Introduction to IP Multicast
BRKRST-126

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About the Speaker

• Dr. Pete Welcher
  – Cisco CCIE #1773, CCSI #94014, CCIP, CCDE written
  – Specialties: Network Design, QoS, MPLS, Wireless, Large-Scale Routing & Switching, High Availability, Management of Networks
  – Customers include large enterprises, federal agencies, hospitals, universities, cell phone provider
  – Taught many of the Cisco router / switch courses
  – Reviewer for many Cisco Press books, book proposals
  – Designed and reviewed revisions to the Cisco DESGN and ARCH courses
• Over 140 articles, plus prior seminars, posted
  – http://www.netcraftsmen.net/welcher/
IP Multicast at Cisco Live 2008

- BRKRST-1261: Introduction to IP Multicast
- BRKRST-2261: Deploying IP Multicast
- BRKRST-2262: Multicast Security
- BRKRST-2263: Multicast Network Management
- BRKRST-3261: Advances in IP Multicast
- BRKWT-2102: IP Multicast and Multipoint Design for IP/TV Services
- TECRST-1008: Enterprise IP Multicast

Session Goal

To Provide You with a Thorough Understanding of the Concepts, Mechanics and Protocols Used to Build IP Multicast Networks
Agenda

- Why Multicast?
- Multicast Fundamentals
- PIM Protocols
- RP Choices
- Multicast at Layer 2
- Interdomain IP Multicast
- Some Latest Additions

Unicast vs. Multicast

Number of Streams
Multicast Uses

- Any applications with multiple receivers
  - One-to-many or many-to-many
- Live video distribution
- Collaborative groupware
- Periodic data delivery—"push" technology
  - Stock quotes, sports scores, magazines, newspapers, adverts
- Server/Website replication
- Reducing network/resource overhead
  - More than multiple point-to-point flows
- Resource discovery
- Distributed interactive simulation (DIS)
  - War games
  - Virtual reality

Unicast vs. Multicast

- TCP unicast but not multicast
  - TCP is connection-orientated protocol
  - Requires three-way handshake
  - Reliable due to sequence numbers + Ack
  - Flow control
- UDP unicast and multicast
  - Connectionless
  - Unreliable (application layer awareness)
Multicast Disadvantages

Multicast Is UDP-Based
- **Best effort delivery**: drops are to be expected; multicast applications should not expect reliable delivery of data and should be designed accordingly; reliable multicast is still an area for much research; expect to see more developments in this area; PGM, FEC, QoS
- **No congestion avoidance**: lack of TCP windowing and “slow-start” mechanisms can result in network congestion; if possible, multicast applications should attempt to detect and avoid congestion conditions
- **Duplicates**: some multicast protocol mechanisms (e.g., asserts, registers, and SPT transitions) result in the occasional generation of duplicate packets; multicast applications should be designed to expect occasional duplicate packets
- **Out of order delivery**: some protocol mechanisms may also result in out of order delivery of packets

Multicast Advantages

- **Enhanced efficiency**: controls network traffic and reduces server and CPU loads
- **Optimized performance**: Eliminates traffic redundancy
- **Distributed applications**: Makes multipoint applications possible

Example: Audio Streaming
All Clients Listening to the Same 8 Kbps Audio
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Multicast Components
Cisco End-to-End Architecture

- End stations (hosts-to-routers)
  - IGMP

Campus Multicast
- Switches (Layer 2 optimization)
  - IGMP snooping PIM snooping
- Routers (multicast forwarding protocol)
  - PIM sparse mode or bidirectional PIM

- Multicast routing across domains
  - MBGP

Interdomain Multicast
- Multicast source discover
  - MSDP with PIM-SM
- Source Specific Multicast
  - SSM
**IP Multicast Group Concept**

1. You must be a “member” of a group to receive its data
2. If you send to a group address, all members receive it
3. You do not have to be a member of a group to send to a group

**Multicast Addressing**

IPv4 Header

- **Source Address Can Never Be Class D Multicast Group Address**

- **Source Address Range:** 1.0.0.0 - 223.255.255.255 (Class A, B, C)

- **Destination Address Range:** 224.0.0.0 - 239.255.255.255 (Class D) Multicast Group Address Range
Multicast Addressing—224/4

