Multicast

- **Multicast** = Sending messages to multiple receivers.
- **Unicast** = Sending messages to a single receiver.
- **Broadcast** = Sending messages to ALL receivers in a network. (sometimes also called *flooding*, if the network is multihop).

Layering of Multicast

![Diagram showing the layering of Multicast](image-url)
Example

Multiple unicast

Multicast

Applications of Multicast

• Tele/Video conferencing.
• Distributed interactive games, whiteboards, content delivery (push applications).
• Video/media distribution.
• Various protocol needs,
  – Replicated database updates.
  – Router updates, etc.
• Major application models
  – Point-to-multipoint (single source, multiple receivers).
  – Multipoint-to multipoint (multiple sources, multi receivers).
  – Source(s) may or may not be receiver(s).
• Note, many hosts and most routers on current Internet are not multicast capable!!
Multicast Using Multiple Unicast

- Naïve protocol.
- Too much overhead. Same packet will go over the same link many times for different destinations.

Multicast Using Multi-destination Addressing

- Not scalable. Useful only for small no. of receivers.
Multicast Using Multicast

- Forward via the shortest-path tree rooted at source. *(Source-based tree protocol).*

Theoretical Basis

- Ideally, use a Steiner Tree.
- Minimum cost Steiner Tree problem is NP complete.
  - Graph $G = (V, E)$
  - Positive edge weights $W(e)$
  - $R$ a subset of $V$. $R$ is the set of receivers.
  - Find a minimum-cost subtree of $G$ that includes all of $R$.
  - Shortest path tree – easy approach. But bound unknown! Incremental changes.
Design Choices for Multicast Routing

• **Addressing** – how the multicast destinations (receivers) are to be indicated?
  – List approach – not scalable
  – Group approach – no control; who maintains the group??

• **Routing protocol**
  – Re-use the unicast routing infrastructure?
  – Desirable. But is it too constraining?

Multicast on the Internet
(IP Multicast)

• **Concept of multicast group**
  – Set of nodes wishing to listen to a particular “connection.”
  – Sender(s) need not be group member(s). Sender does not know group members.
  – Each group has a “group address.”
  – Nodes may join/leave group at will. Group size unrestricted.

• **Multicast addressing**
  – Packets sent to a group address, not to individual node address.
  – Group address is a valid IP address.
  – A router will multicast the packet on a LAN (link-layer multicast) if there is a host on the LAN that is a member of the destination group.
Multicast Addressing

• Class D IP address:
  – 224.0.0.0 thru’ 239.255.255.255. High order bits are 1110.
  – Flat address space. No subnetting.

• Link-layer multicast over IEEE 802 style LANs
  – E.g., Ethernet, wireless LANs
  – Lower 23 bits of mcast IP address is copied to the lower 23 bits of MAC address and a specific mcast bit is set.
  – Node picks up the packet if there is an address match with the lower 23 bits for a mcast group the node is listening to.

Group Membership Protocol and Link-layer Multicast: Big Picture

• Local router knows that a host on the LAN is a group member via IGMP (Internet Group Management Protocol).
• Local router forward the packet to host(s) on LAN via link-layer multicast.
IGMP (Internet Group Management Protocol)

- Used by a host to declare membership to a multicast group to the nearest router.

- Router sends IGMP query. Any member host responds with an IGMP report. Randomized delay for response to discourage reply storm.

IGMP (contd.)

- All the router cares about if there is any host at all on the LAN that is a member of a specific group
  - Feedback suppression: If a host hears a report for the same group by another host, it suppresses its own report.
- IGMP v2:
  - Adds group-specific queries.
  - Adds explicit group leave messages by hosts. Lower "leave latency."
- Note, nobody explicitly keeps track all hosts on the Internet that constitute a group.
IP Multicast Components

- **Group membership protocol**
  - Router “knows” whether an attached LAN has a member host for a group.
  - Then it multicasts the packets addressed to that group on the LAN.

- **Link-layer multicast**
  - Hosts listening to that address pick up the packets.

- **Network-layer (IP layer) multicast**
  - Source must somehow route the packet to each router that have an attached LAN with at least one host listening to that mcast address.
Basic Multicast Routing: Reverse Path Forwarding

- One of the original mcast routing protocols on the Internet. Basis of MBone.
- Packet arrives on a link L from Source. Check if L is the link the router would use to send packets to Source.
  - If true, Transmit packet on all links except L.
  - If false, Discard packet.
- Why this rule?
  - Loop freedom.
  - Routing via Shortest Path Tree from destinations to source (reverse tree).
Reverse Path Forwarding

Routing Table Entry for S

S y

Destinations

S to Group

x w

y z

Reverse Path Forwarding

Broadcast via reverse path forwarding.
Need to prune tree for multicast.

Shortest Path Tree to Source
Flood + Prune + Graft = Multicast Forwarding

- Flood

Flood + Prune + Graft = Multicast Forwarding

- Prune unused leaves (no members) and links (not on shortest path to source).
Flood + Prune + Graft = Multicast Forwarding

- Add new members via grafting.
- Graft routers towards shortest path to source.

DVMRP: Distance Vector Multicast Routing Protocol

- Protocol based on reverse path tree based multicast forwarding.
- Uses a distance vector protocol similar to RIP
  - Computes the next hop on the shortest path to every source.
  - Floods the first packet for a <source,group> pair in the entire internetwork based on TTL.
  - All edge routers get this packet.
  - Prune the broadcast tree as described before.
Mbone: Internet Multicast Backbone

- Today, most routers on Internet are not multicast capable.
- Mbone = Virtual network overlaying Internet
  - All nodes on the overlay network are multicast capable. Use DVMRP.
  - Talk to neighboring Mbone routers using IP-in-IP encapsulation (tunneling).

IP-in-IP Encapsulation (Tunneling)

- Put a whole IP packet with a multicast destination inside a “regular” IP packet with a unicast destination.
- The unicast destination is the next hop Mbone router (tunnel endpoint).
- A specific header in the “wrapper” packet indicates that it is using tunneling (protocol type = 4).
- Tunnel endpoint decapsulates the packet for processing.
DVMRP Performance

• Tree is source-based. One tree per <source, group>.

• Uses broadcast and prune to build tree. Sometimes called implicit join.
  – Works better for dense mode (DM) multicast meaning a large group size compared to network size.

• Must broadcast+prune periodically to accommodate link cost changes.

• Must maintain per <source, group> state on ALL routers regardless of their own membership
  – Non-tree routers may still need to “graft” somebody in future.
  – They need to know which direction to forward graft messages.

• => DVMRP not good for
  – Scattered group membership.
  – Large no, of sources / groups.