Multicast

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Topics

- **Multipoint communications**
- **IP Multicast**
  - **Addressing**
  - **IGMP**
- **API support for multicast**
  - **IP multicast API**
- **Multicast application examples**
  - **IP multicast API: sender, recvr**

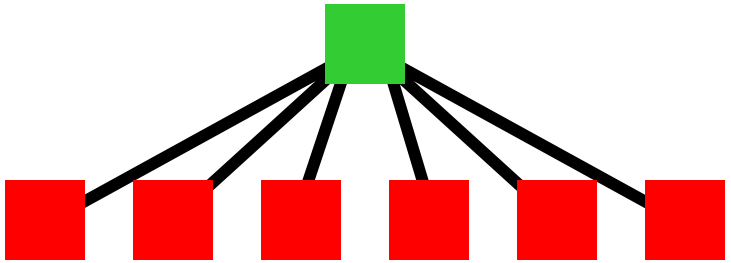
Multipoint Communications

- **Multipoint communications support communications between than two hosts**
  - **One-to-many**
  - **Many-to-many**
- **Unlike broadcast, allows a proper subset of hosts to participate**
- **Example standards**
  - **IP Multicast (RFC 1112, standard)**
  - **ST-II (RFC 1819, experimental)**
  - **T.120 (Data conferencing)**
  - **ATM point-to-multipoint**

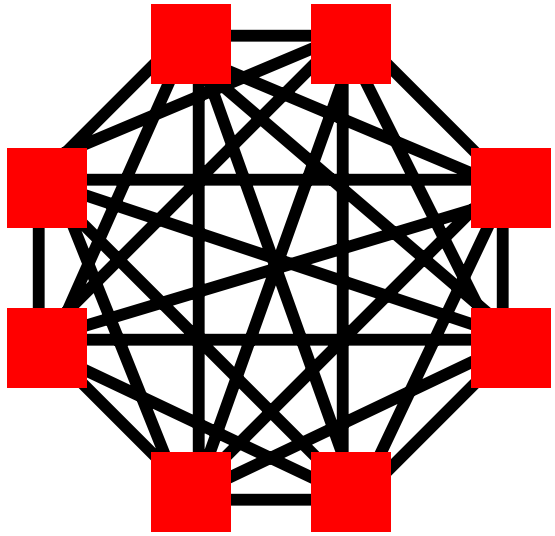
Logical Multipoint Communications (1)

- **Two basic *logical* organizations**
  - **Rooted: hierarchy (perhaps just two levels) that structures communications**
  - **Non-rooted: peer-to-peer (no distinguished nodes)**
- **Different structure could apply to control and data "planes"**
  - **Control plane determines how multipoint session is created**
  - **Data plane determines how data is transferred between hosts in the multipoint session**

Logical Multipoint Communications (2)



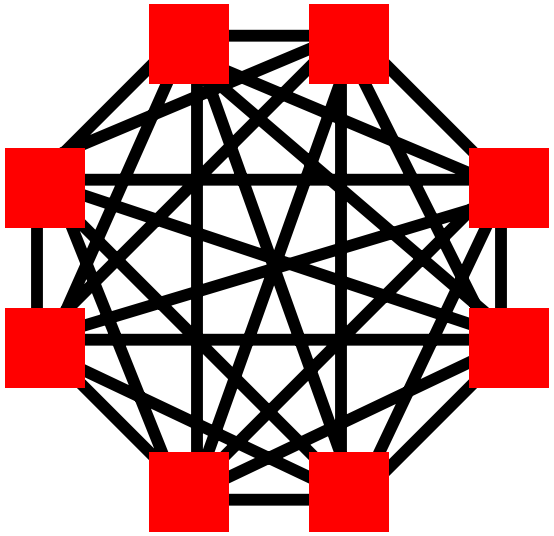
Rooted



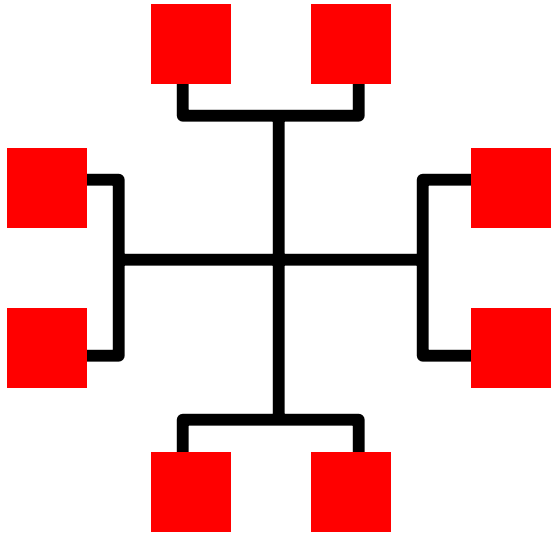
Non-Rooted

Logical Multipoint Communications (3)

- **Non-rooted logical structure does not necessarily imply an implementation using multiple point-to-point connections**



