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You make possible

Introduction to IP Multicast

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BRKIPM-1261

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Barcelona | January 27-31, 2020

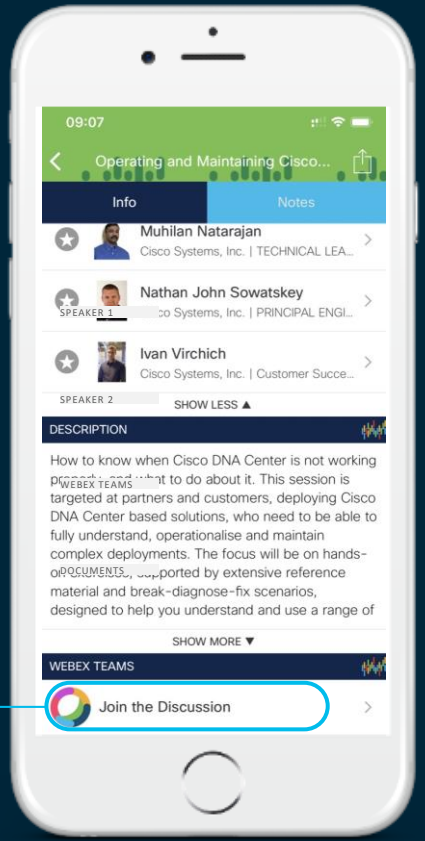
Cisco Webex Teams

Questions?

Use Cisco Webex Teams to chat with the speaker after the session

How

1. Find this session in the Cisco Events Mobile App
2. Click “Join the Discussion”
3. Install Webex Teams or go directly to the team space
4. Enter messages/questions in the team space



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Agenda

- Introduction 
- Multicast Fundamentals
- IGMP/Host Signaling
- Multicast Routing with PIM
- Any-Source Multicast
- Source-Specific Multicast
- IPv6 Multicast
- Summary
- Call to Action! 

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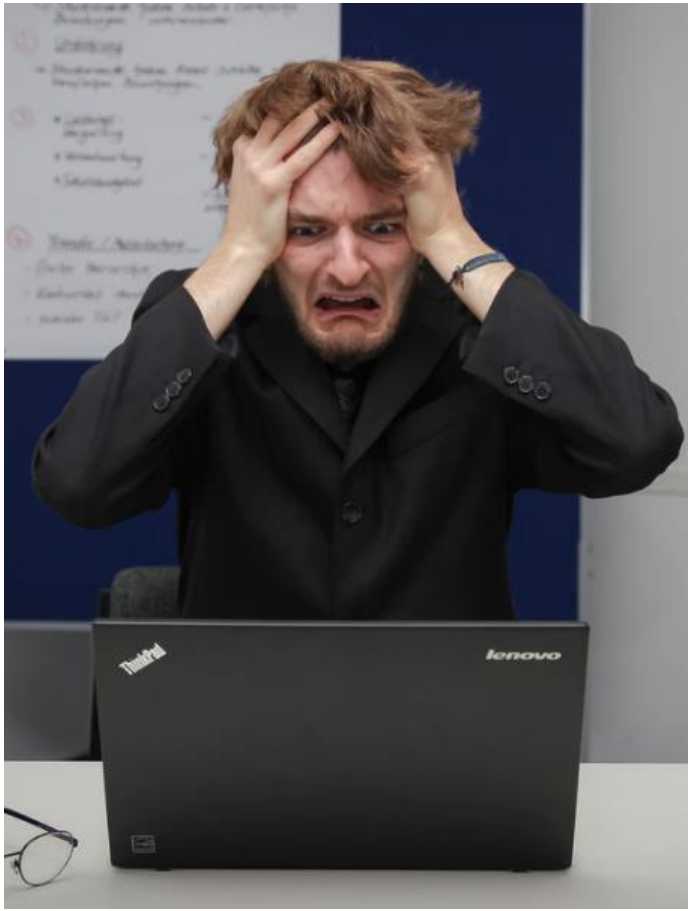
Multicast Fundamentals

Multicast

Alive and Well In Your Network

It’s Too Late to Be Afraid!



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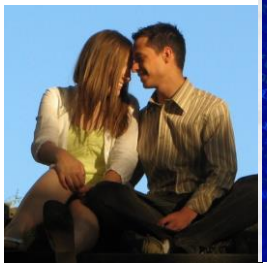
Multicast Contrasted

- Unicast



- Broadcast

- Multicast

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Problem Solving with Multicast

Server **Overload**

Exhausted Resources

Wasted Bandwidth

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Problem Solving with Multicast

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Problems Multicast Can't Solve

- Application Must Resolve Issues the Network Cant – UDP Based Traffic

- Multicast Is Not Natively Supported on the Internet – Trust Issues

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How Do Multicast IP Addresses Work?

Similar to a radio station's broadcast frequency, a multicast IP address is just where the traffic goes

It will never be configured on a physical interface, and traffic will never originate from a multicast address

IP Range: 224.0.0.0 – 239.255.255.255

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How Do MAC Addresses Work?

- MAC addresses are 48 bits in length
- The first 24 bits are based on Organizationally Unique Identifier

- The last 24 bits are based on a unique interface address (BIA)

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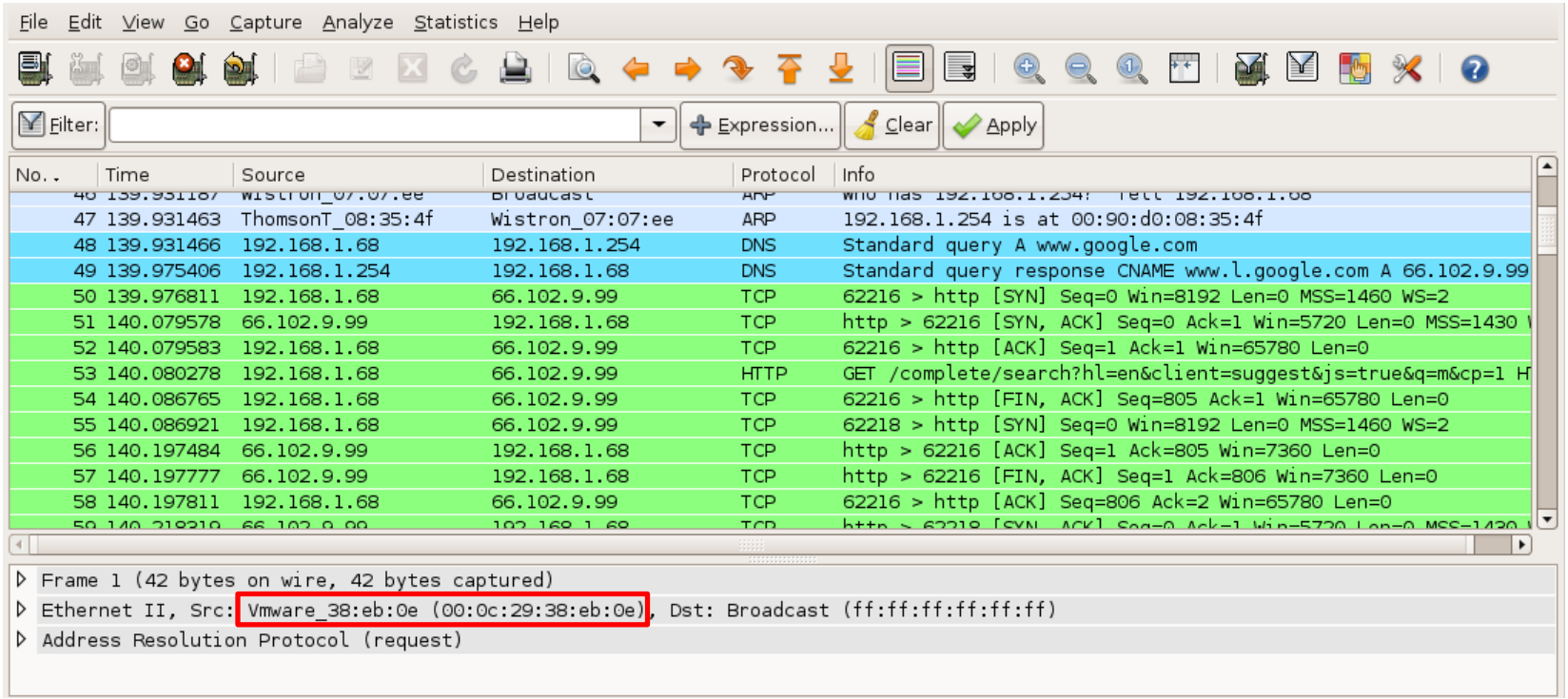
How Do MAC Addresses Work?



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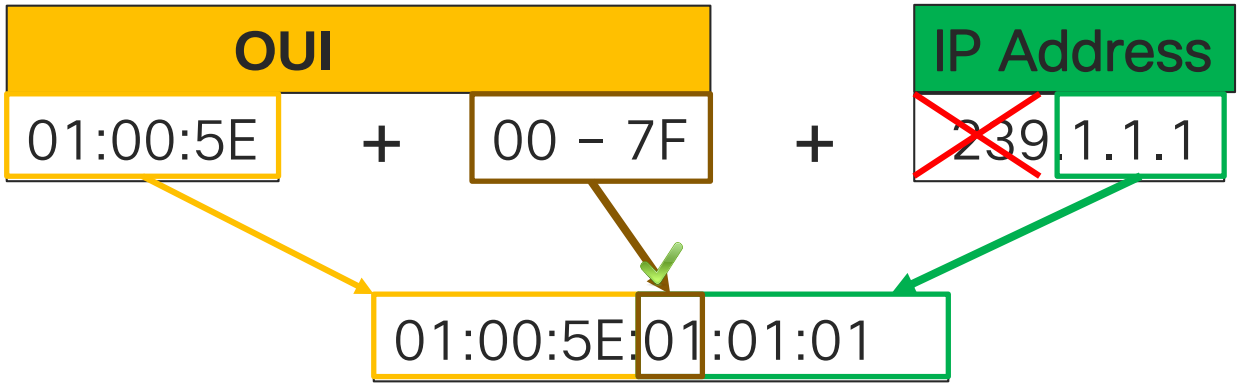
How Do Multicast MAC Addresses Work?

- In IPv4, multicast MAC address is derived from combination of OUI and IPv4 address (converted to hex)



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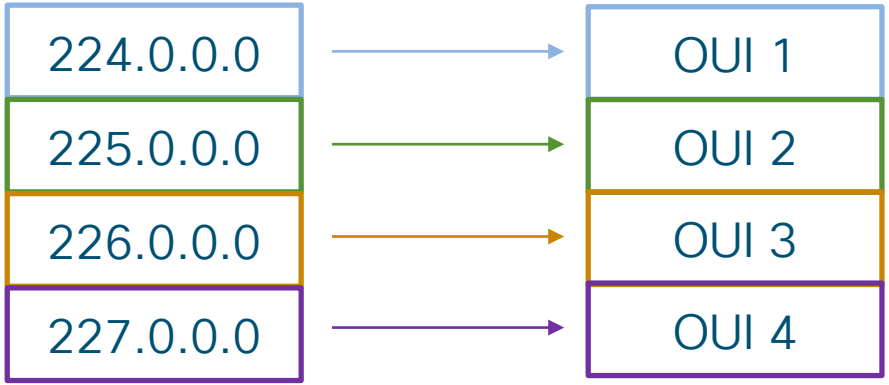
How Do Multicast MAC Addresses Work?

- To cover all multicast group IPs, 16 separate OUIs were needed



Etc…

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How Do Multicast MAC Addresses Work?

- In 1985, OUI had to be bought from IEEE at a high cost for each

```
00-10-7B    (hex)              Cisco Systems, Inc
00107B      (base 16)          Cisco Systems, Inc
                               170 W.TASMAN DR.-SJA-2
                               SAN JOSE  CA  95134-1706
                               US

00-90-6D    (hex)              Cisco Systems, Inc
00906D      (base 16)          Cisco Systems, Inc
                               80 West Tasman Drive
                               San Jose  CA  94568
                               US

00-90-BF    (hex)              Cisco Systems, Inc
0090BF      (base 16)          Cisco Systems, Inc
                               80 West Tasman Drive
                               San Jose  CA  94568
                               US

00-50-80    (hex)              Cisco Systems, Inc
005080      (base 16)          Cisco Systems, Inc
                               170 W. TASMAN DR.
                               SAN JOSE  CA  95134-1706
                               US
```

=

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How Do Multicast MAC Addresses Work?

- Instead 1 OUI was purchased, half was reserved for other projects

Usable Multicast MAC Address Range
01:00:5E:00:00:00 – 01:00:5E:7F:FF:FF

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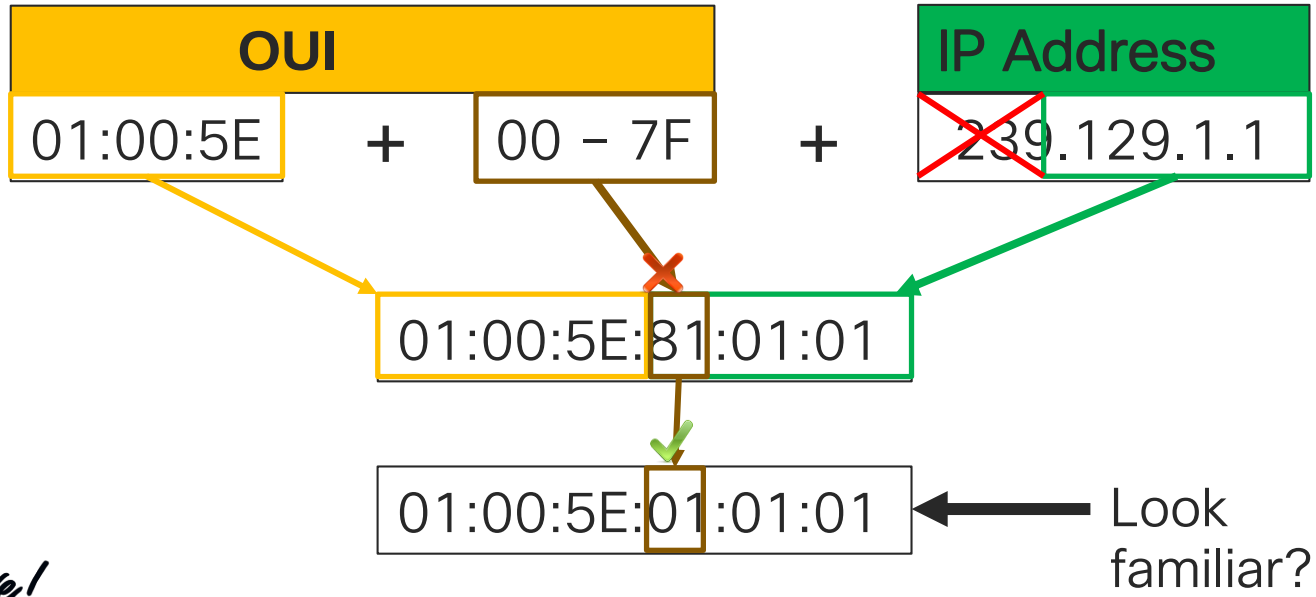
How Do Multicast MAC Addresses Work?

- Example of a converted IPv4 multicast IP that will not fit the boundary when converted – Offending bit must be set to 0



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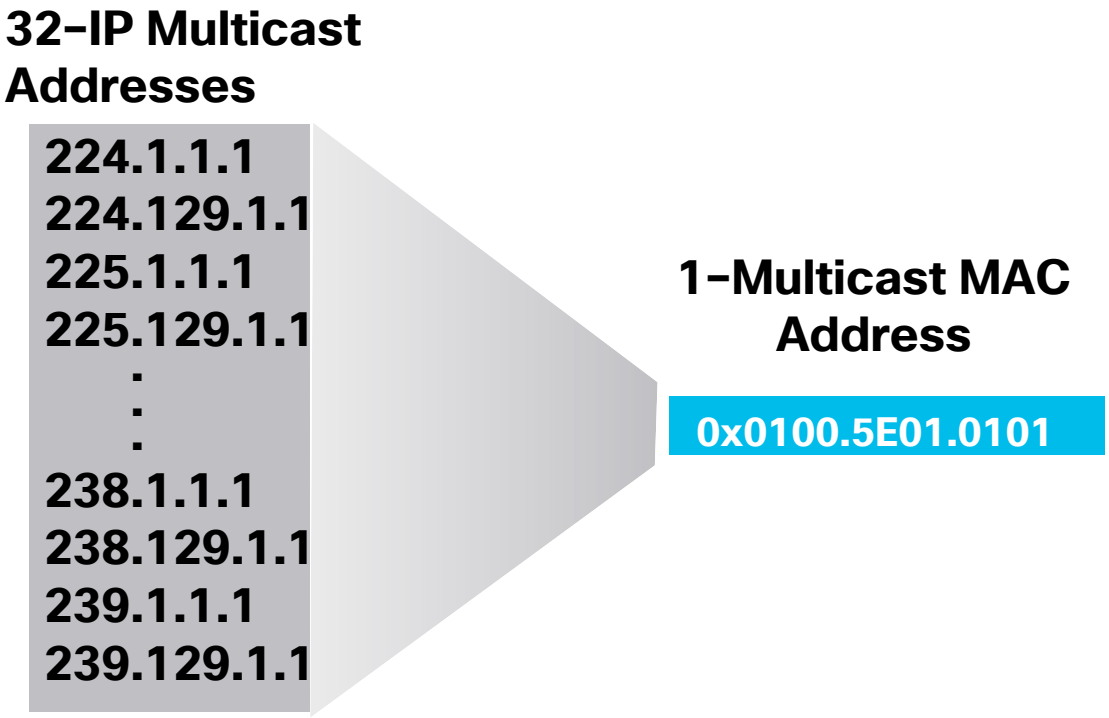
IPv4 Multicast MAC Address Fail



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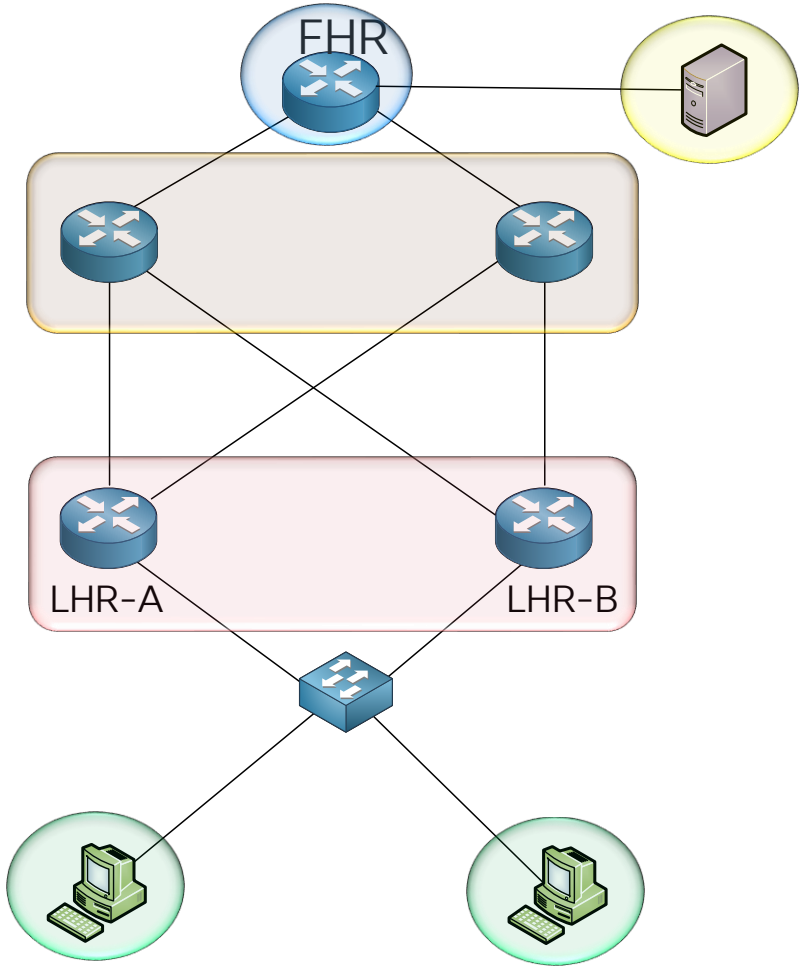
Multicast Routing Terminology

Multicast Routing is Source-Based!

