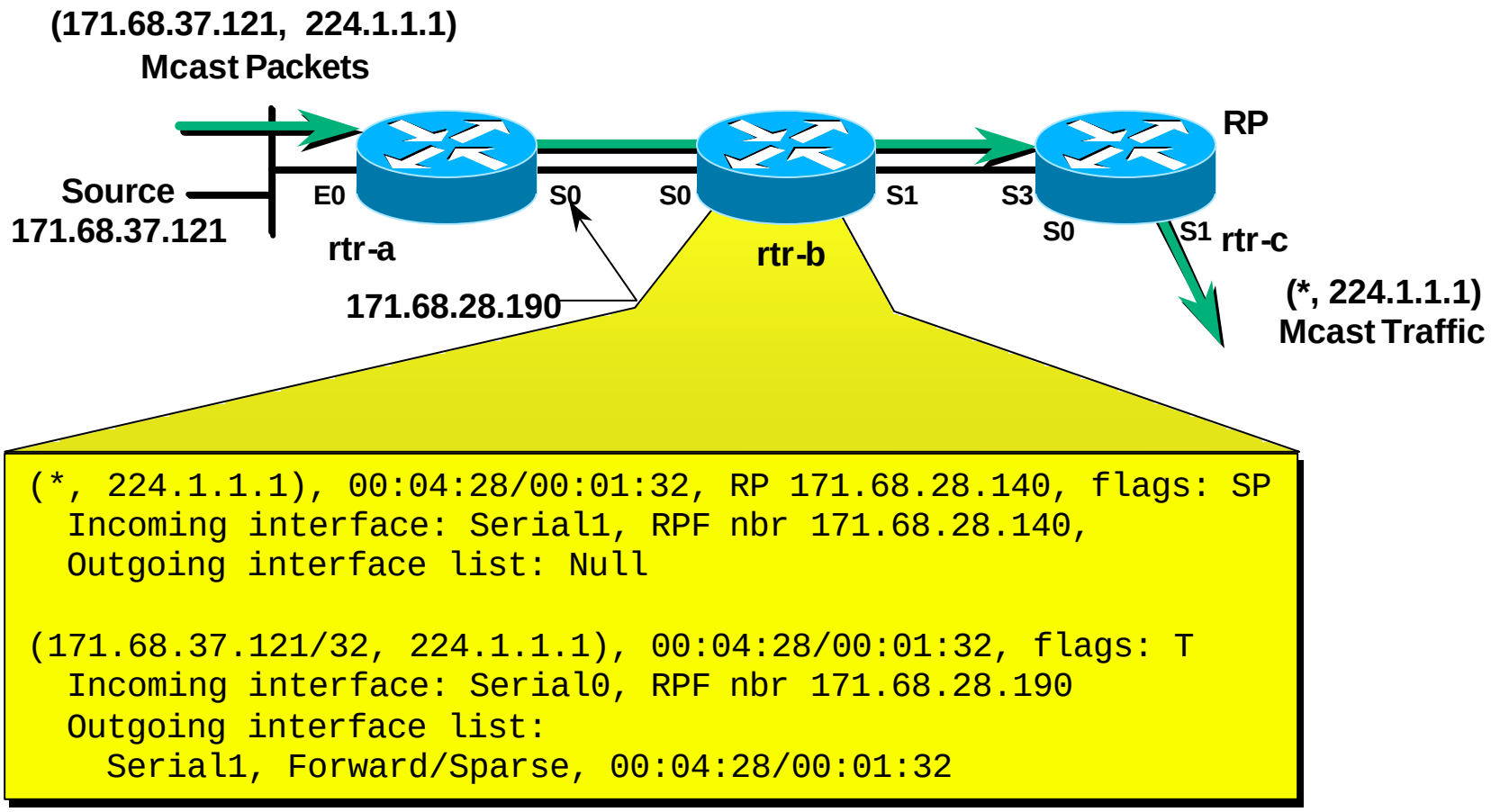
PIM SM Registering

Source Registers First



Final state in “rtr-b” after Receivers Join

A

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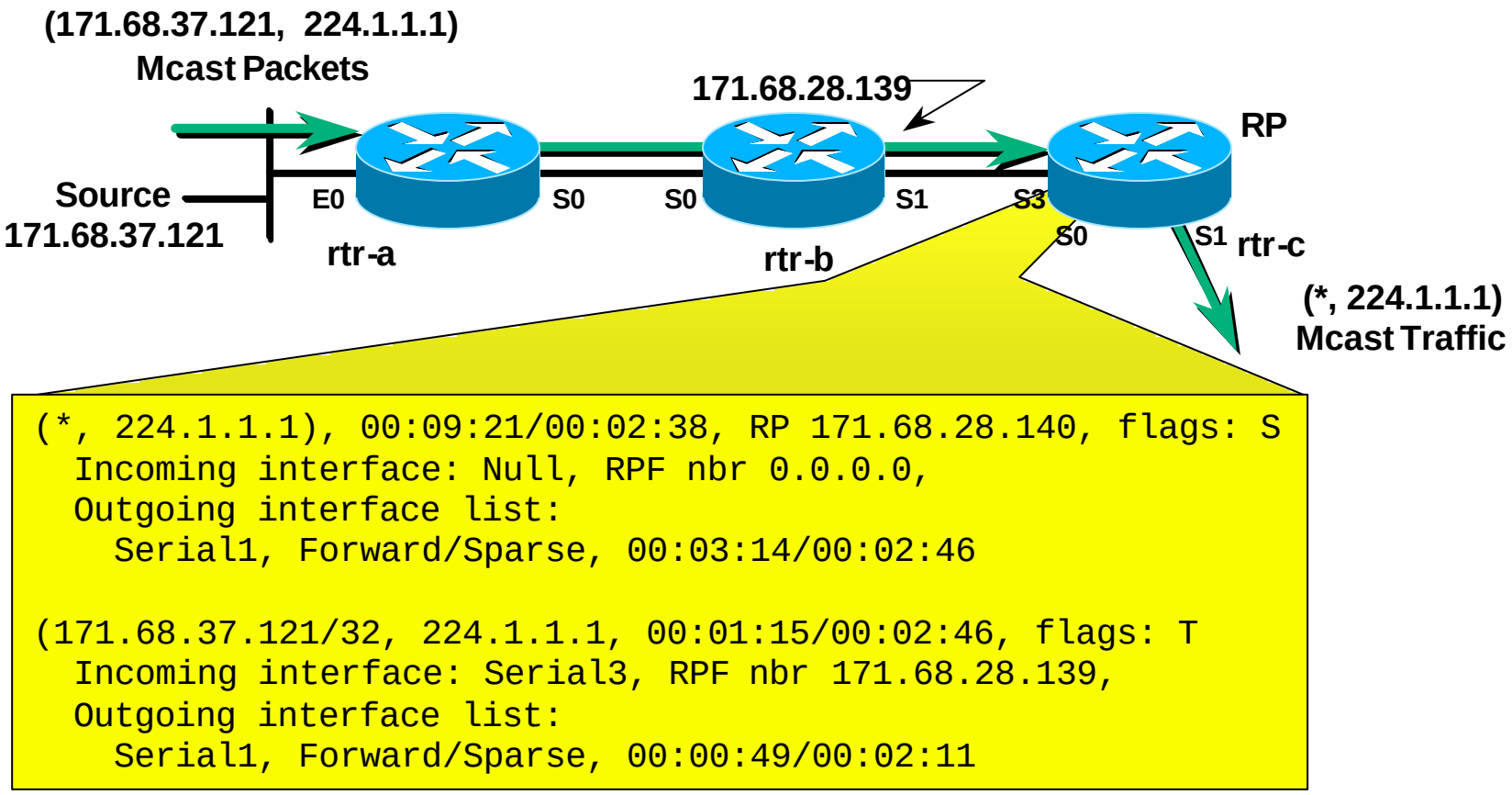
PIM SM Registering

Source Registers First




```
(*, 224.1.1.1), 00:09:21/00:02:38, RP 171.68.28.140, flags: S
  Incoming interface: Null, RPF nbr 0.0.0.0,
  Outgoing interface list:
    Serial1, Forward/Sparse, 00:03:14/00:02:46

(171.68.37.121/32, 224.1.1.1, 00:01:15/00:02:46, flags: T
  Incoming interface: Serial3, RPF nbr 171.68.28.139,
  Outgoing interface list:
    Serial1, Forward/Sparse, 00:00:49/00:02:11
```

Final state in “RP” after Receivers Join

A

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PIM SM Register Examples

- Receivers Join Group First
- Source Registers First
- Receivers along the SPT

B

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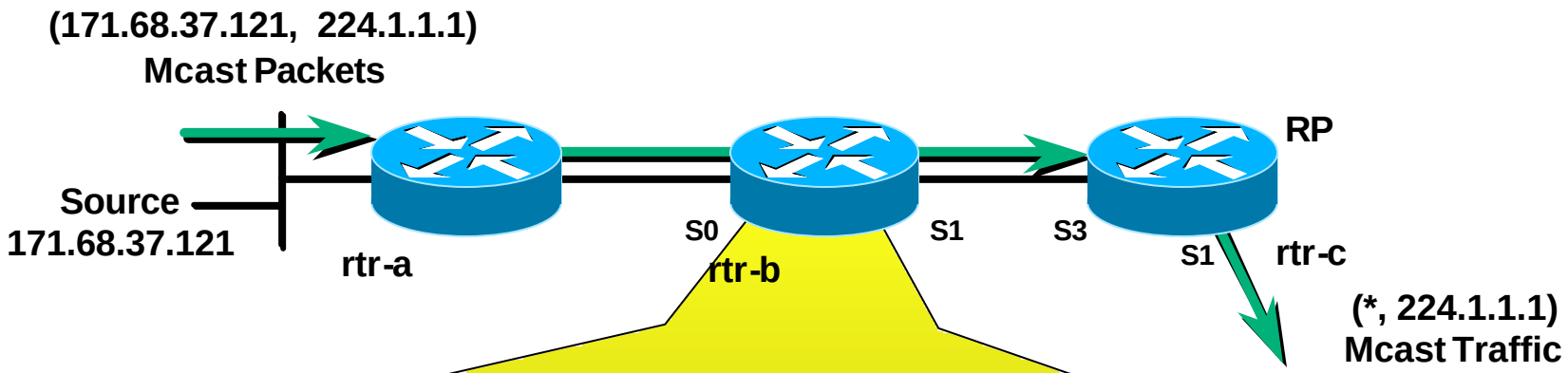
PIM SM Registering
Receivers along the SPT




```
(*, 224.1.1.1), 00:04:28/00:01:32, RP 171.68.28.140, flags: SP
  Incoming interface: Serial1, RPF nbr 171.68.28.140,
  Outgoing interface list: Null

(171.68.37.121/32, 224.1.1.1), 00:04:28/00:01:32, flags: T
  Incoming interface: Serial0, RPF nbr 171.68.28.190
  Outgoing interface list:
    Serial1, Forward/Sparse, 00:04:28/00:01:32
```

Current state in “rtr-b”

B

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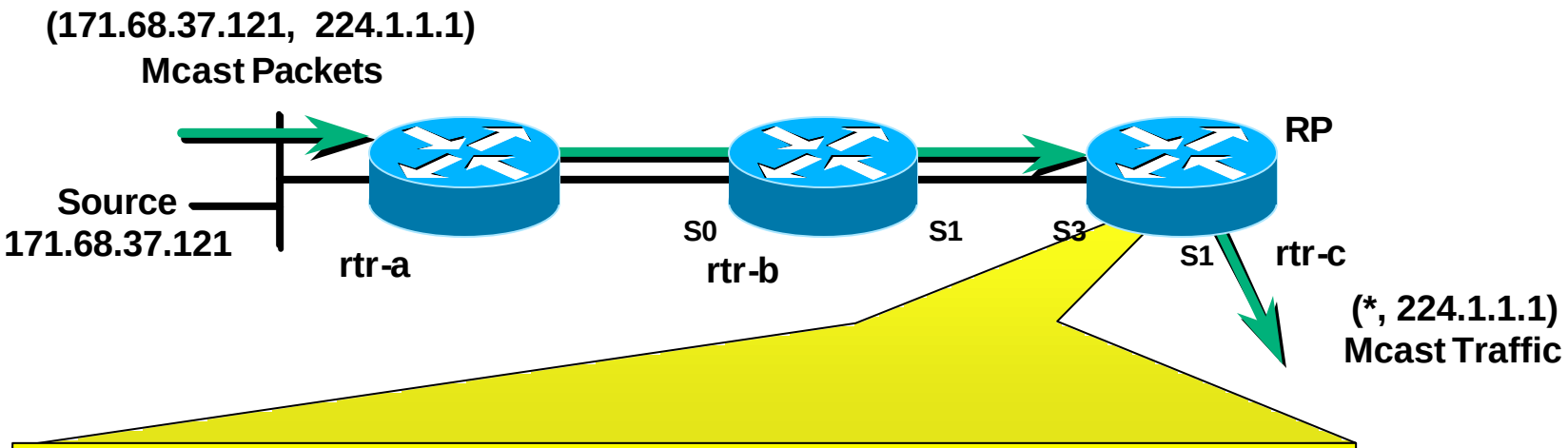
PIM SM Registering

Receivers along the SPT




```
(*, 224.1.1.1), 00:09:21/00:02:38, RP 171.68.28.140, flags: S
  Incoming interface: Null, RPF nbr 0.0.0.0,
  Outgoing interface list:
    Serial1, Forward/Sparse, 00:03:14/00:02:46

(171.68.37.121/32, 224.1.1.1, 00:01:15/00:02:46, flags: T
  Incoming interface: Serial3, RPF nbr 171.68.28.139,
  Outgoing interface list:
    Serial1, Forward/Sparse, 00:00:49/00:02:11
```

Current state in the RP

B

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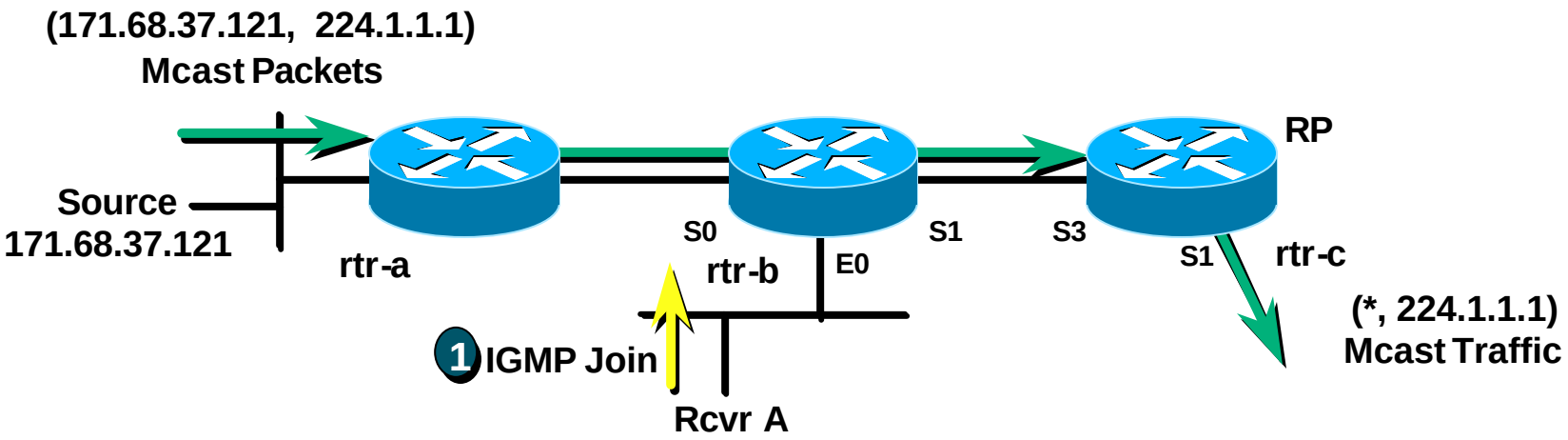
PIM SM Registering
Receivers along the SPT



1. "Rcvr A" wishes to receive group G traffic. Sends IGMP Join for G.

B

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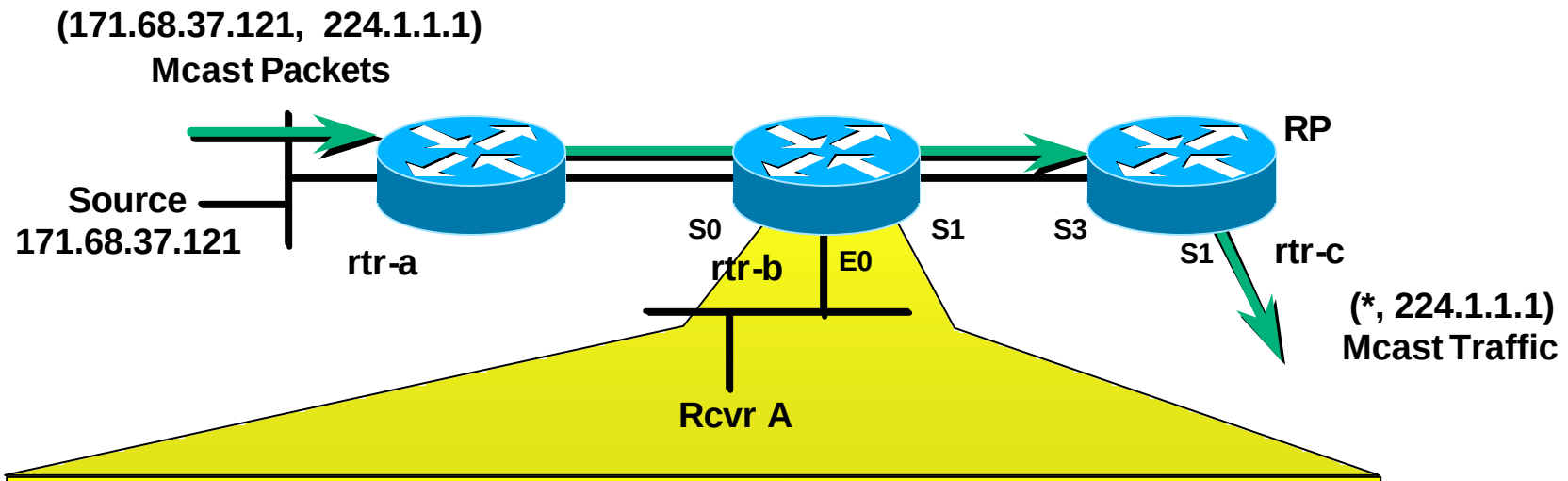
PIM SM Registering

Receivers along the SPT




```
(*, 224.1.1.1), 00:04:28/00:01:32, RP 171.68.28.140, flags: SC
  Incoming interface: Serial1, RPF nbr 171.68.28.140,
  Outgoing interface list:
    Ethernet0, Forward/Sparse, 00:00:30/00:02:30

(171.68.37.121/32, 224.1.1.1), 00:04:28/00:01:32, flags: CT
  Incoming interface: Serial0, RPF nbr 171.68.28.190
  Outgoing interface list:
    Serial1, Forward/Sparse, 00:04:28/00:01:32
    Ethernet0, Forward/Sparse, 00:00:30/00:02:30
```

Added Interfaces

State in "rtr-b" after "Rcvr A" joins group

B

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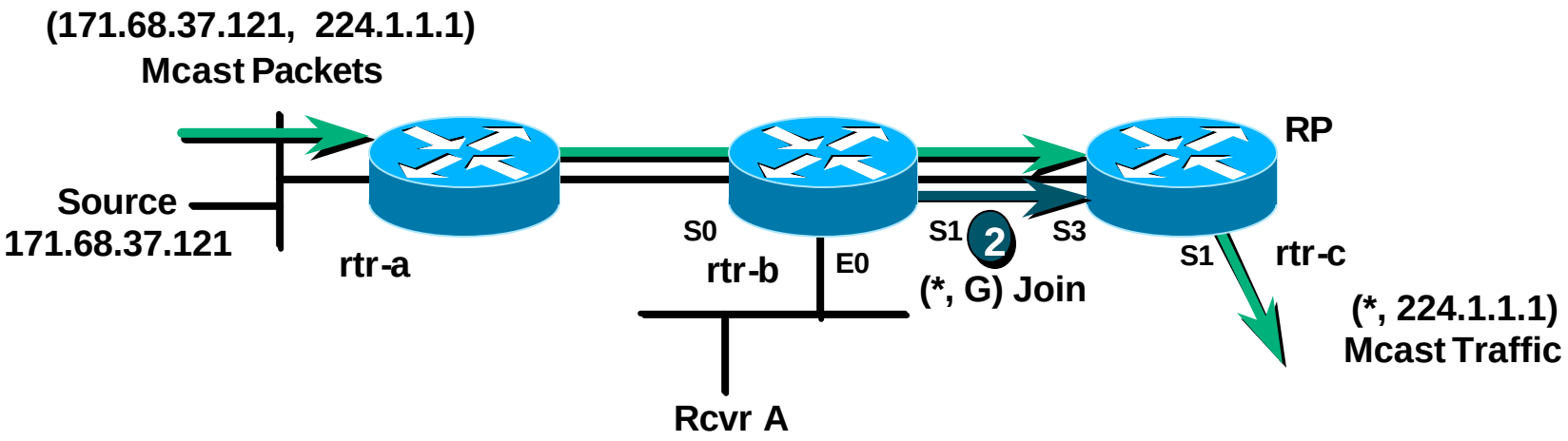
PIM SM Registering
Receivers along the SPT



2 "rtr-b" triggers a (*,G) Join to join the Shared Tree

B

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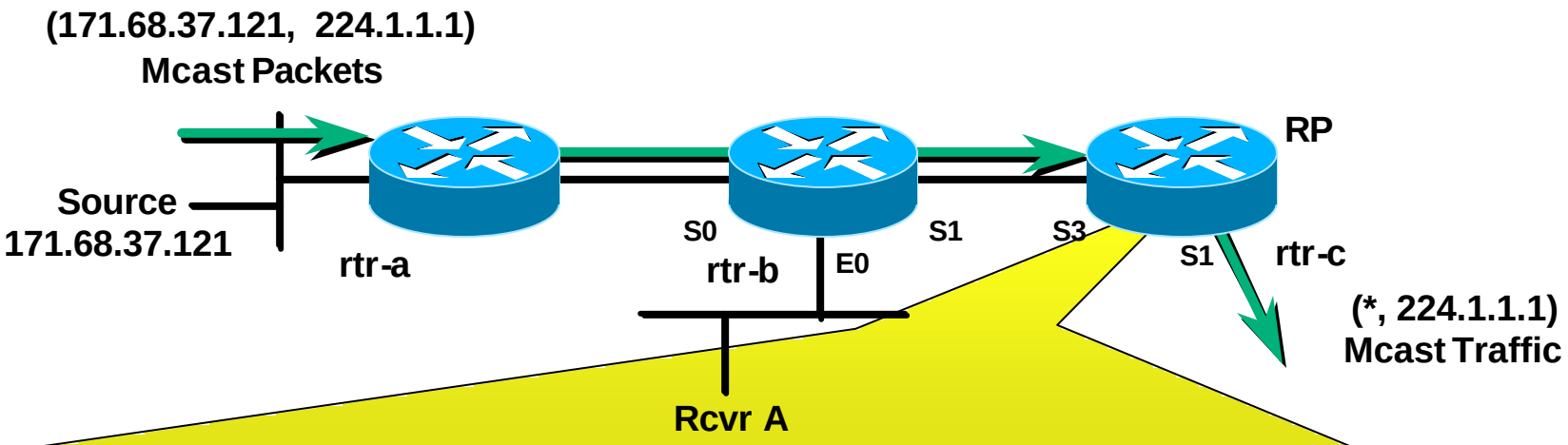
PIM SM Registering

Receivers along the SPT




```
(*, 224.1.1.1), 00:09:21/00:02:38, RP 171.68.28.140, flags: S
  Incoming interface: Null, RPF nbr 0.0.0.0,
  Outgoing interface list:
    Serial1, Forward/Sparse, 00:03:14/00:02:46
    Serial3, Forward/Sparse, 00:00:10/00:02:50

(171.68.37.121/32, 224.1.1.1, 00:01:15/00:02:46, flags: T
  Incoming interface: Serial3, RPF nbr 171.68.28.139,
  Outgoing interface list:
    Serial1, Forward/Sparse, 00:00:49/00:02:11
```

State in “RP” after “rtr-b” joins Shared Tree

B

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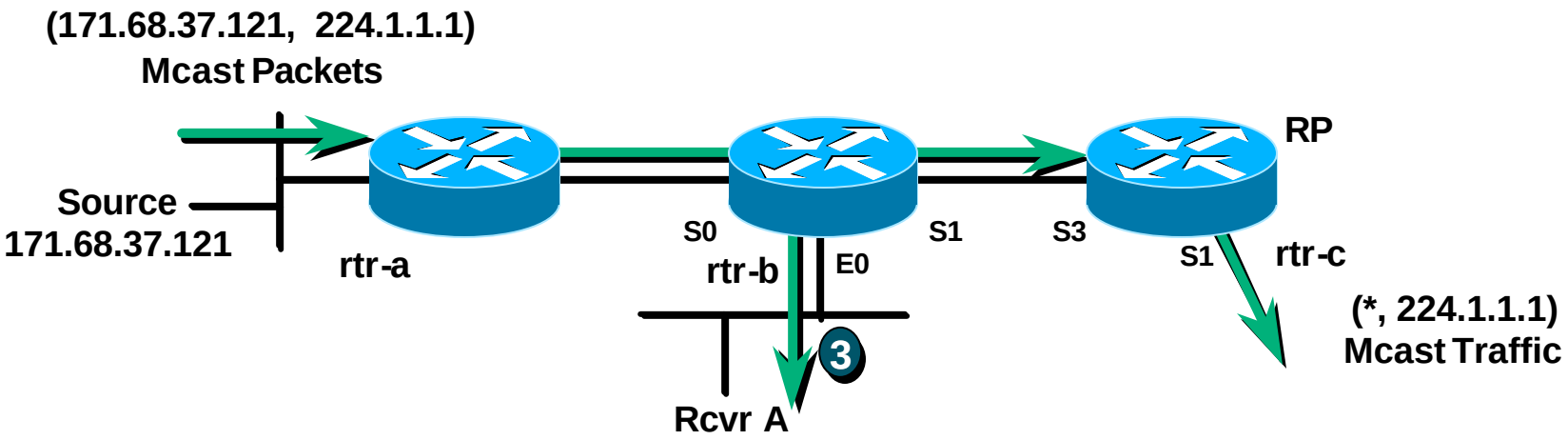
PIM SM Registering

Receivers along the SPT



3. **Group G traffic begins to flow to "Rcvr A".**

   (Note: 171.68.37.121 traffic doesn't flow to RP then back down to rtr-b)

B

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PIM Protocol Mechanics

- PIM Neighbor Discovery
- PIM State
- PIM SM Joining
- PIM SM Registering
- PIM SM SPT-Switchover
- PIM SM Pruning

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PIM SM SPT-Switchover

- **SPT Thresholds may be set for any Group**
  - **Access Lists may be used to specify which Groups**
  - **Default Threshold = 0kbps (I.e. immediately join SPT)**
  - **Threshold = “infinity” means “never join SPT”.**
  - **Don’t use values in between “0” and “infinity”.**
- **Threshold triggers Join of Source Tree**
  - **Sends an (S,G) Join up SPT for next “S” in “G” packet received.**

