Internetworking

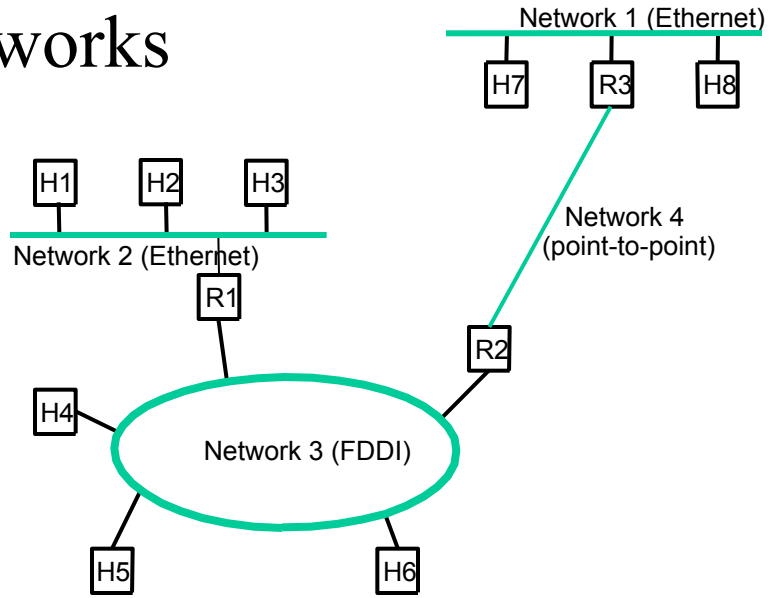
Simple Internetworking (IP) 4.1

Subnetting 4.3.1

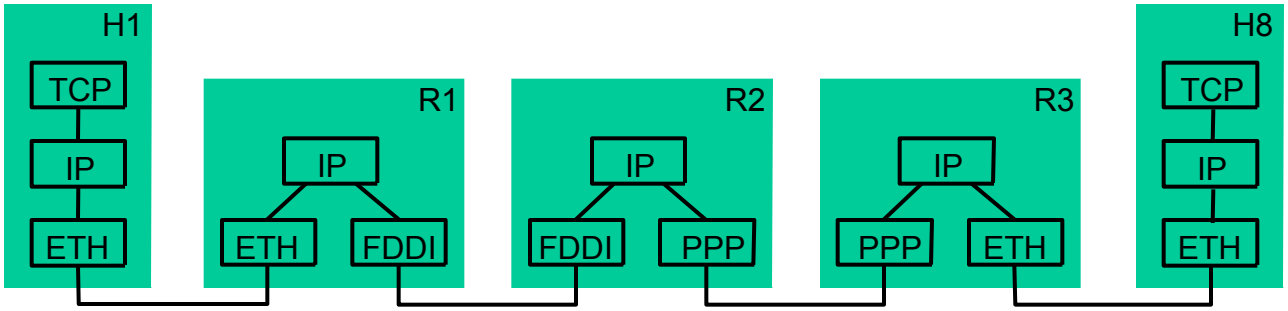
IP Version 6 (IPv6) 4.3.5

IP Internet

- Concatenation of Networks

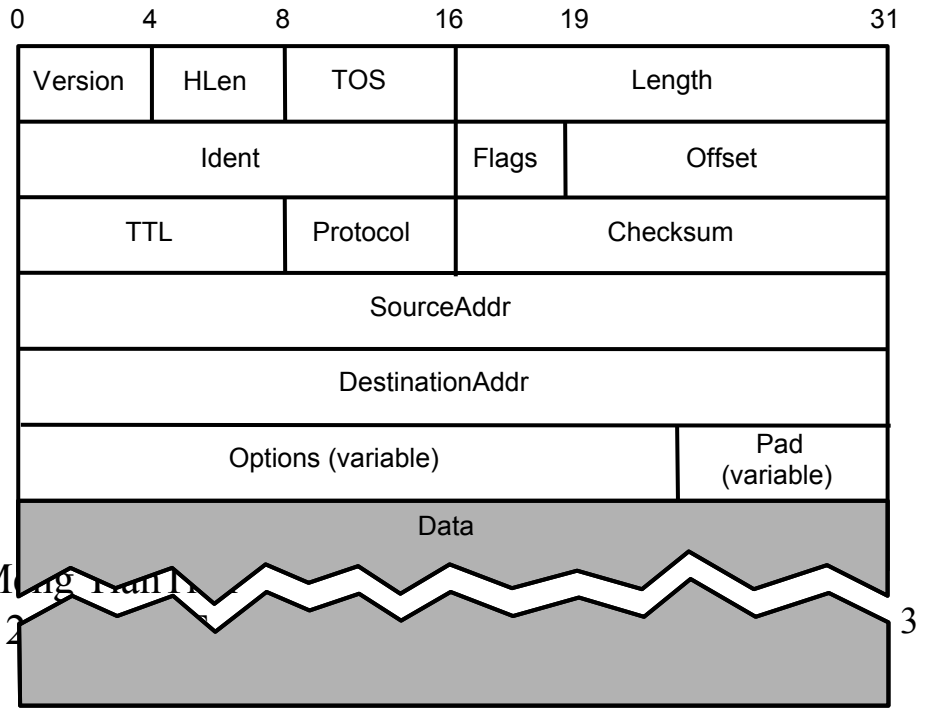


- Protocol Stack



Service Model

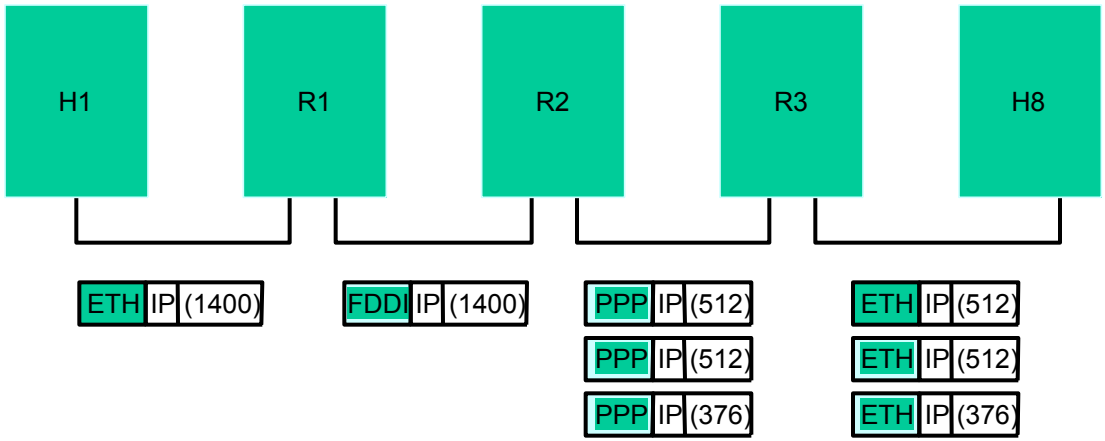
- Connectionless (datagram-based)
- Best-effort delivery (unreliable service)
  - packets are lost
  - packets are delivered out of order
