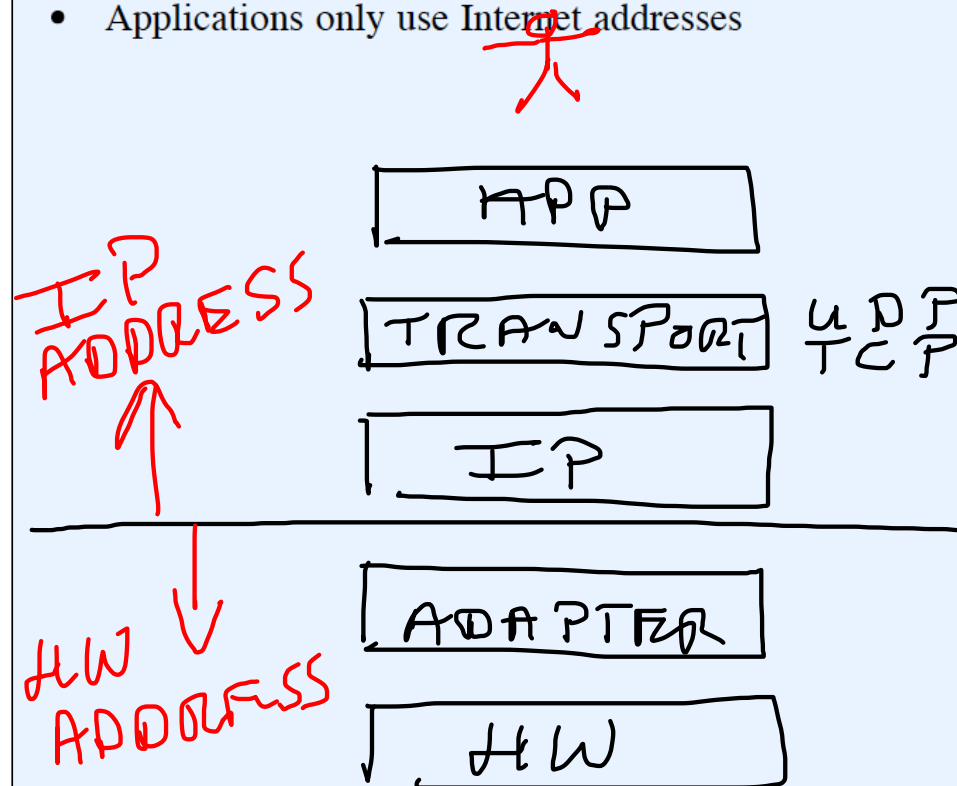


PART V

**MAPPING INTERNET ADDRESSES
TO PHYSICAL ADDRESSES
(ARP)**

Motivation

- Must use hardware (physical) addresses to communicate over network
- Applications only use Internet addresses



Example

- Computers A and B on same network
- Application on A generates packet for application on B
- Protocol software on A must use B's hardware address when sending a packet

