

PART XVI

INTERNET MULTICASTING

Hardware Multicast

- Form of broadcast
- Only one copy of a packet traverses the net
- NIC initially configured to accept packets destined to
 - Computer's unicast address
 - Hardware broadcast address
- User can dynamically add (and later remove)
 - One or more multicast addresses

A Note About Hardware Multicast

Although it may help to think of multicast addressing as a generalization that subsumes unicast and broadcast addresses, the underlying forwarding and delivery mechanisms can make multicast less efficient.

Ethernet Multicast

- Determined by low-order bit of high-order byte
- Example in dotted decimal:

01.00.00.00.00.00₁₆

- Remaining bits specify a *multicast group*

IP Multicast

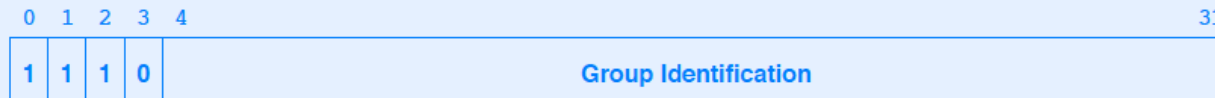
- Group address: each multicast group assigned a unique class D address
- Up to 2^{28} simultaneous multicast groups
- Dynamic group membership: host can join or leave at any time
- Uses hardware multicast where available
- Best-effort delivery semantics (same as IP)
- Arbitrary sender (does not need to be a group member)

Facilities Needed For Internet Multicast

- Multicast addressing scheme
- Effective notification and delivery mechanism
- Efficient Internet forwarding facility

IP Multicast Addressing

- Class D addresses reserved for multicast
- General form:



- Two types
 - Well-known (address reserved for specific protocol)
 - Transient (allocated as needed)

Multicast Addresses

- Address range

224.0.0.0 through 239.255.255.255

- Notes
 - 224.0.0.0 is reserved (never used)
 - 224.0.0.1 is “all systems”
 - 224.0.0.3 is “all routers”
 - Address up through 224.0.0.255 used for multicast routing protocols

Example Multicast Address Assignments

Address	Meaning
224.0.0.0	Base Address (Reserved)
224.0.0.1	All Systems on this Subnet
224.0.0.2	All Routers on this Subnet
224.0.0.3	Unassigned
224.0.0.4	DVMRP Routers
224.0.0.5	OSPF/IGMP All Routers
224.0.0.6	OSPF/IGMP Designated Routers
224.0.0.7	ST Routers
224.0.0.8	ST Hosts
224.0.0.9	RIP2 Routers
224.0.0.10	IGMP Routers
224.0.0.11	Mobile-Agents
224.0.0.12	DHCP Server / Relay Agent
224.0.0.13	All PIM Routers
224.0.0.14	RSVP-Encapsulation
224.0.0.15	All-CBT-Routers
224.0.0.16	Designated-Sbm
224.0.0.17	All-Sbms
224.0.0.18	VRRP

Example Multicast Address Assignments (continued)

Address	Meaning
224.0.0.19 through 224.0.0.255	Other Link Local Addresses
224.0.1.0 through 238.255.255.255	Globally Scoped Addresses
239.0.0.0 through 239.255.255.255	Scope restricted to one organization

Mapping An IP Multicast Address To An Ethernet Multicast Address

- Place low-order 23 bits of IP multicast address in low-order 23 bits of the special Ethernet address:

01.00.5E.00.00.00₁₆

- Example IP multicast address 224.0.0.2 becomes Ethernet multicast address

01.00.5E.00.00.02₁₆

Transmission Of Multicast Datagrams

- Host does *not* install route to multicast router
- Host uses hardware multicast to transmit multicast datagrams
- If multicast router is present on net
 - Multicast router receives datagram
 - Multicast router uses destination address to determine routing

Multicast Scope

- Refers to range of members in a group
- Defined by set of networks over which multicast datagrams travel to reach group
- Two techniques control scope
 - IP's TTL field (TTL of 1 means local net only)
 - Administrative scoping

Host Participation In IP Multicast

- Host can participate in one of three ways:

Level	Meaning
0	Host can neither send nor receive IP multicast
1	Host can send but not receive IP multicast
2	Host can both send and receive IP multicast

- Note: even level 2 requires additions to host software

Host Details For Level 2 Participation

- Host uses *Internet Group Management Protocol (IGMP)* to announce participation in multicast
- If multiple applications on a host join the same multicast group, each receives a copy of messages sent to the group
- Group membership is associated with a specific network:

A host joins a specific IP multicast group on a specific network.