AE

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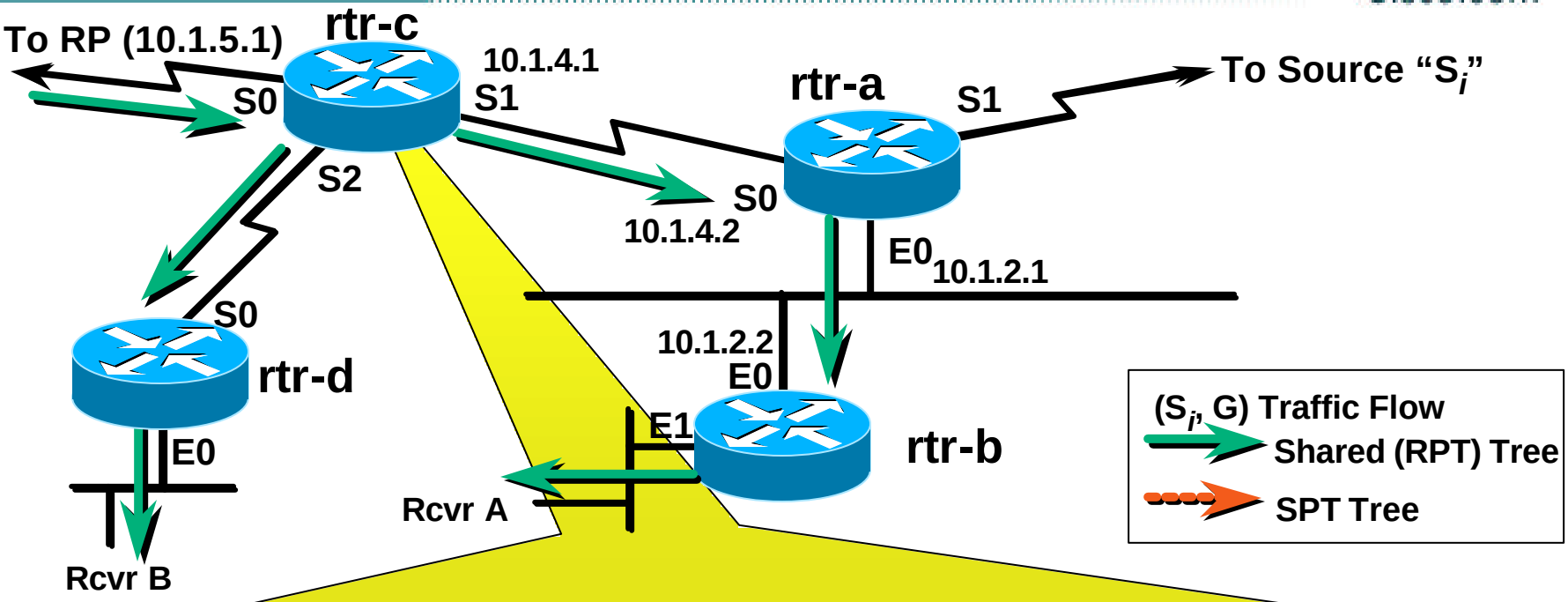
PIM SM SPT-Switchover




```
(*, 224.1.1.1), 00:01:43/00:02:13, RP 10.1.5.1, flags: S
  Incoming interface: Serial0, RPF nbr 10.1.5.1,
  Outgoing interface list:
    Serial1, Forward/Sparse, 00:01:43/00:02:11
    Serial2, Forward/Sparse, 00:00:32/00:02:28
```

State in "rtr-c" before switch

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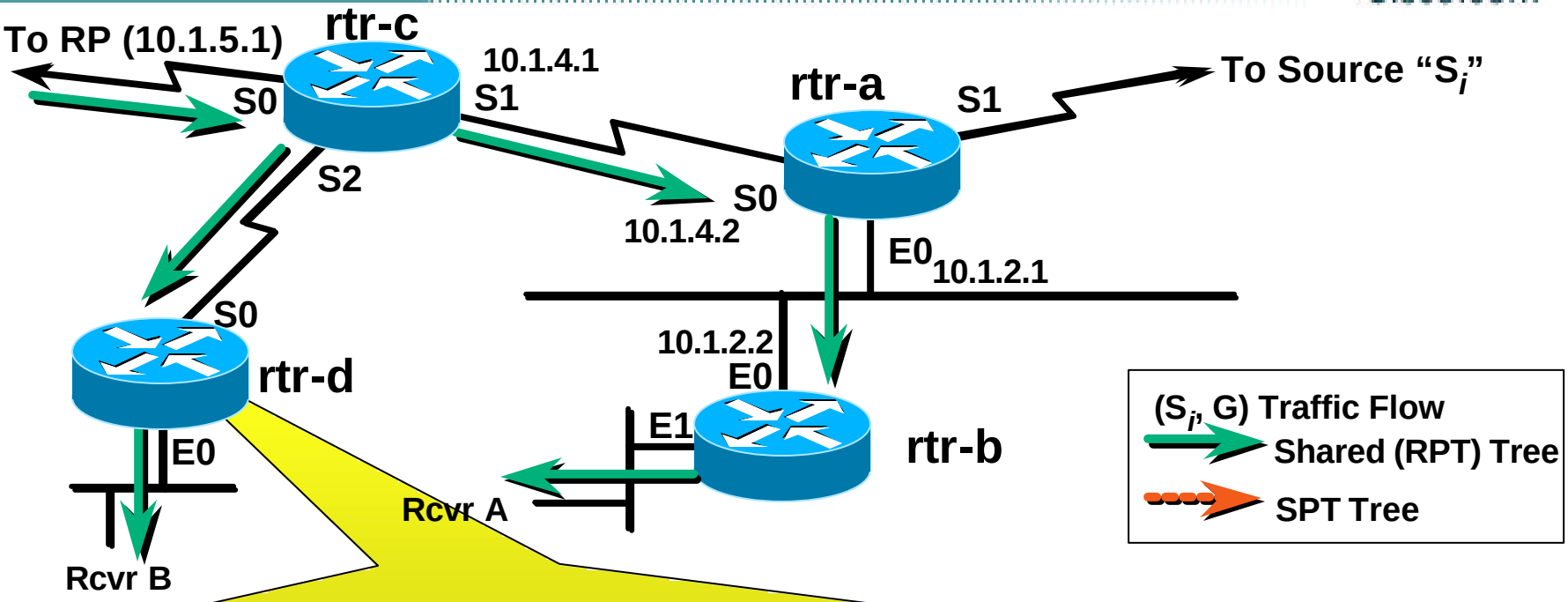
PIM SM SPT-Switchover




```
(*, 224.1.1.1), 00:01:43/00:02:13, RP 10.1.5.1, flags: SC
  Incoming interface: Serial0, RPF nbr 10.1.4.8,
  Outgoing interface list:
    Ethernet0, Forward/Sparse, 00:01:43/00:02:11
```

State in "rtr-d" before switch

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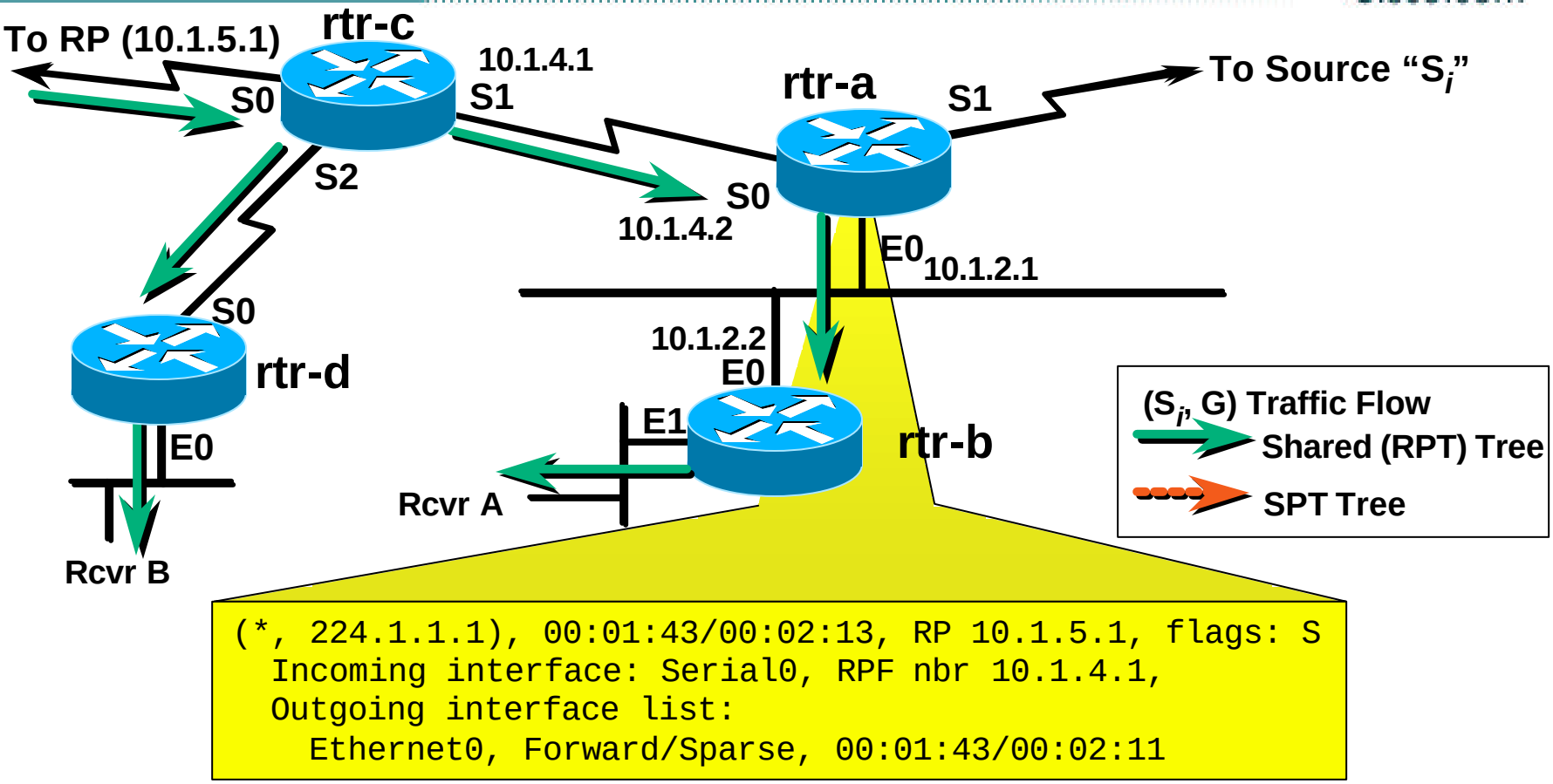
PIM SM SPT-Switchover




```
(*, 224.1.1.1), 00:01:43/00:02:13, RP 10.1.5.1, flags: S
  Incoming interface: Serial0, RPF nbr 10.1.4.1,
  Outgoing interface list:
    Ethernet0, Forward/Sparse, 00:01:43/00:02:11
```

State in "rtr-a" before switch

AE

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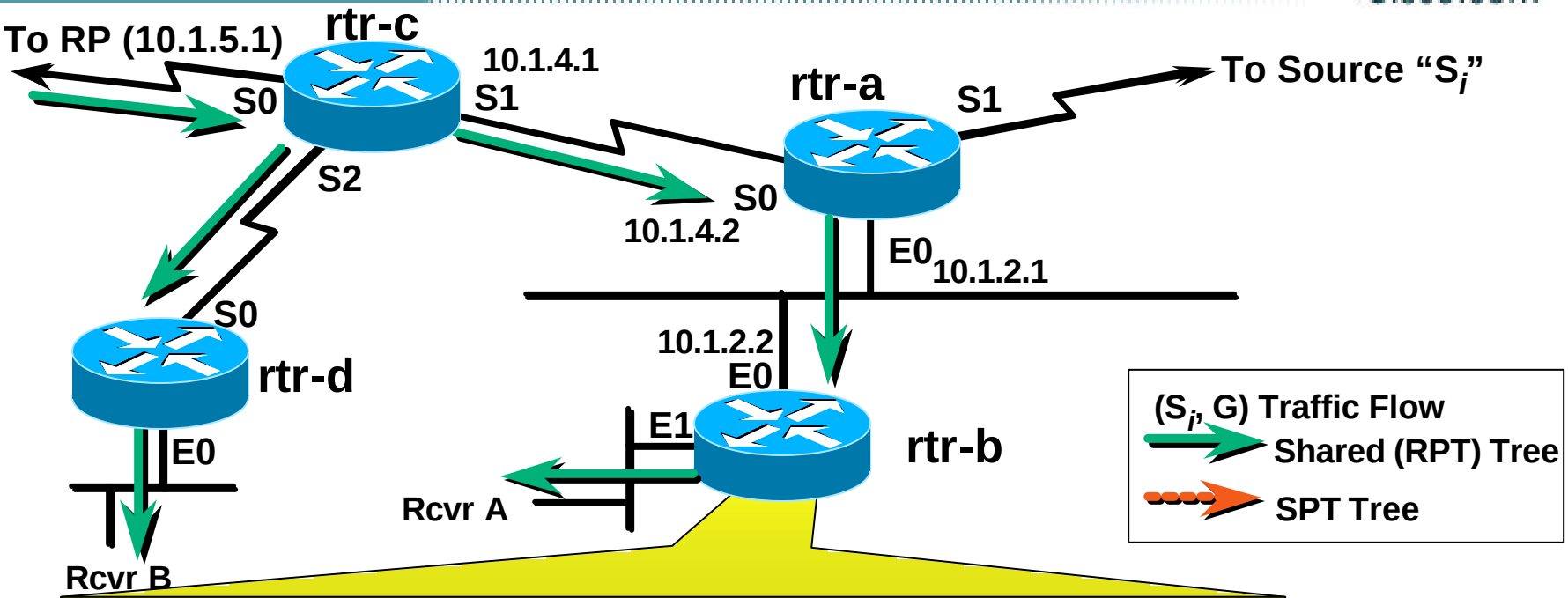
PIM SM SPT-Switchover



State in "rtr-b" before switch

AE

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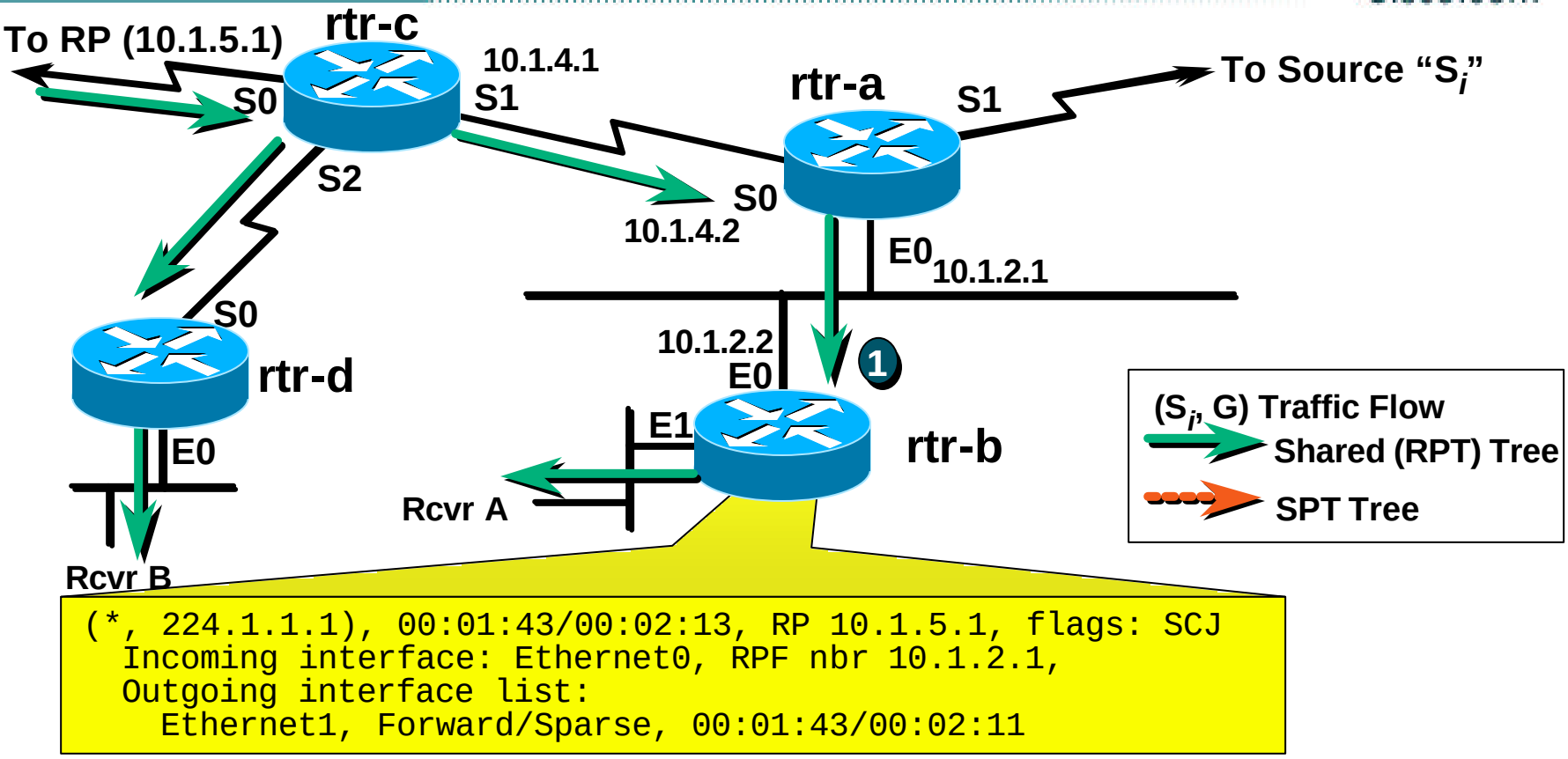
PIM SM SPT-Switchover



1 **New source (S_i,G) packet arrives down Shared tree.**

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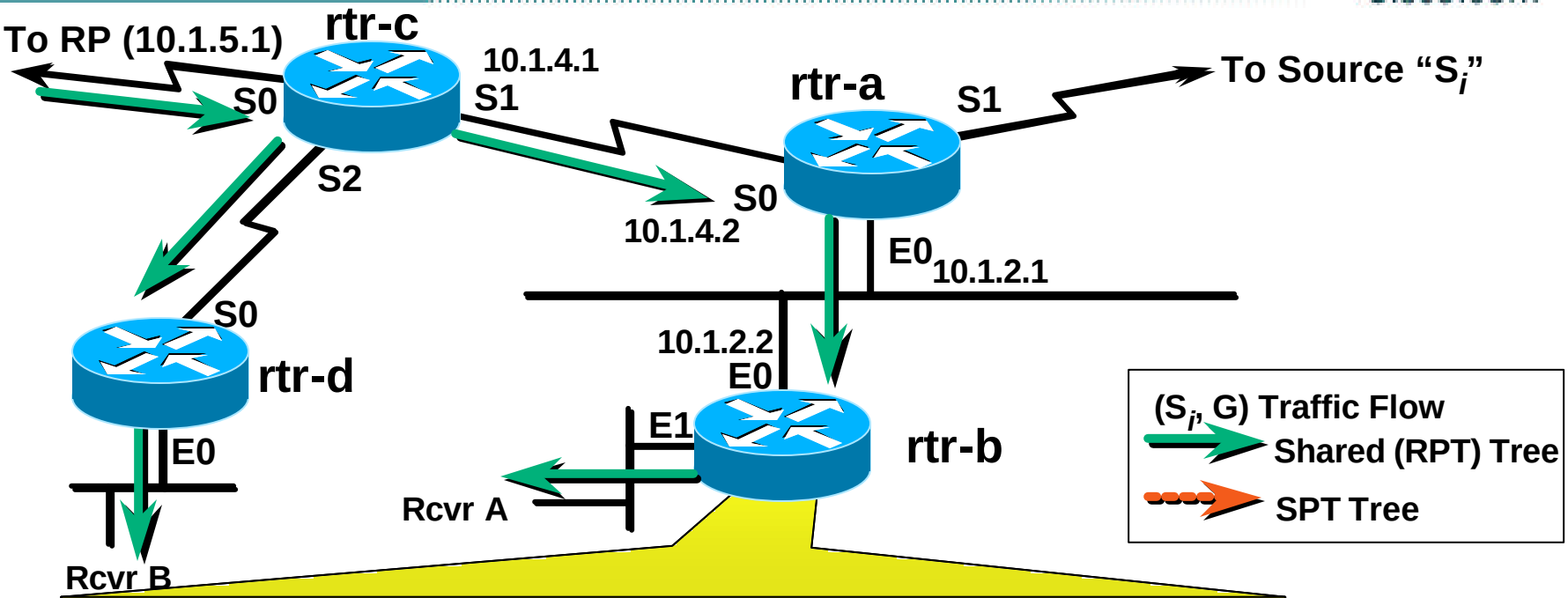
PIM SM SPT-Switchover




```
(*, 224.1.1.1), 00:01:43/00:02:13, RP 10.1.5.1, flags: SCJ
  Incoming interface: Ethernet0, RPF nbr 10.1.2.1,
  Outgoing interface list:
    Ethernet1, Forward/Sparse, 00:01:43/00:02:11

(171.68.37.121/32, 224.1.1.1), 00:00:28/00:02:51, flags: CJT
  Incoming interface: Ethernet0, RPF nbr 10.1.2.1
  Outgoing interface list:
    Ethernet1, Forward/Sparse, 00:00:28/00:02:32
```

2

2 **Create (S_i,G) state.**

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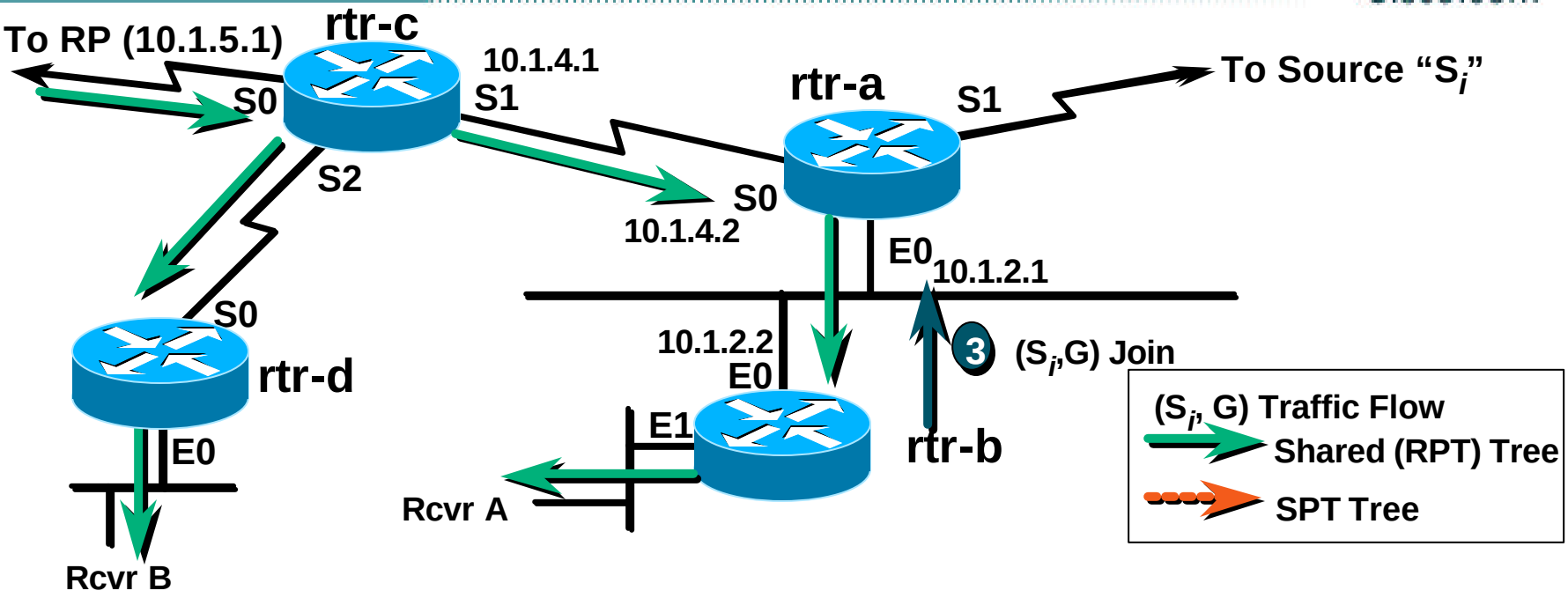
PIM SM SPT-Switchover



3 Send (S_i,G) Join towards S_i .

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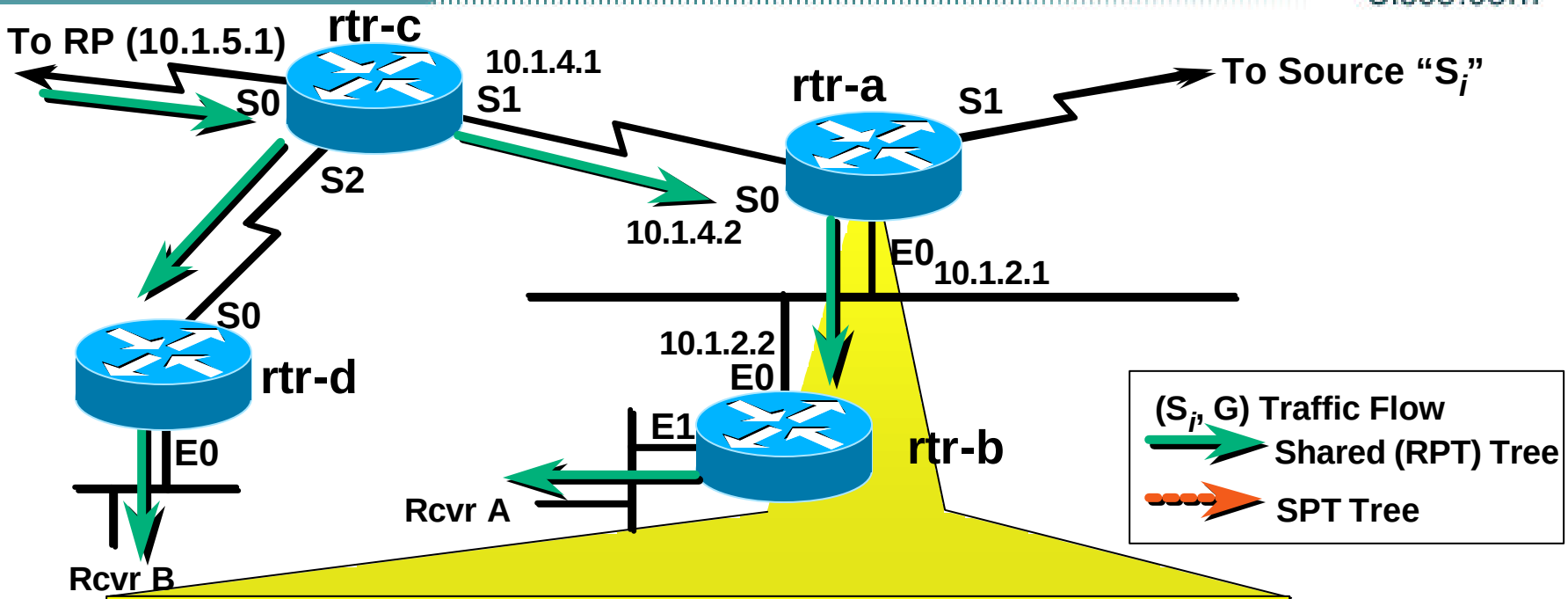
PIM SM SPT-Switchover




```
(*, 224.1.1.1), 00:01:43/00:02:13, RP 10.1.5.1, flags: S
  Incoming interface: Serial0, RPF nbr 10.1.4.1,
  Outgoing interface list:
    Ethernet0, Forward/Sparse, 00:01:43/00:02:11

(171.68.37.121/32, 224.1.1.1), 00:13:28/00:02:53, flags: T
  Incoming interface: Serial1, RPF nbr 10.1.9.2
  Outgoing interface list:
    Ethernet0, Forward/Sparse, 00:13:25/00:02:30
```

New state in "rtr-a"

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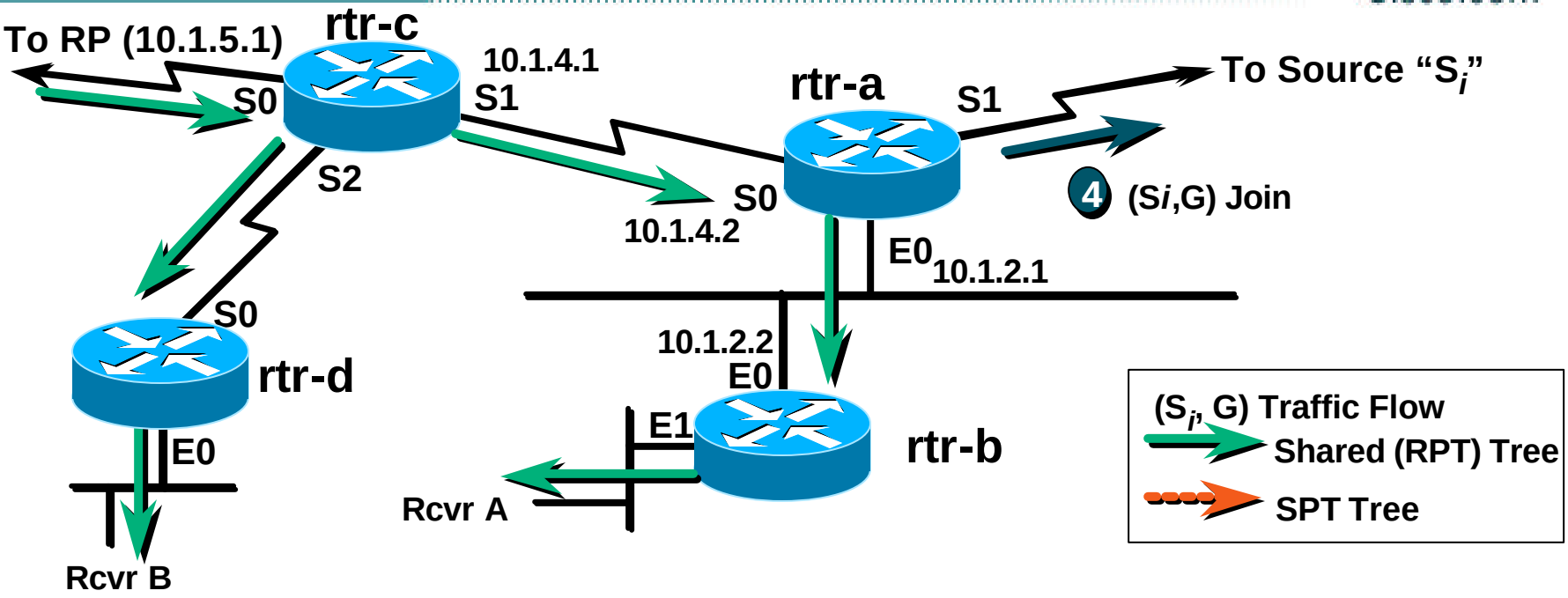
PIM SM SPT-Switchover



4 "rtr-a" forwards (S_i,G) Join toward S_i.

