IP Multicasting

• Multicasting
• Multicast addressing
• IGMP
• Multicast Routing

Applications with multiple receivers

• Many applications transmit the same data at one time to multiple receivers
  • Broadcasts of Radio or Video
  • Videoconferencing
  • Shared Applications

• A network must have mechanisms to support such applications in an efficient manner
Motivation

"Together, Internet broadcasting and multicasting are the next chapters in the evolution of the Internet as a revolutionary catalyst for the information age."

Vint Cerf, Senior vice president of MCI/Worldcom, April 1999.

Multicasting

- Multicast communications refers to one-to-many or many-to-many communications.

IP Multicasting refers to the implementation of multicast communication in the Internet.
Multicasting over a Packet Network

• Without support for multicast at the network layer:

Multiple copies of the same message is transmitted on the same link

• With support for multicast at the network layer:

• Requires two mechanisms:
  (1) Packet forwarding can send multiple copies of same packet
  (2) Multicast routing algorithm which builds a spanning tree (dynamically)
Semantics of IP Multicast

IP multicast works as follows:

- Multicast groups are identified by IP addresses in the range 224.0.0.0 - 239.255.255.255 (class D address)
- Every host (*more precisely: interface*) can join and leave a multicast group dynamically
  - no access control
- Every IP datagram send to a multicast group is transmitted to all members of the group
  - no security, no “floor control”

- The IP Multicast service is unreliable

The IP Protocol Stack

- IP Multicasting only supports UDP as higher layer
- There is no multicast TCP!
IP Multicasting

- There are three essential components of the IP Multicast service:

  - IP Multicast Addressing
  - IP Group Management
  - Multicast Routing

Multicast Addressing

- All Class D addresses are multicast addresses:

  

<table>
<thead>
<tr>
<th>Class D</th>
<th>1</th>
<th>1</th>
<th>1</th>
<th>0</th>
<th>multicast group id</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>28 bits</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class</th>
<th>From</th>
<th>To</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>224.0.0.0</td>
<td>239.255.255.255</td>
</tr>
</tbody>
</table>

- Multicast addresses are dynamically assigned.
- An IP datagram sent to a multicast address is forwarded to everyone who has joined the multicast group.
- If an application is terminated, the multicast address is (implicitly) released.
Types of Multicast addresses

- The range of addresses between 224.0.0.0 and 224.0.0.255, inclusive, is reserved for the use of routing protocols and other low-level topology discovery or maintenance protocols.
- Multicast routers should not forward any multicast datagram with destination addresses in this range.
- Examples of special and reserved Class D addresses, e.g.,
  - 224.0.0.1: All systems on this subnet
  - 224.0.0.2: All routers on this subnet
  - 224.0.1.1: NTP (Network Time Protocol)
  - 224.0.0.9: RIP-2 (a routing protocol)

Multicast Address Translation

- In Ethernet MAC addresses, a multicast address is identified by setting the lowest bit of the “most left byte”

```
-------1--------
```

Not all Ethernet cards can filter multicast addresses in hardware:
- Then: Filtering is done in software by device driver.
Multicast Address Mapping

Ethernet Addresses with 01:00:5e in the first 3 bytes are reserved for IP multicast.

1110xxxx
x-------
--------
--------

Class D IP Address

23-bit address

Identifies Class D

Ignored

IGMP

- The Internet Group Management Protocol (IGMP) is a simple protocol for the support of IP multicast.
- IGMP is defined in RFC 1112.
- IGMP operates on a physical network (e.g., single Ethernet Segment).
- IGMP is used by multicast routers to keep track of membership in a multicast group.
- Support for:
  - Joining a multicast group
  - Query membership
  - Send membership reports
IGMP Protocol

- A host sends an IGMP report when it joins a multicast group.
  (Note: multiple processes on a host can join. A report is sent only for the first process).
- No report is sent when a process leaves a group.
- A multicast router regularly multicasts an IGMP query to all hosts (group address is set to zero).
- A host responds to an IGMP query with an IGMP report.

- Multicast router keeps a table on the multicast groups that have joined hosts. The router only forwards a packet, if there is a host still joined.
- Note: Router does not keep track which host is joined.