IGMP

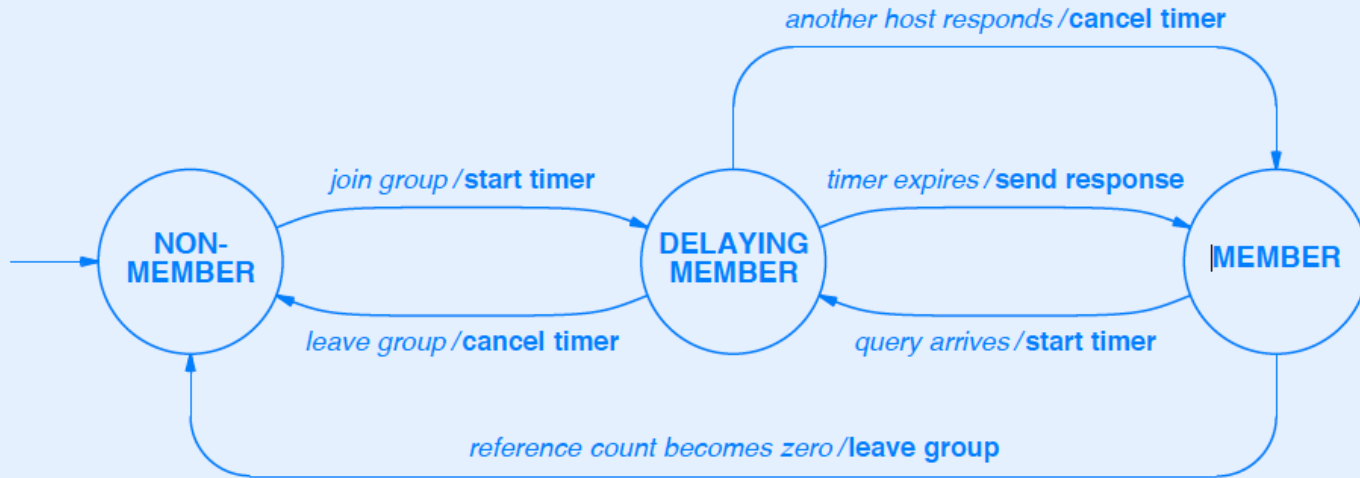
- Allows host to register participation in a group
- Two conceptual phases
 - When it joins a group, host sends message declaring membership
 - Multicast router periodically polls a host to determine if any host on the network is still a member of a group

IGMP Implementation

- All communication between host and multicast router uses hardware multicast
- Single query message probes for membership in all active groups
- Default polling rate is every 125 seconds
- If multiple multicast routers attach to a shared network, one is elected to poll
- Host waits random time before responding to poll (to avoid simultaneous responses)
- Host listens to other responses, and suppresses unnecessary duplicate responses

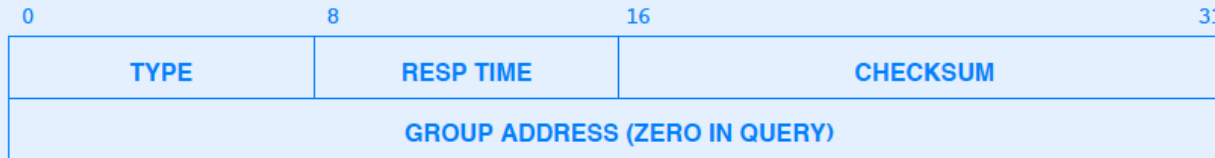
IGMP State Transitions

- Host uses FSM to determine actions:



- Separate state kept for each multicast group

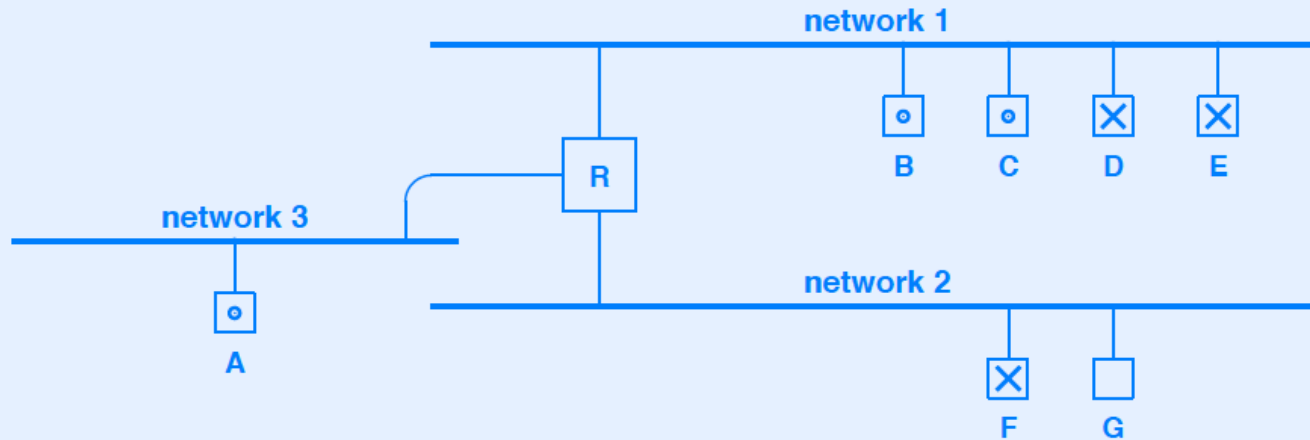
IGMP Message Format



- Message TYPE field is one of:

Type	Group Address	Meaning
0x11	unused (zero)	General membership query
0x11	used	Specific group membership query
0x16	used	Membership report
0x17	used	Leave group
0x12	used	Membership report (version 1)

Multicast Forwarding Example



- Hosts marked with dot participate in one group
- Hosts marked with X participate in another group
- Forwarding depends on group membership

The Complexity Of Multicast Routing

Unlike unicast routing in which routes change only when the topology changes or equipment fails, multicast routes can change simply because an application program joins or leaves a multicast group.

Multicast Forwarding Complication

Multicast forwarding requires a router to examine more than the destination address.

- In most cases, forwarding depends on the source address as well as the destination address

Final Item That Complicates IP Multicast

A multicast datagram may originate on a computer that is not part of the multicast group, and may be forwarded across networks that do not have any group members attached.

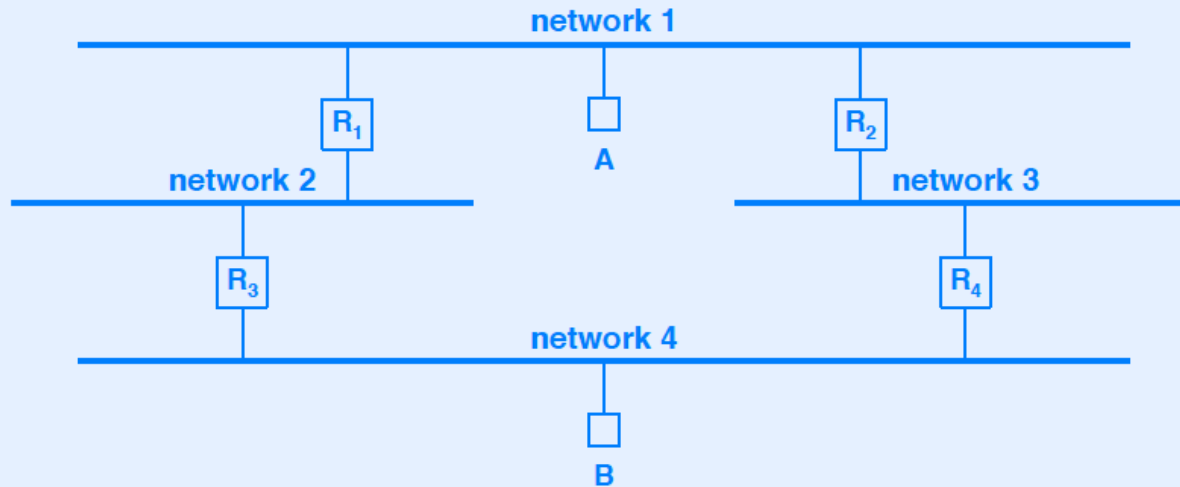
Multicast Routing Paradigms

- Two basic approaches
- Flood-and-prune
 - Send a copy to all networks
 - Only stop forwarding when it is known that no participant lies beyond a given point
- Multicast trees
 - Routers interact to form a “tree” that reaches all networks of a given group
 - Copy traverses branches of the tree

