IPv6 Multicast Primer
Why Multicast?

- Link Operations
- Routing Protocols
- Distance Learning
- Surveillance
- Metering
- Broadcast Video Services
- Efficient Delivery
Mechanism for transmitting information from a single source (root) to many receivers (leaves)

Single copy of a datagram is sent from the source and replicated through the tree to receivers

No restriction on physical or geographical boundary
IPv6 Multicast Trees and Protocols

- Multicast is a normal **IPv6 packet Destination**
- An IPv6 multicast group address always starts with the prefix **FF00::/8 (1111 1111)**
- Multicast Listener Discovery (**MLD**)
- Multicast traffic is forwarded along a multicast tree which can be either a
  - Source Tree (**S, G**)
  - Shared Tree (***, G**)
- IPv6 supports Protocol Independent Multicast (**PIM**) routing protocols only
  - PIM creates the trees that multicast streams are forwarded on
  - PIM operation is the same in IPv6 as IPv4 (RFC 4601 specifies operation over IPv4 and IPv6)
  - PIM identified by the **IPv6 next header 103** (same protocol type as IPv4)
Types of Multicast Groups

• General Any Source Multicast (ASM)
  PIM-SM, PIM-BiDir
  Default for generic multicast and unicast prefix-based multicast
  Start with FF3x::/12

• Source Specific Multicast (SSM)
  Used by PIM-SSM
  FF3x::/32 is allocated for SSM by IANA
  However, at present prefix and plen must be zero so FF3x::/96 is usable as SSM

• Embedded RP groups
  PIM-SM, PIM-BiDir
  Start with FF70::/12
IPv6 Multicast Addressing
IPv6 Multicast Address Format (RFC 4291)

- An IPv6 multicast address has the prefix FF00::/8 (1111 1111)

```
0 R P T Scope Group ID (Variable Format)
```

<table>
<thead>
<tr>
<th>Flags</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>R = 0</td>
<td>No embedded RP</td>
</tr>
<tr>
<td>R = 1</td>
<td>Embedded RP</td>
</tr>
<tr>
<td>P = 0</td>
<td>Not based on unicast</td>
</tr>
<tr>
<td>P = 1</td>
<td>Based on unicast</td>
</tr>
<tr>
<td>T = 0</td>
<td>Permanent address (IANA assigned)</td>
</tr>
<tr>
<td>T = 1</td>
<td>Temporary address (local assigned)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scope</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Node</td>
</tr>
<tr>
<td>2</td>
<td>Link</td>
</tr>
<tr>
<td>3</td>
<td>Subnet</td>
</tr>
<tr>
<td>4</td>
<td>Admin</td>
</tr>
<tr>
<td>5</td>
<td>Site</td>
</tr>
<tr>
<td>8</td>
<td>Organization</td>
</tr>
<tr>
<td>E</td>
<td>Global</td>
</tr>
</tbody>
</table>
Similar to GLOP from v4 (233/8) where the ASN is inserted in middle octets.

Allows Multicast service from organizations that may not have BGP/ASN

Provides a mechanism of creating globally unique multicast groups
IPv6 Embedded RP Multicast Address (RFC 3956)

- Provides a static RP to multicast group mapping mechanism
- Solves interdomain multicast problem as there is no MSDP for IPv6
- Rpid field can be 1 - 15 (1-F hex)
- There can be 15 RPs per scope per prefix
  
  Total of 256 RP addresses per unicast prefix
  
  $2^{32}$ groups per RP
- Embedded RP begin with FF7x::/12
IPv6 Source Specific Multicast Address (RFC 3306)

- Special case of unicast prefix-based address based on Unicast based multicast format
- Prefix Len=0, Network Prefix=0
- FF3x::/32 pool is reserved for SSM addresses
  
  FF3x::/96 initial block allocated from this pool

### Example

- **Unicast Prefix**: 0::
- **Flags**: No RP, Unicast, Temporary
- **Scope**: 8 (Organisation)
- **Group ID**: 8000:247

