CS 204:
Multicast

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Lectures: MWF 12:10-1pm in WCH 139

http://www.cs.ucr.edu/~jiasi/teaching/cs204_spring16/
Overview

• Basics
• Routing algorithms
  • Flooding
  • Spanning trees
  • RPB
  • TRPB
  • RPM
• Implementations of routing algorithms
  • MOSPF
  • DVMRP
  • PIM
• Paper discussion
What is multicast?

• Group of hosts requesting same content

• What would unicast do?
What is Multicast?
What is Multicast?

• One-to-many routing

• Main goal: efficiency

• Example applications
  • Audio/video
  • Software distribution
  • Web-cache updates
  • Teleconferencing
  • Games

• Job of the router
  • Know which groups its hosts are subscribed to
  • Forward packets to hosts
  • Forward packets to other routers
Multicast Service Model

- Anyone can join
- Sender need not be part of the multicast group
- Members can join and leave at will
- Group membership is not explicitly known

- Analogy: radio channel
Multicast Addressing

- **IP address (32 bits)**
  - Class D: 224.0.1.0 to 239.255.255.255

- **MAC address (48 bits)**
  - 01-00-5E-xx-xx-xx
Converting Multicast IP to MAC Address

May not be unique

224.10.8.5

Ethernet Multicast Address

not used

low-order 23-bits mapped

Unique part of MAC address
Limiting the Scope of Multicast Packets

- Each interface assigned a TTL
- IP header also contains TTL
- Forward packet iff packet TTL > interface TTL

<table>
<thead>
<tr>
<th>Initial TTL</th>
<th>Scope</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Restricted to the same host</td>
</tr>
<tr>
<td>1</td>
<td>Restricted to the same subnetwork</td>
</tr>
<tr>
<td>32</td>
<td>Restricted to the same site</td>
</tr>
<tr>
<td>64</td>
<td>Restricted to the same region</td>
</tr>
<tr>
<td>128</td>
<td>Restricted to the same continent</td>
</tr>
<tr>
<td>255</td>
<td>Unrestricted in scope</td>
</tr>
</tbody>
</table>
How do hosts talk to routers?
Multicast API

• **Sender**
  • Same as before: send to multicast IP

• **Receiver**
  • Need to join the multicast group by sending message to router
    • Join-IP-Multicast-Group
    • Leave-IP-Multicast-Group
Router
1. QUERY 224.0.0.1, TTL=1
“Which groups are you part of?”

Each client: “I am part of group $g$”
2. For each group $g$ I am part of, set a random timer $T_g$
3. If I hear another report for group $g$, reset $T_g$
4. When $T_g$ expires, send my report
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Classification

Who is part of my multicast group?
- Flood-and-prune
- Core-based tree

What kind of distribution tree?
- Source-based trees
- Shared tree
How to route the packets?
Flooding

1. Forward the packets
   • On all links except receiving
   • If haven’t seen this packet before

Benefits
• Easy to implement

Disadvantages
• Not scalable
Internet-Wide Spanning Trees

1. Construct a spanning tree
2. Forward the packets
   • on the links of the spanning tree

Advantages
• Spanning tree algorithms are well-known

Disadvantages
• Not the most efficient path
• Concentrates traffic on a few number of links
• Needs the entire Internet topology!
RPB: Source-Specific Spanning Tree

1. Forward packets
   a) If received packet on my shortest path to source
   b) to all “downstream” routers
   c) to hosts on your subnet

Benefits
• Distribute traffic over links because construct a new tree for each source
• Shortest path

Disadvantages
• Forwards packets to routers not connected to multicast groups
How to determine downstream routers?

• Downstream = next router considers me as part of their shortest path to source

• Unicast: route packets **towards destination**
• Multicast: route packets **away from source**
  • Call this **reverse path fowarding**

• Link-state: already have topology
• Distance vector: need to advertise last hop to neighbors
TRPB: Add in IGMP

1. Forward packets
   a) If received packet on my shortest path to source
   b) to all “downstream” routers
   c) to hosts on your subnet if they are part of the multicast group
RPM

1. Forward packets
   a) If received packet on my shortest path to source
   b) to all “downstream” routers
   c) to hosts on your subnet if they are part of the multicast group
   d) If a “prune” message hasn’t been received

Benefits
• Reduce unnecessary traffic in subnets and between routers

Disadvantages
• Periodically, packets sent to all multicast routers
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MOSPF

Link state based
- Modify OSPF
- Compute shortest path between source and set of destinations
- Periodically flood with neighbor information

Disadvantage
- Need to re-compute entire shortest path if user joins/leaves
DVMRP