Non-Rooted:
Logical Organization



Non-Rooted:
Multicast Implementation

Control Plane

- **The control plane manages creation of a multipoint session**
- **Rooted control plane**
  - **One member of the session is the root, *c_root***
  - **Other members are the leafs, *c_leafs***
  - **Normally *c_root* establishes a session**
    - **Root connects to one or more *c_leafs***
    - ***c_leafs* join *c_root* after session established**
- **Non-rooted control plane**
  - **All members are the same (*c_leafs*)**
  - **Each leaf adds itself to the session**

Data Plane

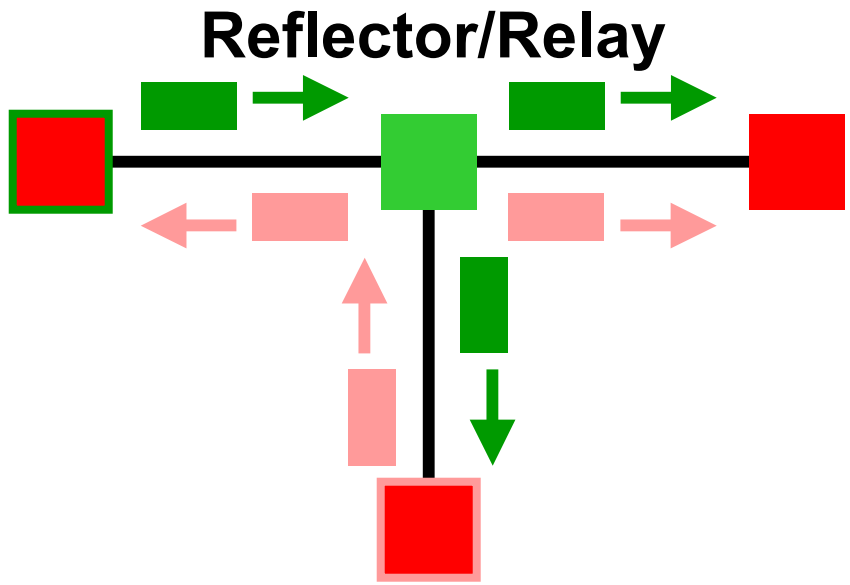
- **The data plane is concerned with data transfer**
- **Rooted data plane**
  - **Special root member, *d_root***
  - **Other members are leafs, *d_leafs***
  - **Data transferred between *d_leafs* and *d_roots***
    - ***d_leaf* to *d_root***
    - ***d_root* to *d_leaf***
  - **There is no direct communication between *d_leafs***
- **Non-rooted data plane**
  - **No special members, all are *d_leafs***
  - **Every *d_leafs* communicate with all *d_leafs***

Forms of Multipoint Communications

- **Server-based -- rooted multipoint communications with server as *d_root***
  - **Passive or inactive**
    - **Relay**
    - **Reflector**
  - **Active**
    - **Bridge or multipoint control unit (MCU)**
- **Strictly peer-to-peer multipoint -- non-rooted**
  - **Multicast**

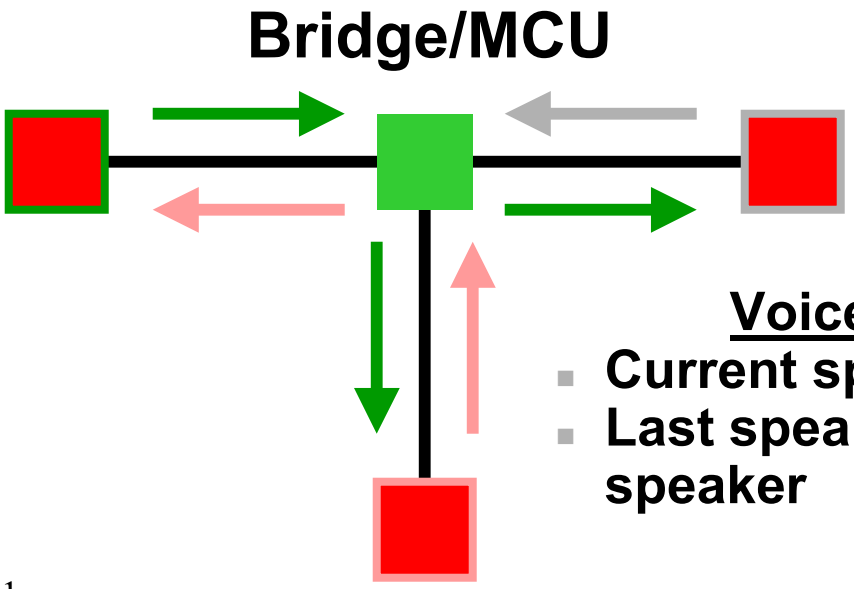
Passive Multipoint Server

- **Server provides a relay or reflector service**
  - **Provides no processing of the data**
- **Minimum requirement is for transport-level semantics, so can operate at the transport or application level**