**SSM Address**: ff38::8000:247

### Range and Usage

<table>
<thead>
<tr>
<th>Range</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>FF3x::4000:0001 - FF3x::7FFF:FFFF</td>
<td>IANA allocation</td>
</tr>
<tr>
<td>FF3x::8000:0000 - FF3x::FFFF:FFFF</td>
<td>Dynamic allocation</td>
</tr>
<tr>
<td>FF3x::0000:0000 - FF3x::3FFF:FFFF</td>
<td>Invalid for IPv6 SSM</td>
</tr>
</tbody>
</table>
Multicast Mapping over Ethernet (RFC 2464)

IPv6 Multicast Address: FF02:0000:0000:0000:0000:0001:FF17:FC0F

Corresponding Ethernet Address: 33:33:FF:17:FC:0F

- IPv6 multicast address to Ethernet mapping
  - 33:33:{Low Order 32 bits of the IPv6 multicast address}
### Well Known Multicast Addresses

<table>
<thead>
<tr>
<th>Address</th>
<th>Scope</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>FF01::1</td>
<td>Node-Local</td>
<td>All Nodes</td>
</tr>
<tr>
<td>FF05::2</td>
<td>Site-Local</td>
<td>All Routers</td>
</tr>
<tr>
<td>FF02::1</td>
<td>Link-Local</td>
<td>All Nodes</td>
</tr>
<tr>
<td>FF02::2</td>
<td>Link-Local</td>
<td>All Routers</td>
</tr>
<tr>
<td>FF02::A</td>
<td>Link-Local</td>
<td>EIGRP</td>
</tr>
<tr>
<td>FF02::C</td>
<td>Link-Local</td>
<td>SSDP – MSFT</td>
</tr>
<tr>
<td>FF02::FB</td>
<td>Link-Local</td>
<td>MDNS - Apple</td>
</tr>
</tbody>
</table>

- FF02, is a permanent address and has link scope
- Rather “Chatty” and running in your network now!
Solicited Node Multicast Address
Solicited-Node Multicast Address

• For each Unicast and Anycast address configured there is a corresponding solicited-node multicast

• Used in neighbor solicitation (NS) messages

• Solicited-node multicast consists of
  \[ \text{FF02:}:1:FF/104 \quad \{\text{lower 24 bits from IPv6 Unicast interface ID}\} \]

### Ethernet Multicast

Uses last 32 bits
**Neighbor Solicitation & Advertisement**

### ICMP Type 135 NS

<table>
<thead>
<tr>
<th>Field</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPv6 Source</td>
<td>A Unicast</td>
</tr>
<tr>
<td>IPv6 Destination</td>
<td>B Solicited Node Multicast FF02::1:FF00:B</td>
</tr>
<tr>
<td>Data</td>
<td>FE80:: address of A</td>
</tr>
<tr>
<td>Code</td>
<td>0 (need link layer)</td>
</tr>
<tr>
<td>Query</td>
<td>What is B link layer address?</td>
</tr>
</tbody>
</table>

### ICMP Type 136 NA

<table>
<thead>
<tr>
<th>Field</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPv6 Source</td>
<td>B Unicast</td>
</tr>
<tr>
<td>IPv6 Destination</td>
<td>A Unicast</td>
</tr>
<tr>
<td>ICMP Option</td>
<td>Type 2 (Target response)</td>
</tr>
<tr>
<td>Data</td>
<td>Link Layer address of B</td>
</tr>
<tr>
<td>Flags</td>
<td>R = Router</td>
</tr>
<tr>
<td></td>
<td>S = Response to Solicitation</td>
</tr>
<tr>
<td></td>
<td>O = Override cache information</td>
</tr>
</tbody>
</table>

- Local Link only, Not Routed
- ARP replacement, Map’s L3 to L2.
Duplicate Address Detection (DAD)

