Unicast (Cont...)

Efficient data distribution

Two main functions:

Multicast:
- One source to many destinations
- One source to one destination

Multicast Routing

Why Study Multicast?
Multicast (Cont...)
Learn of the existence of multicast groups
Replicate packets on appropriate interfaces
Establish state to route packets
Identify links with group members
Announce existence of multicast groups
Router

Multicast State

Multicast (Cont..)

Logical Naming / Anonymous Addressing

Bandwidth Reduction

Applications:
- Bundling (e.g., a letter. Any postal office will do)
- Multicast (e.g., mailing a letter. No postal office will do)
- Concurrency
- Scalability: Single name/address = Group Name, changes
- Scalability: Single address maps to logically related set of destinations
- Single level multicast: mailing lists

Caveats
- What do we do about loss/failure recovery?
- Different users with different stream limits?
- Multicast?
- Different versions of stream (e.g., teleconference, audio, video)
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Common Problems in Multicast

Scalability
- Number of sources
- Number of receivers
- Geographic/network distance (sparse vs. dense groups)
- Message (NACK)
- Implosion

Adaption to many receivers (some receivers are slower than others, some have higher loss rates, etc.)
- Rather than reliable send and ACK, send periodically

Soft state

Common Techniques in Multicast

Delay may be biased to favor certain hosts responding
- Response after randomized delay
- Listen to others responses: if they say the same as what you are planning to say, you don’t need to say it
- Suppression of duplicate responses

These techniques are used in many places
- You are sending to “everyone” or “don’t care” hosts, so they may have lower loss rates, etc.
- Listen to these responses: if they say the same as what you send, don’t repeat

Multicast groups
- Multicast groups can have different scopes
- Destination address is class D IP address
- Hosts may send to many groups
- Hosts may belong to many groups
- Addresses must be unique in space and time
- Members are the intended receivers
- Senders may or may not be members

Support dynamic creation of groups, dynamic memberships
- Groups can have different scopes
- Global addressing (name rather than IP address)
- Multicast address allocation (later)
- Some hosts may need to be excluded

Multicast in Multicasting

- Other parts of the architecture
- Assumption of scope determined by multicast protocols and TTL
- Scoping must be used with caution
- LAN (local scope)
- Global addressing (names)
- Groups have different scopes

Example Applications
- Push-based systems
- Broadcast audio/video
- Multi-player games
- Teleconferencing (audio, video, shared whiteboards, text)
- Server/service location
- Distributed applications
- Software distribution
- Web content updates
- Sensor networks
- Sensor-based systems
- Location services

Scope
- LAN (local scope)
- Campus/admin scoping
- TTL scoping must be used with caution
- Concept of scope important to multipoint protocols and applications

Dynamic Sources
- Support dynamic creation of groups, dynamic memberships
- Hosts send to many groups
- Hosts belong to many groups
- Address family must be used with caution
- Destination address is class D IP address
- Senders may or may not be members
- Members are the intended recipients

Other Parts of the Architecture
- Assume address is advertised
- Avoid collisions as much as possible
- Use randomization
- Can’t have highly used address space
- Multiple multicast groups per conference... different applications... different layers... more later
Some Concepts

Application-level Multicast

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Cons of application-level multicast:
- cannot use link-level multicast
- duplicate data on links
- does not know source network topology
- does not have direct access to multicast routing and
- cannot use link-level multicast
- does not need help from ISP

Some Concepts

Aside: active networks
Network level multicast
Application level multicast

Why Not Just Use Application-level Multicast?

Pros of application-level multicast:
- can deploy applications today and does not need help
- can deploy application-level multicast

Src
### Components of the IP Multicast Architecture

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hosts</td>
<td>End systems connected to the Internet</td>
</tr>
<tr>
<td>Routers</td>
<td>Core network devices that forward packets</td>
</tr>
<tr>
<td>Service Model</td>
<td>The framework for how multicast traffic is handled</td>
</tr>
<tr>
<td>IGMP (Internet Group Management Protocol)</td>
<td>Protocols that advertise group membership and membership status</td>
</tr>
<tr>
<td>Multicast Routing Protocols</td>
<td>Protocols that manage the distribution of multicast traffic</td>
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</table>

Each group identified by a single IP address.