  - duplicate copies of a packet are delivered
  - packets can be delayed for a long time
- Datagram format

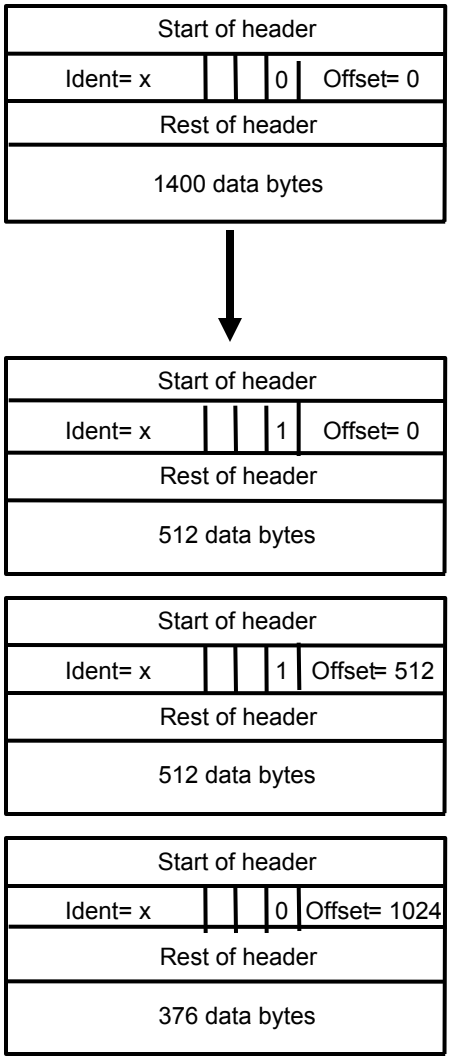


Fragmentation and Reassembly

- Each network has some MTU
- Design decisions
  - fragment when necessary (MTU < Datagram)
  - try to avoid fragmentation at source host
  - re-fragmentation is possible
  - fragments are self-contained datagrams
  - delay reassembly at destination host
  - do not recover from lost fragments

