CS 640: Introduction to Computer Networks

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Lecture 12 -
Multicast

Multicast

- Unicast: one source to one destination
  - Web, telnet, FTP, ssh
- Broadcast: one source to all destinations
  - Never used over the Internet
  - LAN applications
- *Multicast*: one source to many destinations
  - Several important applications
- Multicast goal: efficient data distribution

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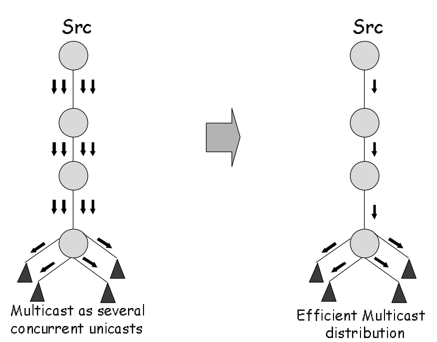
Multicast – Efficient Data Distribution



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Multicast Example Applications

- Broadcast audio/video
- Push-based systems
- Software distribution
- Web-cache updates
- Teleconferencing (audio, video, shared whiteboard, text editor)
- Multi-player games
- Server/service location
- Other distributed applications

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The Road Ahead

- IP Multicast Service Basics (host API)
- Host/Router Interaction
- Multicast Routing Basics
- MOSPF/DVMRP

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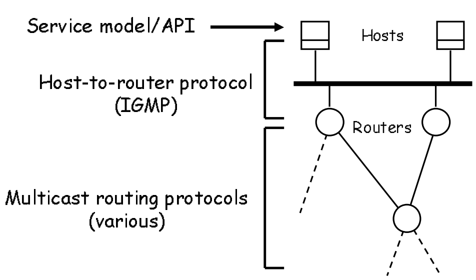
IP Multicast Architecture



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Logical Addressing/Naming

- Single name/address maps to logically related set of destinations
  - Destination set == multicast group
- Key challenges: dynamics & scalability
  - Single name/address independent of group growth or changes

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Multicast Router Responsibilities

- Learn of the existence of multicast groups (through peer advertisements)
- Identify incident links with group members
- Establish state to route packets
  - Replicate packets on appropriate interfaces
  - Routing entry:

Grp, incoming interface	List of outgoing interfaces

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IP Multicast Service Model (rfc1112)

- Each group identified by a single IP address
- Groups may be of any size
- Members of groups may be located anywhere in the Internet
- Members of groups can join and leave at will
- Senders need not be members
- Group membership not known explicitly

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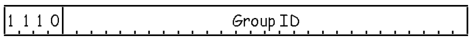
IP Multicast Addresses

- Class D IP addresses
  - 224.0.0.0 – 239.255.255.255



- How to allocate these addresses?
  - Well-known multicast addresses, assigned by IANA
  - Transient multicast addresses, assigned and reclaimed dynamically
    - e.g., by "sdr" program

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IP Multicast API

- Sending – same as before
  - Use sockets as usual, send to multicast IP
- Receiving – two new operations
  - Join-IP-Multicast-Group(group-address, interface)
  - Leave-IP-Multicast-Group(group-address, interface)
  - Receive multicast packets for joined groups via normal IP-Receive operation
  - Implemented using socket options

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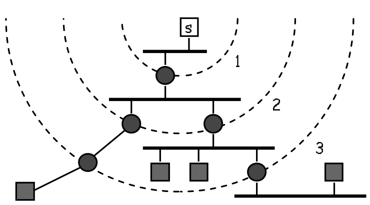
TTL-based Multicast Scope Control

- TTL expanding-ring search to reach or find a nearby subset of a group



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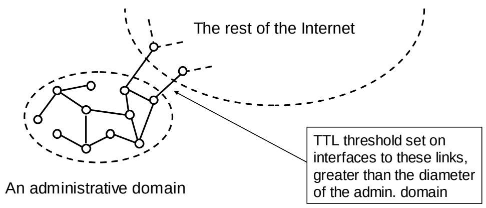
Administrative Scope Control

- Administrative TTL Boundaries to keep multicast traffic within an administrative domain, e.g., for privacy or resource reasons



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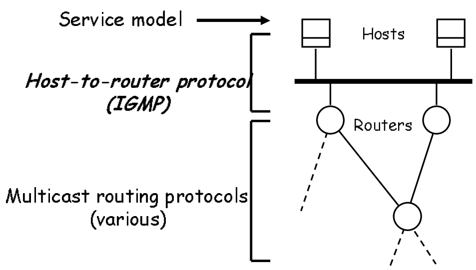
IP Multicast Architecture