- **Reserved link-local addresses**
  - 224.0.0.0–224.0.0.255
  - Transmitted with TTL = 1
    - Examples
      - 224.0.0.1 All systems on this subnet
      - 224.0.0.2 All routers on this subnet
      - 224.0.0.5 OSPF routers
      - 224.0.0.13 PIMv2 routers
      - 224.0.0.22 IGMPv3

- **Other reserved addresses**
  - 224.0.1.0–224.0.1.255
    - Not local in scope (transmitted with TTL > 1)
    - Examples
      - 224.0.1.1 NTP (Network Time Protocol)
      - 224.0.1.32 Mtrace routers
      - 224.0.1.78 Tibco Multicast1

Multicast Addressing—224/4

- **Administratively scoped addresses**
  - 239.0.0.0–239.255.255.255
    - Private address space
      - Similar to RFC1918 unicast addresses
      - Not used for global Internet traffic—scoped traffic

- **SSM (Source Specific Multicast) range**
  - 232.0.0.0–232.255.255.255
    - Primarily targeted for Internet-style broadcast

- **GLOP (honest, it’s not an acronym)**
  - 233.0.0.0–233.255.255.255
    - Provides /24 group prefix per ASN
Multicast Addressing

IP Multicast MAC Address Mapping

Be Aware of the 32:1 Address Overlap

32-IP Multicast Addresses

1-Multicast MAC Address

224.1.1.1
224.129.1.1
225.1.1.1
225.129.1.1
...
238.1.1.1
238.129.1.1
239.1.1.1
239.129.1.1

0x0100.5E01.0101
How Are Multicast Addresses Assigned?

- **Static global group address assignment**
  - Temporary method to meet immediate needs
  - Group range: 233.0.0.0–233.255.255.255
    - Your AS number is inserted in middle two octets
    - Remaining low-order octet used for group assignment
  - Defined in RFC 2770
    - “GLOP Addressing in 233/8”
- **Manual address allocation by the admin**
  - Is still the most common practice

Host-Router Signaling: IGMP

- How hosts tell routers about group membership
- Routers solicit group membership from directly connected hosts
- RFC 1112 specifies version 1 of IGMP
  - Supported on Windows 95
- RFC 2236 specifies version 2 of IGMP
  - Supported on latest service pack for Windows and most UNIX systems
- RFC 3376 specifies version 3 of IGMP
  - Supported in Window XP and various UNIX systems
Host-Router Signaling: IGMP

Joining a Group

- Host sends IGMP report to join group

Router sends periodic queries to 224.0.0.1

- One member per group per subnet reports
- Other members suppress reports
Host-Router Signaling: IGMPv2

Leaving a Group (IGMPv2)

- Host sends leave message to 224.0.0.2
- Router sends group-specific query to 224.1.1.1
- No IGMP report is received within ~ 3 seconds
- Group 224.1.1.1 times out

Host-Router Signaling: IGMPv3

RFC 3376

- Adds include/exclude source lists
- Enables hosts to listen only to a specified subset of the hosts sending to the group
- Requires new `IPMulticastListen` API
- New IGMPv3 stack required in the OS
- Apps must be rewritten to use IGMPv3 include/exclude features
Host-Router Signaling: IGMPv3

New Membership Report Address

- **224.0.0.22 (IGMPv3 routers)**
  - All IGMPv3 hosts send reports to this address
    - Instead of the target group address as in IGMPv1/v2
  - All IGMPv3 routers listen to this address
  - Hosts do not listen or respond to this address

- **No report suppression**
  - All hosts on wire respond to queries
    - Host's complete IGMP state sent in single response
  - Response interval may be tuned over broad range
    - Useful when large numbers of hosts reside on subnet

IGMPv3—Joining a Group

- Joining member sends IGMPv3 report to 224.0.0.22 immediately upon joining
IGMPv3—Joining Specific Source(s)

- IGMPv3 report contains desired source(s) in the include list
  - Only "included" source(s) are joined

IGMPv3—Maintaining State

- Router sends periodic queries
- All IGMPv3 members respond
- Reports contain multiple group state records
Multicast L3 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