Consequence

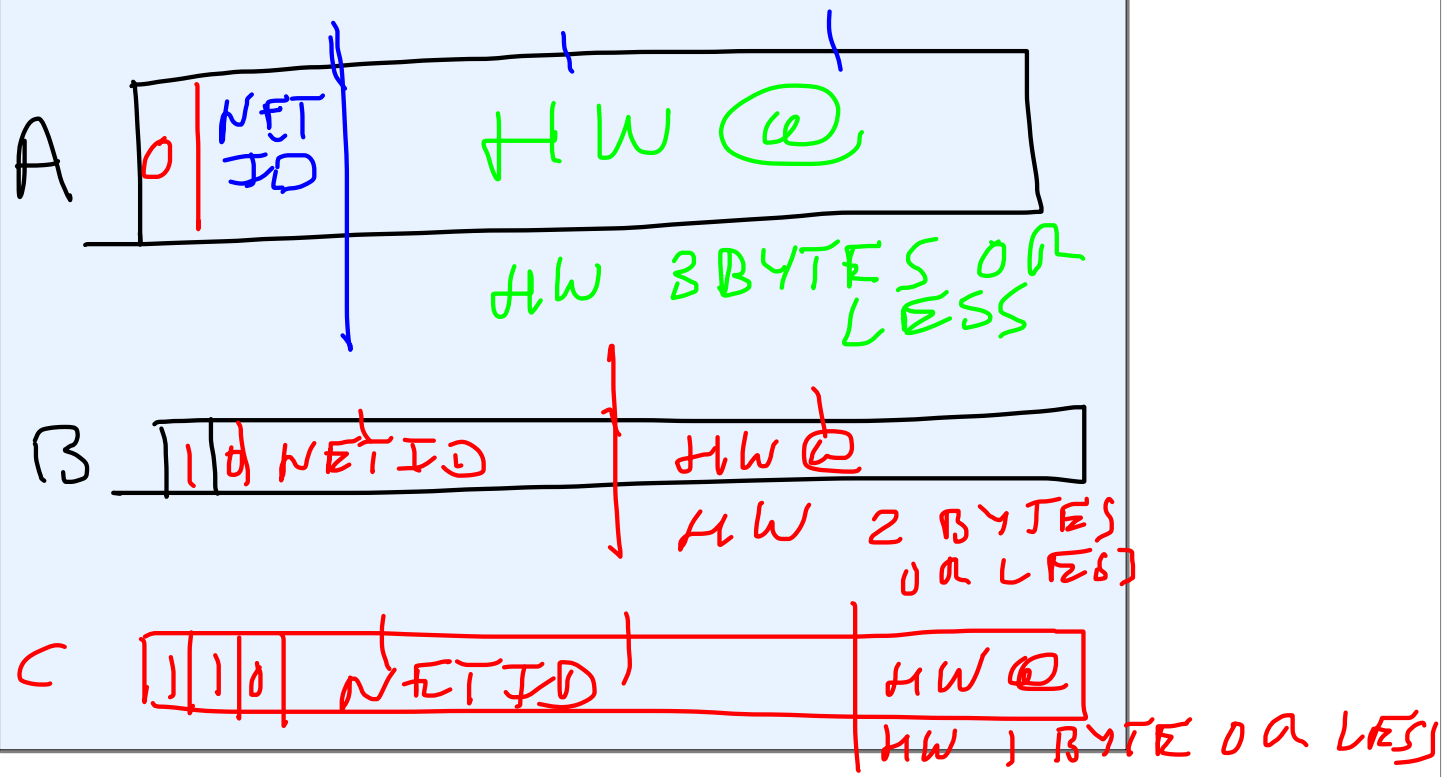
- Protocol software needs a mechanism that maps an IP address to equivalent hardware address
- Known as *address resolution* problem

Address Resolution

- Performed at each step along path through Internet
- Two basic algorithms
 - Direct mapping
 - Dynamic binding
- Choice depends on type of hardware

Direct Mapping

- Easy to understand
- Efficient
- Only works when hardware address is small
- Technique: assign computer an IP address that encodes the hardware address



Example Of Direct Mapping

- Hardware: proNet ring network
- Hardware address: 8 bits
- Assume IP address 192.5.48.0 (24-bit prefix)
- Assign computer with hardware address K an IP address 192.5.48.K
- Resolving an IP address means extracting the hardware address from low-order 8 bits

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Dynamic Binding

- Needed when hardware addresses are large (e.g., Ethernet)
- Allows computer A to find computer B's hardware address
 - A starts with B's IP address
 - A knows B is on the local network
- Technique: broadcast query and obtain response
- Note: dynamic binding only used across one network at a time

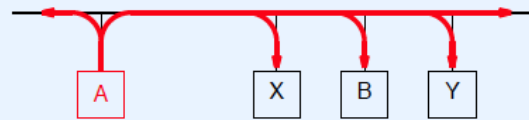
Internet Address Resolution Protocol (ARP)

- Standard for dynamic address resolution in the Internet
- Requires hardware broadcast
- Intended for LAN
- Important idea: ARP only used to map addresses within a single physical network, never across multiple networks