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Internet Group Management Protocol

- End system to router protocol is IGMP
- Each host keeps track of which mcast groups it has subscribed to
  - Socket API informs IGMP process of all joins
- Objective is to keep router up-to-date with group membership of entire LAN
  - Routers need not know who all the members are, only that *members exist*

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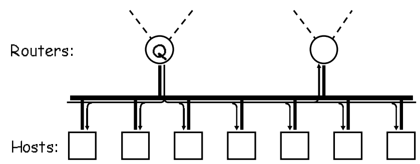
How IGMP Works



- On each link, one router is elected the "querier"
- Querier periodically sends a Membership Query message to the all-systems group (224.0.0.1), with TTL = 1
- On receipt, hosts start random timers (between 0 and 10 seconds) for each multicast group to which they belong

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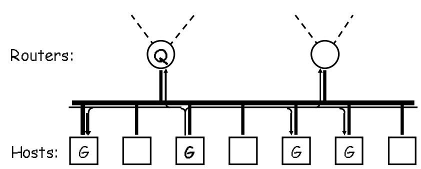
How IGMP Works (cont.)



- When a host's timer for group *G* expires, it sends a Membership Report <u>to group *G*</u>, with TTL = 1
- Other members of *G* hear the report and stop their timers
- Routers hear <u>all</u> reports, and time out non-responding groups
  - "Soft state" again

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How IGMP Works (cont.)

- Note that, in normal case, only one report message per group present is sent in response to a query
- Query interval is typically 60-90 seconds
- When a host first joins a group, it sends one or two immediate reports, instead of waiting for a query

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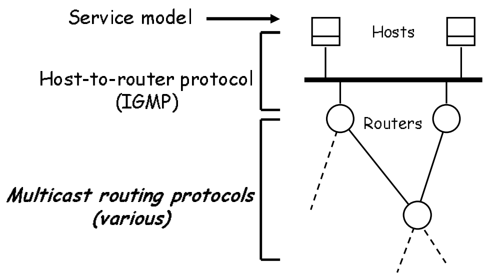
IP Multicast Architecture



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Routing Techniques

- Basic objective – routers must collectively build distribution tree for multicast packets
- Flood and prune
  - Begin by flooding traffic to entire network
  - Prune branches with no receivers
  - Examples: DVMRP, PIM-DM
  - *Unwanted state where there are no receivers*
- Link-state multicast protocols
  - Routers advertise groups for which they have receivers to entire network
  - Compute trees on demand
  - Example: MOSPF
  - *Unwanted state where there are no senders*

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Routing Techniques (Contd.)

- Core based protocols
  - Specify "meeting place" aka core
  - Sources send initial packets to core
  - Receivers join group at core
  - Requires mapping between multicast group address and "meeting place"
  - Examples: CBT, PIM-SM

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Shared vs. Source-Based Trees

- Source-based trees
  - Separate shortest path tree for each sender
  - DVMRP, MOSPF, PIM-DM, PIM-SM
- Shared trees
  - Single tree shared by all members
  - Data flows on same tree regardless of sender
  - CBT, PIM-SM

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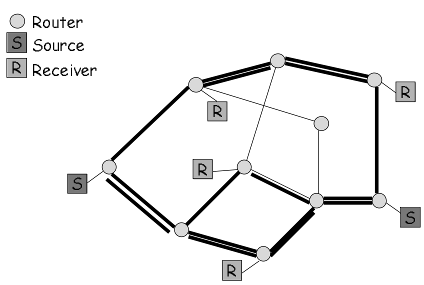
Source-based Trees



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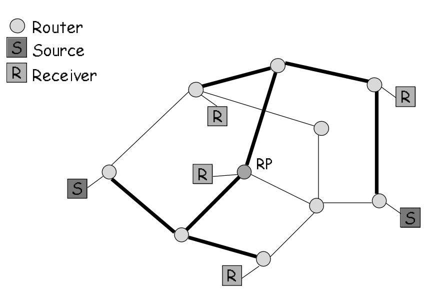
Shared Tree



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Shared vs. Source-Based Trees

