Introduction to IPv4 Multicast

SANOG 8 Tutorial

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Agenda

- Introduction
- Multicast addressing
- Group Membership Protocol
- PIM-SM / SSM
- MSDP
- MBGP
- Summary

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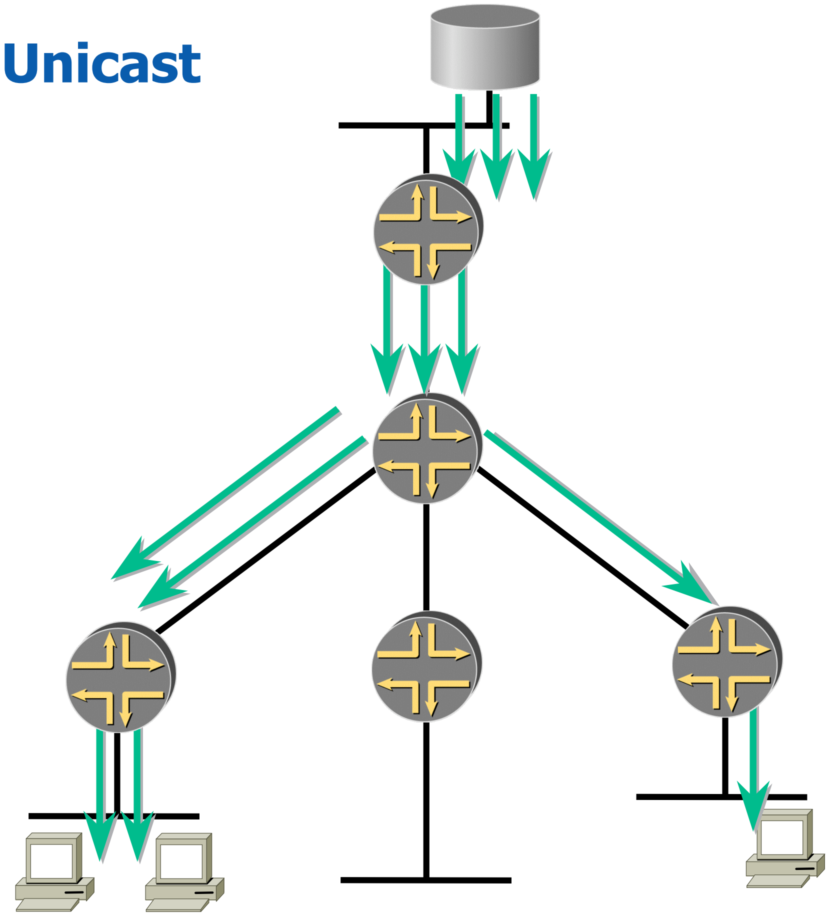
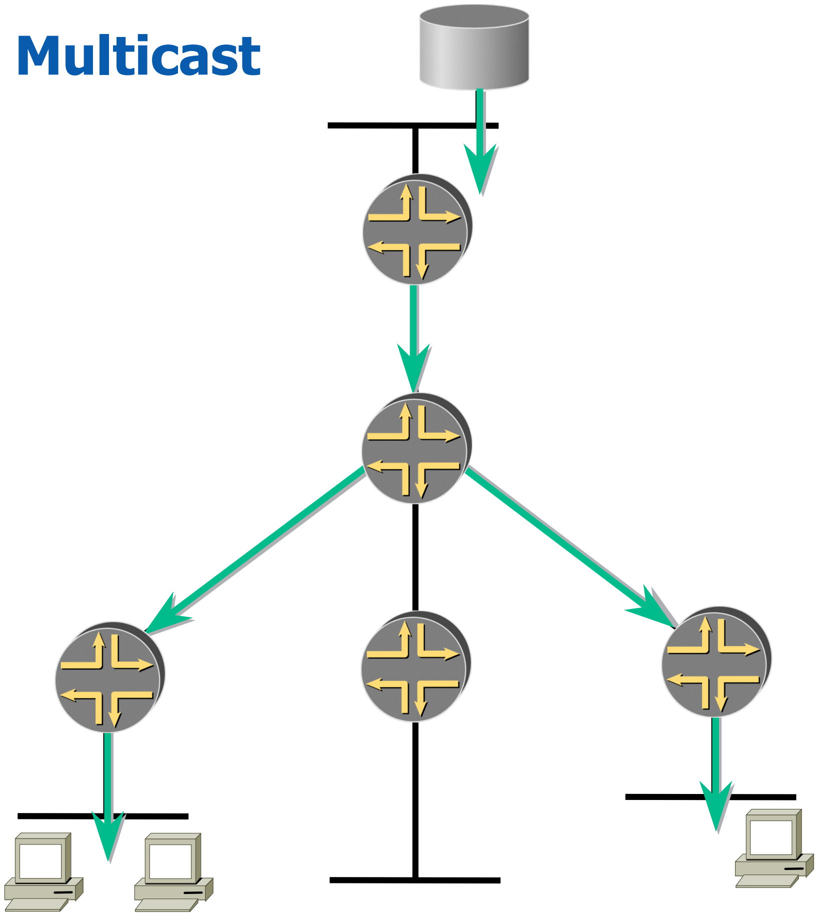
What is Multicasting?

Unicast



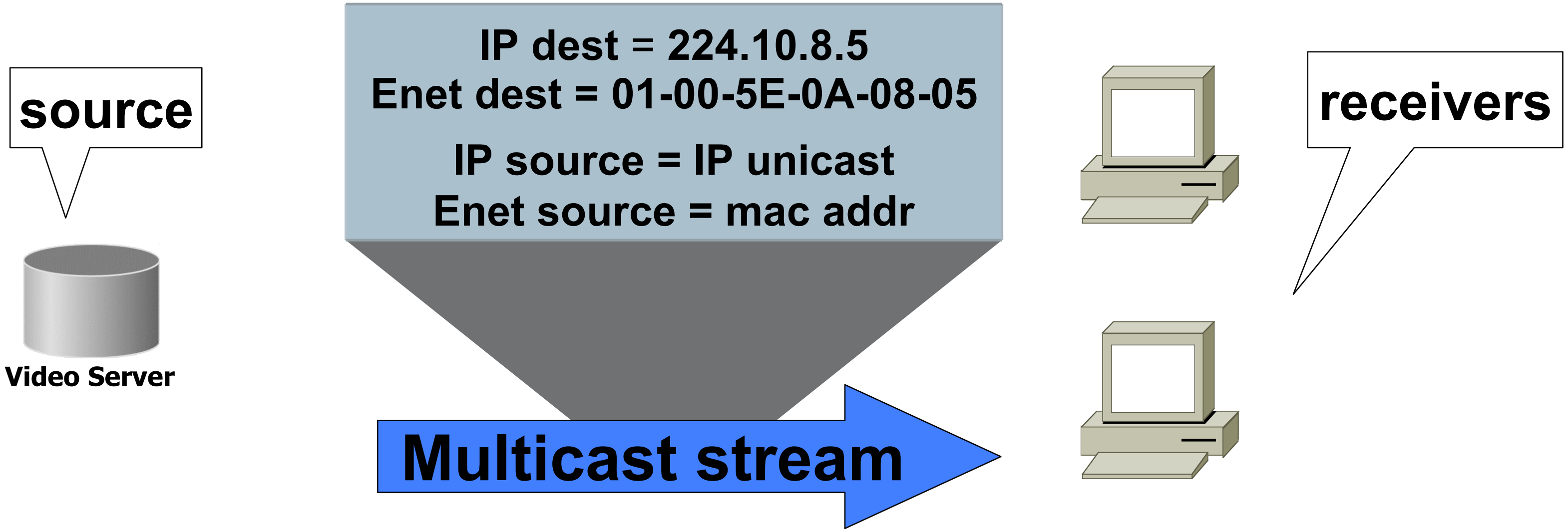
Multicast



Multicast Uses

- Any Applications with multiple receivers
  - 1-to-many or many-to-many
- Live Video distribution
- Collaborative groupware
- Periodic Data Delivery - "Push" technology
  - stock quotes, sports scores, magazines, newspapers, ads
- Reducing Network/Resource Overhead
  - more efficient to establish multicast tree rather then multiple point-to-point links
- Distributed Interactive Simulation (DIS)
  - wargames
  - virtual reality

Glossary of Terms: the basics



- Source = source of multicast stream
- Multicast stream = IP packet with multicast address as IP destination address. a.k.a. multicast group.
  - s,g (unicast source, group) reference
  - UDP packets (TTL > 1 for routed nets)
- Receiver = receiver (s) of multicast stream

IP Multicast Building Blocks

- The SENDERS send
  - Multicast Addressing - rfc1700
  - class D (224.0.0.0 - 239.255.255.255)
- The RECEIVERS inform the routers what they want to receive
  - Internet Group Management Protocol (IGMP) - rfc2236 -> version 2
- The routers make sure the STREAMS make it to the correct receiving nets.
  - Multicast Routing Protocols (PIM-SM/SSM)
  - RPF (reverse path forwarding) – against source address

Multicast Forwarding

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

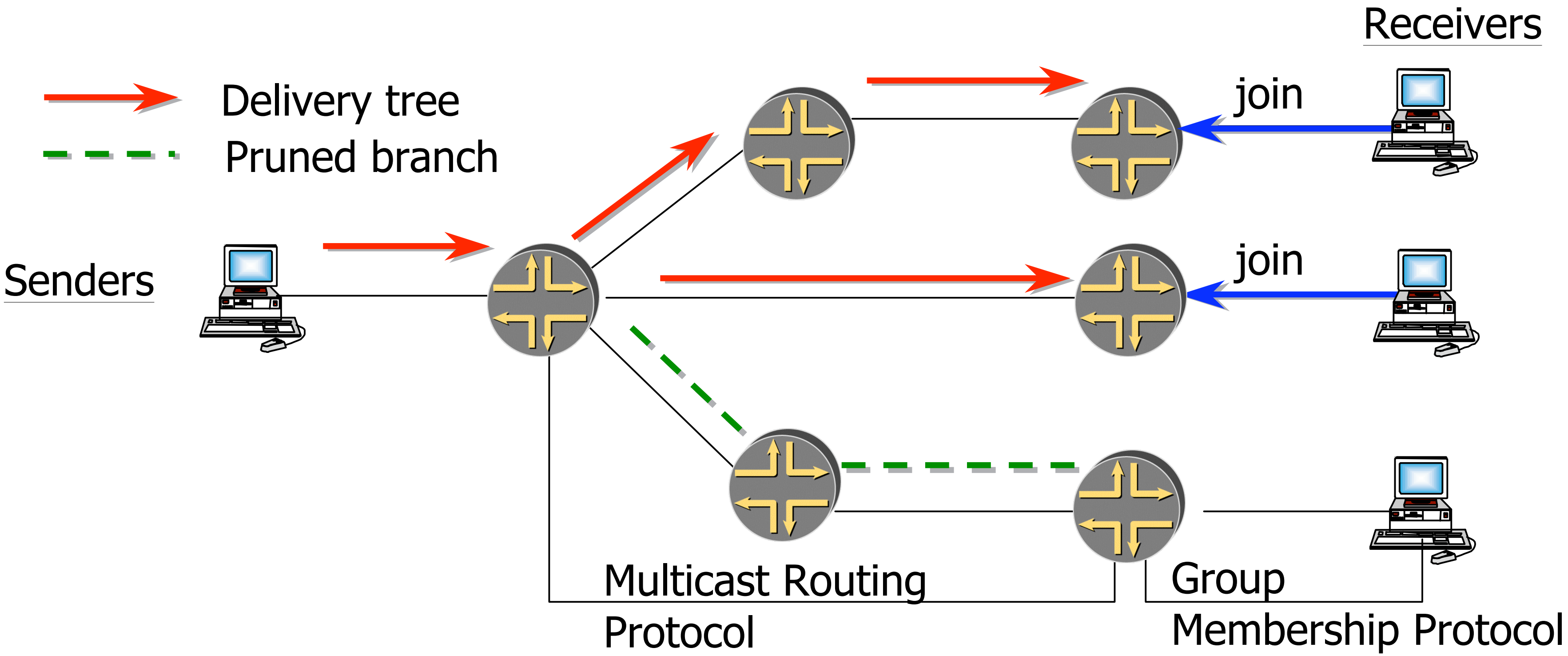
Multicast Forwarding: **Reverse Path Forwarding (RPF)**

- What is RPF?
  - A router forwards a multicast datagram only if received on the up stream interface to the source (i.e. it follows the distribution tree).
- The RPF Check
  - The source IP address of incoming multicast packets are checked against a unicast routing table.
  - If the datagram arrived on the interface specified in the routing table for the source address; then the RPF check succeeds.
  - Otherwise, the RPF Check fails.

Reverse Path Forwarding

- Multicast uses unicast routes to determine path back to source
- RPF checks ensure packets won’t loop
- Routes contain incoming interface
    - Packets matching are forwarded
    - Packets mis-matching are dropped

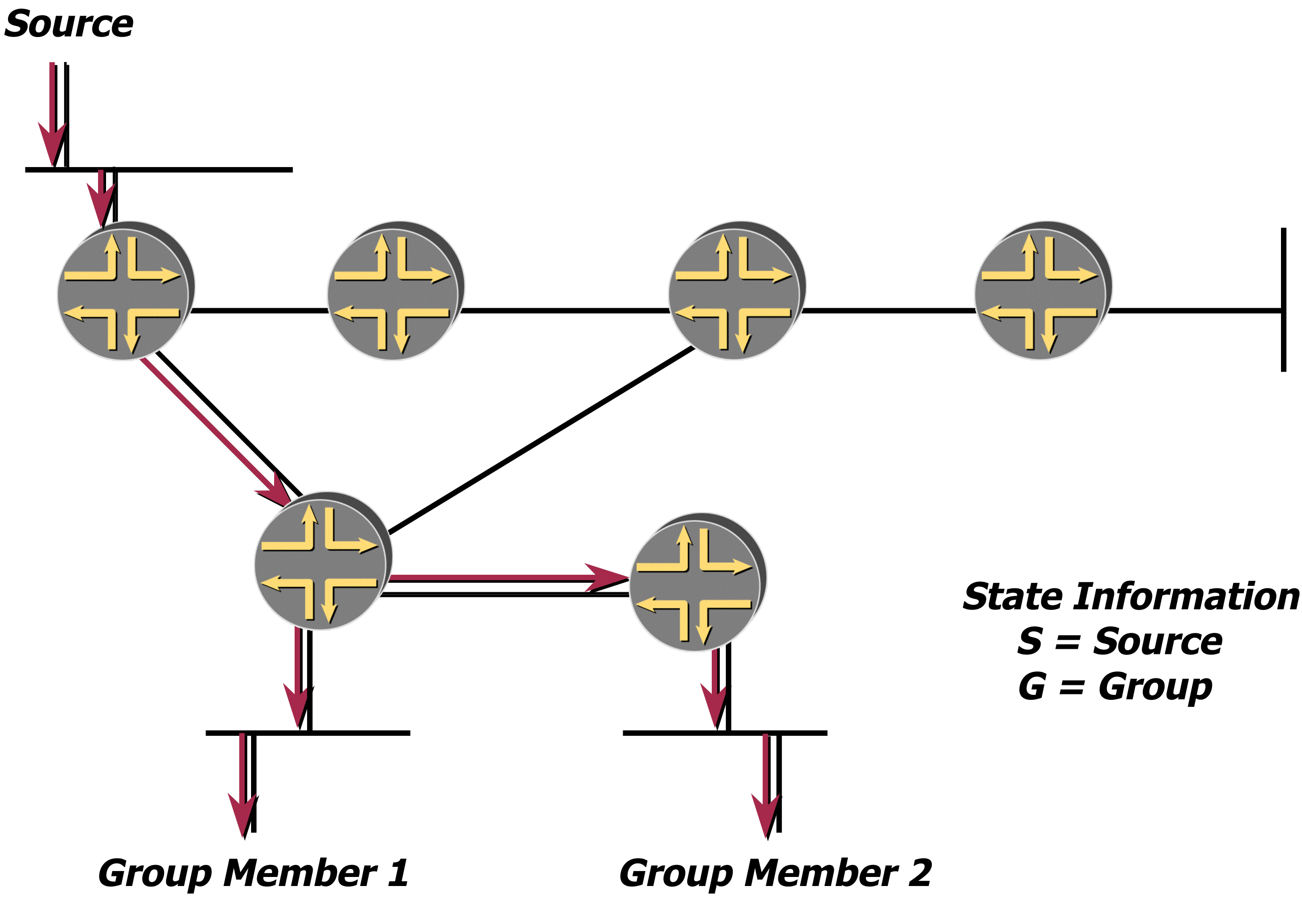
IP Multicast Components



- **Group Membership Protocol - enables hosts to dynamically join/leave multicast groups. Membership info is communicated to nearest router**
- **Multicast Routing Protocol - enables routers to build a delivery tree between the sender(s) and receivers of a multicast group**