Unicast vs. Multicast Forwarding

Unicast Forwarding

- Destination IP address directly indicates where to forward packet
- Forwarding is hop-by-hop
  - Unicast routing table determines interface and next-hop router to forward packet
Unicast vs. Multicast Forwarding

Multicast Forwarding

- Destination IP address (group) doesn’t directly indicate where to forward packet
- Forwarding is connection-oriented
  - Receivers must first be “connected” to the tree before traffic begins to flow
    - Connection messages (PIM joins) follow unicast routing table toward multicast source
    - Build multicast distribution trees that determine where to forward packets
    - Distribution trees rebuilt dynamically in case of network topology changes

Reverse Path Forwarding (RPF)

The RPF Calculation

- The multicast source address is checked against the unicast routing table
- This determines the interface and upstream router in the direction of the source to which PIM joins are sent
- This interface becomes the “Incoming” or RPF interface
  - A router forwards a multicast datagram only if received on the RPF interface
Reverse Path Forwarding (RPF)

- RPF calculation
  - Based on source address
  - Best path to source found in unicast route table
  - Determines where to send join
  - Joins continue towards source to build multicast tree
  - Multicast data flows down tree

Reverse Path Forwarding (RPF)

- RPF calculation
  - Based on source address
  - Best path to source found in unicast route table
  - Determines where to send join
  - Joins continue towards source to build multicast tree
  - Multicast data flows down tree
  - Repeat for other receivers
Reverse Path Forwarding (RPF)

- RPF calculation
  - What if we have equal-cost paths?
    - We can’t use both
  - Tie-breaker
    - Use highest next-hop IP address

Multicast Distribution Trees

Shortest Path or Source Distribution Tree

Notation: (S, G)
S = Source
G = Group

Source 1

Source 2

Receiver 1

Receiver 2
**Multicast Distribution Trees**

### Shortest Path or Source Distribution Tree

Notation: \((S, G)\)
- \(S\) = Source
- \(G\) = Group

Source 1

A

B

D

F

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

Receiver 1

Receiver 2

Source 2

**Multicast Distribution Trees**

### Shared Distribution Tree

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

Receiver 1

Receiver 2

(RP) PIM Rendezvous Point

Shared Tree
Multicast Distribution Trees

**Shared Distribution Tree**

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

- Source 1
- Source 2
- A
- B
- D (RP)
- F
- C
- E
- Receiver 1
- Receiver 2

**Characteristics of Distribution Trees**

- **Source or shortest path trees**
  - Uses more memory O (S x G) but you get optimal paths from source to all receivers; minimizes delay

- **Shared trees**
  - Uses less memory O(G) but you may get suboptimal paths from source to all receivers; may introduce extra delay
Multicast Tree Creation

- PIM join/prune control messages
  - Used to create/remove distribution trees
- Shortest path trees
  - PIM control messages are sent toward the source
- Shared trees
  - PIM control messages are sent toward RP

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- Why Multicast?
- Multicast Fundamentals
- PIM Protocols
- RP Choices
- Multicast at Layer 2
- Interdomain IP Multicast
- Some Latest Additions
Major Deployed PIM Variants

PIM-SM
- **ASM**
  - Any Source Multicast/RP/SPT/shared tree
- **SSM**
  - Source Specific Multicast, no RP, SPT only
- **BiDir**
  - Bidirectional PIM, no SPT, shared tree only

PIM-SM Shared Tree Join

- (`*, G`) Join
- Shared Tree
- Receiver
- (`*, G`) State Created Only Along the Shared Tree
PIM-SM Sender Registration

(S, G) Join

Source

Receiver

RP

Traffic Flow

Shared Tree

Source Tree

(S, G) Register (unicast)

(S, G) Join

(S, G) State Created Only Along the Source Tree

Traffic Flow

Shared Tree

Source Tree

(S, G) Register (unicast)

(S, G) Register-Stop (unicast)

Receiver

RP

(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

PIM-SM SPT Switchover

Last-Hop Router Joins the Source Tree
Additional (S, G) State Is Created Along New Part of the Source Tree
PIM-SM SPT Switchover

Traffic Begins Flowing Down the New Branch of the Source Tree

Additional (S, G) State Is Created Along the Shared Tree to Prune Off (S, G) Traffic