AE

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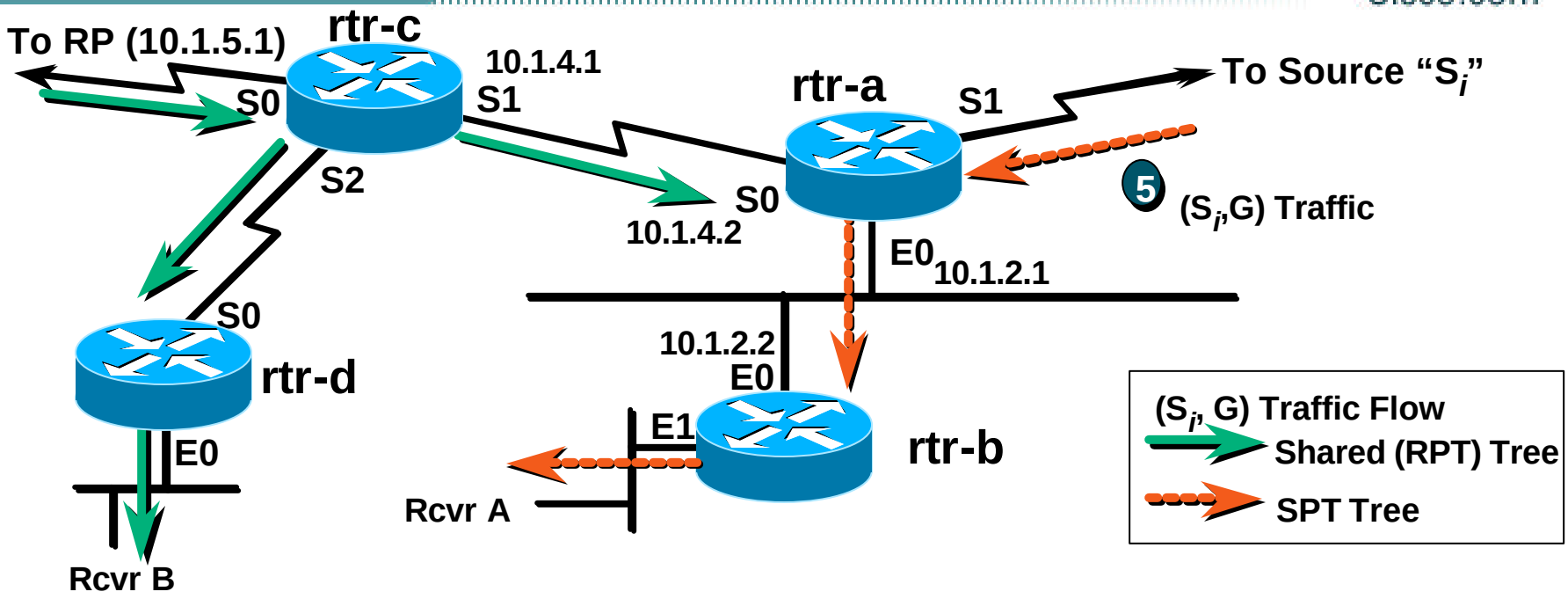
PIM SM SPT-Switchover



4. "rtr-a" forwards (S_i,G) Join toward S_i.
5. (S_i, G) traffic begins flowing down SPT tree.

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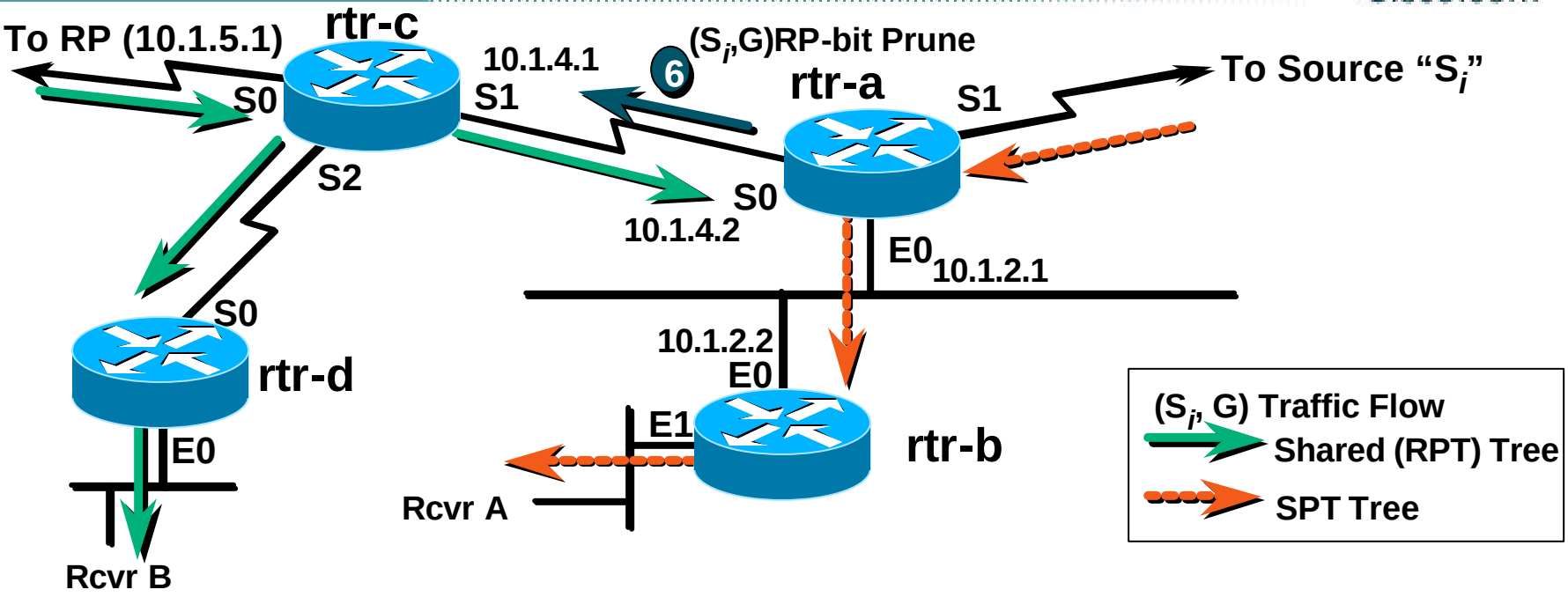
PIM SM SPT-Switchover



4. "rtr-a" forwards (S_i,G) Join toward S_i.
5. (S_i, G) traffic begins flowing down SPT tree.
6. SPT & RPT diverge, triggering (S_i,G)RP-bit Prunes toward RP.

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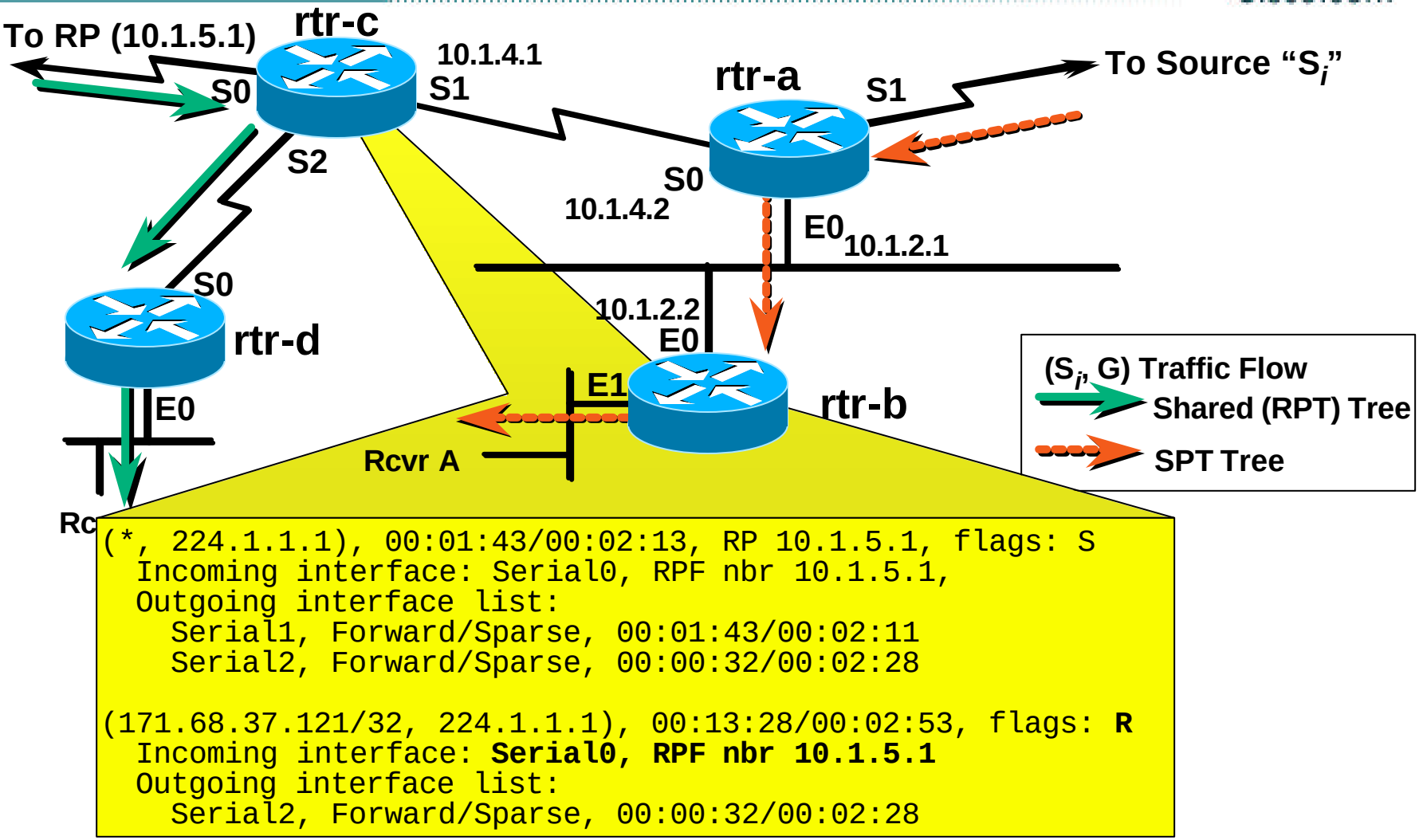
PIM SM SPT-Switchover




```
(*, 224.1.1.1), 00:01:43/00:02:13, RP 10.1.5.1, flags: S
  Incoming interface: Serial0, RPF nbr 10.1.5.1,
  Outgoing interface list:
    Serial1, Forward/Sparse, 00:01:43/00:02:11
    Serial2, Forward/Sparse, 00:00:32/00:02:28

(171.68.37.121/32, 224.1.1.1), 00:13:28/00:02:53, flags: R
  Incoming interface: Serial0, RPF nbr 10.1.5.1
  Outgoing interface list:
    Serial2, Forward/Sparse, 00:00:32/00:02:28
```

State in "rtr-c" after receiving the (S_i, G) RP-bit Prune

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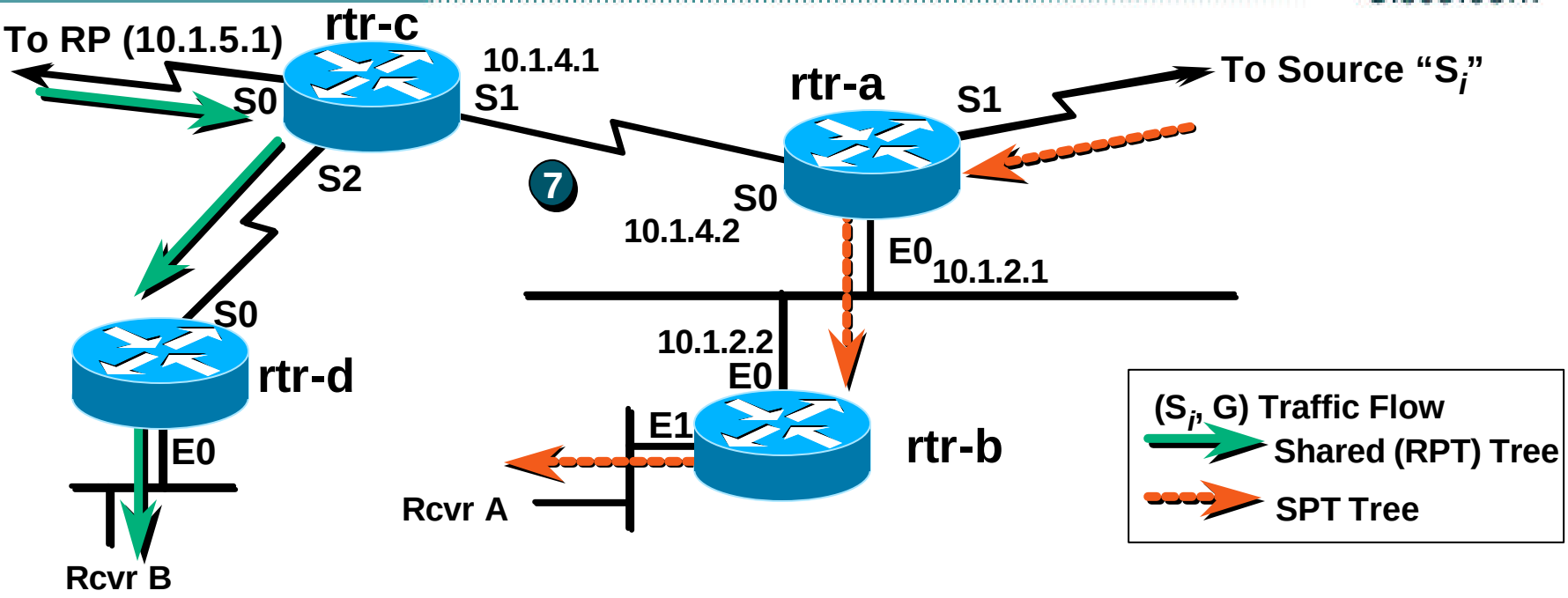
PIM SM SPT-Switchover



7 **Unnecessary (S_i, G) traffic is pruned from the Shared tree.**

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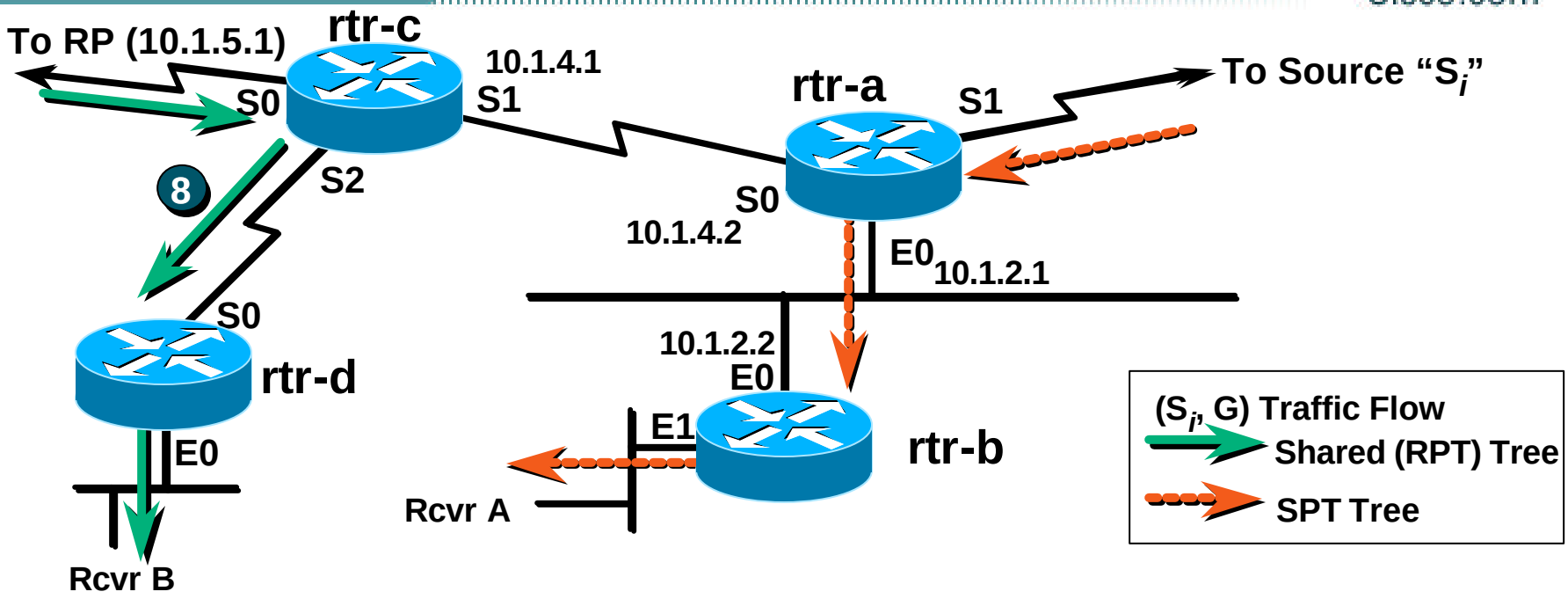
PIM SM SPT-Switchover



7. Unnecessary (S_i, G) traffic is pruned from the Shared tree.
8. (S_i, G) traffic still flows via other branches of the Shared tree.

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PIM Protocol Mechanics

- PIM Neighbor Discovery
- PIM State
- PIM SM Joining
- PIM SM Registering
- PIM SM SPT-Switchover
- PIM SM Pruning

HC

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PIM SM Pruning

- IGMP group times out / last host sends Leave
- Interface removed from all (*,G) & (S,G) entries
  - IF OIL of the (*,G) becomes empty (Null);
    THEN send Prune up shared tree toward RP
  - Any (S, G) state allowed to time-out
- Each router along path “prunes” interface
  - IF OIL of the (*,G) becomes empty (Null);
    THEN send Prune up shared tree toward RP
  - Any (S, G) state allowed to time-out

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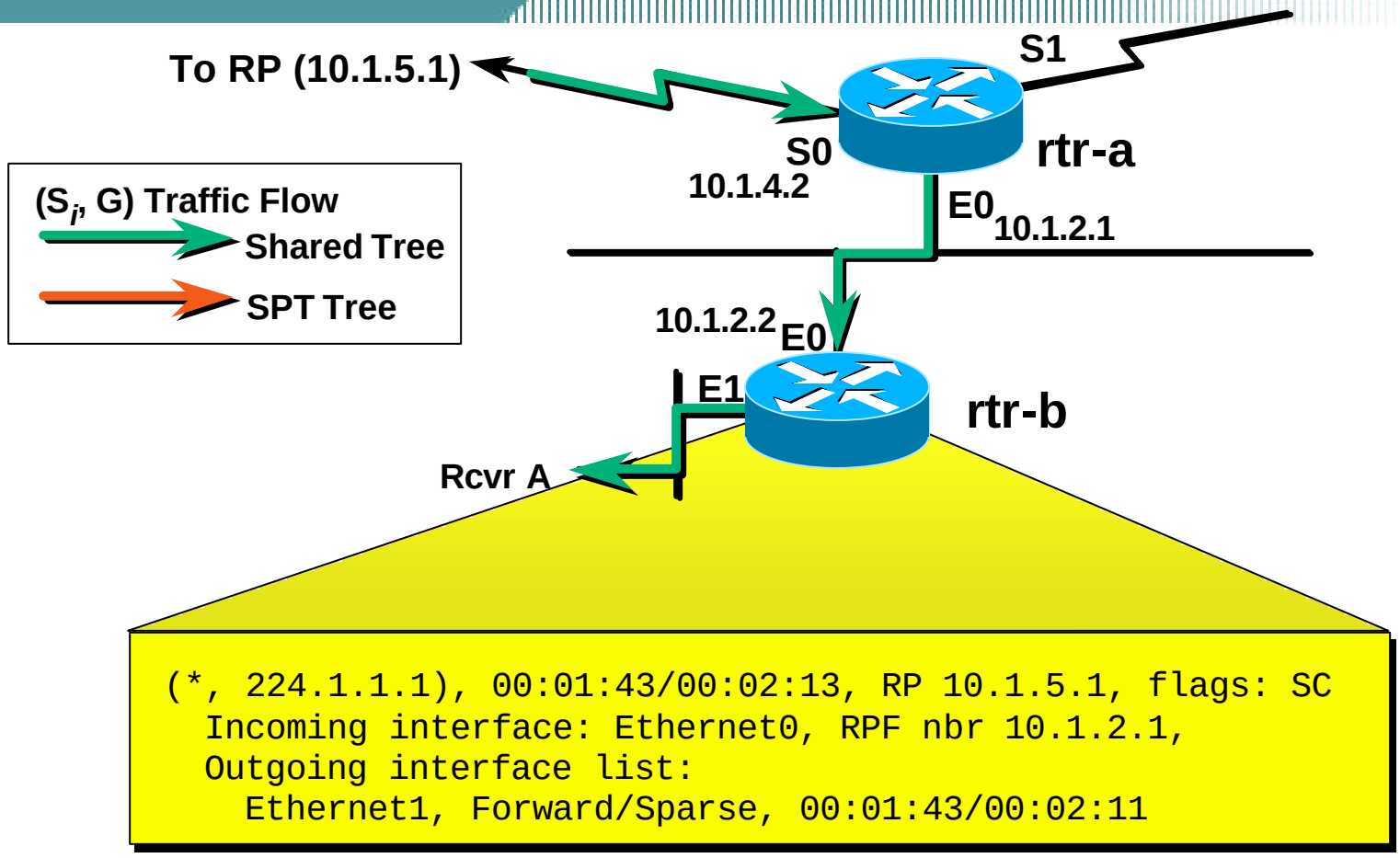
PIM SM Pruning
Shared Tree Case




```
(*, 224.1.1.1), 00:01:43/00:02:13, RP 10.1.5.1, flags: SC
  Incoming interface: Ethernet0, RPF nbr 10.1.2.1,
  Outgoing interface list:
    Ethernet1, Forward/Sparse, 00:01:43/00:02:11
```

State in “rtr-b” before Pruning

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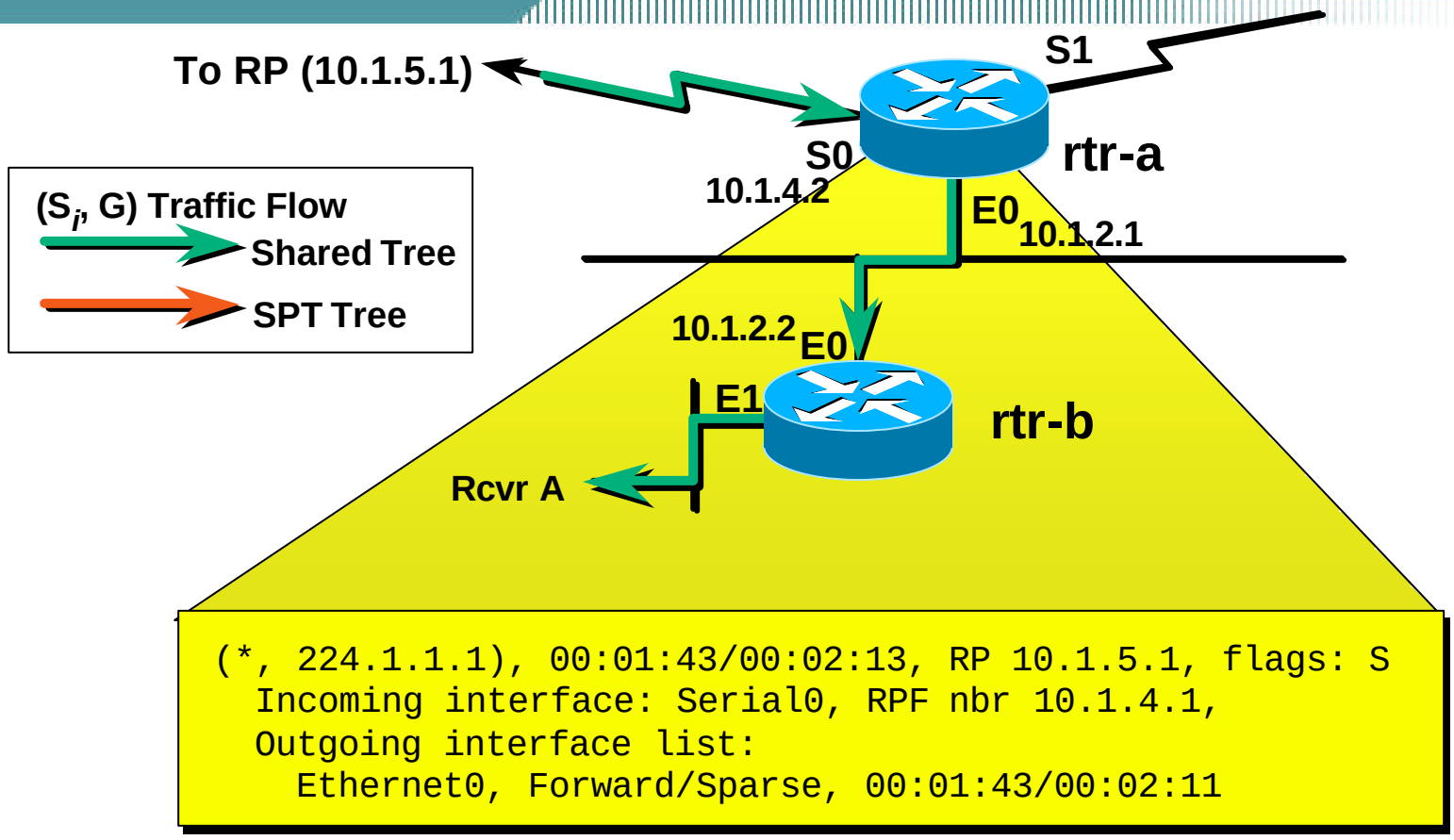
PIM SM Pruning
Shared Tree Case




```
(*, 224.1.1.1), 00:01:43/00:02:13, RP 10.1.5.1, flags: S
  Incoming interface: Serial0, RPF nbr 10.1.4.1,
  Outgoing interface list:
    Ethernet0, Forward/Sparse, 00:01:43/00:02:11
```

State in “rtr-a” before Pruning

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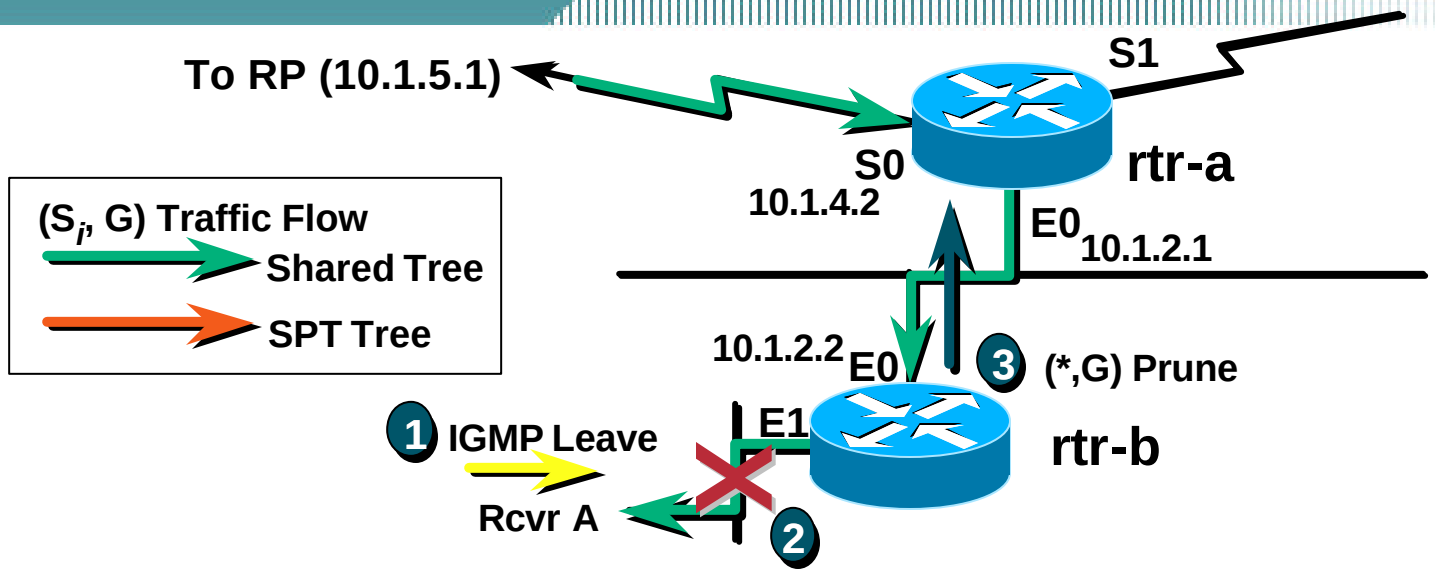
PIM SM Pruning
Shared Tree Case



1. "rtr-b" is a Leaf router. Last host "Rcvr A", leaves group G.
2. "rtr-b" removes E1 from (*,G) and any (S$_i$,G) *"oilists"*.
3. "rtr-b" (*,G) *"oilist"* now empty; sends (*,G) Prune toward RP.