- Source – Device sending multicast traffic
- Receiver – Device receiving multicast traffic

- First-Hop Router – FHR attached to source network segment
- Last-Hop Router – LHR attached to receiver network segment
- Multicast Router – Router enabled for multicast traffic



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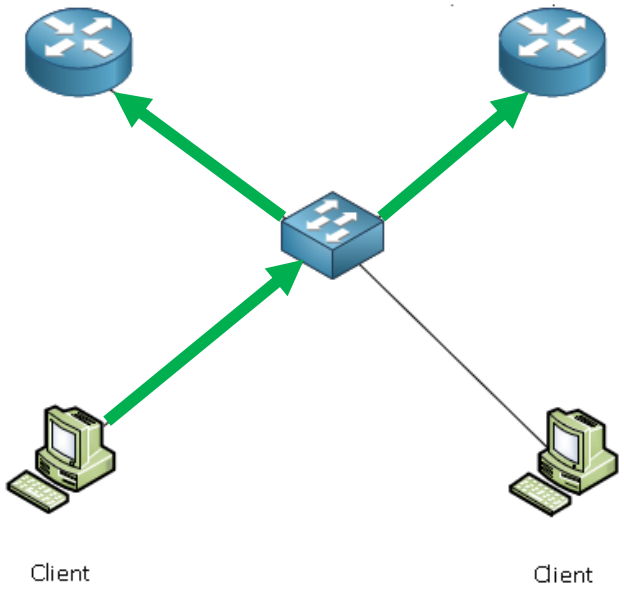
IGMP Introduced

- Multicast receiver sends IGMP message to multicast routers in order to receive or discontinue multicast traffic
- Multicast operates on a ‘pull’ model because receivers signal for the delivery of multicast traffic



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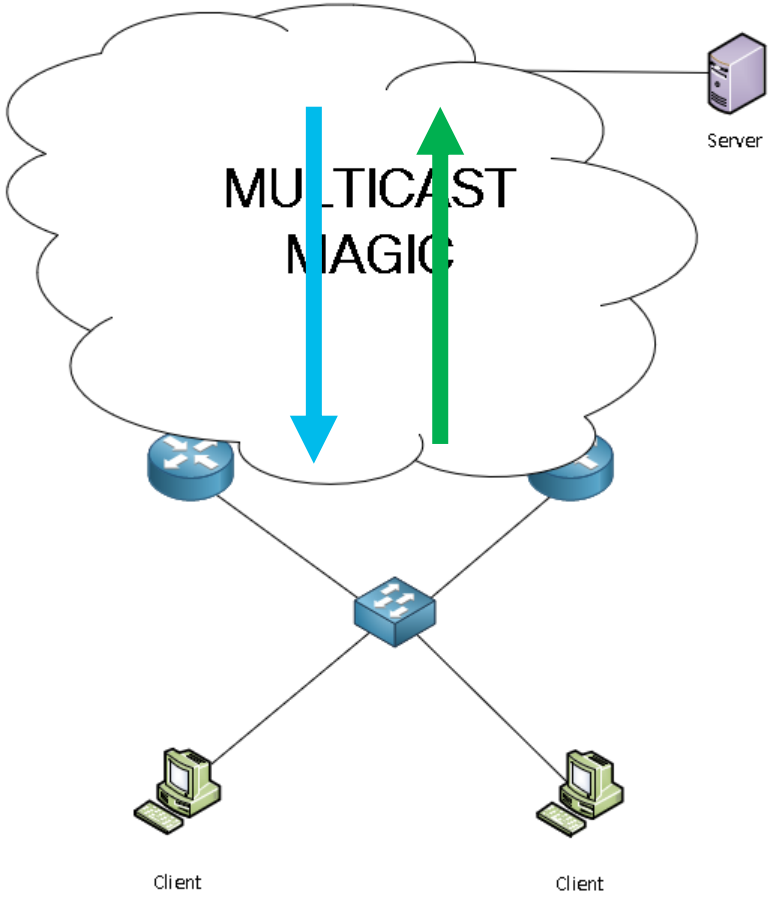
PIM Introduced

- Multicast routers convert IGMP messages into PIM Joins to build a loop-free ‘canal’ hop-by-hop toward the source
- When the ‘canal’ is built to the FHR, the floodgate is opened, with traffic following the path back to the receiver



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Routing Protocols and Link Local Multicast

How Does it Work?

Link Local Multicast Range: 224.0.0.0/24

Only One Side Listening

Interface added to EIGRP Dynamic Neighbor Discovery

Interface not listening on 224.0.0.10

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Routing Protocols and Link Local Multicast

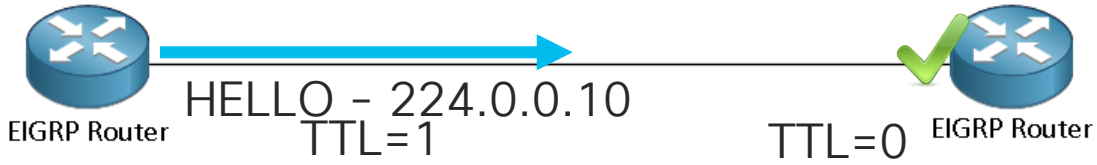
How Does it Work?

Link Local Multicast Range: 224.0.0.0/24

Both Sides Listening

Interface added to EIGRP
Dynamic Neighbor Discovery

Interface listening
on 224.0.0.10



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IGMP / Host Signaling

IGMP: Raise Your Hand if You Want Multicast

Internet Group Management Protocol

- Two main messages
  - IGMP Membership Report: From the receiver to multicast router
  - IGMP Membership Query: From the multicast router to check interest

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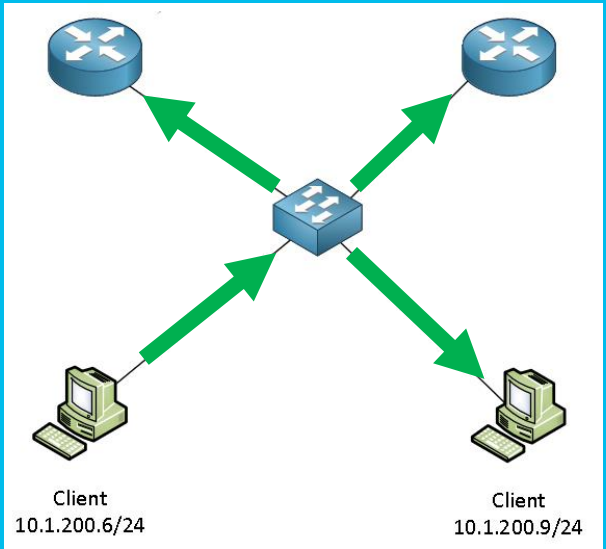
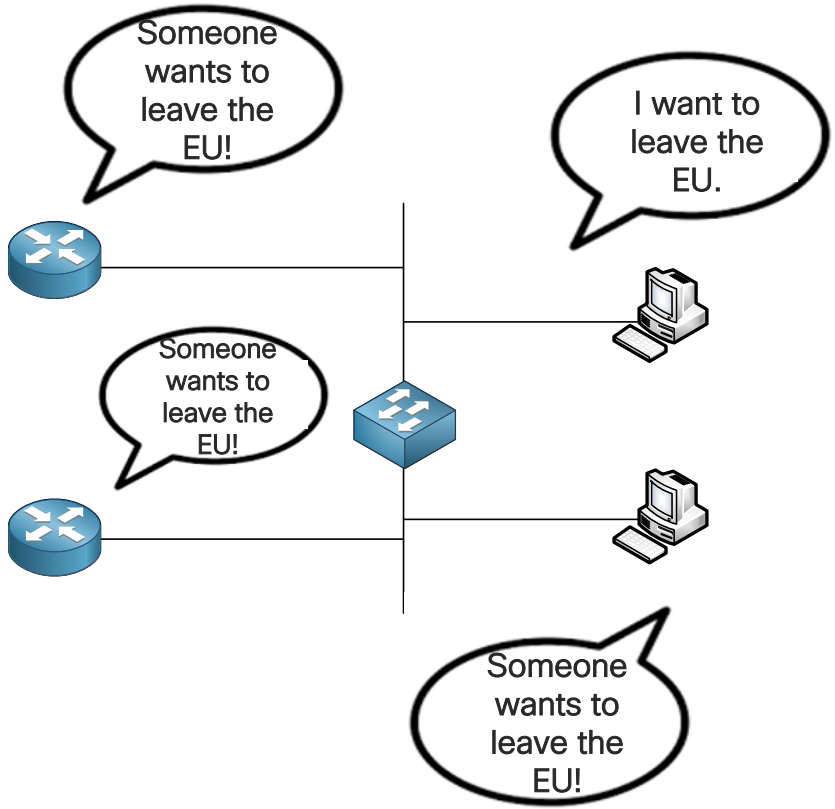
BREXIT

Brexit: Report





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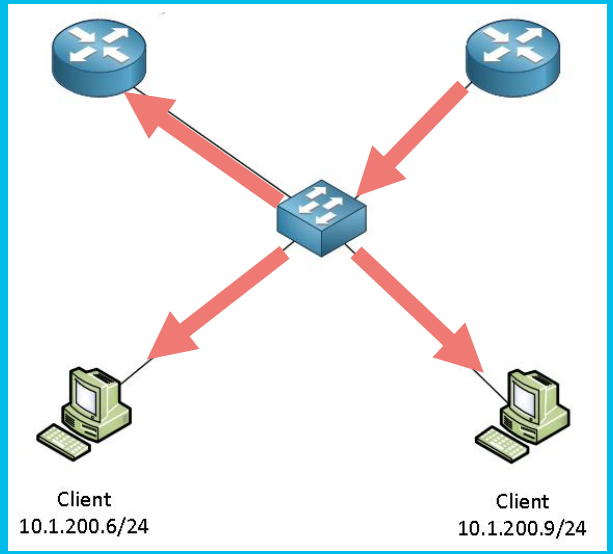
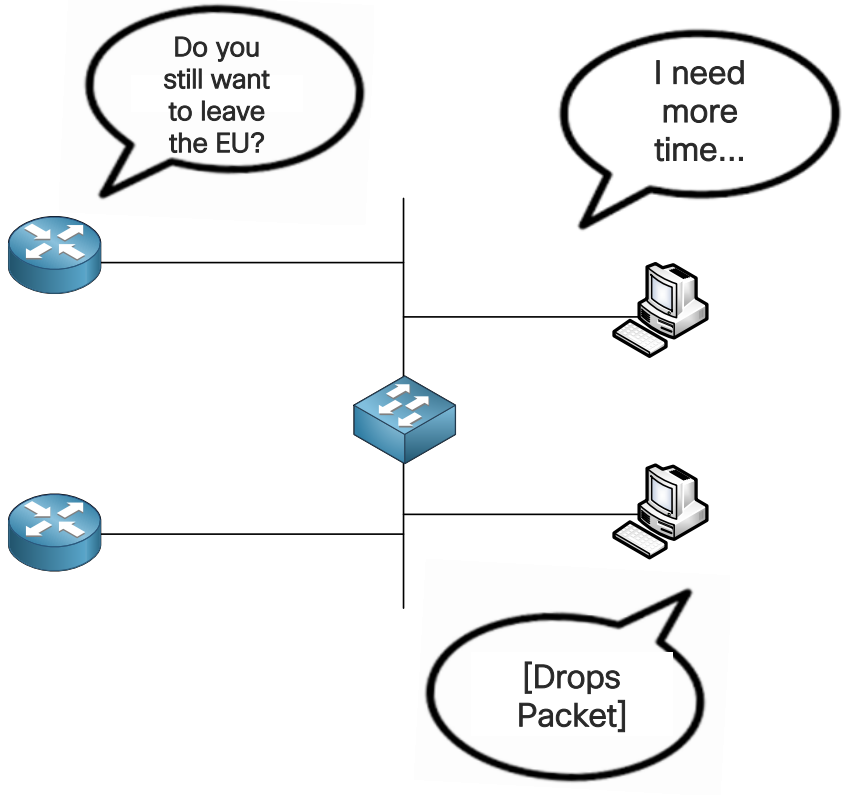
Brexit: Query





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IGMP: Raise Your Hand if You Want Multicast

Internet Group Management Protocol

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- Version 1 is deprecated

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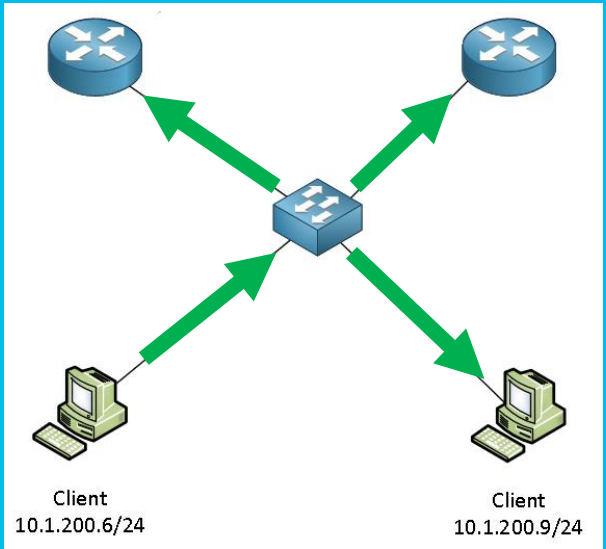
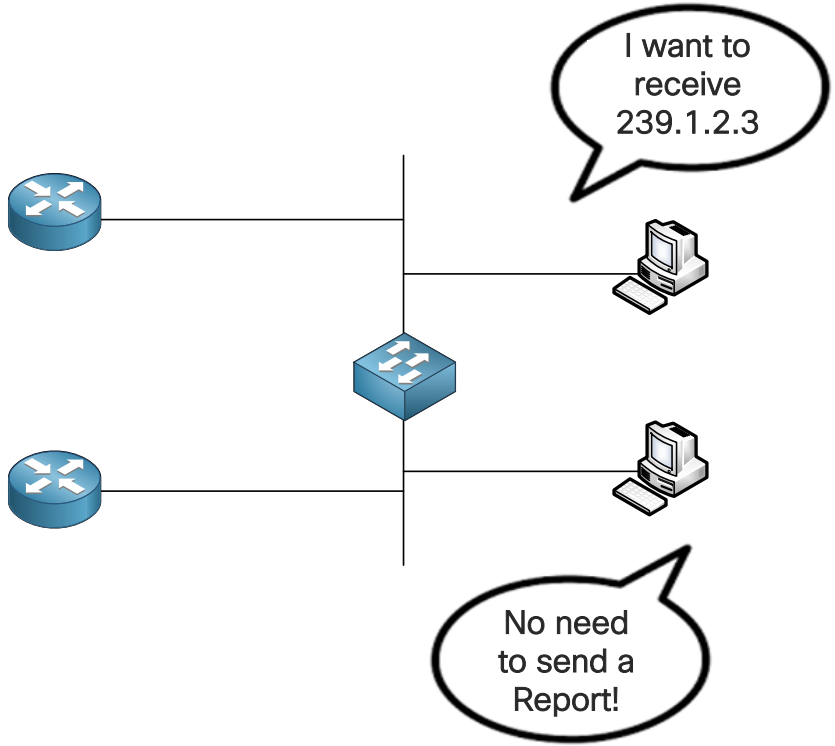
IGMPv1 Report