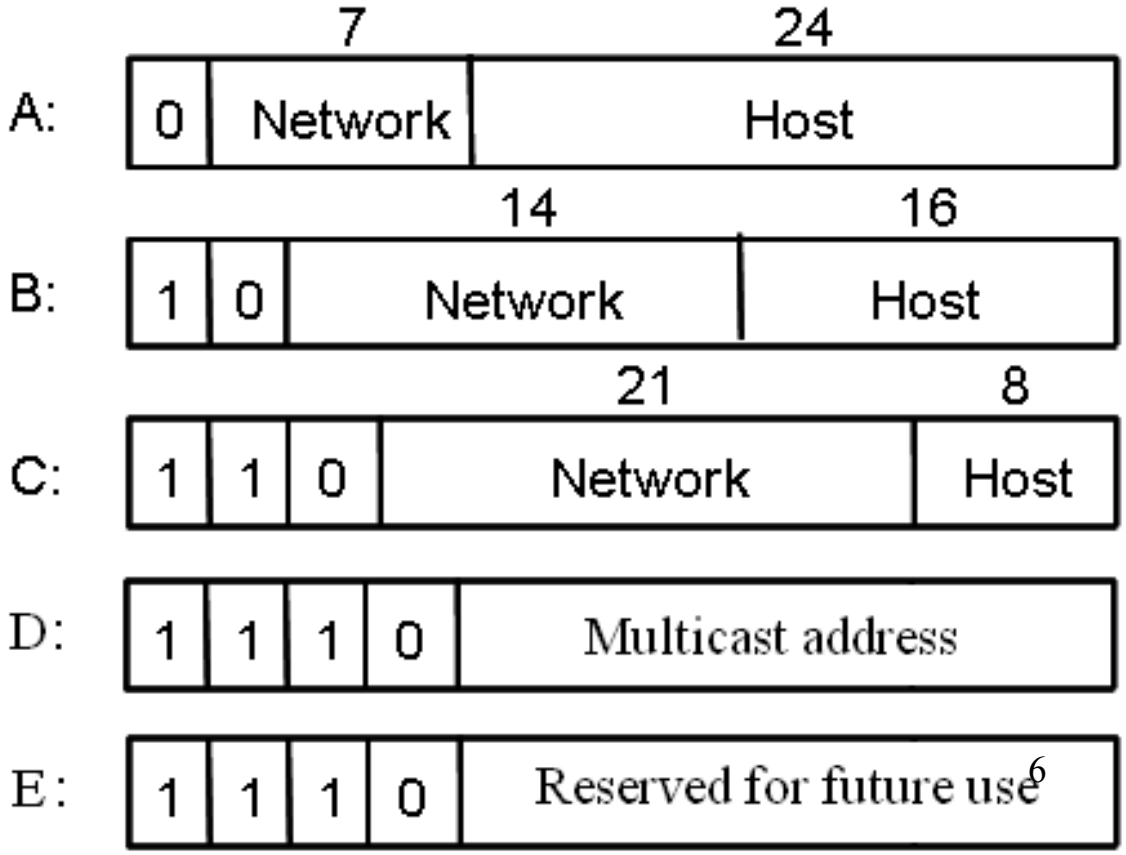
Example


H1
R1
R2
R3
H8
ETH IP (1400)
FDDI IP (1400)
PPP IP (512)
PPP IP (512)
PPP IP (376)
ETH IP (512)
ETH IP (512)
ETH IP (376)


Start of header
Ident= x
0
Offset= 0
Rest of header
1400 data bytes
Start of header
Ident= x
1
Offset= 0
Rest of header
512 data bytes
Start of header
Ident= x
1
Offset= 512
Rest of header
512 data bytes
Start of header
Ident= x
0
Offset= 1024
Rest of header
376 data bytes

