Chapter 7

ARP and RARP

Outline

- ARP
- ARP Package
- RARP

Logical Addresses

- The hosts and routers are recognized at the network level by their *logical addresses*
  - A **logical address** is an internet address
  - Called a *logical* address because it is usually implemented in software
  - The logical addresses in the TCP/IP are called **IP address** and are 32 bits long

Physical Address

- However, hosts/routers are recognized at the physical layer by their *physical address*
  - A **physical address** is an local address
  - Called a *physical* address because it is usually implemented in hardware
  - Examples
    - 48-bit MAC addresses in Ethernet

Translation

- We need both the physical address and the logical address for packet delivery
- Thus, we need to be able to map a logical address to its corresponding physical address and vice versa
- Solutions
  - ***Static mapping***
  - ***Dynamic mapping***

Static Mapping

- Create a table that associates a logical address with a physical address and store in each machine
- However, physical addresses may change
  - A machine could change its NIC resulting in a new physical address
  - In some LANs, such as LocalTalk, the physical address changes every time the computer is turned on
  - A mobile station can move from one physical network to another, resulting in a change in its physical address

Dynamic Mapping

- Use a protocol to find another address
- ARP: Address Resolution Protocol
  - Map a logical address to a physical address
- RARP: Reverse Address Resolution Protocol
  - Map a physical address to a logical address

Figure 7.1

ARP and RARP

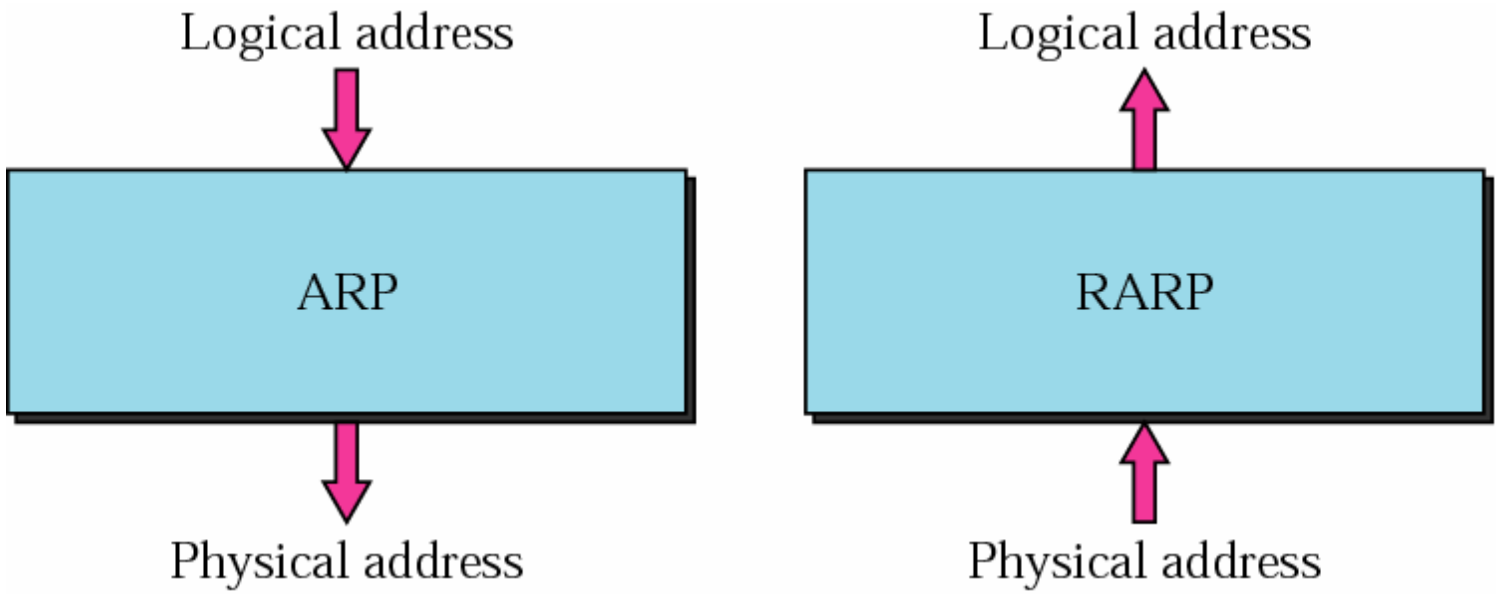
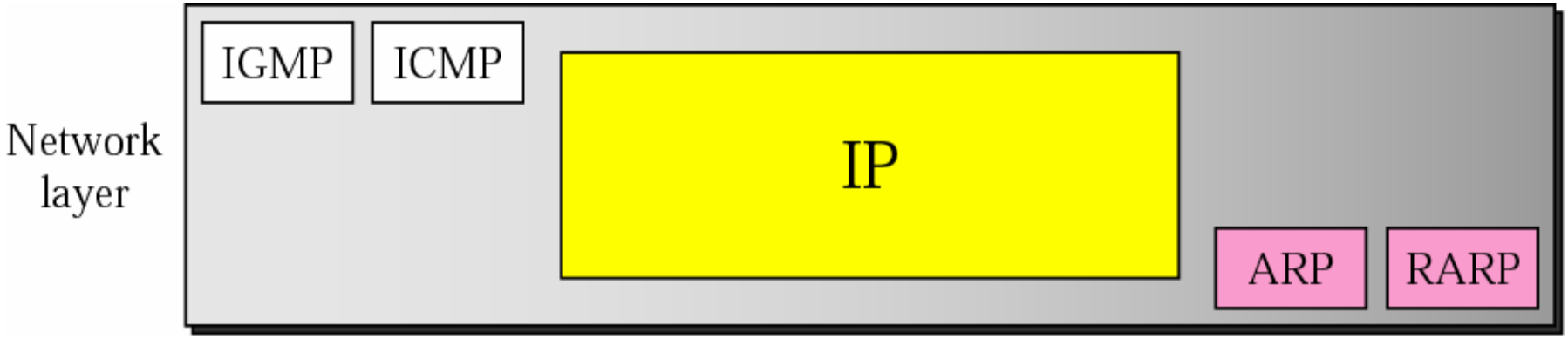


Figure 7.2

Position of ARP and RARP in TCP/IP Protocol Suite



7.1

ARP

ARP Operation

- To find the physical address of another host or router on its network
  - Send an ARP request message
- ARP request message
  - The physical address of the sender
  - The IP address of the sender
  - The physical address of the receiver is ***0s***
  - The IP address of the receiver

ARP Operation (Cont.)

- Then, ARP request message is broadcast by the physical layer
  - For example: in Ethernet, MAC header's destination address is all *1s* (broadcast address)
  - Received by every station on the physical network
- The intended recipient send back an ARP reply message
  - ARP reply message packet is ***unicast***