Traffic Flow Is Now Pruned Off of the Shared Tree and Is Flowing to the Receiver via the Source Tree
PIM-SM SPT Switchover

Traffic Flow
Shared Tree
Source Tree
(S, G) Prune

Receiver

(S, G) Traffic Flow is No Longer Needed by the RP so It Prunes the Flow of (S, G) Traffic

Traffic Flow
Shared Tree
Source Tree

Receiver

(S, G) Traffic Flow is Now Only Flowing to the Receiver via a Single Branch of the Source Tree
“The default behavior of PIM-SM is that routers with directly connected members will join the shortest path tree as soon as they detect a new multicast source.”

PIM-SM Frequently Forgotten Fact

PIM-SM—Evaluation

• Effective for sparse or “dense” distribution of multicast receivers
• Advantages
  – Traffic only sent down “joined” branches
  – Can switch to optimal source-trees for high traffic sources dynamically
  – Unicast routing protocol-independent
  – Basis for interdomain, multicast routing
• When used with MBGP, MSDP and/or SSM
Source Specific Multicast

- Assume a one-to-any multicast model
  - Example: video/audio broadcasts, stock market data
- Why does ASM need a shared tree?
  - So that hosts and first hop routers can learn who the active source is for the group—source discovery
- What if this was already known?
  - Hosts could use IGMPv3 to signal exactly which (S, G) SPT to join
  - The shared tree and RP wouldn’t be necessary
  - Different sources could share the same group address and not interfere with each other
- Result: Source Specific Multicast (SSM)
- RFC 3569: An Overview of Source Specific Multicast (SSM)

PIM Source Specific Mode

<table>
<thead>
<tr>
<th>Source</th>
<th>Receiver Learns of Source, Group/Port</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Receiver Sends IgGMPv3 (S,G) Join</td>
</tr>
<tr>
<td></td>
<td>First-Hop Send PIM s,g Join Directly</td>
</tr>
<tr>
<td></td>
<td>Toward Source</td>
</tr>
</tbody>
</table>

(S, G) Join

IGMPv3 (S, G) Join

Receiver 1

Out-of-Band Source Directory
Example: Web Server

Receiver 1 learns of source, group/port through out-of-band source directory. Upon receiving a multicast stream, it sends an IGMPv3 (S, G) join to the first-hop router, which then sends a PIM s,g join directly toward the source.
**PIM Source Specific Mode**

- Source
- Result: Shortest Path Tree Rooted at the Source, with No Shared Tree

- A
- B
- C
- D
- E
- F
- Receiver 1

---

**SSM—Evaluation**

- Ideal for applications with one source sending to many receivers
- Uses a simplified subset of the PIM-SM protocol
  - Simpler network operation
- Solves multicast address allocation problems
  - Flows differentiated by both source and group
    - Not just by group
    - Content providers can use same group ranges
      - Since each (S,G) flow is unique
- Helps prevent certain DoS attacks
  - “Bogus” source traffic
    - Can’t consume network bandwidth
    - Not received by host application
Many-to-Many State Problem

- Creates huge amounts of (S,G) state
  - State maintenance workloads skyrocket
  - High OIL fan-out makes the problem worse
- Router performance begins to suffer
- Using shared trees only
  - Provides some (S, G) state reduction
  - Results in (S, G) state only along SPT to RP
  - Frequently still too much (S, G) state
- Need a solution that only uses (*, G) state

Bidirectional PIM—Overview
Bidirectional PIM—Overview

- Source Traffic Forwarded Bidirectionally Using (*,G) State
- Shared Tree
- Receiver
- RP
- Sender/Receiver

Bidir PIM—Evaluation

- Ideal for many to many applications
- Drastically reduces network mroute state
  - Eliminates all (S,G) state in the network
    - SPTs between sources to RP eliminated
    - Source traffic flows both up and down shared tree
  - Allows many-to-any applications to scale
    - Permits virtually an unlimited number of sources
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- PIM Protocols
- RP Choices
- Multicast at Layer 2
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PIM-SM ASM RP Requirements

- Group to RP mapping
  - Consistent in all routers within the PIM domain
- RP redundancy requirements
  - Eliminate any single point of failure
How Does the Network Know About the RP?