Active Multipoint Server

- **Server receives inputs from hosts and does application-level processing**
  - **Select receivers for “chat room” applications**
  - **Select video source for videoconferencing MCUs**
- **Server uses application-level semantics**

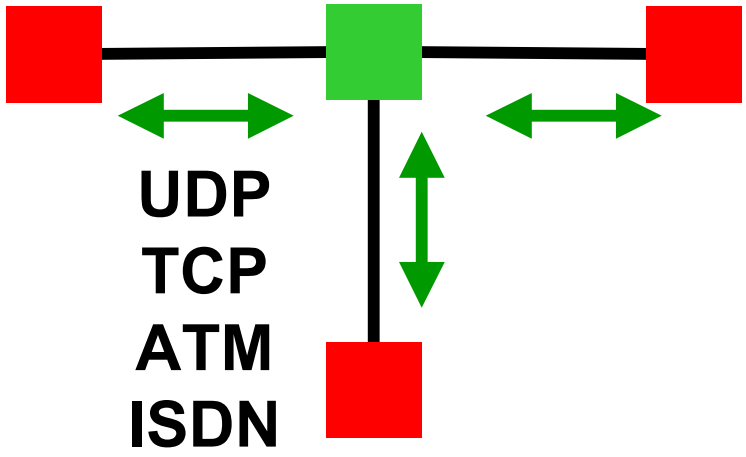


Voice activated video

- **Current speaker shown**
- **Last speaker shown for current speaker**

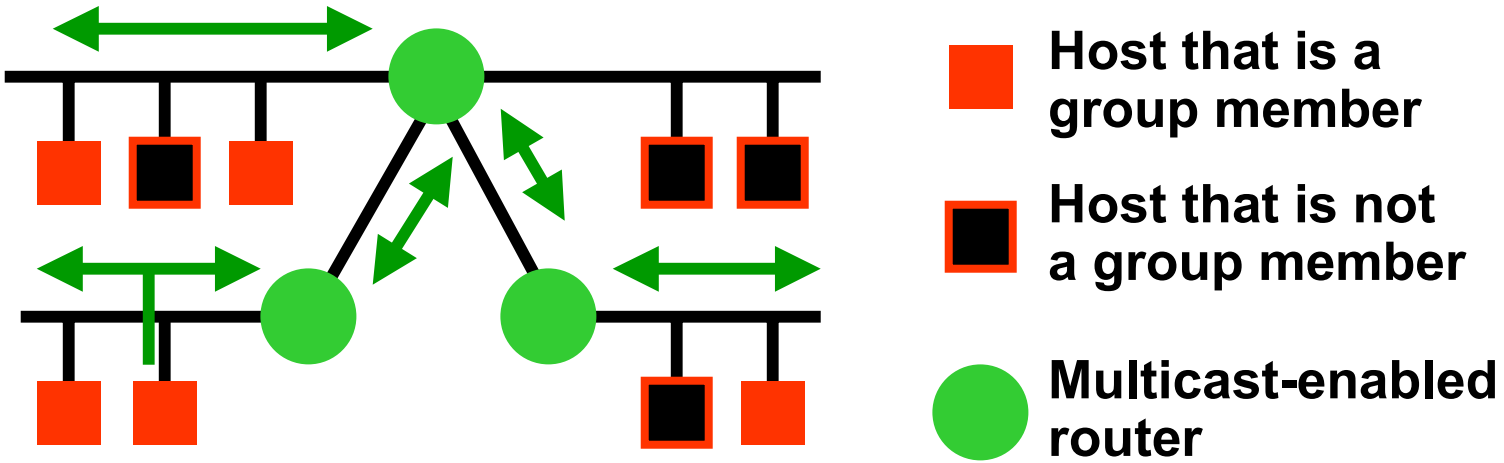
Multipoint Servers

- **Transport mechanism can be general since only point-to-point communications must be supported between end hosts (clients) and the reflector (server)**
  - **Reliable or unreliable**
  - **Connection-oriented or connectionless**
  - **Stream or datagram**



Multicast Communication (1)

- **Communication is peer-to-peer**
  - **No infrastructure for inherently broadcast network**
  - **Requires router knowledge in routed networks**
- **Multicasting provided at network protocol level, e.g. IP multicast**



Multicast Communication (2)

