Introduction

- Delivery from a sender to a group of receivers.
- Applications
  - Software updates
  - WWW Caching
  - Multimedia content distribution, example live class lectures, rock concerts
  - Interactive gaming
- Efficient implementation needs explicit support at the network layer.
  - How do you route multicast packets?

Multicast

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Implementation

- Two approaches:
  - Naïve: Multicast implemented as multiple unicast connections. Requires no explicit router support for multicast. (Fig. On left)
  - Efficient: Multicast aware routers. Only a single copy of a multicast traverses any link in the network.

Addressing

- Problem: How do you address the receivers of a multicast group.
- Solution:
  - Header carries all receiver addresses
    - Doesn’t scale.
- Solution:
  - Use address indirection.
  - All multicast receivers are addressed by a single group address. Any packet destined to a multicast group address is delivered to all receivers of the multicast group.
  - Internet uses Class D addresses for multicast
    - Range: 224.0.0.0 – 239.255.255.255
    - Some addresses are reserved.

IGMP: Internet Group Management Protocol

- Problem: How does a receiver “join” a multicast group?
- Solution 1: Sender explicitly lists all receivers.
  - Not dynamic. Sender needs to know all possible receivers.
  - Multicast is inherently dynamic. Senders may not know intended receivers.
- Solution 2: Receivers use a group management protocol to indicate that they are interested in “joining” a multicast group.

IGMP: Internet Group Management Protocol

- IGMP is the standard group management protocol used to indicate receiver membership.
- IGMP supports 3 kinds of messages and an optional 4th message.
  - 2 membership query messages: general and specific. Used by multicast aware router
  - 1 membership report message: Used by receiver host to indicate multicast groups that it is interested in
  - 1 optional membership leave message: Used by receiver host to indicate that it is no longer interested in a multicast group.
- IGMP only works at the edge. It is used by a receiver to indicate group membership to its first hop router
  - IGMP does not work in the interior of the network. It is not used for multicast routing.
Multicast routing

- Problem: Receivers use IGMP to indicate group membership to their first hop multicast aware router. How does a multicast aware router receive data from the sender(s) of the multicast group?
- Two solutions:
  - Group shared tree
  - Source based trees

Group Shared Trees

- Single spanning tree connects senders and receivers.
- Ideally, the spanning tree should be a minimum spanning tree.
  - Problem is NP complete.
  - Approximations exist that can build a spanning tree within a constant of the ideal solution.
  - Not used in practice.
  - Tree changes when link costs change
  - Multicast aware routers need to know all link costs within the network.

Core Based Trees

- Elect a single router to be the core of the multicast tree.
- Each multicast aware router sends a join message towards the core.
- When the join message reaches a router that already receives the multicast group, the link containing the join message is grafted on to the multicast tree.
- Advantages:
  - Exploits unicast tables for forwarding the join message.
  - Multicast aware routers don’t need to maintain link state.

Source Based Trees

- Each sender builds a least cost spanning tree from itself to all receivers.
  - Different from group based tree, which uses a single tree between all senders and receivers.
  - Source based tree may have different links, since least cost is w.r.t. sender.
- Problem: Each sender needs to know all links costs to derive the least cost spanning tree.
- Solution: Reverse Path Forwarding.

Reverse Path Forwarding

- If a router receives a multicast message on its least cost path to the sender of the multicast message, it forwards the message on all its outgoing links.
  - Simple mechanism to break loops.
- Advantage: Each router only needs to know the next hop along its least cost path to sender.
- Problem: Can result in a lot of unwanted multicast packets.

Reverse Path Forwarding: Pruning

- If a multicast router receives a multicast message for which it has no receivers, it will send a prune message back upstream.
- What happens if a receiver later joins a multicast aware router that has already sent a prune message?
  - Send an “un-prune” or graft message back upstream.
  - Use a TTL to timeout bad prunes.
### Internet Multicast Routing: DVMRP
- DVMRP (RFC 1075) implements source based trees with RPF, pruning and grafting.
- Uses distance vector to determine shortest path back to sender.
- Uses dependencies of downstream routers to send upstream prune messages.
- Uses an explicit graft message to “un-prune” a previously pruned link.
  - Also supports TTL on prune messages. Default of 2 hrs.

### Internet Multicast Routing: MOSPF
- Multicast version of OSPF (RFC 1584).
  - Runs on routers that already support OSPF.
- Adds additional multicast sender/receiver/group fields to the link state advertisement sent out by OSPF routers.
- Each routers builds least cost trees from its senders to all receivers.

### Internet Multicast Routing: CBT
- CBT (RFC 2201, 2189) uses a single group shared tree between senders and receivers of a multicast group.
- Receivers join the multicast group by sending an explicit join message to the core.
- After (and if) the join is acked, receivers periodically send keepalive messages.
- Receivers that fail to send keepalive messages are automatically pruned.

### Internet Multicast Routing: PIM
- Protocol Independent Multicast (RFC 2362) offers 2 modes of operation.
  - Dense mode, where multicast routers are close to each other
  - Sparse mode, where.
- Dense mode uses RPF with prune and graft.
- Sparse mode uses a CBT approach. Uses soft state instead of join/ack.
  - Justification is that RPF will be expensive, with lot of prune messages. Routers that are not involved in a multicast group should not have to waste effort sending prune messages.