- **Static configuration**
  - Manually on every router in the PIM domain
- **AutoRP**
  - Originally a Cisco® solution
  - Facilitated PIM-SM early transition
- **BSR**
  - `draft-ietf-pim-sm-bsr`

Static RPs

- **Hard-configured RP address**
  - When used, must be configured on every router
  - All routers must have the same RP address
  - RP failover not possible
    - Exception: if anycast RPs are used
- **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
Auto-RP—From 10,000 Feet

**RP-Announcements Multicast to the Cisco Announce (224.0.1.39) Group**

- A: DC-RP 1.1.1.1
- B: C-RP 2.2.2.2

**Discovery**

**RP-Discoveries Multicast to the Cisco Discovery (224.0.1.40) Group**

- A: Discovery
- B: Discovery
- C: Discovery
- D: Discovery

C-RP 1.1.1.1
C-RP 2.2.2.2
BSR—From 10,000 Feet

BSR Election Process

Highest Priority C-BSR Is Elected as BSR
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L2 Multicast Frame Switching

**Problem:** Layer 2 Flooding of Multicast Frames

- Typical L2 switches treat multicast traffic as unknown or broadcast and must "flood" the frame to every port
- Static entries can sometimes be set to specify which ports should receive which group(s) of multicast traffic
- Dynamic configuration of these entries would cut down on user administration
L2 Multicast Frame Switching

IGMPv1–v2 Snooping

- Switches become “IGMP”-aware
- IGMP packets intercepted by the NMP or by special hardware ASICs
  - Requires special hardware to maintain throughput
- Switch must examine contents of IGMP messages to determine which ports want what traffic
  - IGMP membership reports
  - IGMP leave messages
- Impact on low-end, Layer-2 switches
  - Must process all Layer 2 multicast packets
  - Admin load increases with multicast traffic load
  - Generally results in switch meltdown

Impact of IGMPv3 on ICMP Snooping

- IGMPv3 reports sent to separate group (224.0.0.22)
  - Switches listen to just this group
  - Only IGMP traffic—no data traffic
  - Substantially reduces load on switch CPU
  - Permits low-end switches to implement IGMPv3 snooping
- No report suppression in IGMPv3
  - Enables individual member tracking
- IGMPv3 supports source-specific includes/excludes
Summary—Frame Switches

IGMP Snooping

- Switches with Layer 3-aware hardware/ASICs
- High-throughput performance maintained
- Increases cost of switches
- Switches without Layer 3-aware hardware/ASICs
- Suffer serious performance degradation or even meltdown!
- Shouldn’t be a problem when IGMPv3 is implemented

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### MBGP Overview

**MBGP: Multiprotocol BGP**

- Defined in RFC 2858 (extensions to BGP)
- Can carry different types of routes
  - Unicast
  - Multicast
- Both routes carried in same BGP session
- Does **not** propagate multicast state info
  - That’s PIM’s job
- Same path selection and validation rules
  - AS-Path, LocalPref, MED...

---

**Separate BGP tables maintained**

- Unicast prefixes for unicast forwarding
- Unicast prefixes for multicast RPF checking

**AFI = 1, Sub-AFI = 1**

- Contains unicast prefixes for unicast forwarding
- Populated with BGP unicast NLRI

**AFI = 1, Sub-AFI = 2**

- Contains unicast prefixes for RPF checking
- Populated with BGP multicast NLRI
MBGP Overview

MBGP Allows Divergent Paths and Policies

• Same IP address holds dual significance
  – Unicast routing information
  – Multicast RPF information
• For same IPv4 address two different NLRI with different next-hops
• Can therefore support both congruent and incongruent topologies

MSDP

• RFC 3618
• ASM only
  – RPs knows about all sources in their domain
    • Sources cause a “PIM Register” to the RP
    • Tell RPs in other domains of it’s sources
      – Via MSDP SA (Source Active) messages
  – RPs know about receivers in a domain
    • Receivers cause a “(*, G) Join” to the RP
    • RP can join the source tree in the peer domain
      – Via normal PIM (S, G) joins
  – MSDP required for interdomain ASM source discovery
MSDP Overview

MSDP Example

MSDP Peers

Multicast Traffic

Domain A

Domain B

Domain C

Domain D

Domain E

S

RP

Join

(S, 224.2.2.2)