Figure 7.2

ARP Operation

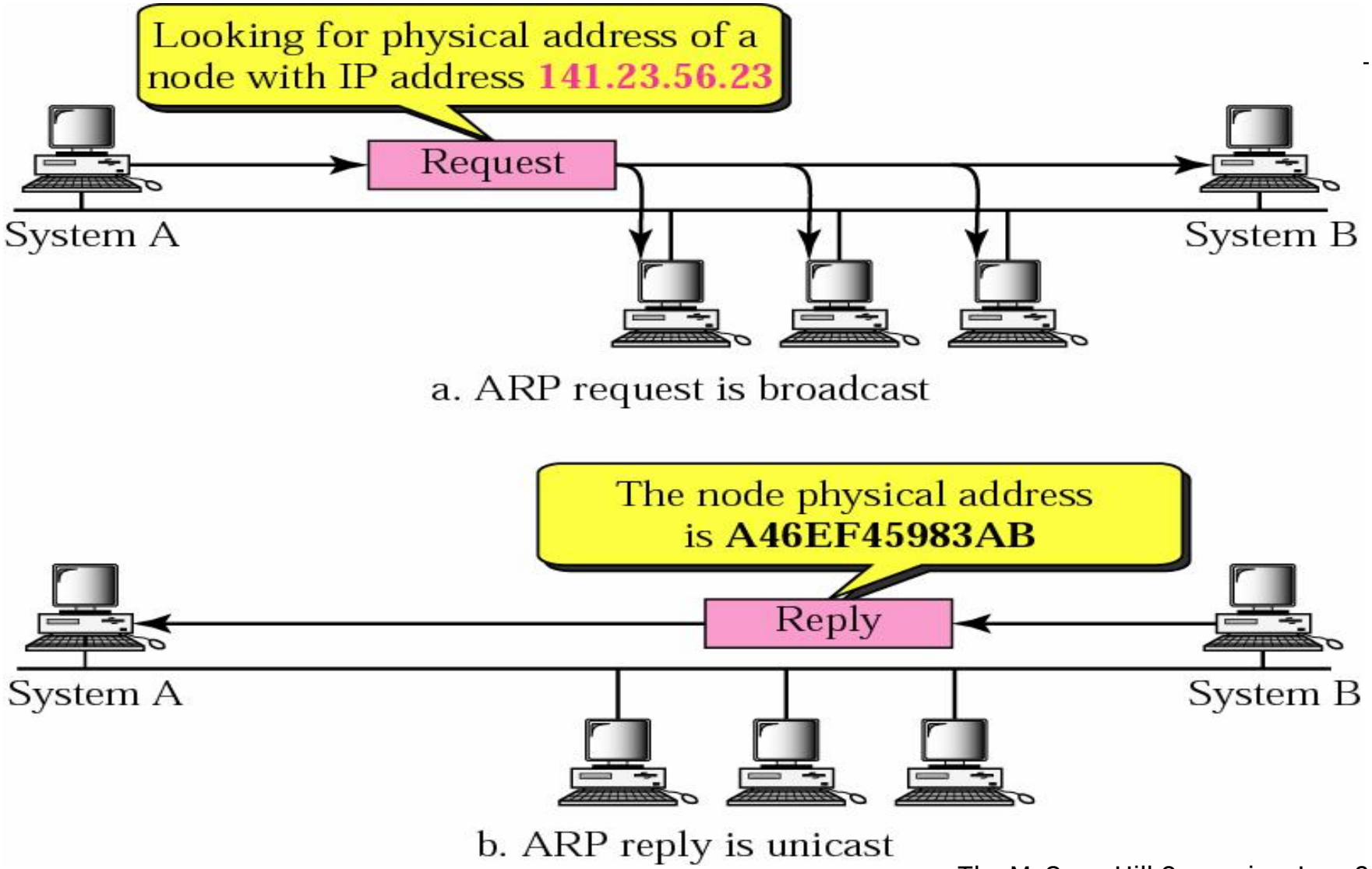
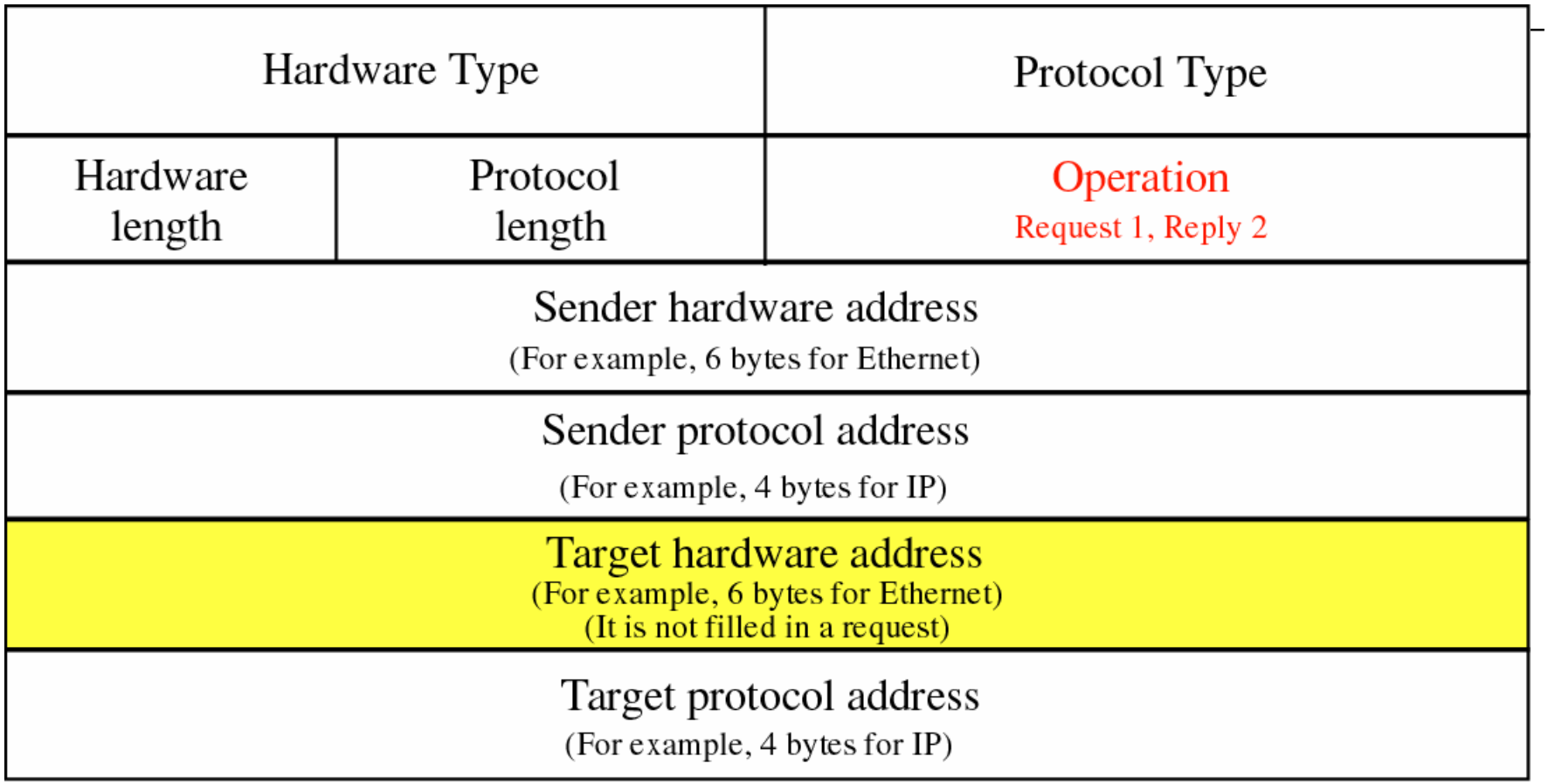


Figure 7.4

ARP Packet



Packet Format

- HTYPE (Hardware type)
  - 16-bit field defining the underlying type of the network
    - Ethernet is given the type 1
    - ARP can be used on any physical network
- PTYPE (Protocol type)
  - 16-bit field defining the protocol
    - IPv4 is 0800_{16}
    - ARP can be used with any higher-level protocol

Packet Format (Cont.)

- HLEN (Hardware length)
  - 8-bit field defining the length of the physical address in bytes
    - Ethernet has the value of 6
- PLEN (Protocol length)
  - 8-bit field defining the length of the logical address in bytes
    - IPv4 has the value of 4
- OPER (Operation)
  - 16-bit field defining the type of packet
  - (1) = ARP request, (2) = ARP reply

Packet Format (Cont.)

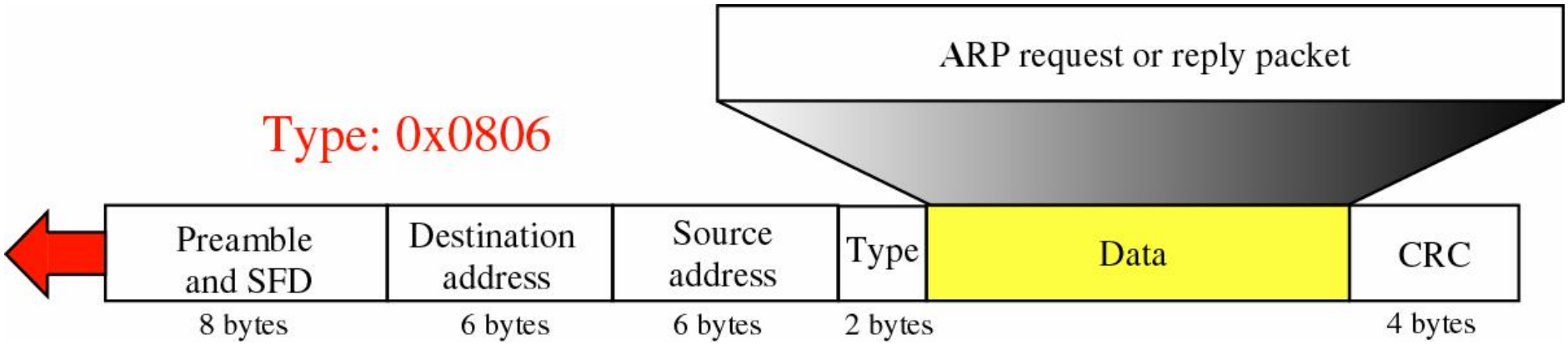
- SHA (Sender hardware address)
  - A variable-length field defining the physical address of the sender
- SPA (Sender protocol address)
  - A variable-length field defining the logical address of the sender

Packet Format (Cont.)

