Multicast Routing in Internetworks and Extended LANs

- An introduction to multicast communication
- Distance Vector Multicast Routing (DVMRP)
  - Reverse Path Flooding
  - Reverse Path Broadcasting
  - Truncated Reverse Path Broadcasting
  - Reverse Path Multicasting
- Multicast Routing in other environments
  - Link-state multicast routing
  - Spanning tree multicast routing

Multicast Communication

- Benefits of multicast
  - Reduce transmission overhead on the network
  - Reduce the load on the server
  - Reduce the time for destinations to receive the information
- Costs? (later)
- IP multicast paradigm
  - Group addressing
    - The sender need not to know the membership of the group and need not itself be a member of the group.
    - Hosts can join and leave groups at will, with no need to synchronize or negotiate with other members of the group or with potential senders of the group.
  - Best effort (high probability of delivery)
  - Low delay

Multicast Communication (cont.)

- IP multicast address
  - Class D address: 224.0.0.1 to 239.255.255.255
  - Only as destination address
  - No ICMP error message can be generated about multicast datagrams
- IGMP (Internet Group Management Protocol)
  - When a host joins a new multicast group, it sends an IGMP message to the ‘all hosts’ multicast address declaring its membership
  - Local router periodically poll hosts on the local network to determine which hosts remain members of which groups

Multicast Communication (cont.)

- Minimum Steiner Tree Problem
  - Given $G = (V, E, d)$, where $V$ is the set of vertices, $E$ is the set of edges, $d: E \rightarrow \mathbb{R}$ is the cost of edges
  - A subset $S \subseteq V$
  - Find a subgraph $G'=(V',E')$ of $G$, i.e., $V' \subseteq V$, $E' \subseteq E$, such that
    - $G'$ is a tree
    - $G'$ spans $S$, i.e., $S \subseteq V'$
    - The total cost of edges $\sum_{e \in E'} d(e)$ is minimal.
  - MST is NP hard
  - Shortest path tree from a sender

Distance-Vector Multicast Routing Protocol (DVMRP)

- Assumptions
  - Dense mode
    - A lot of receivers
  - Extension to distance vector routing protocol
  - Reverse shortest path forwarding
- Distance vector routing
  - Routing table entry
    - (destination, distance, next-hop address, next-hop link, age)
  - Information exchanged between routers
    - Distance vector $= \{(destination, distance), \ldots\}$

Reverse Path Flooding (RPF)

- Simple flooding
  - Forwards to all incident links except the one on which the packet arrives
- Problem of simple flooding
  - circles in the forwarding path: packets may be forwarded in the network forever
- Solution by RPF:
  - A router forwards a packet originating at source S iff it arrives via the shortest path from the router back to S
Reverse Path Broadcasting (RPB)

- Problems with RPF
  - A packet may be forwarded in a link multiple times, or
  - A router may receive a packet multiple times
- Solution by RPB
  - Each router identifies (independently) which of its links are ‘child’ links in the shortest reverse path tree rooted at any given source S.
  - The parent is the one with the minimum distance to S (tie breaking by lowest address)
  - Information is available from the distance vectors exchanged with other routers. (protocol-dependant)

Truncated Reverse Path Broadcasting (TRPB)

- Problems with RPB
  - A packet may be forwarded to a link with no multicast group members attached
- Solution by TRPB
  - Identify leaf link (those child links that no other router uses to reach S)
  - Every router periodically sends a packet on each of its links, saying this is my next hop to these destinations, or, Split horizon, infinity as the distance to a destination
  - Detect group membership
  - Forward a copy out all child links for S except leaf links which have no members of G.

Reverse Path Multicasting (RPM)

- Problem with TRPB
  - A packet may be forwarded to routers from which there is no downstream members
- Solution by RPM
  - Non-membership report (NMR) is sent back to the router that is one hop towards the source, when the packet reaches a router for whom all of the child links are leaves and none of them have members of the group
  - NMR is sent from the router one-hop-back if it receives NMRs from all of its child routers, and if its child links have no members.
  - An NMR includes an age (soft-state)
  - Cancellation messages when a router finds a new member
- On-demand pruning

Link-State Multicast Routing

- Link state routing protocol
  - Every router receives information about all links and all routers
  - Shortest-path spanning tree rooted at itself, using Dijkstra’s algorithm
- Link state multicast routing protocol
  - Routers include as part of the ‘state’ of a link
    - A list of groups that have members on that link
  - Any router can compute the shortest path multicast tree from any source to any group
  - Each router uses the tree to determine whether to forward or not and where to forward

Spanning-tree Multicast Routing

- Single spanning-tree (data link layer protocol)
- Propagate every multicast packet across every segment of the extended LAN
  - Forward the packet to all branches except the incoming one
- Membership-report from every member
  - Source address: the member
  - Destination address: all-bridges in the extended LAN
- Forward the packet over only those branches that are identified by non-expired table entries
  - Table entries are set up when receiving membership report
  - Soft-state (periodic update)
  - Techniques to reduce the number of membership reports