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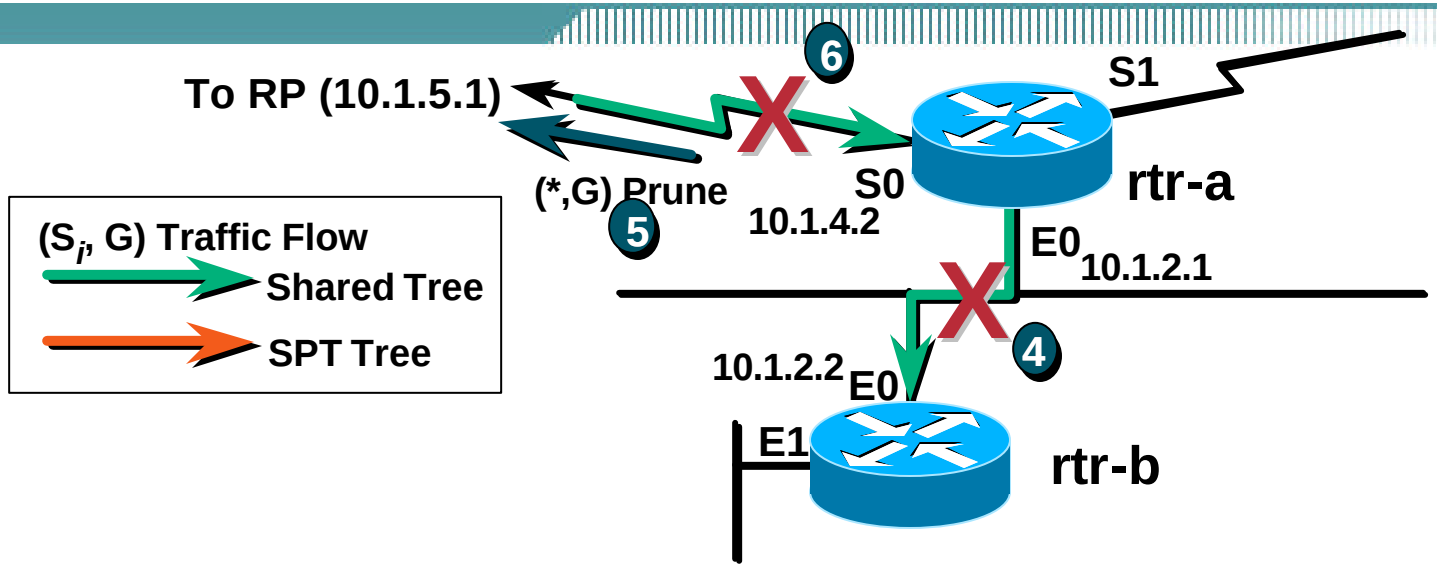
PIM SM Pruning
Shared Tree Case



4. "rtr-a" receives Prune; removes E0 from (*,G) "*oilist*".
   (After the 3 second Multi-access Network Prune delay.)
5. "rtr-a" (*,G) "*oilist*" now empty; send (*,G) Prune toward RP.
6. Pruning continues back toward RP.

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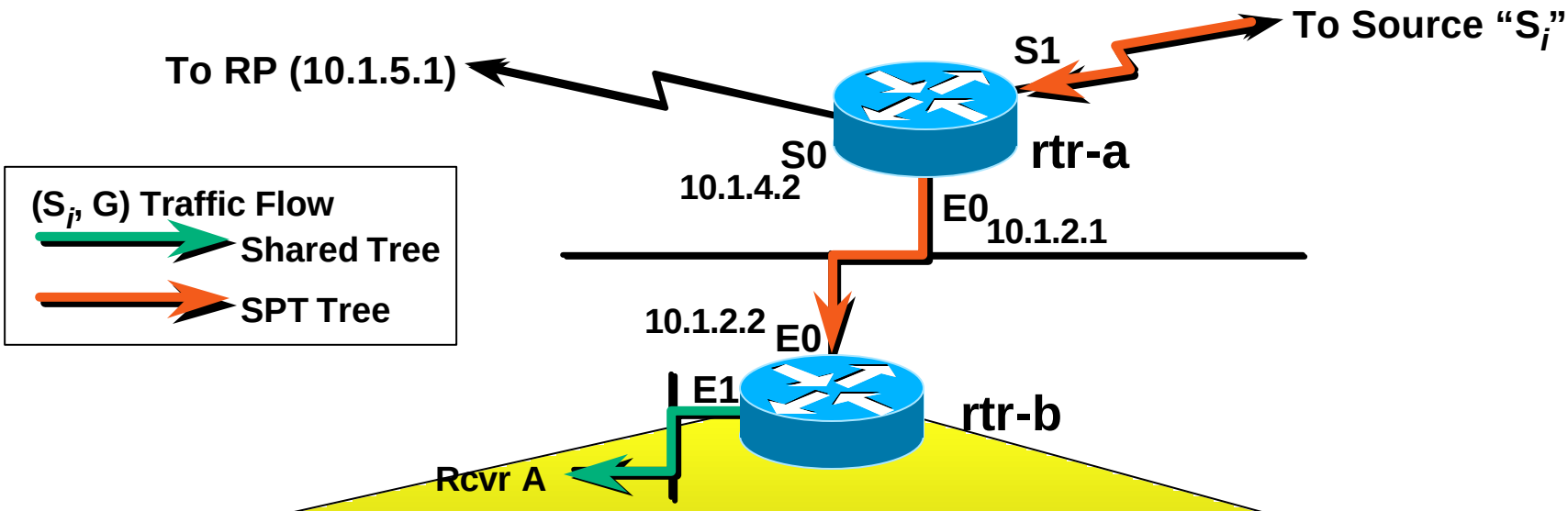
PIM SM Pruning
Source (SPT) Case




```
(*, 224.1.1.1), 00:01:43/00:02:59, RP 10.1.5.1, flags: SC
  Incoming interface: Ethernet0, RPF nbr 10.1.2.1,
  Outgoing interface list:
    Ethernet1, Forward/Sparse, 00:01:43/00:02:11

(171.68.37.121/32, 224.1.1.1), 00:01:05/00:01:55, flags: CJT
  Incoming interface: Ethernet0, RPF nbr 10.1.2.1
  Outgoing interface list:
    Ethernet1, Forward/Sparse, 00:01:05/00:02:55
```

State in "rtr-b" before Pruning

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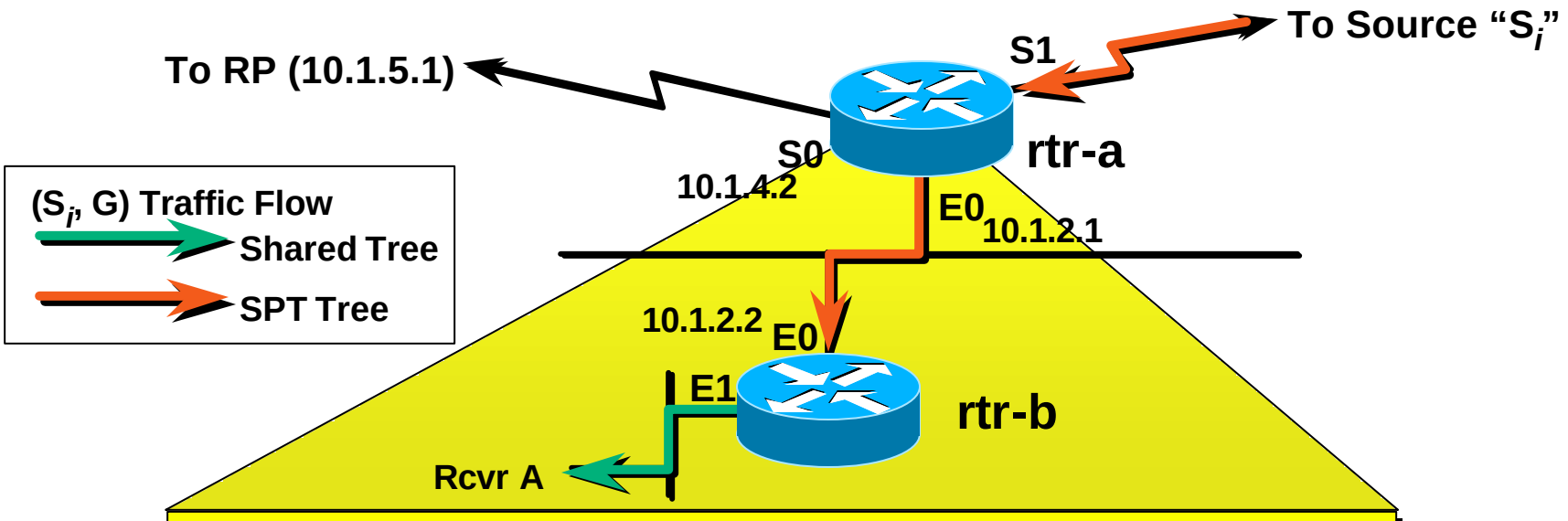
PIM SM Pruning
Source (SPT) Case




```
(*, 224.1.1.1), 00:01:43/00:02:59, RP 10.1.5.1, flags: S
  Incoming interface: Serial0, RPF nbr 10.1.4.1,
  Outgoing interface list:
    Ethernet0, Forward/Sparse, 00:01:43/00:02:11

(171.68.37.121/32, 224.1.1.1), 00:01:05/00:01:55, flags: T
  Incoming interface: Serial1, RPF nbr 10.1.9.2
  Outgoing interface list:
    Ethernet0, Forward/Sparse, 00:01:05/00:02:55
```

State in "rtr-a" before Pruning

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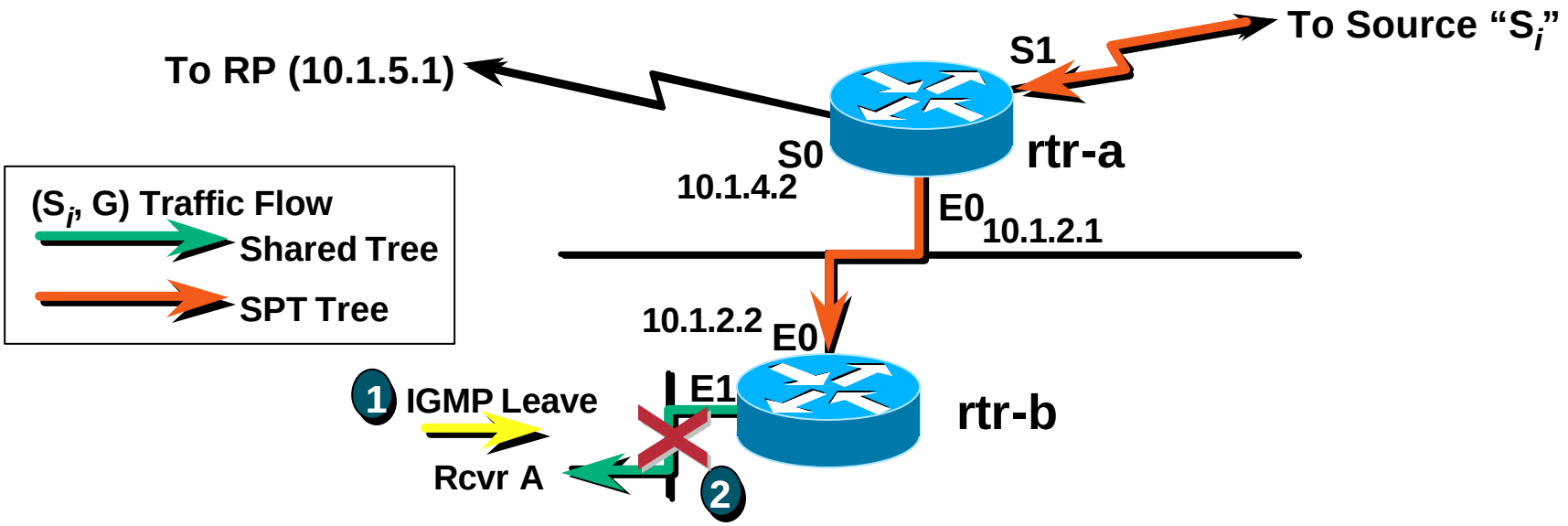
PIM SM Pruning
Source (SPT) Case



1. "rtr-b" is a Leaf router. Last host "Rcvr A", leaves group G.
2. "rtr-b" removes E1 from (*,G) and all (S,G) *OIL's*.

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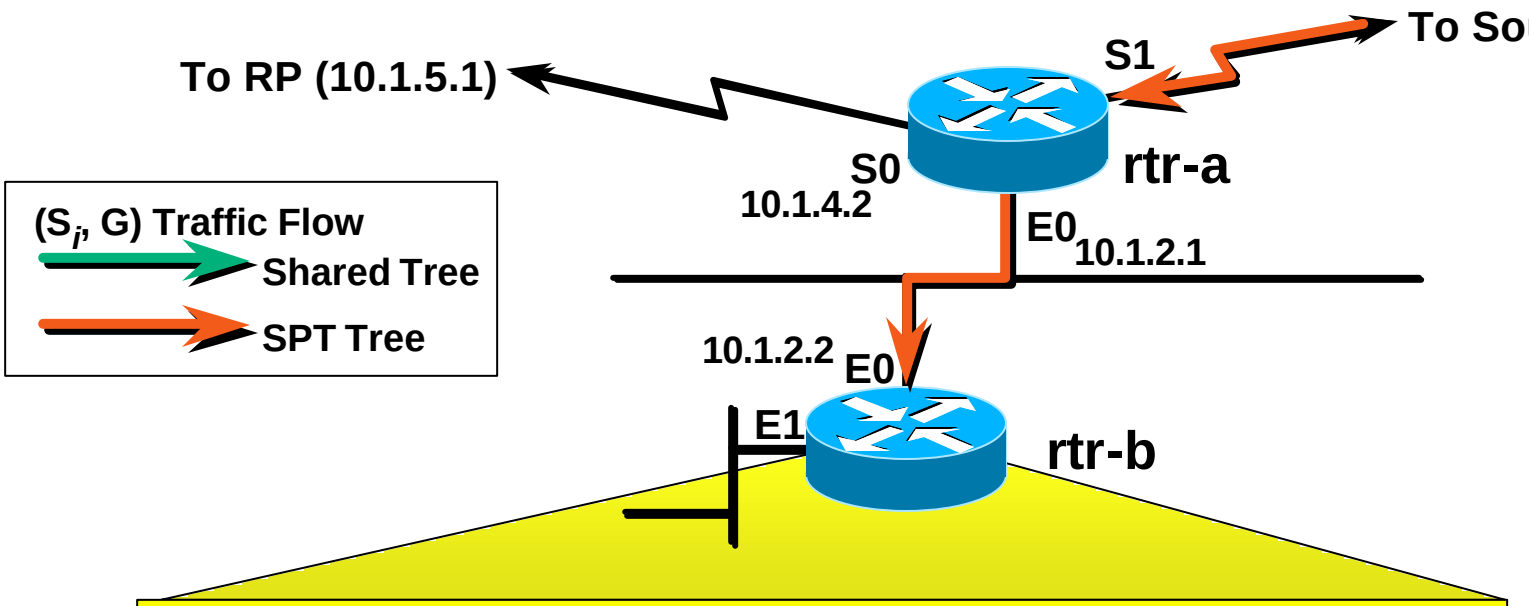
PIM SM Pruning
Source (SPT) Case




```
(*, 224.1.1.1), 00:02:32/00:02:59, RP 10.1.5.1, flags: SP
  Incoming interface: Ethernet0, RPF nbr 10.1.2.1,
  Outgoing interface list:

(171.68.37.121/32, 224.1.1.1), 00:01:56/00:00:53, flags: PT
  Incoming interface: Ethernet0, RPF nbr 10.1.2.1
  Outgoing interface list:
```

State in "rtr-b" after Pruning

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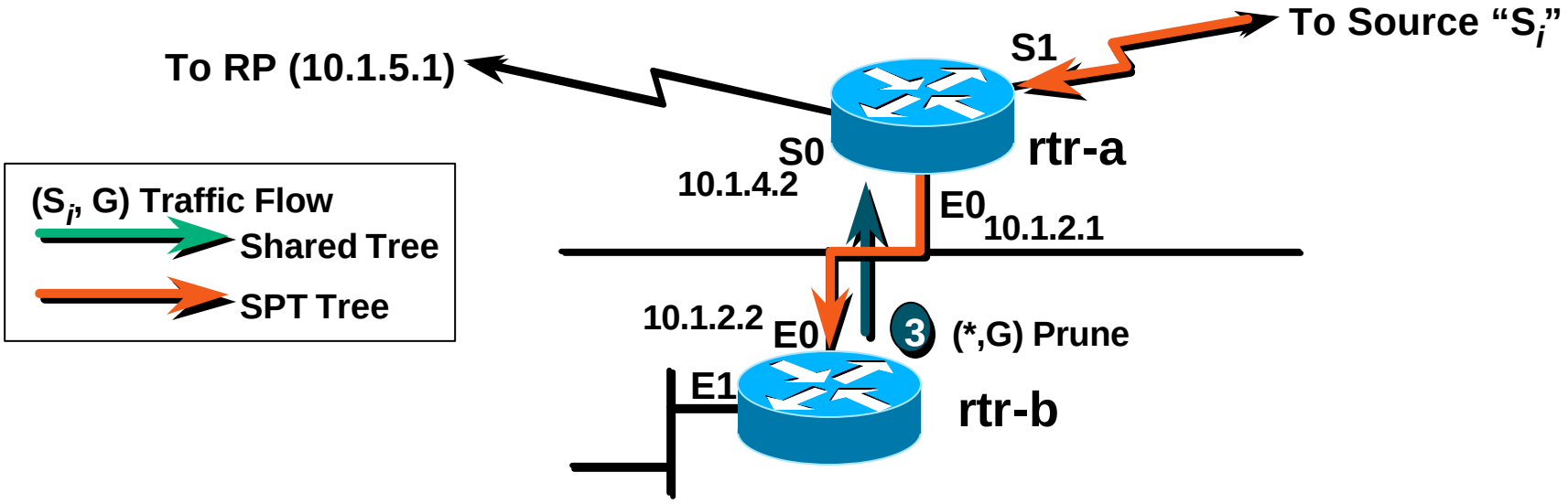
PIM SM Pruning
Source (SPT) Case



3 "rtr-b" (*,G) OIL now empty; sends (*,G) Prune toward RP.

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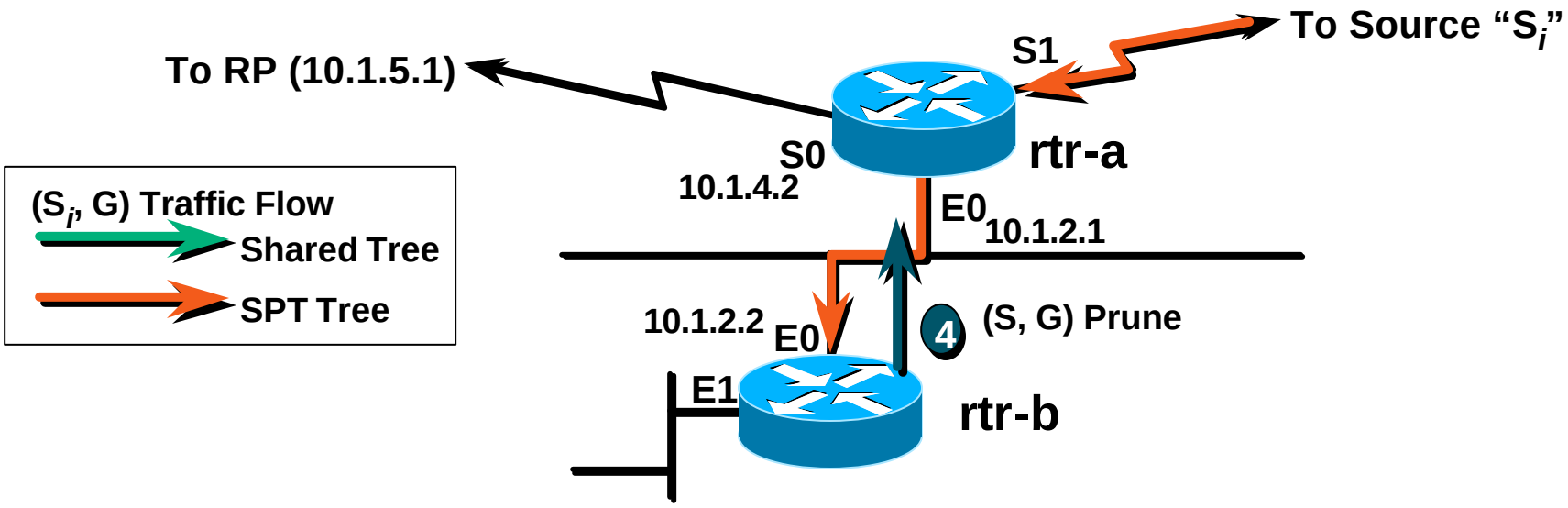
PIM SM Pruning
Source (SPT) Case



3. "rtr-b" (*,G) OIL now empty; sends (*,G) Prune toward RP.
4. "rtr-b" (S,G) OIL now empty; sends (S, G) Prune towards S_i.

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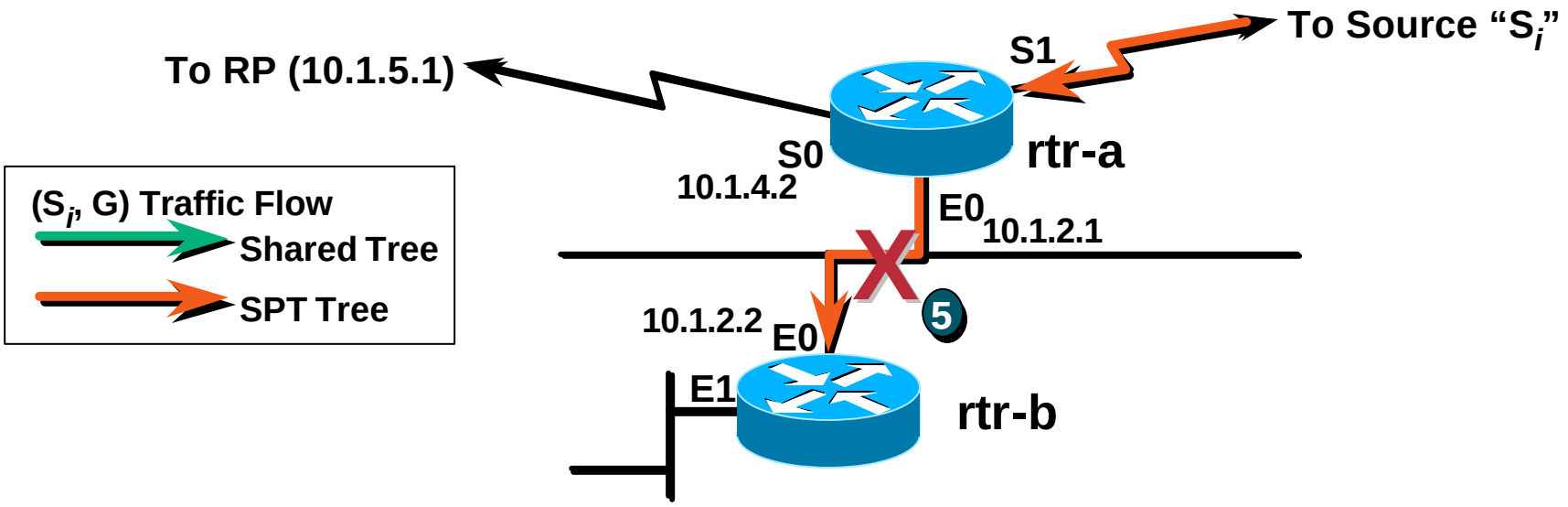
PIM SM Pruning
Source (SPT) Case



5 "rtr-a" receives (*, G) Prune; removes E0 from (*,G) & (S,G) OIL's

(After the 3 second Multi-access Network Prune delay.)

