Binding Protocol Addresses

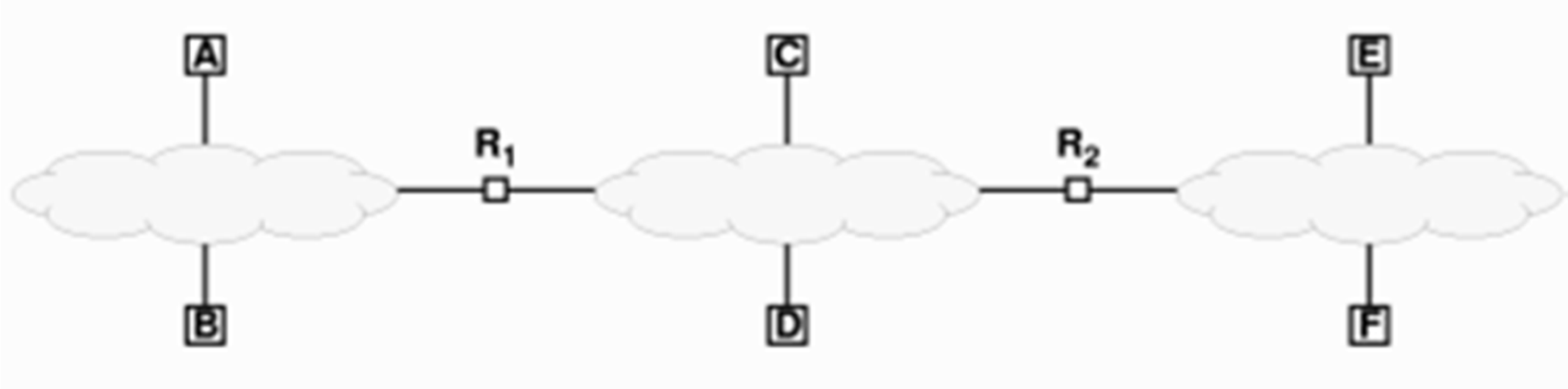
- IP protocol software works with *IP addresses* when forwarding **packets**:
  - The outcome of the routing process is the IP address of the ***Next Hop.***
  - The ***Next Hop*** can be another router or, it can be the destination host residing on a *directly connected* LAN.
  - Refer to examples given in class.
- Recall that IP addresses cannot be used when forwarding **frames** across *a physical network:*
  - Only MAC addresses are relevant for this task.

Binding Protocol Addresses

- Therefore the ***Next Hop*** IP address must be translated to an equivalent *hardware/MAC address* before the frame can be transmitted:
  - This translation is known as ***Address Resolution***.
- Once translated, the IP address is said to be *resolved.*
- Address resolution is *local* to a network.
- Refer to the next slide for an example.

Binding Protocol Addresses

- Any host connected to a LAN can only resolve the IP addresses of other stations/routers connected to the same LAN:
  - Hosts A, B and router R1 can resolve each others IP addresses but, neither hosts A nor B can resolve Hosts C, D, E, F or router R2s' IP addresses.



Address Resolution Techniques

- The algorithm used to translate a protocol address into a hardware address depends upon the protocol and hardware addressing schemes in use.
- However, there are three categories of address resolution algorithms as follows:
  - Table lookup
  - Closed-form computation
  - Message exchange

Address Resolution With *Table Lookup*

- Here an array is used to store information about address bindings.
- The main advantages of the table lookup approach are:
  - It can be used to store arbitrary address bindings.
  - A protocol address can be mapped to an arbitrary hardware address .
  - It is straightforward and easy to program.

IP Address	Hardware Address
197.15.3.2	0A:07:4B:12:82:36
197.15.3.3	0A:9C:28:71:32:8D
197.15.3.4	0A:11:C3:68:01:99
197.15.3.5	0A:74:59:32:CC:1F
197.15.3.6	0A:04:BC:00:03:28
197.15.3.7	0A:77:81:0E:52:FA

Address Resolution With *Closed-Form Computation*

- For *configurable MAC addressing* it is possible to choose addresses that make *closed-form address resolution* possible.
- A *resolver* computes the MAC address from the IP address using a mathematical function.
- If the relationship is simplistic, the computation requires only a few arithmetic operations (e.g. a single Boolean AND operation):

  hardware_address = ip_address AND Oxff

- Closed-form computation can be very efficient because both the *hardware* and *IP addresses* can be changed.

