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

4/16/2001 2

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

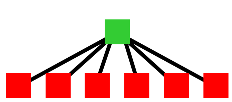
4/16/2001 3

Logical Multipoint Communications (1)

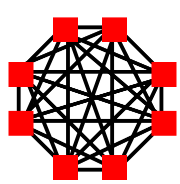
- Two basic *logical* organizations
  - Rooted: hierarchy (perhaps just two levels) that structures communications
  - Non-rooted: peer-to-peer (no distinguished nodes)
- Different structure could apply to control and data "planes"
  - Control plane determines how multipoint session is created
  - Data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

4/16/2001 4

Logical Multipoint Communications (2)



Rooted

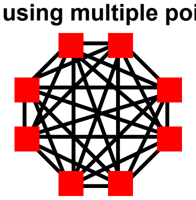


Non-Rooted

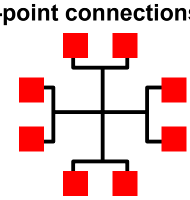
4/16/2001 5

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

4/16/2001 6

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

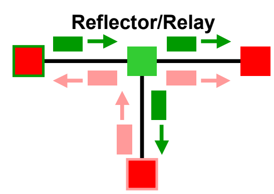
- The data plane is concerned with data transfer
- Rooted data plane
  - Special root member, *d_root*
  - Other members are leafs, *d_leafs*
  - Data transferred between *d_leafs* and *d_roots*
    - *d_leaf* to *d_root*
    - *d_root* to *d_leaf*
  - There is no direct communication between *d_leafs*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

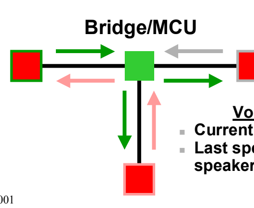
Passive Multipoint Server

- 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

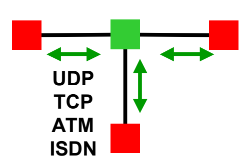
- Server receives inputs from hosts and does application-level processing
  - Select receivers for "chat room" applications
  - Select video source for videoconferencing MCUs
- Server uses application-level semantics



Voice activated video
- Current speaker shown
- Last speaker shown for current speaker

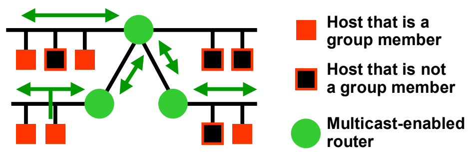
Multipoint Servers

- 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

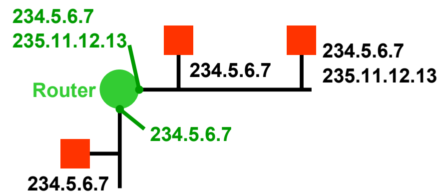
Multicast Interference and Security

- 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

4/16/2001 19

Multicast Routing (1)

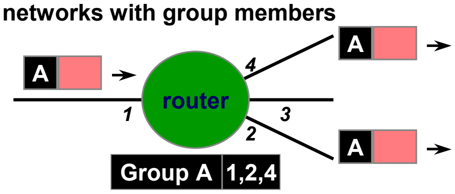
- Multicast routers *do not* maintain a list of individual members of each host group
- Multicast routers *do* associate zero or more host group addresses with each interface



4/16/2001 20

Multicast Routing (2)

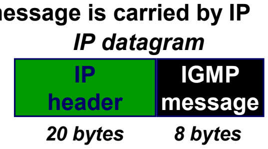
- Multicast router maintains table of multicast groups that are active on its networks
- Datagrams forwarded only to those networks with group members



4/16/2001 21

IGMP (1)

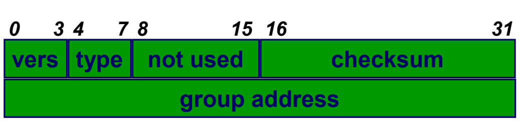
- IGMP (RFC 1112, RFC 2236) provides information to routers so that it can build its multicast routing table
  - Hosts (service providers, not applications) send reports of all groups with at least one joined process
  - Routers send queries for reports
- IGMP message is carried by IP



4/16/2001 22

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



4/16/2001 23

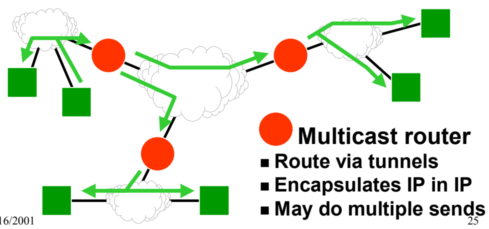
IGMP (3)

- 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

4/16/2001 24

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



4/16/2001 25

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)

4/16/2001 26

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)

4/16/2001 27

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

4/16/2001 28

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
);
```

4/16/2001 29

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;
```

4/16/2001 30

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));
```

4/16/2001 31

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

4/16/2001 32

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
);
```

4/16/2001 33

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

4/16/2001 34

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

4/16/2001 35

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

4/16/2001 36

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
);
```

4/16/2001 37

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

4/16/2001 38

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
;
```

4/16/2001 39

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)

4/16/2001 40

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
;
```

4/16/2001 41

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