19. Multicast Communication

- Multicast within a subnet
- Reverse path forwarding
- IGMP
- PIM
- Scalable multicast forwarding

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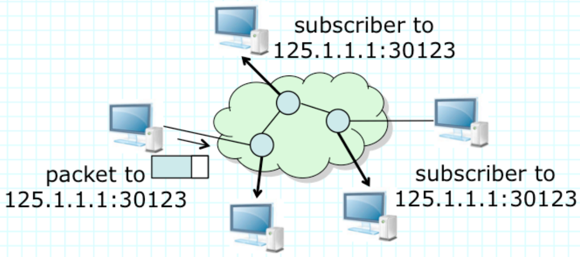
Multicast in a Subnet



- Within switched subnet, multicasting relies on Ethernet
  - » IP multicast address embedded in Ethernet multicast address
    - more precisely, low 23 bits are embedded
  - » switches deliver multicast packets to all hosts (simple case)
- Receiving application configures multicast socket (UDP)
  - » bind to specific port, join multicast group
- Sending app sends UDP packet on multicast socket
  - » use multicast address/port, set TTL to 1

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Basic Multicast Receiver

```
/** usage: Rcvr mcAdr port iface */
import java.io.*; import java.net.*;
public class Rcvr {
  public static void main(String args[]) throws Exception {
    // form multicast group from command-line arguments
    int port = Integer.parseInt(args[1]);
    InetSocketAddress group = new InetSocketAddress(
        InetAddress.getByName(args[0]),port);
    // open multicast socket and join group
    MulticastSocket sock = new MulticastSocket(port);
    NetworkInterface iface = NetworkInterface.getByName(args[2]);
    sock.joinGroup(group,iface);
    // create buffer and packet
    byte[] inBuf = new byte[1000];
    DatagramPacket inPkt = new DatagramPacket(inBuf,inBuf.length);
    while (true) {
      // receive packet and print payload
      sock.receive(inPkt);
      System.out.println(new
        String(inBuf,0,inPkt.getLength(),"US-ASCII"));
} } }
```

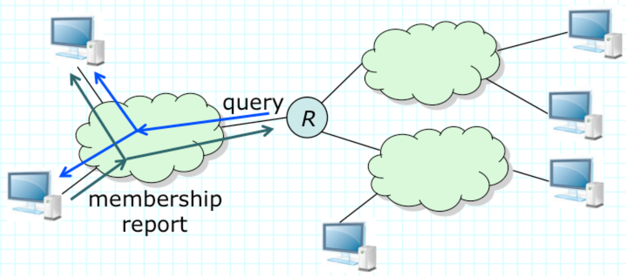
Basic Multicast Sender

```
/** usage: Sender mcAdr port iface ttl message */
import java.io.*; import java.net.*;
public class Sender {
  public static void main(String args[]) throws Exception {
    // from multicast group address from command-line arguments
    int port = Integer.parseInt(args[1]);
    InetSocketAddress group = new InetSocketAddress(
        InetAddress.getByName(args[0]),port);

    // open multicast socket, set interface and time to live
    MulticastSocket sock = new MulticastSocket();
    sock.setNetworkInterface(NetworkInterface.getByName(args[2]));
    sock.setTimeToLive(Integer.parseInt(args[3]));

    // create buffer and packet to send
    byte[] outBuf = args[4].getBytes("US-ASCII");
    DatagramPacket outPkt = new DatagramPacket(
                              outBuf,outBuf.length,group);
    sock.send(outPkt); // send packet to group
    sock.close();
} }
```

Internet Group Multicast (RFC 2236)

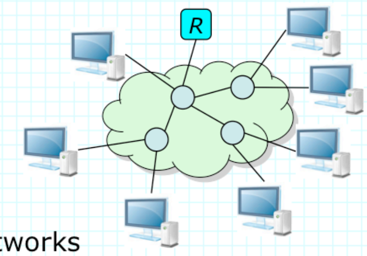


- To forward among subnets, router needs to know about multicast subscribers
  - » router multicasts *membership query* packets
  - » hosts respond with *membership reports* after random delay
    - suppress duplicate reports; usually just one actual report per group
- Router forwards multicast packets among networks based on membership information
  - » subscriptions timeout if not renewed periodically