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MSDP Overview

MSDP Example

MSDP Peers
Multicast Traffic
MSDP wrt SSM—Unnecessary

ASM MSDP Peers (Irrelevant to SSM)

Domain A

Domain B

Domain C

Domain D

Domain E

Source in 232/8

S

Receiver Learns S and G Out of Band, i.e., Webpage

MSDP wrt SSM—Unnecessary

ASM MSDP Peers (Irrelevant to SSM)

Domain A

Domain B

Domain C

Domain D

Domain E

Source in 232/8

S

Receiver Learns S and G Out of Band, e.g., Webpage
Anycast RP—Overview

- Redundant RP technique for ASM which uses MSDP for RP synchronization
  - Uses single 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 and receivers join/register with closest RP
      - Closest RP determined from the unicast routing table
      - 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
Anycast RP—Overview

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Multicast VPN—Customer Requirement

- MPLS VPN customers want to run multicast within their VPNs
- Multicast deployment is expanding
- MPLS VPNs do not support multicast today
- Multicast options in MPLS VPNs today
  - GRE tunnels from CE to CE

Multicast VPN (MVPN)

- Allows an ISP to provide its MPLS VPN customers the ability to transport their multicast traffic across MPLS packet-based core networks
- Requires IPmc enabled in the core
- MPLS may still be used to support unicast
- A scalable architecture solution for MPLS networks based on native multicast deployment in the core
Multicast VPN (MVPN)

- Uses draft-rosen-vpn-mcast encapsulation and signaling to build MVPN Multicast VPN (MVPN):
  - GRE encapsulation
  - PIM inside PIM
- Not universally deployed
  - Not all VPN providers offer MVPN services

IPv4 Versus IPv6 Multicast

<table>
<thead>
<tr>
<th>IP Service</th>
<th>IPv4 Solution</th>
<th>IPv6 Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Address Range</td>
<td>32-Bit, Class D</td>
<td>128-Bit (112-Bit Group)</td>
</tr>
<tr>
<td>Routing</td>
<td>Protocol-Independent All IGPs</td>
<td>Protocol-Independent All IGPs and BGP4+ with v6 Mcast SAFI</td>
</tr>
<tr>
<td></td>
<td>and GBP4+</td>
<td></td>
</tr>
<tr>
<td>Forwarding</td>
<td>PIM-DM, PIM-SM: ASM, SSM, BiDir</td>
<td>PIM-SM: ASM, SSM, BiDir</td>
</tr>
<tr>
<td>Group Management</td>
<td>IBMPv1, v2, v3</td>
<td>MLDv1, v2</td>
</tr>
<tr>
<td>Domain Control</td>
<td>Boundary/Border</td>
<td>Scope Identifier</td>
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<tr>
<td>Interdomain Source Discovery</td>
<td>MSDP Across Independent PIM Domains</td>
<td>Single RP Within Globally Shared Domains</td>
</tr>
</tbody>
</table>
IPv6 Multicast Addresses (RFC 3513)

<table>
<thead>
<tr>
<th>FF</th>
<th>Flags</th>
<th>Scope</th>
<th>0</th>
<th>Interface-ID</th>
</tr>
</thead>
</table>

Flags = {T or Lifetime, 0 if Permanent, 1 if Temporary}
P Proposed for Unicast-Based Assignments
Others Are Undefined and Must Be Zero

Scope = {1 = interface-local, 2 = link, 4 = admin-local, 5 = site, 8 = organization, E = global}

IPv6 Layer 2 Multicast Addressing Mapping

<table>
<thead>
<tr>
<th>FF</th>
<th>Flags</th>
<th>Scope</th>
<th>High-Order</th>
<th>Low-Order</th>
</tr>
</thead>
</table>

IPv6 Multicast Address

112 Bits

80 Bits Lost

33-33-xx-xx-xx

Ethernet MAC Address
Unicast-Based Multicast Addresses

<table>
<thead>
<tr>
<th>FF</th>
<th>Flags</th>
<th>Scope</th>
<th>Rsrvd</th>
<th>Plen</th>
<th>Network-Prefix</th>
<th>Group-ID</th>
</tr>
</thead>
</table>