Global Addresses

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



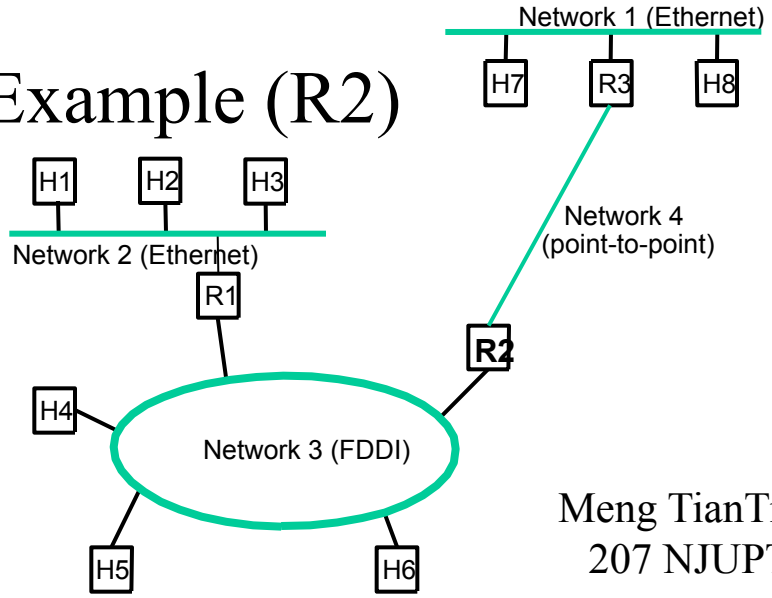
IP Address

	the max net NO.	the first available net ID	the last available net ID	the max number in the net
A	126 ($2^7 - 2$)	1	126	16,777,214
B	16,384 (2^{14})	128.0	191.255	65,534
C	2,097,152 (2^{21})	192.0.0	223.255.255	254

Datagram Forwarding

- Strategy
  - every datagram contains destination's address
  - if connected to destination network, then forward to host
  - if not directly connected, 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

Routers

Routers are often called “layer 3 devices”. They operate at the third layer, or OSI network layer.

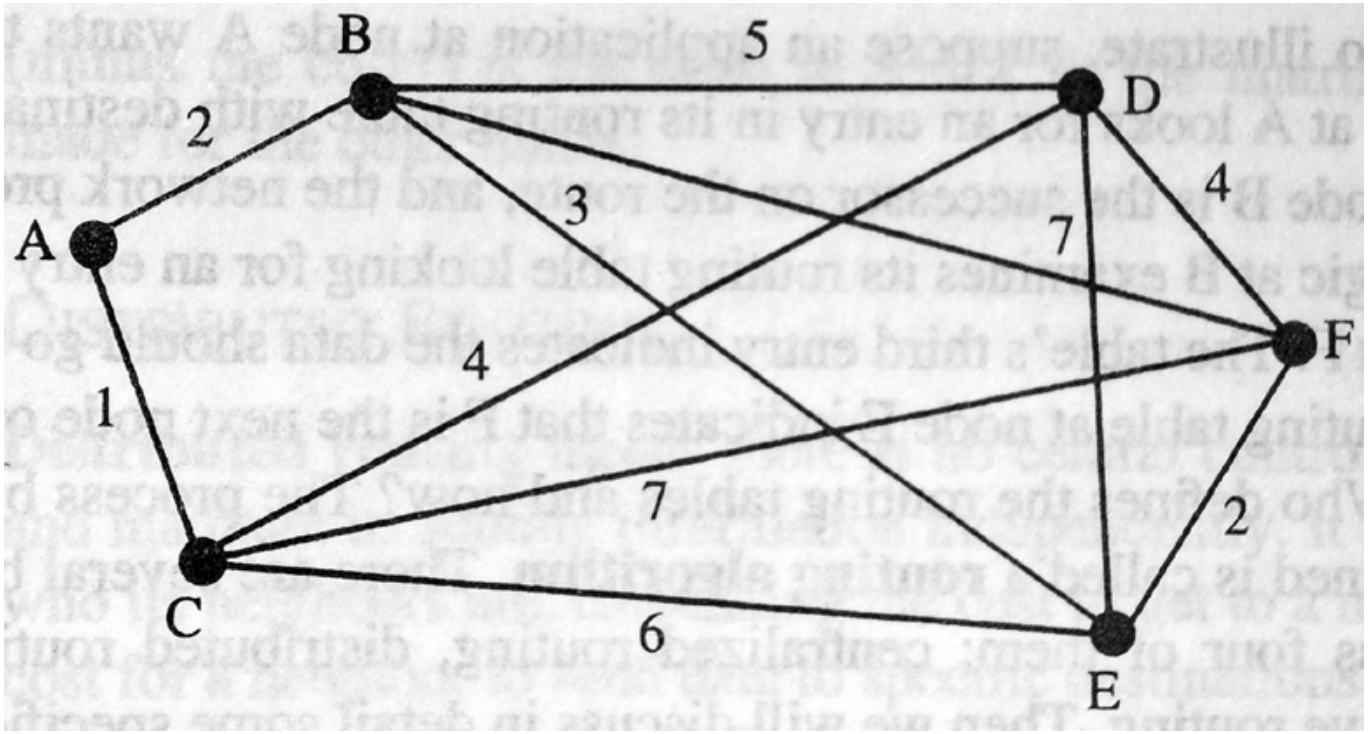
The device that connects a LAN to a WAN or a WAN to a WAN.