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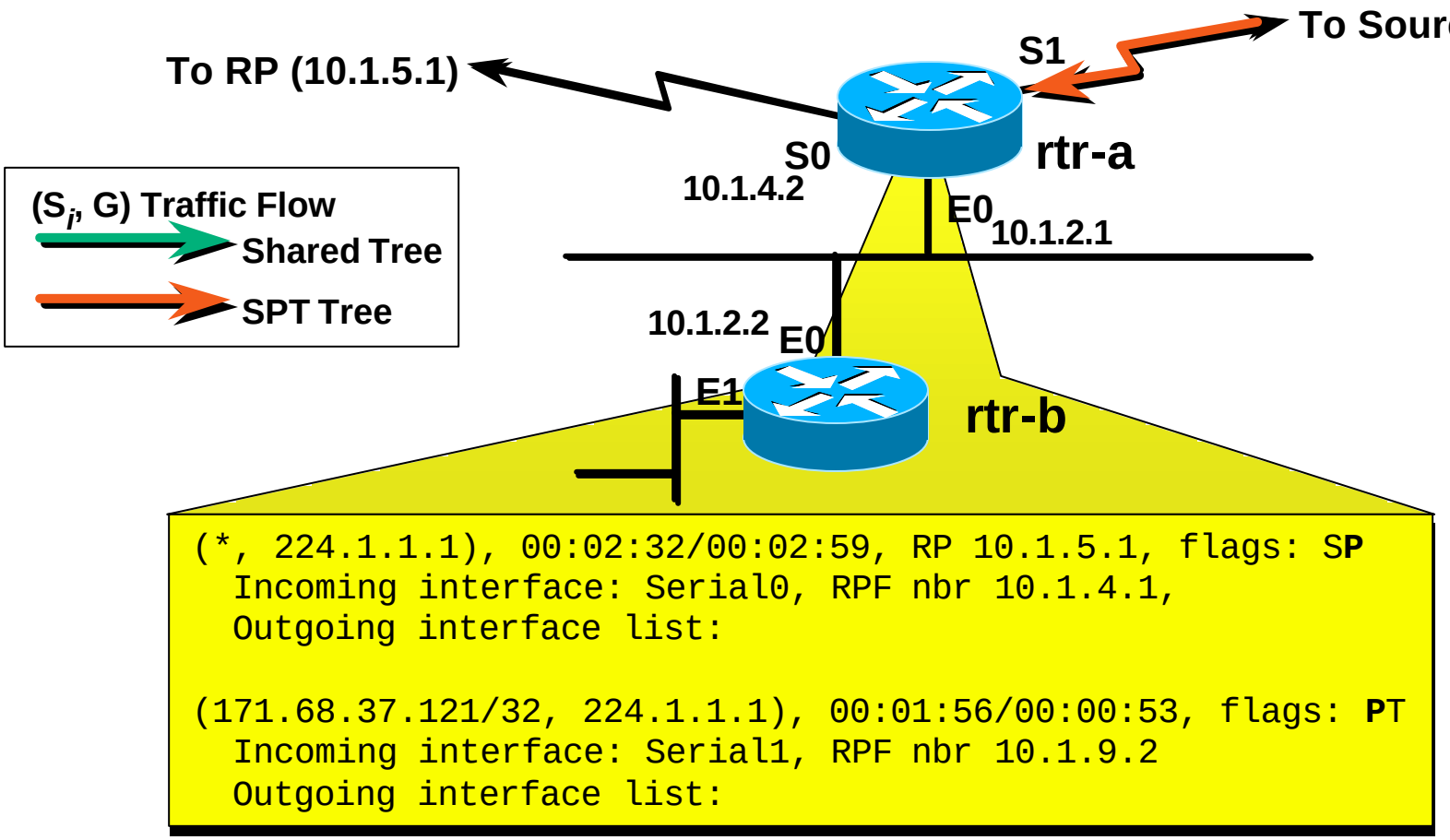
PIM SM Pruning
Source (SPT) Case




```
(*, 224.1.1.1), 00:02:32/00:02:59, RP 10.1.5.1, flags: SP
  Incoming interface: Serial0, RPF nbr 10.1.4.1,
  Outgoing interface list:

(171.68.37.121/32, 224.1.1.1), 00:01:56/00:00:53, flags: PT
  Incoming interface: Serial1, RPF nbr 10.1.9.2
  Outgoing interface list:
```

State in "rtr-a" after Pruning

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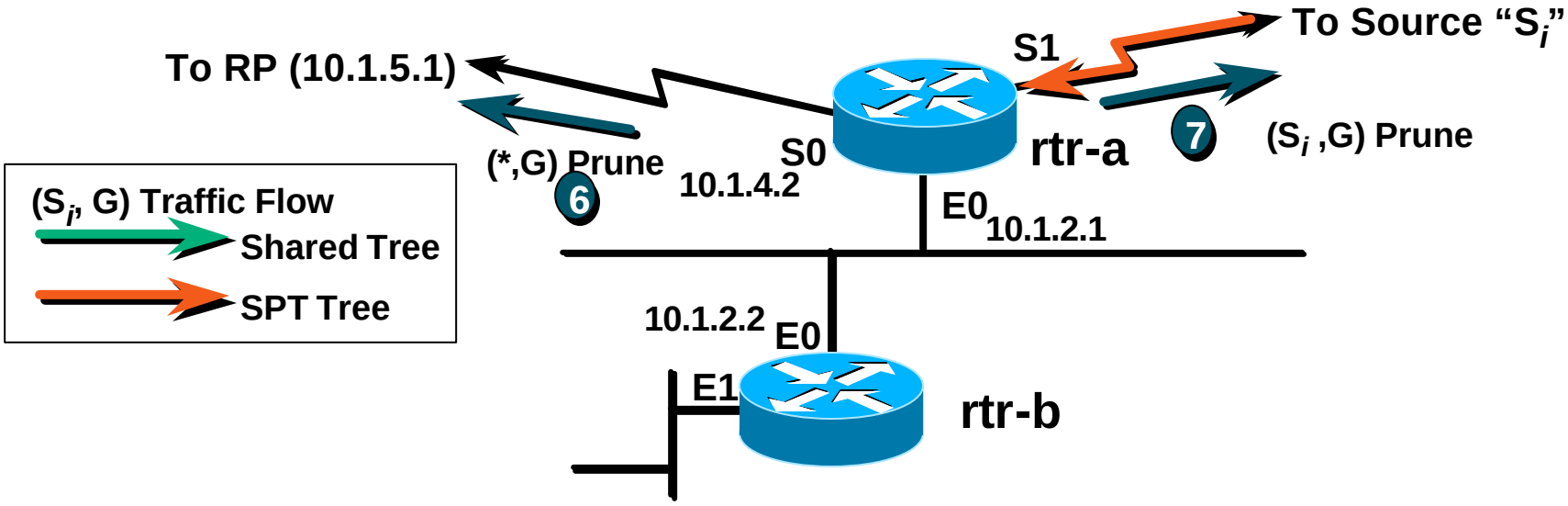
PIM SM Pruning
Source (SPT) Case



6 "rtr-a" (*,G) *OIL* now empty; sends (*,G) Prune toward RP.

7 "rtr-a" (S,G) *OIL* now empty; sends (S,G) Prune towards S_i.

HC

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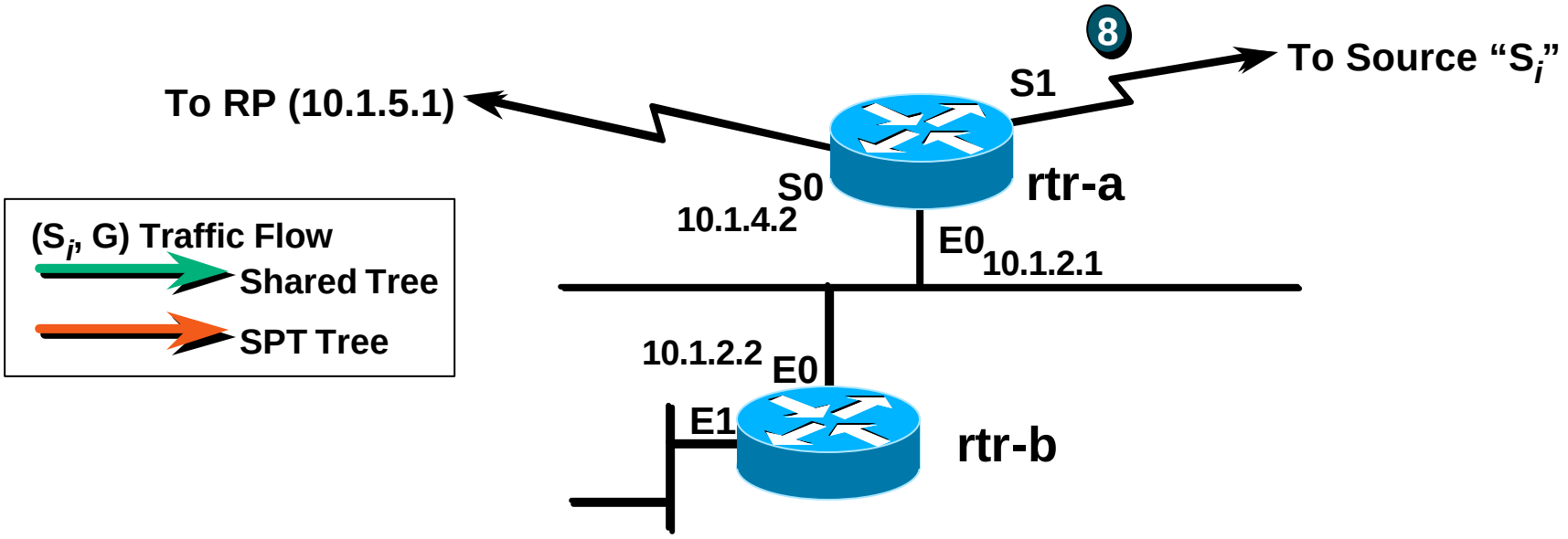
PIM SM Pruning
Source (SPT) Case



6. "rtr-a" (*,G) *OIL* now empty; sends (*,G) Prune toward RP.
7. "rtr-a" (S,G) *OIL* now empty; sends (S,G) Prune towards S_i.
8. (S_i,G) traffic ceases flowing down SPT.

HC

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Agenda

- What and Why?
- PIM-SM Review
- PIM-SM Protocol Mechanics
- **Rendezvous Points**
- Tools & Examples

D

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Rendezvous Points

- Until now we have assumed a RP
- Without a RP PIM SM does not work
- It is fundamental to know the RP and how it is chosen/configured
  - Show commands later will enable you to do that.
  - The following is a overview of possible RP choices
  - Auto-RP is most common method in use

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Rendezvous Points

- Auto-RP
- Bootstrap Router (BSR)
- Static configuration
- Anycast RP

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Auto-RP

- Candidate RPs Announce their availability on 224.0.1.39
- Mapping Agents choose which RP will be used for a group range and send Discover messages on 224.0.1.40 to all routers in the network.

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Auto-RP Fundamentals

- **Candidate RPs**
  - **Configured via global config command**

    ```
    ip pim send-rp-announce <intfc> scope <ttl> [group-list
     acl]
    ```

  - **Multicast RP-Announcement messages**
    - **Sent to Cisco-Announce (224.0.1.39) group**
    - **Sent every rp-announce-interval (default: 60 sec)**
  - **RP-Announcements contain:**
    - **Group Range (default = 224.0.0.0/4)**
    - **Candidate's RP address**
    - **Holdtime = 3 x <rp-announce-interval>**

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Auto-RP Fundamentals

- **Mapping agents**
  - **Configured via global config command**

    ```
    ip pim send-rp-discovery scope <ttl>
    ```

  - **Receive RP-Announcements**
    - **Select highest C-RP IP address as RP for group range**
    - **Stored in Group-to-RP Mapping Cache with holdtimes**
  - **Multicast RP-Discovery messages**
    - **Sent to Cisco-Discovery (224.0.1.40) group**
    - **Sent every 60 seconds or when changes detected**
  - **RP-Discovery messages contain:**
    - **Contents of MA's Group-to-RP Mapping Cache**

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Auto-RP Fundamentals

- All Cisco routers
  - Join Cisco-Discovery (224.0.1.40) group
    - Automatic
    - No configuration necessary
  - Receive RP-Discovery messages
    - Stored in local Group-to-RP Mapping Cache
    - Information used to determine RP for group range

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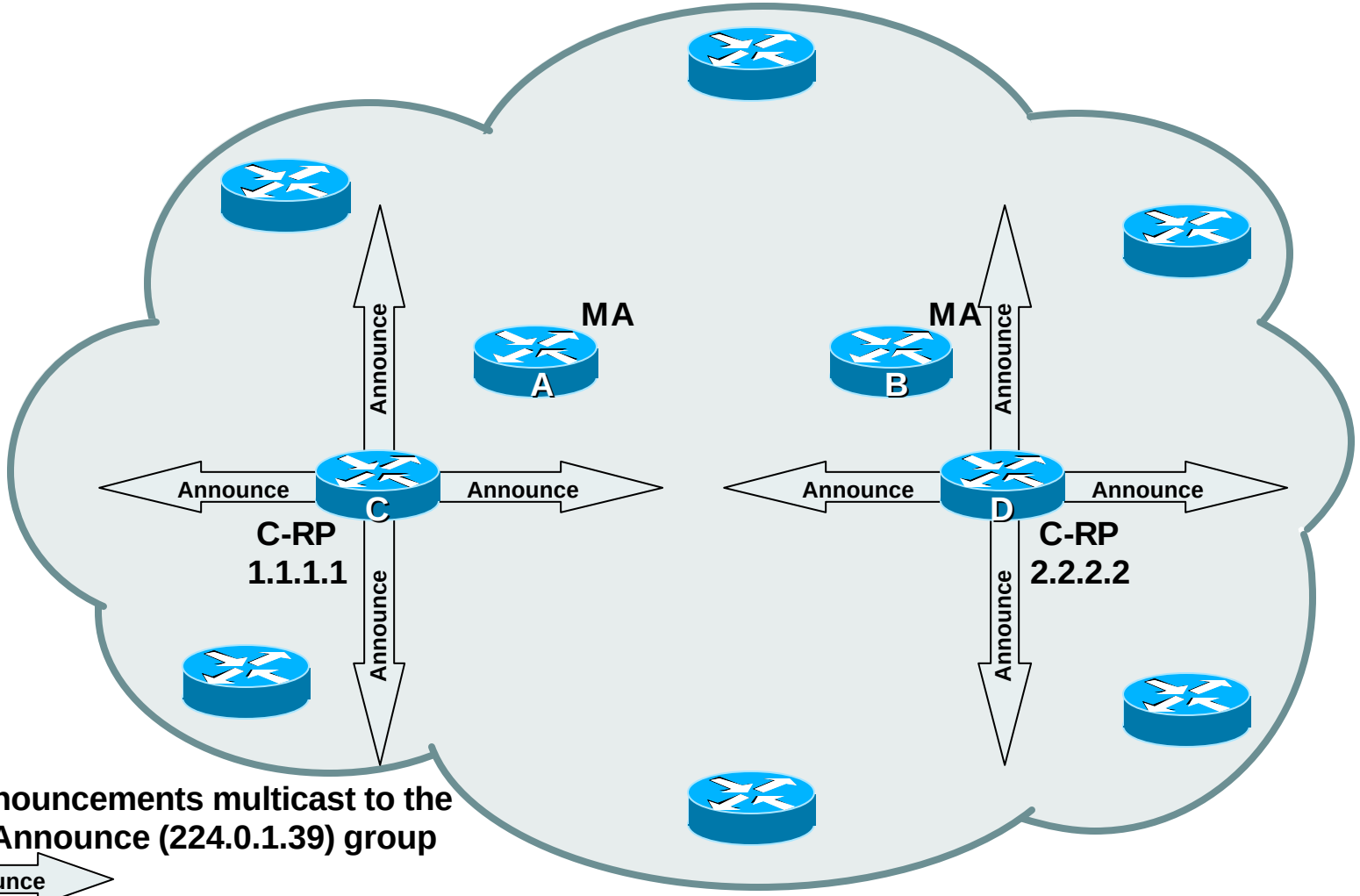
Auto-RP—From 10,000 Feet



RP-Announcements multicast to the Cisco Announce (224.0.1.39) group

Announce

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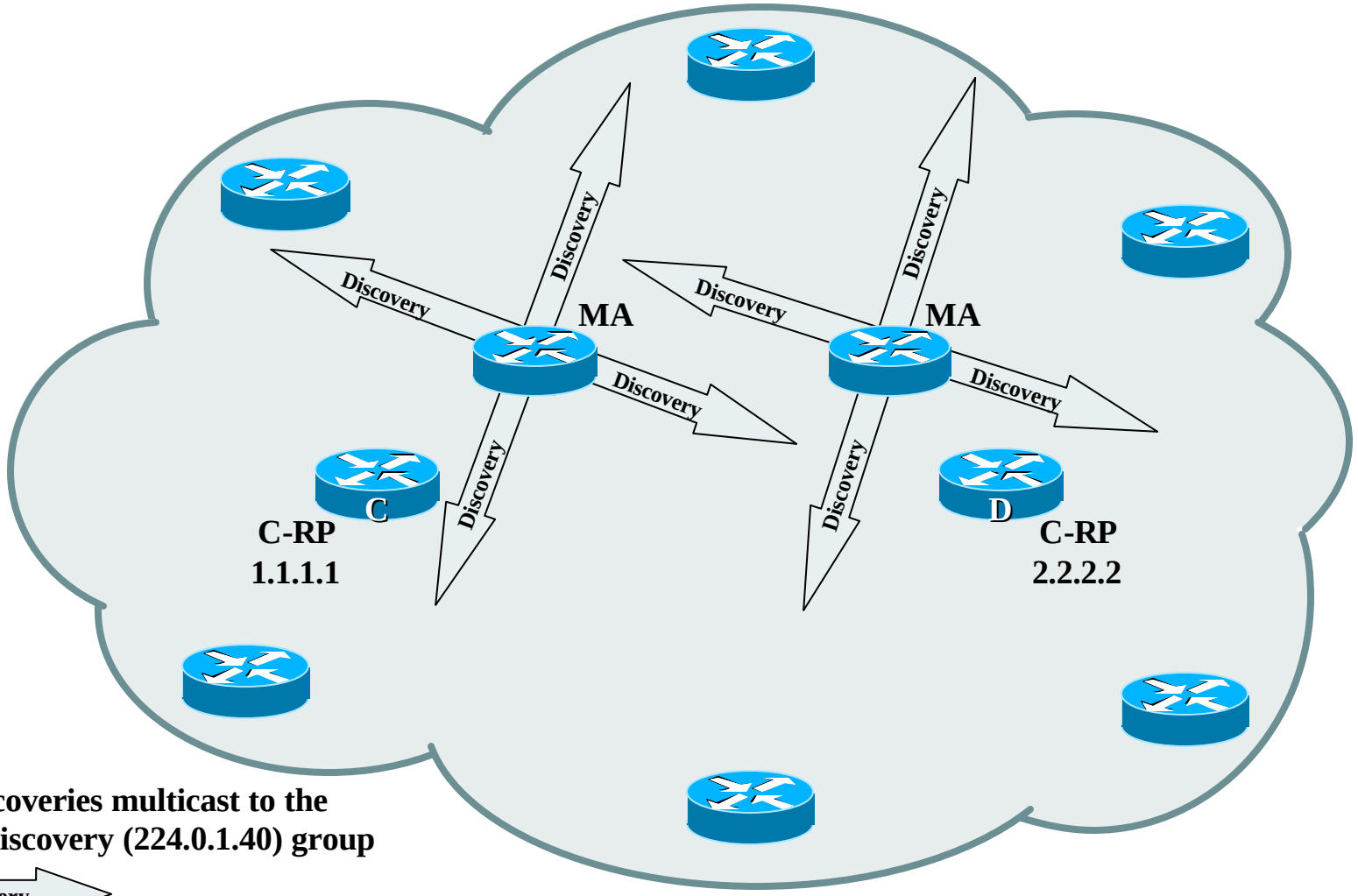
Auto-RP—From 10,000 Feet



RP-Discoveries multicast to the Cisco Discovery (224.0.1.40) group

Discovery

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PIMv2 BSR Overview

- A single Bootstrap Router (BSR) is elected
  - Multiple Candidate BSR's (C-BSR) can be configured
  - C-RP's unicast C-RP announcements to the BSR
    - BSR stores *ALL* C-RP announcements in the "RP-set"
  - BSR periodically multicasts BSR messages.
    - BSR Messages contain entire RP-set and IP address of BSR
  - All routers select the RP from the RP-set
    - All routers use the same selection algorithm; select same RP
- BSR ***cannot*** be used with Admin-Scoping

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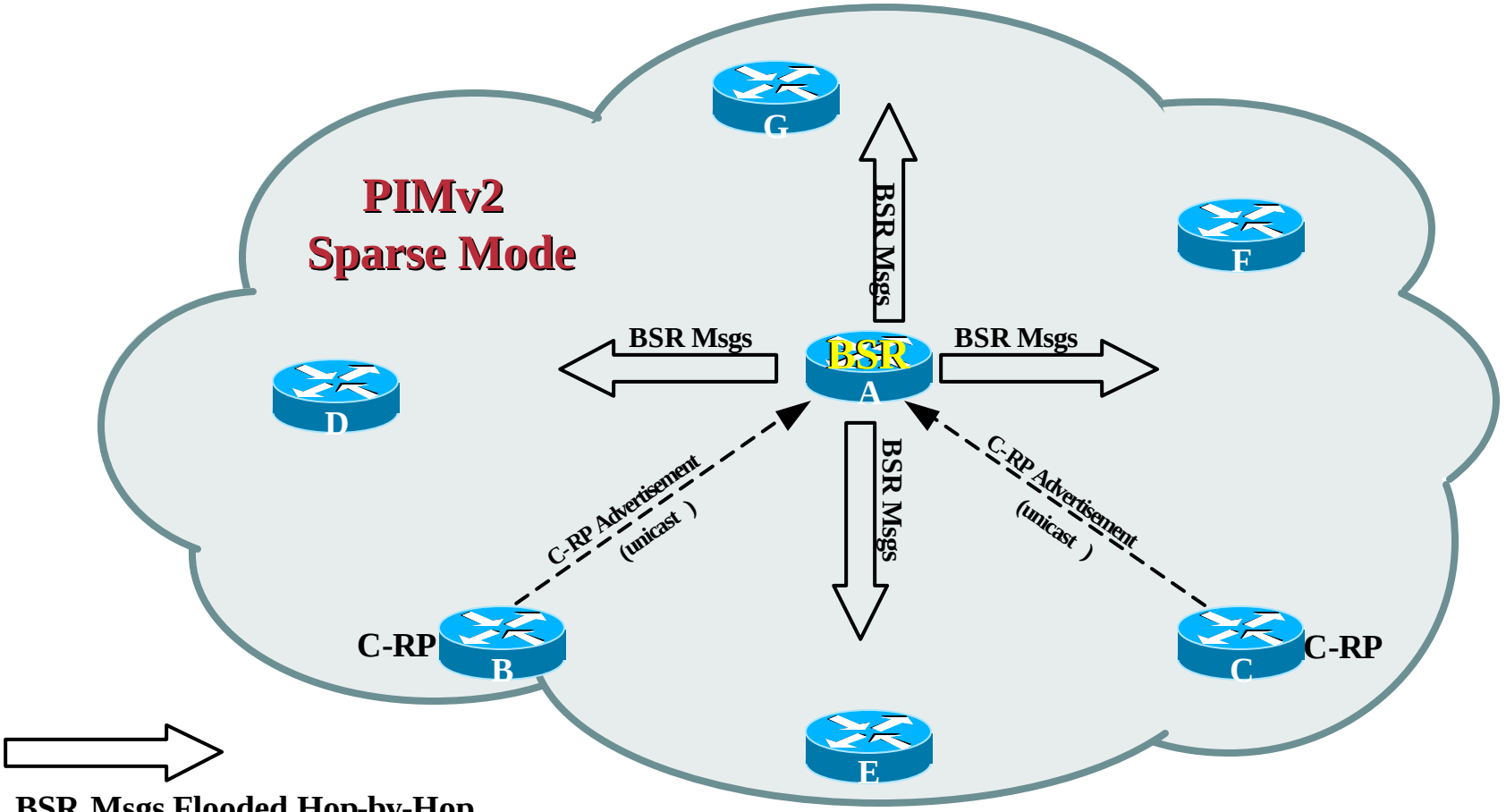
Basic PIMv2 BSR



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Static RP's

- **Hard-coded RP address**
  - **When used, must be configured on every router**
  - **All routers must have the same RP address**
  - **RP fail-over not possible**
    - **Exception: If Anycast RPs are used. (More on that later.)**
  - **Group can *never* fall back into Dense mode.**
- **Command**

```
ip pim rp-address <address> [group-list <acl>] [override]
```

  - **Optional group list specifies group range**
    - **Default: Range = 224.0.0.0/4 *(Includes Auto-RP Groups!!!!)***
  - **Override keyword "overrides" Auto-RP information**
    - **Default: Auto-RP learned info takes precedence**

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Anycast RP – Overview

- Uses single statically defined RP address
  - Two or more routers have same RP address
    - RP address defined as a Loopback Interface.
    - Loopback address advertised as a Host route.
  - Senders & Receivers Join/Register with closest RP
    - Closest RP determined from the unicast routing table.
  - Can *never* fall back to Dense mode.
    - Because RP is statically defined.
- MSDP session(s) run between all RPs
  - Informs RPs of sources in other parts of network
  - RPs join SPT to active sources as necessary

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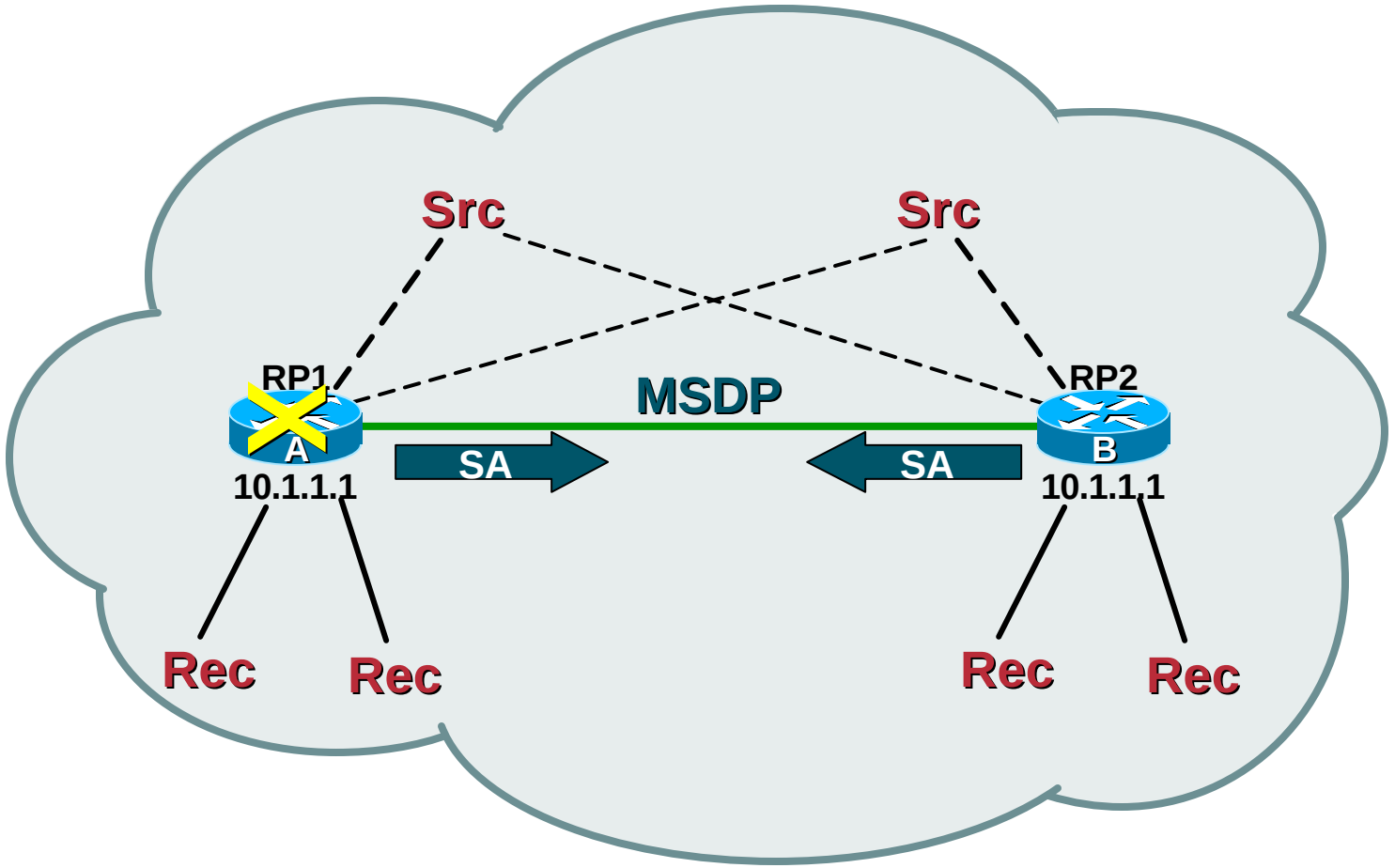
Anycast RP – Overview