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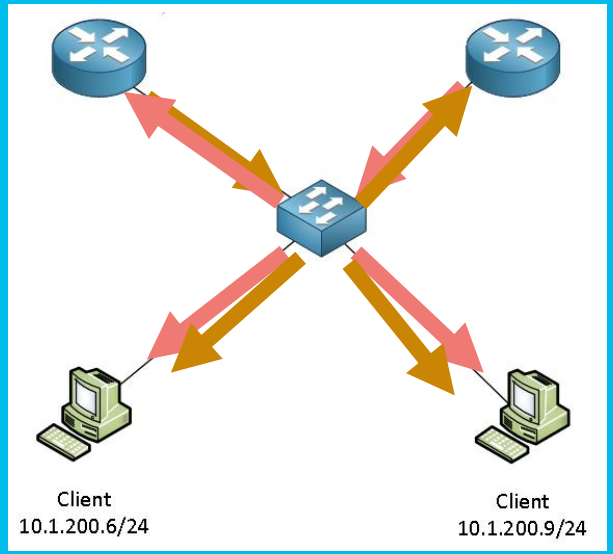
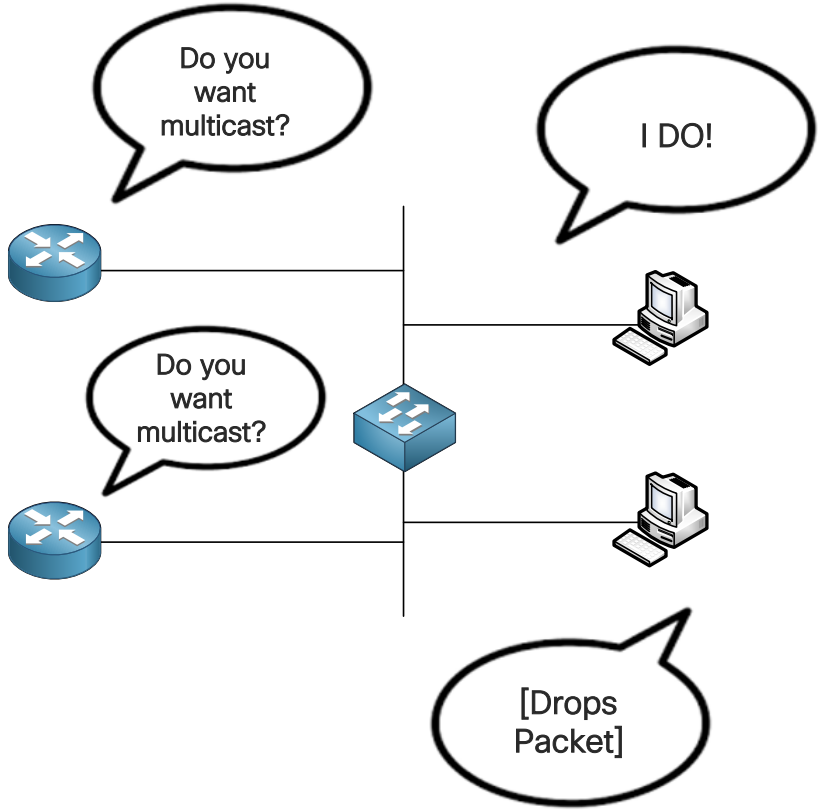
IGMPv1 Query





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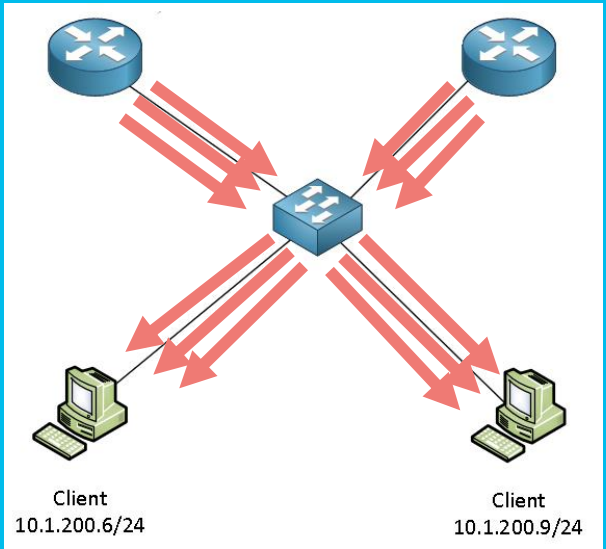
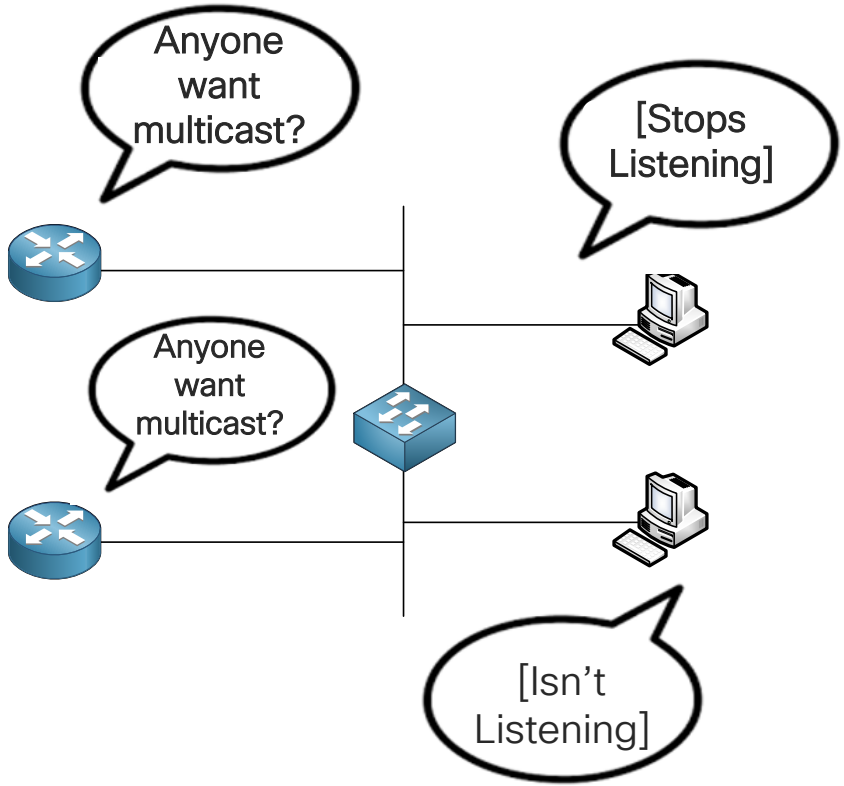
IGMPv1 Fail!





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IGMP: Raise Your Hand if You Want Multicast

Internet Group Management Protocol

- Two main messages
  - IGMP Membership Report: From the receiver to multicast router
  - IGMP Membership Query: From the multicast router to check interest
- Version 2 is the default version on Cisco devices

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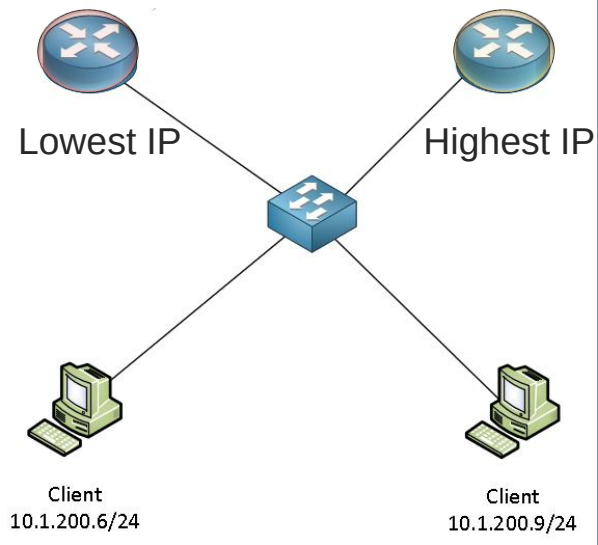
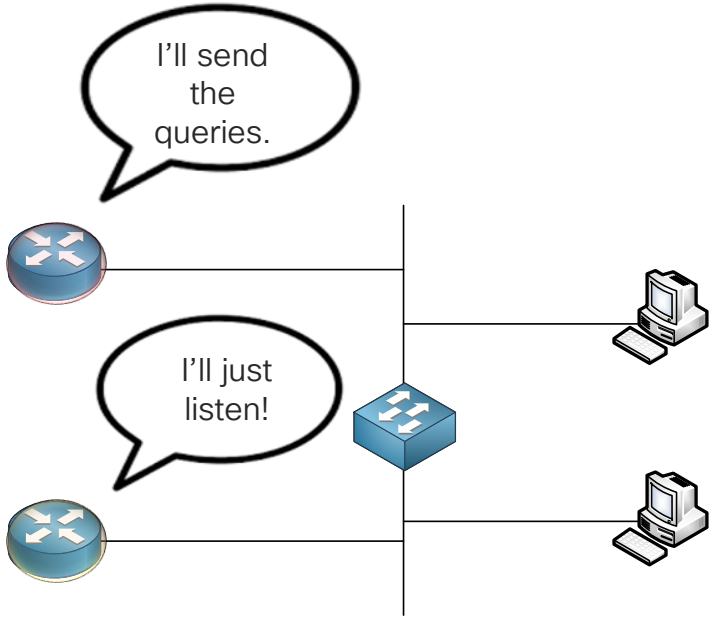
IGMPv2
Hold an Election!





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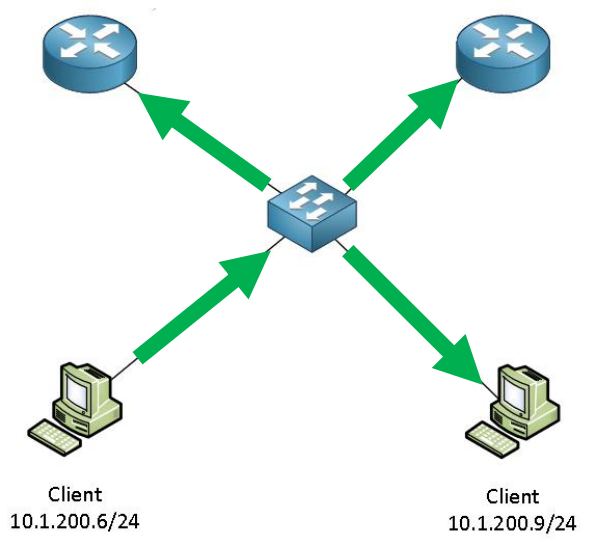
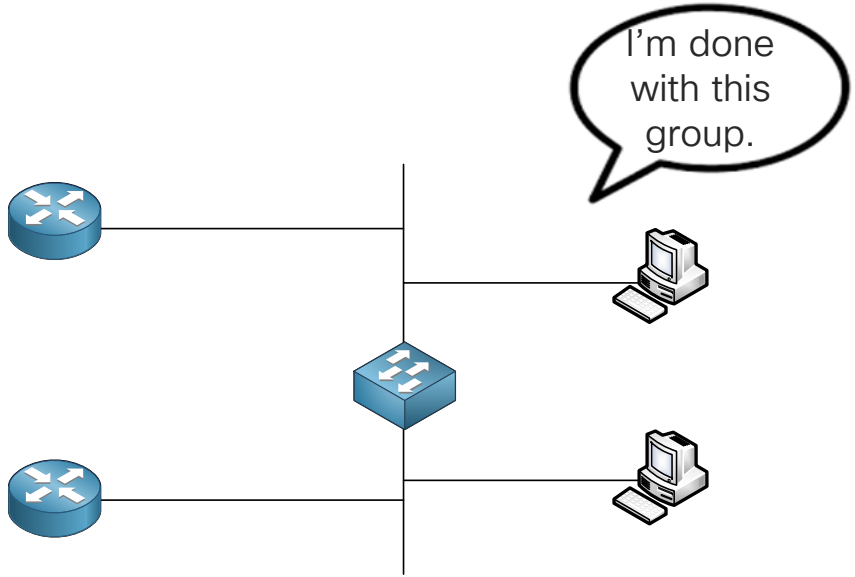
IGMPv2
Now You Can Leave!





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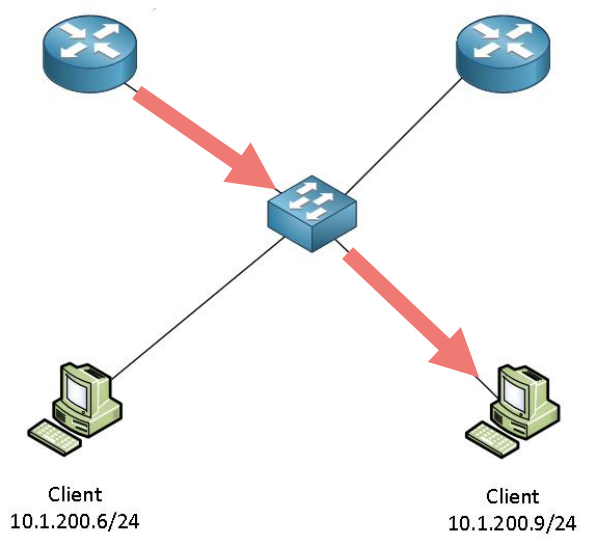
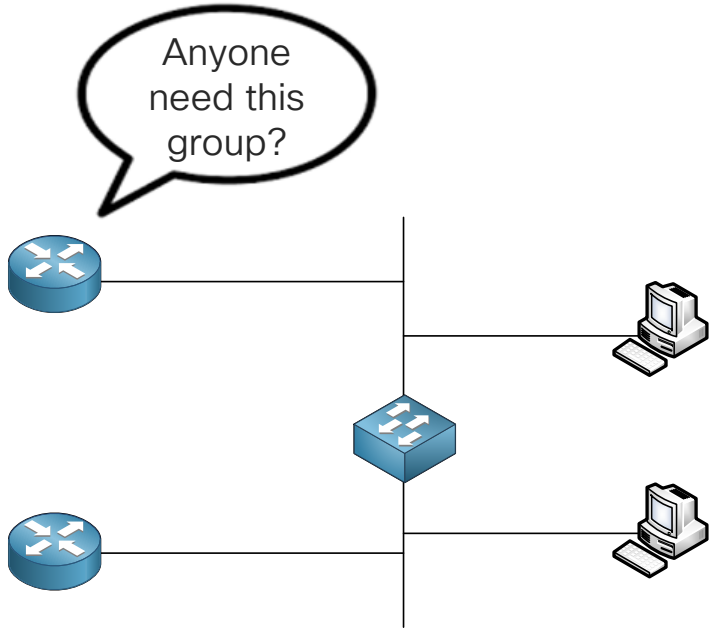
IGMPv2
Group-Specific Query!





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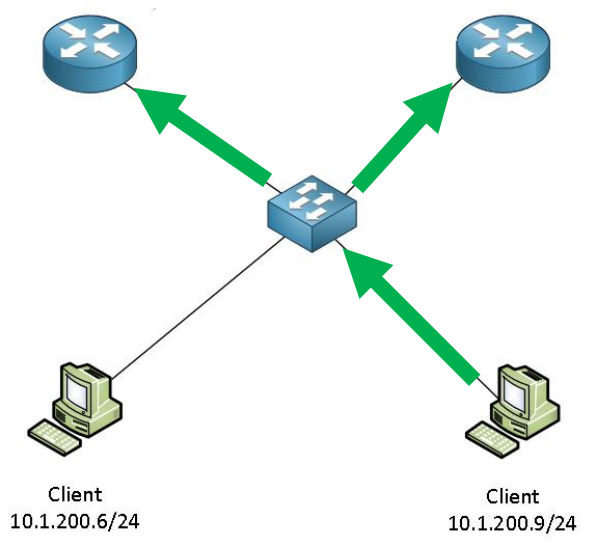
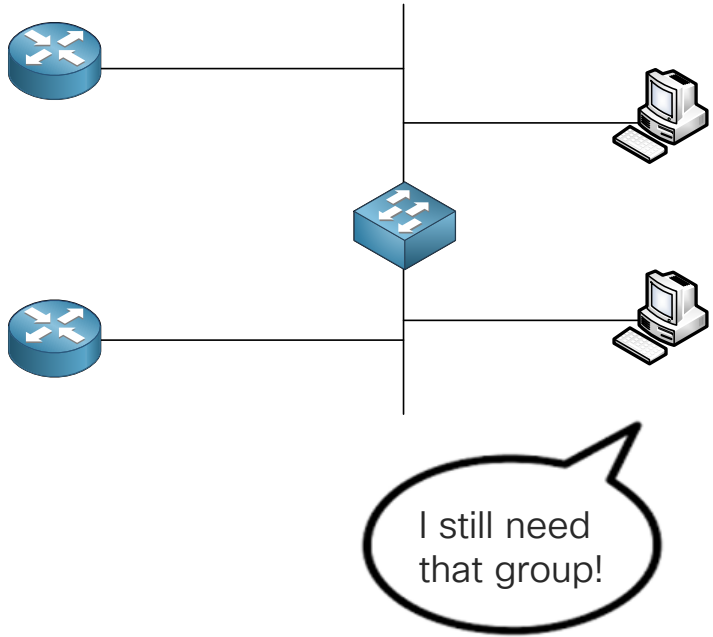
IGMPv2
Group-Specific Query!