- Source-based trees
  - Shortest path trees – low delay, better load distribution
  - More state at routers (per-source state)
  - Efficient for dense-area multicast
- Shared trees
  - Higher delay (bounded by factor of 2), traffic concentration
  - Choice of core affects efficiency
  - Per-group state at routers
  - Efficient for sparse-area multicast

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Multicast OSPF (MOSPF)

- Add-on to OSPF (Open Shortest-Path First, popular link-state, intra-domain routing protocol)
- Multicast-capable routers flag link state routing advertisements
- Link-state packets include multicast group addresses to which local members have joined
- Routing algorithm augmented to compute shortest-path distribution tree from a source to any set of destinations

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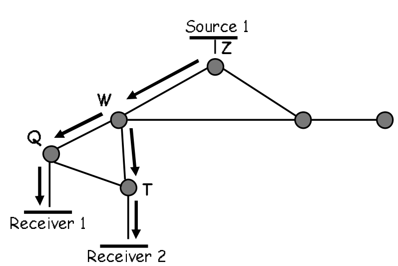
Example



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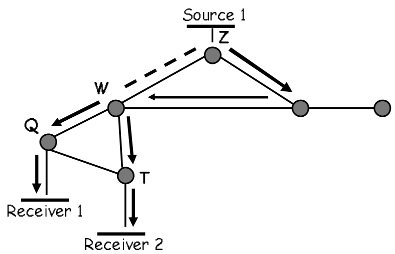
Link Failure/Topology Change



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Impact on Route Computation

- Can't pre-compute multicast trees for all possible sources
- Compute on demand when first packet from a source S to a group G arrives
- New link-state advertisement
  - May lead to addition or deletion of outgoing interfaces if it contains different group addresses
  - May lead to re-computation of entire tree if links are changed

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Distance-Vector Multicast Routing

- DVMRP consists of two major components:
  - A conventional distance-vector routing protocol (like RIP)
  - A protocol for determining how to forward multicast packets, based on the routing table
- DVMRP router forwards a packet if
  - The packet arrived from the link used to reach the source of the packet (reverse path forwarding check – RPF)
  - If downstream links have not pruned the tree

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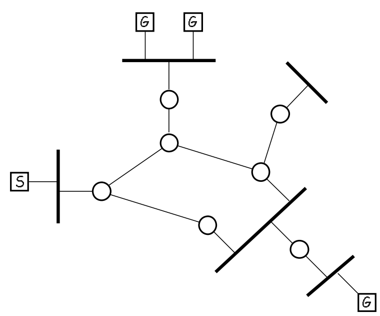
Example Topology



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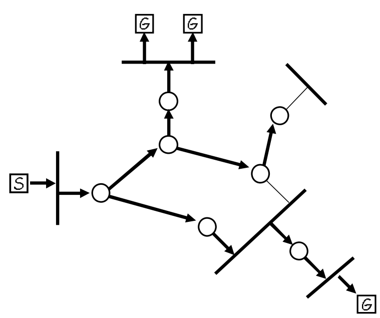
Broadcast with Truncation



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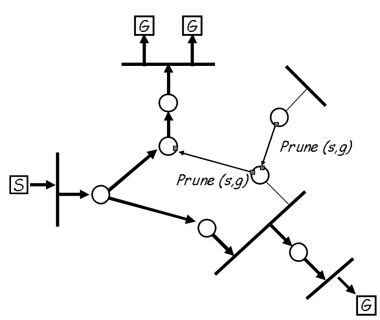
Prune



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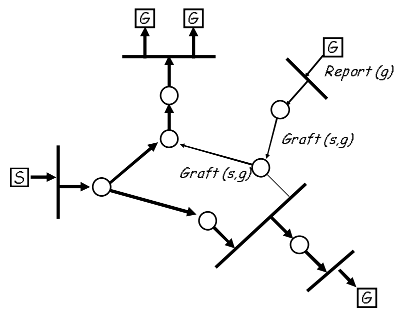
Graft



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Failure of IP Multicast

- Not widely deployed even after 15 years!
  - Use carefully – e.g., on LAN or campus, rarely over WAN
- Various failings
  - Scalability of routing protocols
  - Hard to implement TCP equivalent
  - Hard to get applications to use IP Multicast without existing wide deployment
  - Hard to get router vendors to support functionality and hard to get ISPs to configure routers to enable multicast
    - Economic incentives?

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Next Lecture

- IP-Foo
  - NAT
  - IPv6
  - Tunneling
  - Management
- 10/19
  - Mid-term
  - In-class
  - Closed-book

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