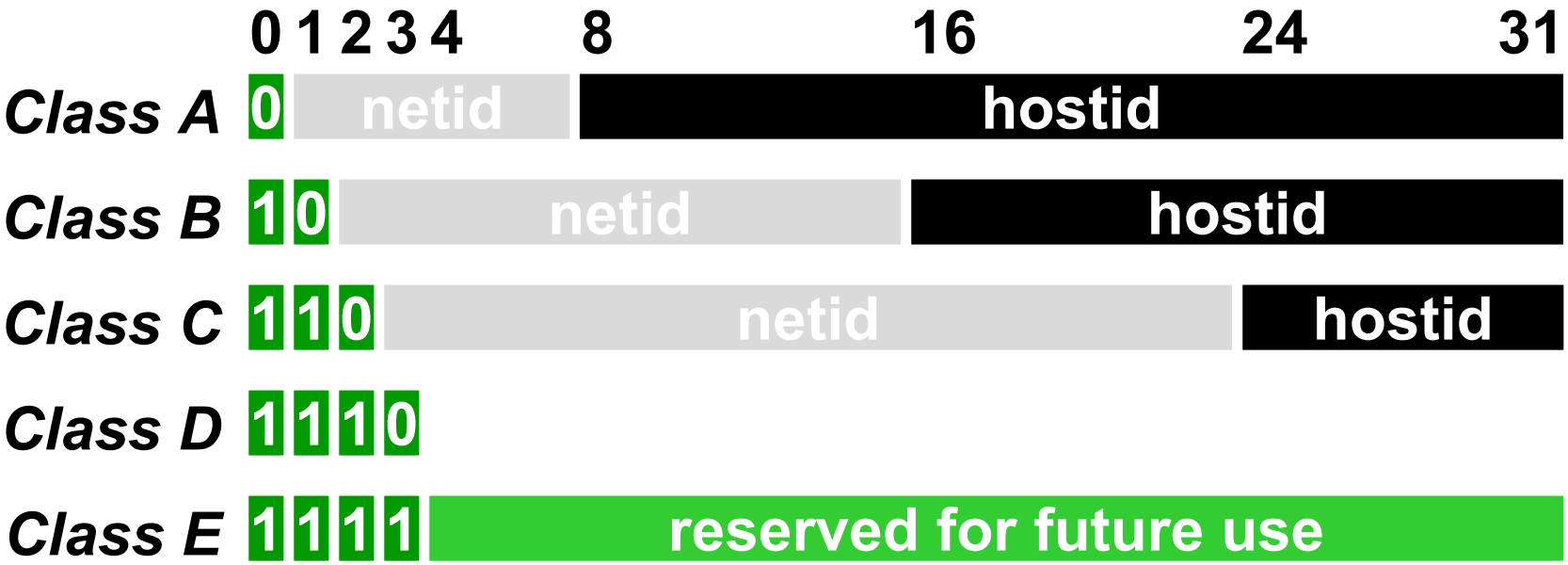
- **Transport mechanism and network layer must support multicast**
- **Internet multicast limited to UDP**
  - **Unreliable: No acknowledgements or other error recovery schemes (perhaps at application level)**
  - **Connectionless: No connection setup (although there is routing information provided to multicast enabled routers)**
  - **Datagram: Message-based multicast**

IP Multicast

- **IP supports multicasting**
  - **Uses only UDP, not TCP (other experimental transport protocols support multicast)**
  - **Special IP addresses (Class D) identify multicast groups**
  - **Internet Group Management Protocol (IGMP) to provide group routing information**
  - **Multicast-enabled routers selectively forward multicast datagrams**
  - **IP TTL field limits extent of multicast**
- **Requires underlying network and adapter to support broadcast or, preferably, multicast**
  - **Ethernet supports multicast**

Multicast Addresses

- **Multicast addresses**
  - **Class D: 224.0.0.0 — 239.255.255.255**
  - **“Well-known” and dynamic assignment within this group**



Multicast Address Assignment

- **224.0.0.0 — 224.0.0.255 reserved for routing, topology discovery, maintenance protocols**
  - **Not forwarded by routers**
- **224.0.0.0 — 232.255.255.255 assigned (RFC 1700, ftp://ftp.isi.edu/in-notes/iana/assignments/multicast-addresses)**
- **239.000.000.000 — 239.255.255.255 are "administratively scoped (RFC 2365)**
  - **239.192.000.000 — 239.251.255.255 organization-local scope**
  - **239.255.000.000 — 239.255.255.255 site-local scope**