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IGMP: Raise Your Hand if You Want Multicast

Internet Group Management Protocol

- Two main messages
  - IGMP Membership Report: From the receiver to multicast router
  - IGMP Membership Query: From the multicast router to check interest
- Version 3 is the newest version and has been around over 15 years

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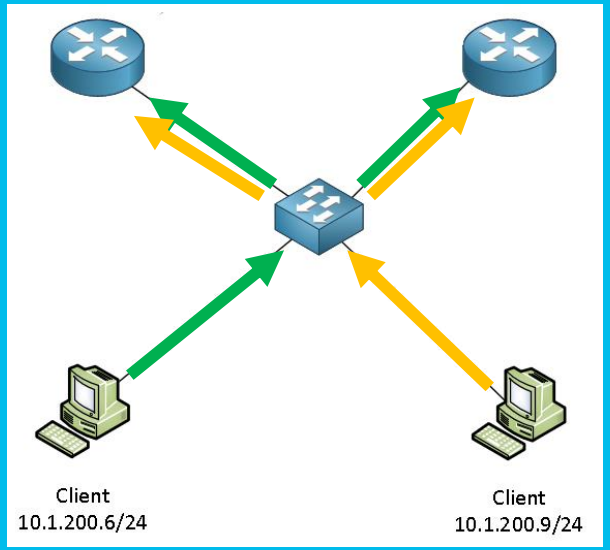
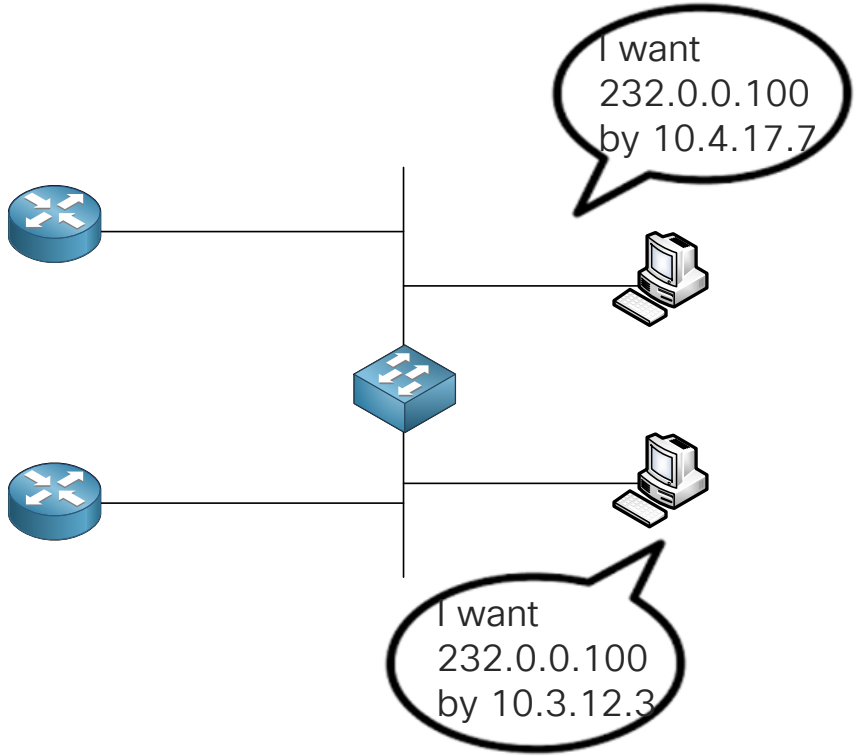
IGMPv3
Let's Talk Sources!





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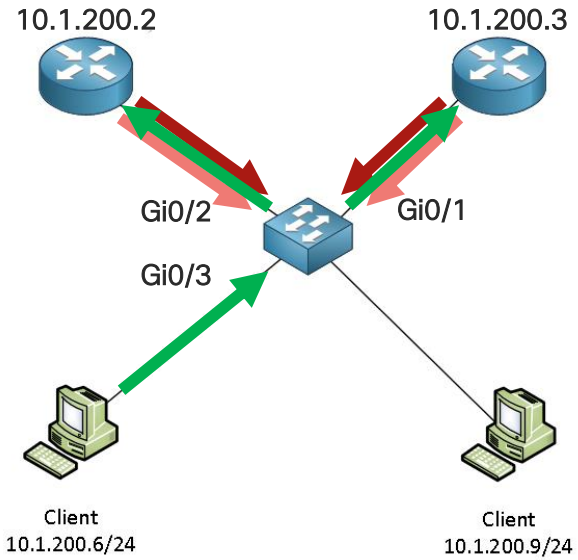
IGMP Snooping: Show Me Your Hands




```
L2-ACCESS#show ip igmp snooping querier
Vlan      IP Address               IGMP Version    Port
-----------------------------------------------------------
200       10.1.200.2               v2              Gi0/1
```

```
L2-ACCESS#sh ip igmp snooping mrouter
Vlan    ports
----    -----
 200    Gi0/1(dynamic), Gi0/2(dynamic)
```

```
L2-ACCESS#sh ip igmp snooping groups
Vlan      Group                    Version     Port List
-----------------------------------------------------------
200       239.1.2.3                v2          Gi0/3
```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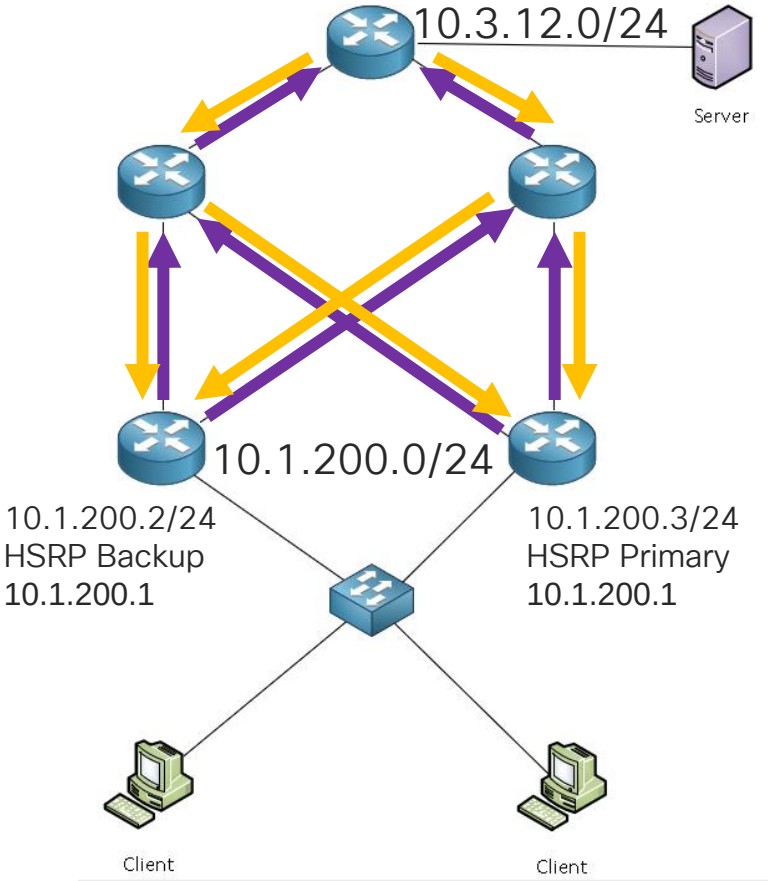
Multicast Routing

Unicast Control Plane Review



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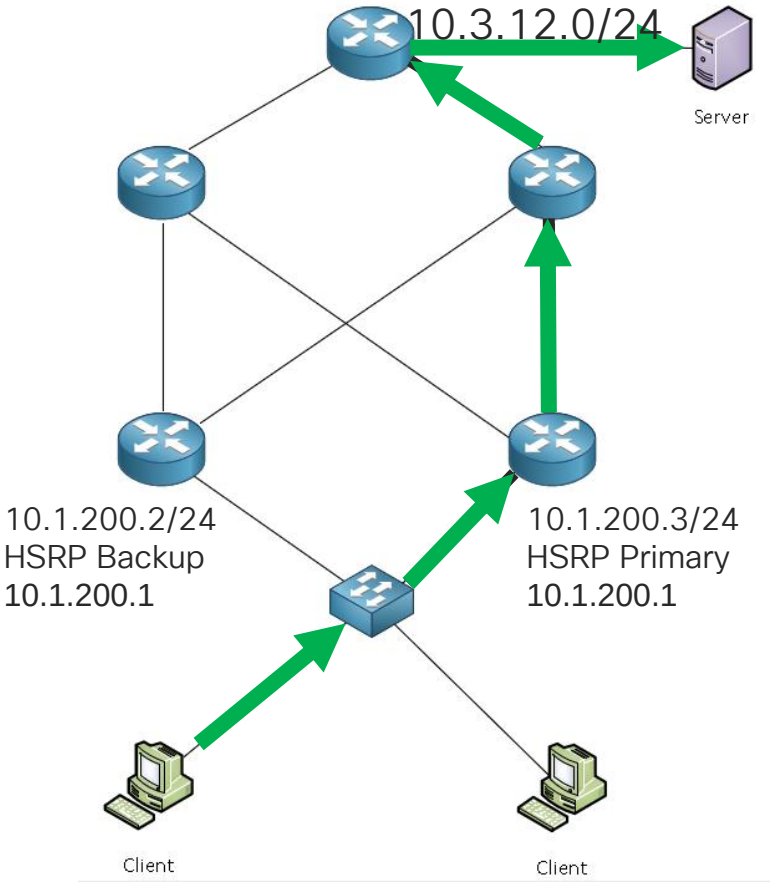
Unicast Data Flow Review



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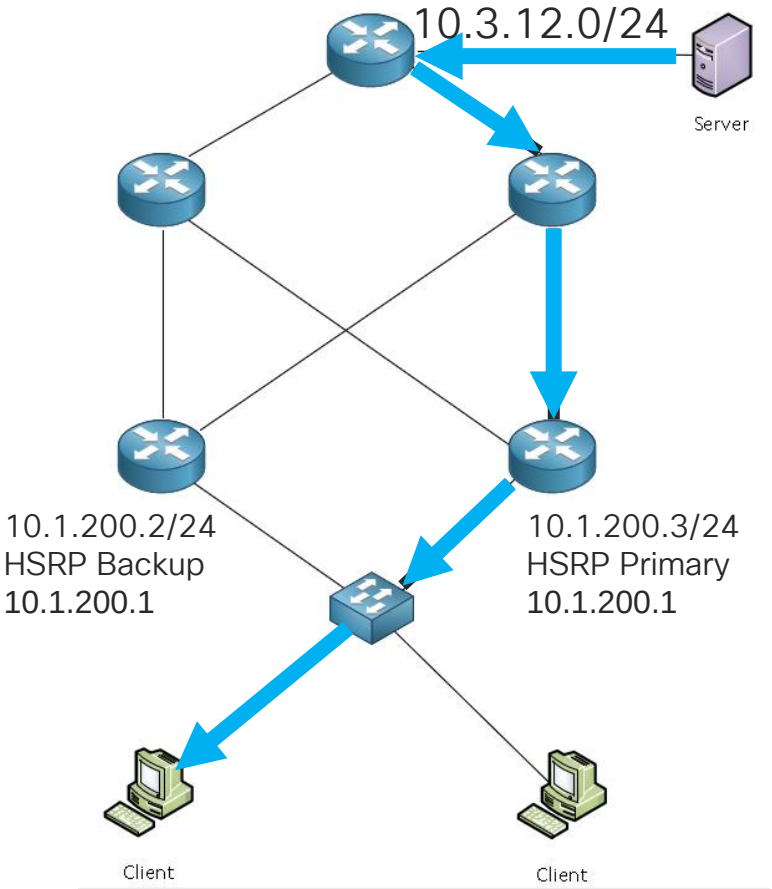
Unicast Data Flow Review



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Multicast routing is **not** enabled by default on Cisco devices

Enable multicast routing with the ***ip multicast-routing [distributed]*** global command

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Multicast Routing Explained

Protocol-Independent Multicast Basics

- PIM is a link-local protocol which works on a hop-by-hop basis
- PIM relies upon unicast routing decisions to build a loop-free multicast river

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Multicast Routing Explained

Protocol-Independent Multicast Modes

- PIM-DM (Dense Mode) is legacy and should not be used
- PIM-SM (Sparse Mode) is the current implementation
- PIM-SDM (Sparse-Dense-Mode) is deprecated and unused

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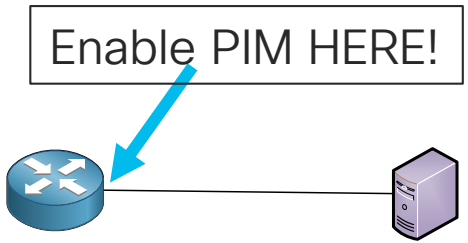
Multicast Routing Explained

Protocol-Independent Multicast Requirements

- Multicast traffic can only be forwarded on interfaces with PIM enabled via the ***ip pim (mode)*** command
- PIM **MUST** be enabled toward the source in order to listen for multicast traffic!



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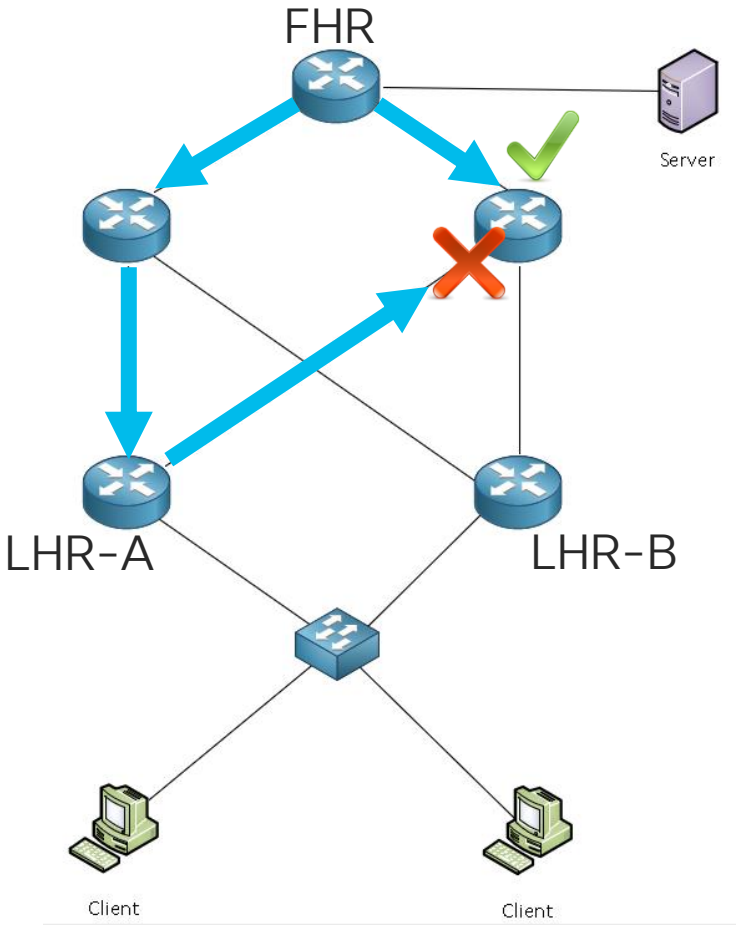
Multicast Routing Explained

Reverse Path Forwarding

- PIM uses a Reverse-Path Forwarding (**RPF**) check to ensure multicast routing is loop-free
  - When multicast data packets are received by a multicast router, the interface is checked based on where the source of the multicast river is located
  - If the interface is the same one which would be used to forward traffic to the source via the unicast routing table, the packet is allowed
  - If not, the packet is dropped



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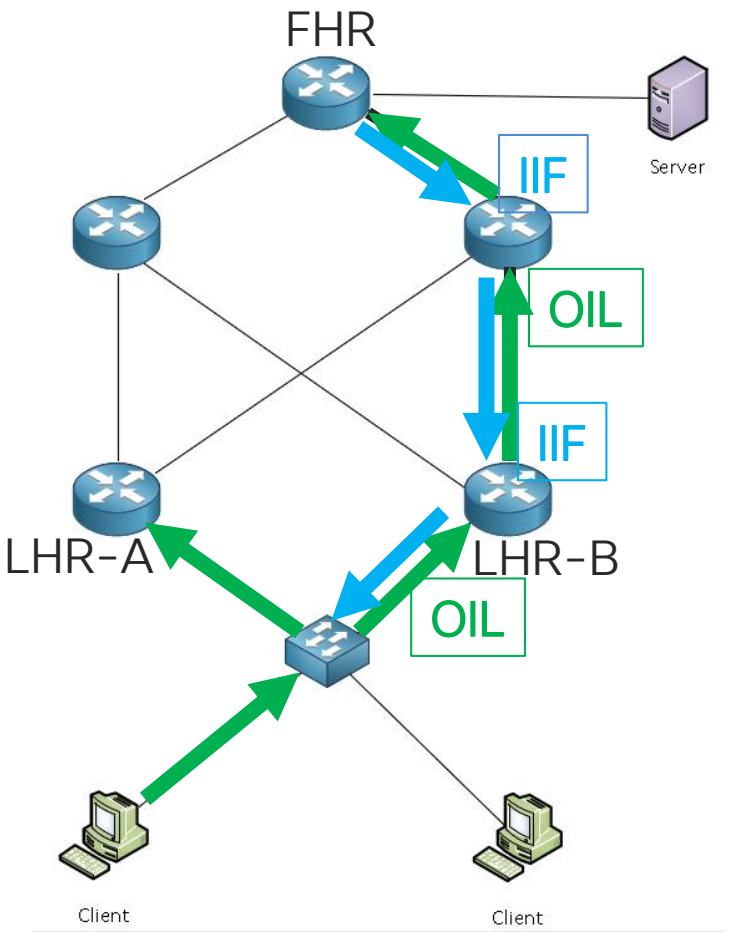
Multicast Routing Explained

Incoming Interface / Outgoing Interface List

- Traffic flows from the source of the river downstream to receivers
- The interface which is used to route upward to the source of the multicast river is the **incoming** interface (**IIF**) – One allowed per router, per group
- The interface which is used to route away from the source of the multicast river is the **outgoing** interface (**OIL**) – Based on PIM Joins received



