April 12, 2005 -
No classes - attend
Senior Design Projects conference

Chapter 4 roadmap
4.1 Introduction and Network Service Models
4.2 VC and Datagram Networks
4.3 What's Inside a Router
4.4 The Internet (IP) Protocol
4.5 Routing Algorithms
4.6 Routing in the Internet
4.7 Broadcast and Multicast Routing

Router Architecture Overview
Two key router functions:
- run routing algorithms/protocol (RIP, OSPF, BGP)
- switching datagrams from incoming to outgoing link
**Input Port Functions**

- **Physical layer**: bit-level reception
- **Data link layer**: e.g., Ethernet

- **Decentralized switching**:
  - Given datagram dest., lookup output port using routing table in input port memory
  - Goal: complete input port processing at line speed
  - Queuing: if datagrams arrive faster than forwarding rate into switch fabric

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**Input Port Queuing**

- Fabric slower than input ports combined → queueing may occur at input queues
- **Head-of-the-Line (HOL) blocking**: queued datagram at front of queue prevents others in queue from moving forward
- Queuing delay and loss due to input buffer overflow!

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**Three types of switching fabrics**

- Memory
- Bus
- Crossbar
Switching Via Memory

First generation routers:
- packet copied by system's (single) CPU
- speed limited by memory bandwidth (2 bus crossings per datagram)

Modern routers:
- input port processor performs lookup, copy into memory
- Cisco Catalyst 8500

Switching Via a Bus

- datagram from input port memory to output port memory via a shared bus
- bus contention: switching speed limited by bus bandwidth
- 1 Gbps bus, Cisco 1900: sufficient speed for access and enterprise routers (not regional or backbone)

Switching Via An Interconnection Network

- overcome bus bandwidth limitations
- Banyan networks, other interconnection nets initially developed to connect processors in multiprocessor
- Advanced design: fragmenting datagram into fixed length cells, switch cells through the fabric
- Cisco 12000: switches 6 Gbps through the interconnection network
Output Ports

- Buffering required when datagrams arrive from fabric faster than the transmission rate
- Scheduling discipline chooses among queued datagrams for transmission

Output port queueing

- Buffering when arrival rate via switch exceeds output line speed
- Queueing (delay) and loss due to output port buffer overflow

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   - IPv6
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**IPv4 datagram format**

- **IPv protocol version number**
- **header length (bytes)**
- "type" of data
- max number of hops remaining (decremented at each router)
- upper layer protocol
to deliver payload to

**IPv6**
- **Initial motivation:** 32-bit address space completely allocated by 2008.
- **Additional motivation:**
  - header format helps speed processing/forwarding
  - header changes to facilitate QoS
  - new "anycast" address: route to "best" of several replicated servers
- **IPv6 datagram format:**
  - fixed-length 40 byte header
  - no fragmentation allowed

**IPv6 Header (Cont)**
- **Priority:** identify priority among datagrams in flow
- **Flow Label:** identify datagrams in same "flow." (concept of "flow" not well defined)
- **Next header:** identify upper layer protocol for data
Other Changes from IPv4

- **Checksum**: removed entirely to reduce processing time at each hop
- **Options**: allowed, but outside of header, indicated by "Next Header" field
- **ICMPv6**: new version of ICMP
  - additional message types, e.g., "Packet Too Big"
  - multicast group management functions

Transition From IPv4 To IPv6

- Not all routers can be upgraded simultaneously
  - no "flag days"
  - How will the network operate with mixed IPv4 and IPv6 routers?
- Two proposed approaches:
  - **Dual Stack**: some routers with dual stack (v6, v4) can "translate" between formats
  - **Tunneling**: IPv6 carried as payload in IPv4 datagram among IPv4 routers

Dual Stack Approach
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Multicast: one sender to many receivers

- **Multicast**: act of sending datagram to multiple receivers with single “transmit” operation
  - analogy: one teacher to many students
- **Question**: how to achieve multicast

**Multicast via unicast**

- source sends N unicast datagrams, one addressed to each of N receivers
- routers forward unicast datagrams
- multicast receiver (red)
- not a multicast receiver (red)
Multicast: one sender to many receivers

- Multicast: act of sending datagram to multiple receivers with single "transmit" operation
- Analogy: one teacher to many students
- Question: how to achieve multicast

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 datagrams

Question: how to achieve multicast

Application-layer multicast
- End systems involved in multicast copy and forward unicast datagrams among themselves

Internet Multicast Service Model

Multicast group concept: use of indirection
- Hosts addresses IP datagram to multicast group
- Routers forward multicast datagrams to hosts that have "joined" that multicast group
Multicast groups

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

- host group semantics:
  - anyone can "join" (receive) multicast group
  - anyone can send to multicast group
  - no network-layer identification to hosts of members

- needed: infrastructure to deliver mcast-addressed datagrams to all hosts that have joined that multicast group

Joining a mcast group: two-step process

- 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 datagram flow
  - many protocols (e.g., DVMRP, MOSPF, PIM)

IGMP: Internet Group Management Protocol

- host: sends IGMP report when application joins mcast group
  - IP_ADD_MEMBERSHIP socket option
  - host need not explicitly "unjoin" group when leaving
- router: sends IGMP query at regular intervals
  - host belonging to a mcast group must reply to query
IGMP

**IGMP version 1**
- **router:** Host Membership Query msg broadcast on LAN to all hosts
- **host:** Host Membership Report msg to indicate group membership
  - randomized delay before responding
  - implicit leave via no reply to Query
- RFC 1112

**IGMP v2:** additions include
- group-specific Query
- Leave Group msg
- last host replying to Query can send explicit Leave Group msg
- router performs group-specific query to see if any hosts left in group
- RFC 2236

**IGMP v3:** under development as Internet draft