Multicast Versus Unicast Addressing

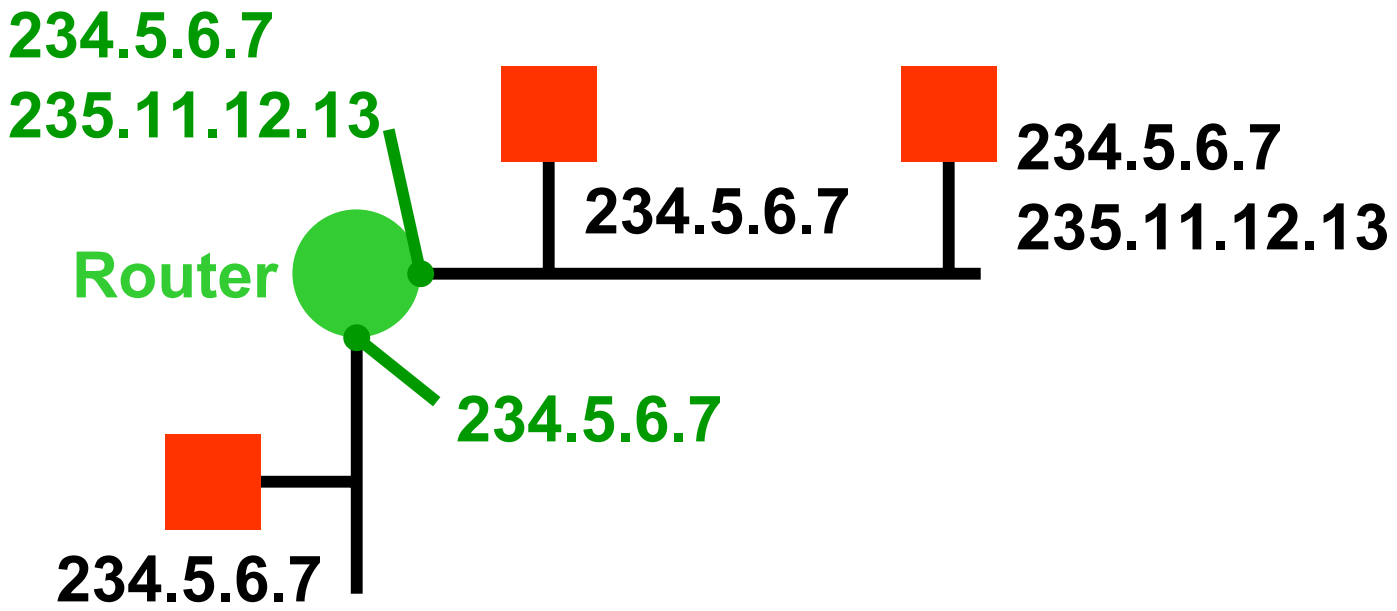
- **IP unicast address**
  - **Statically bound to a *single* local network interface on a *single* IP network**
- **IP host group (multicast) address**
  - **Dynamically bound to a *set* of local network interfaces on a *set* of IP networks**
  - **Host group address not bound to a set of IP unicast addresses**

Multicast Interference and Security

- **Host cannot assume that …**
  - **Datagrams sent to any host group address will reach only the intended hosts, or**
  - **Datagrams received as a member of a transient host group are intended for the recipient**
- **Misdeliveries must be detected by the application**
- **If content is sensitive, then datagrams should …**
  - **Have their data encrypted, or**
  - **Be routed according to administrative controls that limit extent of transmission**

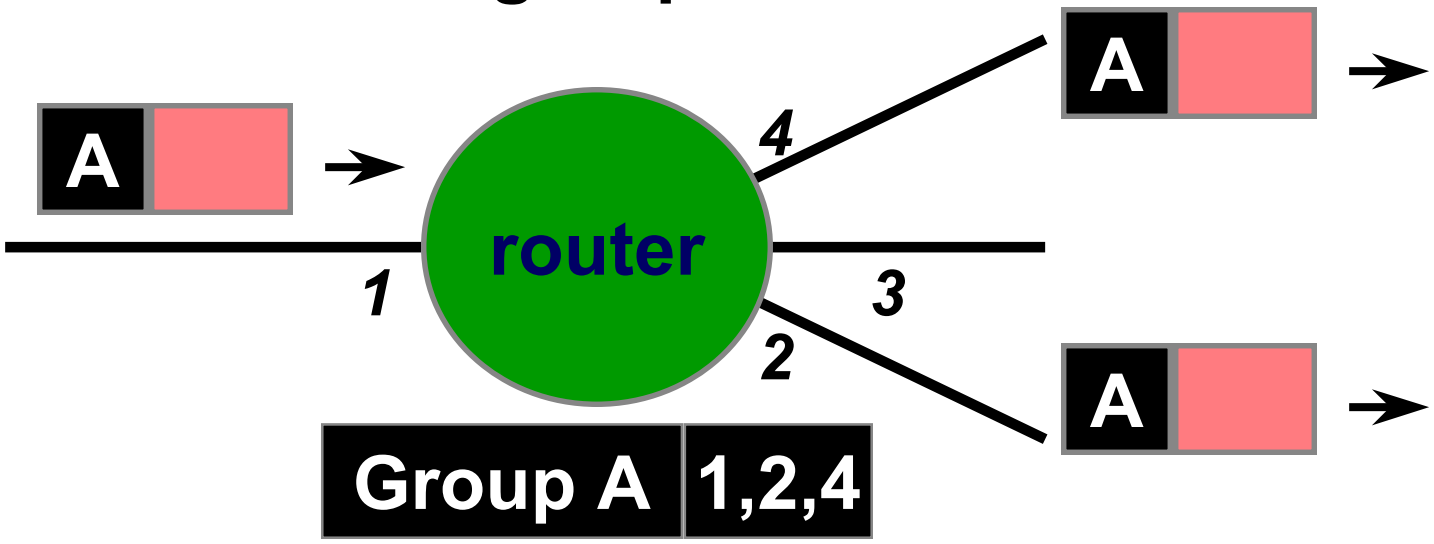
Multicast Routing (1)