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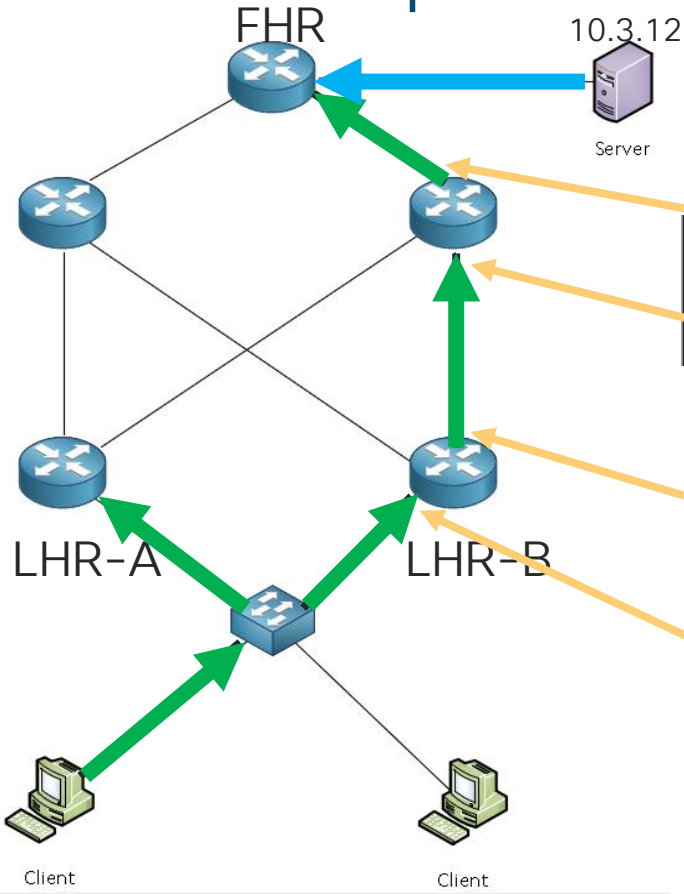
Multicast Loop-Free Forwarding: Joining




```
(10.3.12.2, 232.0.0.100), 00:25:55/00:03:14, flags: sT
  Incoming interface: GigabitEthernet0/1, RPF nbr 10.2.14.1
  Outgoing interface list:
    GigabitEthernet0/2, Forward/Sparse, 00:25:50/00:03:14
```

```
(10.3.12.2, 232.0.0.100), 00:27:22/00:02:32, flags: sTI
  Incoming interface: GigabitEthernet0/1, RPF nbr 10.2.104.4
  Outgoing interface list:
    GigabitEthernet0/2, Forward/Sparse, 00:27:22/00:02:32
```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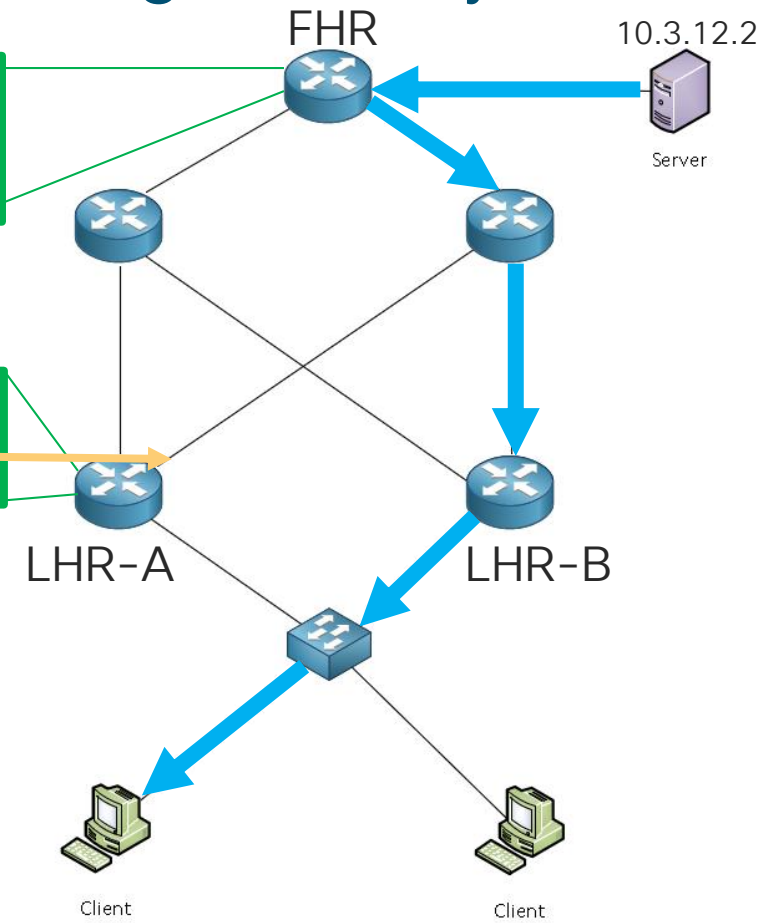
Multicast Loop-Free Forwarding: Delivery

```
(10.3.12.2, 232.0.0.100), 00:30:59/00:03:00, flags: sT
  Incoming interface: GigabitEthernet0/2, RPF nbr 0.0.0.0
  Outgoing interface list:
    GigabitEthernet0/4, Forward/Sparse, 00:30:58/00:03:00
```

```
(10.4.17.7, 232.0.0.100), 00:38:22/00:02:37, flags: sPT
  Incoming interface: GigabitEthernet0/3, RPF nbr 10.2.45.4
  Outgoing interface list: Null
```



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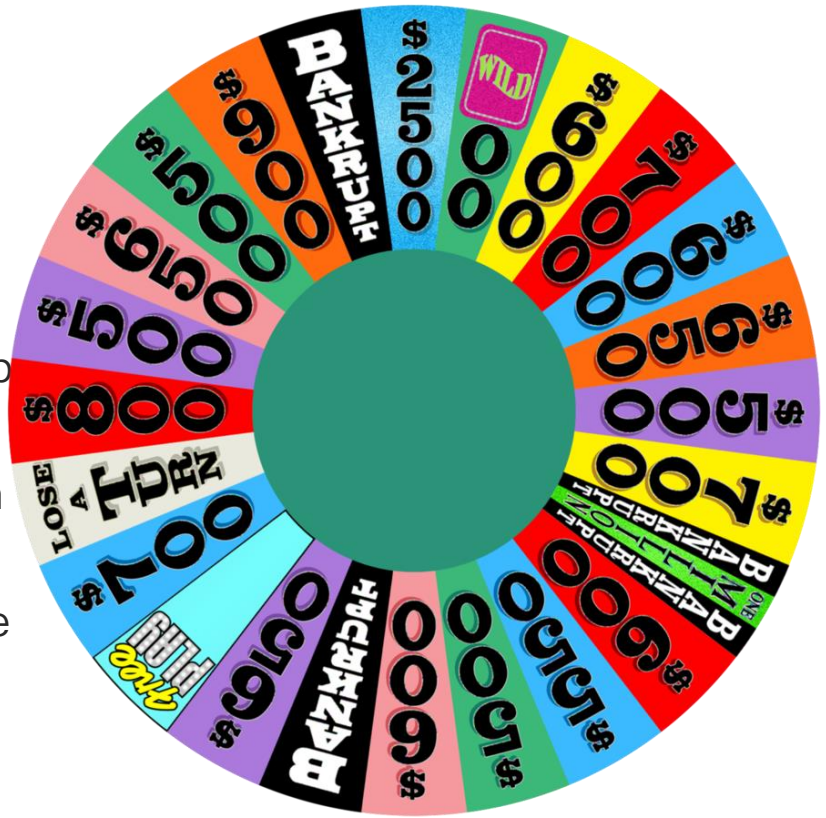
Any-Source Multicast

Wheel of Sources!

Any-Source Multicast

- Used in cases where the receiver does not know the sources sending to a multicast group
- ASM is the only option in IGMP version 1 and 2, and is supported but not required in version 3
- Multicast routers must learn which sources are sending to the multicast group in order to deliver traffic



By MarioGS - https://commons.wikimedia.org/w/index.php?curid=29159295

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Not Without My RP: The Any-Source Multicast Story

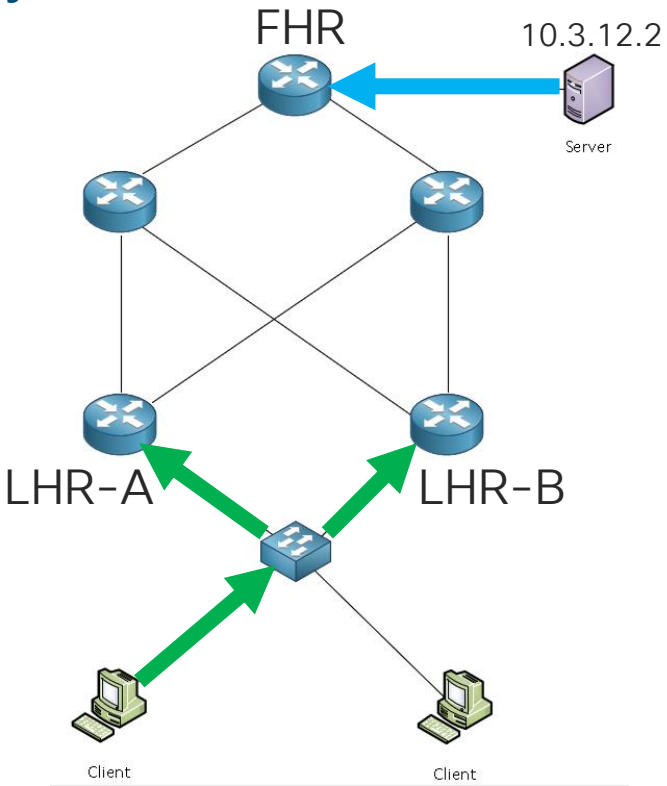
The Summer Blockbuster Movie!

Starring:

- The First-Hop Router

Co-Starring:

- The Last-Hop Router Twins



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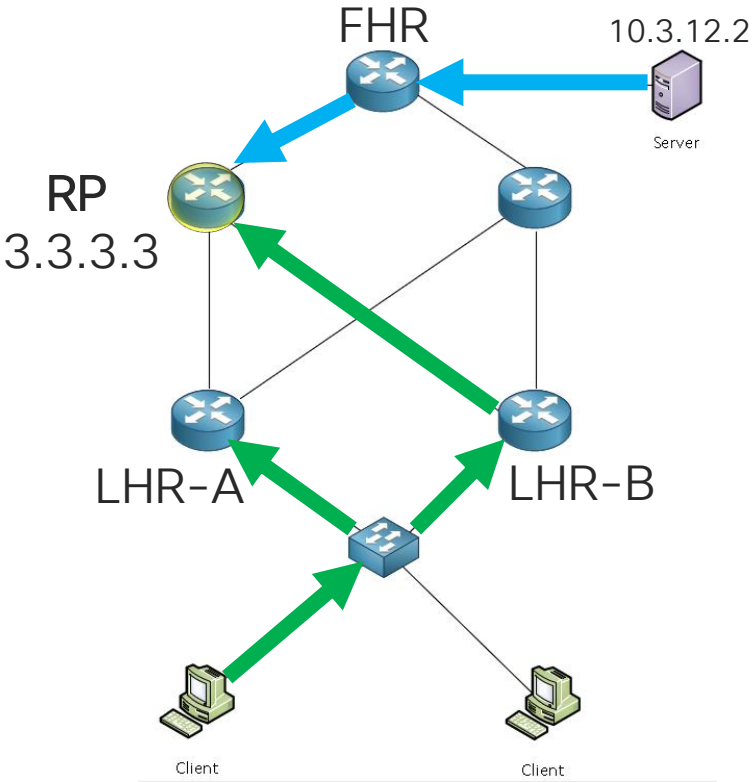
Not Without My RP: The Any-Source Multicast Story

The Summer Blockbuster Movie!

And Introducing…

- The Rendezvous Point!



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The Rendezvous Point: Multicast Food Delivery

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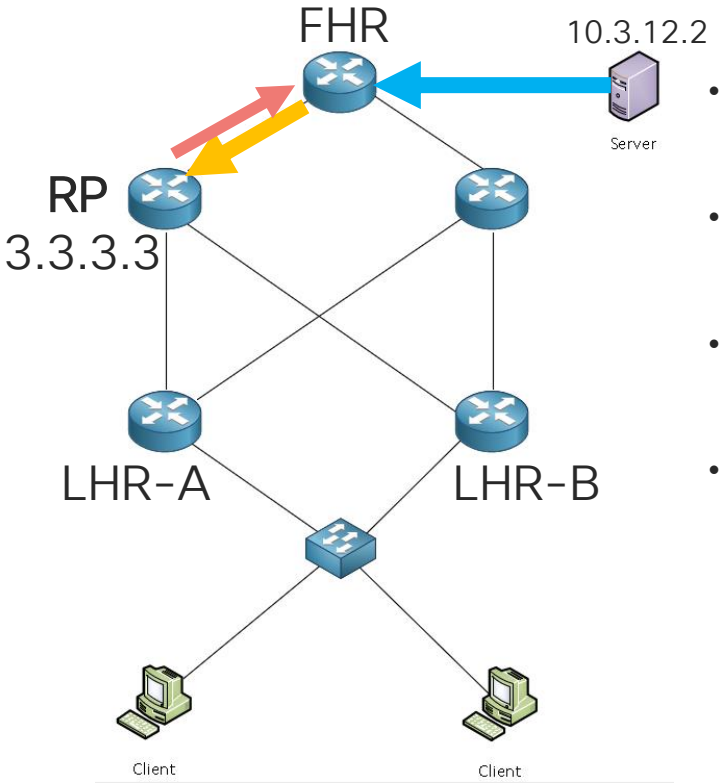
PIM Source Register

A Restaurant Signs Up To Be Listed!



- When a source sends multicast traffic to a group, it hits the FHR first
- FHR sends a PIM Register unicast message encapsulated in PIM Tunnel to RP
- At this point the multicast traffic is being sent in unicast tunneling to RP
- What happens next depends on whether any receivers exist yet. If there are no receivers, RP sends PIM Register Stop Message to FHR

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Welcome to RP Eats! What Are You Looking For?

I really want Paella...

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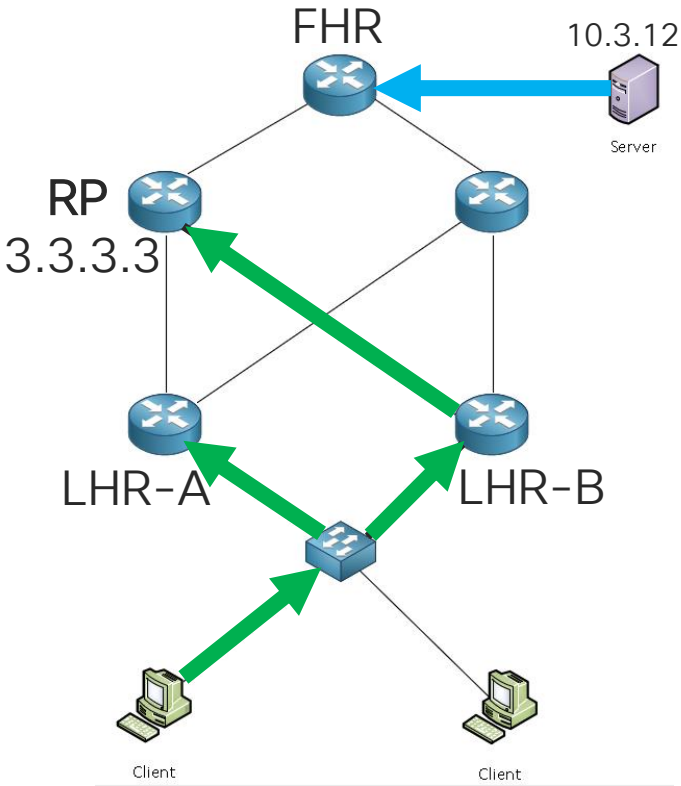
(*, G) PIM Join: The RP River

Order Paella!



- Receiver signals interest in multicast group
- Designated multicast router for the segment forwards PIM Join toward RP
- RPF Check is conducted against RP address, NOT source address!

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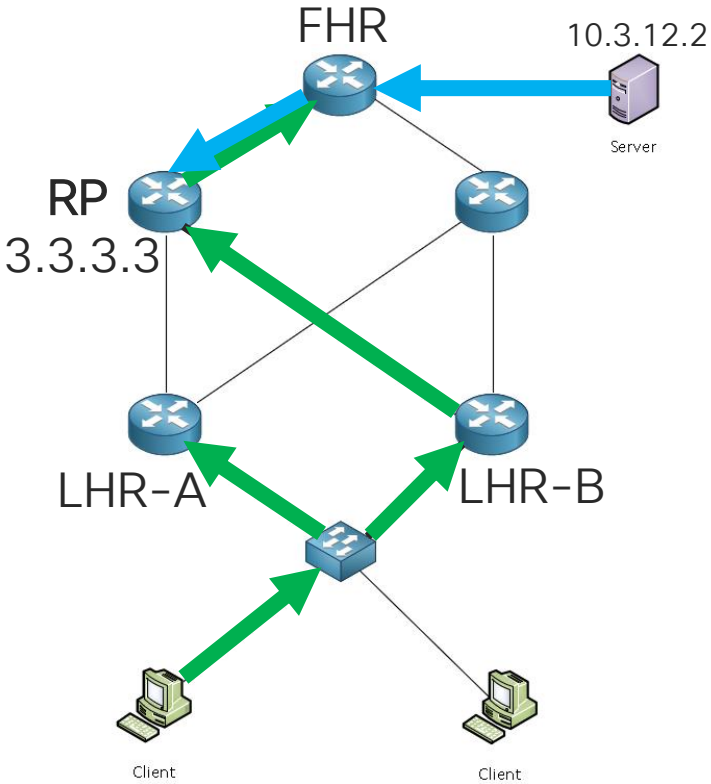
(S, G) PIM Join From RP: The Source River

Placing the Order



- RP sends a PIM Join toward FHR
- FHR adds interface facing RP to OIL
- RP has now joined the source river

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Order Placed!