- THA (Target hardware address)
  - A variable-length field defining the physical address of the target
  - For an ARP request operation packet
    - This field is all 0s
- TPA (Target protocol address)
  - A variable-length field defining the logical address of the target

Figure 7.5

Encapsulation of ARP Packet



- An ARP packet is encapsulated directly into a data link frame
- Type field indicates that the data carried by the frame is an ARP packet

Operations

- The sender knows the target's IP address
- IP asks ARP to create an ARP request message
  - The sender physical address
  - The sender IP address
  - The target physical address field is filled with 0s
  - The target IP address
- The message is passed to the data link layer to encapsulate in a data link frame
  - Physical destination address is broadcast address

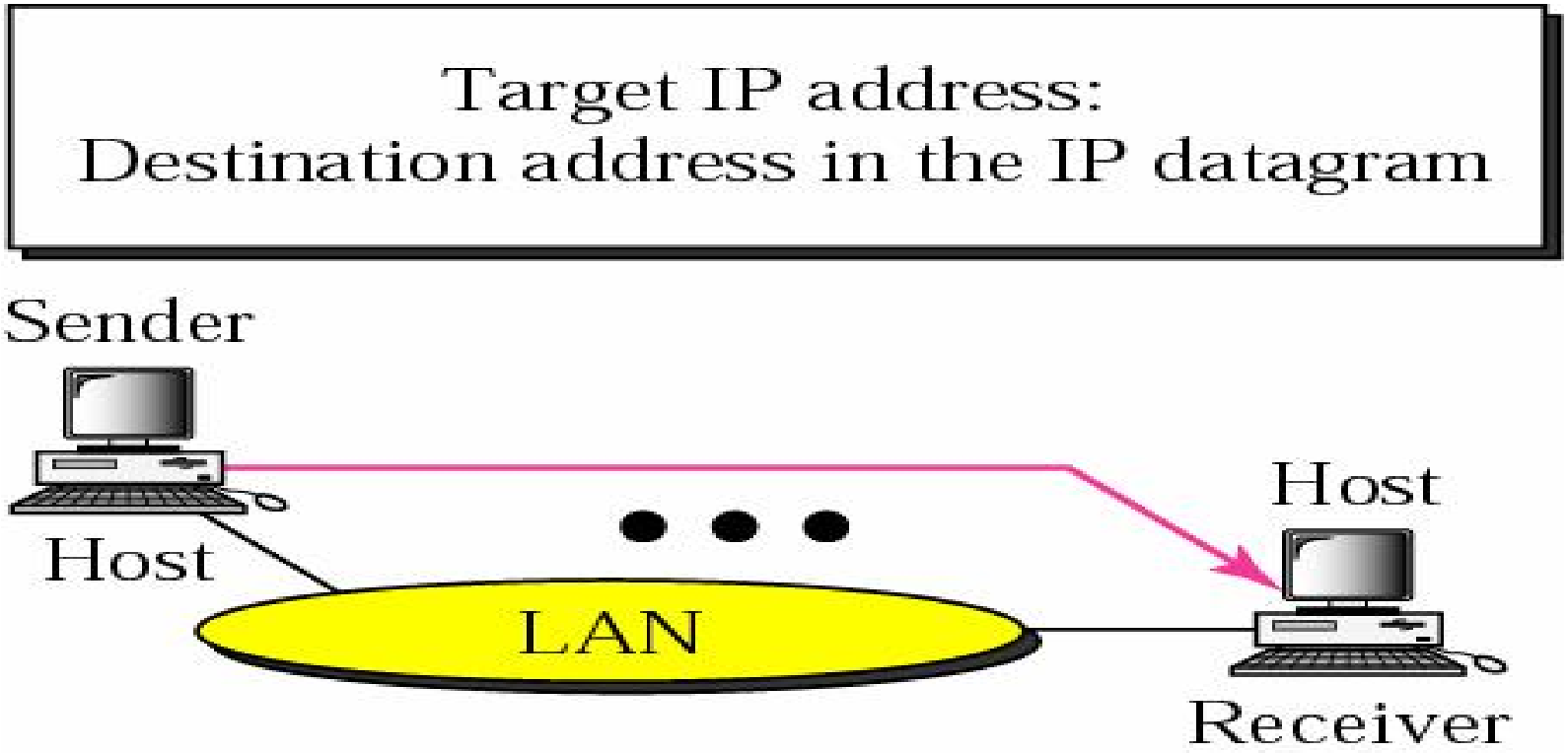
Operations (Cont.)

- Every host or routers receives the frame and since the destination address is broadcast, pass it to the ARP
  - All machines' ARP except the one targeted drop the packet
- The target reply with an ARP reply message that contains its physical address and is unicast
- The sender receives the reply message and knows the target's physical address

Four Cases to Use ARP

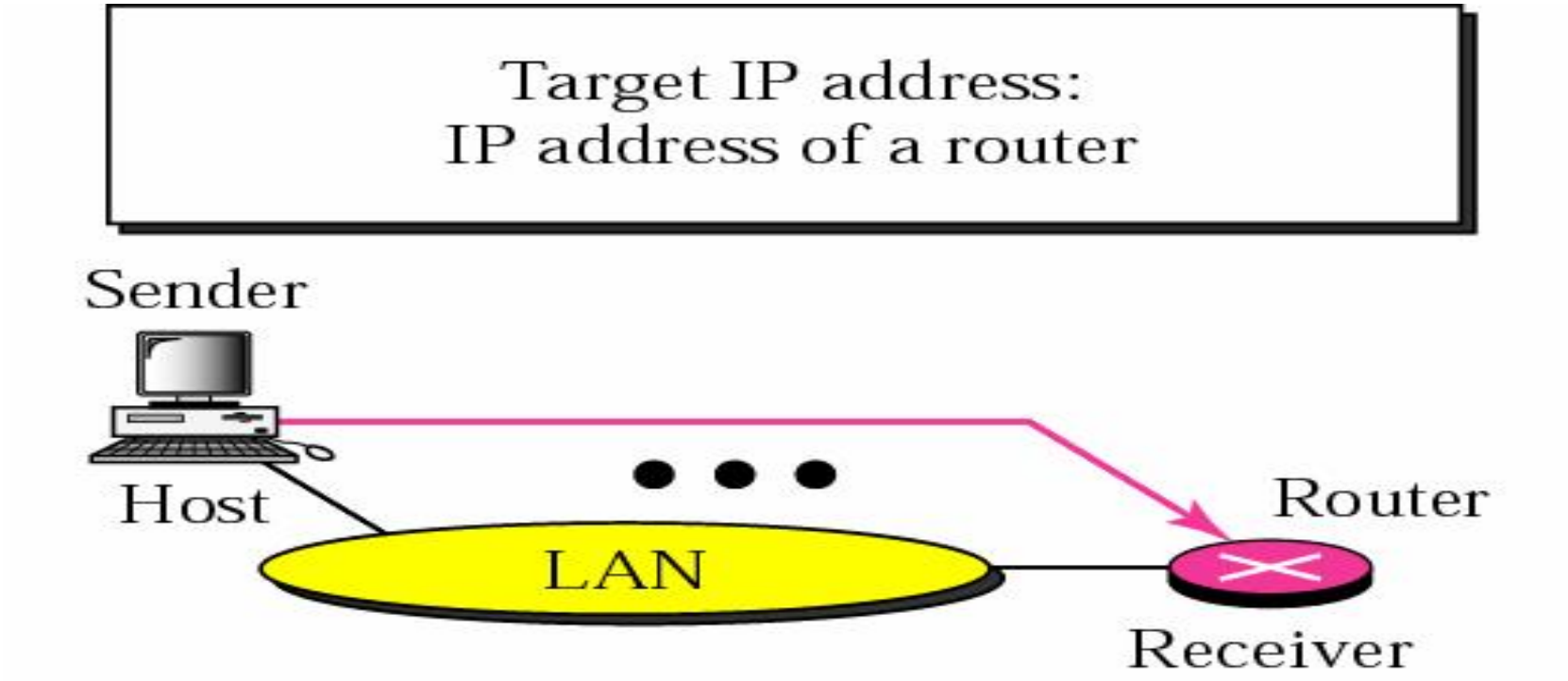
- ***Case 1:*** The sender is a host and wants to send a packet to another host on the same network
  - Use ARP to find another host's physical address
- ***Case 2:*** The sender is a host and wants to send a packet to another host on another network
  - Sender looks at its routing table
  - Find the IP address of the next hop (router) for this destination
  - Use ARP to find the router's physical address

Four Cases Using ARP: Case 1



Case 1. A host has a packet to send to another host on the same network.