- **Multicast routers *do not* maintain a list of individual members of each host group**
- **Multicast routers *do* associate zero or more host group addresses with each interface**



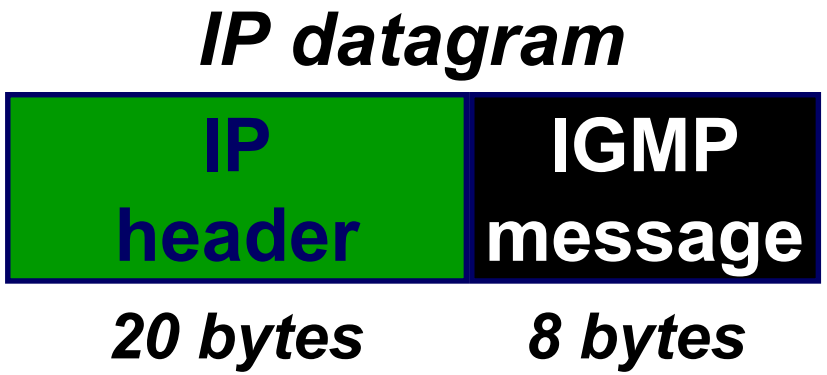
Multicast Routing (2)

- **Multicast router maintains table of multicast groups that are active on its networks**
- **Datagrams forwarded only to those networks with group members**



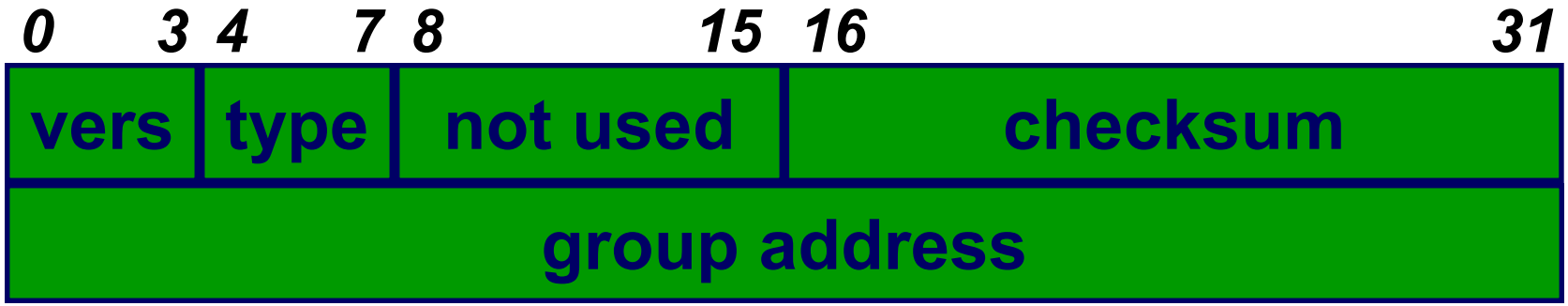
IGMP (1)

- **IGMP (RFC 1112, RFC 2236) provides information to routers so that it can build its multicast routing table**
  - **Hosts (service providers, not applications) send reports of all groups with at least one joined process**
  - **Routers send queries for reports**
- **IGMP message is carried by IP**



IGMP (2)

- **IGMP message format**
  - **4-bit IGMP version (=1,2,3)**
  - **4-bit IGMP type**
    - **1: Query sent by a router**
    - **2: Report sent by a host**
  - **32-bit group address (Class D IP address)**
  - **16-bit checksum**