Multicast Distribution Trees

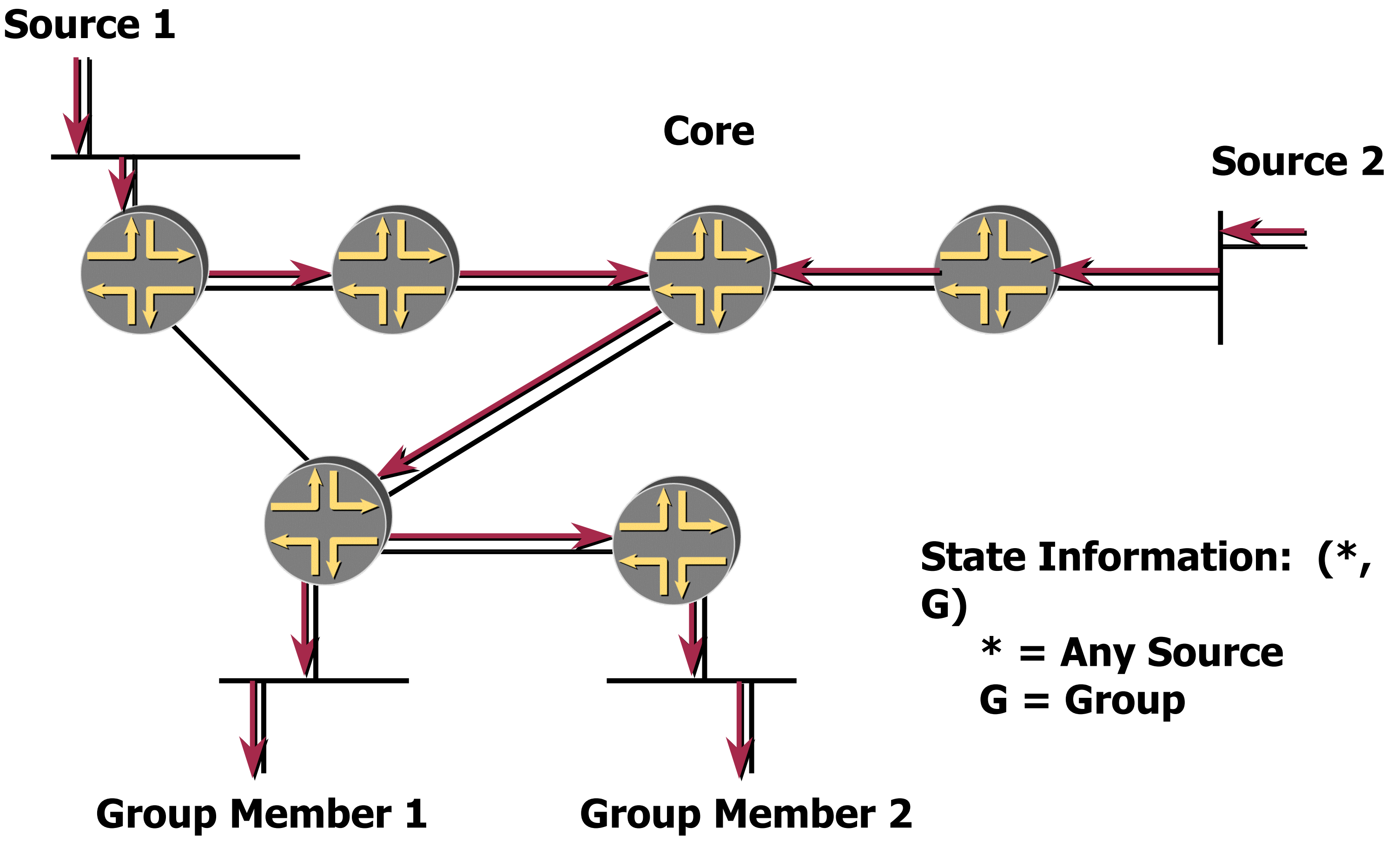
Shortest Path or Source Based Distribution Tree



State Information: (S, G)
S = Source
G = Group

Multicast Distribution Trees

Shared or Core Based Distribution Tree



State Information: (*, G)

*** = Any Source**

G = Group

Multicast Distribution Trees

- Source or Shortest Path trees
  - More resource intensive; requires more state→ n(S x G)
  - You get optimal paths from source to all receivers, minimizes delay
  - Best for one-to-many distribution
- Shared or Core Based trees
  - Uses less resources; less state →n(G)
  - You may get sub optimal paths from source to all receivers, depending on topology
  - The RP (core) itself and its location *may* affect performance
  - Best for many-to-many distribution
  - May be necessary for source discovery (PIM-SM)

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Multicast Addressing

- IP Multicast Group Addresses
  - 224.0.0.0–239.255.255.255
  - Class “D” Address Space
    - High order bits of 1st Octet = “1110”

Multicast Addressing

- Contolled by Internet Assigned Numbers Authority - IANA
  - http://www.iana.org/assignments/multicast-addresses
    - 224.0.0.0/24: link local multicast range
    - 224.2.0.0/16: SAP/SDP range
    - 232.0.0.0/8: SSM range
    - 233.0.0.0/8: AS-encoded statically assigned GLOP range
    - 239.0.0.0/8: administratively scoped multicast range

Multicast Addresses - Layer 2

- **RFC 1700 - ethernet**

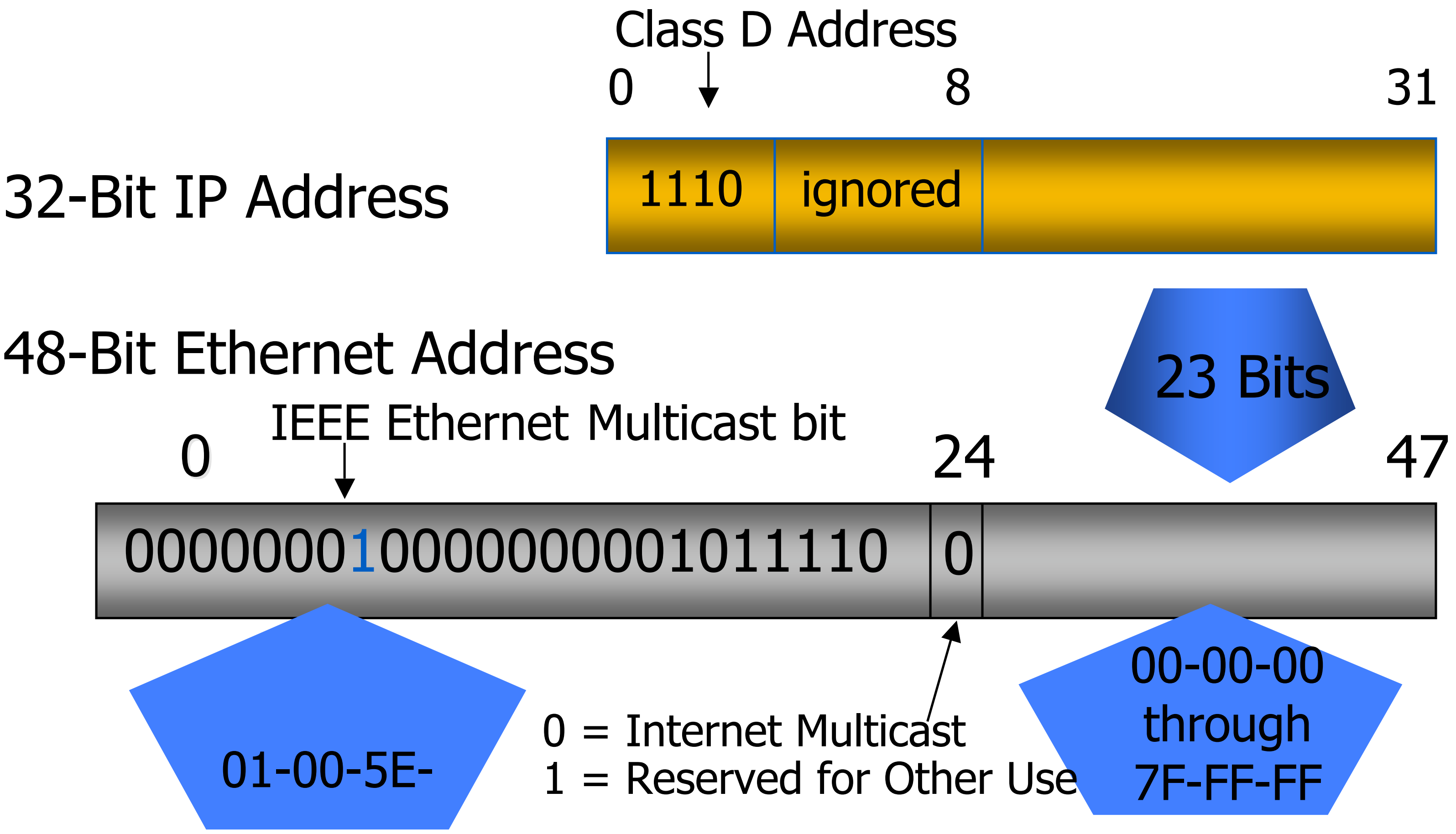
```
                                 224.       10.        8.        5        <--  Class D IP address
0000 0001   0000 0000   0101 1110   0xxx xxxx   xxxx xxxx   xxxx xxxx   <--  IANA's reserved block 01-00-5E
          |                                  |
          Multicast Bit                      0 = Internet Multicast
                                             1 = IANA reserved
0000 0001   0000 0000   0101 1110   0000 1010   0000 1000  0000 0101    <--  MAC address 01-00-5E-0A-08-05
```

224.10.8.5 multicast stream maps to 01-00-5E-0A-08-05 ethernet layer 2 address.

- **rfc 1469 TR**
- **rfc 1390 FDDI**
- **rfc 2226 & 2022 - ATM**
- **rfc 1209 SMDS (broadcast)**

Ethernet Multicast Addressing

- IANA Owns 01-00-5E Vendor Address Block
- Half of It Assigned for IP Multicast



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Internet Group Management Protocol (IGMP)

- How hosts tell routers about group membership
- Routers solicit group membership from directly connected hosts
- RFC 1112 specifies version 1 of IGMP
  - Supported on Windows 95
- RFC 2236 specifies version 2 of IGMP
  - Supported on latest service pack for Windows, newer Windows releases, and most UNIX systems
- IGMP version 3 is specified in RFC 3376
  - Provides source include-list capabilities
  - See www.ietf.org for more information

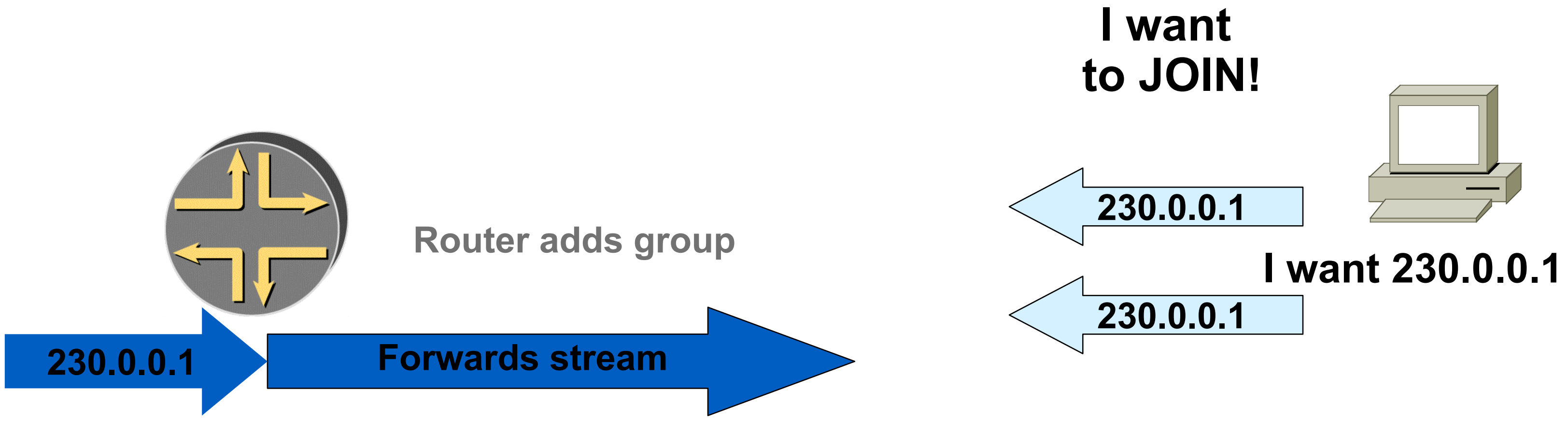
IGMP Details

- **Router:**
  - **sends Membership Query messages to All Hosts (224.0.0.1)**
    - query-interval = 125 secs default
  - **router with lowest IP address is Querier (rest non-queriers)**
  - **If lower-IP address query heard, backoff to non-querier state**
  - **listens for reports (whether querier or not) and adds group to membership list for that interface**
    - query-response-interval = 10 secs default

IGMP Details

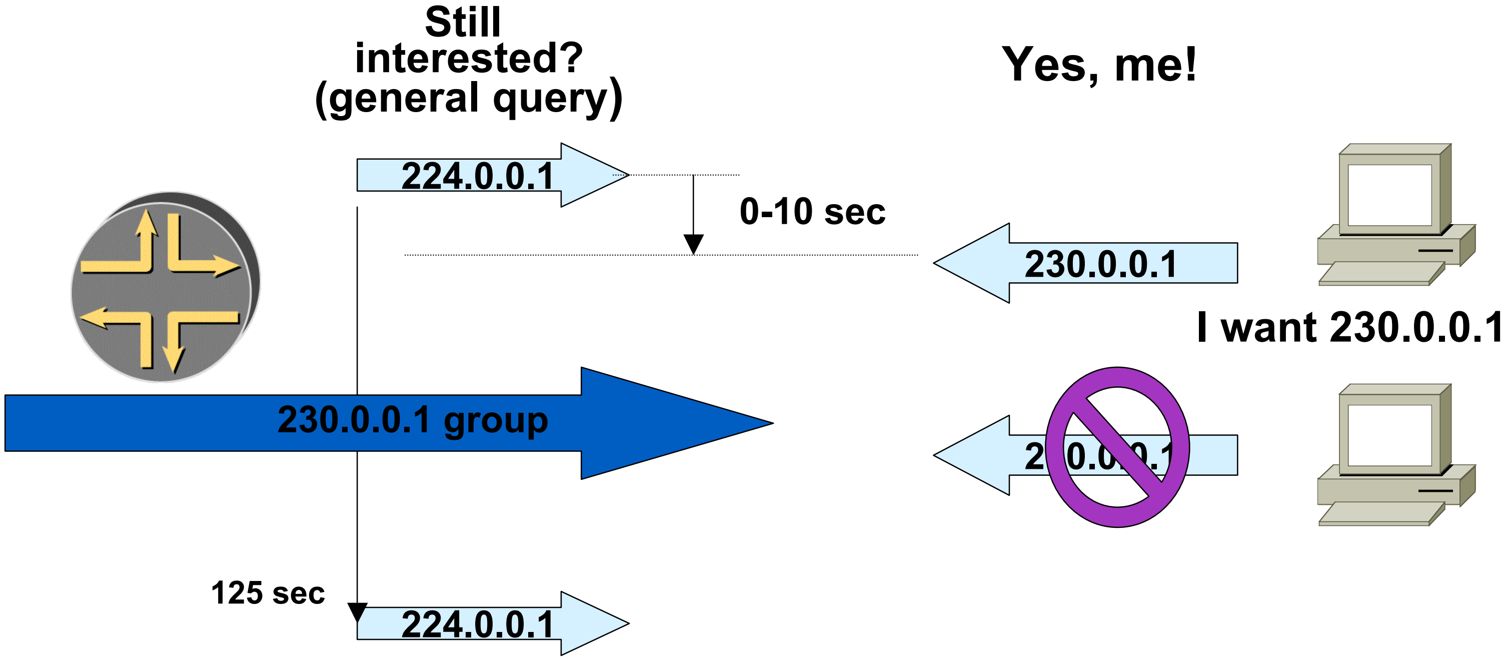
- Host:
  - sends Membership Report messages, if joined
    - waits 0-10 sec (def).
    - Hosts listen to other host reports
    - Only 1 host responds
  - Join messages (unsolicited Membership Report) to group address (e.g. 224.10.8.5)
  - Leave messages to All Routers (224.0.0.2)
  - IGMPv1/2 reports group membership ONLY – No sources