Four Cases Using ARP: Case 2

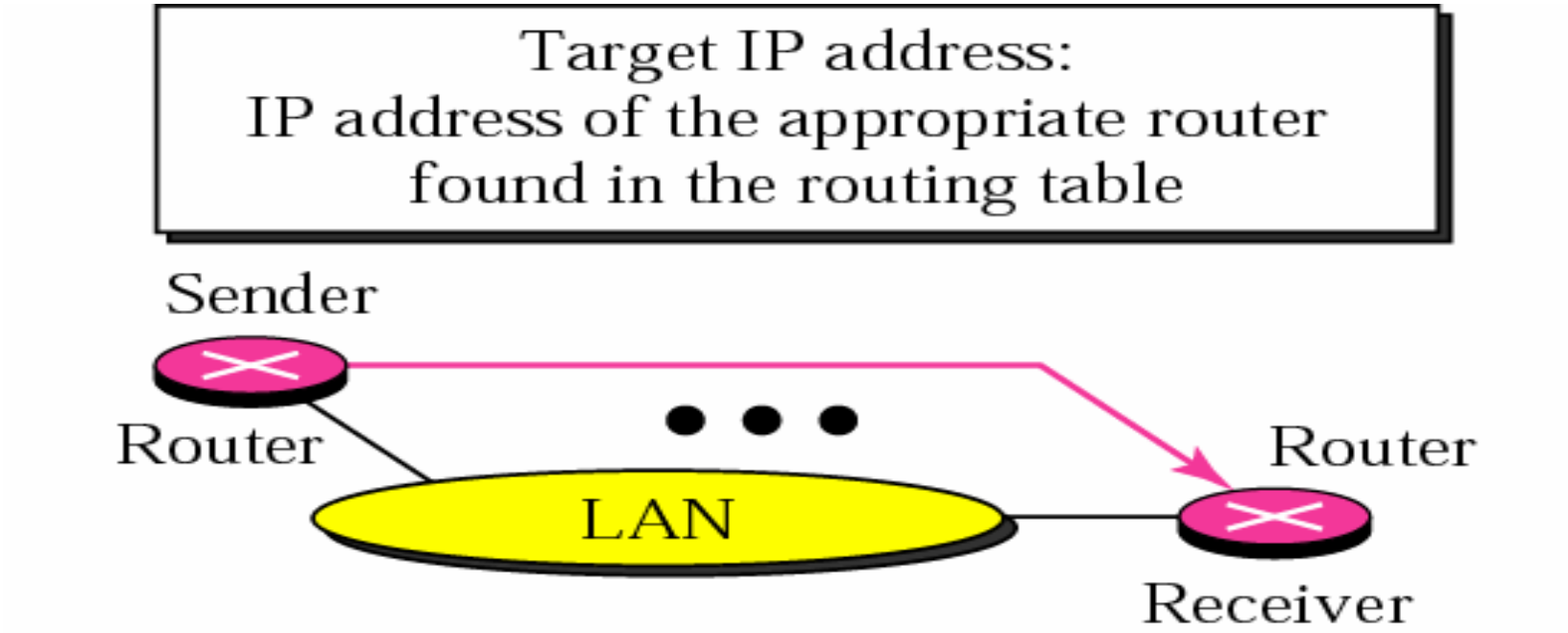


Case 2. A host wants to send a packet to another host on another network. It must first be delivered to a router.

Four Cases to Use ARP (Cont.)

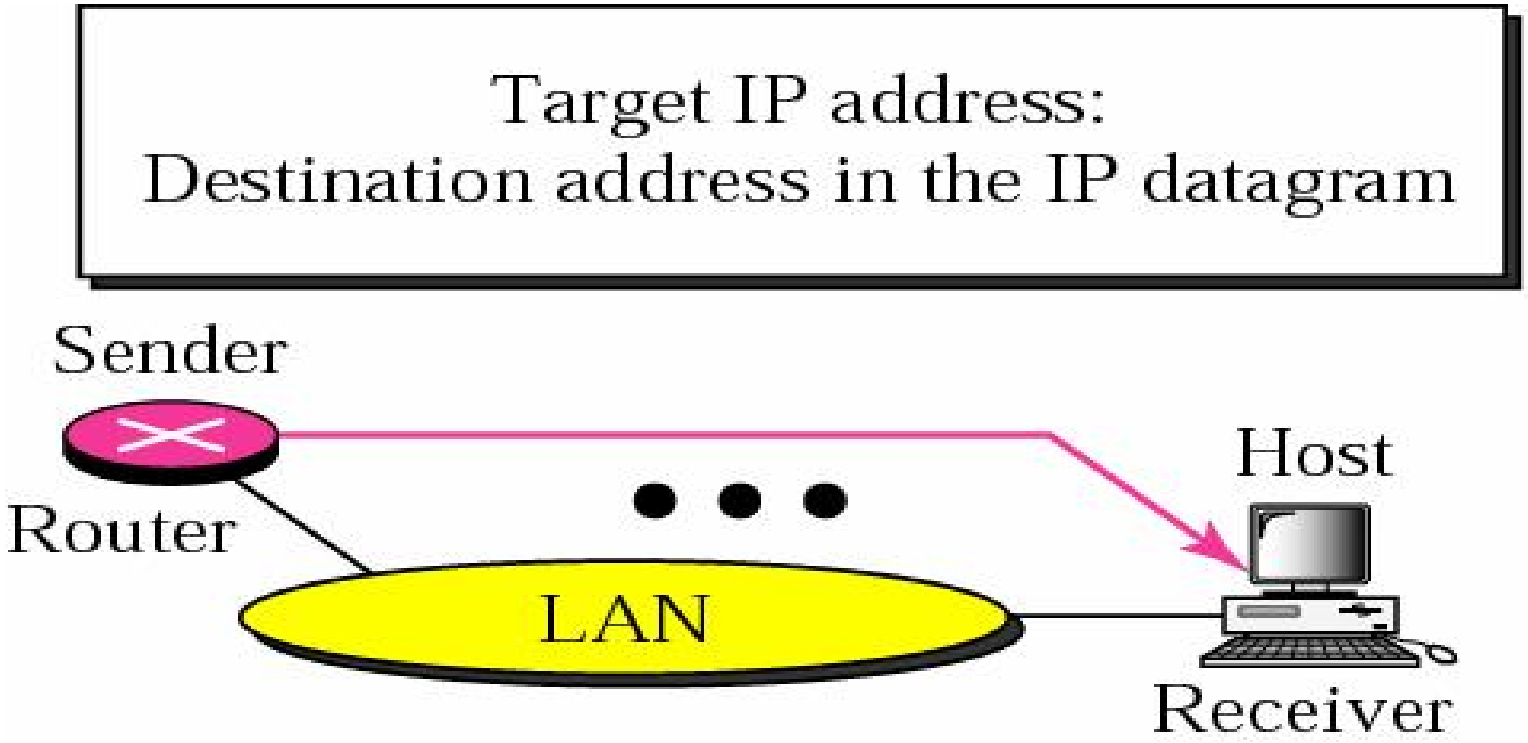
- ***Case 3:*** the sender is a router and received a datagram destined for a host on another network
  - Router check its routing table
  - Find the IP address of the next router
  - Use ARP to find the next router's physical address
- ***Case 4:*** the sender is a router that has received a datagram destined for a host in the same network
  - Use ARP to find this host's physical address

Four Cases Using ARP: Case 3



Case 3. A router receives a packet to be sent to a host on another network. It must first be delivered to the appropriate router.

Four Cases Using ARP: Case 4



Case 4. A router receives a packet to be sent to a host on the same network.

Note

An ARP request is broadcast;

an ARP reply is unicast.