- **RFC 3306**—unicast-based multicast addresses
  - Similar to IPv4 GLOP addressing
  - Solves IPv6 global address allocation problem
  - Flags = 00PT
    - P = 1, T = 1 \(\rightarrow\) Unicast-based multicast address

- **Example**
  - Content provider’s unicast prefix
    - 1234:5678:9abc::/64
  - Multicast address
    - FF36:0030:1234:5678:9abc::0001

IP Routing for Multicast

- **RPF-based on reachability to v6 source same as with v4 multicast**
- **RPF still protocol-independent**
  - Static routes, mroutes
  - Unicast RIB: BGP, ISIS, OSPF, EIGRP, RIP, etc.
  - Multiprotocol BGP (mBGP)
    - Support for v6 mcast subaddress family
    - Provide translate function for nonsupporting peers
IPv6 Multicast Forwarding

- **PIM-Sparse Mode (PIM-SM)**
  - RFC4601
- **PIM Source Specific Mode (SSM)**
  - RFC3569 SSM overview (v6 SSM needs MLDv2)
  - Unicast, prefix-based multicast addresses ff30::/12
  - SSM range is ff3X::/32
    - Current allocation is from ff3X::/96
- **PIM BiDirectional Mode (BiDir)**
  - draft-ietf-pim-bidir-09.txt

RP Mapping Mechanisms for IPv6 PIM-SM

- Static RP assignment
- BSR
- Auto-RP—no current plans
- Embedded RP
Embedded RP Addressing—RFC3956

- Proposed new multicast address type
  - Uses unicast-based multicast addresses (RFC 3306)
- RP address is embedded in multicast address
- Flag bits = 0RPT
  - R = 1, P = 1, T = 1 → Embedded RP address
- Network-Prefix::RPadr = RP address
- For each unicast prefix you own, you now also own:
  - 16 RPs for each of the 16 multicast scopes (256 total) with $2^{32}$ multicast groups assigned to each RP ($2^{40}$ total)

**Embedded RP Addressing—Example**

Multicast Address with Embedded RP Address

<table>
<thead>
<tr>
<th>8</th>
<th>4</th>
<th>4</th>
<th>4</th>
<th>4</th>
<th>8</th>
<th>64</th>
<th>32</th>
</tr>
</thead>
<tbody>
<tr>
<td>FF</td>
<td>Flags</td>
<td>Scope</td>
<td>Rsvd</td>
<td>RPadr</td>
<td>Plen</td>
<td>Network-Prefix</td>
<td>Group-ID</td>
</tr>
</tbody>
</table>

- **Example Address**: FF76:0130:1234:5678:9abc::4321
  - Resulting RP Address: 1234:5678:9abc::1
Multicast Listener Discover—MLD

- MLD is equivalent to IGMP in IPv4
- MLD messages are transported over ICMPv6
- Version number confusion
  - MLDv1 corresponds to IGMPv2
    - RFC 2710
  - MLDv2 corresponds to IGMPv3, needed for SSM
    - RFC 3810
- MLD snooping
  - draft-ietf-magma-snoop-12.txt

More Information

- White papers
- Web and mailers
- Cisco Press®

RTFB

- CCO multicast
  - http://www.cisco.com/go/ipmulticast
- Customer support mailing list
  - tac@cisco.com
Any Questions?

- For a copy of the presentation, email me at pjw@netcraftsmen.net
- References: see web article I will post at http://www.netcraftsmen.net/welcher/papers/index.htm

About Chesapeake Netcraftsmen:
- Cisco Premier Partner
- Cisco Customer Satisfaction Excellence rating
- We wrote the original version of the Express Foundations courses required for VAR Premier Partner status (and took and passed the tests), and the recent major CCDA/CCDP refresh
- Cisco Advanced Specializations:
  - Advanced Unified Communications (and IP Telephony)
  - Advanced Wireless
  - Advanced Security
  - Advanced Routing & Switching
  - Advanced Data Center Networking Infrastructure
- We have deep expertise in Routing and Switching (several R&S and two double CCIE’s)
- We do network / security / net mgmt / unified communications Design and Assessment
- Expertise and experience in many other areas as well
So You Still Want More?

