

# Internetworking

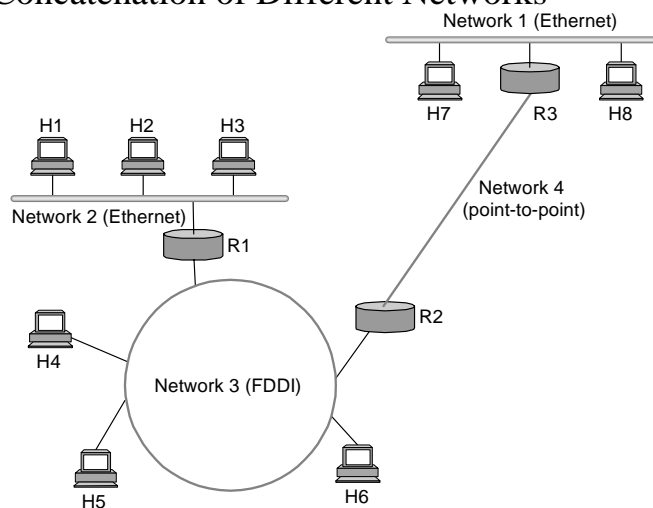
## Outline

- Best Effort Service Model
- Global Addressing Scheme

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# Internetworking

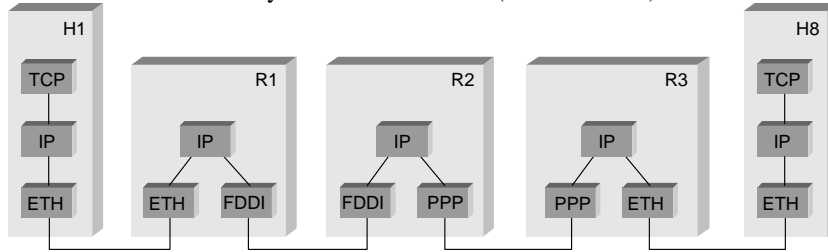
- Concatenation of Different Networks



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# IP Internet

- Connecting Problem 1: Heterogeneity of Networks
  - Solution: Layered Protocol Stack (IP over ..... )

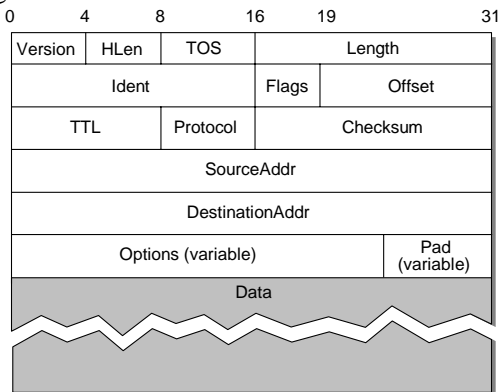


- Problem 2: Scalability in Routing and Addressing
  - Solution: Address Hierarchy

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# Service Model

- Connectionless (datagram-based)
- Best-effort delivery (unreliable service)
  - packets can be lost, delayed, duplicated, delivered out of order.
- Datagram format: IP header



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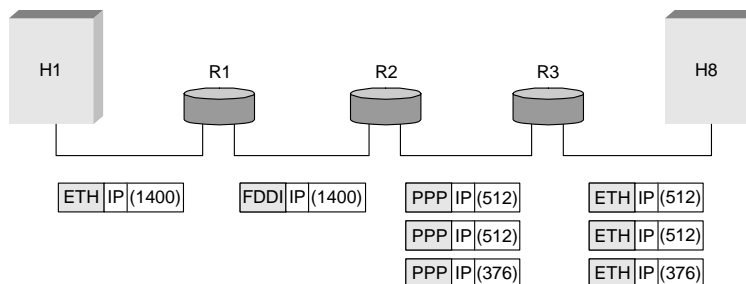
## IP Header

- **Version** (always set to the value 4 for IP v4)
- **IP Header Length** (number of 32-bit words forming the header, usually five)
- **Size of Datagram** (in bytes, header + data)
- **Flags** 3 bits: R (reserved bit set to 0) DF (Don't fragment) MF (More fragments)
- **Time To Live** (Number of hops /links which the packet may be routed over, decremented by most routers - used to prevent accidental routing loops)
- **Protocol** (the type of transport packet being carried (e.g. 1 = ICMP; 6 = TCP; 17= UDP).
- **Header Checksum** (A 1's complement checksum of IP header, updated whenever the packet header is modified by a node. Packets with an invalid checksum are discarded by all nodes in an IP network)
- **Source Address / Destination Address**

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## Fragmentation and Reassembly