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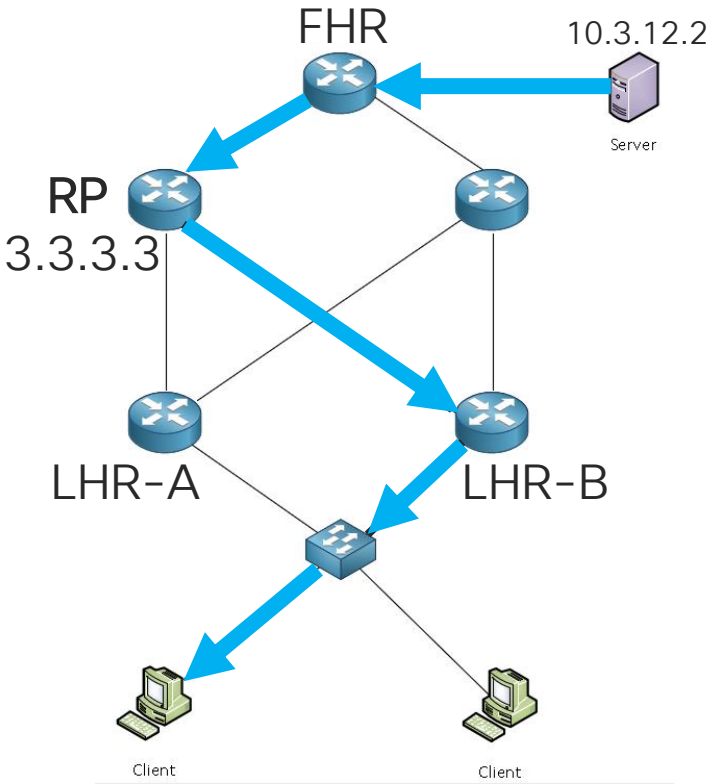
RP River Traffic Flow

Your Order Has Been Placed!



- Multicast traffic flows down the RP/shared river following OIL
- LHR now learns multicast source
- While traffic flows to receiver, LHR now builds a separate PIM Join directly to the source

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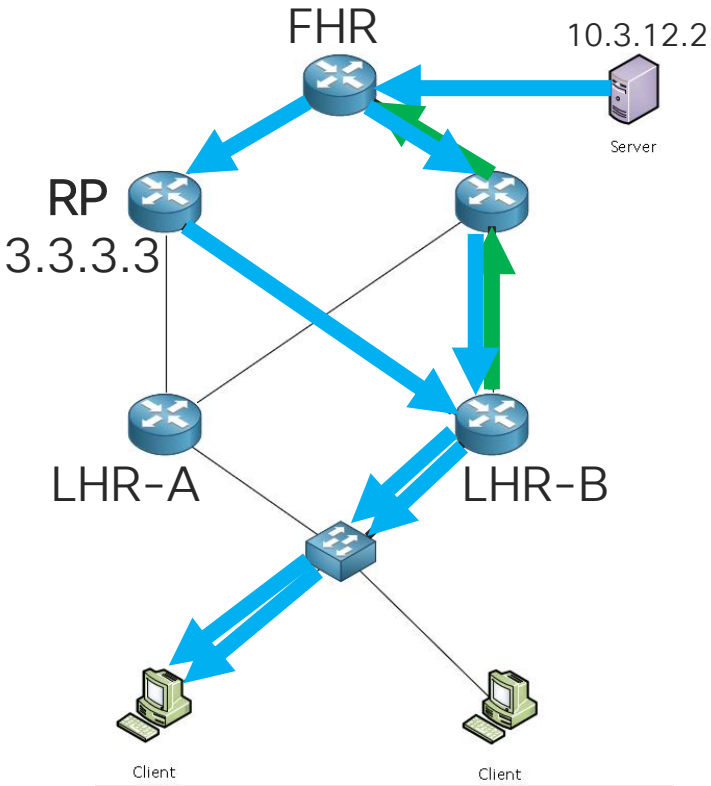
(S, G) PIM Join From LHR: The Source River

Time For Order Delivery!



- LHR sends new PIM Join toward multicast source, using RPF check against source instead of RP
- FHR adds interface to OIL and traffic flows down OIL to LHR using source river
- LHR and receiver now have two multicast feeds but only need one

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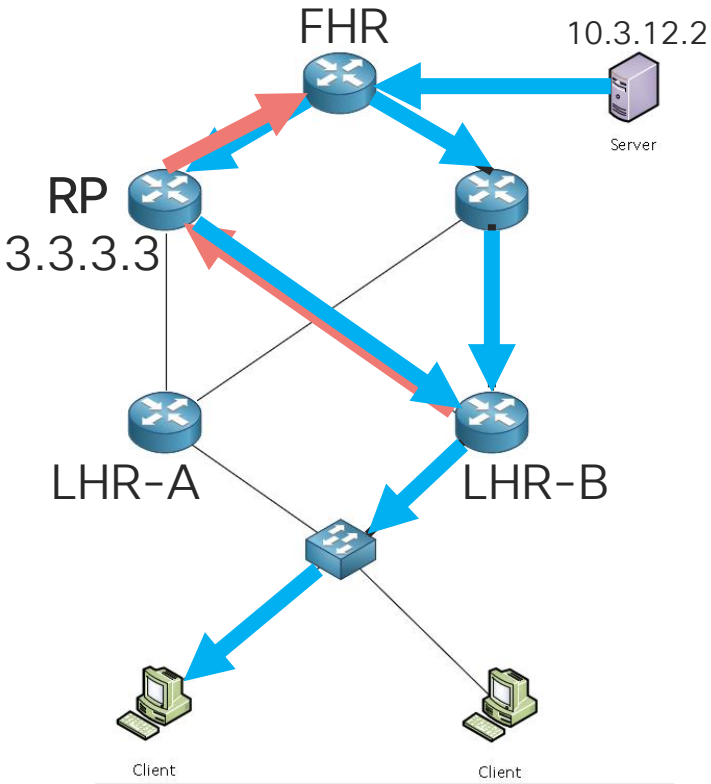
(*, G) Prune From LHR to RP

Thanks for Using RP Eats. See You Next Time!



- LHR sends a PIM Prune message to the RP for the (*,G) entry
- RP prunes the interface from OIL and ceases delivering traffic
- If there are no other OIL built for that (S,G) then the RP will prune itself

cisco Live!

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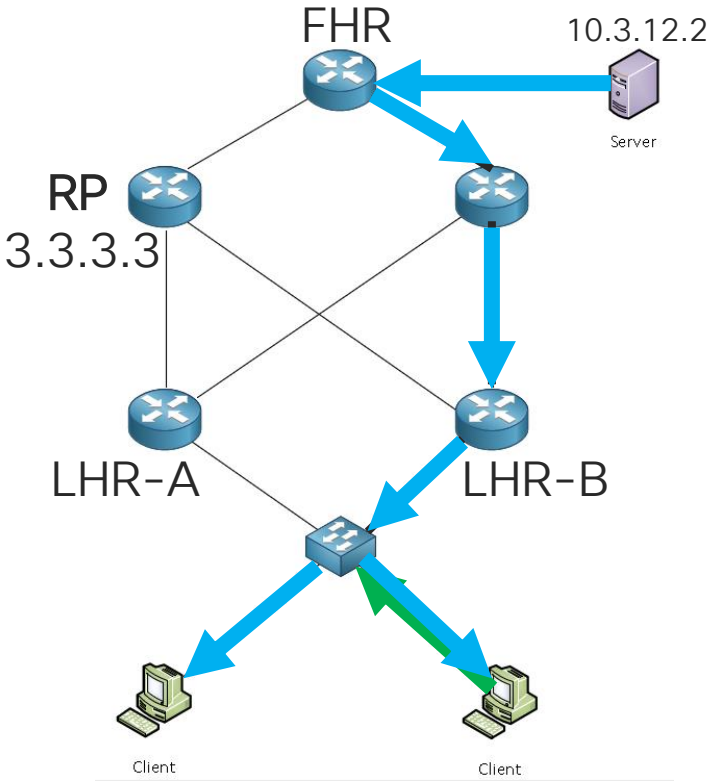
What If We Add Another Receiver?

Shortcutting the River



- If another receiver downstream from the OIL signals an interest, canals do not need to be rebuilt
- Multicast ‘trench’ takes places where interface is added to OIL and traffic flows from closest multicast router on the source river to receiver downstream

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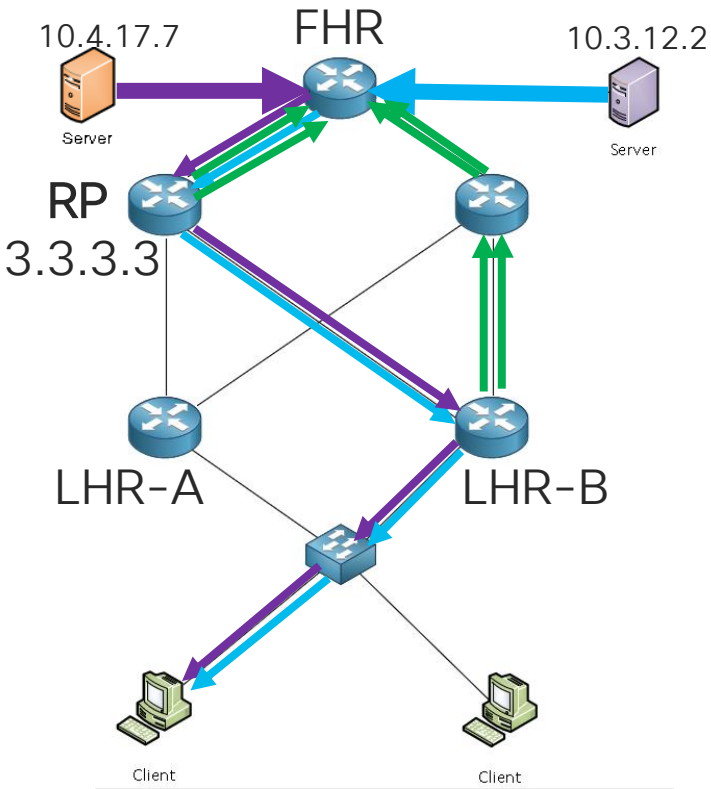
What If We Have Two Sources for the Same Group?

Any-Source is Every-Source



- All steps are the same until the RP needs to join the source river for multicast group
- RP will send (S,G) for each source registered for that multicast group and join multiple source rivers
- Multiple source feeds will be delivered down RP river to LHR and receiver
- LHR will also send (S,G) Join to each source and deliver multiple feeds

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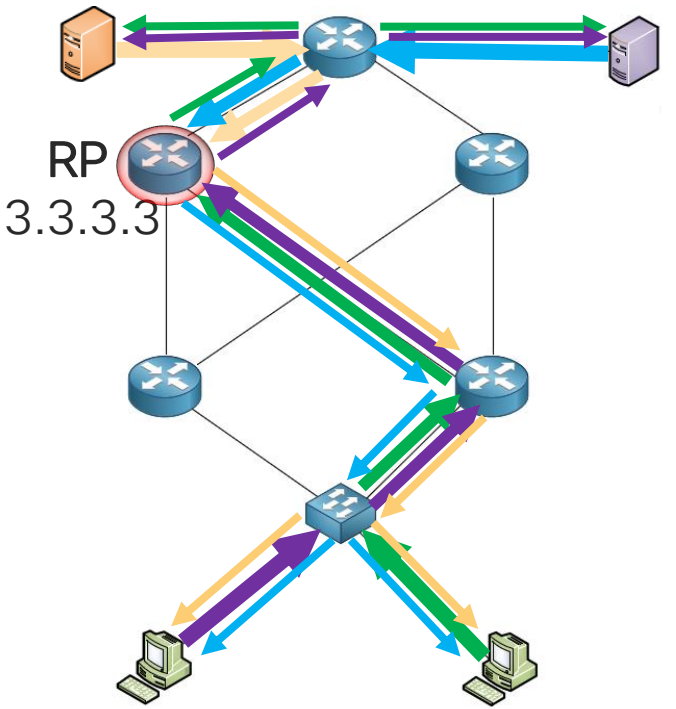
BiDirectional PIM

Many-to-Many Multicast Solution



- Multicast could require immense state tracking – for each source there is tracked multicast (S,G) pair
- BiDir PIM solves this by eliminating source rivers altogether – this means RP is always in the data plane
- The RPF Check is eliminated. Instead each segment determines who will forward traffic by electing Designated Forwarder – similar to Spanning Tree

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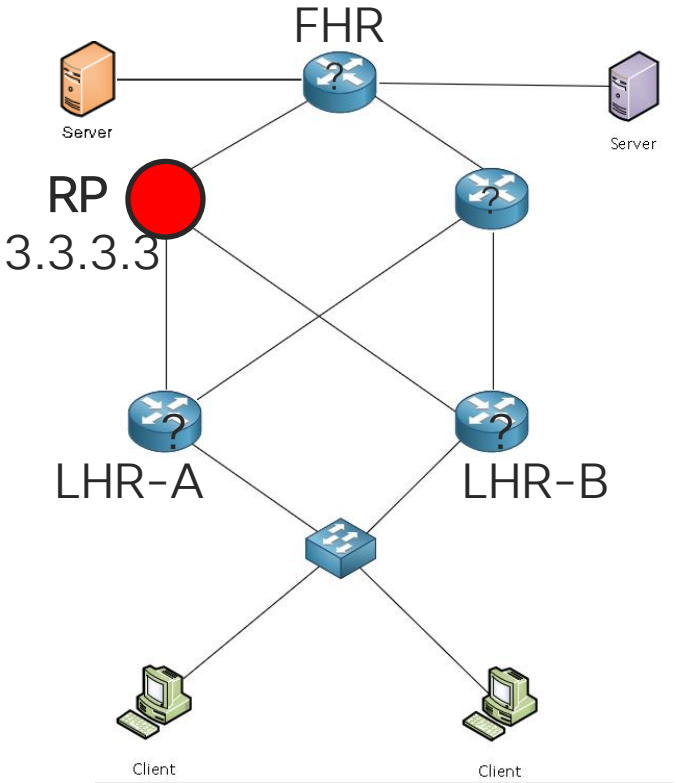
Rendezvous Point Redundancy/ Dynamic RP

Rendezvous Points are Important!

We Need Redundancy and Dynamic Election!



RP Problems to Solve:

- How do all multicast routers agree on which one is the RP?
- When the RP fails in ASM, multicast traffic will fail if not already on source river. How do we provide redundancy?

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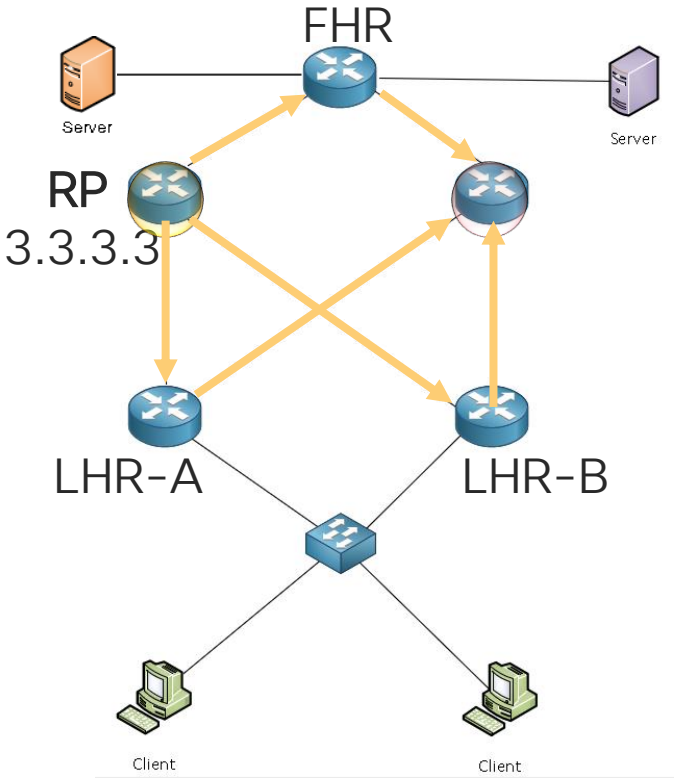
Solving Both Problems the Old Way

AutoRP: The Legacy Option



AutoRP Details:

- Uses Mapping Agent to listen for RP advertisements
- Dedicated multicast groups to learn/advertise RP addresses
  - 224.0.1.39 – Used by Candidate RP to advertise willingness to be an RP to MA

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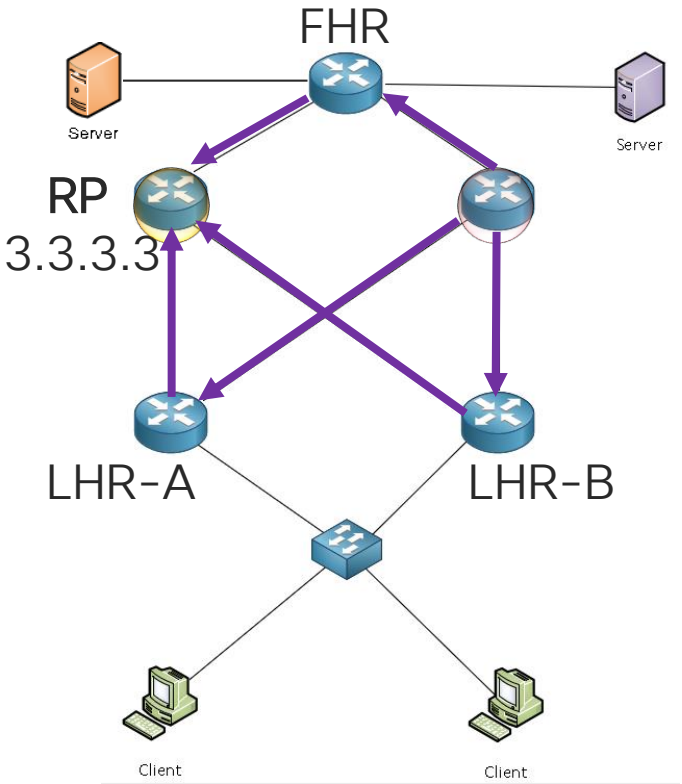
Solving Both Problems the Old Way