- Internet IP multicast
- AMT—Automatic Multicast Tunneling

Internet IP Multicast

- We can build multicast distribution trees.
  - PIM
- We can RPF on interdomain sources
  - MBGP
- We can find interdomain active ASM sources
  - MSDP
- So interdomain IP Multicast is in every home, right?
Internet IP Multicast

- What worked?
- What didn’t work?
- What’s being done to fix it?

What Worked?

As Long as IP Multicast Is Enabled on Every Router from the Source to the Receivers, the Benefits of IP Multicast Are Realized
What Worked?

The Benefits Being an Unlimited Number of Receivers Can Be Served with a Single Stream of Content at No Additional Costs.

What Didn’t?

Even Though the Content Owner and Core Provider Are IP Multicast-Enabled, the Majority of Edge Networks Are Still Unicast-Only.
What Didn’t?

More Receivers Consumes More Resources and Costs the Content Owner More Money

Content Owner

Mcast-Enabled ISP

Unicast-Only Network

Mcast-Enabled Local Provider

Session Description File Defines Mcast Timeout, and the Backup Unicast Transport

Mcast Traffic

Mcast Join

Ucast Request

Ucast Stream

To Gain Maximum Audience Size, Unicast Fallback Streams (i.e., Servers) Are Deployed

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What’s Wrong?

- Multicast in the Internet is an all or nothing solution
  - Each receiver must be on an IP multicast-enabled path
  - Many core networks have IP multicast-enabled, but few edge networks accept multicast transit traffic
- Even Mcast-aware content owners are forced to provide unicast streams to gain audience size
- Unicast will never scale for streaming content
  - Splitters/caches just distribute the problem
    - Still has a cost per user
  - As receiver BW increases, problem gets worse
  - Creates a nonfunctional business model
  - Will never bring rich content to IP

AMT—Automatic Multicast Tunneling

- Automatic IP multicast without explicit tunnels
- Allow multicast content distribution to extend to unicast-only connected receivers
  - Bring the flat scaling properties of multicast to the Internet
- Provide the benefits of multicast wherever multicast is deployed
  - Let the networks which have deployed multicast benefit from their deployment
- Work seamlessly with existing applications
  - No OS kernel changes
AMT—Automatic Multicast Tunneling

The AMT Anycast Address Allows for All AMT Gateway to Find the “Closest” AMT Relay— the Nearest Edge of the Multicast Topology of the Source

Once the Multicast Join Times Out, an AMT Join Is Sent from the Host Gateway Toward the Global AMT Anycast Address

AMT—Automatic Multicast Tunneling

AMT Request Captured by the AMT Relay Router
AMT—Automatic Multicast Tunneling

(S,G) is learned from the AMT Join message. Then (S,G) PIM Join is sent toward the source.

AMT Relay replicates stream on behalf of downstream AMT receiver, adding a unicast header destined to the receiver.
AMT—Automatic Multicast Tunneling

Additional Receivers Are Served by the AMT Relays; the Benefits of IP Multicast Are Retained by the Content Owner and All Enabled Networks in the Path.

Unicast-Only Network

Mcast-Enabled ISP

Mcast-Enabled Local Provider

Content Owner

Mcast Traffic

Mcast Join

AMT Request

Ucast Stream

Enables Multicast Content to a Large (Global) Audience

Creates an Expanding Radius of Incentive to Deploy Multicast
AMT—Automatic Multicast Tunneling

- Content Owner
- Mcast-Enabled ISP
- Mcast-Enabled Local Provider

Creates an Expanding Radius of Incentive to Deploy Multicast

Enables Multicast Content to a Large (Global) Audience

Mcast Traffic
- Mcast Join
- AMT Request
- Ucast Stream

Unicast-Only Network

Enables Multicast Content to a Large (Global) Audience

Mcast Traffic
- Mcast Join
- AMT Request
- Ucast Stream
Internet IP Multicast

- Will Internet IP multicast have a future?
- P2P solutions working toward over the top video solution today without end-to-end multicast
- Maybe that was just a dream… ;-)  
- IP multicast deployment growing rapidly to provide edge-network content to the home
- Over the top video may use AMT, P2P, and/or could develop through cooperation with edge providers— but it’s coming