Reverse Path Forwarding

- Early flood-and-prune approach
- Actual algorithm is *Truncated Reverse Path Forwarding (TRPF)*

Example Topology In Which TRPF Delivers Multiple Copies



Multicast Trees

A multicast forwarding tree is defined as a set of paths through multicast routers from a source to all members of a multicast group. For a given multicast group, each possible source of datagrams can determine a different forwarding tree.

Examples Of Multicast Routing Protocols

- Reverse Path Multicasting (RPM)
- Distance-Vector Multicast Routing Protocol (DVMRP)
- Core-Based Trees (CBT)
- Protocol Independent Multicast - Dense Mode (PIM-DM)
- Protocol Independent Multicast - Sparse Mode (PIM-SM)

Reverse Path Multicasting (RPM)

- Early form
- Routers flood datagrams initially
- Flooding pruned as group membership information learned

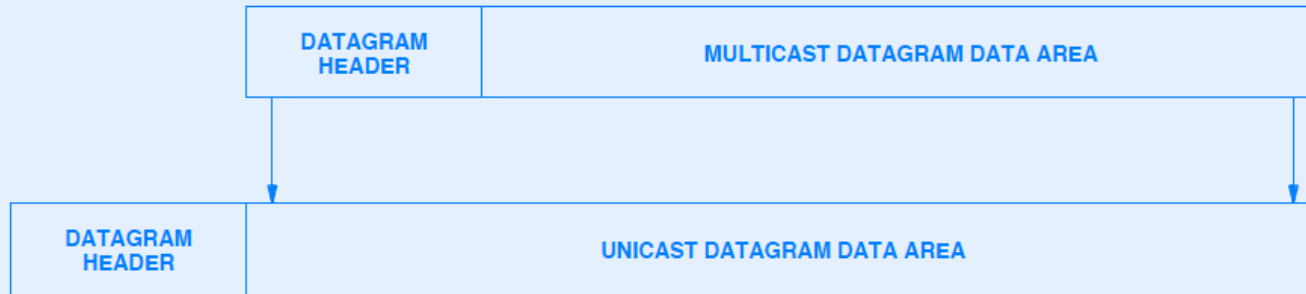
Distance-Vector Multicast Routing Protocol (DVMRP)

- Early protocol
- Defines extension of IGMP that routers use to exchange multicast routing information
- Implemented by Unix *mrouterd* program
 - Configures tables in kernel
 - Supports tunneling
 - Used in Internet's *Multicast backBONE* (*MBONE*)

Topology In Which Tunneling Needed



Encapsulation Used With Tunneling



- IP travels in IP

Core-Based Trees (CBT)

- Proposed protocol
- Better for sparse network
- Does not forward to a net until host on the net joins a group
- Request to join a group sent to “core” of network
- Multiple cores used for large Internet

Division Of Internet

Because CBT uses a demand-driven paradigm, it divides the internet into regions and designates a core router for each region; other routers in the region dynamically build a forwarding tree by sending join requests to the core.

Protocol Independent Multicast - Dense Mode (PIM-DM)

- Allows router to build multicast forwarding table from information in conventional routing table
- Term “dense” refers to density of group members
- Best for high density areas
- Uses flood-and-prune approach

Protocol Independent Multicast - Sparse Mode (PIM-SM)

- Allows router to build multicast forwarding table from information in conventional routing table
- Term “sparse” refers to relative density of group members
- Best for situations with “islands” of participating hosts separated by networks with no participants
- Uses tree-based approach

Question For Discussion

- How can we provide reliable multicast?

Summary

- IP multicasting uses hardware multicast for delivery
- Host uses Internet Group Management Protocol (IGMP) to communicate group membership to local multicast router
- Two forms of multicast routing used
 - Flood-and-prune
 - Tree-based

Summary

(continued)

- Many multicast routing protocols have been proposed
 - TRPF
 - DVMRP
 - CBT
 - PIM-DM
 - PIM-SM