More on IP and the Network Layer

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Recap on Network Layer

- **Principle**: two basic types of routing protocols
  - link state routing
  - distance vector routing
- **Practice**: the Internet protocol (IP)
  - hierarchical addressing
  - hierarchical routing: intra-AS and inter-AS

IPv6

- **Initial motivation**: address depletion ⇒ 32-bit address space completely allocated by 2008.
  - 128-bit addresses
- **Additional motivation**:
  - simplification help speed processing/forwarding
  - fixed-length 40 byte header
  - no fragmentation allowed
  - header changes to facilitate QoS
  - flow label
  - new "anycast" address: route to one of a set of several servers

Transition From IPv4 To IPv6

- It is difficult to change the network layer protocol
  - The large number of routers and administrative autonomy makes simultaneous change impossible.
  - Routers speaking different protocols do not naturally work together.
  - What should we do?
- Two proposed approaches:
  - **Dual Stack**: some routers with dual stack (v6, v4) can "translate" between formats
  - **Tunneling**: IPv6 carried as payload in IPv4 packet among IPv4 routers
**Dual Stack Approach**

A-to-B: IPv6  
B-to-C: IPv4  
D-to-E: IPv4  
E-to-F: IPv6

**Tunneling Approach**

A-to-B: IPv6 inside IPv4  
B-to-C: IPv6 inside IPv4  
D-to-E: IPv6 inside IPv4  
E-to-F: IPv6

**Outline**

- IPv6
- **Multicast routing**
  - basic concept
  - Principle: basic approaches
  - Practice: protocols

**Multicast**

- **Multicast**: act of sending packet to multiple receivers with single "transmit" operation
- Applications?
- **Multicast via unicast**
  - source sends N unicast packets, one addressed to each of N receivers
  - no change on routers
  - problem?
  - not a multicast receiver

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Do you see any problem?
Ideal Network Multicast

Router actively participate in multicast, making copies of packets as needed and forwarding towards multicast receivers.

Multicast routers (red) duplicate and forward multicast packets.

Internet Multicast Service Model

Multicast group concept: use of indirection
- hosts send IP packets with the multicast group address
- routers forward multicast packets to hosts that have "joined" that multicast group

Multicast Groups

- class D Internet addresses reserved for multicast:
  - 1110 Multicast Group ID
  - 28 bits

- Service semantics:
  - anyone can "join" (receive) multicast group
  - anyone can send to multicast group

- What is needed?
  - Mechanism for hosts to join a multicast group
  - Infrastructure to deliver mcast-addressed packets to all hosts that have joined that multicast group

Joining A Multicast Group

- local: host informs local mcast router of desire to join group
  - IGMP (Internet Group Management Protocol)
- wide area: local router interacts with other routers to receive mcast packet flow
**IGMP: Internet Group Management Protocol**

- **host**: sends IGMP report when application joins mcast group
- **local router**: sends IGMP query at regular intervals
- **host belonging to a mcast group must reply to query**
- **host need not explicitly “unjoin” group when leaving**

**Wide-area Multicast Routing**

- **Goal**: find path/paths (tree) connecting routers having local mcast group members
  - **source-based tree**: one tree per source
    - shortest path trees, reverse path forwarding
  - **group-shared tree**: group uses one tree
    - minimal spanning (Steiner), center-based trees

**Shortest Path Tree**

- **mcast forwarding tree**: tree of shortest path routes from source to all receivers
  - Dijkstra's algorithm

**Reverse Path Forwarding**

- rely on router’s knowledge of unicast shortest path from it to sender
- each router has simple forwarding behavior:

  ```
  if (mcast packet received on incoming link on shortest path back to source)
  then flood packet onto all outgoing links
  else ignore packet
  ```
Reverse Path Forwarding: Example

- result is a source-specific reverse SPT
- problems with this approach?

Reverse Path Forwarding: Pruning

- forwarding tree contains subtrees with no mcast group members
- no need to forward packets down subtree
- “prune” mgs sent upstream by router with no downstream group members

Shared-Tree: Steiner Tree

- Steiner Tree: minimum cost tree connecting all routers with attached group members
  - problem is NP-complete
  - heuristic approximation exists

- not used in practice:
  - computational complexity
  - information about entire network needed
  - monolithic: rerun whenever a router needs to join/leave

Center-based Trees

- single delivery tree shared by all
- one router identified as "center" of tree
- to join:
  - edge router sends unicast join-msg addressed to center router
  - join-msg "processed" by intermediate routers and forwarded towards center
  - join-msg either hits existing tree branch for this center, or arrives at center
  - path taken by join-msg becomes new branch of tree for this router
Center-based Trees: An Example

Suppose R6 chosen as center:

Internet Multicasting Routing

- **DVMRP**: distance vector multicast routing protocol, based on RPF (reverse path forwarding) and pruning
  - first and the most commonly supported
- **PIM**: protocol independent multicast
  - separate the dense and sparse mode
  - PIM dense-mode is based on RPF/pruning, similar to DVMRP
  - PIM sparse-mode is based on Center-based Trees
- Neither is widely deployed
  - how to do multicast in the Internet when only a small portion of routers support multicast

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