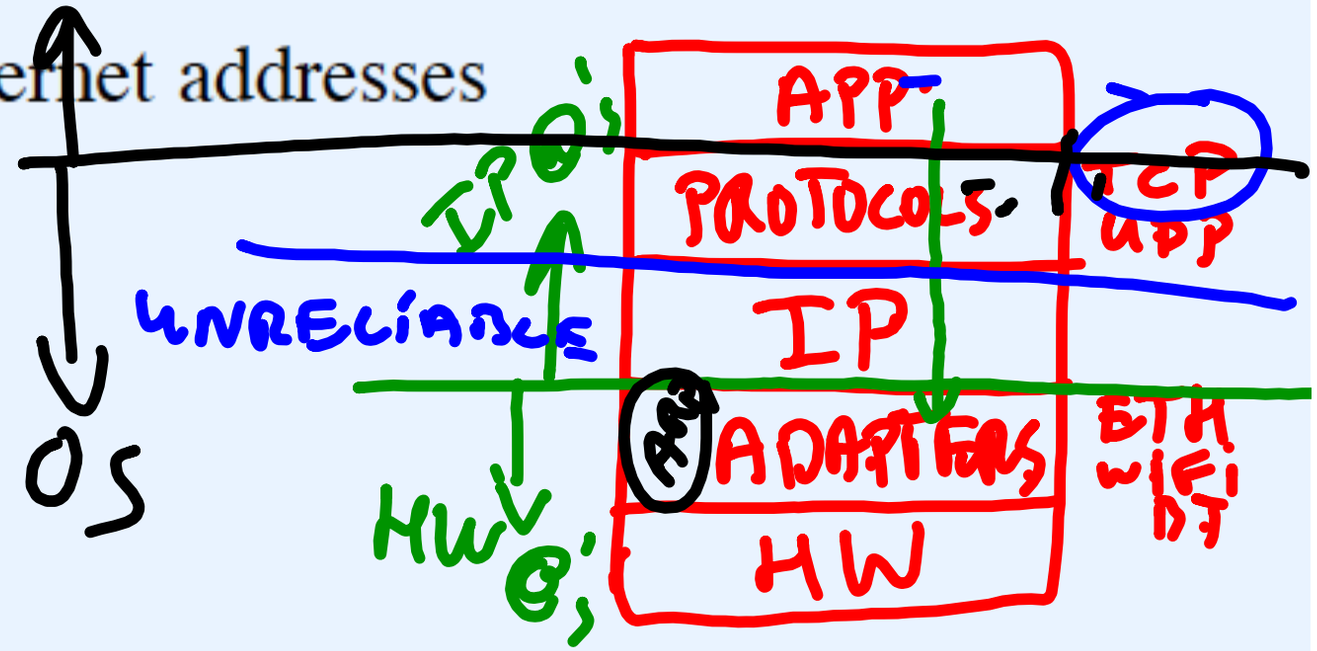
PART V

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

ARP CACHE

20 min TIMER

IP_B | HW_B

IP_A

A

HW_A

C

IP_C

HW_C

IP_B | HW_D

IP_D

B

HW_B

IP_A | HW_A

BROADCAST

Hi, I AM

IP_A / HW_A

LOOKING FOR

IP_B

ARP REQ

D

IP_D

HW_D

ARP REPLY

UNICAST

Hi, I AM

IP_B / HW_B

I AM TALKING WITH

IP_A / HW_A

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

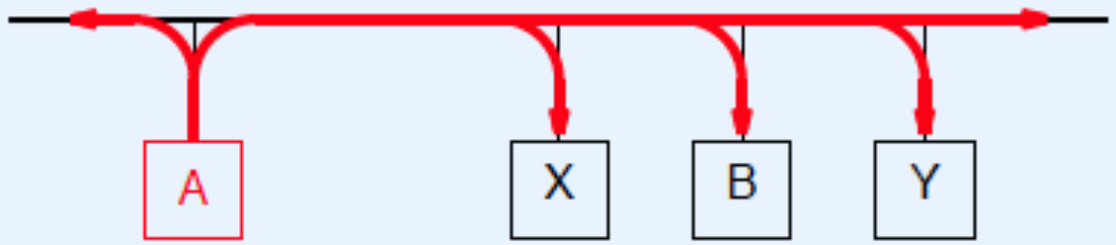
- Needed when hardware addresses are large (e.g., Ethernet)
- Allows computer A to find computer B's hardware address
  - A starts with B's IP address
  - A knows B is on the local network
- Technique: broadcast query and obtain response
- Note: dynamic binding only used across one network at a time