IGMP Protocol Flow - Join a Group



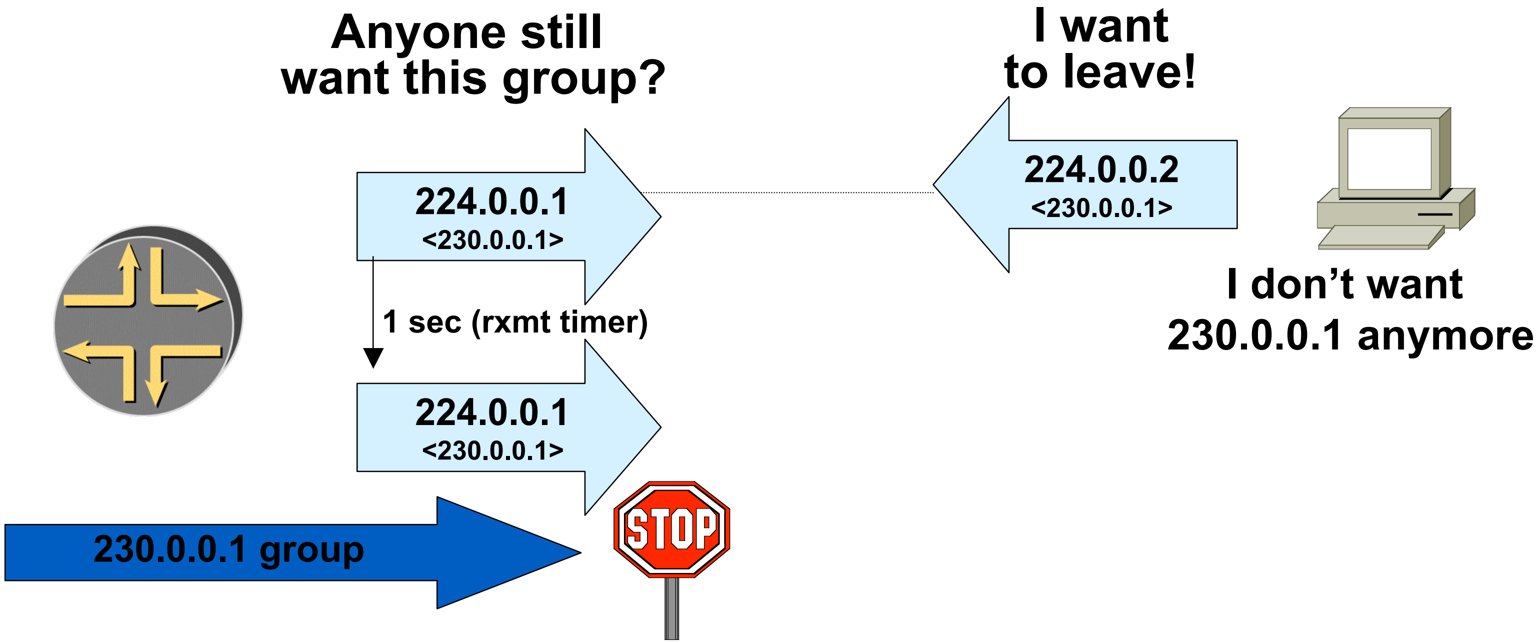
- Router triggers group membership request to PIM.
- Hosts can send unsolicited *join* membership messages – called reports in the RFC (usually more than 1)
- Or hosts can join by responding to periodic query from router

IGMP Protocol Flow - Querier



- Hosts respond to *query* to indicate (new or continued) interest in group(s)
    - only 1 host should respond per group
        - Hosts fall into idle-member state when same-group report heard.
- After 260 sec with no response, router times out group

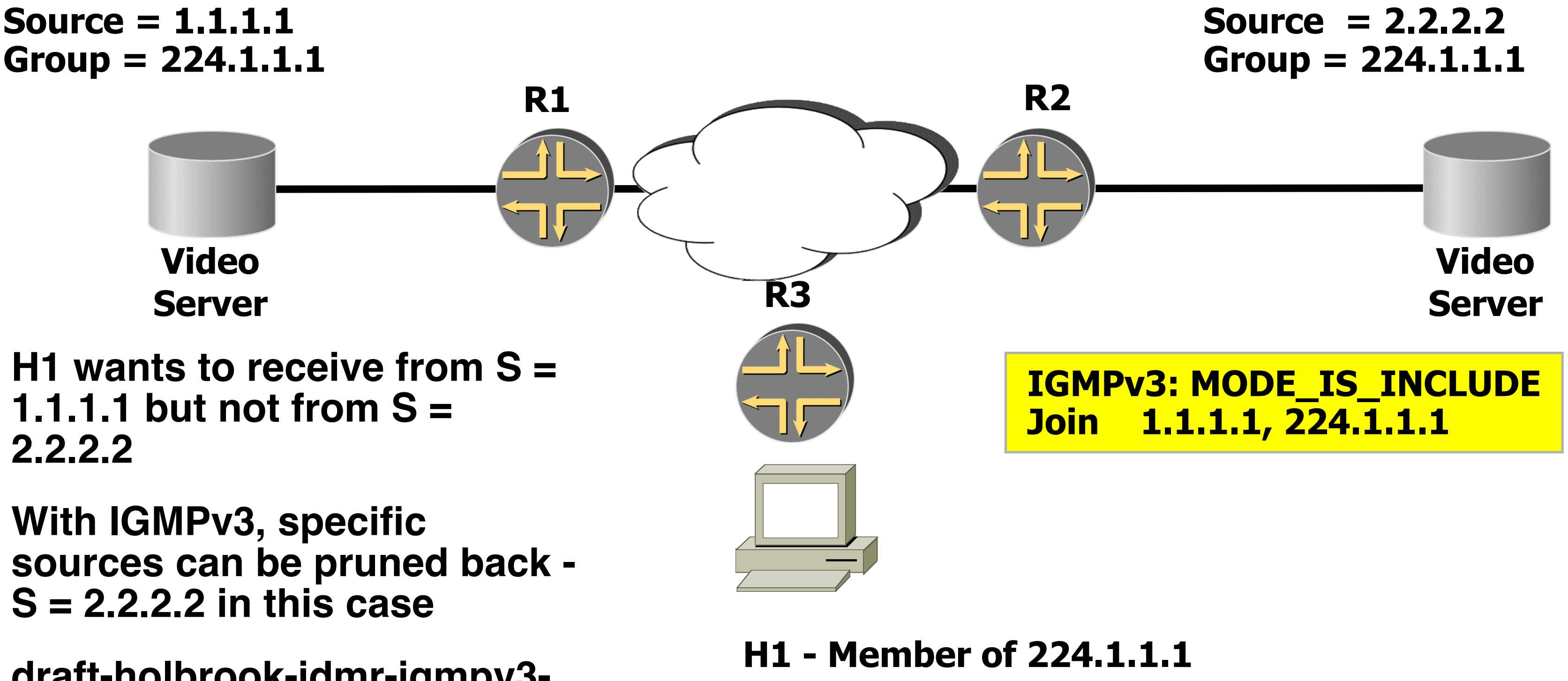
IGMP Protocol Flow - Leave a Group



- Hosts that support IGMP v2 send *leave* messages to all routers group indicating group they're leaving.
  - Router follows up with 2 *group-specific queries* messages
- IGMP v1 hosts leave by not responding to *queries* (260 sec timeout)

IGMPv3

Enables hosts to listen only to a specified subset of the hosts sending to the group



- H1 wants to receive from S = 1.1.1.1 but not from S = 2.2.2.2
- With IGMPv3, specific sources can be pruned back - S = 2.2.2.2 in this case
- draft-holbrook-idmr-igmpv3-ssm-01.txt

IGMP Details

- IGMP Version 2
  - Multicast router with lowest IP address is elected querier
    - IGMPv1 was mcast protocol specific and potentially conflicted.
  - Group-Specific Query message is defined. Enables router to transmit query to specific multicast address rather than to the "all-hosts" address of 224.0.0.1
  - Leave Group message is defined. Last host in group wishes to leave, it sends Leave Group message to the "all-routers" address of 224.0.0.2. Router then transmits Group-Specific query and if no reports come in, then the router removes that group from the list of group memberships for that interface
- IGMP Version 3
  - Group-Source Report message is defined. Enables hosts to specify which senders it can receive or not receive data from.
  - Group-Source Leave message is defined. Enables host to specify the specific IP addresses of a (source,group) that it wishes to leave.

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PIM-SM

- Protocol Independent Multicast - sparse mode
  - explicit join: assumes everyone does not want the data
  - uses unicast routing table for RPF checking
  - data and joins are forwarded to RP for initial rendezvous
  - all routers in a PIM domain must have RP mapping
  - when load exceeds threshold forwarding swaps to shortest path tree (default is first packet)
  - state increases (not everywhere) as number of sources and number of groups increase
  - source-tree state is refreshed when data is forwarded and with Join/Prune control messages

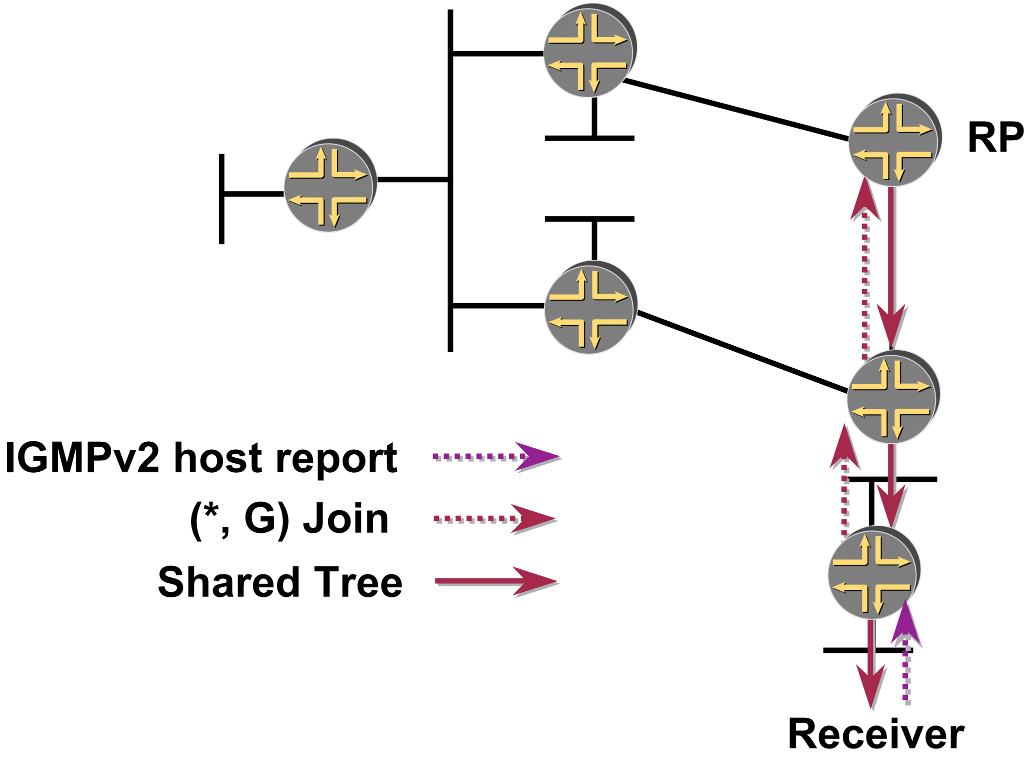
PIM-SM Operation
Designated Router (DR)

- Neighboring PIM-SM routers multicast periodic “Hello” messages to each other - default 30 secs.
  - Hello-interval tunable for faster convergence
- On receipt of a Hello message
  - a router stores the IP address and priority for that neighbor
- Router with highest IP address is selected as the DR, if the priorities match
- When DR goes down:
  - new one selected by scanning all neighbors on the interface and choosing the one with the highest IP address
- DR sends
  - “Join/Prune” messages toward the RP from receiver network
  - “Register” messages toward the RP from source network

PIM Sparse-Mode :RP

- Allows Source Trees or Shared Trees
- Rendezvous Point (RP)
  - Matches senders with receivers
  - Provides network source discovery
  - Root of shared tree
- Typically use shared tree to bootstrap source tree
- RP’s can be learned via:
  - Static configuration – RECOMMENDED
  - Auto-RP (V1 & V2)
  - Bootstrap Router (V2)

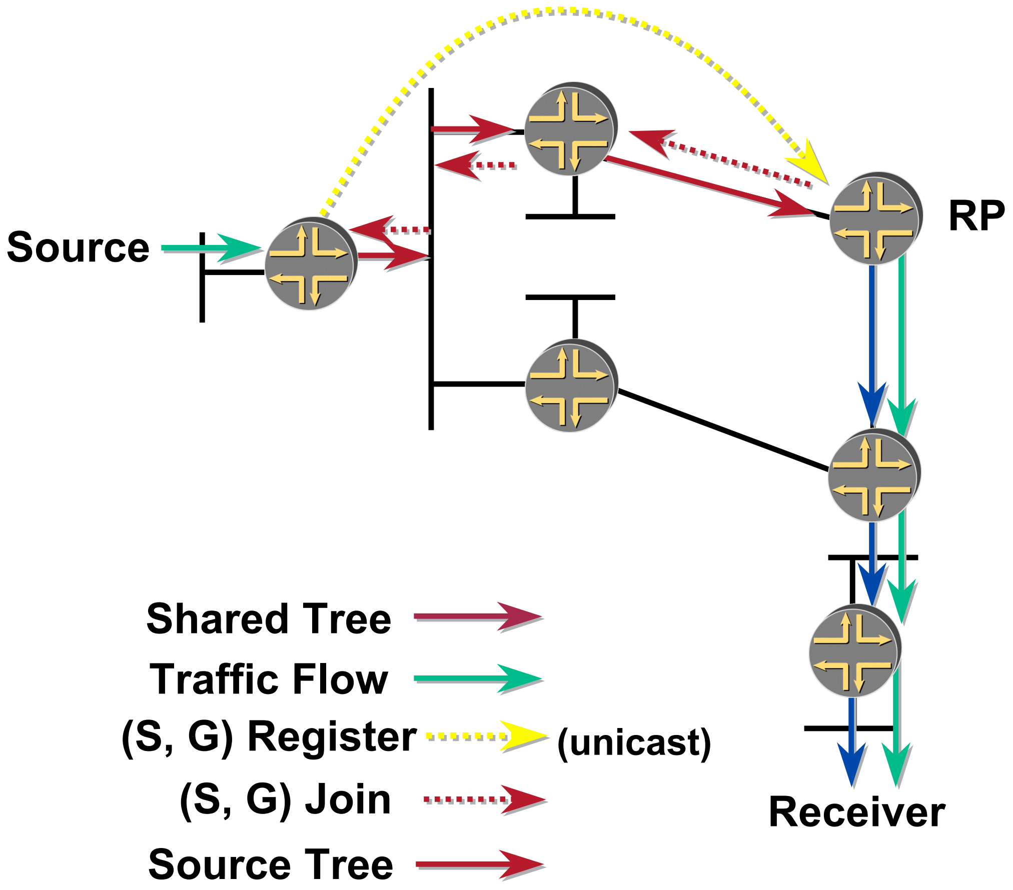
PIM-SM Shared Tree Join



Receiver announces desire to join group G with igmpv2 host report – (*,G).

(*, G) State created from the RP to the receiver.

PIM-SM Sender Registration



Source

RP

Receiver

Shared Tree

Traffic Flow

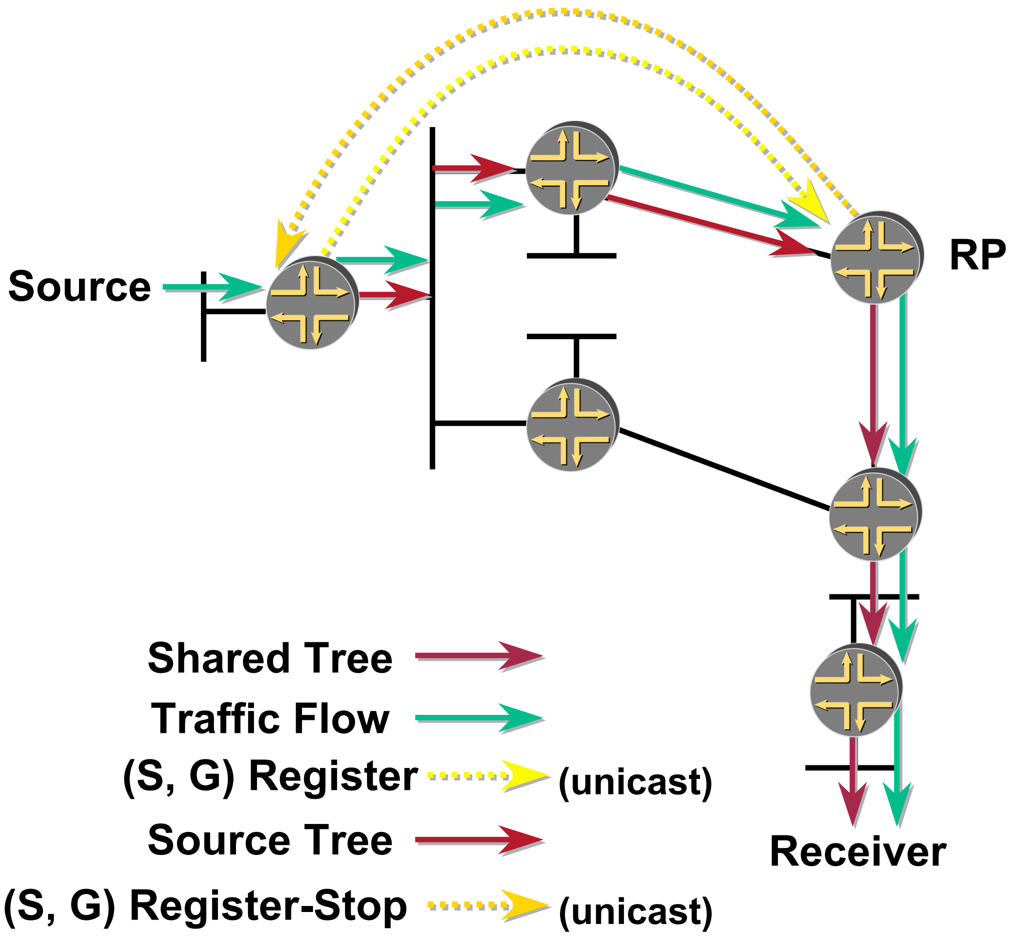
(S, G) Register (unicast)

(S, G) Join

Source Tree

(S, G) State created only along the Source Tree.