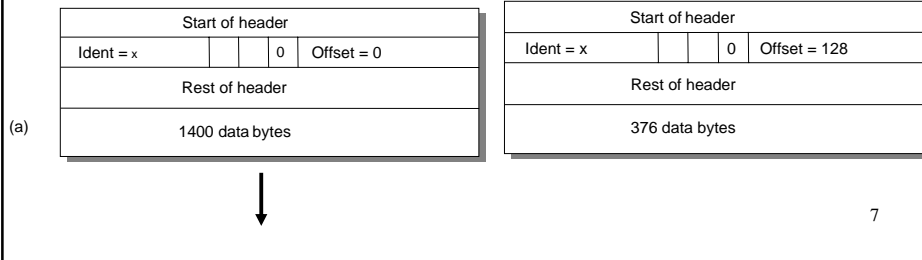
- Each network has some MTU (max trans. Unit)
- Design decisions
  - fragment (re-fragment) when necessary (MTU < Datagram)
  - fragments are self-contained datagrams
  - delay reassembly until destination host
  - do not recover from lost fragments
  - try to avoid fragmentation at senders (packet size < local MTU)



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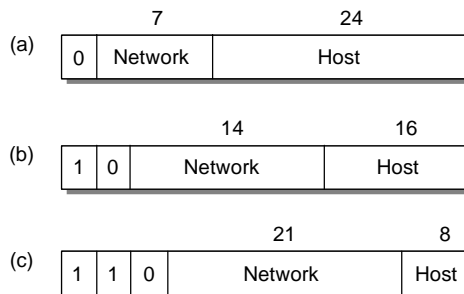
# Example

- **FDDI MTU 523 bytes** = 20 + 512
- **Fragmentation Offset** offset from the start of the original sent packet, in units of 8 bytes ( $512 / 8 = 64$ )
- **Identification** ( 16-bit number which together with the source address uniquely identifies this packet)
- **Flag MF** (more fragments) = 1;



# Global Addresses

- **Properties**
  - globally unique
  - hierarchical: network + host
  - Class A, B, C
- **Dot Notation**
  - 10.3.2.4
  - 128.96.33.81
  - 192.12.69.77



## Datagram Forwarding Strategy

- Every datagram contains destination's address
- if connected to destination network, then forward to the host in LAN
  - If network number of destination IP == my network number
- if not directly connected, then forward to some router
  - each host has a default router configured
- Each router maintains a forwarding table
  - forwarding table maps **network number** (rather than host address) into next hop or interface number (if directly connected)
  - Otherwise send to its (the router's) default router

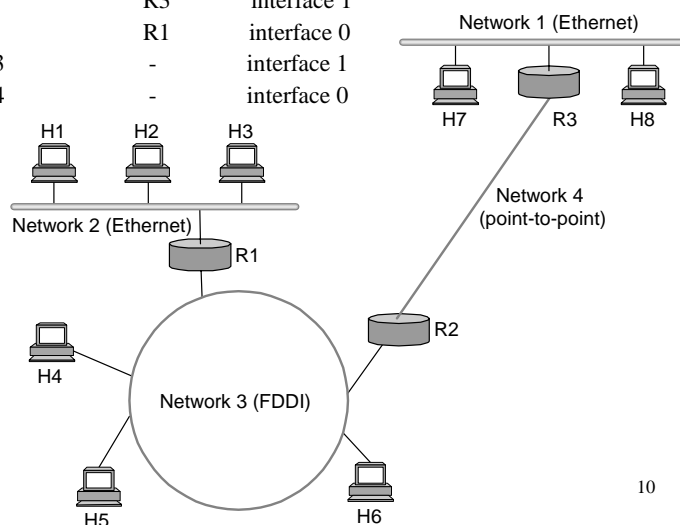
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**Traffic:** H1 → H3, H1 → H8

**R1:** default router is R2

**R2 Routing Table:**

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



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## Address Translation in LAN

- Map IP addresses into physical addresses of the destination host (if connected directly) or the next hop router
- ARP
  - Each host caches its table of IP to physical address bindings
  - table entries are discarded if not refreshed
    - timeout in about 10 minutes
  - broadcast request if IP address not in table
  - target machine send its physical address to the sender
  - target machine also updates add entry of the source in its table
    - It is likely that the target will send IP packets to the source later on.
  - Other hosts (who receives the broadcasted request) update table if already have an entry

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## 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=1 or response=2

0	8	16	31
Hardware type = 1		ProtocolType = 0x0800 (IP)	
HLen=48(Eth)	PLen=32(IP)	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)			

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## Internet Control Message Protocol (ICMP)

- Error/control messages sent by routers to the source IP.
- Echo (ping)
- TTL exceeded (traceroute)
- Redirect
  - E.g. Two routers are attached to the network.
  - Can be returned by the default router of the host
- Destination Unreachable / Fragmentation Needed and DF Set
  - On some modern computers, Don't Fragment (DF) flag is set in the IP header.
  - The router with smaller MTU discards the IP datagram and sends an ICMP message (type 3 / subtype 4) with its MTU to the sending host.
  - PMTU (Path MTU) discovery (RFC 1191)
  - Non-PMTU-compliant routers or firewalls may cause problem.

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