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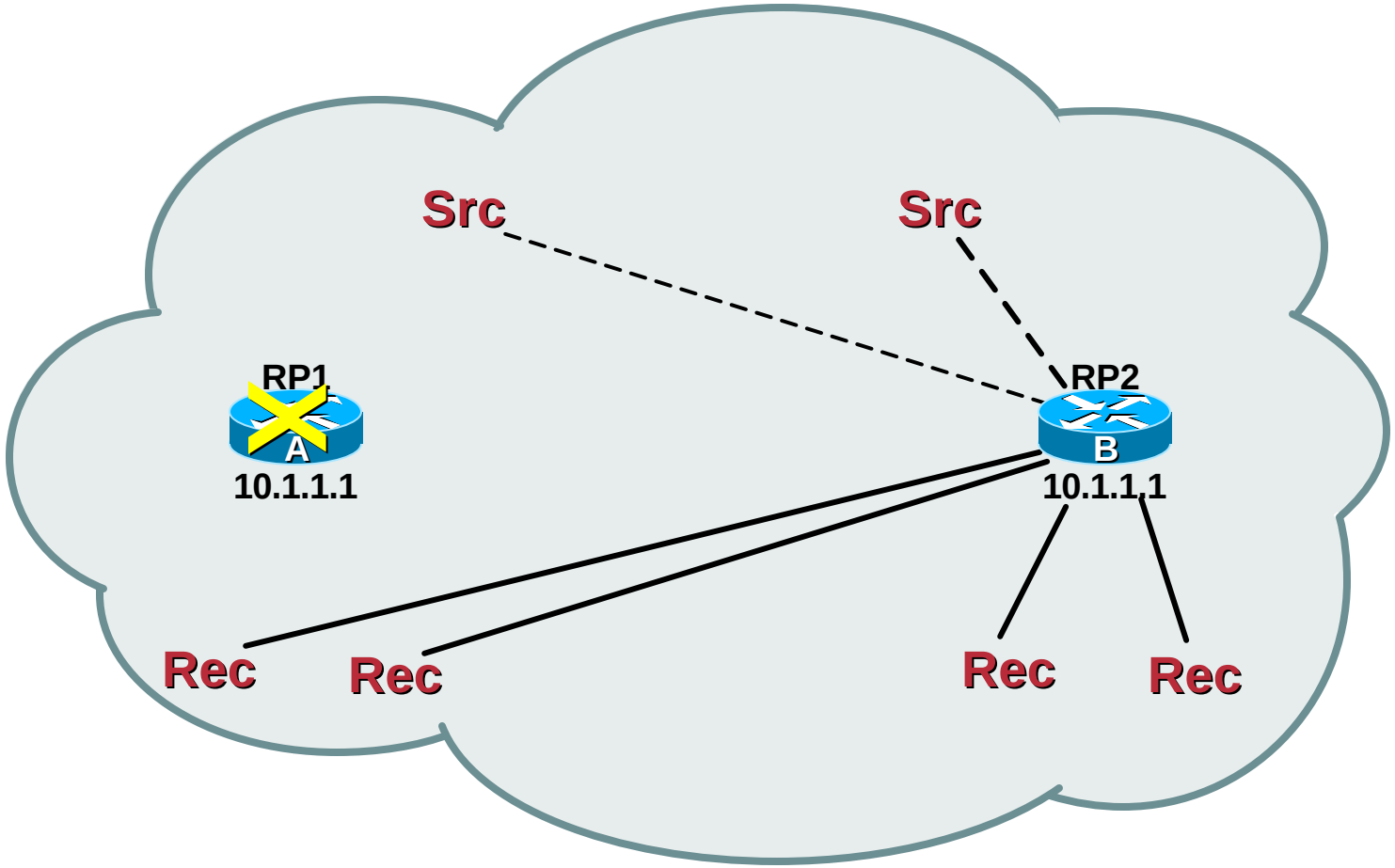
Anycast RP – Overview



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Agenda

- What and Why?
- PIM-SM Review
- PIM-SM Protocol Mechanics
- Rendezvous Points
- Tools & Examples

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Tools and Examples

- **Cheat sheet again!**
- **Show commands**
- **Timer details**
- **Debug commands**
- **Tools**
- **Selection of examples**

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Troubleshooting Cheat Sheet

- Make sure you have a source before trying to debug a problem
- Make sure you have a receiver before trying to debug a problem
- Work backward from the receiver toward the source
  - Check the last-hop has (S,G) state -- if not…
  - Check the last-hop has (*,G) state

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Troubleshooting Cheat Sheet

- **Check IGMP membership on PIM DR on Last Hop LAN**
  - **Did the receiver correctly indicate it wants to receive traffic**
- **Check RP address in (*,G) entry on the DR**
  - **If there is no RP, you are trying to forward dense-mode traffic. Is this what you want?**
- **Check RPF interface to RP in (*,G) entry**
  - **“show ip rpf <RP>” will point you to the next hop in the (*,G) tree**

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Troubleshooting Cheat Sheet

- If the (*,G) information is correct then check the (S,G) information
  - Is the IIF correct
  - Is the OIF correct
- Move up the shortest-path toward the source
  - “show ip rpf <source>” will point you to the next hop
  - Is this the same as the information in the mroute entry
  - Is this what you would expect when looking at the unicast routing table

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Troubleshooting Cheat Sheet

- Is the (S,G) state correct in the RP?
- What is the RPF router?
- Is the source sending with an incorrect TTL
  - TTL = 1 is a common problem. Most applications default to this. (S,G) state does not get created anywhere in this case

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Troubleshooting Cheat Sheet

Cisco.com

- What forwarding model are you using?
- Data-triggered events
  - Sparse
  - Dense

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Tools and Examples

- Cheat sheet again!
- **Show commands**
- Timer details
- Debug commands
- Tools
- Selection of examples

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Show Commands

- show ip igmp groups
- show ip igmp interface
- show ip mroute
- show ip pim interface
- show ip pim neighbor
- show ip pim rp
- show ip pim rp mapping
- show ip rpf

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Show ip igmp group xxxx

Cisco.com

```
mc1-36a_R6#sh ip igmp group 239.1.2.3
IGMP Connected Group Membership
Group Address    Interface            Uptime    Expires   Last Reporter
239.1.2.3        Ethernet1/0          00:01:07  never     172.16.8.6
```

B

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Show ip igmp interface


```
mc1-36a_R6#sh ip igmp interface e1/0
Ethernet1/0 is up, line protocol is up
  Internet address is 172.16.8.6/24
  IGMP is enabled on interface
  Current IGMP version is 2
  CGMP is disabled on interface
  IGMP query interval is 60 seconds
  IGMP querier timeout is 120 seconds
  IGMP max query response time is 10 seconds
  Last member query response interval is 1000 ms
  Inbound IGMP access group is not set
  IGMP activity: 1 joins, 0 leaves
  Multicast routing is enabled on interface
  Multicast TTL threshold is 0
  Multicast designated router (DR) is 172.16.8.6 (this system)
  IGMP querying router is 172.16.8.6 (this system)
  Multicast groups joined (number of users):
      239.1.2.3(1
```

B

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Show ip mroute


```
mc1-36a_R6#sh ip mrou 239.1.2.3
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, C - Connected, L - Local, P - Pruned
       R - RP-bit set, F - Register flag, T - SPT-bit set, J - Join SPT
       M - MSDP created entry, X - Proxy Join Timer Running
       A - Advertised via MSDP
Outgoing interface flags: H - Hardware switched
Timers: Uptime/Expires
Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 239.1.2.3), 03:11:05/00:00:00, RP 111.1.1.1, flags: SC
  Incoming interface: Null0, RPF nbr 0.0.0.0
  Outgoing interface list:
    Ethernet1/0, Forward/Sparse, 00:00:14/00:02:45
```

More details on timers later in session

ABCDEF

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Show ip pim interface


```
mc1-36a_R6#show ip pim interface

Address          Interface          Version/Mode    Nbr    Query     DR
                                                    Count  Intvl
172.16.10.6      Serial0/0          v2/Sparse        1     30      0.0.0.0
172.16.7.6       Ethernet0/1        v2/Sparse        1     30      172.16.7.6
172.16.8.6       Ethernet1/0        v2/Sparse        0     30      172.16.8.6
```

CEF

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Show ip pim neighbor

Cisco.com

```
mc1-36a_R6#sh ip pim neighbor
PIM Neighbor Table
Neighbor Address  Interface          Uptime    Expires   Ver  Mode
172.16.10.3       Serial0/0          7w0d      00:01:26  v2
172.16.7.5        Ethernet0/1        7w0d      00:01:30  v2
```

CEF

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Show ip pim rp


```
mc1-36a_R6#sh ip pim rp 239.1.2.3
Group: 239.1.2.3, RP: 111.1.1.1, v2, uptime 00:23:36, expires never
```

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Show ip pim rp mapping


```
Router# show ip pim rp mapping

PIM Group-to-RP Mappings
This system is an RP
This system is an RP-mapping agent

Group(s) 224.0.1.39/32, uptime: 1w4d, expires: never
    RP 171.69.10.13 (sj-eng-mbone.cisco.com)
    Info source: local
Group(s) 224.0.1.40/32, uptime: 1w4d, expires: never
    RP 171.69.10.13 (sj-eng-mbone.cisco.com)
    Info source: local
Group(s) 239.255.0.0/16, uptime: 1d03h, expires: 00:02:28
    RP 171.69.143.25 (lwei-cisco-isdn.cisco.com), PIMv2 v1
    Info source: 171.69.143.25 (lwei-cisco-isdn.cisco.com)
Group(s): 224.0.0.0/4, Static
    RP: 171.69.10.13 (sj-eng-mbone.cisco.com)sh ip pim rp 239.1.2.3
```

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Show ip rpf <source>


```
mc1-72a_R1#sh ip rpf 172.16.8.22
RPF information for ? (172.16.8.22)
  RPF interface: Serial2/1
  RPF neighbor: ? (172.16.1.2)
  RPF route/mask: 172.16.8.0/24
  RPF type: unicast (ospf 100)
  RPF recursion count: 0
  Doing distance-preferred lookups across tables
```

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Tools and Examples

- Cheat sheet again!
- Show commands
- Timer details
- Debug commands
- Tools
- Selection of examples

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PIM Timers

The secret of PIM is in the Timers

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PIM Timers

- The secret to understanding PIM is to watch the timers.
- 3 minutes is the “magic” number.
- Interface expiration timers are updated every minute by JOIN messages so if the expire timer goes below 2:00 the route is not being used.
- It may mean that the route has not been correctly pruned

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PIM Timers

- Entry expiration timers are updated when data is forwarded so if the timer drops below 2:59, the source has stopped sending.
- The IGMP cache has to be updated periodically
- The RP cache has to be updated periodically

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PIM Timers

- If you find yourself debugging a problem that just isn't making sense, you are probably debugging the wrong problem
  - IGMP cache
  - RP cache
  - Application problems

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Mroute Entries

- Source Tree
- Shared Tree
- Pruned Tree

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PIM Source Tree

- In IOS a (*,G) entry is always created whenever a (S,G) entry is created.
- The Source-tree may overlap the Shared-tree in which case the (*,G) entry will be non-NULL.
- The Source-tree may be independent of the Shared-tree in which case the (*,G) entry will be NULL.
- SSM
- Dense
- Sparse

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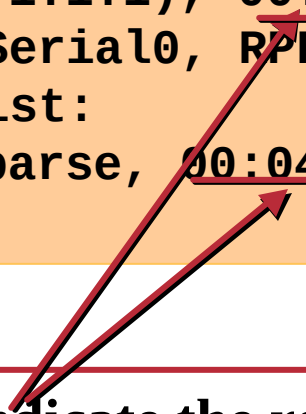
PIM SM Source Tree

- **(S,G) forwarding entry**

```
(171.68.37.121/32, 224.1.1.1), 00:04:28/00:01:32, flags: T
  Incoming interface: Serial0, RPF nbr 171.68.28.190
  Outgoing interface list:
    Serial1, Forward/Sparse, 00:04:28/00:01:32
```



NOTE: These uptimes indicate the receiver has always been present

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PIM SM Source Tree

- (S,G) forwarding entry

```
(171.68.37.121/32, 224.1.1.1), 00:04:28/00:01:32, flags: T
  Incoming interface: Serial0, RPF nbr 171.68.28.190
  Outgoing interface list:
    Serial1, Forward/Sparse, 00:04:28/00:01:32
```

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PIM SM Source Tree

- (S,G) forwarding entry

```
(171.68.37.121/32, 224.1.1.1), 00:04:28/00:01:32, flags: T
  Incoming interface: Serial0, RPF nbr 171.68.28.190
  Outgoing interface list:
    Serial1, Forward/Sparse, 00:04:28/00:01:32
```

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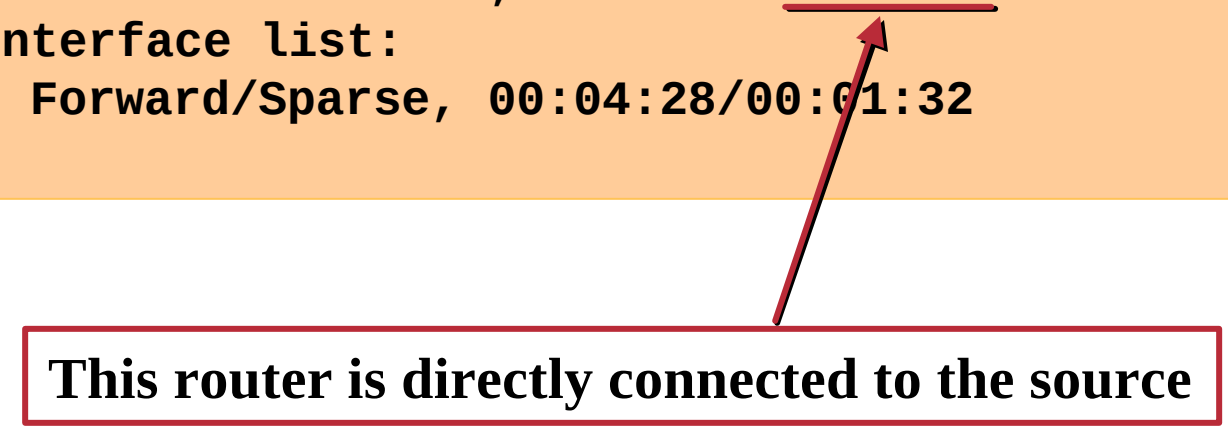
PIM SM Source Tree

- (S,G) forwarding entry

```
(171.68.37.121/32, 224.1.1.1), 00:04:28/00:01:32, flags: T
  Incoming interface: Serial0, RPF nbr 0.0.0.0
  Outgoing interface list:
    Serial1, Forward/Sparse, 00:04:28/00:01:32
```



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PIM Shared Tree

- (*,G) state
- Bi-directional PIM
- Sparse-mode
- NOT SSM or Dense

DH

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PIM SM Shared Tree

- (*,G) forwarding entry

```
(*, 224.1.1.1), 00:04:28/00:01:32, RP 171.68.28.140, flags: S
  Incoming interface: Serial1, RPF nbr 171.68.28.140,
  Outgoing interface list:
    Serial0, Forward/Sparse, 00:04:28/00:01:32
```

All Sources for this group will be forwarded out the olist

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PIM SM Shared Tree

- (*,G) forwarding entry

```
(*, 224.1.1.1), 00:04:28/00:01:32, RP 171.68.28.140, flags: S
  Incoming interface: Serial1, RPF nbr 171.68.28.140,
  Outgoing interface list:
    Serial0, Forward/Sparse, 00:04:28/00:01:32
```


This always points to the RP

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PIM SM Shared Tree

- (*,G) forwarding entry

```
(*, 224.1.1.1), 00:04:28/00:01:32, RP 171.68.28.140, flags: S
  Incoming interface: Serial1, RPF nbr 171.68.28.140,
  Outgoing interface list:
    Serial0, Forward/Sparse, 00:04:28/00:01:32
```

This is the next-hop to the RP from “sh ip RPF”

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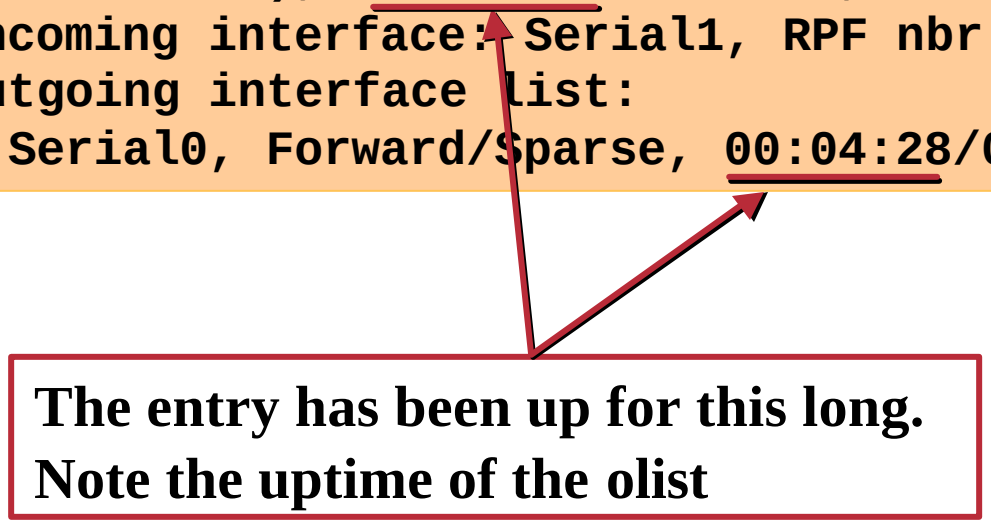
PIM SM Shared Tree

- (*,G) forwarding entry

```
(*, 224.1.1.1), 00:04:28/00:01:32, RP 171.68.28.140, flags: S
  Incoming interface: Serial1, RPF nbr 171.68.28.140,
  Outgoing interface list:
    Serial0, Forward/Sparse, 00:04:28/00:01:32
```



DH

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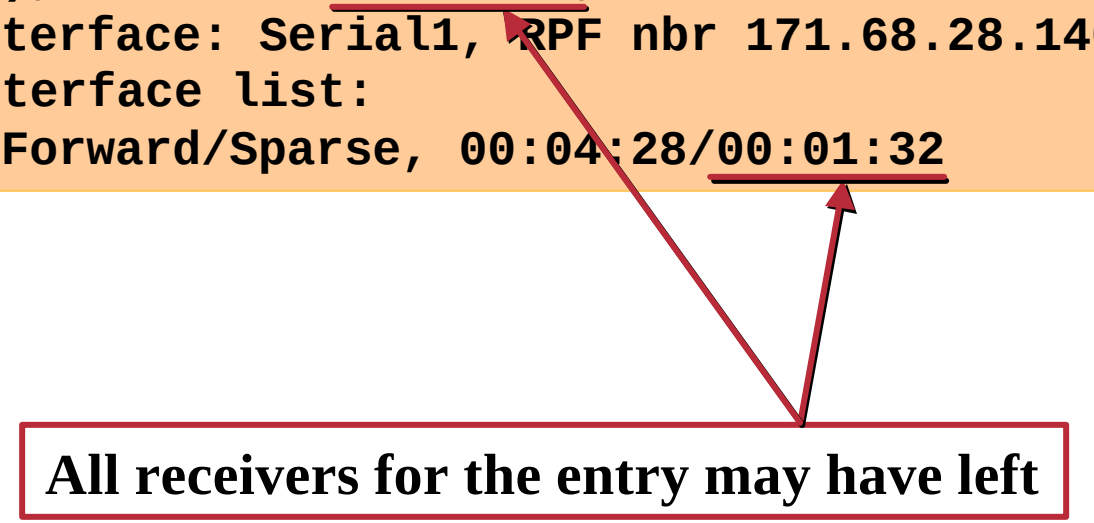
PIM SM Shared Tree

- (*,G) forwarding entry

```
(*, 224.1.1.1), 00:04:28/00:01:32, RP 171.68.28.140, flags: S
  Incoming interface: Serial1, RPF nbr 171.68.28.140,
  Outgoing interface list:
    Serial0, Forward/Sparse, 00:04:28/00:01:32
```



BH

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PIM SM Shared Tree

- (*,G) forwarding entry

```
(*, 224.1.1.1), 00:04:28/00:01:32, RP 171.68.28.140, flags: S
  Incoming interface: Serial1, RPF nbr 171.68.28.140,
  Outgoing interface list:
    Serial0, Forward/Sparse, 00:04:28/00:01:32
```

A sparse-mode group must have an RP

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(S,G,RP-bit) State

- Only exists in Sparse-Mode
- Traffic is pruned on shared tree
  - (S,G,RP-bit) with a non-NULL olist is forwarding traffic down the shared tree.

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PIM Shared Tree

- **(S,G)RP-bit forwarding entry**

```
(171.68.37.121/32, 224.1.1.1), 00:04:28/00:01:32, flags: RP
  Incoming interface: Serial0, RPF nbr 171.68.28.190
  Outgoing interface list:
    NULL
```

Points toward the RP!!!!

Last-hop router is sending (s,g,r) prunes

Note R-flag

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Tools and Examples

- Cheat sheet again!
- Show commands
- Timer details
- **Debug commands**
- Tools
- Selection of examples

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Debugging commands

- **Debugging commands**
  - **These are a few basic debugs to be used along with show commands**

```
Debug ip mpacket
Debug ip pim
Debug ip igmp
```


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Debugging commands

- **Debug ip mpacket**

```
*Sep 12 14:48:01.651: IP: s=172.16.8.22 (Ethernet1/0) d=224.1.1.1 (Serial0/0) ld
*Sep 12 14:48:02.651: IP: s=172.16.8.22 (Ethernet1/0) d=224.1.1.1 (Serial0/0) ld
*Sep 12 14:48:03.651: IP: s=172.16.8.22 (Ethernet1/0) d=224.1.1.1 (Serial0/0) ld
```

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Debugging commands

- **Debug ip pim**

```
mc1-36b_R3#deb ip pim
PIM debugging is on
mc1-36b_R3#
*Sep 18 08:21:47.585: PIM: Received v2 Hello on ATM3/0.200 from 10.10.92.2
*Sep 18 08:21:47.585: PIM: Received v2 Join/Prune on ATM3/0.200 from 10.10.92.2s
*Sep 18 08:21:47.585: PIM: Join-list: (*, 224.0.1.40) RP 111.1.1.1, RPT-bit sett
*Sep 18 08:21:47.585: PIM: Add ATM3/0.200/10.10.92.2 to (*, 224.0.1.40), Forware
*Sep 18 08:21:49.233: PIM: Received v2 Hello on Serial0/1 from 172.16.3.2
*Sep 18 08:21:51.449: PIM: Send v2 Hello on Ethernet0/1
*Sep 18 08:21:53.449: PIM: Send v2 Hello on Serial0/1
*Sep 18 08:21:56.585: PIM: Received v2 Join/Prune on ATM3/0.200 from 10.10.92.2s
*Sep 18 08:21:56.585: PIM: Join-list: (*, 224.1.1.1) RP 111.1.1.1, RPT-bit set,t
*Sep 18 08:21:56.585: PIM: Add ATM3/0.200/10.10.92.2 to (*, 224.1.1.1), Forwarde
*Sep 18 08:21:59.449: PIM: Building Join/Prune message for 224.1.1.1
```

ARD

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Debugging commands

- **Debug ip igmp**

```
R1#debug ip igmp
12:32:51.065: IGMP: Send v2 Query on Ethernet1 to 224.0.0.1
12:32:51.069: IGMP: Set report delay time to 9.4 seconds for 224.0.1.40 on Ethernet1
12:32:56.909: IGMP: Received v1 Report from 192.168.9.1 (Ethernet1) for 239.255.0.1
12:32:56.917: IGMP: Starting old host present timer for 239.255.0.1 on Ethernet1
12:33:01.065: IGMP: Send v2 Report for 224.0.1.40 on Ethernet1
12:33:01.069: IGMP: Received v2 Report from 192.168.9.4 (Ethernet1) for 224.0.1.40
12:33:51.065: IGMP: Send v2 Query on Ethernet1 to 224.0.0.1
```

B

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Tools and Examples

- Cheat sheet again!
- Show commands
- Timer details
- Debug commands
- **Tools**
- Selection of examples

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Active tools

- There are times when you have to “discover” where the problem is happening
  - mtrace
  - mstat
  - mrinfo
  - MRM
  - Heartbeat

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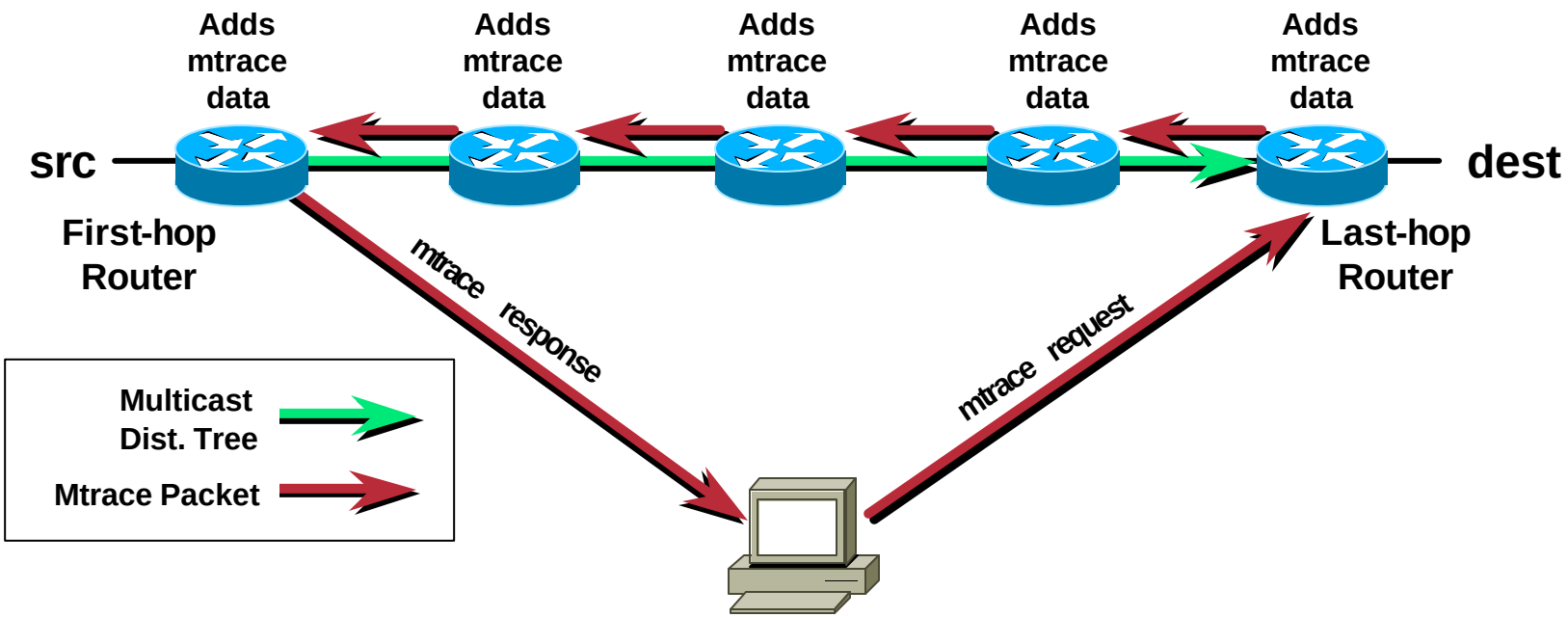
mtrace/mstat—How it works

Cisco.com

Mtrace Packet Flow



Note: Mtrace packets use special IGMP packets with IGMP Type codes of 0x1E and 0x1F.

