IP Multicast

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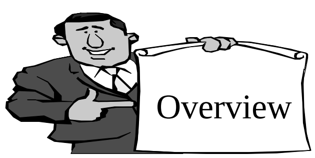


- **Why IP multicast ? Multicast apps ...**
- **Concepts: groups, scopes, trees**
- **Multicast addresses, LAN multicast**
- **Group management: IGMP**
- **Multicast routing and forwarding: MBONE, PIM etc**
- **Reliable Multicast Transport Protocols**

Why IP multicast ?

- **Need for efficient delivery to multiple destinations across inter/intranets**
- **Broadcast:**
  - **Send a copy to every machine on the net**
  - **Simple, but inefficient**
  - **All nodes "must" process the packet even if they don't care**
  - **Wastes *more* CPU cycles of slower machines ("*broadcast radiation*")**
  - **Network loops lead to "*broadcast storms*"**

Why IP multicast ? (contd)

- Replicated Unicast:
  - Sender sends a copy to each receiver in turn
  - Receivers need to register or sender must be preconfigured
  - Sender is focal point of all control traffic
  - Latency = time between the first and last receiver getting a copy {can be large if transmission times are large}

Why IP multicast ?

- Application-layer relays:
  - A “relay” node or set of nodes does the replicated unicast function instead of the source
  - Multiple relays can handle “groups” of receivers and reduce number of packets per multicast => efficiency
  - Manager has to manually configure names of receivers in relays etc => too much administrative burden
- Alternative: build replication/multicast engine at the network layer

Multicast applications

- News/sports/stock/weather updates
- Distance learning
- Routing updates (OSPF, RIP etc)
- Pointcast-type “push” apps
- Videoconferencing, shared whiteboards
- Distributed interactive gaming or simulations
- Email distribution lists
- IPv6 over IPv4
- Voice-over-IP
- Database replication

Multicast apps characteristics

- Number of (simultaneous) senders to the group
- The size of the groups
  - Number of members (receivers)
  - Geographic extent
  - Diameter of the group measured in router hops
- The longevity of the group
- Number of aggregate packets/second
- The peak/average used by source
- Level of human interactivity
  - Lecture mode vs interactive
  - Data-only (eg database replication) vs multimedia

IP multicast concepts

- Message sent to multicast "group" (of receivers)
  - Senders need not be group members
  - Each group has a "group address"
  - Use "group address" instead of destination address in IP packet sent to group
  - Groups can have any size;
  - End-stations (receivers) can join/leave at will

IP multicast concepts (contd)

- Packets are not unnecessarily duplicated or delivered to destinations outside the group
  - Distribution tree for delivery/distribution of packets
  - Packets forwarded "away" from the source
  - No more that one copy of packet appears on any subnet
  - Packets delivered only to "interested" receivers => multicast delivery tree changes dynamically
  - Network has to actively discover paths between senders and receivers

- Non-member nodes even on a single subnet do not receive packets (unlike subnet-specific broadcast)
- Group membership on a single subnet is achieved through IGMP (and ICMPv6 in IPv6)
- Tree is built by multicast routing protocols. Current multicast tree over the internet is called MBONE.
- Anycast: delivers a packet to *one of a group* (hopefully the closest)

Multicast addresses

- Class D addresses: 224.0.0.0 thru' 239.255.255.255
- Each multicast address represents a *group of arbitrary size, called a "host group"*
- There is no structure within class D address space like subnetting => flat address space
- Addresses 224.0.0.x and 224.0.1.x are reserved. See assigned numbers RFC 1700
  - Eg: 224.0.0.2 = all routers on this subnet
- Addresses 239.0.0.0 thru 239.255.255.255 are reserved for private network (or intranet) use

Multicast IP over IEEE 802 LANs

- MAC address = 6 bytes = OUI + 3-byte address
- Special OUI for IETF: 0x01-00-5E.
  - Of remaining 3 bytes (24 bits), one bit is reserved
  - Remaining 23 bits = lower order 23 bits from IP class D address. Simpler than unicast forwarding ! No ARP etc.
- 32 class D addrs may map to one MAC addr

```
1110 xxxx x yyy yyyy yyyy yyyy yyyy yyyy
                    ↓
00000001 00000000 0101 1110 yyy yyyy yyyy yyyy yyyy yyyy
```