IGMP Packet Format

- IGMP messages are only 8 bytes long

```
14 bytes                       20 bytes                       8 bytes
Ethernet Header       IP header        IGMP Message
```

```
<table>
<thead>
<tr>
<th>Version</th>
<th>Type</th>
<th>(unused)</th>
<th>Checksum</th>
</tr>
</thead>
<tbody>
<tr>
<td>(= 0)</td>
<td>(=1-2)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

32-bit Class D address
```

- Type: 1 = sent by router, 2 = sent by host
IGMP Protocol

Host A        Host B

Ethernet       Multicast Router

IGMP query

IGMP Report

IGMP Protocol

Host A        Host B

Ethernet       Multicast Router

IGMP query

IGMP report
IGMP group address = group address
Dest IP address = 224.0.0.1
src IP address = router's IP address
src IP address = host's IP address
Multicast Routing Protocols

- **Goal:** Build a spanning tree between all members of a multicast group

There are several multicast routing protocols in use:

- **DVMRP** (Distance Vector Multicast Routing Protocol)
  - Can be thought of as an extension of RIP to multicasting
- **MOSPF** (Multicast Open Shortest Path First)
  - Can be thought of as an extension of OSPF to multicasting
- **PIM** (Protocol Independent Multicast)
  - Runs in two modes: sparse mode (PIM-SM) and dense mode (PIM-DM)
DVMRP (We will only discuss DVMRP)

- Development of DVMRP is best explained as a number of improvements:
  - Reverse Path Forwarding
    - builds a spanning tree starting at a source node
  - Truncated Broadcasting
    - LANs where no host is listening are truncated
  - Pruning
    - Branches of the tree are “pruned” if no one is listening below
  - Grafting
    - Branches of the tree are quickly added if new members join

= DVMRP (Distance Vector Multicast Routing Protocol)

Reverse Path Forwarding

- Algorithm for loop free flooding for packet from a node (“Sender” or S) to all other nodes

- Reverse Path Forwarding Rule:
  If a packet from is received on the interface that the router uses to send packets to the sender S, only then will the packet be forwarded along the other interfaces. Otherwise, the packet is dropped.
Reverse Path Forwarding

Sender

- Blue arrow shows the next hop of the reverse path as indicated by the arrow.
- Orange arrows show where packets are forwarded.
- Red arrows show where packets are dropped.

Truncated Broadcasting

- A router forwards a packet on a local network, only if there are multicast group members.

- This is easy, since a router knows about membership of local networks from IGMP protocol.
Pruning

- **Prune message** removes a link from the multicast tree
  - No multicast messages are sent on a pruned link
  - Prune message is sent in response to a multicast packet

- **Who sends prune messages?**
  - A router with no group members in its local network and no connection to other routers
  - A router with no group members in its local network which has received a prune message on all interfaces
  - A router with group members which has received a packet from a neighbor not on its shortest reverse path
Prune messages

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Prune messages

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Prune messages

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Graft Messages

- In DVMRP (similar to RIP), routing tables entries time out after some time. So, flooding and pruning is repeated periodically.
- With current method, new members cannot be added until the next flooding/pruning cycle.

- **Optimization:**
  - Routers can send a "graft" message to hook into an existing (pruned) tree.
  - Graft message propagates upstream in the shortest path tree until it reaches a router which is part of the current tree.

  Graft messages cancel prune messages.
DVMRP Protocol

• DVMRP uses IGMP to exchange routing datagrams

<table>
<thead>
<tr>
<th>Version (= 1)</th>
<th>Type (3)</th>
<th>Subtype</th>
<th>Checksum</th>
<th>Tagged Data</th>
</tr>
</thead>
</table>

Subtype:
1 = Response
2 = Request
3 = Non-membership report
4 = Non-membership Cancellation

DVMRP Routing Table

<table>
<thead>
<tr>
<th>Source Subnet</th>
<th>From Gateway</th>
<th>Metric</th>
<th>Status</th>
<th>TTL</th>
<th>In-Vif</th>
<th>Out-Vif</th>
</tr>
</thead>
<tbody>
<tr>
<td>216.234.131/24</td>
<td>128.143.2.23</td>
<td>3</td>
<td>up</td>
<td>40</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>216.168.95/24</td>
<td>128.143.2.23</td>
<td>3</td>
<td>up</td>
<td>40</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>216.168.94/24</td>
<td>128.143.2.23</td>
<td>3</td>
<td>up</td>
<td>40</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
### DVMRP Forwarding Table

Represents the shortest path source rooted tree for each (source, group) pair.

<table>
<thead>
<tr>
<th>Source Subnet</th>
<th>Multicast Group</th>
<th>TTL</th>
<th>In-VIF</th>
<th>Out-VIF</th>
</tr>
</thead>
<tbody>
<tr>
<td>207.126.96/19</td>
<td>224.0.1.1</td>
<td>40</td>
<td>1P</td>
<td>0p</td>
</tr>
<tr>
<td>128.233/16</td>
<td>224.0.1.22</td>
<td>40</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>198.32.251/24</td>
<td>224.0.1.32</td>
<td>40</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

- P in the In-VIF implies a prune message has been sent to the upstream router.
- p in the Out-VIF implies the router has received a prune message.

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### Conclusion

- Two separate processes for unicast and multicast routing
- DVMRP is an interior gateway protocol
- Disadvantage of being a distance vector algorithm