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

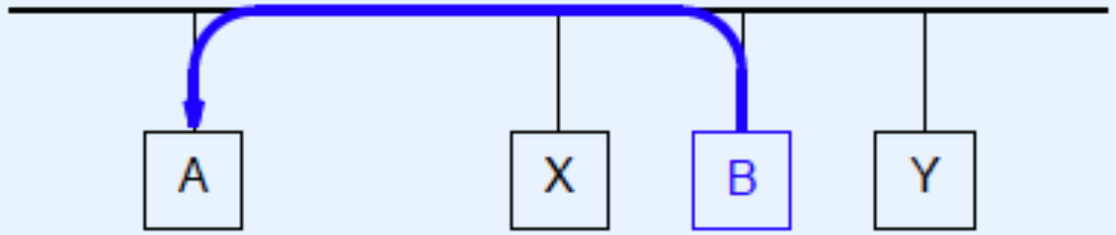
ARP

- 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

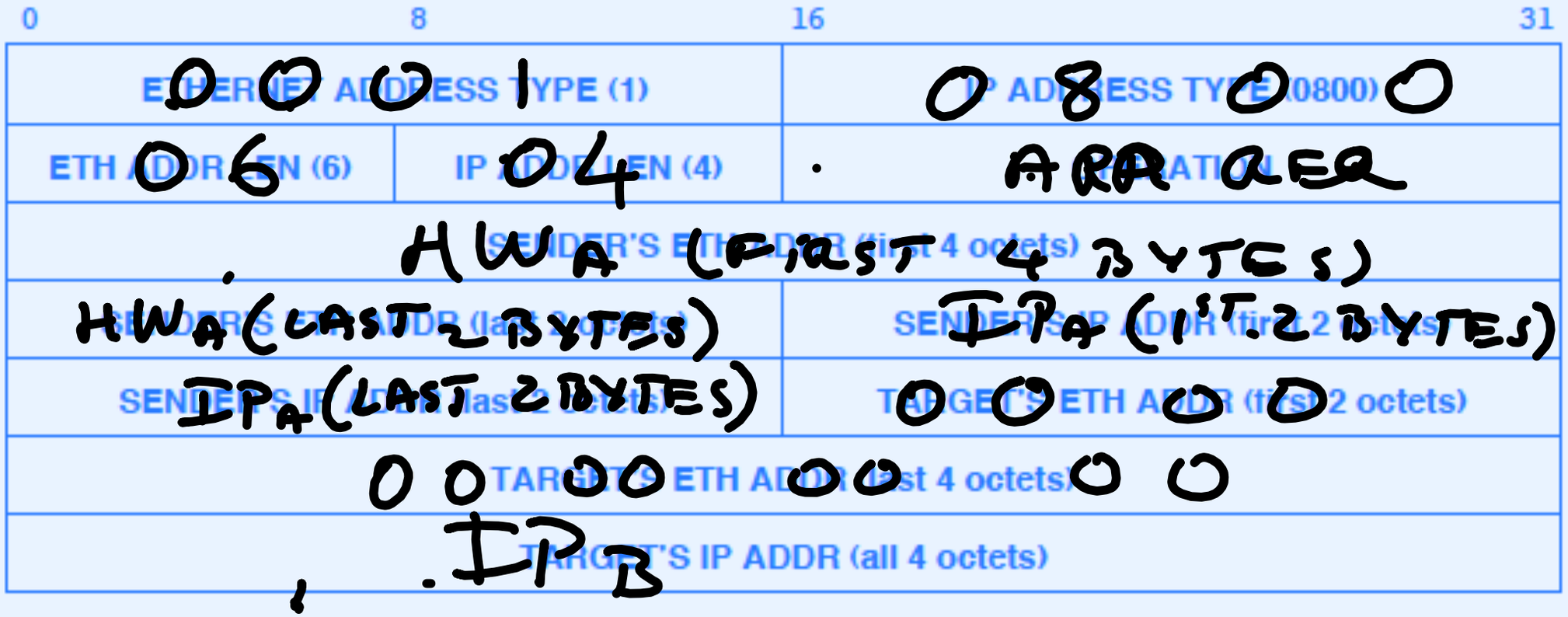


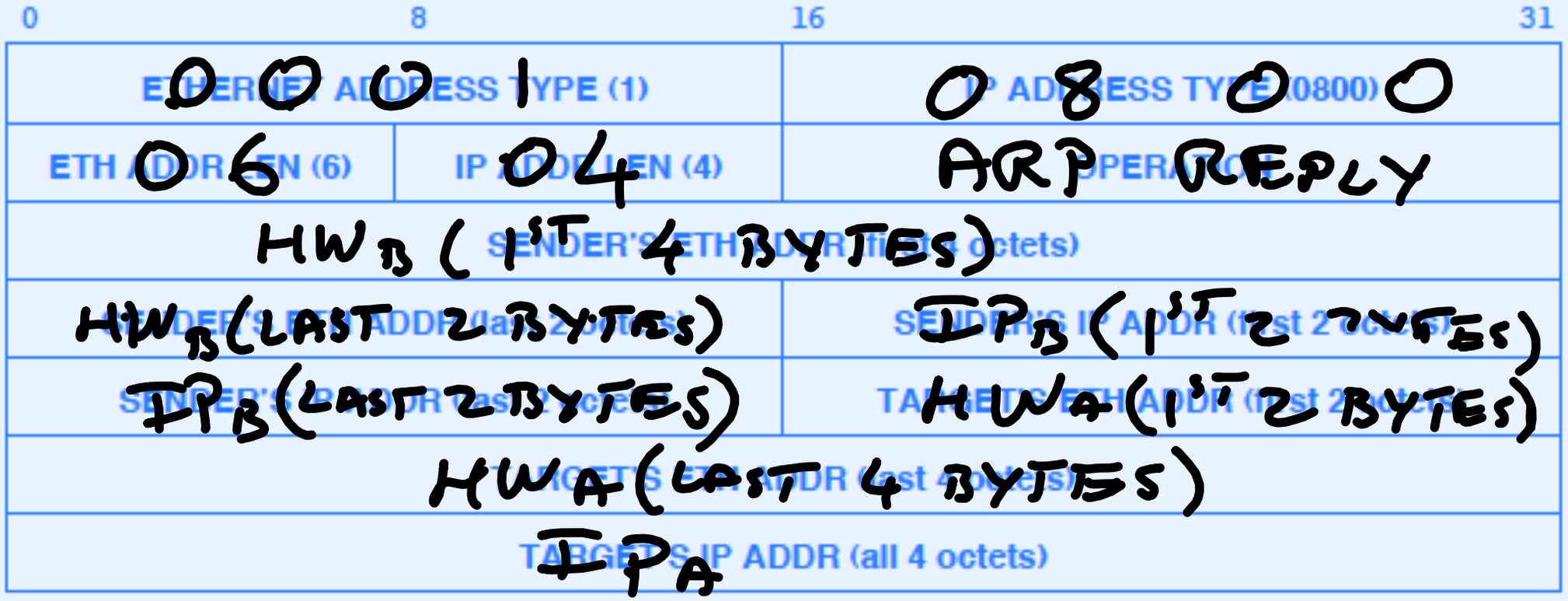
A broadcasts request for B

(across local net only)