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mtrace

- **Shows:**
  - **Multicast path from source to receiver.**
    - **Similar to unicast “trace” command**
    - **Trace path between any two points in network**
    - **TTL Thresholds & Delay shown at each node**
- **Troubleshooting Usage:**
  - **Find where multicast traffic flow stops.**
    - **Focus on router where flow stops**
  - **Verify path multicast traffic is following.**
    - **Identify sub-optimal paths.**

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mtrace


```
dallas-gw>mtrace bloom-iptv-svr bwilliam-ss5 224.2.156.43
Type escape sequence to abort.
Mtrace from 172.17.67.43 to 171.68.37.121 via group 224.2.156.43
From source (?) to destination (bwilliam-ss5.cisco.com)
Querying full reverse path...
 0  bwilliam-ss5 (171.68.37.121)
-1  dallas-gw (171.68.37.1) PIM  [default]
-2  wan-gw4 (171.68.86.193) PIM  [172.17.0.0/16]
-3  bloomington-mn-gw (171.68.27.2) PIM [172.17.67.0/24]
-4  bloom-mnlab (171.68.39.28) PIM [172.17.67.0/24]
-5  bloom-iptv-svr (172.17.67.43)
dallas-gw>
```


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mstat

- **Shows:**
  - **Multicast path in pseudo graphic format.**
    - **Trace path between any two points in network**
    - **Drops/Duplicates shown at each node**
    - **TTLs & Delay shown at each node**
- **Troubleshooting Usage:**
  - **Locate congestion point in the flow.**
    - **Focus on router with high drop/duplicate count**
    - **Duplicates indicated as “negative” drops**

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mstat

Cisco.com

```
dallas-gw>mstat 172.17.67.43 bwilliam-ss5 224.2.156.43
  Source         Response Dest    Packet Statistics For     Only For Traffic
172.17.67.43     171.68.86.194    All Multicast Traffic     From 172.17.67.43
     |       __/  rtt 547  ms   Lost/Sent = Pct  Rate     To 224.2.156.43
     v      /     hop 547  ms   ---------------------     -------------------
172.17.67.33
171.68.39.28     bloom-mnlab
     |     ^      ttl   0
     v     |      hop -409 ms    -11/168 = --%  16 pps     0/67 = 0%  6 pps
171.68.39.1
171.68.27.2      bloomington-mn-gw
     |     ^      ttl   1
     v     |      hop 379  ms    -9/170 = --%   17 pps    -3/67 = --%  6 pps
171.68.27.1
171.68.86.193    wan-gw4
     |     ^      ttl   2
     v     |      hop 28   ms    -3/195 = --%   19 pps     0/70 = 0%   7 pps
171.68.86.194
171.68.37.1      dallas-gw
     |      \__   ttl   3
     v         \  hop 0    ms        196        19 pps           70    7 pps
171.68.37.121    171.68.86.194
  Receiver       Query Source
```


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mstat

Cisco.com

```
dallas-gw>mstat 172.17.67.43 bwilliam-ss5 224.2.156.43
  Source        Response Dest    Packet Statistics For     Only For Traffic
172.17.67.43    171.68.86.194    All Multicast Traffic     From 172.17.67.43
     |       __/  rtt 399  ms   Lost/Sent = Pct  Rate     To 224.2.156.43
     v      /     hop 399  ms   ---------------------     --------------------
172.17.67.33
171.68.39.28    bloom-mnlab
     |     ^      ttl   0
     v     |      hop 119  ms    77/694 = 11%  69 pps    0/65 = 0%    6 pps
171.68.39.1
171.68.27.2     bloomington-mn-gw
     |     ^      ttl   1
     v     |      hop -150 ms    395/609 = 65% 60 pps    44/65 = 68%  6 pps
171.68.27.1
171.68.86.193   wan-gw4
     |     ^      ttl   2
     v     |      hop 30   ms    -8/39 = --%    3 pps    -1/21 = --%  2 pps
171.68.86.194
171.68.37.1     dallas-gw
     |      \__   ttl   3
     v         \  hop 0    ms        39         3 pps           22    2 pps
171.68.37.121   171.68.86.194
  Receiver      Query Source
```


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mrinfo


```
ip1-26a#mrinfo 171.1.0.6
171.1.0.6 [version  12.1] [flags: PMA]:
  171.1.0.6 -> 171.1.0.3 [1/0/pim]
  171.1.0.6 -> 171.1.0.8 [1/0/pim]
  171.1.1.6 -> 171.1.1.2 [1/0/pim/querier]
  171.1.3.6 -> 0.0.0.0 [1/0/pim/querier/leaf]
```

The same information as “show ip pim neighbor”

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Multicast Routing Monitor

- MRM uses routers to send test data
- Only the routers sending receiving or managing need MRM configured.
- Can be run continually in background or when needed.
- Originally an IETF Draft

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Multicast Routing Monitor

- MRM requires minimum Cisco IOS version 12.0(5)T
- Uses the concept of:
  - Test sender
  - Test receiver
  - Manager

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Multicast Routing Monitor

- Test sender
- Possible to set parameters od test traffic on Test-Manager. The defaults are:
- Packet-delay 200 milliseconds = 5 packets ps
- RTP is the protocol used for the test packet vs UDP
- Sent out all multicast enabled interfaces

```
mc1-36a_R6(config-if)#ip mrm test-sender
```


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Multicast Routing Monitor

- Test receiver set up on a router interface.
- Possible to set parameters of receiver reporting via Test-Manager defaults are:
  - Window of 5 seconds
  - Report delay 1 second
  - Loss of 0 percent
  - monitor

```
mc1-72a_R1(config-if)#ip mrm test-receiver
```


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Multicast Routing Monitor

- Test Manager
- Manager controls Sender and Receiver via unicast control messages.
- Manager uses ACL associated with sender and receiver to define sender and reciver addresses.

```
mc1-72a_R1(config)#ip mrm manager networkers2002….
```


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Multicast Routing Monitor


```
ip mrm manager networkers2002
 manager Loopback1 group 238.1.2.3
 senders 2
 receivers 1
access-list 1 permit 192.168.1.1
access-list 2 permit 172.16.8.6
```

```
interface Ethernet1/0
ip address 172.16.8.6 255.255.255.0
ip mrm test-sender
```

```
interface Ethernet3/0
ip address 192.168.1.1 255.255.255.0
ip mrm test-receiver
```


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Multicast Heartbeat

- IP Multicast Heartbeat
- Raises SNMP trap when traffic falls below a threshold
- A monitoring tool

```
snmp-server enable traps ipmulticast-heartbeat
ip multicast heartbeat 224.0.1.53 1 1 10
```


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Tools and Examples

- Cheat sheet again!
- Show commands
- Timer details
- Tools
- Selection of examples

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Examples

- RPF failure
- Designated Router
- PIM versions
- TTL values
- Auto-RP ‘Scope issues’

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Incongruent routing & RPF failure

- How does RPF work?
- What if preferred Unicast route to source is not Multicast enabled?
- Use sh ip mroute to determine RPF neighbour.
- Multicast data arriving on this link will be RPF checked what will happen?

EF

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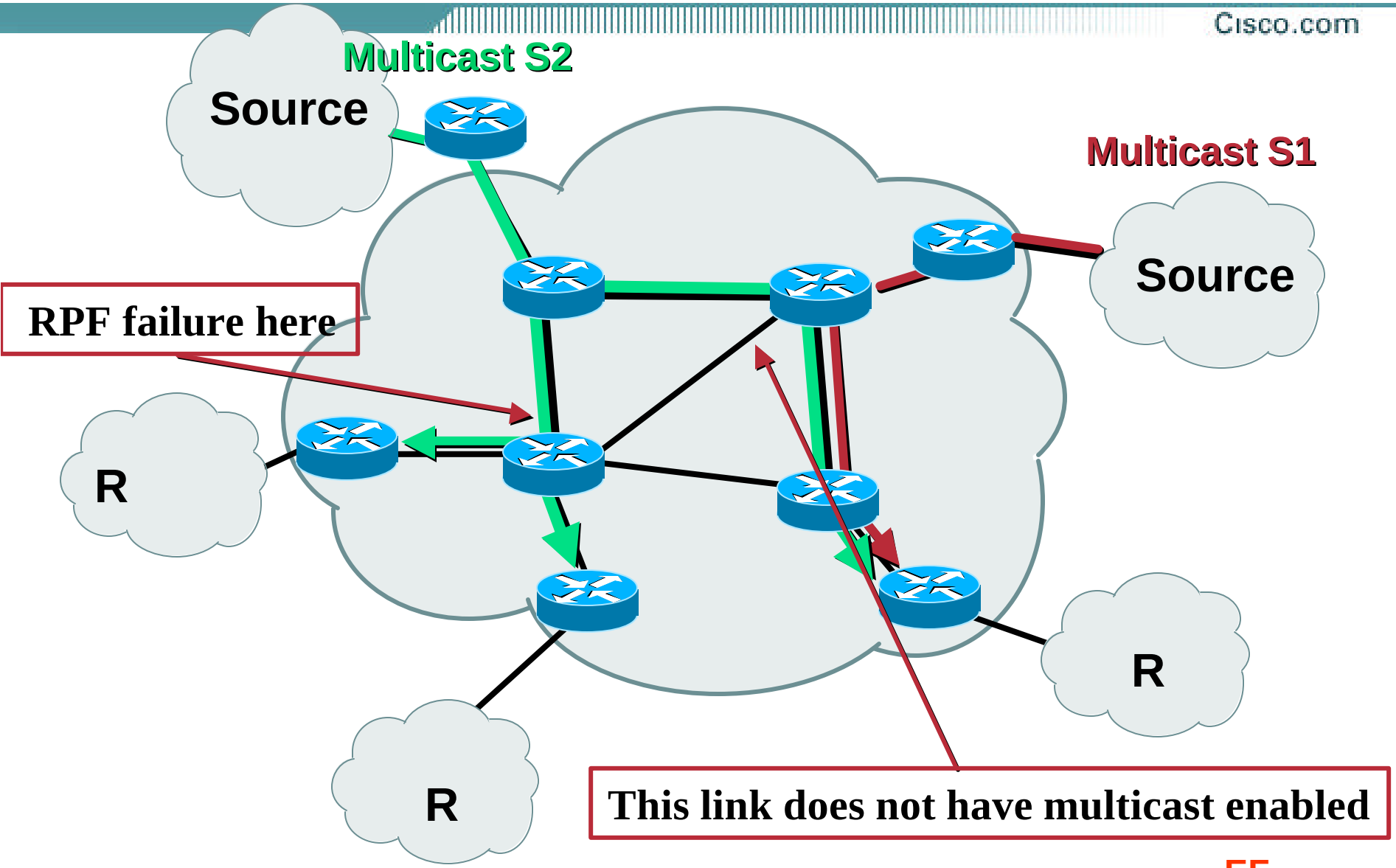
RPF failure from incongruent routing



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Examples

- RPF failure
- **Designated Router**
- PIM versions
- TTL values
- Auto-RP ‘Scope issues’

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Unexpected Designated Router

- What is the DR function?
- Unexpected router on link
- Unexpected router becomes DR
- Unexpected router has missing or incorrect RP information.
- Register fails! RP-DR SPT fails.. PIM SM fails
- How is a DR determined?
  - IP address
  - DR priority

ABD

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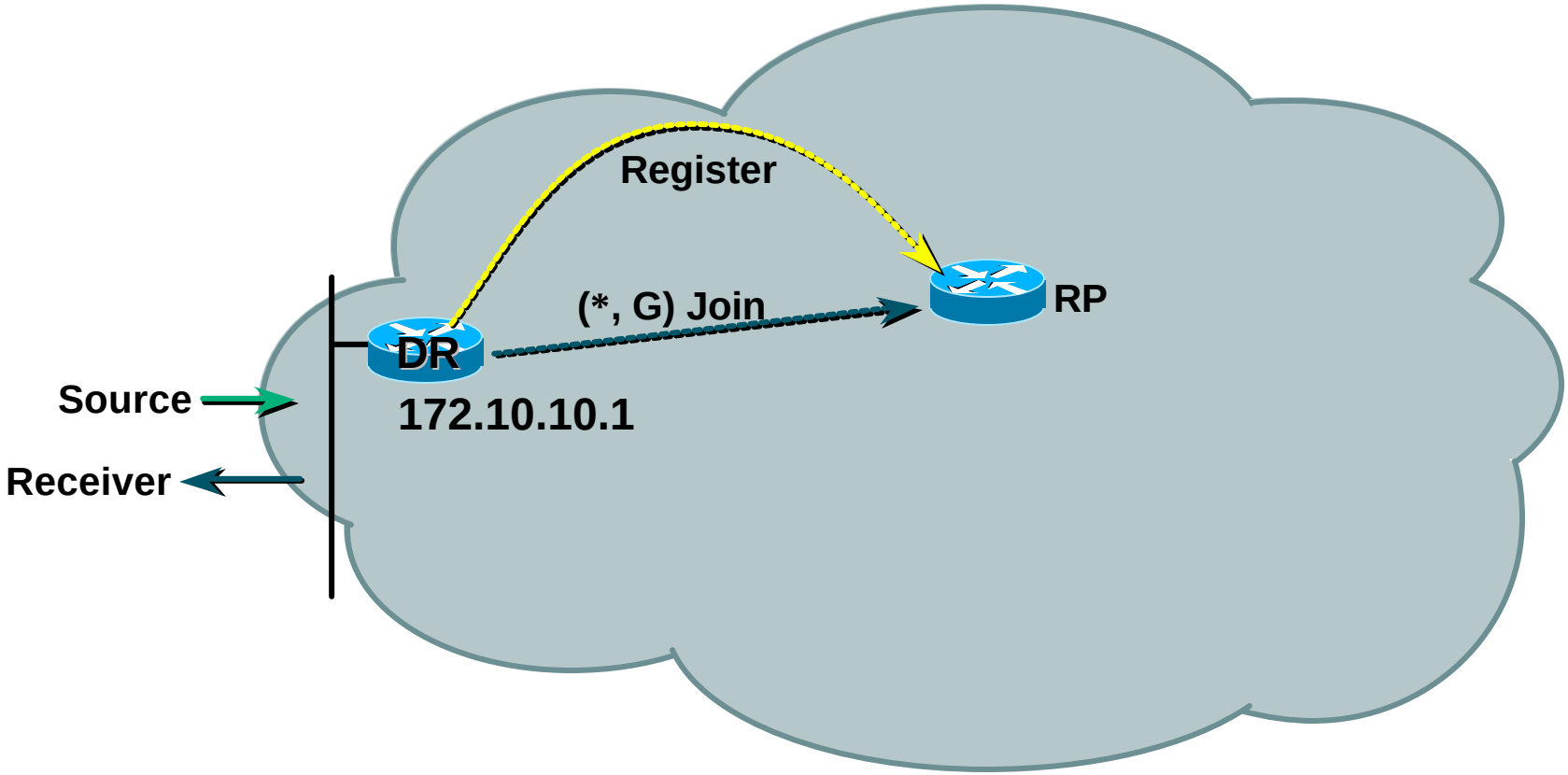
Unexpected Designated Router



ABD

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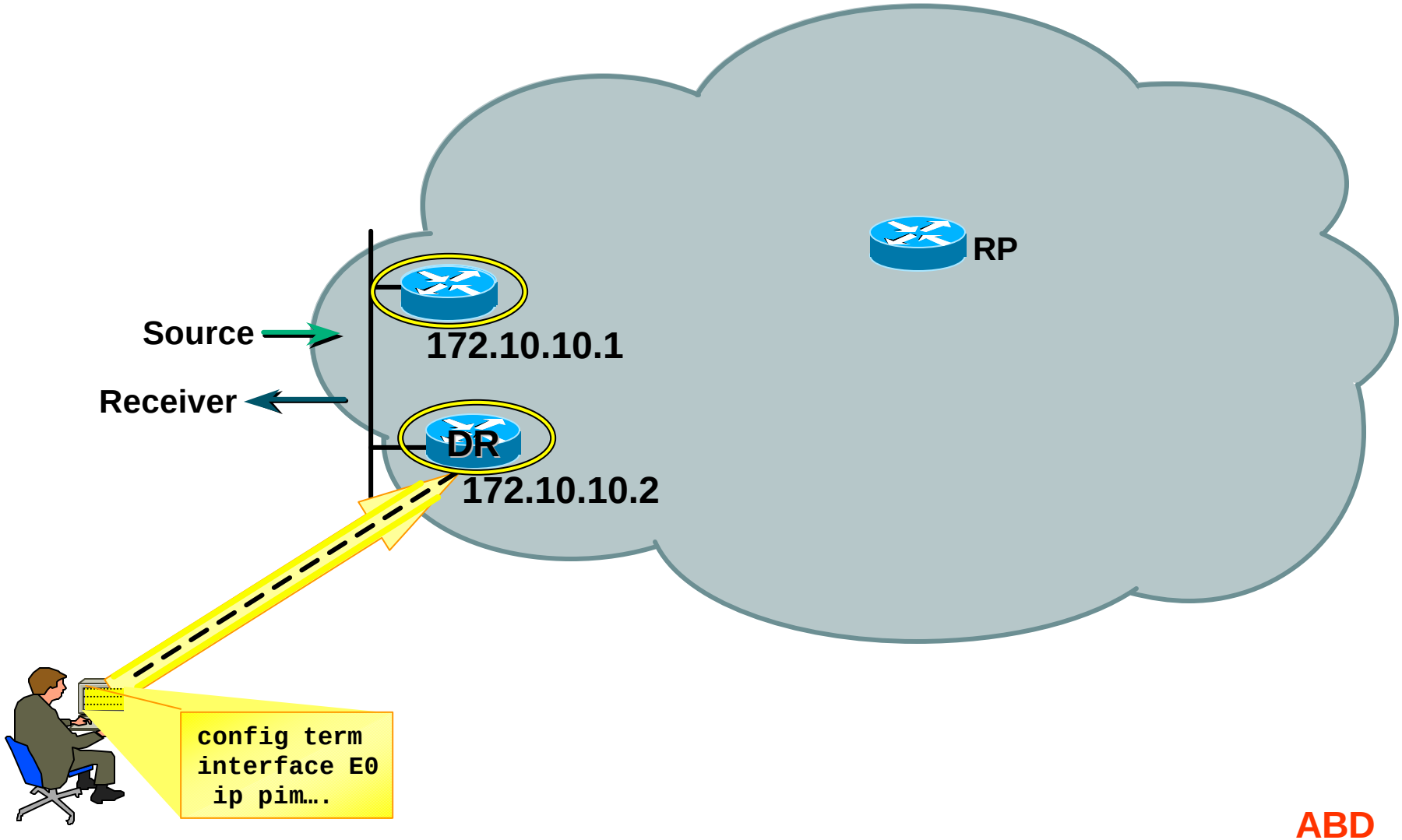
Unexpected Designated Router



ABD

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Examples

- RPF failure
- Designated Router
- PIM versions
- TTL values
- Auto-RP ‘Scope issues’

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Mixing PIM versions

- Don’t
- PIM v1 not discussed in presentation
- Pim v2 since IOS version 12.0
- RP source state changes

AD

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Mixing PIM versions

- 1 possible problem
- DR fails to send periodic register
- State loss on RP!
  - RP sends register stop
- Make sure RP is PIMv1 if any leaf routers may be PIMv1

AD

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Examples

- RPF failure
- Designated Router
- PIM versions
- TTL values
- Auto-RP ‘Scope issues’

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TTL values

- Regular IP TTL
- Applications may not be IPmc aware
- Default TTL for IP multicast is sometimes 1
- Needs to be adjusted!
- Very common problem
- Auto-RP is an Application

G

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TTL values

- Where is source?
- Show ip mroute on first hop
  - What if no state?
- Is application working?
  - Debug ip mpacket
  - Or check TTL

G

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Examples

- RPF failure
- Designated Router
- PIM versions
- TTL values
- **Auto-RP ‘Scope issues’**

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Auto RP with incorrect TTL

- RP information must be coherent in the network.
- RP advertisements use TTL
  - This is an advantage of Auto-RP over BSR the ability to ‘scope’
- TTL must be set correctly

GD

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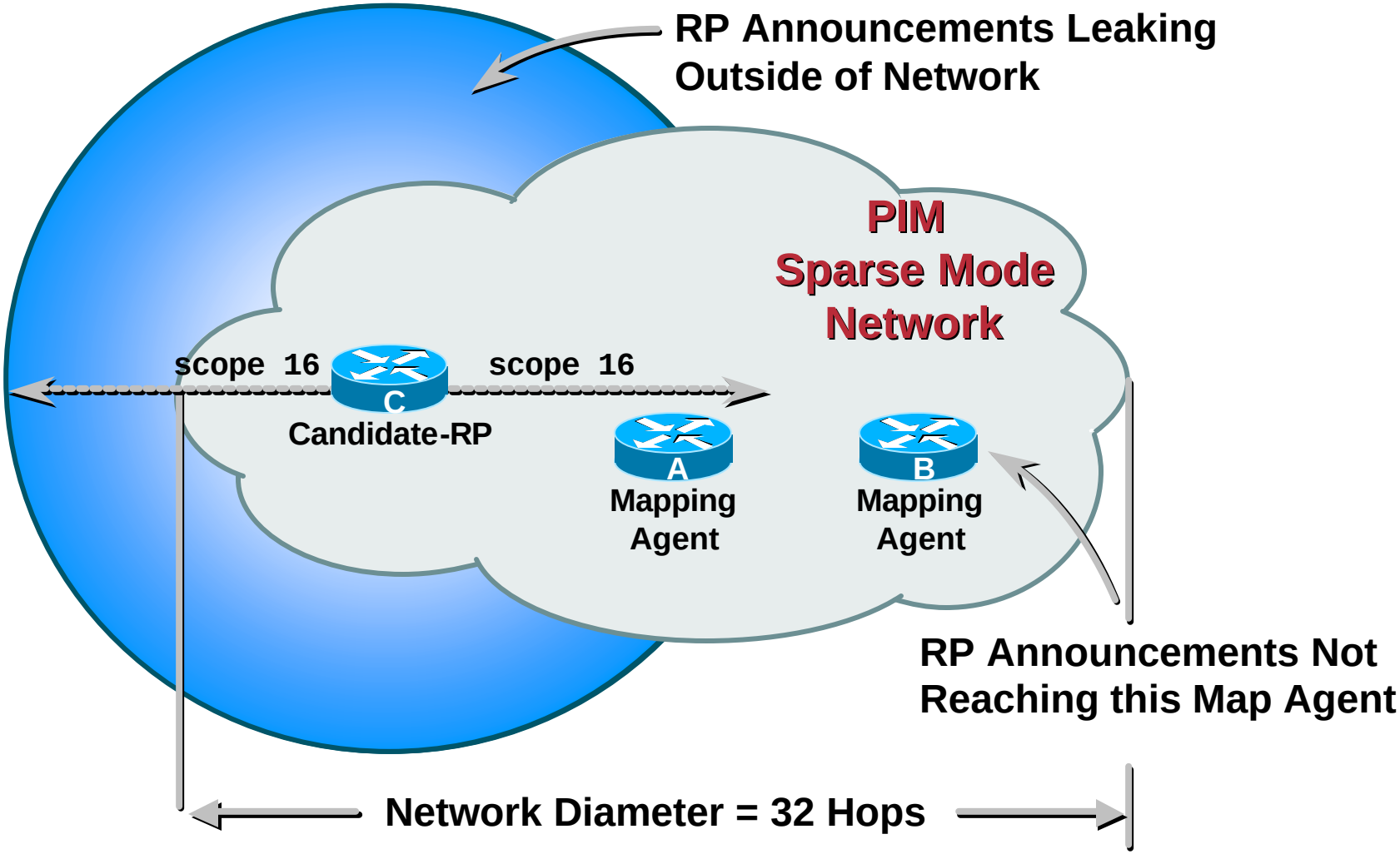
Auto-RP Announcement Scope



GD

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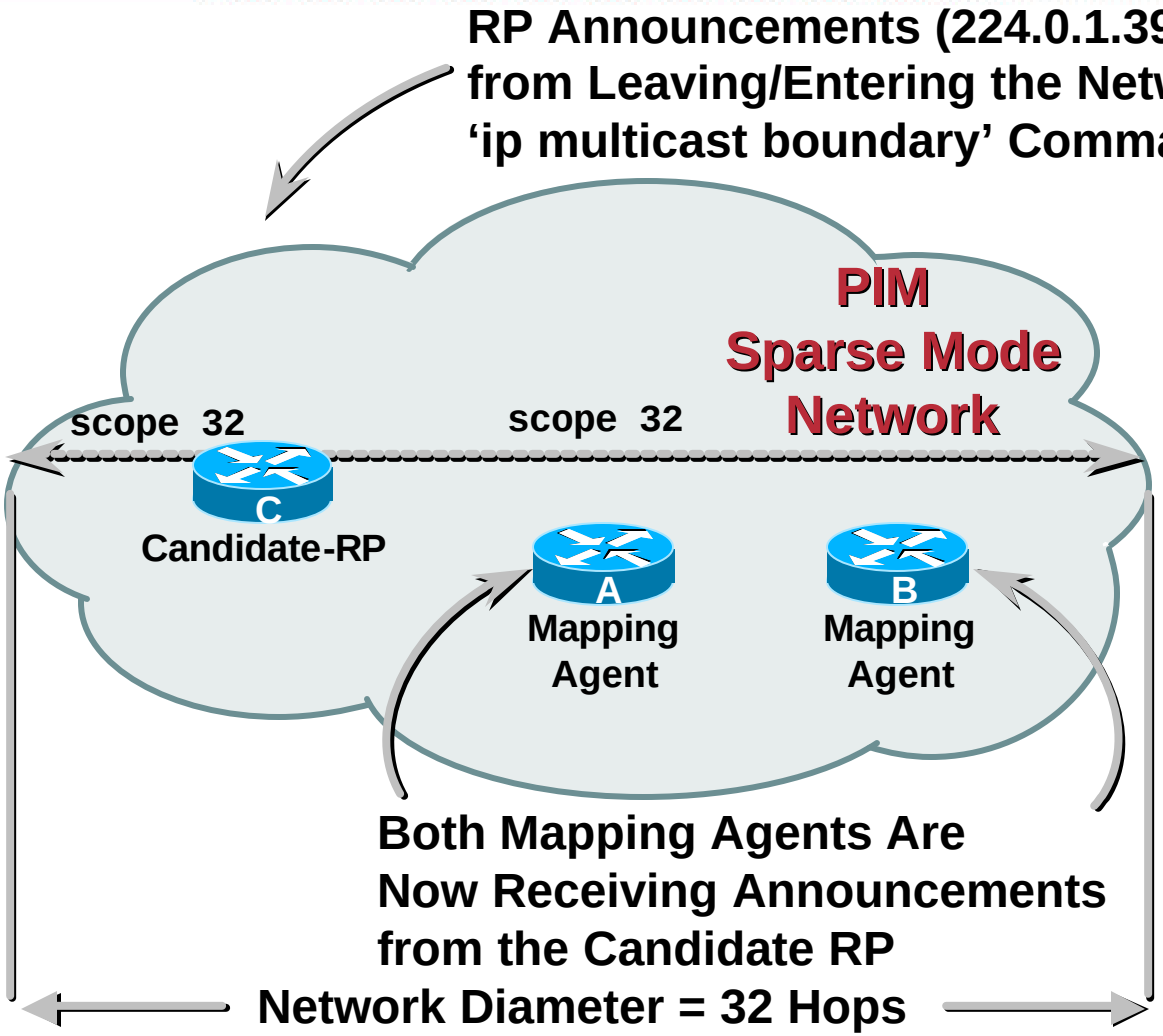
Auto-RP Announcement Scope