Distance-vector based
- Pass messages with (dest, cost) to neighbors
- If dest = multicast source, pass cost = infinity to upstream router
## DVMRP details

### Routing table

<table>
<thead>
<tr>
<th>Source Subnet</th>
<th>Subnet Mask</th>
<th>From Gateway</th>
<th>Metric</th>
<th>Status</th>
<th>TTL</th>
<th>InPort</th>
<th>OutPorts</th>
</tr>
</thead>
<tbody>
<tr>
<td>128.1.0.0</td>
<td>255.255.0.0</td>
<td>128.7.5.2</td>
<td>3</td>
<td>Up</td>
<td>200</td>
<td>1</td>
<td>2,3</td>
</tr>
<tr>
<td>128.2.0.0</td>
<td>255.255.0.0</td>
<td>128.7.5.2</td>
<td>5</td>
<td>Up</td>
<td>150</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>128.3.0.0</td>
<td>255.255.0.0</td>
<td>128.6.3.1</td>
<td>2</td>
<td>Up</td>
<td>150</td>
<td>2</td>
<td>1,3</td>
</tr>
<tr>
<td>128.4.0.0</td>
<td>255.255.0.0</td>
<td>128.6.3.1</td>
<td>4</td>
<td>Up</td>
<td>200</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

### Forwarding table

<table>
<thead>
<tr>
<th>Source Subnet</th>
<th>Multicast Group</th>
<th>TTL</th>
<th>InPort</th>
<th>OutPorts</th>
</tr>
</thead>
<tbody>
<tr>
<td>128.1.0.0</td>
<td>224.1.1.1</td>
<td>200</td>
<td>1 Pr</td>
<td>2p 3p</td>
</tr>
<tr>
<td>224.2.2.2</td>
<td>100</td>
<td>1</td>
<td>2p 3</td>
<td></td>
</tr>
<tr>
<td>224.3.3.3</td>
<td>250</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>128.2.0.0</td>
<td>224.1.1.1</td>
<td>150</td>
<td>2</td>
<td>2p 3</td>
</tr>
</tbody>
</table>

p = prune message sent/received
Protocol Independent Multicast (PIM)

• Why maintain a separate multicast routing table?

• Look at unicast routing table
  • If unicast path (destination = multicast source)
• Agnostic to which unicast routing algorithm is used

• Dense mode: assume everyone is part of multicast group, and explicitly remove
• Sparse mode: assume nobody is part of multicast group, and explicitly join
PIM-Dense

• Similar to DVMRP
• Reverse-path-forwarding
  • Instead of distance vector, use unicast routing table
PIM-Sparse

Center-based tree
- RP administratively configured

Source
1. Register with RP
2. Send packets to RP

Receiver
1. Send join message to RP

RP
1. Create the (*,group) tree
### Summary

Who is part of the multicast group?
- Flood-and-prune
- Core-based tree

What kind of distribution tree?
- Source-based trees
- Shared tree

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Flood-and-prune or center-based?</th>
<th>Source-based or shared tree?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flooding/spanning tree</td>
<td>Flood</td>
<td>Shared</td>
</tr>
<tr>
<td>RPB</td>
<td>Flood</td>
<td>Source</td>
</tr>
<tr>
<td>RPM</td>
<td>Flood-and-prune</td>
<td>Source</td>
</tr>
<tr>
<td>DVMRP</td>
<td>Flood-and-prune</td>
<td>Source</td>
</tr>
<tr>
<td>PIM-Dense</td>
<td>Flood-and-prune</td>
<td>Source</td>
</tr>
<tr>
<td>PIM-Sparse</td>
<td>Center-based</td>
<td>Mostly shared, can be source</td>
</tr>
</tbody>
</table>
Tunneling

Q: how to connect “islands” of multicast routers in a “sea” of unicast routers?

- mcast datagram encapsulated inside “normal” (non-multicast-addressed) datagram
- normal IP datagram sent thru “tunnel” via regular IP unicast to receiving mcast router (recall IPv6 inside IPv4 tunneling)
- receiving mcast router unencapsulates to get mcast datagram
Who Uses IP Multicast?

• Testbeds
  • MBONE (DVMRP)
  • Internet2

• Live video CDNs?

• Wireless?
A Case for End System Multicast

Unicast  Network multicast  End system multicast
Paper Discussion

• Mesh vs source-based tree vs shared tree?

• How did they test?

• What are the drawbacks?
Sources

• *Computer Networking: A Top-Down Approach*, Kurose & Ross
• “Introduction to IP Multicast Routing,” Chuck Semeria and Tom Maufer