### IP Multicast Service Model (RFC-1112)

- **Groups** can be of any size.
- **Members** can join and leave at will.
- **Senders** need not be members.

- **Overview**:
  - Each multicast address is like a radio frequency, on which anyone can transmit, and to which anyone can tune-in.

#### Address Allocation

- **Class D IP addresses**:
  - `224.0.0.0` to `239.255.255.255` assigned for multicast use.
  - **Two administrative categories**:
    - Transient multicast addresses, assigned and reclaimed for example, `224.0.0.1` is `all hosts` and `224.0.0.2` is `all routers`.  
    - Well-known multicast addresses assigned by IANA

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- **Address Allocation**:
  - **Initially**, random allocation
  - **Later**, more careful schemes
  - **But are they?** (recall the birthday paradox)
  - **Outside the scope of this class, but...**

#### IP Multicast Addresses

- **In dotted decimal notation**: `224.0.0.0` to `239.255.255.255`  
  - **Group membership not known explicitly**
  - Network builds multicast distribution tree to send data
  - Responsibility of designated router on same LAN as host

- **Outside the scope of this class, but...**

#### IP Multicast Service -- Sending

- **Must provide sending application a way to**:  
  - Specify outgoing network interface, if >1 available
  - Specify outgoing network interface if >1 available
  - Specify outgoing network interface if >1 available
  - Enable/Disable loopback if the sending host is a member of the destination group on the outgoing interface

- **Address Selection**:
  - Dynamic allocation
  - Transient: multicast address assigned and reclaimed
  - Well-known: multicast address assigned for IANA

#### Address Selection

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#### Source Allocation

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#### IP Multicast Service -- Receiving

- Multicast routing protocols (e.g., PIM)  
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  - Routing protocol (e.g., OSPF)  
  - Service model

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  - Service model
Join-IP-Multicast-Group (group-address, interface)

Two new operations:

- IP Multicast Service -- Receiving
- Leave-IP-Multicast-Group (group-address, interface)

- Receive multicast packets for joined groups via normal IP-Receive operation
- Note: neither sender nor receiver know group size or membership (recall the radio frequency analogy to reach or find a nearby subset of a group)

Multicast Scope Control:

1. TTL Expanding-ring Search
   - To keep multicast traffic within an administrative domain, e.g., for privacy or resource reasons

2. Administrative TTL Boundaries
   - To administer a domain, set a TTL threshold on interfaces to these links, greater than the diameter of the administrative domain

3. Administratively-scoped Addresses
   - Uses address range 239.0.0.0/8 to keep multicast traffic within an administrative domain, supports overlapping (not just nested) domains

MBone = Multicast Backbone

An "interconnected" set of multicast-capable routers, providing the IP multicast service on the Internet, can be thought of as a virtual network overlaid on the Internet.

Other uses include mutual exclusion, group membership, etc.

Some use native multicast (e.g., MBone) for everything, while others tunnel multicast between themselves. This is the MBone -- Multicast Backbone.

Components of the MBone:

- H: host/router
- R: MBone router
- P: part of MBone
- L: physical link
- T: tunnel

RFC 1112 -- "Send with my company/country/continent/etc.

RFC 1981 -- "Hierarchical domain name system"

TTL Expanding-ring Search

- Expand TTL on routers
- Revert TTL on hosts

Multicast Scope Control:

1. TTL Expanding-ring Search

- If size of group exceeds the TTL threshold, routers will discard packets

2. Administrative TTL Boundaries

- Set TTL threshold on interfaces to these links

3. Administratively-scoped Addresses

- Uses address range 239.0.0.0/8 for domains

- Supports overlapping (not just nested) domains

IP Multicast Service -- Receiving

- Two new operations:
  - Leave-IP-Multicast-Group
  - Join-IP-Multicast-Group
A method for sending multicast packets through multicast-ignorant routers.

Each end of tunnel is manually configured with two tunnel addresses that form a virtual point-to-point link: one tunnel address is an IP multicast address and the other address is an IP unicast address at each end of tunnel.

- IP multicast packet is encapsulated in a unicast packet
- Tunnel header
- Transport header
- Data...

MBone Tunnels