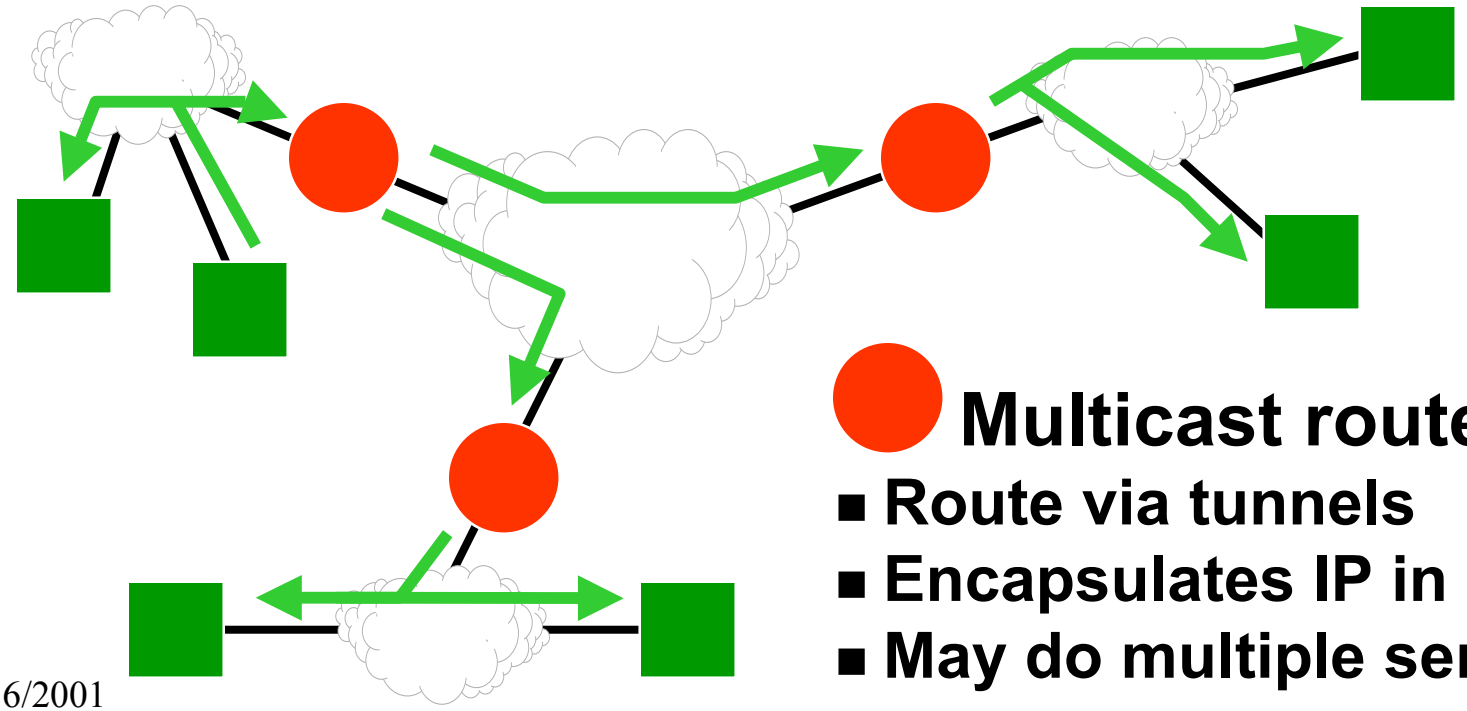


IGMP (3)

- **Joining a group**
  - **Host sends group report when the first process joins a given group**
  - **Application requests join, service provider (end-host) sends report**
- **Maintaining table at the router**
  - **Multicast router periodically queries for group information**
  - **Host (service provider) replies with an IGMP report for each group**
  - **Host does not notify router when the last process leaves a group -- this is discovered through the lack of a report for a query**

MBONE: Internet Multicast Backbone

- **The MBone is a virtual network on top of the Internet**
  - **Routers that support IP multicast**
  - **IP tunnels between such routers and/or subnets**



Multicast router

- **Route via tunnels**
- **Encapsulates IP in IP**
- **May do multiple sends**

API Requirements

- **The application program interface must explicitly support multicast**
  - **IP service interface extended to provide two new operations (RFC 1112)**
    - **JoinHostGroup (group-address, interface)**
    - **LeaveHostGroup (group-address, interface)**
- **JoinHostGroup binds a host group address to an interface**
- **LeaveHostGroup removes the binding**
- **These are conceptual, not the actual API calls (as we'll see)**

IP Multicast API

- **Data is sent and received using a standard datagram socket**
  - **sendto() to send — or send() with prior connect()**
  - **recvfrom() to receive**
- **Host group address treated like standard IP address for sendto(), recvfrom(), and connect() calls**
- **Port numbers play standard role**
- **New socket options — set using setsockopt() — enable multicast**
  - **Protocol level is IP (IPPROTO_IP)**

Add Membership Socket Option (1)

- **Option: IP_ADD_MEMBERSHIP**
- **Parameter: Multicast address structure**
- **Operation**
  - **Supports "JoinHostGroup" of RFC 1112 — allows a host's interface to join a multicast group**
    - **Required to receive multicast datagrams**
    - **Not required to send multicast datagrams**
  - **Each interface can be in multiple groups**
  - **Multiple interfaces can be in the same group**
  - **Causes host to send IGMP report if this is a new group address for this host**
  - **Tells network adapter multicast group address**

Add Membership Socket Option (2)

- **Example call to setsockopt():**

```
setsockopt(
   sock,                  socket
   IPPROTO_IP,            level
   IP_ADD_MEMBERSHIP,     option
   (char *) &mreq,        argument
   sizeof(mreq)           argument size
);
```

Multicast Address Structure

- **Multicast address structure specifies the multicast group address and the interface**
  - **Interface specified as an IP address**
  - **INADDR_ANY specifies use of the default multicast interface**

```
struct ip_mreq {
  struct in_addr imr_multiaddr; // group
  struct in_addr imr_interface; // interface
}
```

```
char group[]="234.5.6.7";
mreq.imr_multiaddr.s_addr = inet_addr(group);
mreq.imr_interface.s_addr = INADDR_ANY;
```