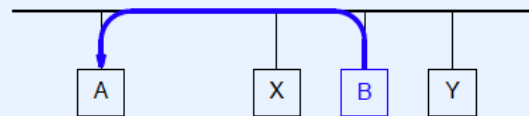
ARP

- Machine A broadcasts ARP request with B's IP address
- All machines on local net receive broadcast
- Machine B replies with its physical address
- Machine A adds B's address information to its table
- Machine A delivers packet directly to B

Illustration Of ARP Request And Reply Messages



A broadcasts request for B
(across local net only)



B replies to request

ARP Packet Format When Used With Ethernet

	0	8	16	31
ETHERNET ADDRESS TYPE (1)		IP ADDRESS TYPE (0800)		
ETH ADDR LEN (6)	IP ADDR LEN (4)	ARP OPCODE (00000001)		
SENDER'S ETH ADDR (first 2 octets)		HWA FIRST 4 BYTES		
SENDER'S ETH ADDR (last 2 octets)		HWA LAST 2 BYTES		
SENDER'S IP ADDR (first 2 octets)		SENDER'S IP ADDR (first 2 BYTES)		
SENDER'S IP ADDR (last 2 octets)		00 00		
TARGET'S ETH ADDR (first 2 octets)		00 00 00 00		
TARGET'S ETH ADDR (last 4 octets)		00 00		
TARGET'S IP ADDR (all 4 octets)				
IPB				

ARP Packet Format When Used With Ethernet

	0	8	16	31
ETHERNET ADDRESS TYPE (1)		IP ADDRESS TYPE (0800)		
ETH ADDR LEN (6)	IP ADDR LEN (4)	ARP OP REPLY		
HWB		1 ST 4 BYTES		
SENDER'S ETH ADDR (last 2 bytes)		SENDER'S IP ADDR (first 2 octets)		
HWB LAST 2 BYTES		IPB 1 ST 2 BYTES		
SENDER'S IP ADDR (last 2 octets)		HWA 1 ST 2 BYTES		
IPB LAST 2 BYTES		TARGET'S ETH ADDR (last 4 octets)		
HWA		TARGET'S IP ADDR (all 4 octets)		
IPA				

Observations About Packet Format

- General: can be used with
 - Arbitrary hardware address
 - Arbitrary protocol address (not just IP)
- Variable length fields (depends on type of addresses)
- Length fields allow parsing of packet by computer that does not understand the two address types

Retention Of Bindings

- Cannot afford to send ARP request for each packet
- Solution
 - Maintain a table of bindings
- Effect
 - Use ARP one time, place results in table, and then send many packets

ARP Caching

- ARP table is a cache
- Entries time out and are removed
- Avoids stale bindings
- Typical timeout: 20 minutes

Algorithm For Processing ARP Requests

- Extract sender's pair, (IA,EA) and update local ARP table if it exists
- If this is a request and the target is "me"
 - Add sender's pair to ARP table if not present
 - Fill in target hardware address
 - Exchange sender and target entries
 - Set operation to *reply*
 - Send reply back to requester

Algorithm Features

- If A ARPs B, B keeps A's information
 - B will probably send a packet to A soon
- If A ARPs B, other machines do not keep A's information
 - Avoids clogging ARP caches needlessly

Conceptual Purpose Of ARP

- Isolates hardware address at low level
- Allows application programs to use IP addresses

ARP Encapsulation

- ARP message travels in data portion of network frame
- We say ARP message is *encapsulated*

