

Housekeeping

- Questions
- Feedback on class: your role in teaching me to teach
- Make an appointment to see me before Oct 10 or just come by during office hours
- Study tactics: anything in a shaded box; open issue section at the end of each chapter

Outline

Self-routing switch fabrics

Batcher-Banyan

Internetworking – Chapter 4

Service Model

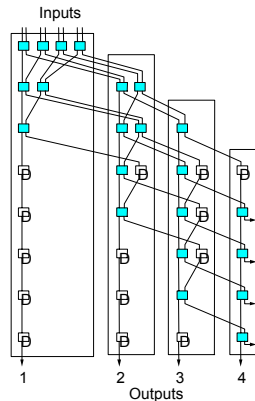
Network of networks

Global Addressing Scheme

Address resolution (ARP)

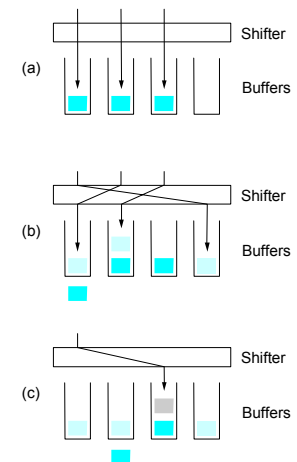
Knockout Switch

- Example crossbar
- Concentrator
 - select l of n packets
- Complexity: n^2



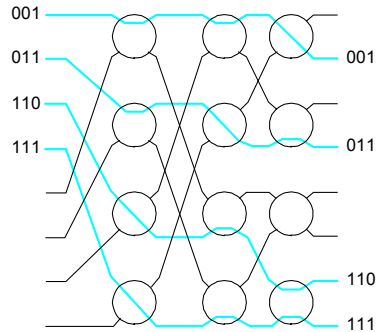
Knockout Switch (cont)

- Output Buffer



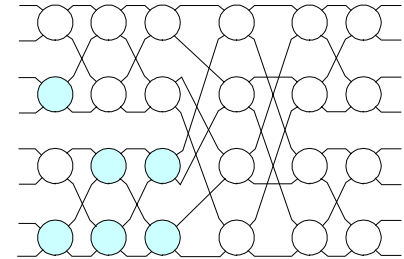
Self-Routing Fabrics – 3.4.5

- Banyan Network
 - constructed from simple 2×2 switching elements
 - self-routing header attached to each packet
 - elements arranged to route based on this header
 - no collisions if input packets sorted into ascending order
 - complexity: $n \log_2 n$



Self-Routing Fabrics (cont)

- Batcher Network
 - switching elements sort two numbers
 - some elements sort into ascending (clear)
 - some elements sort into descending (shaded)
 - elements arranged to implement merge sort
 - complexity: $n \log_2^2 n$



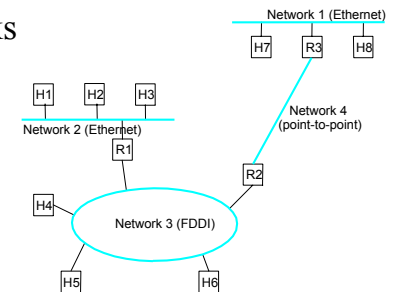
- Common Design: Batcher-Banyan Switch

Chapter 3 Summary

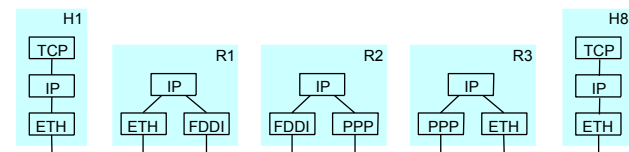
- Forwarding
 - Datagrams
 - Virtual Circuits
 - Source Routing
- Bridges and LAN Switches
 - Source address learning
 - Spanning tree
- ATM
 - Cell structure
 - AAL 3/4, AAL 5
- Switch Hardware – Crossbar and Self-routing

Internetworking – Chapter 4

- Network of Networks



- Protocol Stack



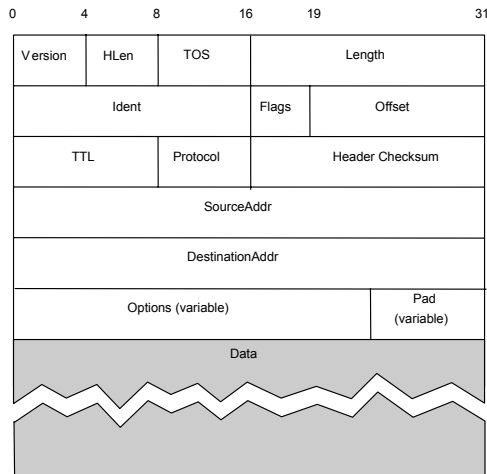
An internet vs The Internet

- An internet
 - A network of networks
 - Many examples: Netware, XNS, DECnet, Arpanet
 - Different protocols (different choices) for solving similar problems
- The Internet
 - Carries traffic using IP and related protocols
 - Implication of “connectedness” to the rest of the world
 - Networks not part of The Internet may use IP