IGMP Details

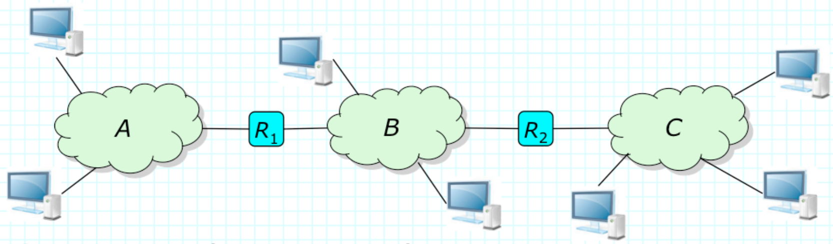
- Message fields
  - » type – query, report, leave group
  - » max response time – max wait time before responding to query
  - » group address – subject multicast addr; 0 for "general query"
- On each subnet, one router plays role of "Querier"
  - » router with smallest IP address acts as querier
  - » issues periodic general membership queries
    - sent on all systems multicast address: 224.0.0.1
- Hosts send reports to subject multicast address
  - » in response to general queries or when first joining a group
- Leave group message sent by host when leaving
  - » sent to all routers group (224.0.0.2)
  - » querier responds with a group-specific query
    - verify that no other group members still out there

IGMP Snooping (RFC 4541)



- Objective
  - » use group membership to limit propagation of multicast packets
  - » learn which hosts are in which group by snooping on IGMP
  - » invented by switch vendors to limit multicast traffic in large switched networks
- Suppression of duplicate membership reports by IGMP interferes with snooping
  - » so send report packets only to routers, not to hosts
    - implies switches must be able to detect which ports go to routers
- Forwarding based on group membership
  - » forwarding can use either Ethernet or IP addresses
    - IP addresses preferred due to non-exact multicast address mapping
    - but not an option for simple Ethernet switches

Multicast Issues in Larger Networks



- IGMP is not always enough
  - » suppose a multicast has members in subnets *A* and *C*, but not *B*
    - routers will not forward packets across *B*
  - » can work if group members are in contiguous subnets
- Multiple paths among subnets can produce multicast duplicates
  - » need to restrict routing of each multicast group to a tree
  - » requires routers to maintain forwarding information for each multicast group

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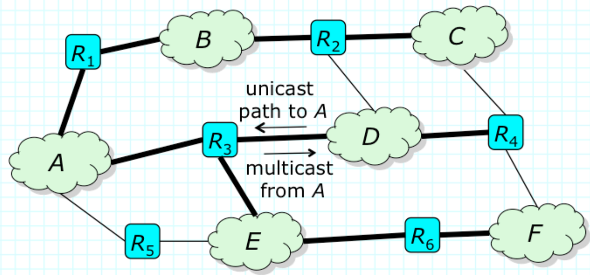
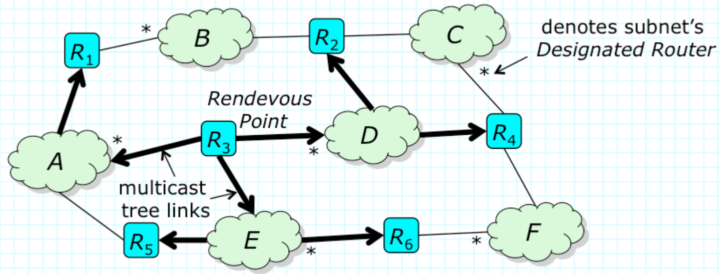
Reverse Path Forwarding



- Efficient distribution of multicast packets requires that packets be forwarded along a tree
  - » in principle, any tree joining subnets can be used and each multicast can use a different tree
  - » internet multicast generally uses reverse of unicast routes
    - so routing based on combination of (source adr, multicast adr)
    - means multicast with many senders requires more routing state
    - more efficient to use *shared tree* through "rendevouz point"

Multicast Using Shared Tree (PIM)



- Rendevous point (RP) serves as multicast tree root
  - » different groups have different RPs, routers can determine assigned RP for each multicast address
- When *Designated Router* (DR) discovers new subscriber
  - » sends join message to RP, creating multicast state along path
- Sending hosts just send packets to multicast address
  - » initially, DR may forward to RP inside unicast packet

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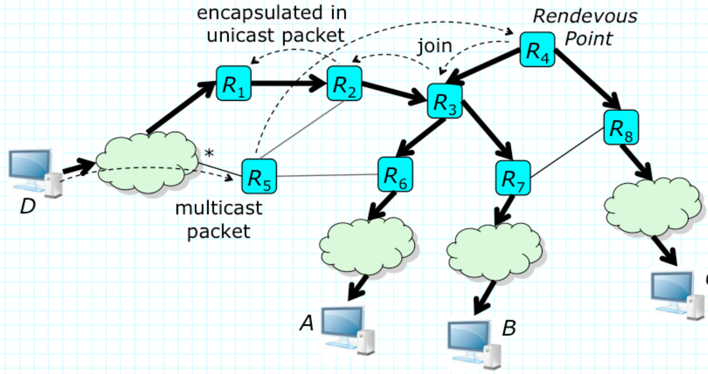
Sending to Multicast Group