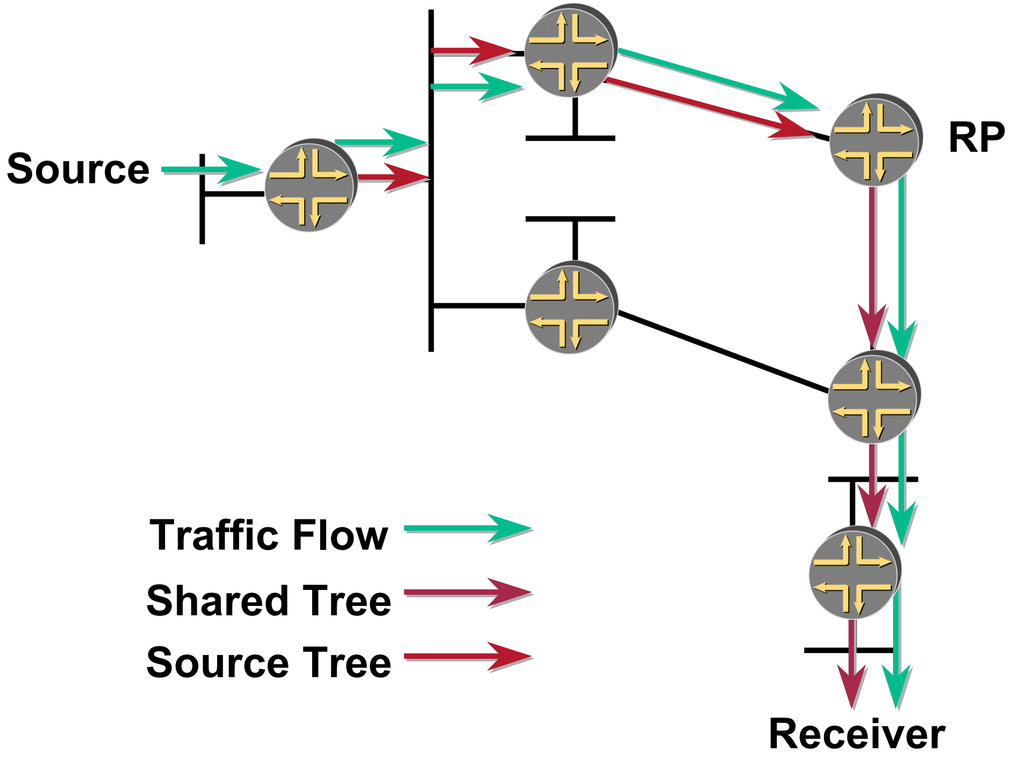
PIM-SM Sender Registration



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

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

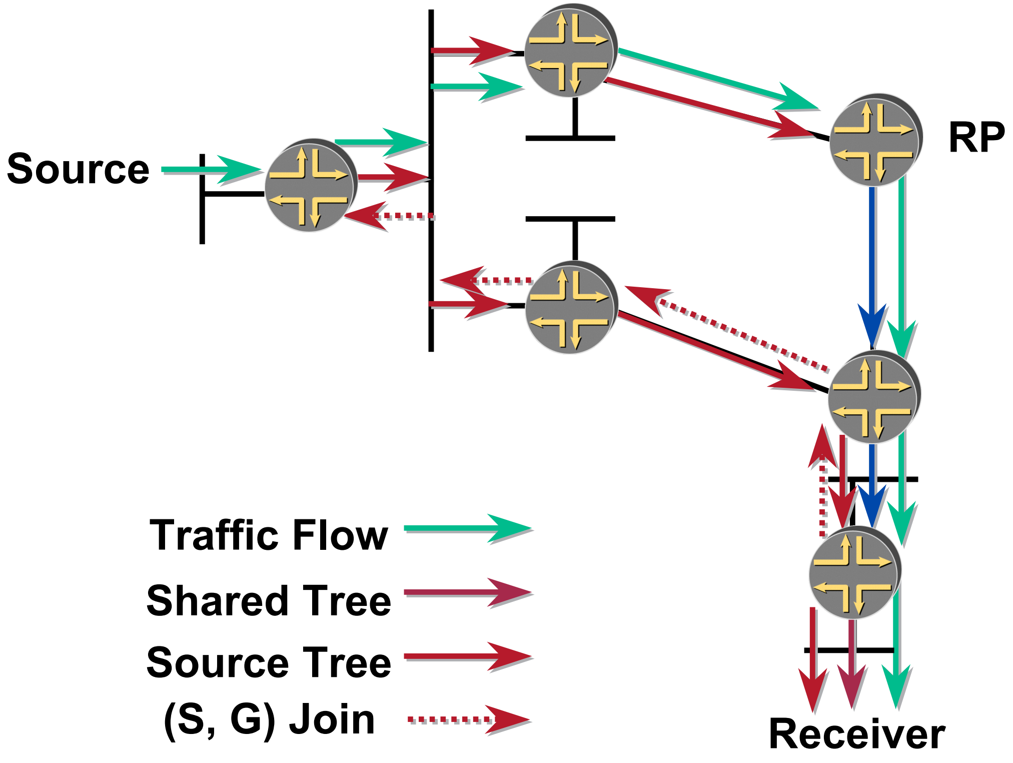
PIM-SM Sender Registration



Source traffic flows natively along SPT to RP.

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

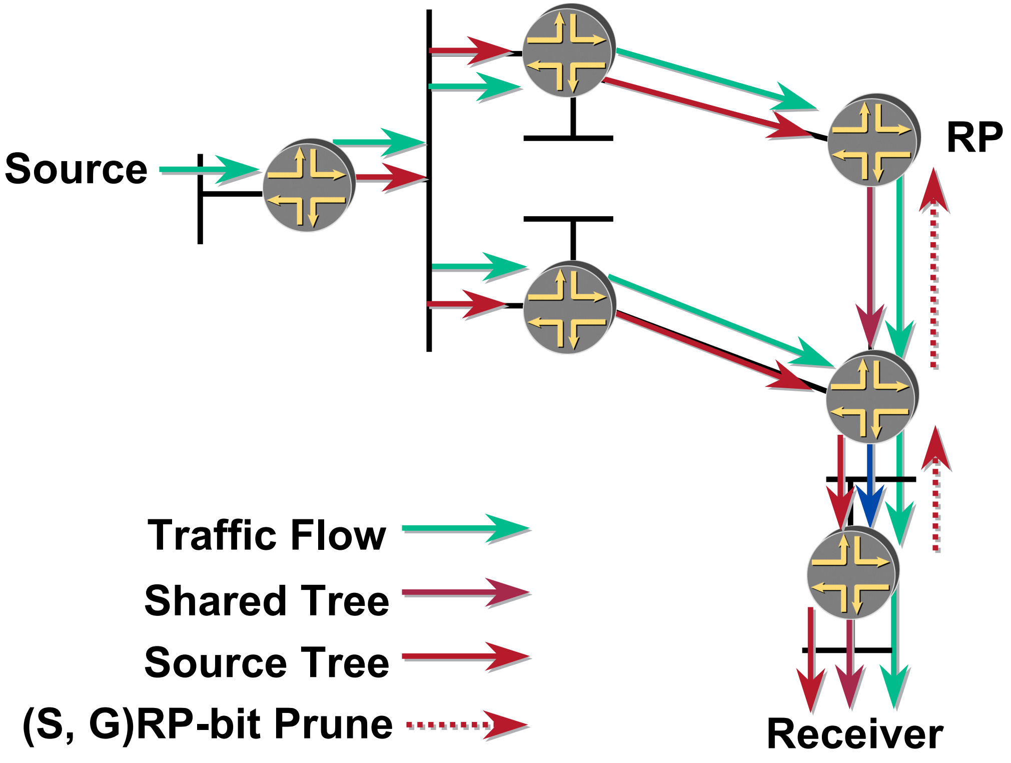
PIM-SM SPT Cutover



Last-hop router joins the Source Tree.

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

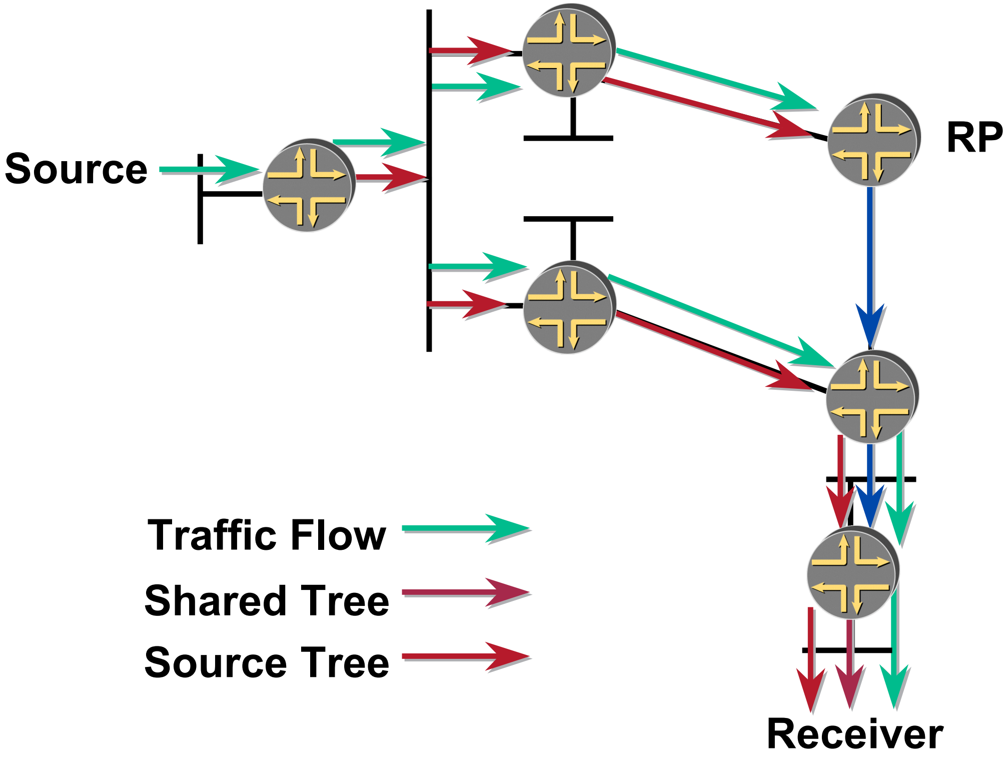
PIM-SM SPT Cutover



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

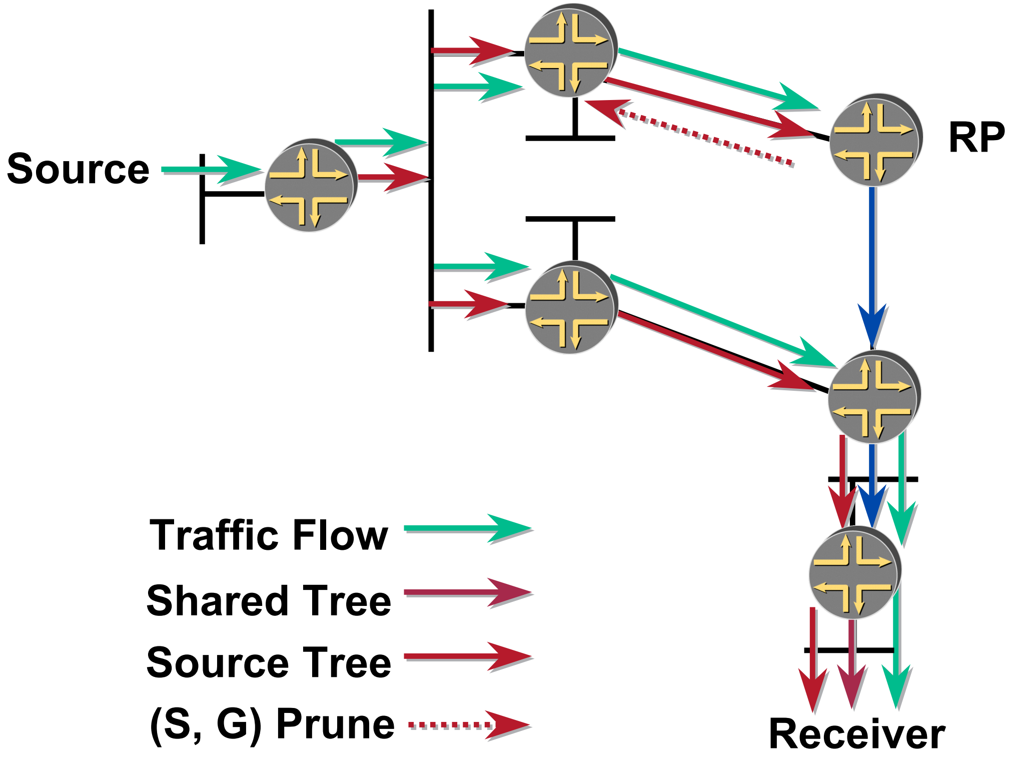
Additional (S, G) State is created along the Shared Tree to prune off (S, G) traffic.

PIM-SM SPT Cutover



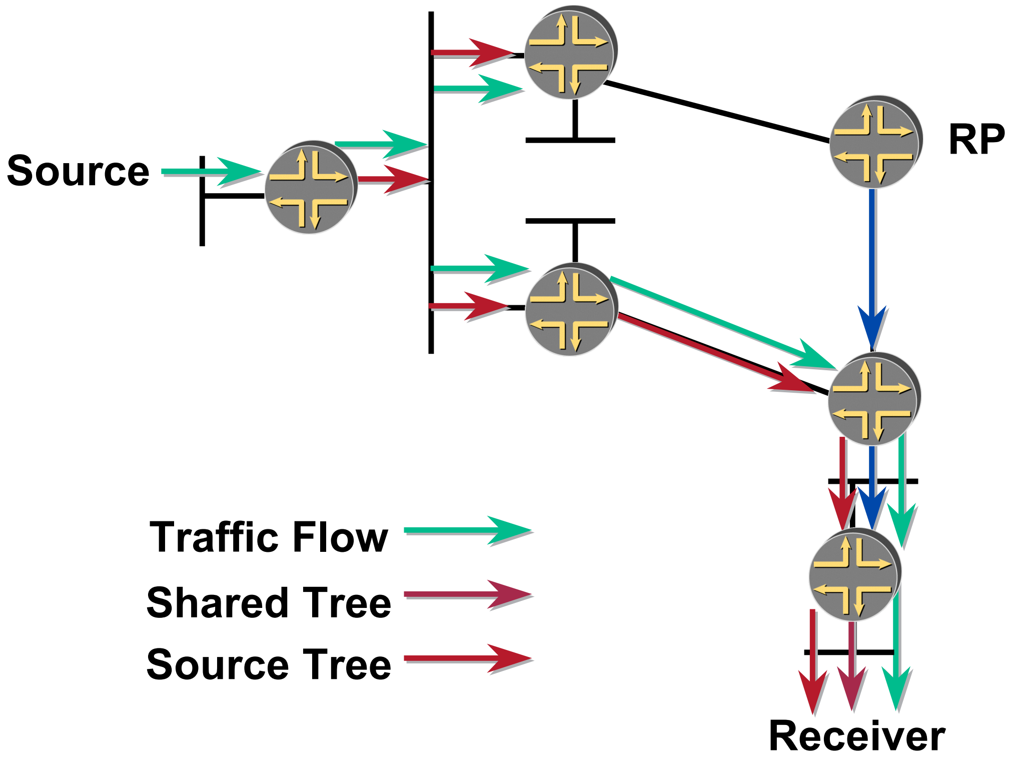
(S, G) Traffic flow is now pruned off of the Shared Tree and is flowing to the Receiver via the Source Tree.