A router accepts an outgoing packet, removes any LAN headers and trailers, and encapsulates the necessary WAN headers and trailers.

Because a router has to make wide area network routing decisions, the router has to dig down into the network layer of the packet to retrieve the network destination address.

Routing Tables

A→F



DESTINATION	NEXT NODE	COST
B	B	2
C	C	1
D	C	5
E	B	5
F	B	7

DESTINATION	NEXT NODE	COST
D	D	5
E	E	3
F	E	5

DESTINATION	NEXT NODE	COST
F	F	2

(a) Partial routing table for node A (b) Partial routing table for node B (c) Partial routing table for node E

Routing – The Problem

- Choose the best path from A to X, knowing (at A) only the logical address of X.
- "Best" could mean
  - Smallest number of hops
  - Shortest time delay
  - Least congested
  - Cheapest
  - Administratively allowed
  - Easiest to discover
  - Any combination of the above
- Solution must be reasonably quick and guaranteed to avoid loops

Routing Algorithm

- The way to define the routing tables
- Four types:
  - Centralized routing: 集中式路由
  - Distributed routing: 分布式路由
  - Static routing: 静态路由
  - Adaptive routing: 自适应路由

Centralized Routing

- All interconnection is generated and maintained at a single central location. That location broadcasts this information to all network nodes.
- Routing matrix
- A→F：

A-B-E-F

source node	A	B	C	D	E	F
A	—	B	C	C	B	B
B	A	—	A	D	E	E
C	A	A	—	D	E	F
D	C	B	C	—	F	F
E	B	B	C	F	—	F
F	E	E	C	D	E	—

Address Translation

- Map IP addresses into physical addresses
  - destination host
  - next hop router
- Techniques
  - encode physical address in host part of IP address
    - e.g. PH add=00100001010100001; IP add=128.96.33.81
  - 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