Multicast over LANs & Scoping

- Multicasts are flooded across MAC-layer bridges along a spanning tree
  - LAN NICs must be specifically programmed to filter multicasts on behalf of the end station
  - But flooding may steal sending opportunity for nonmember stations which want to transmit
- Scope: How far do transmissions propagate?
- Implicit scoping: Reserved Mcast addresses => don't leave subnet. Also called "link-local" addresses

Scope of multicast forwarding

- TTL-based scoping:
  - Each multicast router has a configured TTL threshold
  - It does not forward multicast datagram if TTL <= TTL-threshold
  - Useful at edges of a large intranet as a blanket parameter.
- Administrative scoping:
  - Use a portion of class D address space (239.0.0.0 thru 239.255.255.255)
  - Truly local to admin domain; address reuse possible.
  - In IPv6 scoping is an internal attribute of an an IPv6 multicast address

IGMP

- IGMP: "signaling" protocol to establish, maintain, remove groups on a subnet.
- Router sends *Host Membership Query* to 224.0.0.1 (all multicast hosts on subnet)
- Host responds with *Host Membership report* for each group to which it belongs, *sent to group address*
- Membership report => other hosts in the same group "suppress" reports
- Router periodically broadcasts query to detect if groups have gone away
- Asynchronous reports possible.

IGMPv2

- Distributed with the mrouted source code
- Has a querier election protocol (lowest IP address)
- Hosts may send a "Leave group" message to "all routers" (224.0.0.2) address
  - Querier responds with a Group-specific Query message to see if any group members are available
  - Lower leave latency => responds quickly to membership changes
- Router alert IP option is also enabled
- Bunch of rules for coexistence of IGMPv1 and v2 hosts and routers on a single subnet

Multicast Routing Protocols

- Multicast routing protocols build trees where the "leaves" are the subnets containing at least one group member (detected by IGMP)
- Tree types:
  - *Source-based trees:* one tree per (source, group) pair
  - *Shared trees:* one tree per group
- Tree building methods:
  - *Data driven*: calculate the tree only when the first packet is seen
    - *Broadcast-and-prune:* Multicast tree = broadcast tree - non-multicast branches

Multicast Routing Protocols

    - Run Dijkstra's algorithm to build tree when first packet is seen (MOSPF)
  - A priori: Build tree before any data is transmitted
- Join-styles:
  - *Explicit-join:* The leaves explicitly join the tree
  - *Implicit-join:* All subnets are assumed to be receivers unless they say otherwise (eg via tree pruning)
- Modes:
  - *Dense-mode:* many (or closely located) subnets have at least one group member
  - *Sparse-mode*: few (or widely separated/bandwidth-limited) subnets have at least one group member

Reverse Path Multicast (RPM)

- **Setup broadcast tree (***reverse path broadcasting, RPB***)**
  - **Each node maintains "parent" and "child" links**
  - **If packet from parent (***"reverse-path check")*** send to children; else drop**
  - **If child is actually downstream (eg in terms of the routing metric), remove the child link**
- *Truncated RPB (TRPB):* **Truncate** *leaf* **if IGMP says that there are no receivers for the group.**
- *Reverse-Path Multicasting (RPM):* **truncate** *branch* **if IGMP says that there are no receivers for the group**

DVMRP

- **RPM forwarding tree built on demand from a DVMRP group-independent routing table**
- **Source-based trees, data-driven (broadcast-and-prune), implicit join, dense mode**
- **TTL and admin scoping available; physical or tunnel interfaces possible**
- **Limitations:**
  - **distance-vector => slow to adapt to topology changes;**
  - **Must store source-specific sate even when not on tree => more scaling problems**
  - **No hierarchy (flat routing domain)**

MBONE

- **Internet Multicast Backbone: testbed**
- **Thousands of regions connected by virtual point-to-point links called "tunnels".**
  - **Multicast traffic passes through non-multicast regions using IP-in-IP encapsulation.**
  - **Intermediate routers see only wrappers (regular IP-unicast packets)**
  - **Tunnel endpoint recognizes IP-in-IP (protocol type = 4) and decapsulates datagram for processing**
- **MBONE uses DVMRP (mrouted)**
  - **Limited to few senders. Many small groups also undesired**
- **Tools: sdr (session directory), vic, vat, wb**