PIM-SM SPT Cutover



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

PIM-SM SPT Cutover

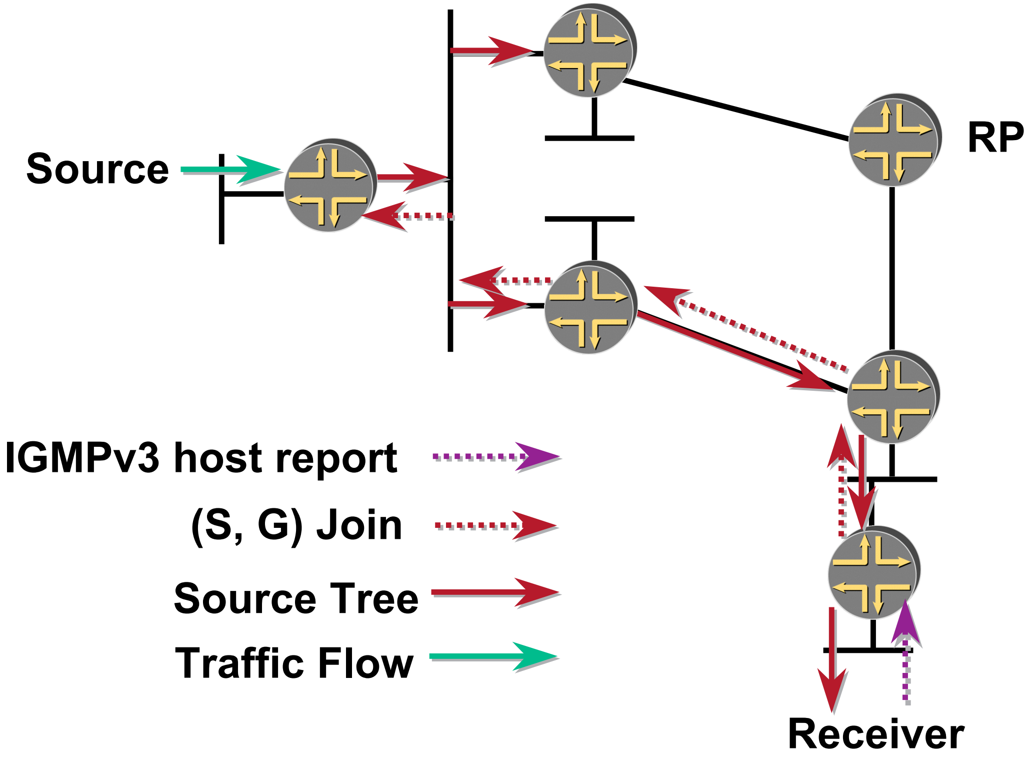


(S, G) Traffic flow is now only flowing to the Receiver via a single branch of the Source Tree.

PIM-SSM

- No shared trees
- No register packets
- No RP mapping required (no RP required!)
- No RP-to-RP source discovery (MSDP)
- Requires IGMP include-source list – IGMPv3
- Hard-coded behavior in 232/8
    - Configurable to expand range

PIM-SSM

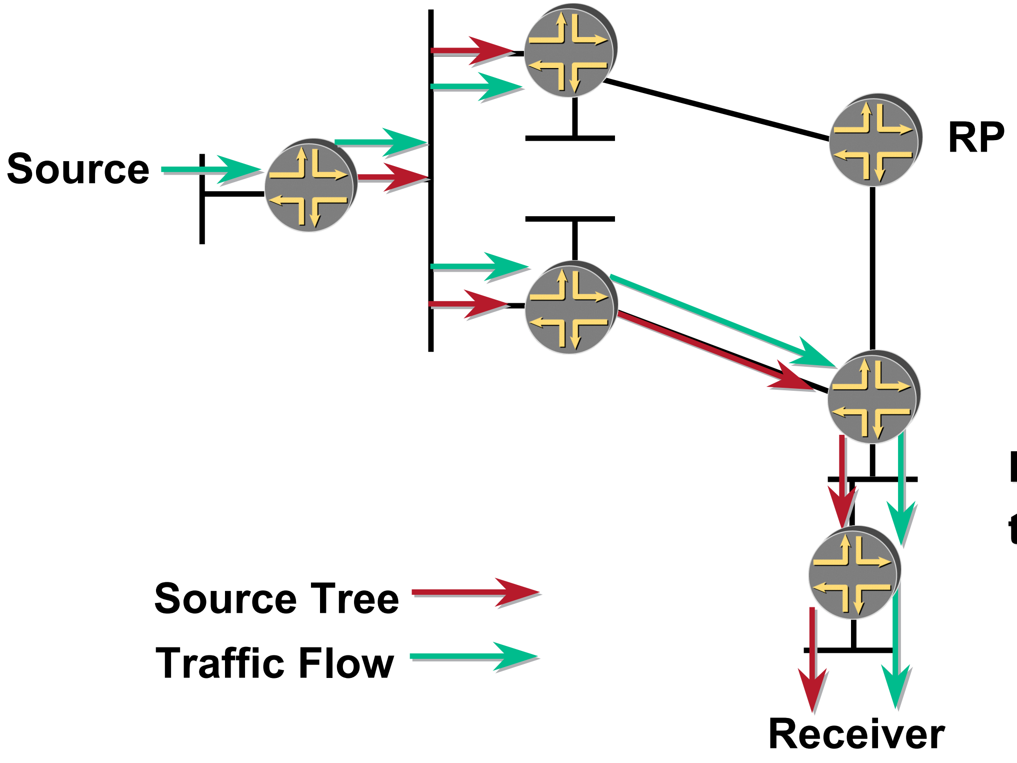


Receiver announces desire to join group G AND source S with an IGMPv3 include-list.

Last-hop router joins the Source Tree.

(S,G) state is built between the source and the receiver.

PIM-SSM



Data flows down the source tree to the receiver.

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MSDP

- Multicast Source Discovery Protocol
  - Allows each domain to control its own RP(s)
  - Interconnect RPs between domains with TCP connections to pass source active messages (SAs)
  - Can also be used within a domain to provide RP redundancy (Anycast-RP)
  - RPs send SA messages for internal sources to MSDP peers
  - SAs are Peer-RPF checked before accepting or forwarding
  - RPs learn about external sources via SA messages and may trigger (S,G)joins on behalf of local receivers
  - MSDP connections typically parallel MBGP connections

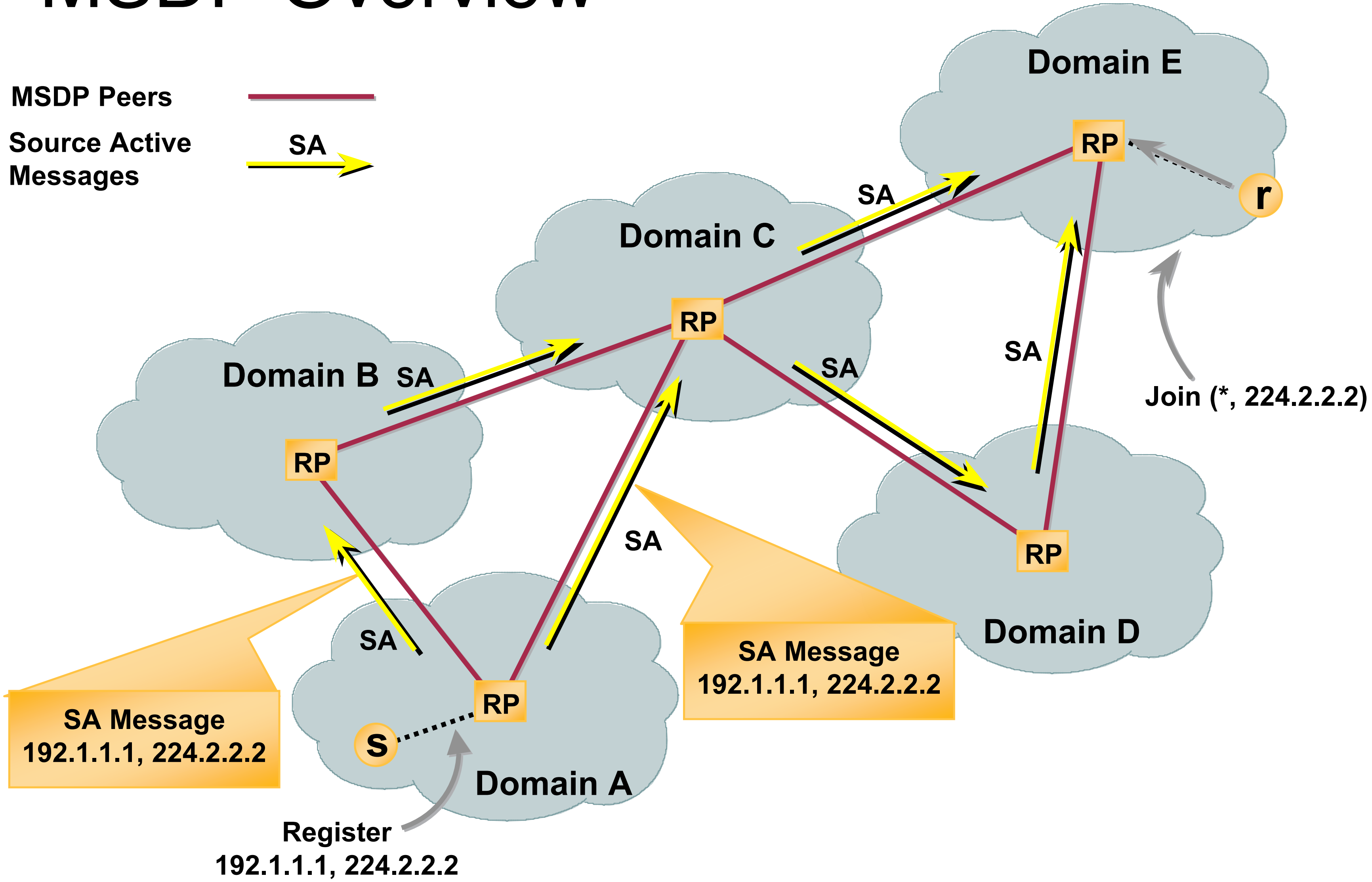
MSDP Operation

- MSDP peers (inter or intra domain)
  - (TCP port 639 w/ higher IP addr LISTENS)
- “FLOOD & join”
  - SA (source active) packets periodically sent to MSDP peers indicating:
    - source address of active streams
    - group address of active streams
    - IP address of RP originating the SA
    - only originate SA’s for your sources w/in your domain
- “flood & JOIN”
  - interested parties can send PIM JOIN’s towards source (creates inter-domain source trees)

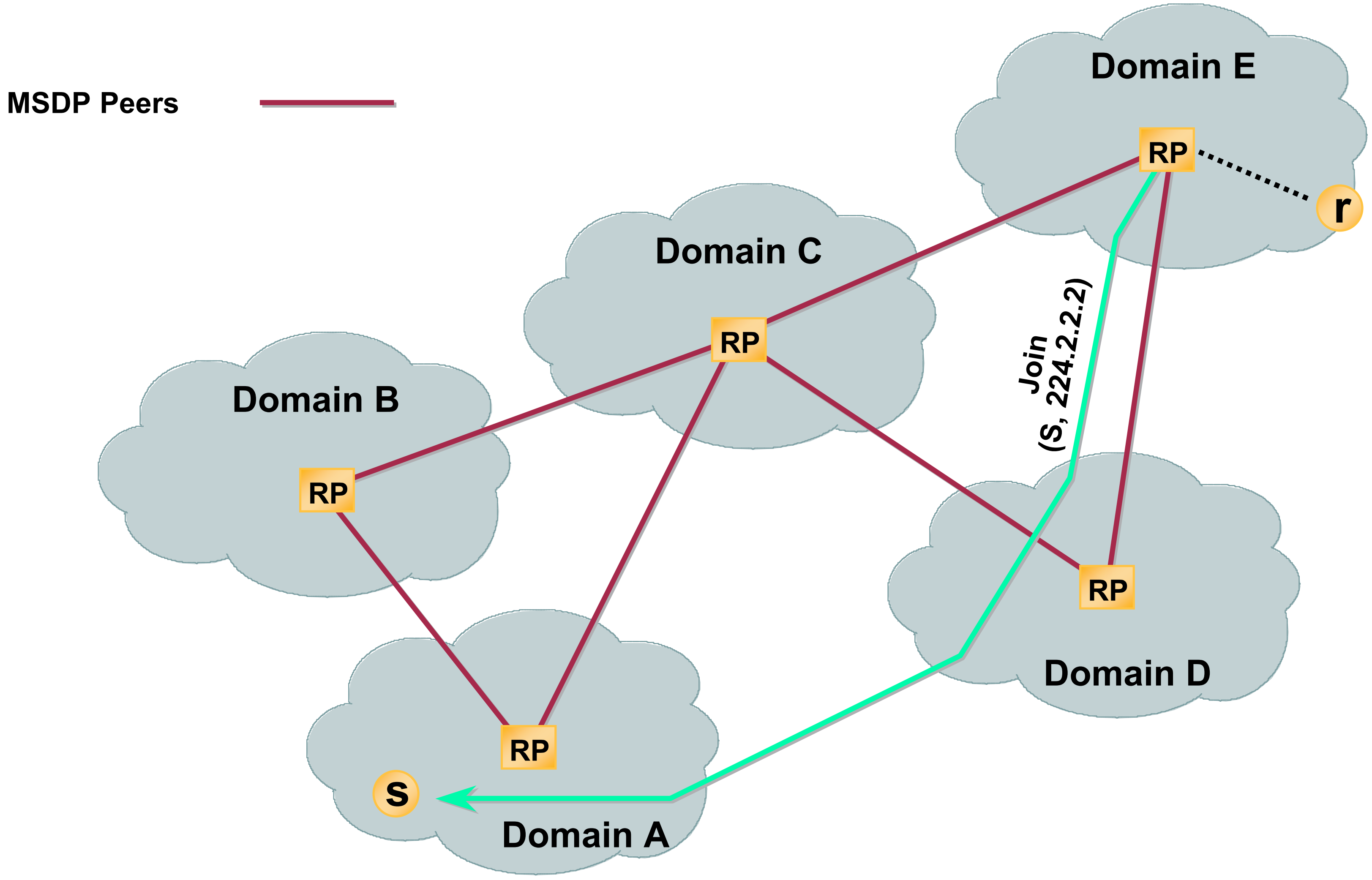
MSDP Source Active Msgs

- Initial SA message sent when source first registers
  - May optionally encapsulate first data packet
- Subsequent SA messages periodically refreshed every 60 seconds as long as source still active by originating RP
- Other MSDP peers don’t originate this SA but only forward it if received
- SA messages cached on router for new group members that may join
  - Reduced join latency
  - Prevent SA storm propagation