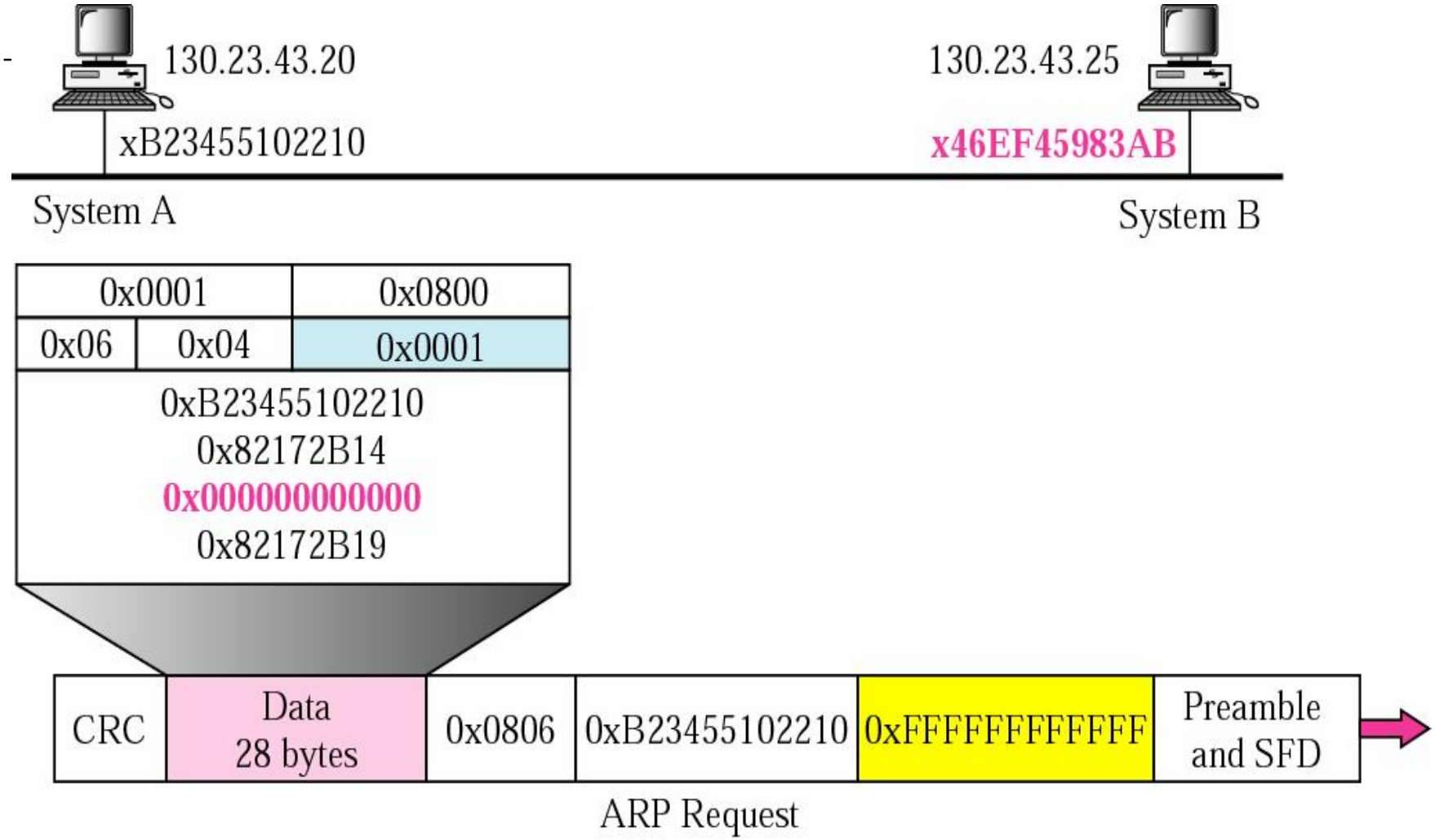
Example 1

- A host with IP address 130.23.43.20 and physical address 0xB23455102210
- Another host with IP address 130.23.43.25 and physical address 0xA46EF45983AB.
- The two hosts are on the same Ethernet network
- Show the ARP request and reply packets encapsulated in Ethernet frames

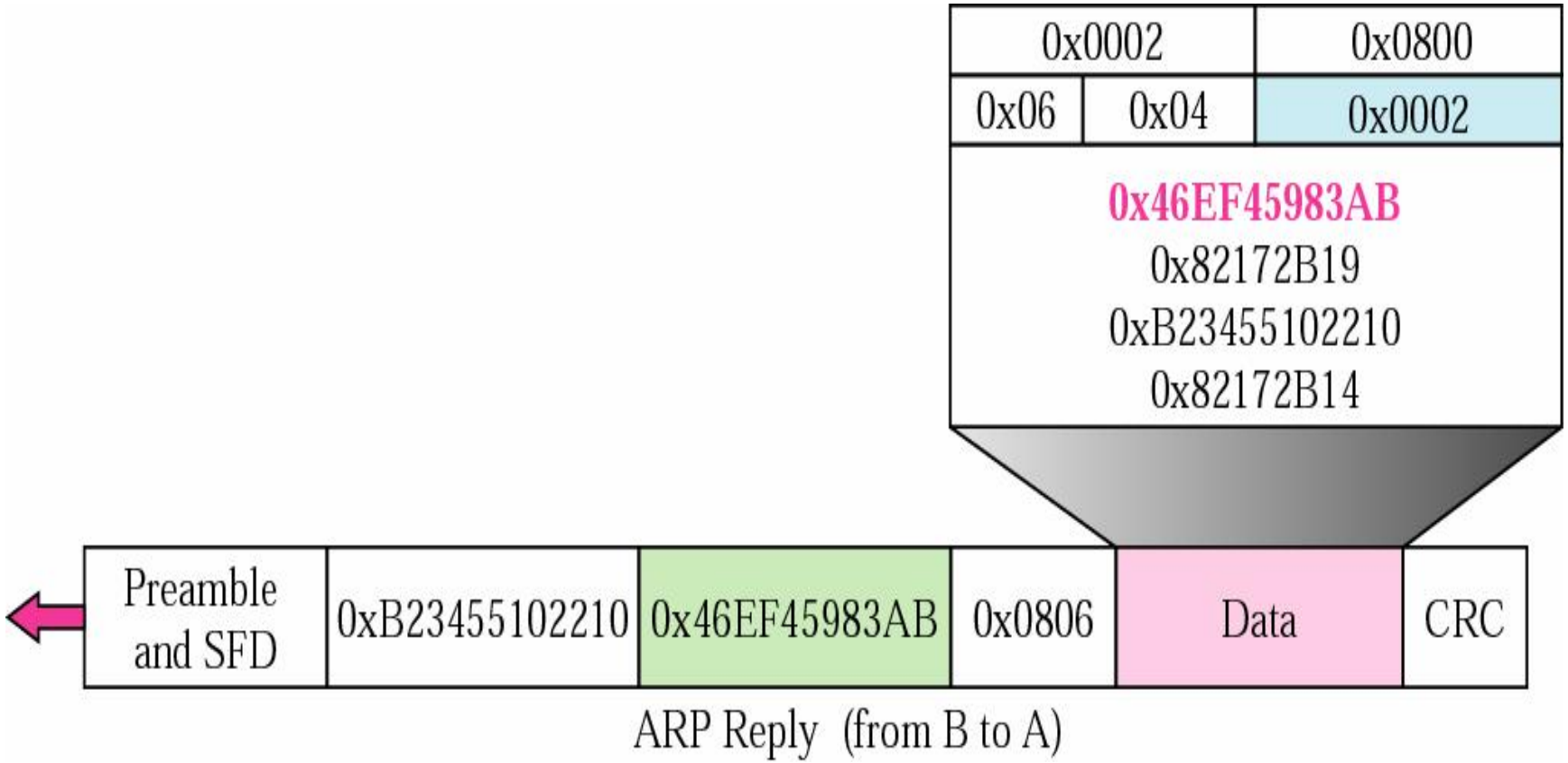
Solution

- Figure 7.7 shows the ARP request and reply packets
- Note that
  - The IP addresses are shown in hexadecimal

Example 1



Example 1 (Continued)



Proxy ARP

- Used to create a subnetting effect
- A router running a proxy ARP
  - Its ARP acts on behalf of a set of hosts
  - If it receives an ARP request message looking for the address of one of these host
    - The router sends an ARP reply announcing its own hardware (physical) address
  - After the router receives the actual IP packet
    - It sends the packet to the appropriate host or router