- Non-subscribing sender's packets sent to RP by DR
  - » RP extracts multicast packet and forwards on shared tree
- RP may initiate join back towards source
  - » adds multicast routing state along path, merges with RP tree
  - » when native packets reach RP, it tells DR to stop encapsulating

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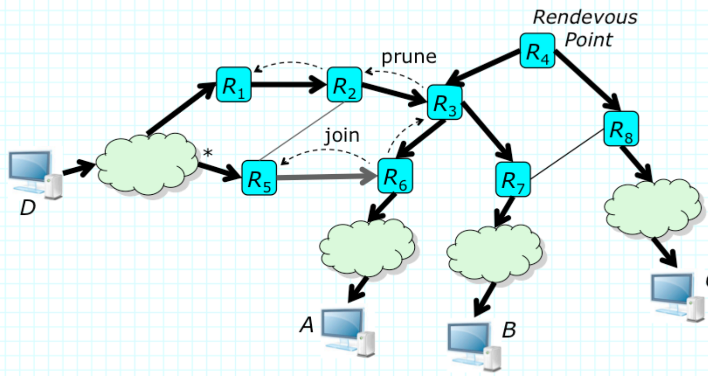
Switch to More Direct Path



- Router in tree may choose to switch to more direct path
  - » sends join back towards source
  - » after packets arrive on direct path, prune links in original path from source
- Note: expensive for multicasts with many senders

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More About PIM (RFC 4601)

- PIM stands for Protocol Independent Multicast
  - » PIM can use routing data from any routing protocol
    - e.g. unicast routing state, or multicast BGP
- Routers must be able to determine RP for any address
  - » can use statically configured mapping based on address ranges
  - » or, a PIM domain can use a *Bootstrap Router* (BSR) to distribute information used to map a multicast address to an RP
    - domain has a defined set of RPs distributed by BSR
    - PIM routers use a hash function to select an RP in this set
      - – e.g. if *N* candidate RPs, hash(multicast address) mod *N* selects one
- PIM generally used only within single routing domain
  - » RFC omits essential details for inter-domain routing
    - e.g. how are RPs coordinated among different domains
  - » BGP extensions may eventually enable inter-domain multicast

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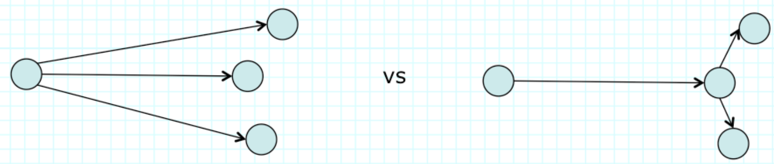
IGMPv3 (RFC 3376)

- Adds support for source-specific multicast using "filters"
  - » include-filter specifies a list of acceptable senders
    - multicast packets are delivered to socket only if sender is on list
  - » exclude-filter specifies a list of blocked senders
  - » hosts have "interface filters" derived from socket filters
  - » not supported by java multicast sockets; linux does support it
- Queries and membership reports are extended to handle "filtered multicasts"
  - » new source-specific query that includes a sender list for target destination address
  - » reports can cover multiple groups and includes a filter per group
- IGMPv3 ignores membership reports from other hosts
  - » so all IGMPv3 hosts in a multicast group will respond to a query
- Can operate in "compatibility mode" with older versions

Which Trees are Best?



- Reverse path forwarding routes multicast packets on shortest paths
  - tends to copy packets near the source
  - copying near destination reduces # of “long-distance packets”
- Best multicast route is a *Steiner tree*
  - Steiner tree for a vertex subset *S* is shortest subtree that includes all vertices in *S*
  - problem is NP-complete, so no efficient algorithm known for finding optimal solution
  - good approximations based on minimum spanning tree

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Other Issues with IP Multicast

- Separate protocol needed to reserve network capacity
  - » RSVP protocol (RFC 2205) can be used for this purpose
  - » but cannot select route based on required network capacity
    - QoS routing has been discussed but never implemented
- No "private" multicast groups
  - » no way to get short-term exclusive use of a multicast address
  - » no way to limit subscribers or limit who can send to an address
    - makes it awkward to use for multi-party teleconferencing
    - privacy requires encryption
- Largely unavailable in public internet
  - » unresolved technical issues for inter-domain routing
  - » no economic benefit to network providers
    - multicast senders benefit as they need not duplicate traffic
    - but ISPs lose money if senders reduce internet access link rate

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