GD

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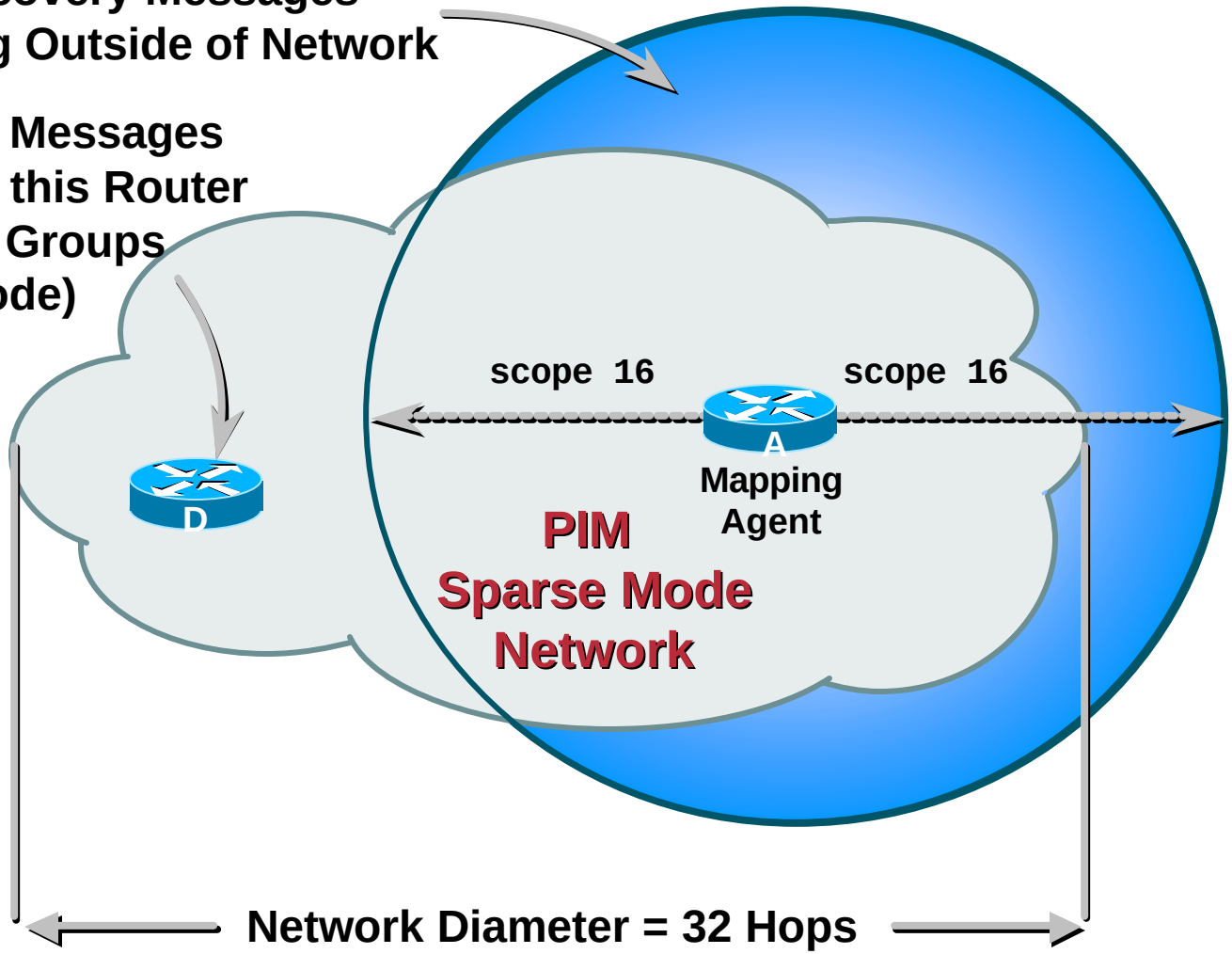
Auto-RP Discovery Scope

RP Discovery Messages
Leaking Outside of Network

RP Discovery Messages
Not Reaching this Router
(Assumes All Groups
Are Dense Mode)



GD

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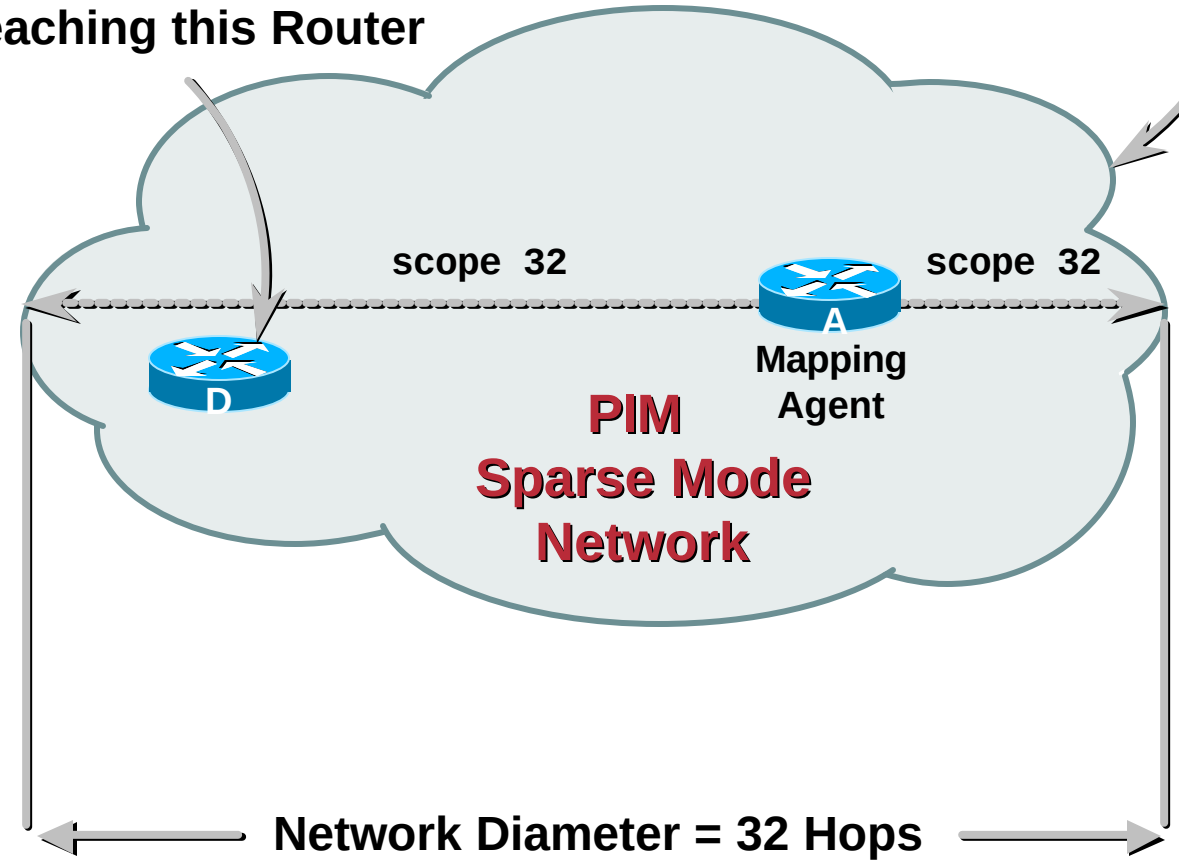
Auto-RP Discovery Scope

RP Discoveries (224.0.1.40) Blocked From Leaving/entering the Network Using 'ip multicast boundary' Commands

RP Discovery Messages Now Reaching this Router



GD

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Debugging Auto-RP Operation

- **Understand the Auto-RP mechanisms**
  - ***This is the fundamental debugging tool for problems with Auto-RP!!!***
- **Verify Group-to-RP Mapping Caches**
  - **First on the Mapping Agents**
    - **Other routers will learn Group-to-RP mapping info from these routers**
      - **If not correct, use debug commands to see what's wrong**
    - **Make sure all MA's have consistent Group-to-RP information**
      - **If not, watch for TTL Scoping problems**
  - **Then on other routers**
    - **If info doesn't match MA, there is a problem distributing the information**
    - **Use show and debug commands to find where the inconsistency is**

D

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Debugging Auto-RP Operation

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- **Insure Auto-RP group state is correct**
  - **Should normally be in Dense mode**
  - **Watch out for mixed DM and SM conditions**
    - **Can occur when Static RP's are also defined**
      - **Always 'deny' Auto-RP groups on Static RP configurations**
    - **Use 'Accept-RP' filters on all routers as insurance**
  - **Watch out for DM problems in NBMA networks**

D

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New Flags

- **Bi-Dir**
- **SSM**
- **MVPN**
- **Hardware**

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Update

- **SSM related flags**
  - **U = URD**
  - **‘s’ = SSM**
  - **I = IGMP report**

```
Router# show ip mroute 232.6.6.6


IP Multicast Routing Table

Flags:D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C -Connected, L
- Local, P - Pruned, R - RP-bit set, F - Register flag, T - SPT-bit set, J -
Join SPT, M - MSDP created entry, X - Proxy Join Timer Running, A -
Advertised via MSDP, U - URD, I - Received Source Specific Host Report

Outgoing interface flags:H - Hardware switched

Timers:Uptime/Expires
```


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Update

***,G is merely a place holder it is always pruned**

```
(*, 232.6.6.6), 00:01:20/00:02:59, RP 0.0.0.0, flags:sSJP
  Incoming interface:Null, RPF nbr 0.0.0.0
  Outgoing interface list:Null

(2.2.2.2, 232.6.6.6), 00:01:20/00:02:59, flags:CTI
  Incoming interface:Ethernet3/3, RPF nbr 0.0.0.0
  Outgoing interface list:
    Ethernet3/1, Forward/Sparse-Dense, 00:00:36/00:02:35
```


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New Flags

- Bi-Dir
- SSM
- MVPN
- Hardware

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Update

- **Bi-dir flag**
  - **B = Bi-dir**

```
PE1#sh ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry,
       X - Proxy Join Timer Running, A - Advertised via MSDP, U - URD,
       I - Received Source Specific Host Report, Z - Multicast Tunnel
       Y - Joined MDT-data group, y - Sending to MDT-data group
Outgoing interface flags: H - Hardware switched
Timers: Uptime/Expires
Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 239.233.0.1), 5d00h/00:00:00, RP 172.16.0.21, flags: BCZ
  Incoming interface: Ethernet0/1, RPF nbr 172.16.203.1
  Outgoing interface list:
    MVRF leuven, Forward/Sparse, 5d00h/00:00:00
```

Bi-dir groups are always *,G

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New Flags

- Bi-Dir
- SSM
- **MVPN**
- Hardware

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Update

- **Multicast Virtual Private Network flags**
  - **Z = Multicast Tunnel Interface**
  - **Y = Receiving Data MDT**
  - **Y = Source of Data MDT**

```
PE1#sh ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry,
       X - Proxy Join Timer Running, A - Advertised via MSDP, U - URD,
       I - Received Source Specific Host Report, Z - Multicast Tunnel
       Y - Joined MDT-data group, y - Sending to MDT-data group
Outgoing interface flags: H - Hardware switched
Timers: Uptime/Expires
Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 239.233.0.1), 5d00h/00:00:00, RP 172.16.0.21, flags: BCZ
  Incoming interface: Ethernet0/1, RPF nbr 172.16.203.1
  Outgoing interface list:
    MVRF leuven, Forward/Sparse, 5d00h/00:00:00
```


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New Flags

- Bi-Dir
- SSM
- MVPN
- Hardware

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Update

- **Hardware flag**
  - **H = MMLS switched**

```
ecsj-6506-d2#sh ip mroute vlan 7
 IP Multicast Routing Table
 Flags: D - Dense, S - Sparse, s - SSM Group, C - Connected, L - Local,
        P - Pruned, R - RP-bit set, F - Register flag, T - SPT-bit set,
        J - Join SPT, M - MSDP created entry, X - Proxy Join Timer Running
        A - Advertised via MSDP, U - URD, I - Received Source Specific Host
            Report
 Outgoing interface flags: H - Hardware switched
 Timers: Uptime/Expires
 Interface state: Interface, Next-Hop or VCD, State/Mode
 (*, 239.254.1.0), 17:15:23/00:02:54, RP 126.0.1.1, flags: SCF
    Incoming interface: GigabitEthernet2/1, RPF nbr 126.1.11.14, RPF-MFD
    Outgoing interface list:
      Vlan7, Forward/Sparse, 00:01:10/00:02:09, H
      Vlan2, Forward/Sparse, 16:30:01/00:02:02, H
```

H flag is always associated with out going interface

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Review

- PIM SM operation
- In-depth understanding of State information
  - Shared Tree
  - Source Tree
  - Join
  - Prune
- Tools/Methodology available
  - Debug
  - Show
  - MRM etc

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Test Yourself

PIM SM operation

- (*,G) is created when?

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Test Yourself

PIM SM operation

- (*,G) is created when?
  - Receipt of a (*,G) Join or IGMP Report
  - Automatically if (S,G) must be created

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Review

PIM SM operation

- **Interfaces in OIL removed**

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Review

PIM SM operation

- Interfaces in OIL removed
  - By receipt of Prune message
    - Interfaces removed from (*,G) are removed from all (S,G)'s
  - Interface Expire timer counts down to zero
    - Timer reset (to 3 min.) by receipt of periodic Join
      or
    - By IGMP membership report

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Review

PIM SM operation

- **R = RP bit**

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Review

PIM SM operation

- R = RP bit
  - (S, G) entries only
  - Set by (S,G)RP-bit Prune
  - Indicates info is applicable to Shared Tree
  - Used to prune (S,G) traffic from Shared Tree
    - Initiated by Last-hop router after switch to SPT
  - Modifies (S,G) forwarding behavior
    - IIF = RPF toward RP (I.e. up the Shared Tree)
    - OIL = Pruned accordingly

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Review

- **PIM SM**
  - **DR -> RP**
  - **RP-> last hop *,G**
  - **RP joins SPT to Source S,G**
  - **Last hop joins SPT S,G**
  - **Joins/Prunes/S,G RP bit Prunes**

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Troubleshooting Resources – TAC Web

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- Technologies pages
  - ✓ Plan, design, implement, and operate information
- Troubleshoot section
  - ✓ Field Notices
  - ✓ Product documentation
  - ✓ TAC Technical Tips

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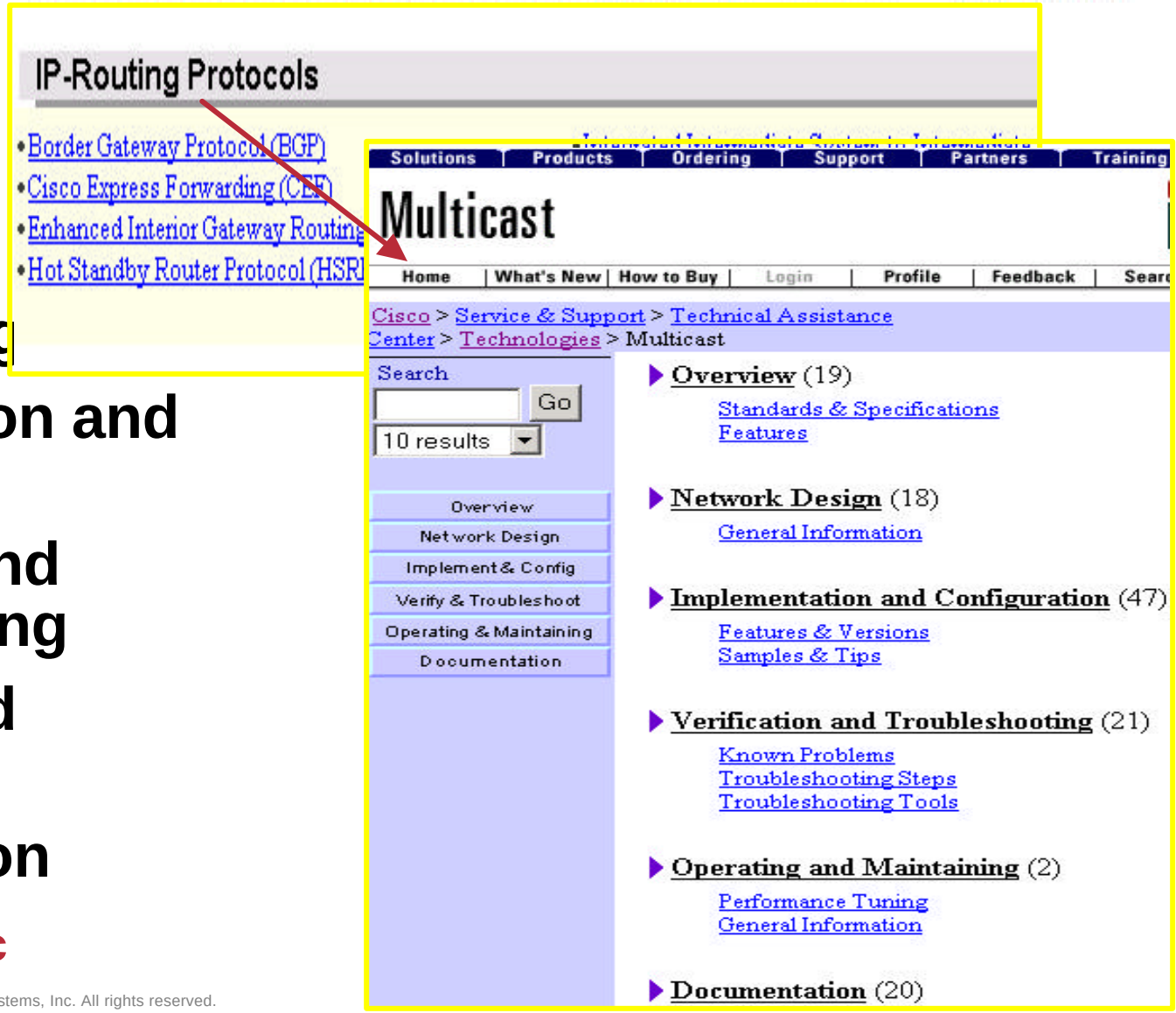
Troubleshooting Resources – TAC Web

- Task-based organization
- Overview
- Network desig
- Implementation and configuration
- Verification and troubleshooting
- Operating and maintaining
- Documentation



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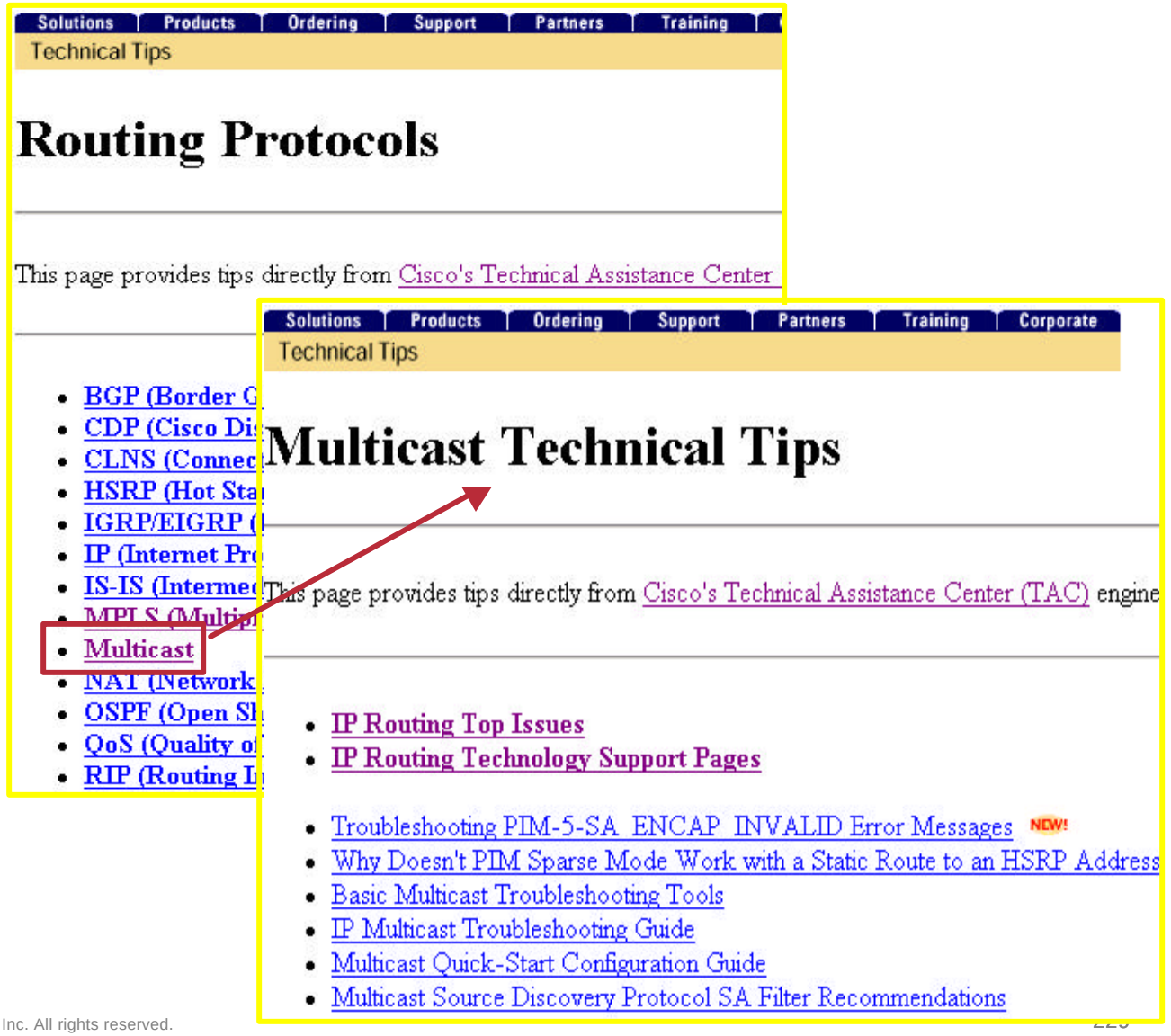
Troubleshooting Resources – TAC Web

Technical Tips by TAC Engineers

- Troubleshooting guides
- Troubleshooting tools
- Configuration guides

…and more



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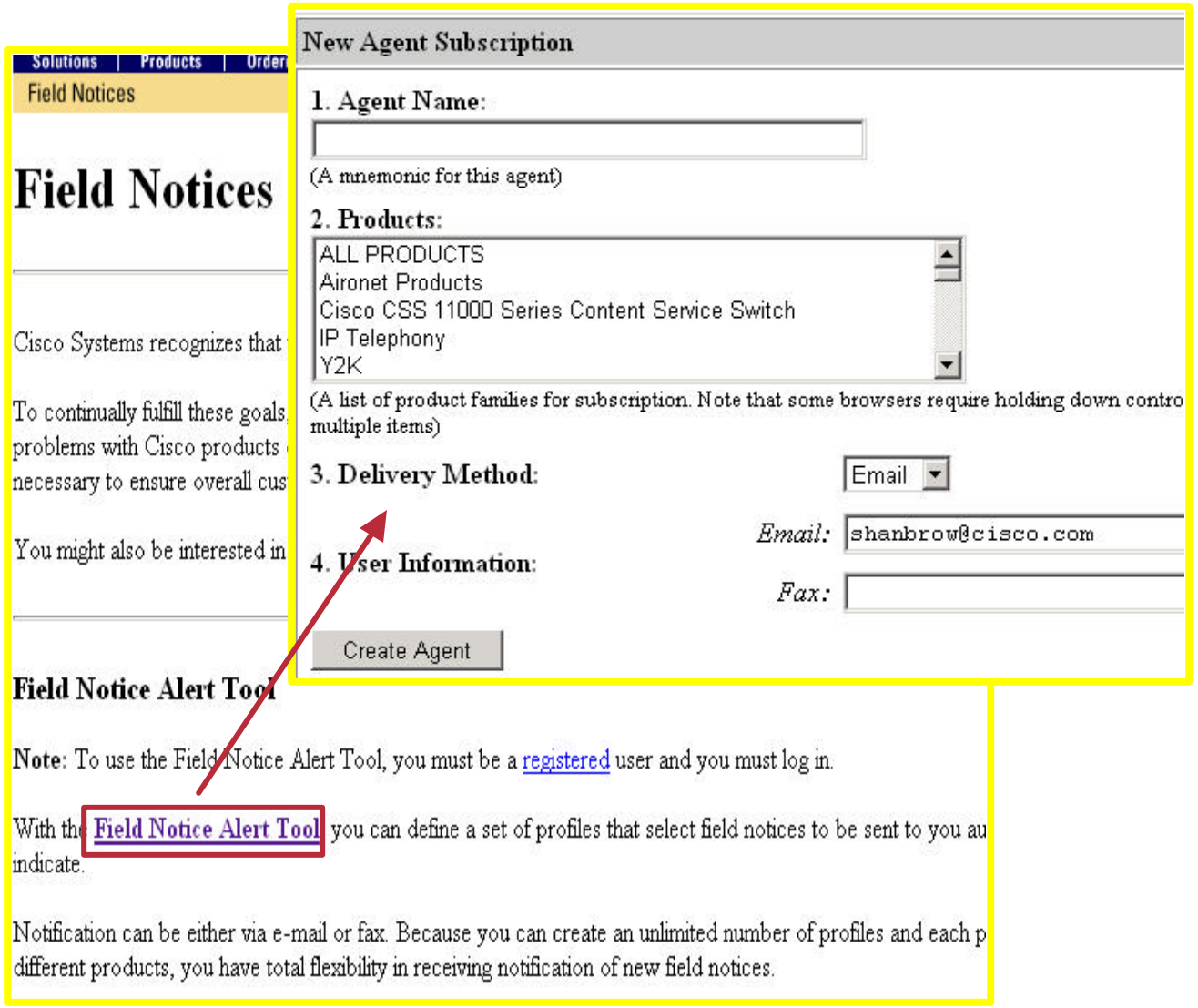
- **Notification of critical problems with Cisco products or technologies.**
- **Includes problem descriptions, safety or security issues, workarounds, and corrective actions**



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More Information

- White Papers
- Web and Mailers
- Cisco Press

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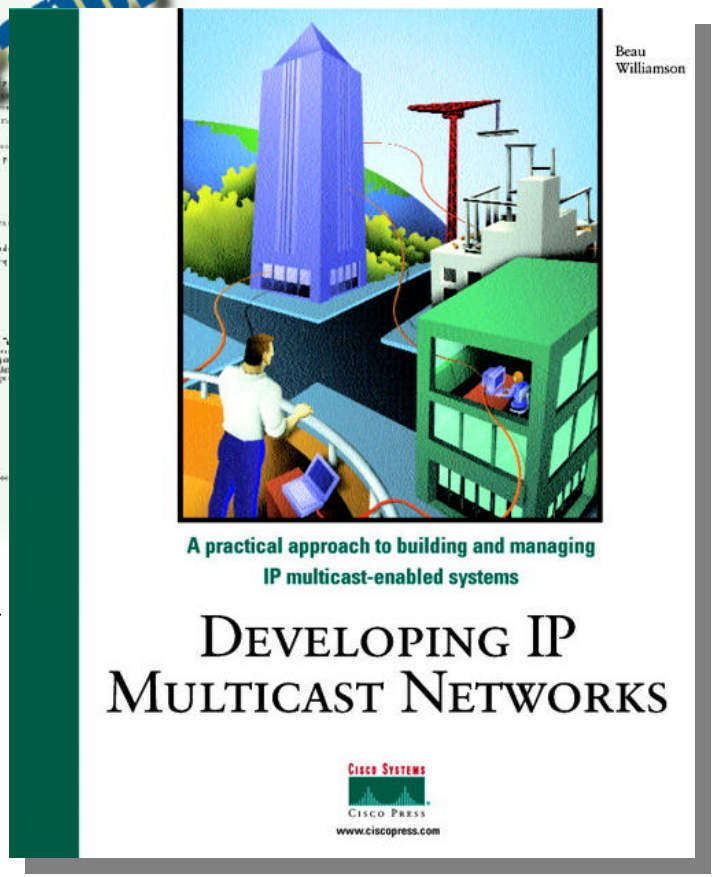

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