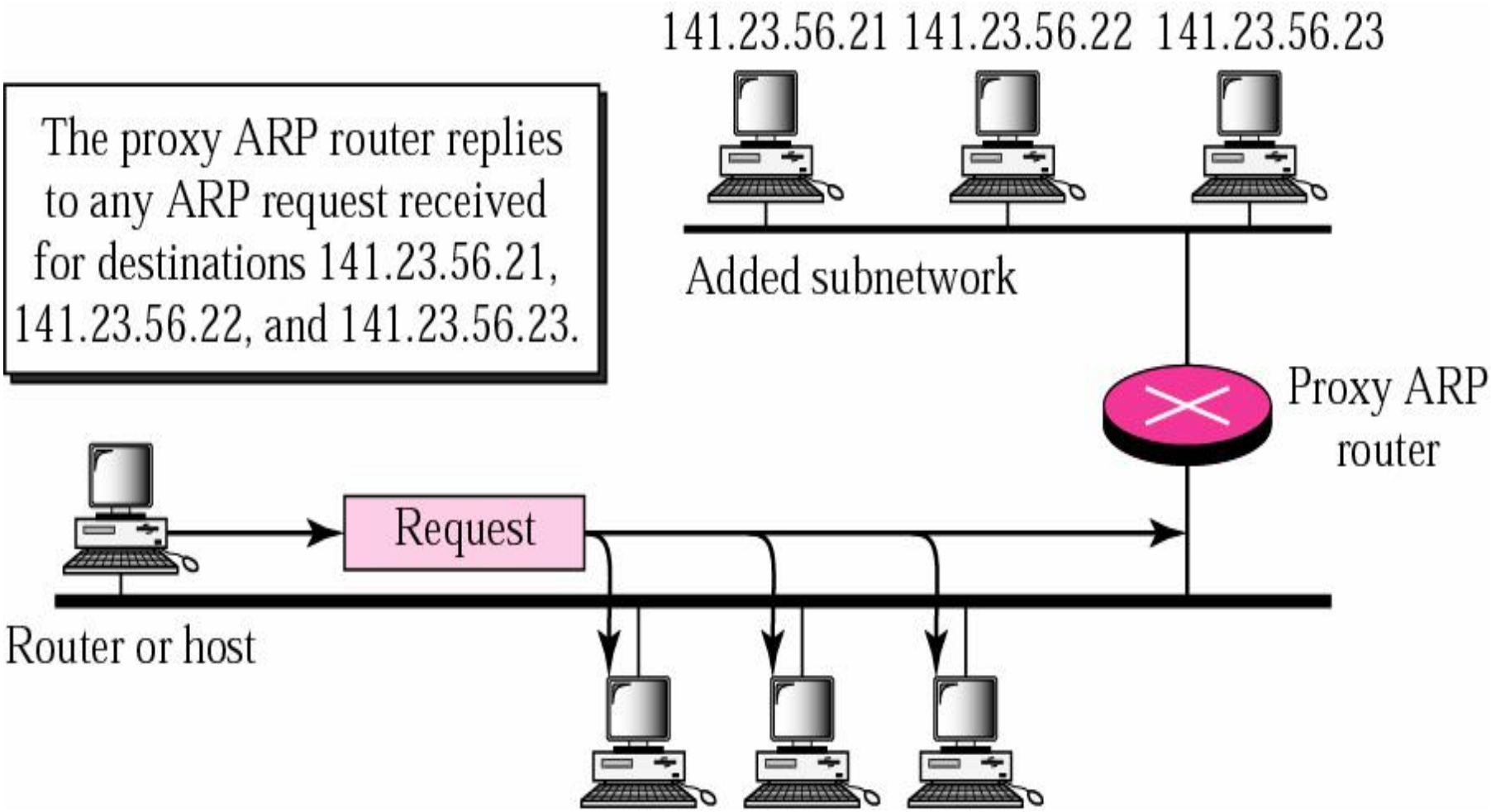
Example

- Administrator need to create a subnet without changing the whole system

- Add a router running a proxy ARP

Figure 7-8

Proxy ARP



7.2

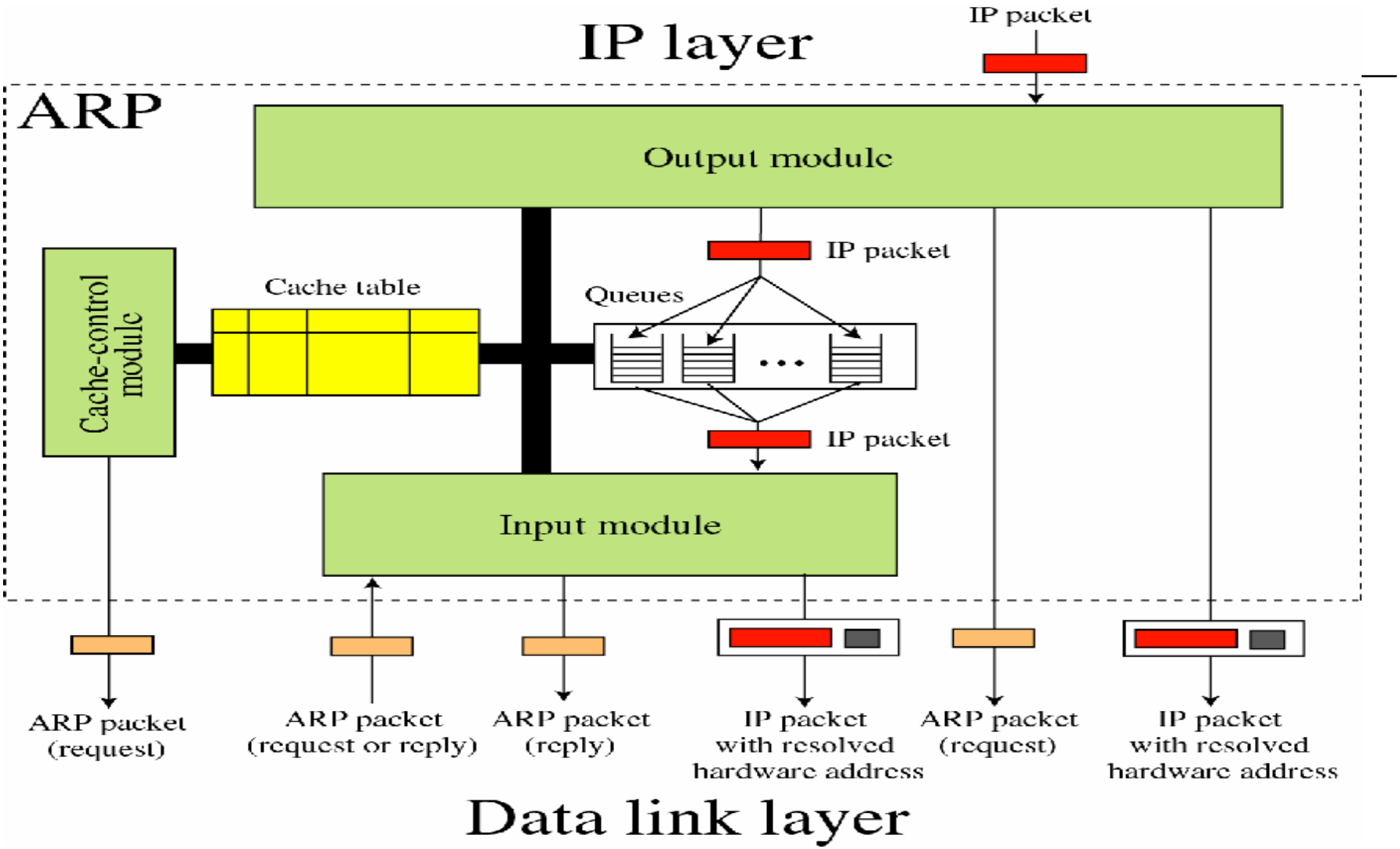
ARP PACKAGE

ARP Package

- Five components in an ARP package
  - A cache table
  - Queues
  - An output module
  - An input module
  - A cache-control module

Figure 7.9

ARP Components



Cache Table

- Inefficient to use ARP to each datagram destined for the same host or router
  - Introduce the cache table

- Cache table: an array of entries that contains the following's entries

Content of a Cache Table Entry

- State:
  - FREE: the lime-to-live for this entry has expired
  - PENDING: a request for this entry has been sent, but the reply has not yet been received
  - RESOLVED: the entry is complete and valid
- Hardware type
- Protocol type
- Hardware length
- Protocol length
  - Above fields are all the same as in the ARP packet

Content of a Cache Table Entry (Cont.)