Node A can start using address A

- Probe neighbors to verify address uniqueness

<table>
<thead>
<tr>
<th>ICMP Type</th>
<th>135 NS</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPv6 Source</td>
<td>UNSPEC = ::</td>
</tr>
<tr>
<td>IPv6 Dest.</td>
<td>A Solicited Node Multicast FF02::1:FF00:A</td>
</tr>
<tr>
<td>Data</td>
<td>FE80:: address of A</td>
</tr>
<tr>
<td>Query</td>
<td>Anyone using A?</td>
</tr>
</tbody>
</table>
IPv6 Interface Example

R1#sh ipv6 int e0
Ethernet0 is up, line protocol is up
IPv6 is enabled, link-local address is FE80::200:CFF:FE3A:8B18
Global unicast address(es):
   2001:DB8:0:1234::1 subnet is 2006:1::/64
Joined group address(es):
   FF02::1
   FF02::2
   FF02::1:FF00:1
   FF02::1:FF3A:8B18
MTU is 1500 bytes
ICMP error messages limited to one every 100 milliseconds
ICMP redirects are enabled
ND DAD is enabled, number of DAD attempts: 1
ND reachable time is 30000 milliseconds
ND advertised reachable time is 0 milliseconds
ND advertised retransmit interval is 0 milliseconds
ND router advertisements are sent every 200 seconds

*If EUI format is used then the 1rst solicited node mcast addr is used for both the LL & GU
Multicast Listener Discovery (MLD)
ICMPv6

<table>
<thead>
<tr>
<th>Type</th>
<th>Code</th>
<th>Checksum</th>
<th>Data</th>
</tr>
</thead>
</table>

- Neighbor Discovery, Router Discovery, Path MTU Discovery and (MLD)
  - Type – (1-127) = Error Messages, (128-255) = Informational Messages
  - Code – More Granularity within the Type
  - Checksum – computed over the entire ICMPv6
  - Data – Diagnostic Information Relative to Packet Processing
# IPv6 Multicast Listener Discovery (MLD)

- MLD uses LL source addresses
- 3 msg types: Query, Report, Done
- MLD packets use “Router Alert” in HBH
- Snooping for efficient delivery at L2 boundary

<table>
<thead>
<tr>
<th>MLD</th>
<th>IGMP</th>
<th>Message Type</th>
<th>ICMPv6 Type</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>MLDv1 (RFC 2710)</td>
<td>IGMPv2 (RFC 2236)</td>
<td>Listener Query</td>
<td>130</td>
<td>Used to find out if there are any multicast listeners</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Listener Report</td>
<td>131</td>
<td>Response to a query, joins a group</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Listener Done</td>
<td>132</td>
<td>Sent by node to report it has stopped listening</td>
</tr>
<tr>
<td>MLDv2 (RFC 3810)</td>
<td>IGMPv3 (RFC 3376)</td>
<td>Listener Query</td>
<td>130</td>
<td>Used to find out if there are any multicast listeners</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Listener Report</td>
<td>143</td>
<td>Enhanced reporting, multiple groups and sources</td>
</tr>
</tbody>
</table>
MLDv1 Example Joining a Group (REPORT)

- Hosts send MLD report to alert router they wish to join a multicast group
- Router then joins the tree to the source or RP
MLDv1 Example Leaving a Group (Query)

I wish to leave ff38::276

MLD Done (A)

ICMP Type 132
IPv6 Source fe80::209:5bff:fe08:a674
IPv6 Destination FF02::2 (All routers)
Hop Limit 1
Group Address ff38::276
Hop-by-Hop Header
Router Alert Yes

I am watching ff38::276

MLD Report (B)

ICMP Type 131
IPv6 Source fe80::250:8bff:fE55:78de
IPv6 Destination FF38::276
Hop Limit 1
Group Address ff38::276
Hop-by-Hop Header
Router Alert Yes

Query

MLD Query (C)

ICMP Type 130
IPv6 Source fe80::207:85ff:fe80:692
IPv6 Destination FF38::276
Hop Limit 1
Group Address ff38::276
Hop-by-Hop Header
Router Alert Yes
MLDv2 Example (Report & Query)

- Query Format MLDv1, MLDv2
- General Query (~125 Seconds) FF02::1
- Group Specific Query FF38::4000:BA11
- Group & Source Specific Query 2001:DB8:CAFÉ::1, FF38::4000:BA11
- Leaving a Group MLDv2
  Ignore Query (silent)
  Filter mode Change Record (report)
Protocol Independent Multicast
PIM and IPv6 (RFC 4601)

- PIM is Join and Prune or PULL mode protocol, and transparent to the IP version. It is the only multicast protocol supported for IPv6 and uses next header type 103.