Protocol-Independent Multicast

- PIM has two variants: Dense mode (DM) and sparse mode (SM)
  - DM builds source-based trees in a data-driven (broadcast-and-prune), implicit join manner
  - SM allows both source-based and shared trees. But the trees are built a priori and using explicit join.
- Not dependent upon mechanisms provided by any particular unicast protocol. Can leverage upon RIP, OSPF, BGP-4 etc
- PIM: broadcasts on all non-incoming interfaces until explicit prune messages are received

MOSPF

- Flood the multicast group membership information along with the link states
- The shortest path multicast tree is built upon demand using Dijkstra's algorithm
  - Note that all routers calculate the same source-based shortest-path delivery tree
  - The datagram is not flooded, only the group membership info is flooded
- For each transmission, determine the downstream branch and forward the packet
  - Use caching to avoid tree calculation for each packet
  - The forwarding is not TTL based

Core-Based Trees (CBT)

- Sparse Mode: shared tree set up before forwarding. Good scaling properties for WAN multicast, with scattered receivers
- Each group has a "core router" which is dynamically discovered (bootstrapping)
- A host which wants to join the group sends a JOIN_REQUEST towards the core and gets a JOIN_ACK from the nearest router already on the tree.
- Forwarding cache = group, {outgoing interface list}

CBT (contd)

- Packet is forwarded onto all outgoing interfaces except the one in which it arrived
- Packet transmission can be bidirectional ("upstream" in a CBT refers to the direction towards the core, not the source)

- Non-tree source employs IP-in-IP encapsulation to send packets to the core

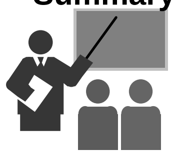
Reliable Multicast Transport

- Problems:
  - Retransmission can make reliable multicast as inefficient as replicated unicast
  - Ack-implosion if all destinations ack at once
  - Source does not know # of destinations
  - "Crying baby": one bad link affects entire group
  - Heterogeneity: receivers, links, group sizes
  - Not all multicast applications need reliability of the type provided by TCP. Some can tolerate reordering, delay, etc
- Egs: Scalable Reliable Multicast (SRM), Lightweight Reliable Multicast Protocol (LRMP), Reliable Multicast Transport Protocol (RMTP), Pragmatic General Multicast (PGM)

Scalable Reliable Multicast (SRM)

- All members get all the data that has been sent to the the multicast group (minimalist reliability)
- Repair requests and responses (retransmissions) are multicast.
- Scope of repair requests and responses can be TTL limited or a separate "local recovery group" can be formed
- Techniques to avoid implosion of repair requests, and reduce control traffic
- An example of an "application level framing" paradigm {like RTP}

Summary



- IP multicast issues and applications
- Multicast over LANs and scoping
- IGMP
- Multicast Routing and MBONE
- Reliable multicast transports

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- J. C. Lin, S. Paul, "RMTP: A Reliable Multicast Transport Protocol", SIGCOMM August 1996
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Broadcast-and-prune

- Build source-based trees. Routers in the tree maintain state per (source, group) pair. Eg: DVMRP, PIM-DM
- "Data-driven": broadcast data to internetwork edges
- If IGMP-derived group databases say that there are no local members, the edge routers send a "prune" message upstream. This is "soft state" stored in on-tree routers.
- Off-tree routers maintain "prune" state per tree to allow "grafting" when members newly appear
- OK for small intranets with densely distributed hosts,
  - Likely that significant fraction of edge LANs will have group members
- Disadvantages: Waste of bandwidth, State in off-tree

Shared Trees

- Central point where all receivers attach.
  - Single delivery tree per group. No separate tree per-source.
  - Better use of router resources. No prune-state in off-tree nodes. No unnecessary waste of bandwidth.
- Tree must exist prior to data flow (not data-driven)
- Receivers "explicitly-join" the tree
- Senders need to find paths to reach the shared tree
- Problems:

DVMRP (contd)

- If router C can receive datagrams from both A and B, then it will receive from A if A's metric to the source is smaller than B's or if they are equal, A has the smaller IP address on its downstream interface
- Separate processes (and updates) for unicast and multicast routing
- "poison-reverse": the subordinate sets the route for the source as infinity in routing updates sent on a common LAN
- DVMRP routing table = shortest path (source-based) spanning tree to every possible source-prefix in the internetwork
- DVMRP forwarding table: built from routing