- Interface number
- Queue number: ARP uses numbered queues to enqueue the packet waiting for address resolution
- Attempts: the number of times an ARP request is sent out for this entry
- Time-out: the lifetime of an entry in seconds
- Hardware address: the destination hardware address
- Protocol address: the destination IP address

Queues

- ARP package maintains a set of queues to hold the IP packets while ARP tries to resolve the hardware address
- Packets for the same destination are usually enqueued in the same queue
- The output module sends unsolved packets into the queue
- The input module removes a packet from the queue and sends it, with the resolved physical address, to data link layer for transmission

Output Module

- Wait until an IP packet from the IP software
- Check the cache table if receiving a IP packet
  - If found and state = RESOLVED
    - Passed to the data link layer for transmission
  - If found and state = PENDING
    - Send packet to this queue and wait
  - If not found
    - Create an entry with state = PENDING
    - Create a queue and enqueue this packet
    - Send an ARP request

Input Module

- Wait until an ARP packet (request or reply) arrives and check the cache table
  - If found state = PENDING
    - Copy the target hardware address in the packet
    - Change the state to RESOLVED
    - Set the value of TIME-OUT for this entry
    - Dequeue the packets from the corresponding queue and set them to the data link layer

Input Module (Cont.)

- If found and state = RESOLVED
  - Copy the target hardware address in the packet
  - Set the value of TIME-OUT for this entry
  - This is because the target hardware address could have been changed
- If not found
  - Create a new entry and adds it to the table

- If the packet is a request
  - Send an ARP reply

Cache-Control Module

- Maintain the cache table by periodically check the cache table, entry by entry
- If state is PENDING
  - Increment the value of attempts by 1
  - If (attempts greater than maximum)
    - Change the state to FREE and Destroy the corresponding queue
  - Else
    - Send an ARP request

Cache-Control Module (Cont.)

- If state is RESOLVED
  - Decrement the value of time-out by the value of elapsed time
  - If (time-out <= 0)
    - Change the state to FREE
    - Destroy the corresponding queue
- If state is FREE
  - Continue to the next entry

Original Cache Table

State	Queue	Attempt	Time-out	Protocol Addr.	Hardware Addr.
R	5		900	180.3.6.1	ACAE32457342
P	2	2		129.34.4.8	
P	14	5		201.11.56.7	
R	8		450	114.5.7.89	457342ACAE32
P	12	1		220.55.5.7	
F					
R	9		60	19.1.7.82	4573E3242ACA
P	18	3		188.11.8.71	

Example 2

- The ARP output module receives an IP datagram from the IP layer with the destination address 114.5.7.89
- It checks the cache table and finds that an entry exists for this destination with the RESOLVED state
- It extracts the hardware address, which is 457342ACAE32, and sends the packet and the address to the data link layer

Example 3

- Twenty seconds later, the ARP output module receives an IP datagram from the IP layer with the destination address 116.1.7.22.
- It checks the cache table and does not find this destination in the table
- The module adds an entry to the table with the state PENDING and the Attempt value 1
- It also creates a new queue for this destination and enqueues the packet
- It then sends an ARP request to the data link layer for this destination

Cache table for Example 3

State	Queue	Attempt	Time-out	Protocol Addr.	Hardware Addr.
R	5		900	180.3.6.1	ACAE32457342
P	2	2		129.34.4.8	
P	14	5		201.11.56.7	
R	8		450	114.5.7.89	457342ACAE32
P	12	1		220.55.5.7	
P	**23**	**1**		**116.1.7.22**	
R	9		60	19.1.7.82	4573E3242ACA
P	18	3		188.11.8.71	

Example 4

- Fifteen seconds later, the ARP input module receives an ARP packet with target protocol (IP) address 188.11.8.71
- The module checks the table and finds this address
- It changes the state of the entry to RESOLVED and sets the time-out value to 900
- The module then adds the target hardware address (E34573242ACA) to the entry
- Now it accesses queue 18 and sends all the packets in this queue, one by one, to the data link layer

Cache table for Example 4

State	*Queue*	*Attempt*	*Time-out*	*Protocol Addr.*	*Hardware Addr.*
R	5		900	180.3.6.1	ACAE32457342
P	2	2		129.34.4.8	
P	14	5		201.11.56.7	
R	8		450	114.5.7.89	457342ACAE32
P	12	1		220.55.5.7	
P	**23**	**1**		**116.1.7.22**	
R	9		60	19.1.7.82	4573E3242ACA
R	**18**		**900**	**188.11.8.71**	**E34573242ACA**

Example 5

- Twenty-five seconds later, the cache-control module waits up
- The time-out values for the first three resolved entries are decremented by 60
- The time-out value for the last resolved entry is decremented by 25
- The state of the next-to-the last entry is changed to FREE because the time-out is zero

Example 5 (Cont.)

- For each of the three pending entries, the value of the attempts field is incremented by one
- Then, the attempts value for one entry (the one with IP protocol address 201.11.56.7) is more than the maximum
  - the state is changed to FREE, the queue is deleted
  - An ICMP message is sent to the original destination

Cache Table for Example 5

State	*Queue*	*Attempt*	*Time-out*	*Protocol Addr.*	*Hardware Addr.*
R	5		840	180.3.6.1	ACAE32457342
P	2	3		129.34.4.8	
F					
R	8		390	114.5.7.89	457342ACAE32
P	12	2		220.55.5.7	
P	**23**	**2**		**116.1.7.22**	
F					
R	18		875	188.11.8.71	E34573242ACA

7.3

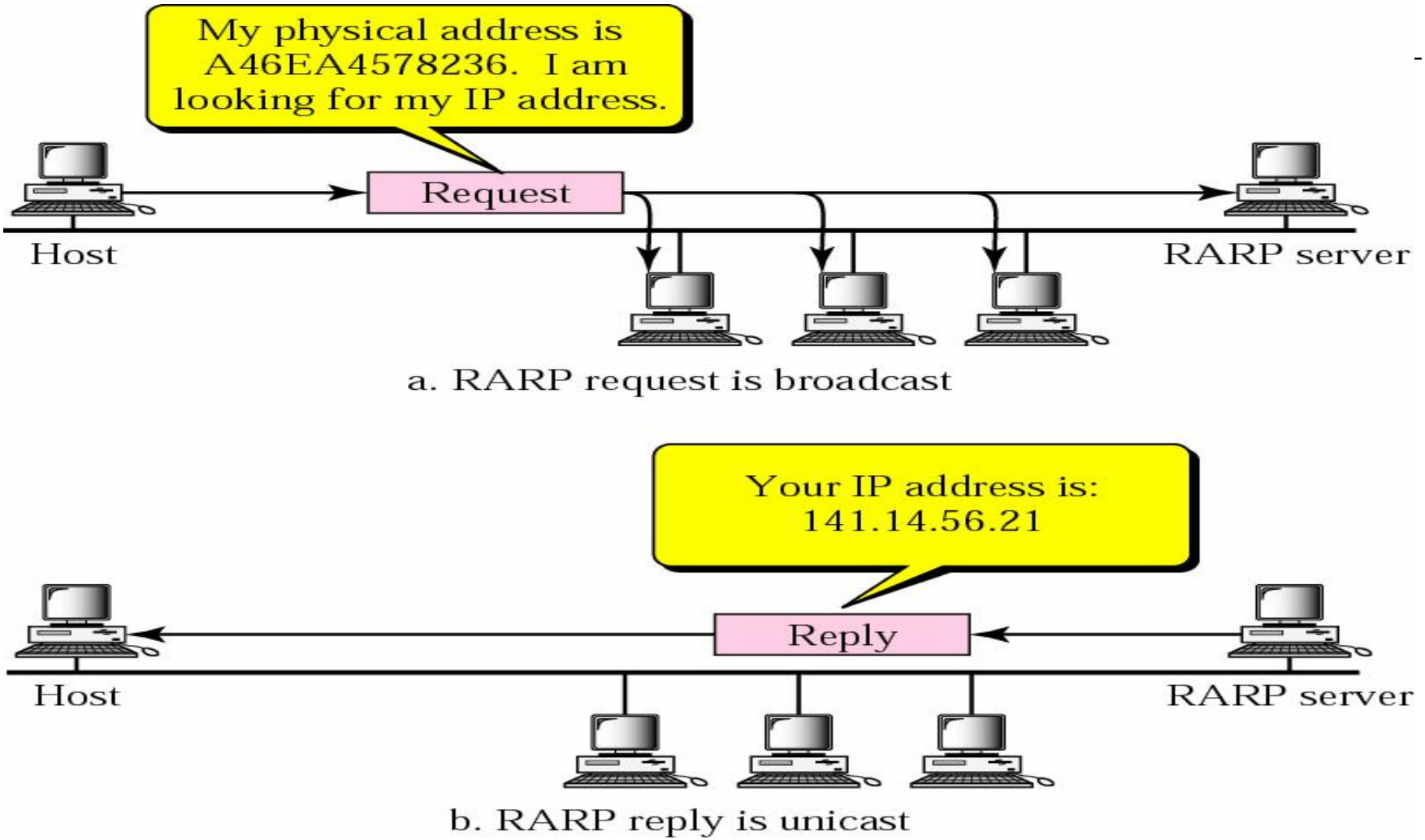
RARP

RARP

- A diskless machine is usually booted from ROM
- It cannot include the IP address
  - IP address are assigned by the network administrator
- Obtain its logical address by the physical address using the RARP protocol