B replies to request


0
8
16
31
ETHERNET ADDRESS TYPE (1)
IP ADDRESS TYPE (0800)
ETH ADDR LEN (6)
IP ADDR LEN (4)
OPERATION
SENDER'S ETH ADDR (first 4 octets)
SENDER'S IP ADDR (first 2 octets)
SENDER'S IP ADDR (last 2 octets)
TARGET'S ETH ADDR (first 2 octets)
TARGET'S ETH ADDR (last 4 octets)
TARGET'S IP ADDR (all 4 octets)
0001
0800
06
04
ARP REQ
HWA (FIRST 4 BYTES)
HWA (LAST 2 BYTES)
IPA (1ST 2 BYTES)
IPA (LAST 2 BYTES)
0000
0000
IPB


0
8
16
31
ETHERNET ADDRESS TYPE (1)
IP ADDRESS TYPE (0800)
ETH ADDR LEN (6)
IP ADDR LEN (4)
ARP OPERATION
SENDER'S ETH ADDR (all 4 octets)
SENDER'S ETH ADDR (last 2 octets)
SENDER'S IP ADDR (first 2 octets)
SENDER'S IP ADDR (last 2 octets)
TARGET'S ETH ADDR (first 2 octets)
TARGET'S ETH ADDR (last 4 octets)
TARGET'S IP ADDR (all 4 octets)
0 0 0 1
0 8 0 0
0 6
0 4
ARP REPLY
HW_B (1ST 4 BYTES)
HW_B (LAST 2 BYTES)
IP_B (1ST 2 BYTES)
IP_B (LAST 2 BYTES)
HW_A (1ST 2 BYTES)
HW_A (LAST 4 BYTES)
IP_A

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, (I_A, E_A) 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

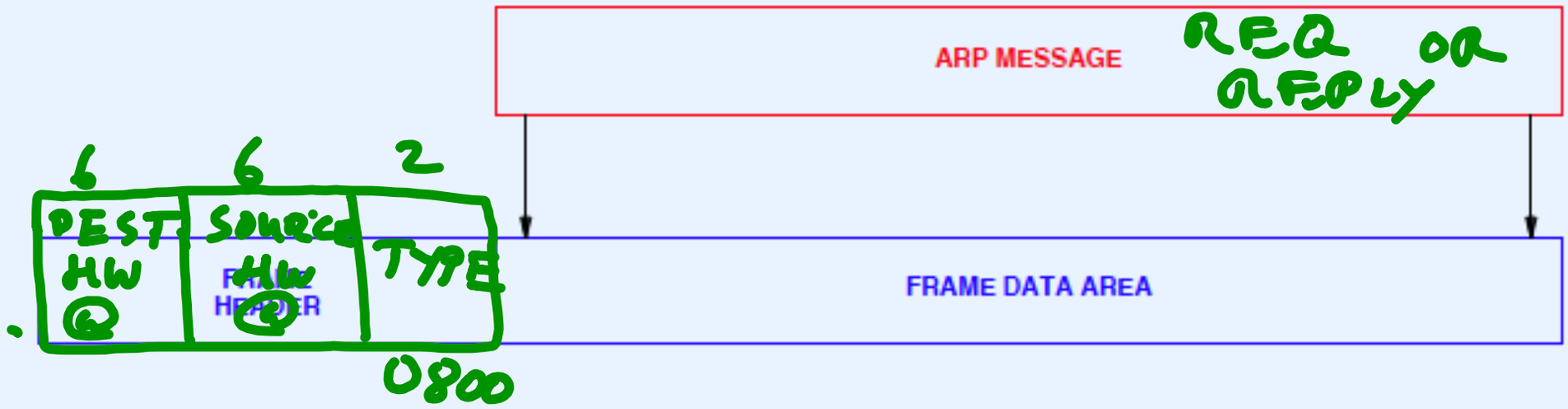
Conceptual Purpose Of ARP

- 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



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