- PIM Sparse-Mode (PIM-SM) - RP is required
  Sparse-Mode for many-to-many applications (Multiple sources, single group)
  Uses shared tree initially but may switch to source tree.

- Bi-directional PIM (PIM-BiDir) - RP is required
  Bi-Directional many-to-many (hosts can be sources and receivers)
  Like PIM-SM but uses a BiDIR shared tree for all traffic.

- PIM Source-Specific Multicast (PIM-SSM) - No RP is required
  For one-to-many applications (Single source, single group)
  Always uses a (S, G) source tree – (S) is learnt somehow or known out of band.
Multicast States (S, G) (*, G)

- Provides the forwarding entries for packet distribution down a tree
- Consists of the Source Address (S) and the Destination Group (G) of the multicast stream
- Expressed as (S, G) for Source Trees
  - Means an explicit source for a multicast group
  - More Memory, Optimal Paths, Less Delay
- Expressed as (*, G) for Shared Trees
  - Means ALL sources for a multicast group
  - Less Memory, Sub Optimal paths, Extra Delay
• Simplest form of tree
  Receiver requires knowledge of source
• Traffic from source (root) to receivers (leaves)
• Shortest path taken
• Packets replicated at branch point
• Forwarding entry states represented as (S, G)
• Provides Optimal routing
  At the expense of more state (S, G)
• Service model is SSM or ASM that has moved to an SPT
• Root is a common point
  Rendezvous Point
  Many multicast groups at RP
• Receivers join RP
  To learn of sources
• Sources only transmit to RP
  RP forward to receivers
• Forwarding represented as (*, G)
• Less state required
  At expense of optimal routing
• Service model is ASM
Bi-Directional Shared Tree

- Traffic can travel in both directions Up and Down the tree
- Source packets do not necessarily have to travel via the RP
- Forwarding entries represented as (*, G)
- Offers improved routing optimality than unidirectional shared tree
- Service model is ASM
Multicast Forwarding

• Multicast forwarding is the opposite of Unicast forwarding
  Unicast is concerned about where the packet is going
  Multicast is concerned about where the packet came from

• Multicast uses Reverse-Path Forwarding (RPF)
  Checks if arriving packet is on reverse path back to source
  If successful, packets is forwarded, otherwise dropped

• RPF procedure for PIM uses unicast routing table to find source
Packet has arrived on wrong Interface
Discard the packet!

Multicast packet from source 2001:db8:face::1

<table>
<thead>
<tr>
<th>Network</th>
<th>Interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001:db8:face::/48</td>
<td>S1</td>
</tr>
<tr>
<td>2001:db8:beef::/48</td>
<td>S0</td>
</tr>
<tr>
<td>2001:db8:f00d::/48</td>
<td>E0</td>
</tr>
</tbody>
</table>
Multicast Forwarding RPF Check

RPF Check Succeeds

Multicast Packet from Source 2001:db8:face::1

Packet arrived on correct interface!
Forward via all outgoing interfaces (i.e. down the distribution tree)

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<tr>
<td>2001:db8:beef::/48</td>
<td>S0</td>
</tr>
<tr>
<td>2001:db8:f00d::/48</td>
<td>E0</td>
</tr>
</tbody>
</table>
Final Thoughts
Key Take Away

- Applications We Haven't Even Built Yet
- Large Privately Owned Multicast Address Space
- Built-in Scoping
- No NAT required
- Embedded RP, Anycast, Etc..
- Multicast is Foundational in IPv6
- Invest in your future - IPv6, the future is now