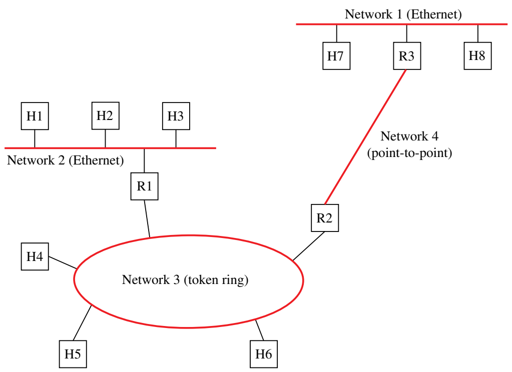
Internetworking

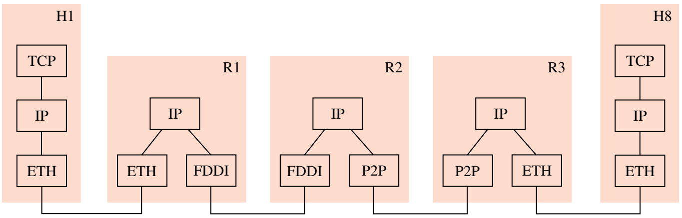
- Outline
  - Best Effort Service Model
  - Global Addressing Scheme

IP Internet

- Concatenation of Networks



- Protocol Stack

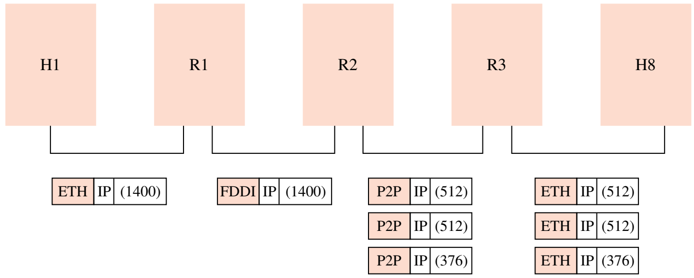


Service Model

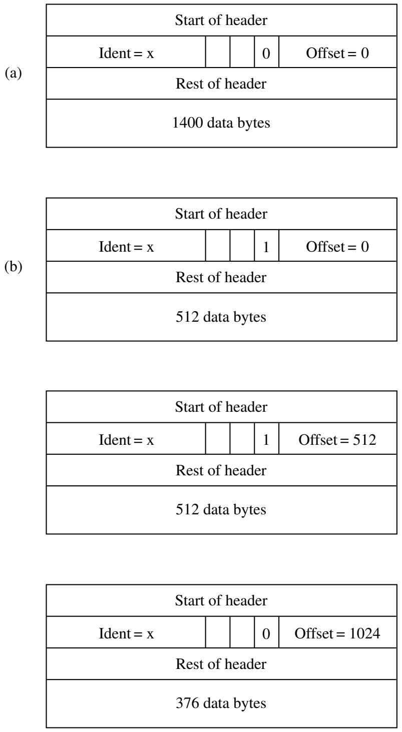
- Connectionless (datagram-based)
- Best-effort delivery (unreliable service)
  - packets are lost
  - packets are delivered out of order
  - duplicate copies of a packet are delivered
  - packets can be delayed for a long time
- Datagram Format
  - Version (4): currently 4
  - Hlen (4): number of 32-bit words in header
  - TOS (8): type of service (not widely used)
  - Length (16): number of bytes in this datagram
  - Ident (16): used by fragmentation
  - Flags/Offset (16): used by fragmentation
  - TTL (8): number of hops this datagram has travelled
  - Protocol (8): demux key (TCP=6, UDP=17)
  - Checksum (16): of the header only
  - DestAddr & SrcAddr (32)

Fragmentation and Reassembly

- Each network has some MTU
- Strategy
  - fragment when necessary (MTU < Datagram)
  - try to avoid fragmentation at source host
  - refragmentation 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

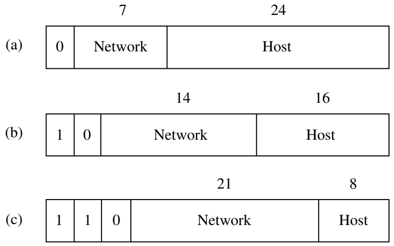


Fragmentation Example



Global Addresses

- Properties
  - globally unique
  - hierarchical: network + host
- Format



- 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 (router R2)

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

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

0	8	16	31
Hardware type = 1		ProtocolType = 0x0800	
HLEN = 48	PLEN = 32	Operation	
SourceHardwareAddr (bytes 0–3)			
SourceHardwareAddr (bytes 4–5)		SourceProtocolAddr (bytes 0–1)	
SourceProtocolAddr (bytes 2–3)		TargetHardwareAddr (bytes 0–1)	
TargetHardwareAddr (bytes 2–5)			
TargetProtocolAddr (bytes 0–3)			

  – 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 table if already have an entry
  – do not refresh table entries upon reference

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