MSDP Overview



MSDP Overview



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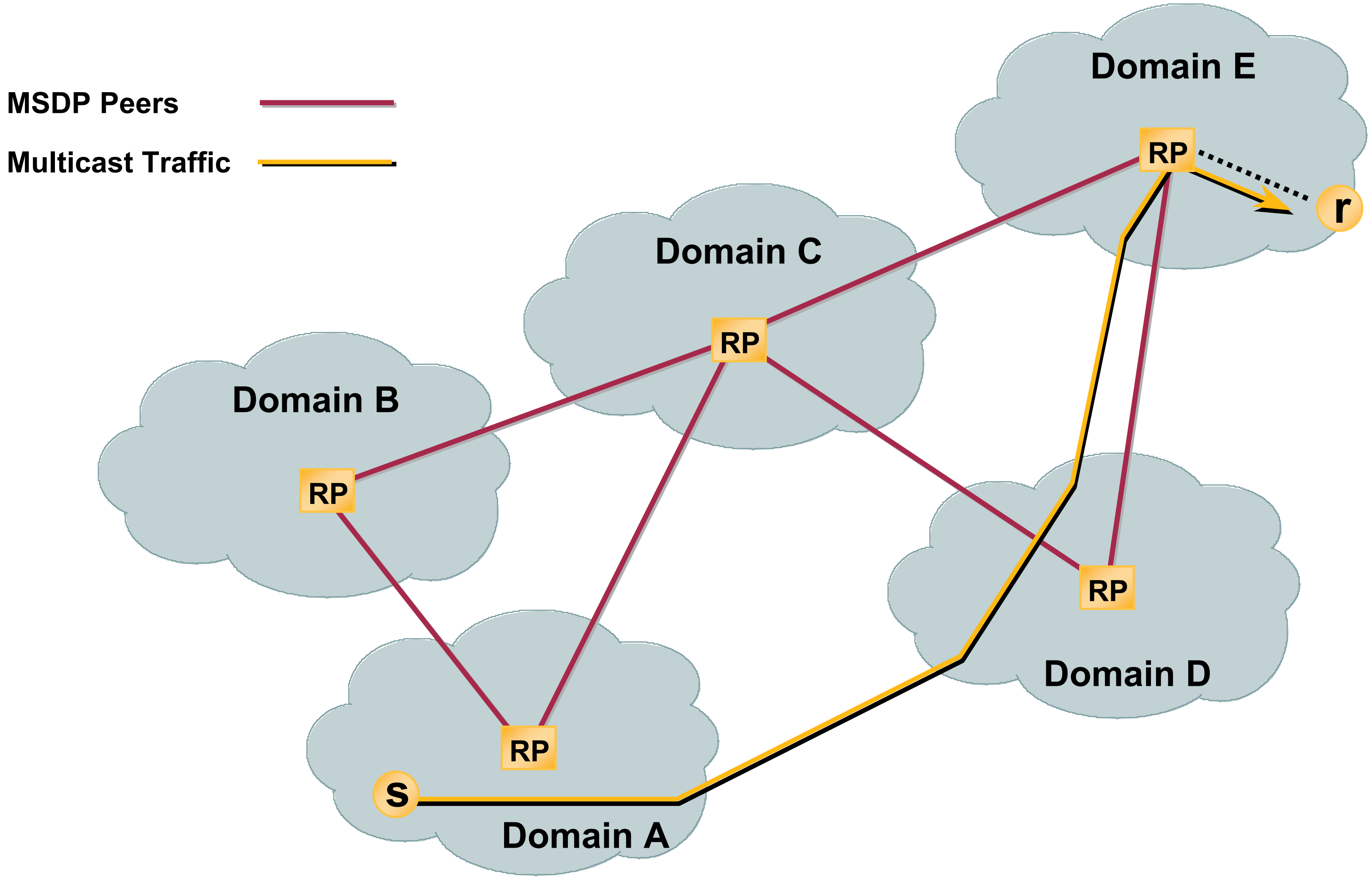


MSDP Peers

Multicast Traffic

Domain E

RP

r

Domain C

RP

Domain B

RP

RP

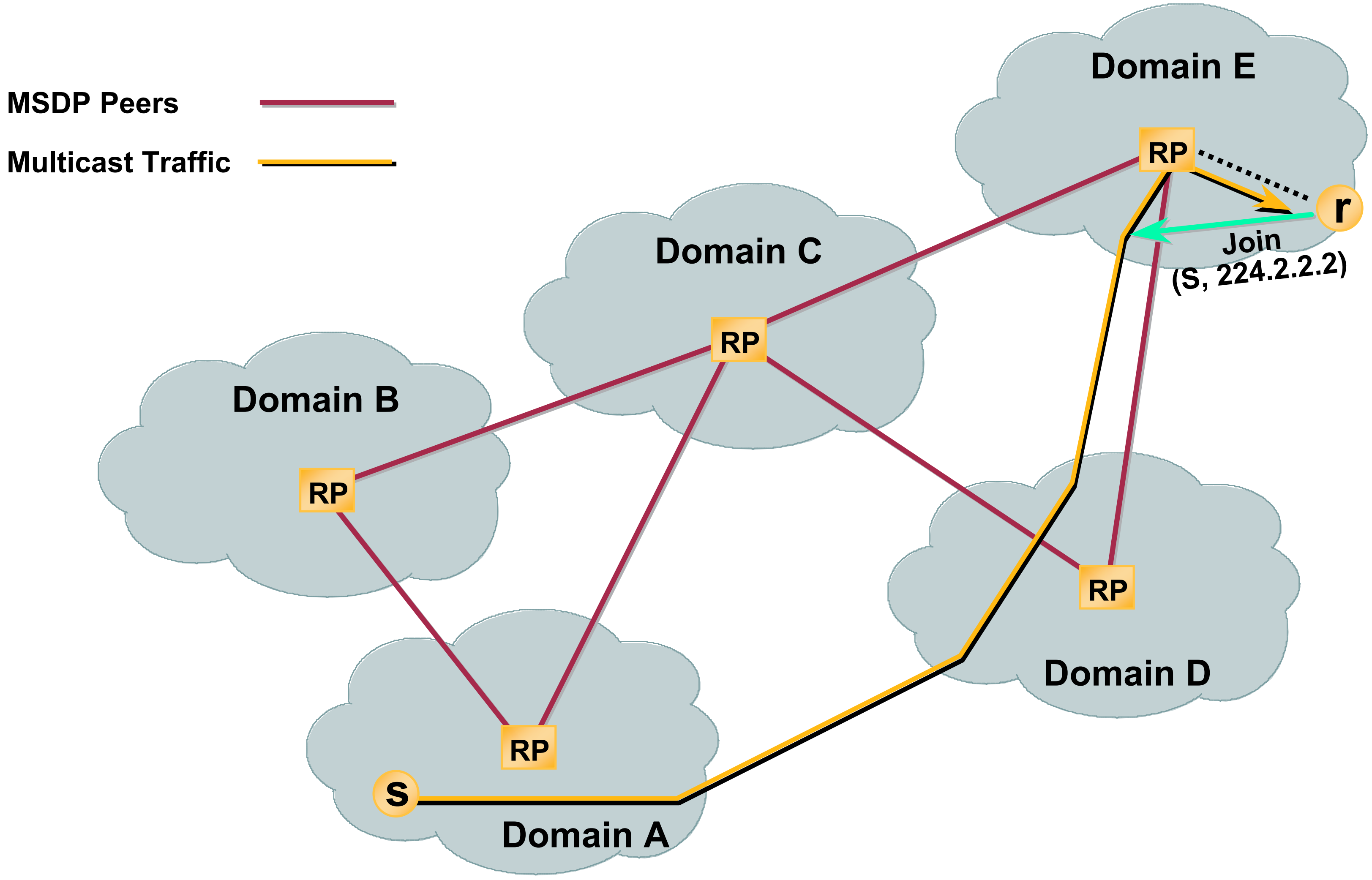
Domain D

RP

S

Domain A

MSDP Overview



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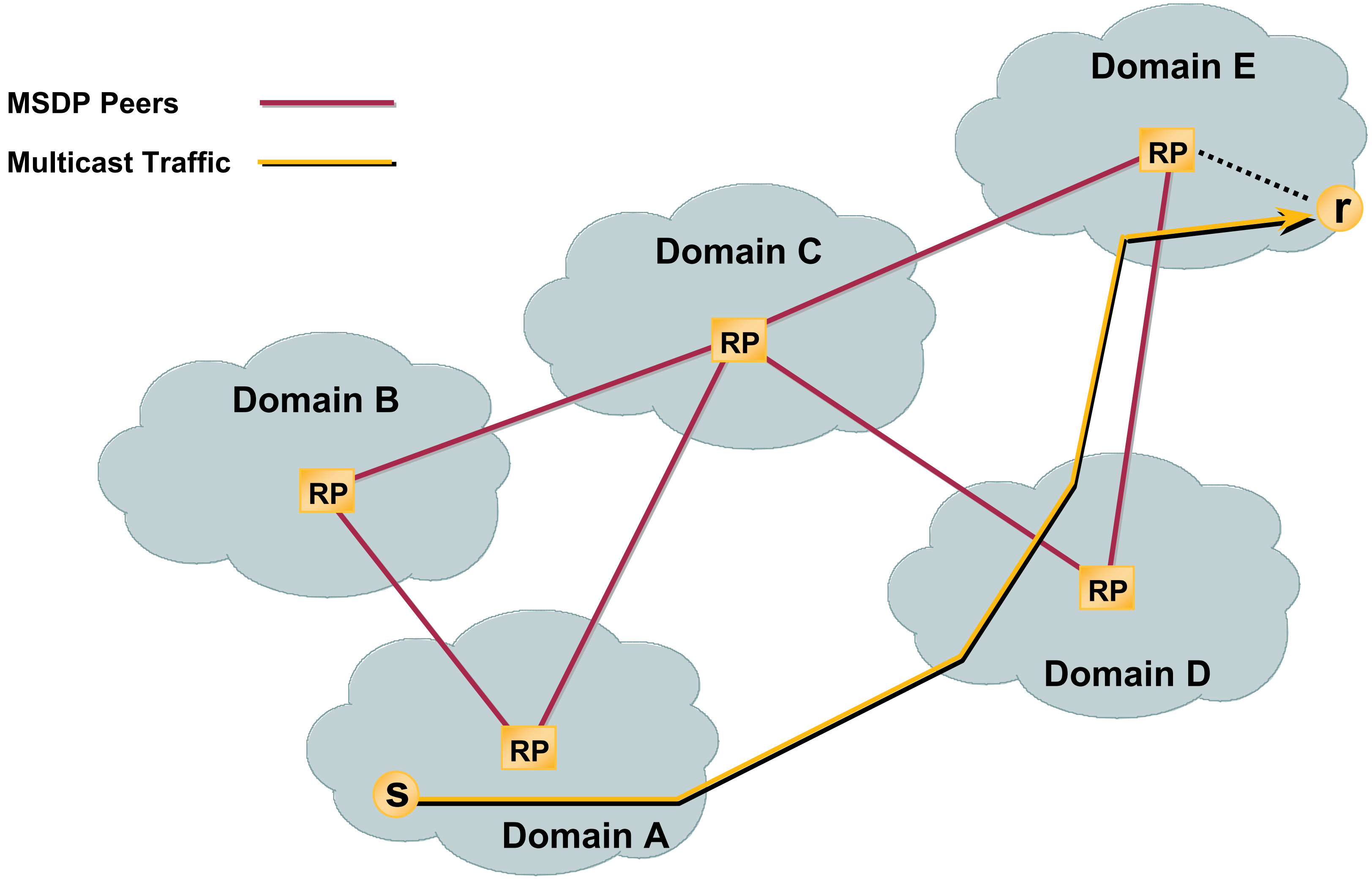


MSDP Peers

- MSDP establishes a neighbor relationship between MSDP peers
  - Peers connect using TCP port 639
  - Peers send keepalives every 60 secs (fixed)
  - Peer connection reset after 75 seconds if no MSDP packets or keepalives are received
- MSDP peers must run mBGP!
  - May be an MBGP peer, a BGP peer or both
  - Required for peer-RPF checking of the RP address in the SA to prevent SA looping
  - Exception: BGP is unnecessary when peering with only a single MSDP peer (default-peer)

Receiving SA Messages

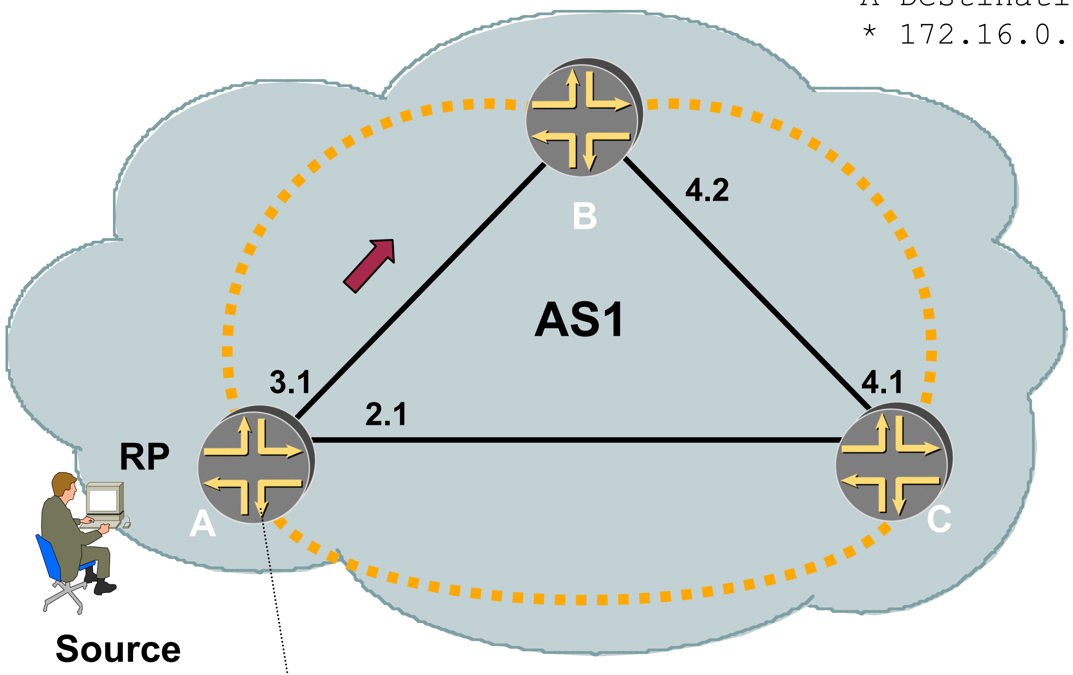
- Skip RPF Check and accept SA if:
  - Sending MSDP peer is default-peer
  - Sending MSDP peer = Mesh-Group peer
- RPF Check the received SA message
  - If the MSDP peer IS THE originating RP – then accept.
  - Lookup best MBGP path to RP in SA message
  - Is the sending MSDP Peer also an MBGP peer?
    - Yes: Is best path to RP via this MBGP peer?
      - If yes, RPF Check Succeeds; process SA message
    - No: Is the first AS in the best path to RP = the first AS in the best path to MSDP peer?
      - If yes, RPF Check Succeeds; process SA message

Receiving SA Messages

- RPF Check rule example cases
  - Case 1: Sending MSDP Peer = iMBGP peer
    - Is best path to RP via this MBGP peer?
  - Case 2: Sending MSDP Peer = eMBGP peer
    - Is best path to RP via this MBGP peer?
  - Case 3: Sending MSDP Peer != BGP peer
    - Is the next AS in best path to RP = AS of the sending MSDP peer?

RPF Check Example

RPF rule when MSDP peer == iMBGP peer



```
          MBGP Table router B
A Destination         Next hop          AS path
* 172.16.0.2/32       >172.16.3.1       i
```

Who is the iMBGP peer adverting this route?
in our example 172.16.3.1

```
      MSDP Peers router B

Peer Address          State
172.16.3.1            Established
172.16.4.1            Established
```

Is the MSDP == MBGP peer?

RPF Success!

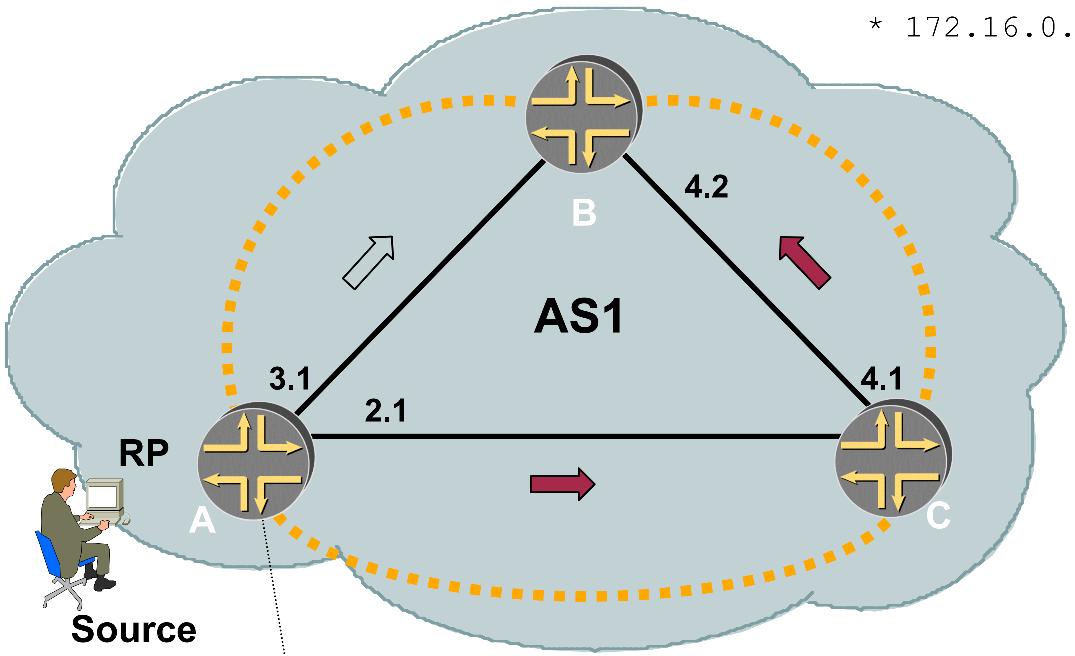
```
rp {
   local {
      address 172.16.0.2;
```

➡ **MSDP SA**

▪▪▪ **MSDP/iMBGP mesh-peering**

RPF Check Example

RPF rule when MSDP peer == iMBGP peer



```
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```

🟥➡ **MSDP SA**

▪▪▪ **MSDP/iMBGP mesh-peering**

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Who is the iMBGP peer adverting this route?
In our example 172.16.3.1