AutoRP: The Legacy Option



AutoRP Details:

- Uses Mapping Agent to listen for RP advertisements
- Dedicated multicast groups to learn/advertise RP addresses
  - 224.0.1.39 – Used by Candidate RP to advertise willingness to be an RP to MA
  - 224.0.1.40 – Used by MA to advertise elected RP to the rest of the multicast routers
- Only these two groups run in Dense Mode

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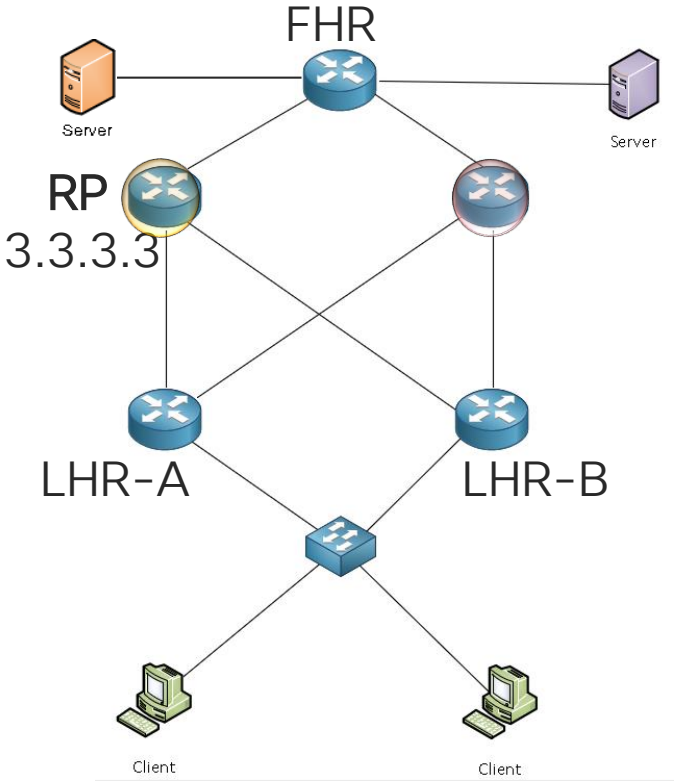
Solving Both Problems the New Way

Bootstrap Router: The Better Option



BSR Details:

- Bootstrap Router listens for RP advertisements (Similar to MA in AutoRP)
- Multicast routers learn the elected BSR in native PIM Hellos

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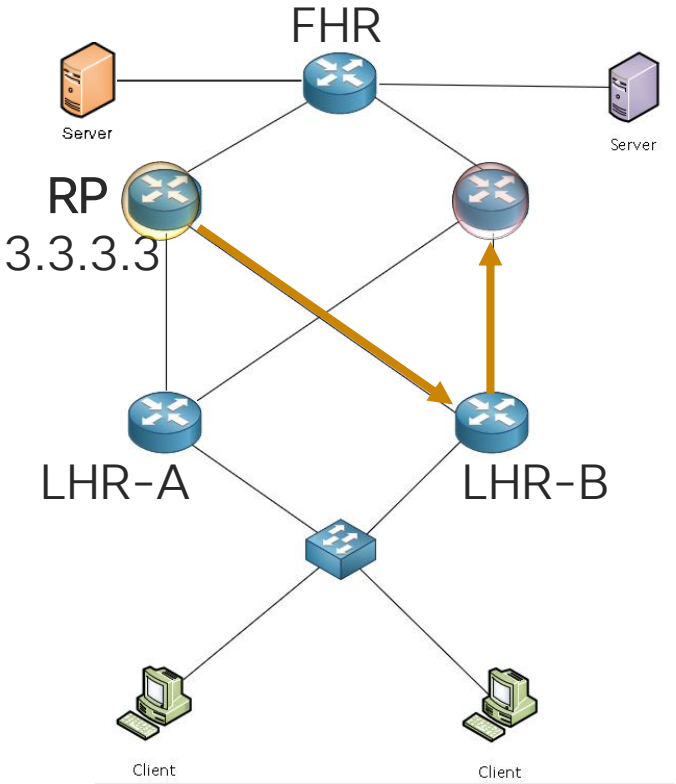
Solving Both Problems the New Way

Bootstrap Router: The Better Option



BSR Details:

- Bootstrap Router listens for RP advertisements (Similar to MA in AutoRP)
- Multicast routers learn the elected BSR in native PIM Hellos
- Candidate RPs send unicast message to active BSR advertising willingness to be RP
- When BSR chooses an RP it advertises the RP on hop-by-hop basis to all others

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Dynamic RP Caveat

Pay Attention to This One!

A dynamically learned RP will take precedence over a statically configured RP!

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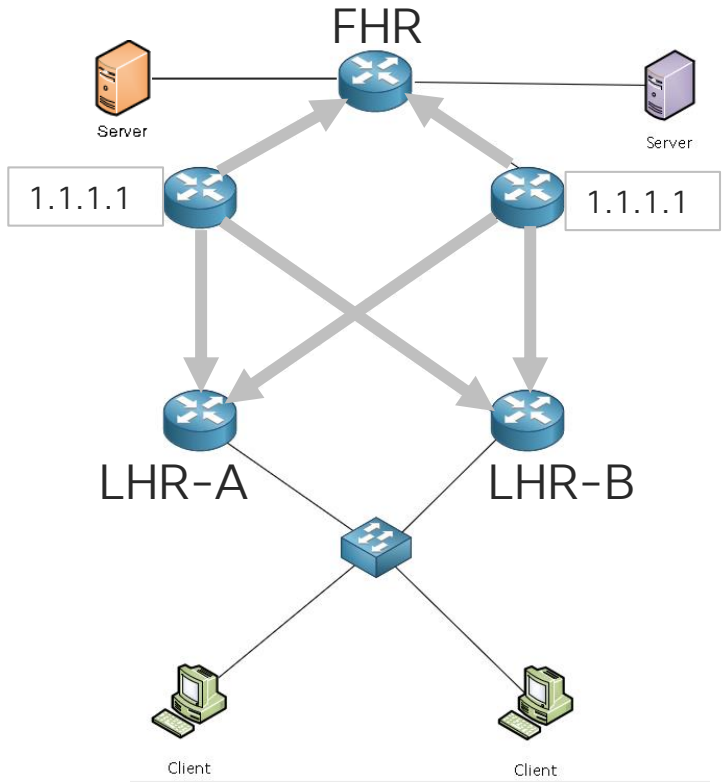
Anycast RP

What is Anycast?

- Technique to advertise a service from multiple devices using the same IP address
- In Anycast RP, advertise the same RP address into unicast infrastructure from multiple routers
- Ensure all multicast routers use it as the RP via any method (Static, BSR, AutoRP)
- Multicast routers will route PIM messages to closest RP (PIM Register, Join, Prune, etc.)



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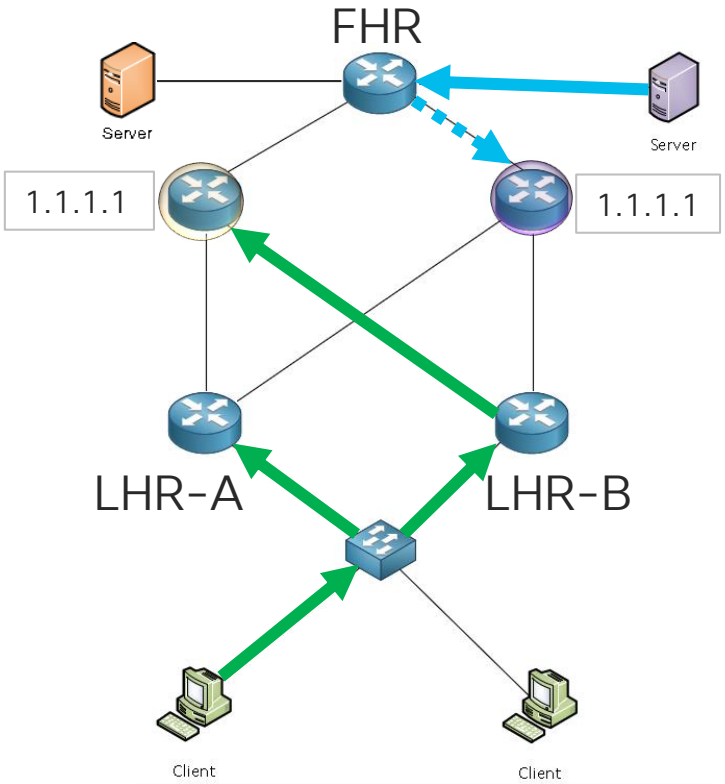
How Anycast RP Works (And How it Doesn't)

See If You Can Spot The Problem!



Steps:

- Source sends to FHR / Receiver sends IGMP Report
- LHR sends PIM Join to 1.1.1.1 / FHR sends PIM Register to 1.1.1.1
- **Disaster!** The PIM Join is forwarded to an RP with no sources

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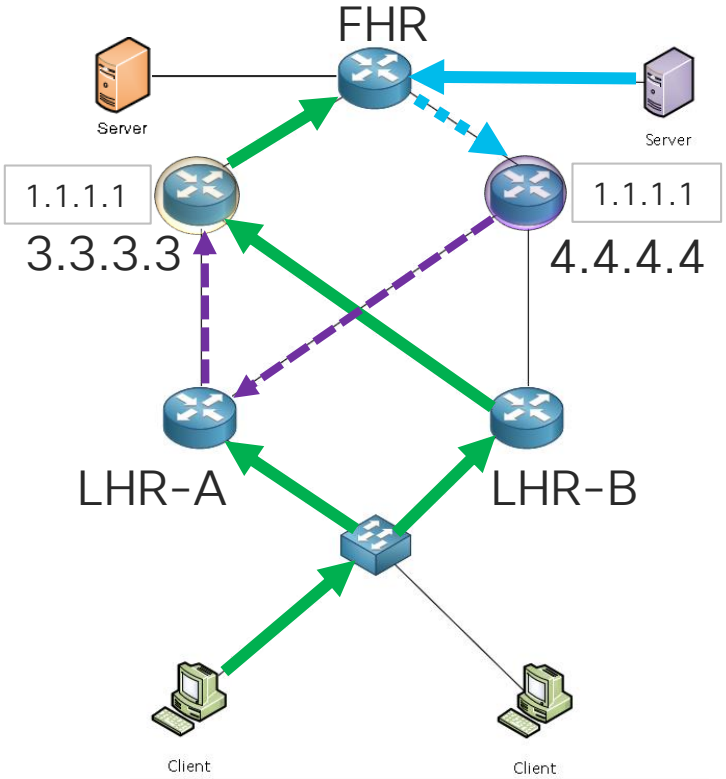
How Do We Resolve This?

All RPs Need to Know All Sources



Option: Multicast Source Discovery Protocol

- Uses unique interfaces to send messages between Anycast RPs (3.3.3.3 / 4.4.4.4)
- When any RP receives PIM Register, sends MSDP Source Active message to other Anycast RPs
- This message contains the IP of source and group address, if another RP has active PIM Joins and OIL for these groups, it triggers that RP to build PIM Join to source

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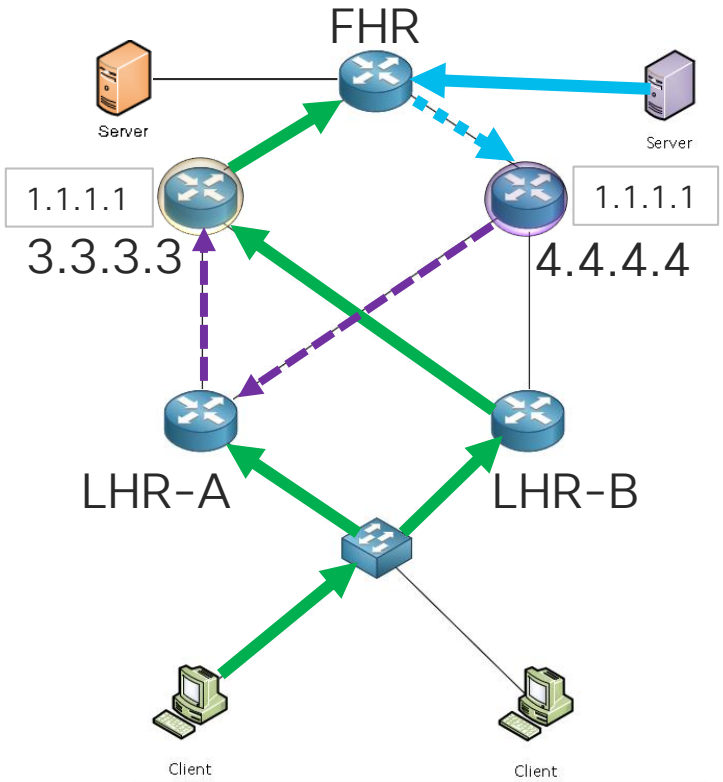
How Do We Resolve This?

All RPs Need to Know All Sources

NEXUS ONLY



Option: Anycast with PIM (RFC 4610)

- Uses native PIM Messaging to share sources, still requires unique addresses
- Statically configure Anycast PIM neighbors and when PIM Register is received, the RP will forward the PIM Register to other RPs
- Anycast RP neighbors acknowledge with PIM Register Stop and send PIM Join toward source if there are receivers

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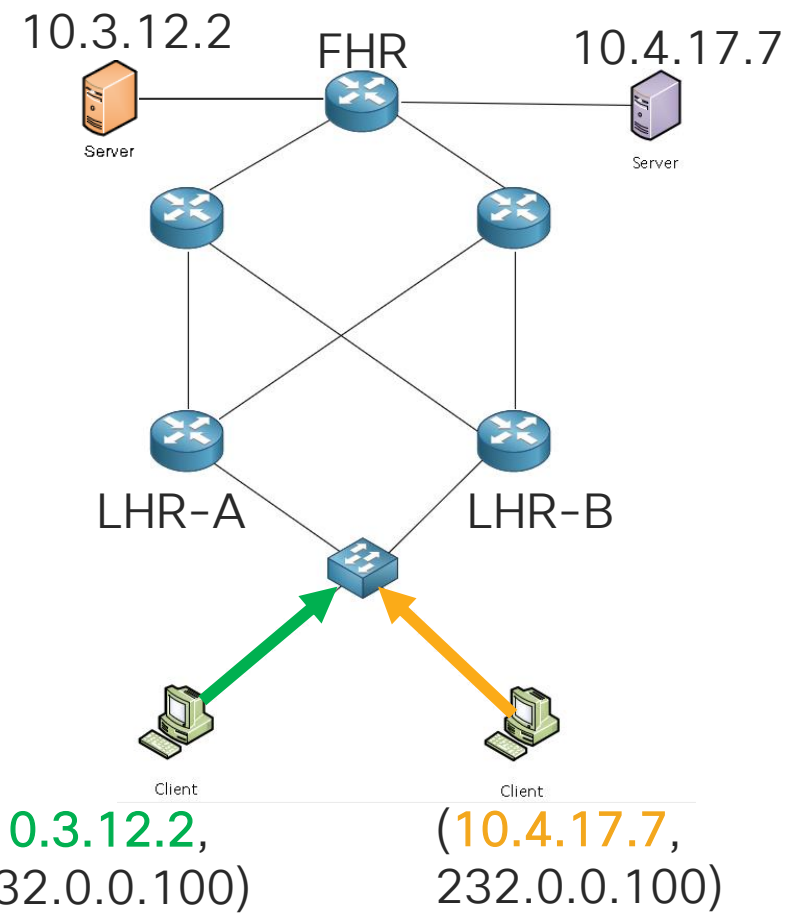
Source-Specific Multicast

What is Source-Specific Multicast?

- Multicast solution that allows receivers to signal the multicast group and source from which they want to receive traffic
- Requires receivers to know sources and use IGMPv3 Report to request source and group pair
- Uses reserved multicast group address range 232.0.0.0/8
- Because the (S,G) pair is specific, a different (S,G) could use the same multicast group address without merging streams



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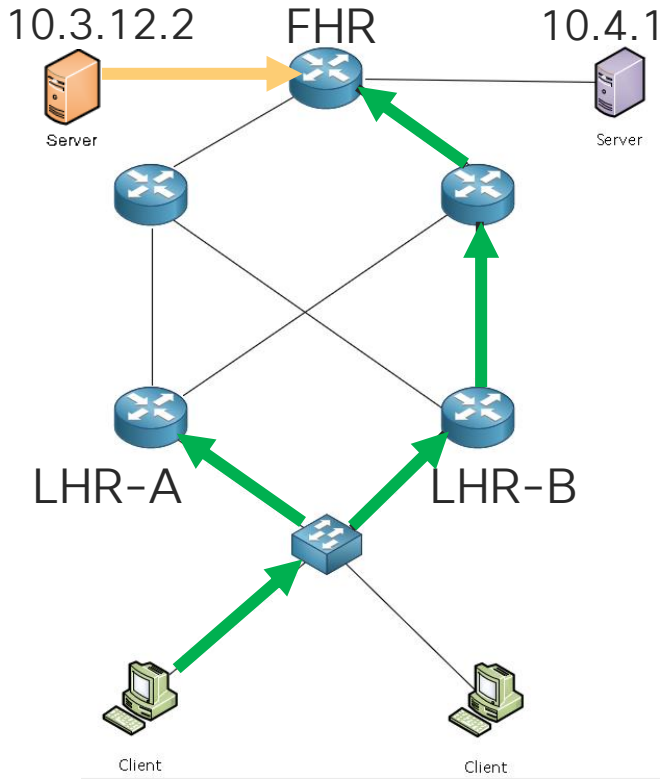
How Is SSM Different Than ASM?