IP Service Model

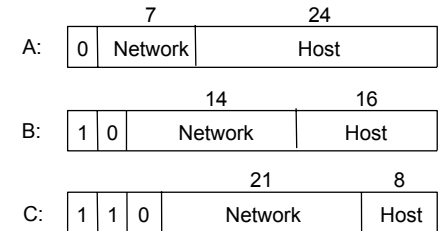
- Connectionless (datagram-based)
- Best-effort delivery (unreliable service)
 - packets may be lost
 - packets may be delivered out of order
 - duplicate copies of a packet may be delivered
 - packets may be delayed for a long time

IP Datagram Format



Global Addresses

- Properties
 - globally unique
 - hierarchical: network + host
- Dot Notation
 - 10.3.2.4
 - 128.96.33.81
 - 192.12.69.77



Datagram Forwarding

- Strategy
 - every datagram contains destination's address
 - if directly connected to destination network, then forward to host
 - if not directly connected to destination network, then forward to some router
 - forwarding table maps network number into next hop
 - each host has a default router
 - each router maintains a forwarding table

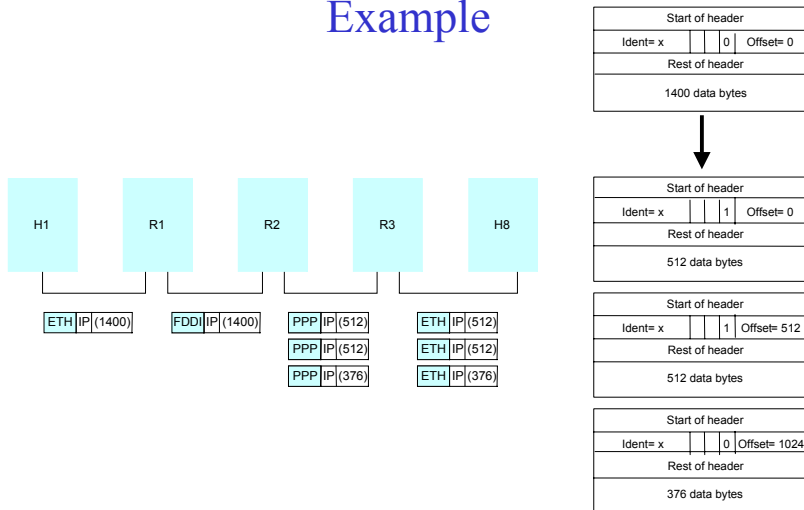
Example (R2)

Network Number	Next Hop
1	R3
2	R1
3	interface 1
4	interface 0

Fragmentation and Reassembly

- Each network has some MTU
- Strategy
 - fragment when necessary (MTU < Datagram)
 - try to avoid fragmentation at source host
 - re-fragmentation is possible
 - fragments are self-contained datagrams
 - use CS-PDU (not cells) for ATM
 - delay reassembly until destination host
 - do not recover from lost fragments

Example



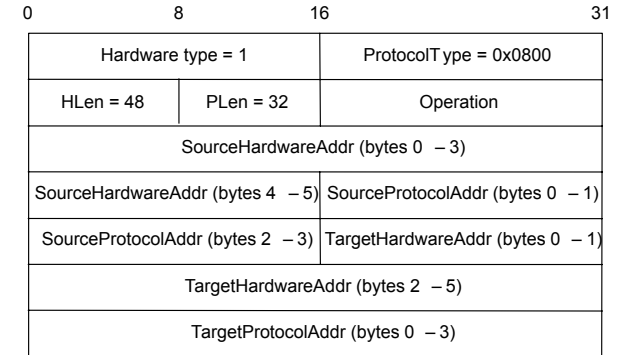
Address Translation

- Map IP addresses into physical addresses
 - destination host
 - next hop router
- Techniques
 - encode physical address in host part of IP address
 - table-based
- ARP
 - table of IP to physical address bindings
 - broadcast request if IP address not in table
 - target machine responds with its physical address
 - table entries are discarded if not refreshed

ARP Details

- Request Format
 - HardwareType: type of physical network (e.g., Ethernet)
 - ProtocolType: type of higher layer protocol (e.g., IP)
 - HLEN & PLEN: length of physical and protocol addresses
 - Operation: request or response
 - Source/Target-Physical/Protocol addresses
- Notes
 - table entries timeout in about 10 minutes
 - update table with source when you are the target
 - update table if already have an entry
 - do not refresh table entries upon reference

ARP Packet Format



Internet Control Message Protocol (ICMP)

- Echo (ping)
- Redirect (from router to source host)
- Destination unreachable (protocol, port, or host)
- TTL exceeded (so datagrams don't cycle forever)
- Checksum failed
- Reassembly failed
- Cannot fragment