```
      MSDP Peers router B

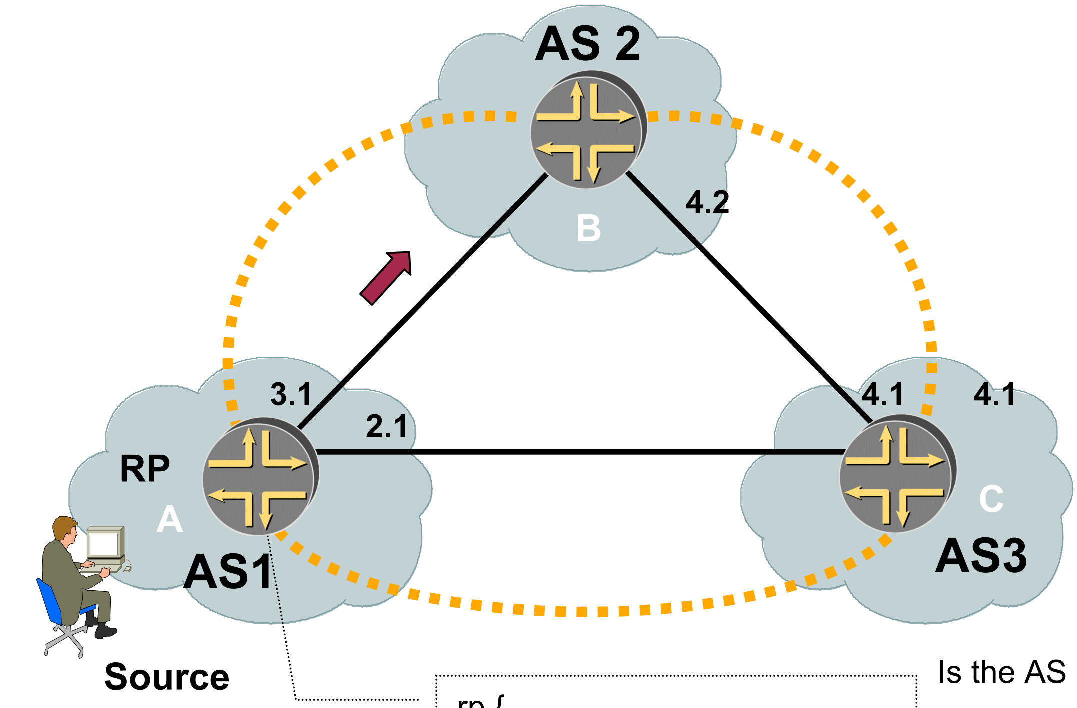
Peer Address         State
172.16.3.1           Established
172.16.4.1           Established
```

Is the MSDP == MBGP peer?

RPF Failure!

RPF Check Example

RPF rule when MSDP == MBGP peer



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```

➡ **MSDP SA**

▪ ▪ ▪ **MSDP/eMBGP mesh-peering**

```
        MSDP Peers router B

    MSDP Peer        State
    172.16.3.1       Established
    172.16.4.1       Established

        BGP Neighbours router B

    Peer             AS
    172.16.3.1       1
    172.16.4.1       3
```

MBGP Table

```
Destination         Next Hop         Path
* 172.16.0.2/32     >172.16.3.1      1 i
  172.16.0.2/32      172.16.4.1      3 1 i
```

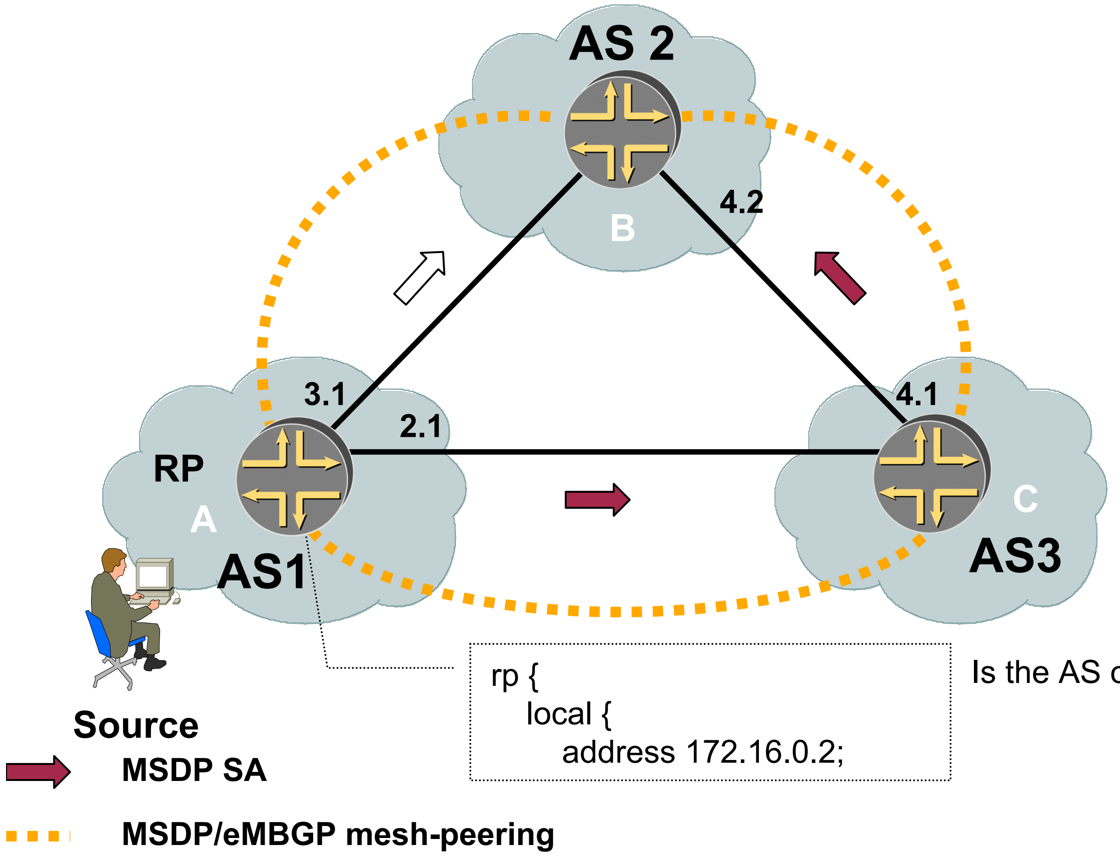
Is the AS of the sending MSDP peer == First AS in RP route?

RPF Success!

Who is the BGP peer adverting this route

RPF Check Example

RPF rule when MSDP == MBGP peer



```
rp {
    local {
        address 172.16.0.2;
```

```
        MSDP Peers router B

MSDP Peer        State
172.16.3.1       Established
172.16.4.1       Established

     BGP Neighbours router B

Neighbor       AS
172.16.3.1     1
172.16.4.1     3
```

BGP Table

```
Destination         Next Hop       Path
* 172.16.0.2/32     >172.16.3.1     1 i
  172.16.0.2/32      172.16.4.1     3 1 i
```

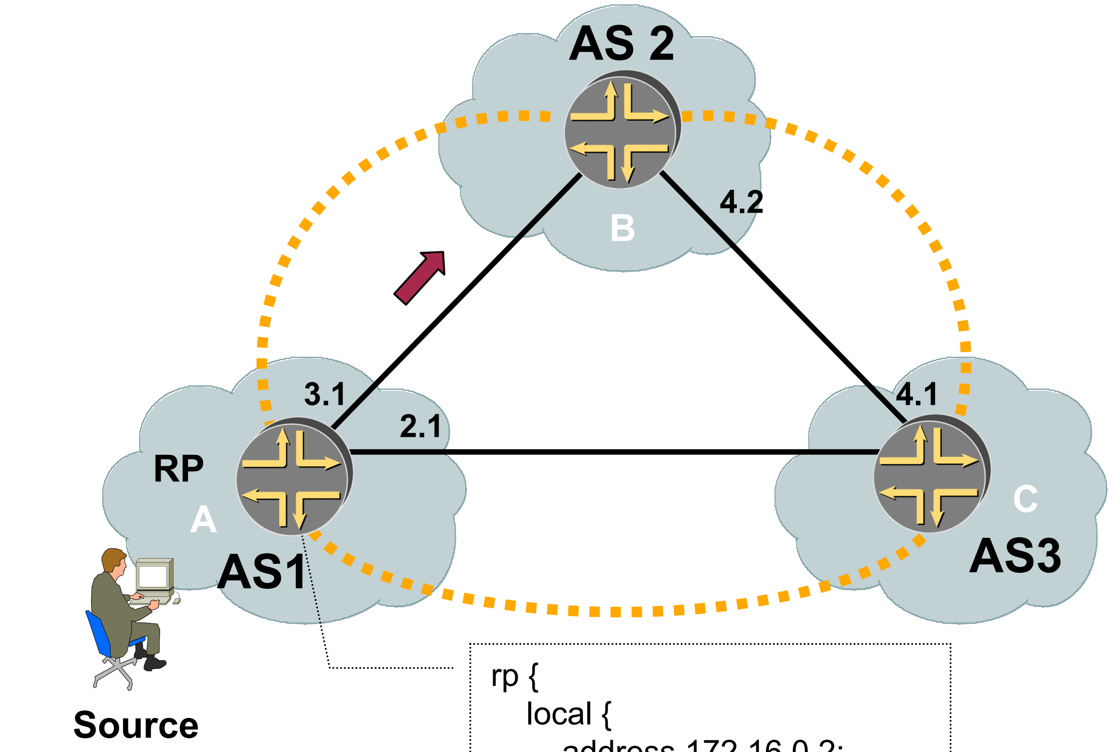
Is the AS of the sending MSDP peer == First AS in RP route?

RPF Failure!

Who is the BGP peer adverting this route

RPF Check Example

RPF rule when MSDP != MBGP peer



```
rp {
   local {
      address 172.16.0.2;
```

➡ MSDP SA

▪ ▪ ▪ MSDP/eMBGP mesh-peering

```
          MSDP Peers router B

MSDP Peer        State
172.16.3.1       Established
172.16.4.1       Established
```

BGP Table router B

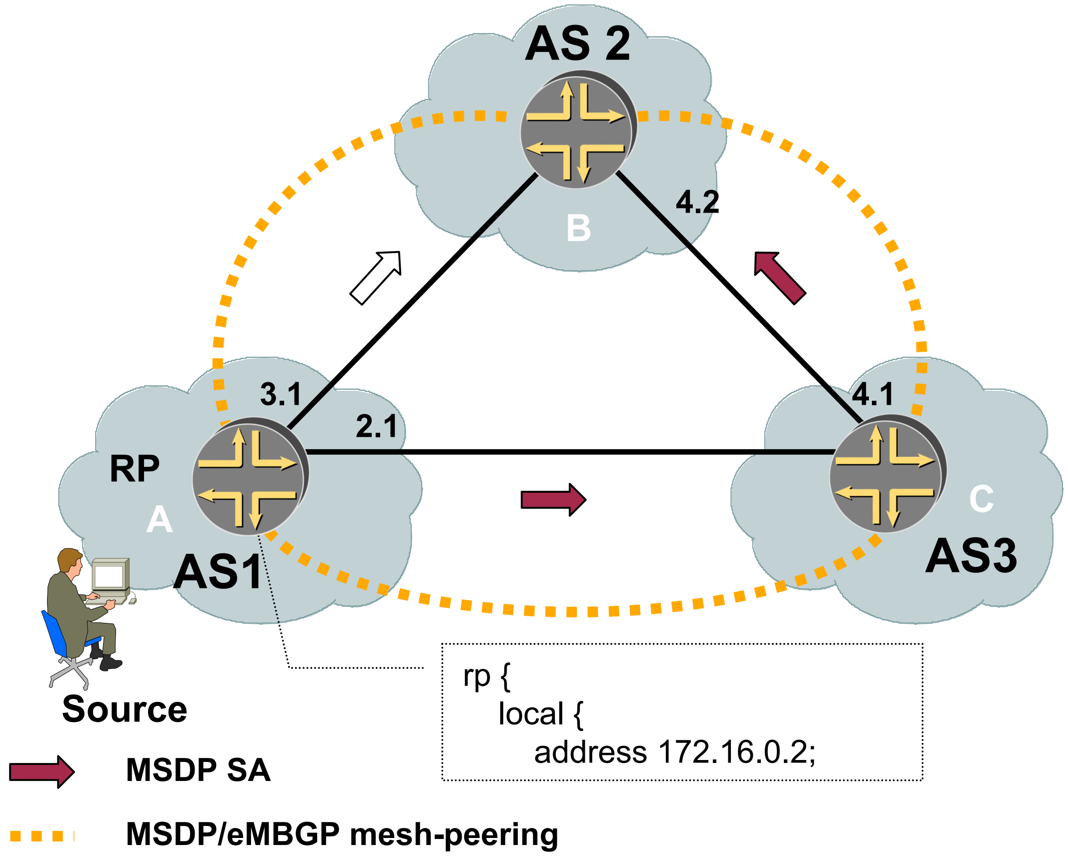
```
Destination            Next Hop    Path
*172.16.0.2/32     >172.16.3.1    1 i
 172.16.0.2/32     >172.16.4.1    3 1 I
*172.16.4.0/24     >172.16.4.1    3 i
*172.16.3.0/24     >172.16.3.1    1 i
```

Is the first AS in the path to the MSDP peer
== First AS in best path to the RP?

RPF Success!

RPF Check Example

RPF rule when MSDP != MBGP peer



```
rp {
    local {
        address 172.16.0.2;
```

```
MSDP Peers router B

MSDP Peer      State
172.16.3.1     Established
172.16.4.1     Established
```

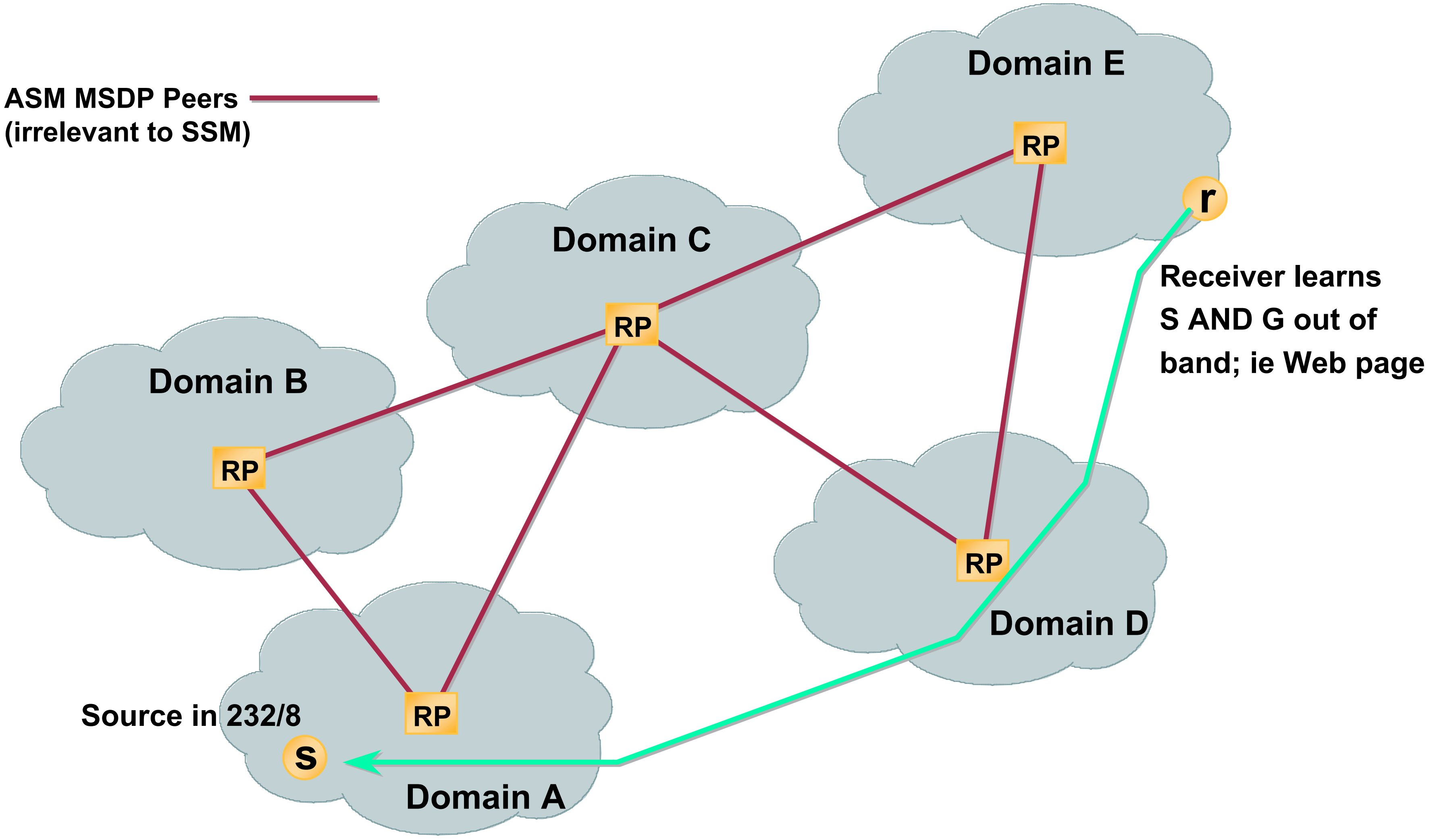
BGP Table router B

