More on IP and the Network Layer

Kai Shen

The Internet Protocol

- Addressing, LAN grouping of addresses
- Packet format
- Hierarchical routing:
  - intra-AS (RIP, OSPF)
  - inter-AS (BGP)

IPv6

- A key motivation: address depletion
  - 128-bit addresses
- Additional motivation:
  - simplification help speed processing/forwarding
  - fixed-length 40 byte header
  - no fragmentation allowed in intermediate routers
  - 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.
- Two proposed approaches:
  - Dual Stack: some routers with dual stack (v6, v4) can "translate" between formats.
**Dual Stack Approach**

Two kinds of routers:
- IPv4 only
- IPv6 capable

Need v4/v6 address translation.

Problems: lose header info, require v4 support on all nodes.

**Tunneling Approach**

Logical view:

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

Think of v4 as the lower (link-layer) protocol.

**IPv6 Deployment**

IPv6 deployment is slow:
- resistance to change \( \Leftrightarrow \) lack of critical mass
- v4/v6 co-existence requires backward compatibility (means additional overhead and complexity)

Address depletion is delayed by incremental techniques like DHCP and NAT.

**Multicast**

- Multicast: act of sending packet to multiple receivers with single "transmit" operation
- Applications??
Multicast via Multiple Unicasts

Multicast via unicast
- source sends N unicast packets, one addressed to each of N receivers
- no change on routers
- problem?

Ideal Network Multicast

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

Local and Wide-Area Multicast Management
- 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

Shortest Path Tree
- Goal: find path/paths (tree) connecting multicast routers having local mcast group members
- Tree of shortest path routes from source to all receivers
- Dijkstra's algorithm
Reverse Path Forwarding

What if we don’t have global network information?

Goal is to forward along shortest paths. Heuristic:

- not to forward when packets clearly have deviated from the shortest paths;
- rely on router’s knowledge of unicast routing table.

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: Pruning

- forwarding tree contains subtrees with no mcast group members
  - "prune" msgs sent upstream by router with no downstream group members

Wide-area Multicast Routing

Goal: find path/paths (tree) connecting multicast routers.

- source-based tree: one tree per source
  - shortest path trees, reverse path forwarding
- group-shared tree: group uses one tree
Shared-Tree Multicast

- Assume complete global network information is available, derive minimum cost tree connecting all relevant routers
  - Steiner tree
  - problem is NP-complete

A Distributed Solution: Center-based Tree

- 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

Comparison

- Compare reverse path forwarding with center-based tree
  - Better multicast delivery along shortest paths produced by reverse path forwarding
  - Too much pruning in a “sparse” system with relatively few interested routers

Internet Multicasting Routing

- DVMRP
  - distance vector multicast routing protocol, based on reverse path forwarding and pruning
- PIM
  - in a sparse mode where DVMRP doesn’t do well, it uses Center-based Trees
- IP multicast deployment?
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