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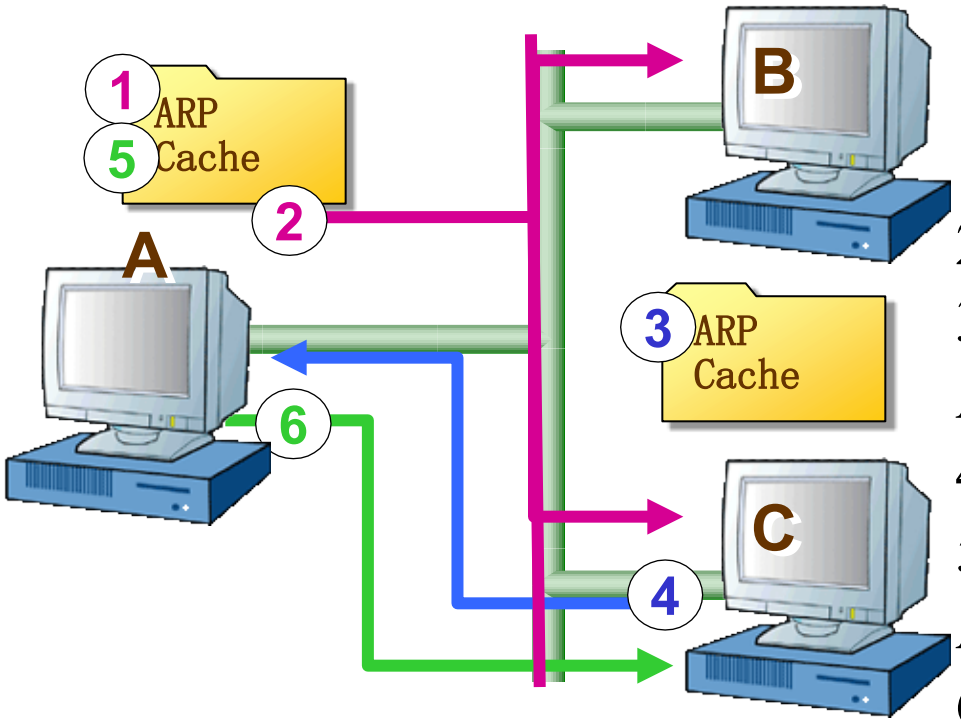
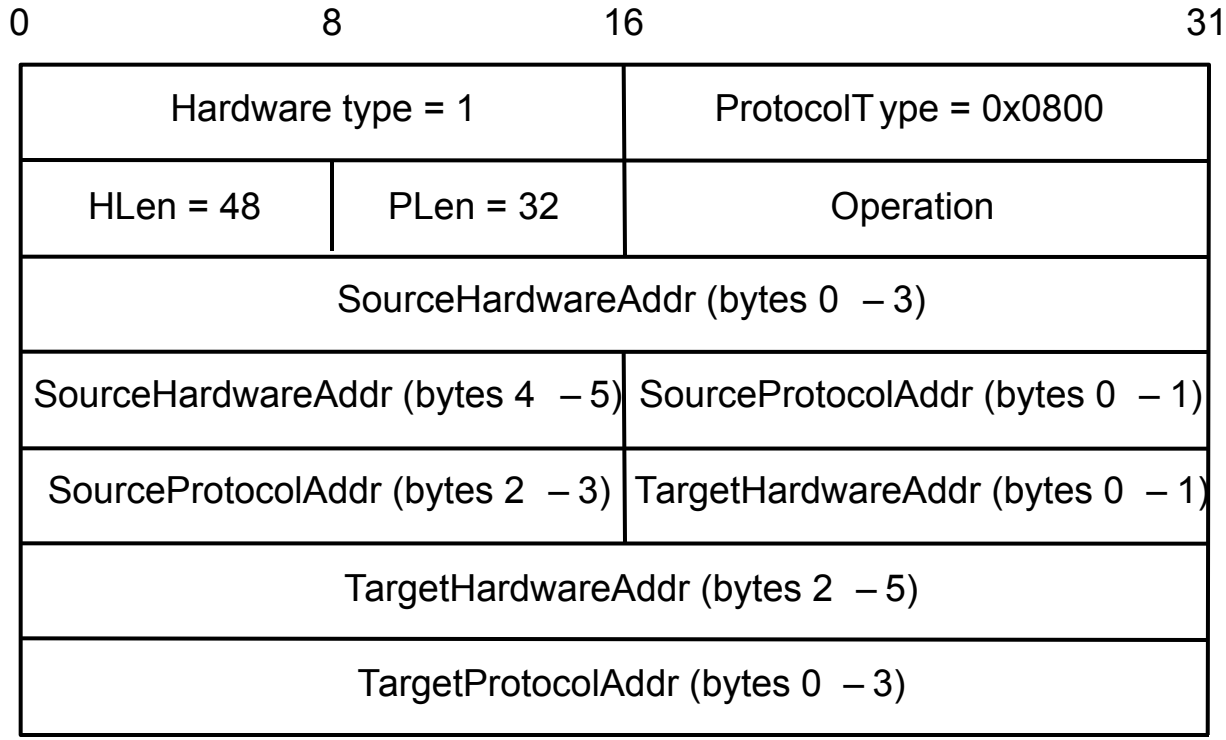
Address Translation



1. A checks the ARP cache
2. A broadcasts ARP request
3. C adds A's information into ARP cache
4. C responds ARP request
5. A adds C's information into ARP cache
6. A sends IP packet

ARP Packet Format



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

Internet Control Message Protocol

- ICMP
- When a router receives an IP packet and finds errors, what should it do?
- Used by the routers to report errors and unexpected events, test the state of the network, perform congestion control, and router updates.
- The Internet is closely monitored by the routers using ICMP.

Internet Control Message Protocol (ICMP)

- Ping:
  - A host sends an ICMP “echo” message
  - As IP packet, “echo” message gets routed to destination
  - At destination, respond by sending an ICMP “echo reply” message
- 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