Illustration Of ARP Encapsulation

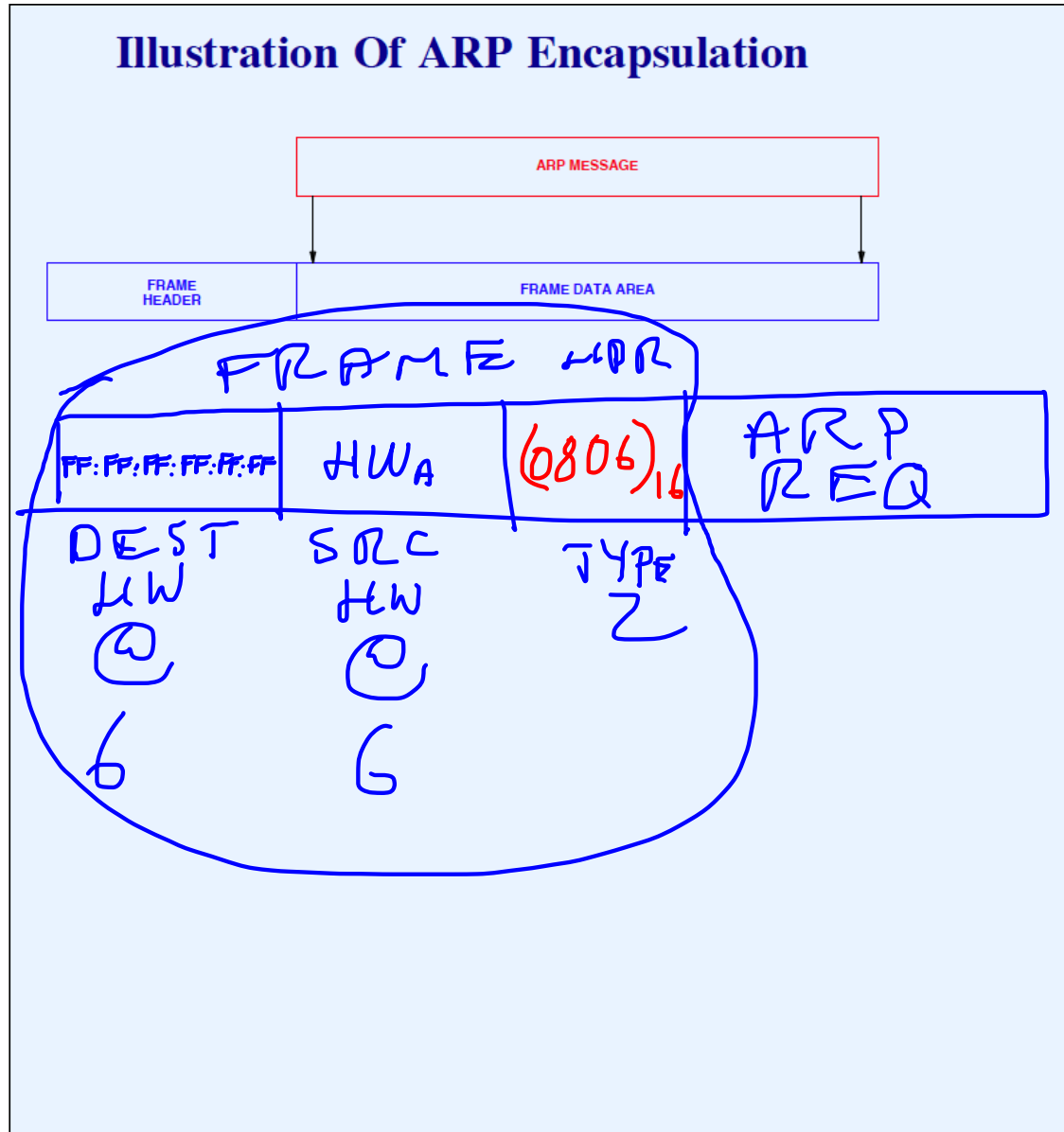
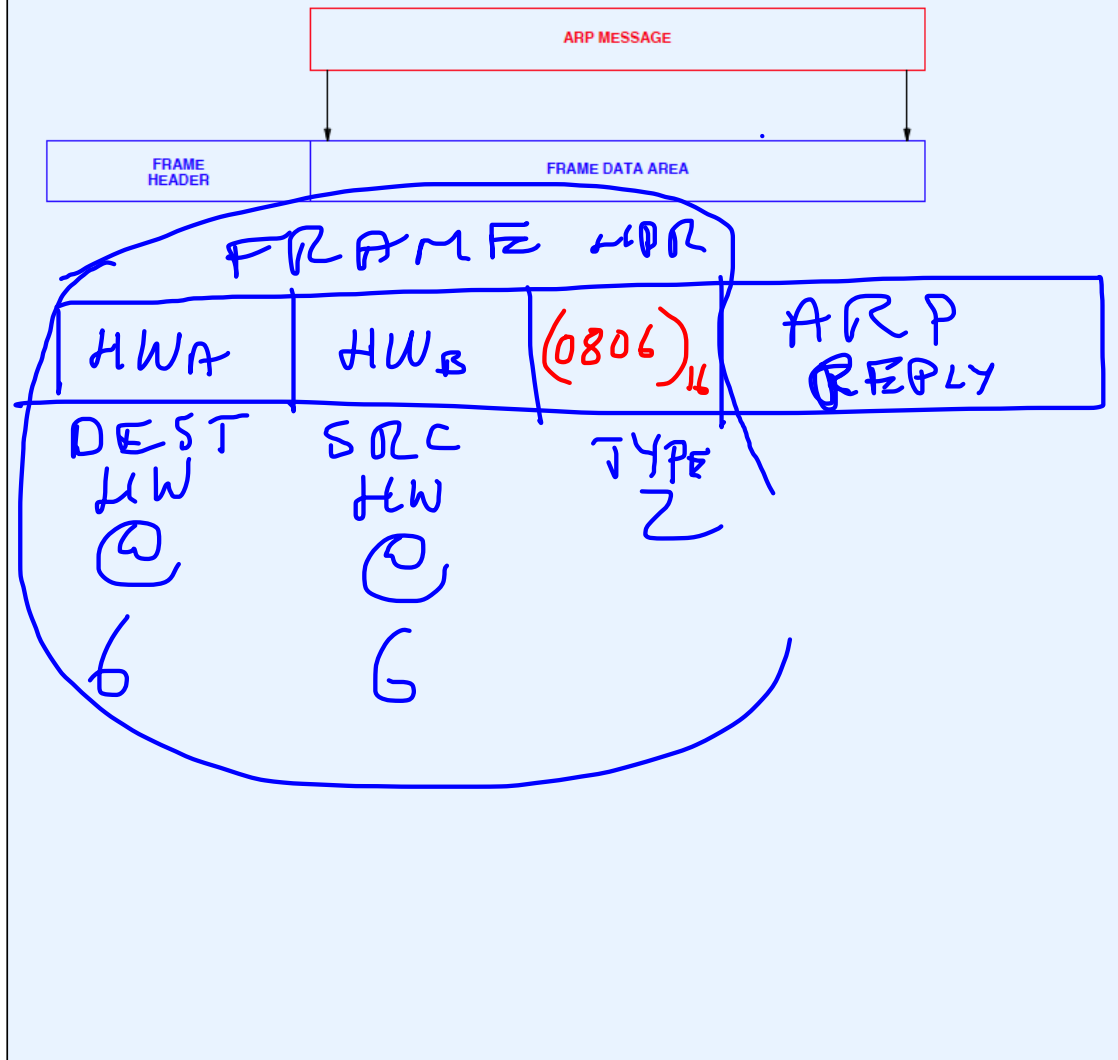


Illustration Of ARP Encapsulation



Ethernet Encapsulation

- ARP message placed in frame data area
- Data area padded with zeroes if ARP message is shorter than minimum Ethernet frame
- Ethernet type 0x0806 used for ARP

Reverse Address Resolution Protocol

- Maps Ethernet address to IP address
- Same packet format as ARP
- Intended for bootstrap
 - Computer sends its Ethernet address
 - RARP server responds by sending computer's IP address
- Seldom used (replaced by DHCP)

Summary

- Computer's IP address independent of computer's hardware address
- Applications use IP addresses
- Hardware only understands hardware addresses
- Must map from IP address to hardware address for transmission
- Two types
 - Direct mapping
 - Dynamic mapping

Summary (continued)

- Address Resolution Protocol (ARP) used for dynamic address mapping
- Important for Ethernet
- Sender broadcasts ARP request, and target sends ARP reply
- ARP bindings are cached
- Reverse ARP was originally used for bootstrap