(10.3.12.2, 232.0.0.100)

- Because the source is known ahead of time through some means, no need for an RP
- Multicast routers build (S,G) PIM Joins toward the source, no need for (*,G) to an RP

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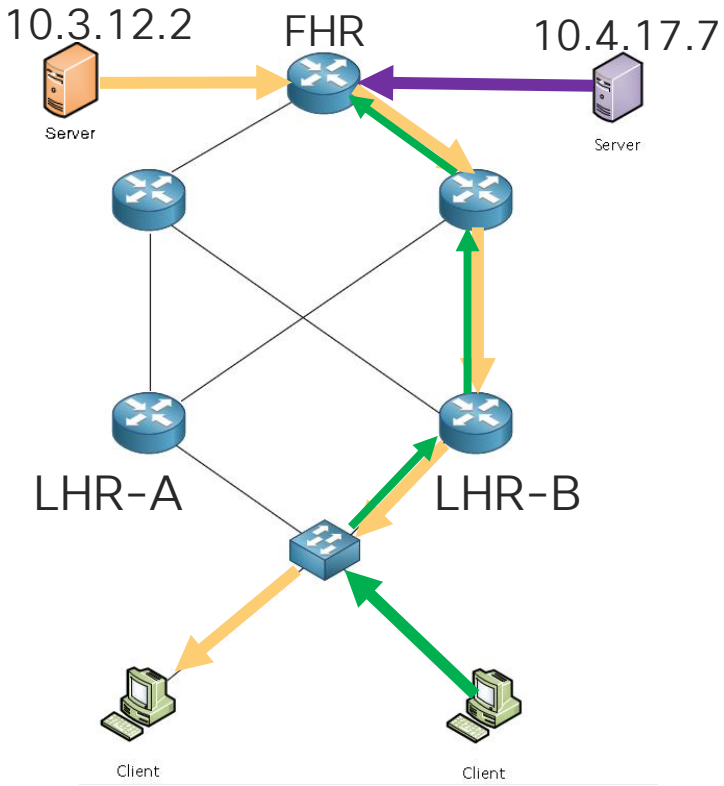
How Is SSM Different Than ASM?



(10.3.12.2, 232.0.0.100) (10.4.17.7, 232.0.0.100)

- SSM traffic is based on (S,G) pair. Even if the group address is same, a flow will be different if the source is different also
- The multicast routers will treat this Join as a separate flow (as it IS a separate flow) and it will follow the normal PIM Join process to the FHR

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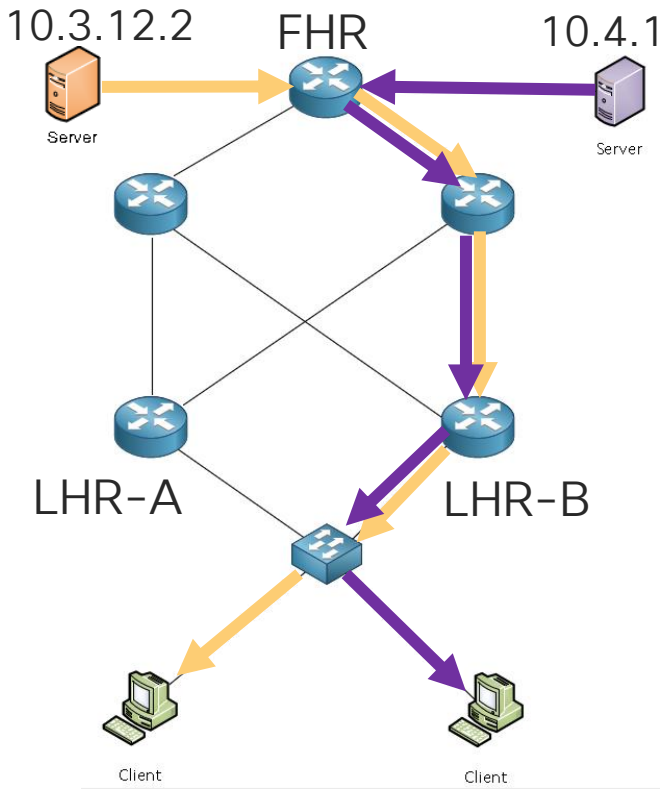
How Is SSM Different Than ASM?



(10.3.12.2, 232.0.0.100) (10.4.17.7, 232.0.0.100)

- SSM is far less complex than ASM but has more stringent requirements:
  - IGMPv3 must be used to request a specific source
  - A method outside multicast must exist for receivers to learn source/group pairs in order to request them (Channel Guide, Browser, etc)
  - SSM is mainly useful for one-to-many applications, does not fit a many-to-many model well

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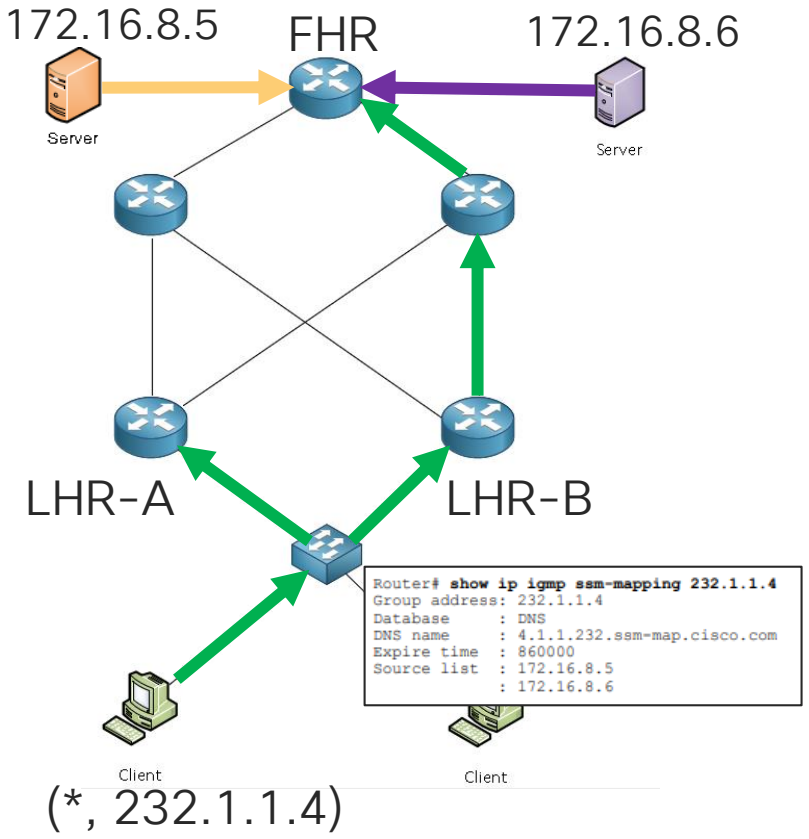
SSM Static/DNS Mapping

- Support SSM using IGMPv1/v2 Reports
- Uses static mapping or DNS lookup to map multicast group report to source
- Multicast router converts IGMPv1/v2 Report to (S,G) PIM Join based on static mapping or using DNS server



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Multicast and IPv6

cisco Live!

IPv4 vs. IPv6 Multicast

IP Service	IPv4 Solution	IPv6 Solution
Address Range	32-Bit, Class D	**128-Bit (112-Bit Group)**
Routing	Protocol-Independent All IGPs and BGP4+	Protocol-Independent All IGPs and BGP4+ **with v6 Mcast SAFI**
Forwarding	**PIM-DM**, PIM-SM: ASM, SSM, BiDir	PIM-SM: ASM, SSM, BiDir
Group Management	IGMPv1, v2, v3	**MLDv1, v2**
Domain Control	Boundary/Border	Scope Identifier
Source Discovery	MSDP	**Single RP Within Globally Shared Domains**

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Recap/Summary

Multicast Axioms

IGMP

- **Version 1 / 2**
  - ASM Only
- **Version 3**
  - SSM / ASM
- **Report**
  - UK – Brexit!
- **Query**
  - EU – Still Want to Brexit?

PIM

- Joins are based on Reports
- RPF Check Uses *Unicast* Best Path to RP / Source
- **Multicast Delivery Order**:
  - Report/PIM Join
  - RPF Check Against RP / Source
  - Add interface to IIF/OIL
  - Forward PIM Join
  - Traffic flows from source when FHR adds an interface to OIL

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Call to Action!

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Next Steps in Learning

Where Do I Go From Here?

- Attend
  - Demystifying IP Multicast in SD-Access – **BRKRST-2820** – Lukasz Ciukaj
  - Multicast in the ACI Fabric – **BRKACI-2608** – John Weston
- Read
  - **Developing IP Multicast Networks** by Beau Williamson (**ISBN-13:** 978-1578700776)
  - **IP Routing on Cisco IOS, IOS XE, and IOS XR** by Brad Edgeworth, et al (ISBN-13: 978-1587144233)
- Watch
  - **Fundamentals of IP Multicast** by Beau Williamson (LiveLessons / O'Reilly Books Online)
- Lab
  - **dCloud** – BRKIPM-1261 – Intro to Multicast Demo

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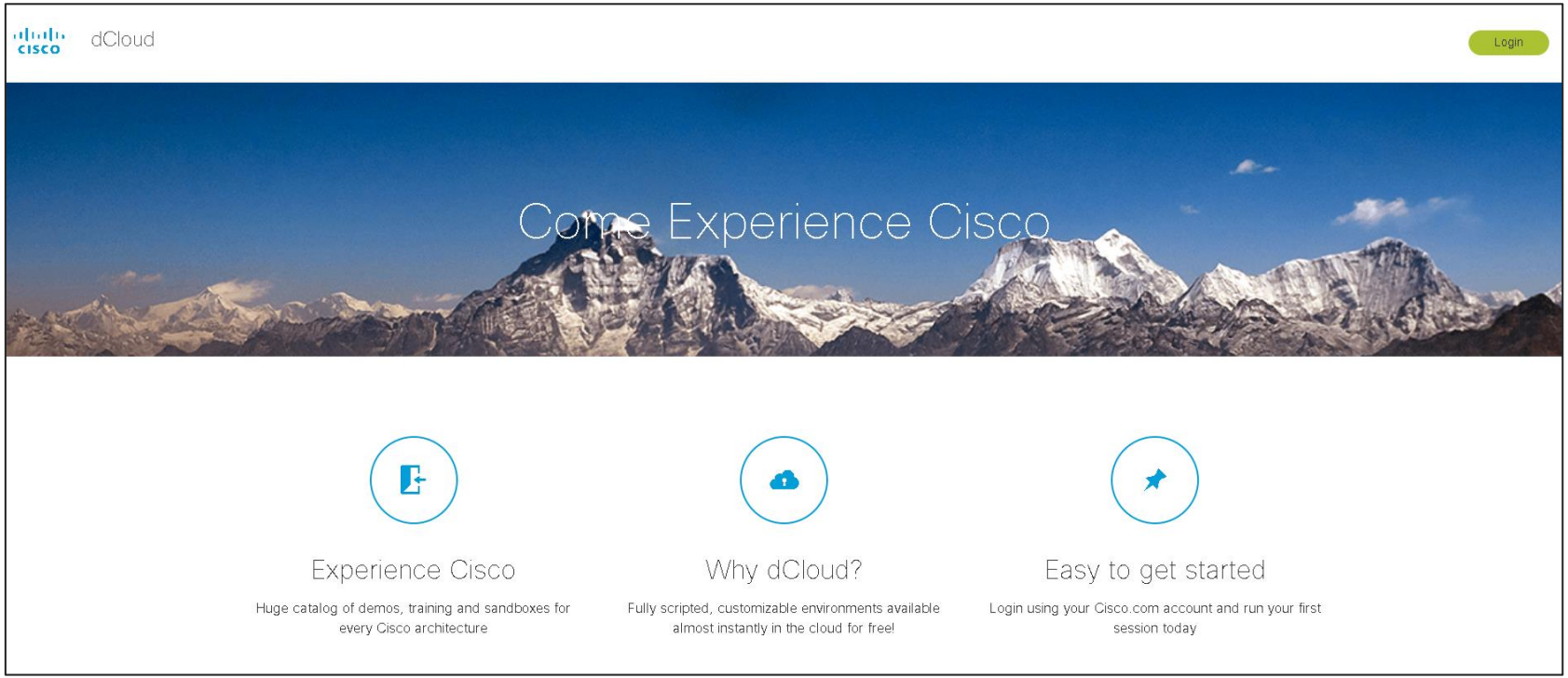
Start With dCloud



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Multicast Demo Menu

localhost:5000

Multicast Breakout Topology Solutions

Start Sandbox Topology

Start SSM Topology

Start BSR Topology

Start AutoRP Topology

Start Anycast-MSDP Topology

Start | Multicast Demo Menu... | Flask Startup - C:\Users...

Multicast Demo Menu

localhost:5000/sandbox

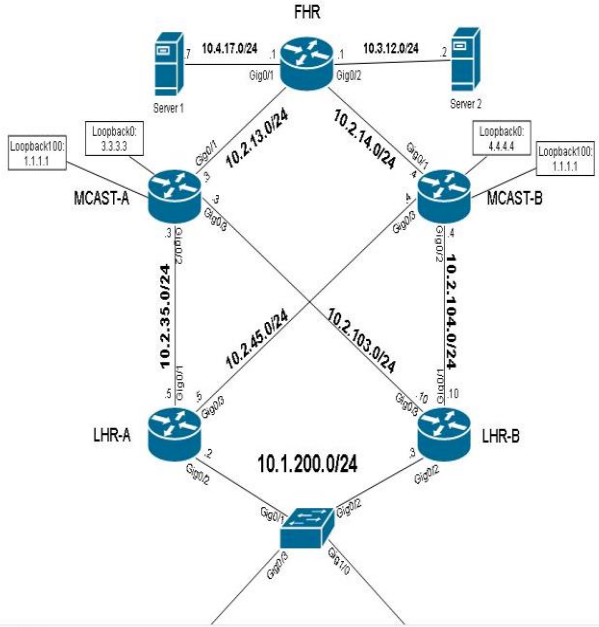
Multicast Breakout Topology Solutions

Please wait for 3 minutes while topology loads.

After topology has loaded, please use Putty Connection Manager shortcut via the Start menu to interact with the topology.

To switch to another topology, use the Back button in the browser.

Multicast Demo Topology



Start | Multicast Demo Menu... | PuTTY Connection Ma... | Flask Startup - C:\Users...

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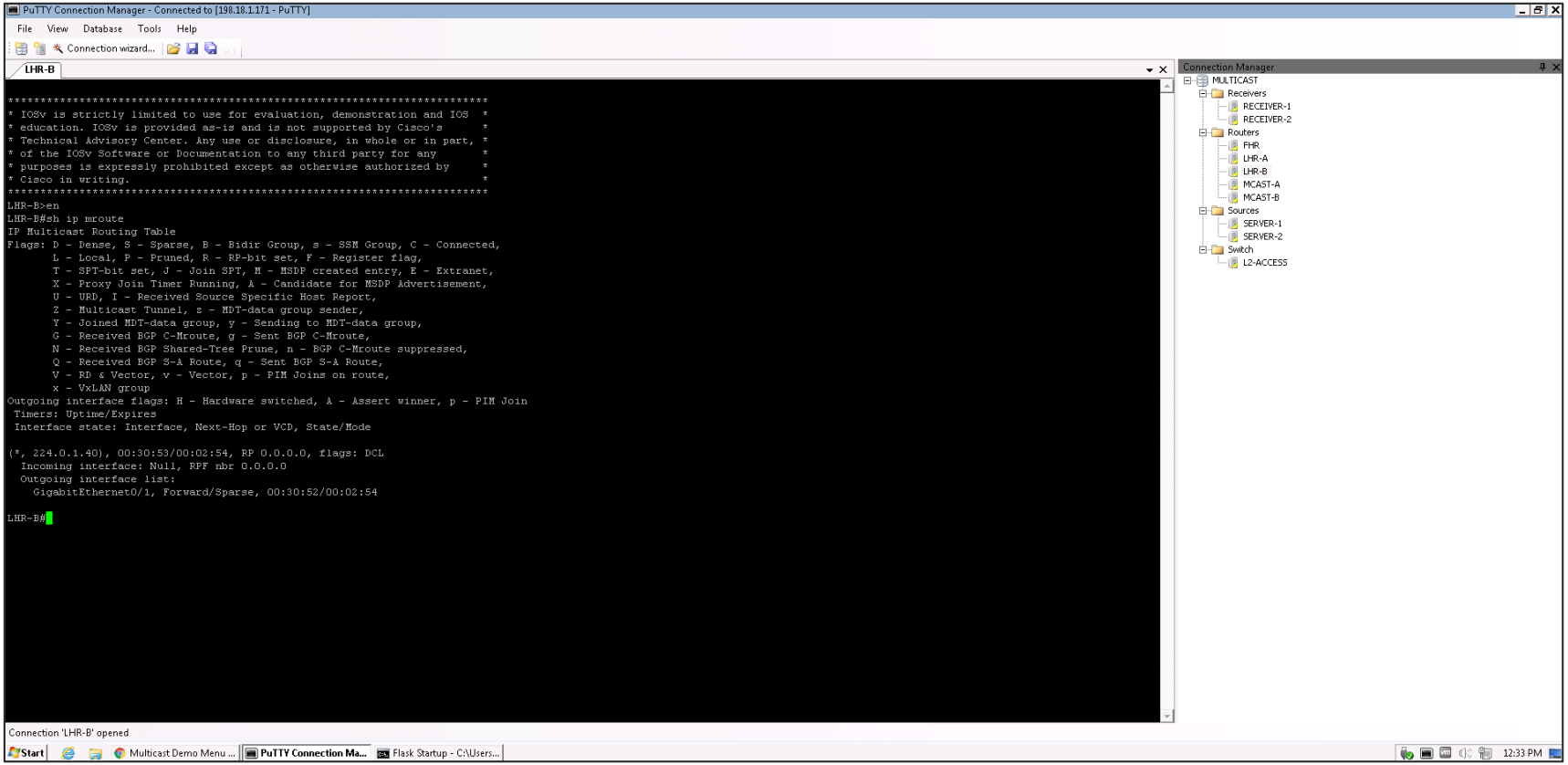
BRKIPM-1261 Demo



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