Multicasting on the Internet
The pieces of the puzzle

- Hosts must support IP multicast
  - Three levels of IP multicast participation
    - Level 0 — Host can neither send nor receive multicast packets
    - Level 1 — Host can send but not receive multicast packets
    - Level 2 — Host can both send and receive multicast packets

- A local multicast router must exist to forward multicast packets
  - Local router must support IGMP
Multicasting on the Internet Today
The MBONE multicast backbone

- A multicast “overlay” network operational since 1992
  » A collection of multicast “islands” connected via IP tunnels

The MBONE Multicast Backbone
Growth of the MBONE

Adapted from Deering p. 6
The MBONE Multicast Backbone

MBONE topology

The MBONE
Multicast message encapsulation

- **Tunnel parameters:**
  - *Destination* — An IP address
  - *Threshold* — The minimum TTL required for a packet to be forwarded across this tunnel
  - *Cost* — A metric used to compute routing “distances”
Multicast Routing on the MBONE

mrouted — RPF with pruning

- Distance Vector Multicast Routing Protocol (DVMRP)
  » Constructs a (separate) multicast routing table based on reverse-path computations to all potential sources
  » For each source network and neighboring router, a bit is maintained indicating if the neighbor thinks this router is the previous hop from the source
  » Routers advertise group membership for pruning of multicast trees

- DVMRP implemented as a set of extensions to IGMP
  » Broadcast of reverse-path information to peer routers
  » Broadcast of group membership information

Routing on the MBONE

Reverse Path Flooding with Pruning

- Unicast routing protocol is used to build a spanning tree
  » Packets initially flood the network
When a multicast packet from source $S$ destined for group $G$ is received...

» Check to see if the reverse path to the source is the shortest

» Is so, forward forward on all interfaces and tunnels if:
  
  ❖ This router is on the shortest path from the source to the tunnel’s destination
  
  ❖ The packet’s TTL is above the tunnel’s threshold
  
  ❖ The tunnel has not been pruned for this source and this group

Routing on the MBONE

Configuring tunnels

Tunnel thresholds limit initial flooding & provide limited policing

<table>
<thead>
<tr>
<th>Traffic Type</th>
<th>Packet TTL</th>
<th>$kbps$</th>
<th>Tunnel Threshold</th>
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<tr>
<td>Canonical IETF Multicast TTL Settings</td>
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<td>GSM Audio 1</td>
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<td>224</td>
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<td>$\geq 250$</td>
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</table>
Routing on the MBONE

Configuring tunnels

- Tunnel costs allow fault tolerance (& optimized performance)

**Multicast Routing Standards**

**Multicast OSPF (MOSPF)**

- Reverse path forwarding & pruning applied to OSPF
  - Largely an intra-autonomous system protocol

- Emphasis is on efficient route computation
  - Add a group membership record to the link-state database
  - Use OSPF link-state map to perform RPF calculations and pruning without flooding

- When a packet arrives at a router...
  - Use link-state database to compute shortest path tree from source to local destinations
  - Prune the tree using group membership information
Multicast Routing Standards

Multicast OSPF (MOSPF)

Group List
yyy.yyy.yyy.yyy
xxx.xxx.xxx.xxx

Group List Summary
yyy.yyy.yyy.yyy
xxx.xxx.xxx.xxx

Multicast Routing Standards
Protocol independent multicast (PIM)

- Two protocols:
  - dense mode
    - Used when the likelihood of a group member existing in a given area is high
    - Based on reverse path forwarding and pruning
  - sparse mode
    - Opposite of dense
    - Based on core-based trees
PIM Dense Mode
Straightforward RPF with pruning

- Similar to DVMRP but independent of routing tables
  - Assume point-to-point routes are symmetric and use whatever unicast routing facility exists

- When a multicast packet is received from source $S$ to group $G$...
  - Check unicast routing tables to confirm incoming interface is the one used for sending packets to $S$
  - If not, the packet is dropped and a $\text{prune}(S, G)$ message is sent upstream
  - If so, forward the packet on all interfaces on which $\text{prune}$ messages have not been received
  - If no such interfaces exist, send a prune message upstream

PIM Dense Mode
RPF with pruning — Problems with broadcast networks

- What if multiple routers on a broadcast network exist?
  - Multicast the $\text{prune}$ to the all routers group (224.0.0.2)
PIM Dense Mode
Problems with broadcast networks

- Multicast the prune to the all routers group (224.0.0.2)
- C responds with a join for group G

The independent multipath problem
  » Routers B and C both forward multicast packets to host A
PIM Dense Mode
Problems with broadcast networks

◆ Competing routers respond to duplicate transmissions with an *assert* message giving their distance to the source
  » Multicast the *assert* to the *all routers group* (224.0.0.2)

◆ The “loser” prunes back from the conflicting interface

PIM Sparse Mode
A variant on Core-Based Trees

◆ Associate a set of “rendezvous points” (RP) with each multicast group
◆ Receivers join the group by sending *join* messages to an RP
◆ Intermediate routers cache a record for the group
PIM Sparse Mode
Sending datagrams to a multicast group

- C has joined the group rooted at RP
- B encapsulates the first multicast packet it sees in a PIM register command and sends to the RP
- The RP sends a join message to B making it the new root of the tree
  » The source’s first multicast packet is resent on the RP tree

PIM Sparse Mode
Evolving to an RPF source-based tree

- D prunes back to the RP
- D sends a join message towards C
Most multicast applications are not flow controlled

What’s the effect of all of this on TCP?
  » Is TCP too “nice” of a protocol?
    (Are multicast applications too “aggressive”?)

How to realize reliable multicast

How can we provide feedback to applications on their performance?
  » How can MBONE applications adapt to congestion?

Is random assignment sufficient for assigning multicast group addresses?

Can a sender tell who is receiving their streams?
Proposal for anycast address type in IPv6
» Address bound to multiple interfaces
» IPv6 routing delivers packets with this address to exactly one interface, based on routing protocol’s notion of “nearest”
» Syntactically identical to unicast IPv6 address

Envisioned use: Set of routers within an ISP for CIDR-like routing