Figure 7.10

RARP Operation



Note

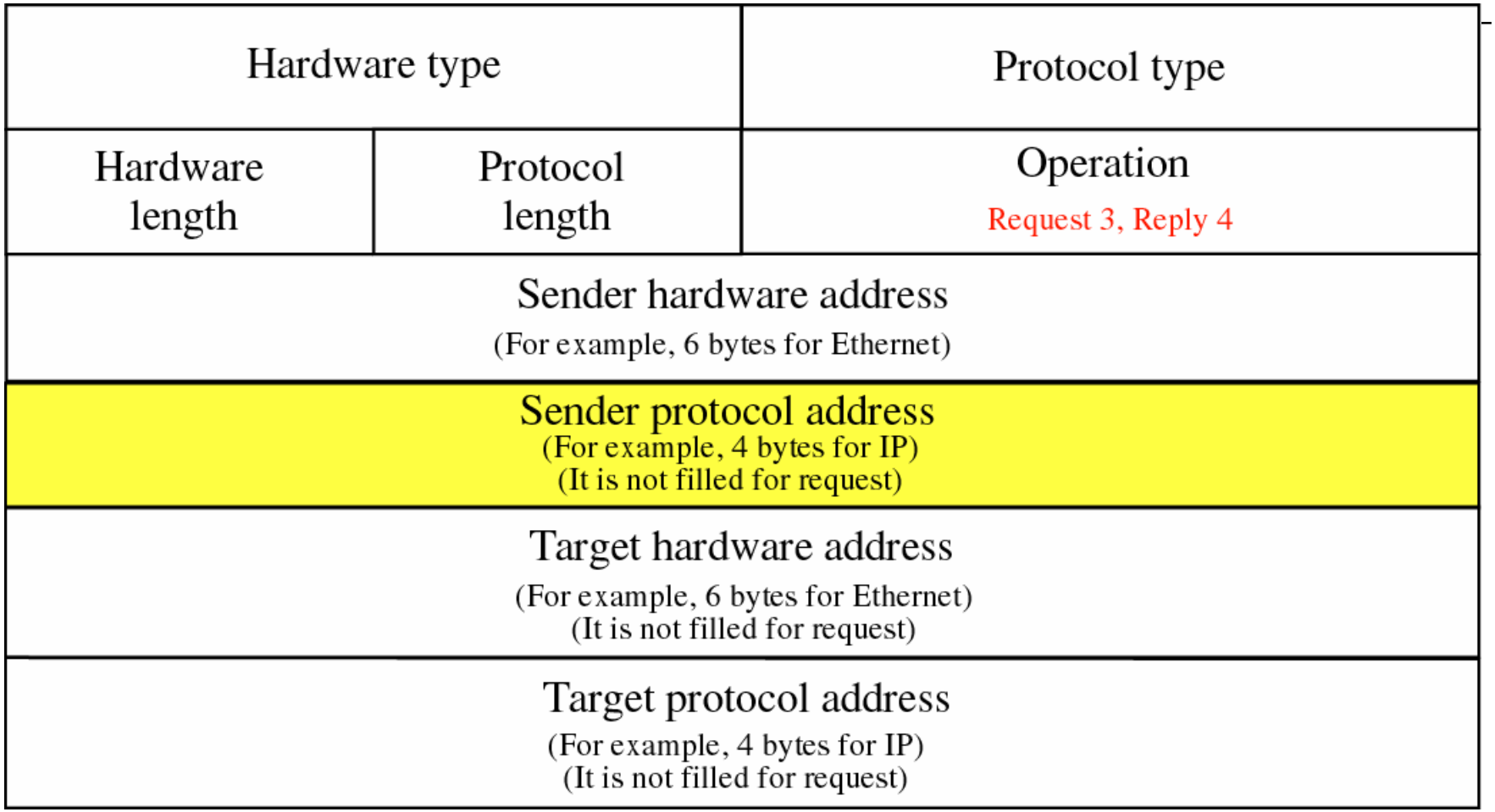
The RARP request packets are broadcast; the RARP reply packets are unicast.

Packet Format

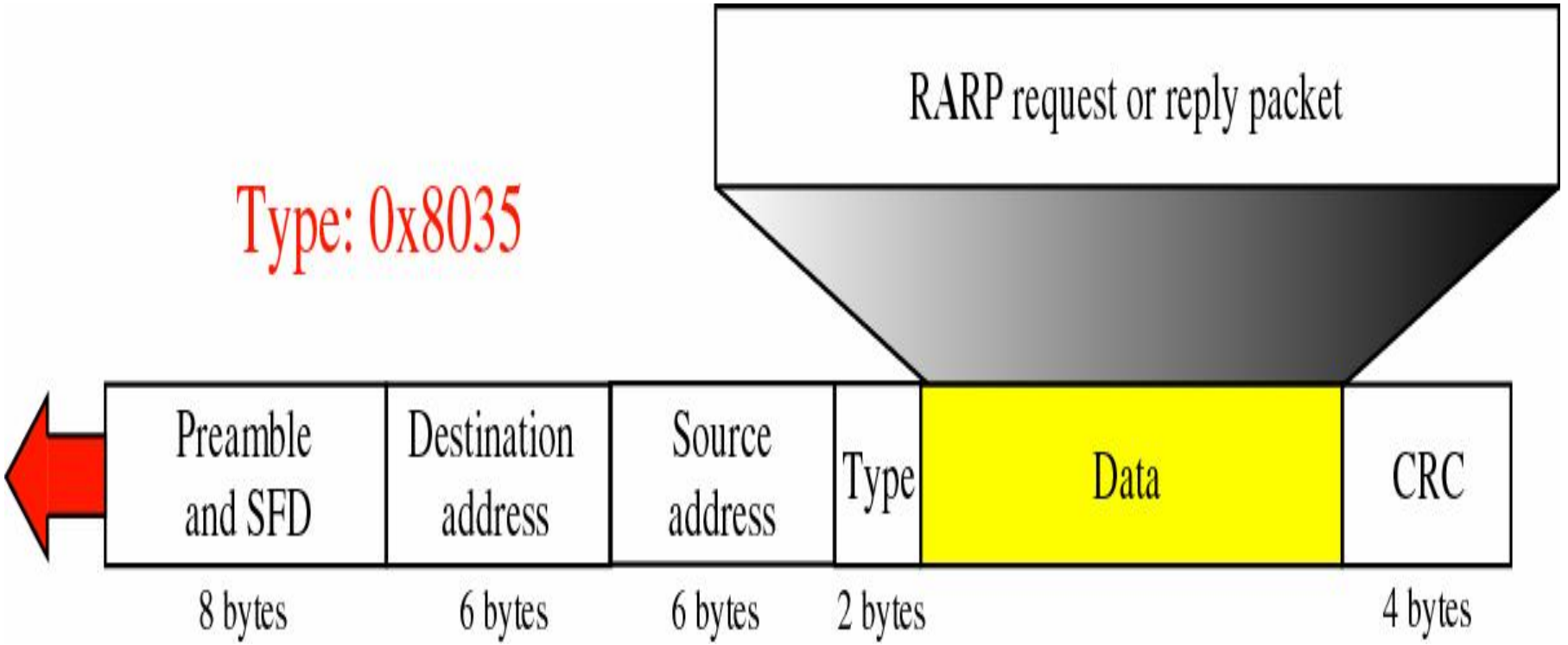
- The format of the RARP packet is the same as the ARP packet
- Except that the operation field is
  - Three for RARP request message
  - Four for RARP reply message

Figure 7.11

RARP Packet



Encapsulation of RARP Packet



Alternative Solutions to RARP

- When a diskless computer is booted, it needs more information in addition to its IP address
  - The subnet mask
  - The IP address of a router
  - The IP address of a name server
- RARP cannot provide this extra information
- Two protocols, BOOTP and DHCP, can be used instead of RARP