```
Destination        Next Hop      Path
*172.16.0.2/32     >172.16.3.1    1 i
 172.16.0.2/32     >172.16.4.1    3 1 I
*172.16.4.0/24     >172.16.4.1    3 i
*172.16.3.0/24     >172.16.3.1    1 i
```

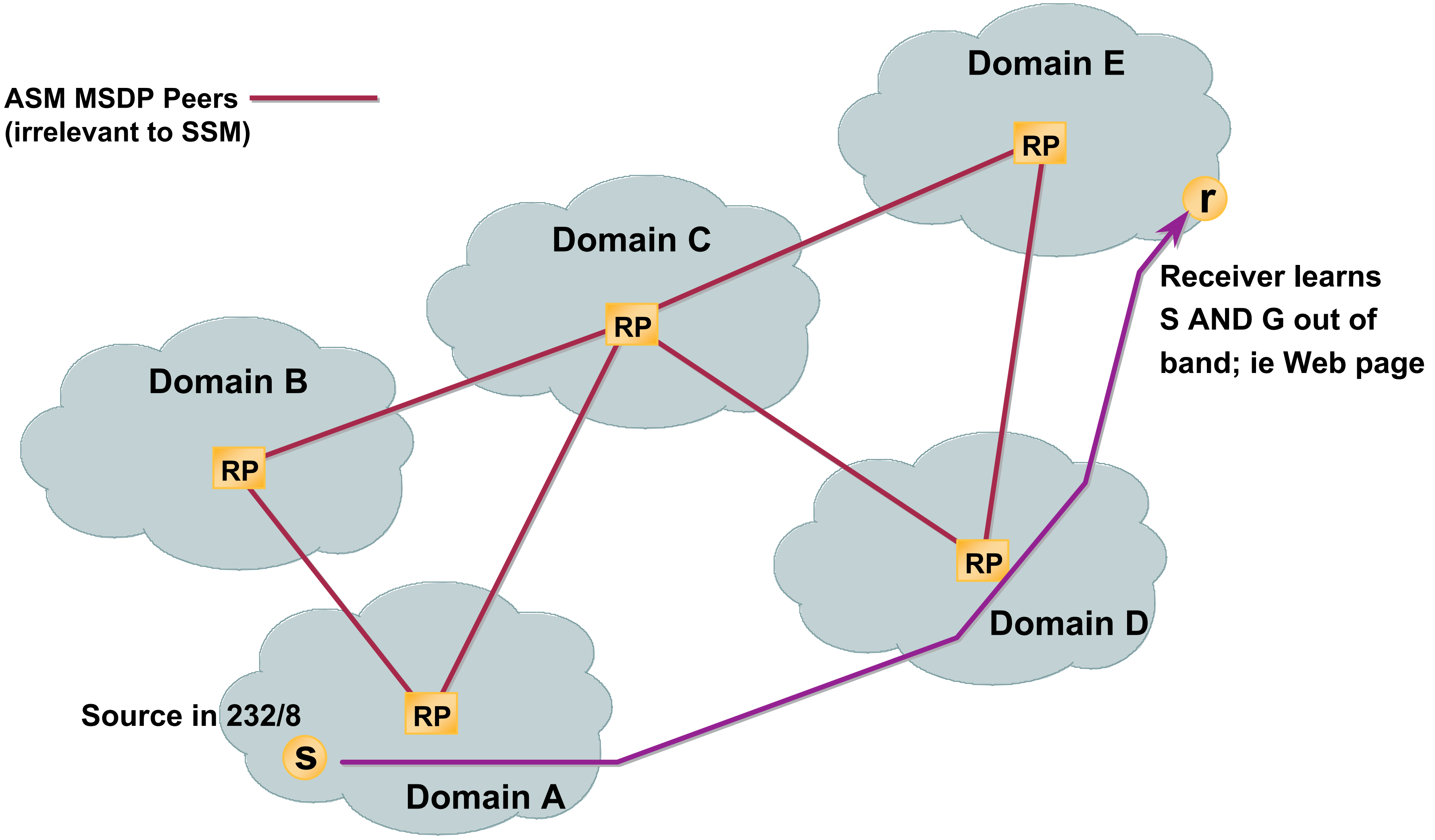
Is the first AS in the path to the MSDP peer
== First AS in best path to the RP?

RPF Failure!

MSDP wrt SSM – Unnecessary!



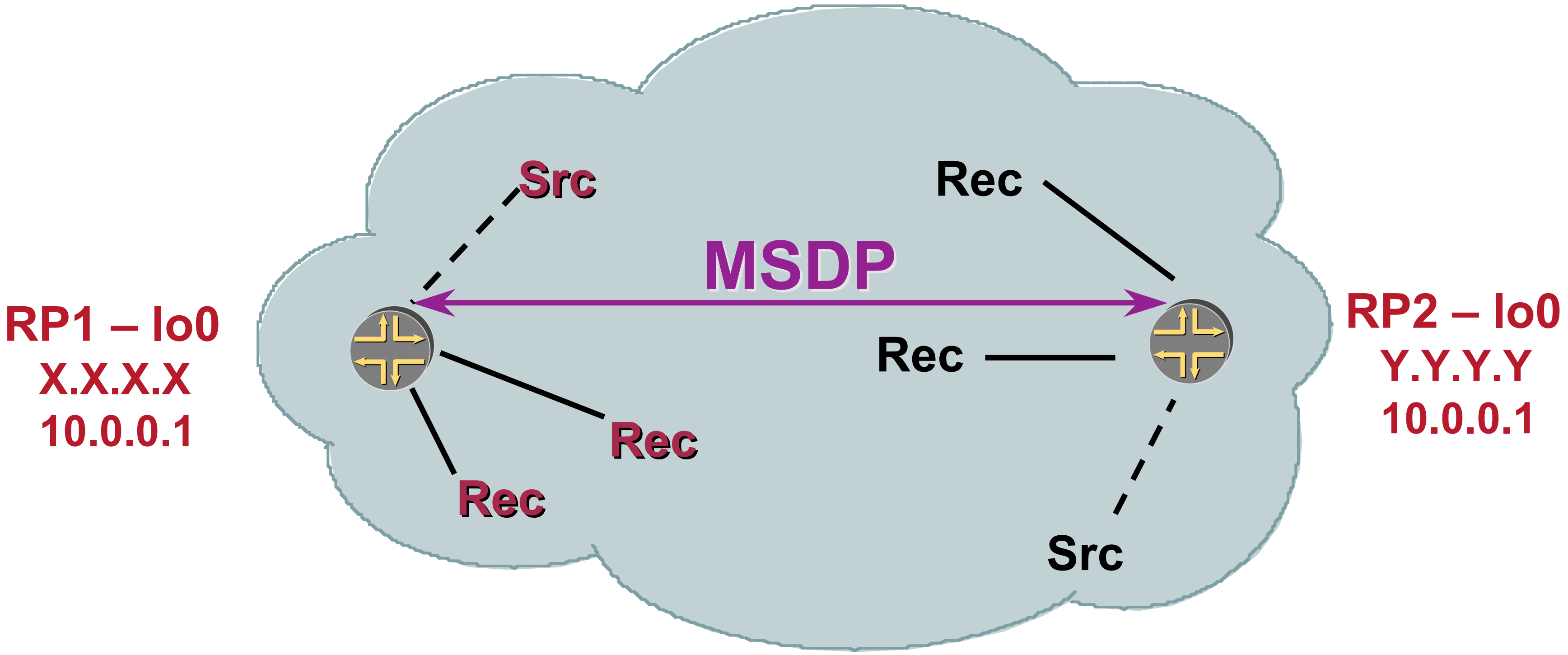
MSDP wrt SSM – Unnecessary!



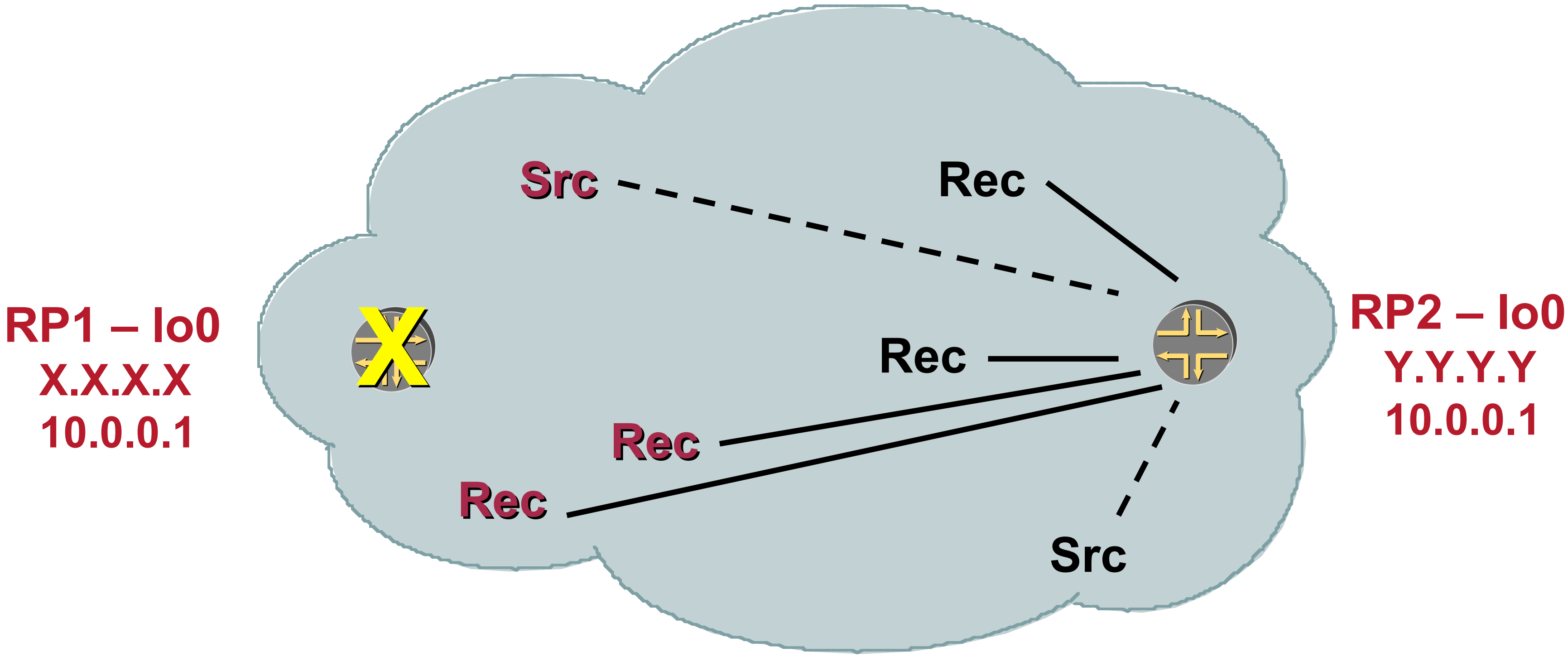
MSDP Application: Anycast-RP

- Within a domain, deploy more than one RP for the same group range
- Sources from one RP are known to other RPs using MSDP
- Give each RP the same /32 IP address
- Sources and receivers use closest RP, as determined by the IGP
- Used intra-domain to provide redundancy and RP load sharing, when an RP goes down, sources and receivers are taken to new RP via unicast routing
    - Fast convergence!

Anycast-RP


Src
Rec
MSDP
RP1 – lo0
X.X.X.X
10.0.0.1
Rec
RP2 – lo0
Y.Y.Y.Y
10.0.0.1
Rec
Rec
Src

Anycast-RP



Agenda

- Introduction
- Multicast addressing
- Group Membership Protocol
- PIM-SM / SSM
- MSDP
- MBGP
- Summary

MBGP—Multiprotocol BGP

- MBGP overview
- MBGP capability negotiation
- MBGP NLRI exchange
- Configuration guidelines

MBGP

- Multiprotocol Extensions to BGP (RFC 2283).
- Tag unicast prefixes as multicast source prefixes for intra-domain mcast routing protocols to do RPF checks.
- WHY? Allows for interdomain RPF checking where unicast and multicast paths are non-congruent.
- DO I REALLY NEED IT?
  - YES, if:
    - ISP to ISP peering
    - Multiple-homed networks
  - NO, if:
    - You are single-homed

MBGP Overview

- MBGP: Multiprotocol BGP
  - Defined in RFC 2283 (extensions to BGP)
  - Can carry different route types for different purposes
    - Unicast
    - Multicast
  - Both route types carried in same BGP session
  - Does not propagate multicast state information
  - Same path selection and validation rules
    - AS-Path, LocalPref, MED, …

MBGP Overview

- New multiprotocol attributes
  - MP_REACH_NLRI
  - MP_UNREACH_NLRI
- MP_REACH_NLRI and MP_UNREACH_NLRI
  - Address Family Information (AFI) = 1 (IPv4)
    - Sub-AFI = 1 (NLRI is used for unicast)
    - Sub-AFI = 2 (NLRI is used for multicast RPF check)
    - Sub-AFI = 3 (NLRI is used for both unicast and multicast RPF check)
- SAFI 1 -> RIB inet.0
- SAFI 2 -> RIB inet.2
- Multicast uses SAFI 2 routes for RPF
- Allows for different policies between multicast and unicast

Ribs & Rib groups

- Routing Information Base (RIB)
  - Simply a routing table with a purpose
- RIB Group
  - Primary import RIB
  - Optional list of secondary import RIBs
  - Export RIB
- Well known JUNOS ribs
  - Inet.0 – Primary unicast rib
  - Inet.1 – Multicast forwarding rib
  - Inet.2 – Multicast source rib (RPF)
  - Inet.3 – MPLS rib
  - Inet.4 – MSDP SA rib

MBGP—Capability Negotiation

- BGP routers establish BGP sessions through the OPEN message
- OPEN message contains optional parameters
- BGP session is terminated if OPEN parameters are not recognised
- New parameter: CAPABILITIES
    - Multiprotocol extension
    - Multiple routes for same destination
- Configures router to negotiate either or both NLRI
    - If neighbor configures both or subset, common NRLI is used in both directions
    - If there is no match, notification is sent and peering doesn’t come up
    - If neighbor doesn’t include the capability parameters in open, session backs off and reopens with no capability parameters
        - Peering comes up in unicast-only mode

MBGP—Summary

- Solves part of inter-domain problem
  - Can exchange unicast prefixes for multicast RPF checks
  - Uses standard BGP configuration knobs
  - Permits separate unicast and multicast topologies if desired
- Still must use PIM to:
  - Build distribution trees
  - Actually forward multicast traffic
  - PIM-SM recommended

Agenda

- Introduction
- Multicast addressing
- Group Membership Protocol
- Multicast Forwarding Algorithm
- PIM-SM / SSM
- MSDP
- MBGP
- Summary

The Soup

- IGMP - Internet Group Management Protocol is used by hosts and routers to tell each other about group membership.
- PIM-SM - Protocol Independent Multicast-Sparse Mode is used to propagate forwarding state between routers.
- SSM - Source Specific Multicast utilizes a subset of PIM's functionality to guaranty source-only trees in the 232/8 range.
- MBGP - Multiprotocol Border Gateway Protocol is used to exchange routing information for interdomain RPF checking.
- MSDP - Multicast Source Discovery Protocol is used to exchange ASM active source information between RPs.

Multicast Transit Design Objectives

- PIM Border Constraints
  - Confine registers within domain
  - Confine local groups
  - Confine RP announcements
  - Control SA advertisements via MSDP
- Border RPF check
  - RPF check against unicast routes to multicast sources
- MSDP RPF check
  - RPF check toward RP in received SAs

ISP Requirements at the MIX

- Current solution: MBGP + PIM-SM + MSDP
  - Environment
    - ISPs run iMBGP and PIM-SM (internally)
    - ISPs multicast peer at a public interconnect
  - Deployment
    - Border routers run eMBGP
    - The interfaces on interconnect run PIM-SM
    - RPs’ MSDP peering must be consistant with eMBGP peering
    - All peers set a common distance for eMBGP

Thank you!

More Information

- For more information on Multicast, please refer to the following intranet sites:
  - http://www-int.juniper.net/sales/sales_training/technology_detail.html#14