Reusing Port Numbers

- **What if you want to have multiple sockets on the same host listen to the same multicast group?**
  - **Need to bind the same port number to all sockets**
  - **This will cause an error when bind is called for the second and later sockets … unless socket has been set to reuse address**
- **Set SO_REUSEADDR socket option**

```
OptValue = 1;
setsockopt(sock, SOL_SOCKET, SO_REUSEADDR,
    (char *) &OptValue, sizeof(OptValue));
```

Drop Membership Socket Option (1)

- **Option: IP_DROP_MEMBERSHIP**
- **Parameter: Multicast address structure**
- **Operation**
  - **Supports "LeaveHostGroup" of RFC 1112 — allows host to leave a multicast group**
  - **Host's TCP/IP implementation maintains a counter for each group address**
    - **Incremented for IP_ADD_MEMBERSHIP**
    - **Decremented for IP_DROP_MEMBERSHIP**
  - **If count reaches zero**
    - **Tells adapter to drop multicast address**
    - **Won't report group address for IGMP query**

Drop Membership Socket Option (2)

- **Need to set group address and interface in ip_mreq structure (same values as used with IP_ADD_MEMBERSHIP)**
- **Example call to setsockopt():**

```
setsockopt(
   sock,                    socket
   IPPROTO_IP,              level
   IP_DROP_MEMBERSHIP,      option
   (char *) &mreq,          argument
   sizeof(mreq)             argument size
);
```

Receiving Multicast Data

- Create a standard SOCK_DGRAM socket
- Set SOL_REUSEADDR option for socket
- Bind address to socket
  - Specify port
- Set IP_ADD_MEMBERSHIP option for socket
  - Specify host group address
- After these steps complete successfully, receive multicast data for specified group address and port using recvfrom()
- Drop group membership when finished using IP_DROP_MEMBERSHIP option

Sending Multicast Data

- **Use standard SOCK_DGRAM socket**
- **Sending alone does not require group membership**
- **To send multicast datagrams:**
  - **Use sendto() to send to appropriate group address and port number, or**
  - **Use connect() to set group address and port and then use send()**
- **Concerns (controlled with socket options)**
  - **Interface used to send: IP_MULTICAST_IF**
  - **Extent of multicast: IP_MULTICAST_TTL**
  - **Receiving own data: IP_MULTICAST_LOOP**

Multicast Interface Socket Option (1)

- **Option: IP_MULTICAST_IF**
- **Parameter: Interface (struct in_addr)**
- **Operation**
  - **Overrides the default for the interface is used to send multicast datagrams**
  - **Relevant only for hosts with multiple interfaces**
  - **Interface specified in IP_ADD_MEMBERSHIP option will take precedence**

Multicast Interface Socket Option (2)

- **Example:**

```
struct in_addr if_addr;

setsockopt(
   sock,                    socket
   IPPROTO_IP,              level
   IP_MULTICAST_IF,         option
   (char *) &if_addr,       argument
   sizeof(if_addr)          argument size
);
```

Time To Live Socket Option (1)

- **Option: IP_MULTICAST_TTL**
- **Parameter: TTL value (int)**
- **Operation**
  - **Controls the time-to-live (TTL) value that IP will use for multicast datagrams**
  - **Default TTL is 1 — multicast datagrams will not leave the local network**
  - **To send multicast datagrams beyond the local network …**
    - **TTL must be greater than 1, *and***
    - **Intermediate routers must support multicast**
  - **Group address 224.0.0.0 — 224.0.0.255 not routed, regardless of TTL value**

Time To Live Socket Option (2)

- **Example to set multicast TTL to 0**
  - **TTL = 0 will confine multicast traffic to local host**

```
int ttl = 0;

setsockopt(
   sock,                    socket
   IPPROTO_IP,              level
    IP_MULTICAST_TTL,       option
   (char *) &ttl,           argument
   sizeof(ttl)              argument  size
;
```

Multicast Loop Socket Option (1)

- **Option: IP_MULTICAST_LOOP**
- **Parameter: Boolean (TRUE to enable)**
- **Operation**
  - **If enabled (default), socket will receive a copy of multicast datagrams that were sent on that socket**
  - **Even if disabled, host with two interfaces may receive a copy on the other interface(s)**

Multicast Loop Socket Option (2)

- **Example:**

```
BOOL opt = FALSE;

setsockopt(
   sock,                    socket
   IPPROTO_IP,              level
    IP_MULTICAST_LOOP,      option
   (char *) &opt,           argument
   sizeof(opt)              argument size
;
```

You should now be able to …

- **Describe and distinguish between different forms of multipoint communications**
- **Describe the operation of IP multicast**
- **Describe the addressing scheme for IP multicast**
- **Describe the basic operation of IGMP**
- **Associate application actions with IGMP and IP multicast operation**
- **Analyze and design multicast applications using both the IP multicast API**