Address Resolution With *Message Exchange*

- This is *a distributed approach* to Address Resolution.
- To resolve an address a station sends a message across a network and receives a reply.
- There are two distributed designs to choose from:
  - The network includes a server that is assigned the task of answering address resolution requests.
    - The advantage of this scheme is that it is *centralized.*
  - Or, each computer on the network participates in address resolution by agreeing to answer resolution requests for its own address:
    - The advantage of this scheme is that it is *distributed.*
-

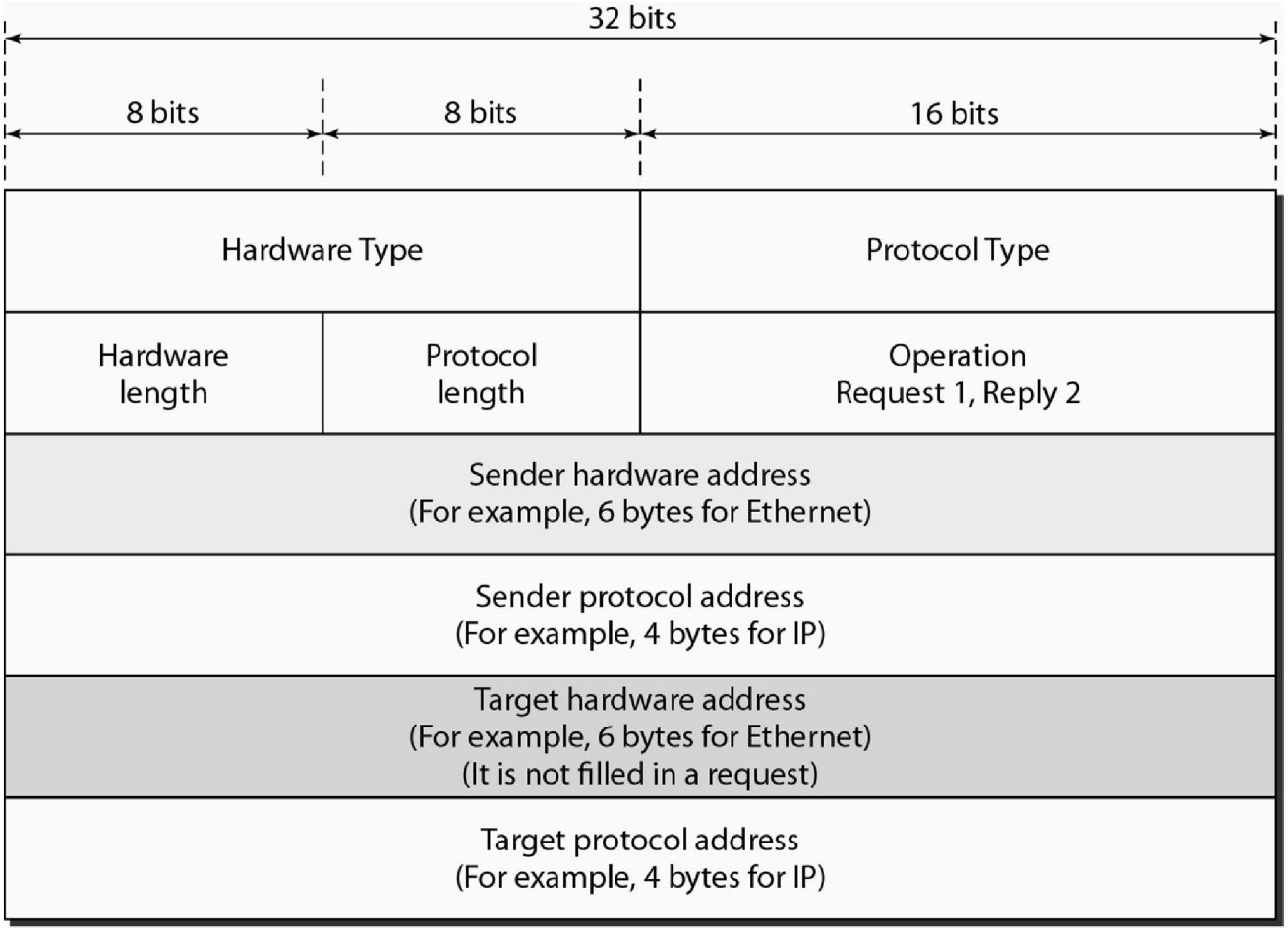
Address Resolution With Message Exchange

- Fortunately the TCP/IP protocol suite defines a protocol for Distributed Address Resolution:
  - This protocol is known as the *Address Resolution Protocol* (ARP).
  - It specifies the exact format and meaning of messages used to resolve addresses.

Address Resolution With Message Exchange

- The protocol defines two messages used in the exchange:
  - An ***ARP Request Message*** containing the *IP address* to be resolved.
  - An **ARP *Reply Message*** containing the *IP address* and its associated *MAC address.*

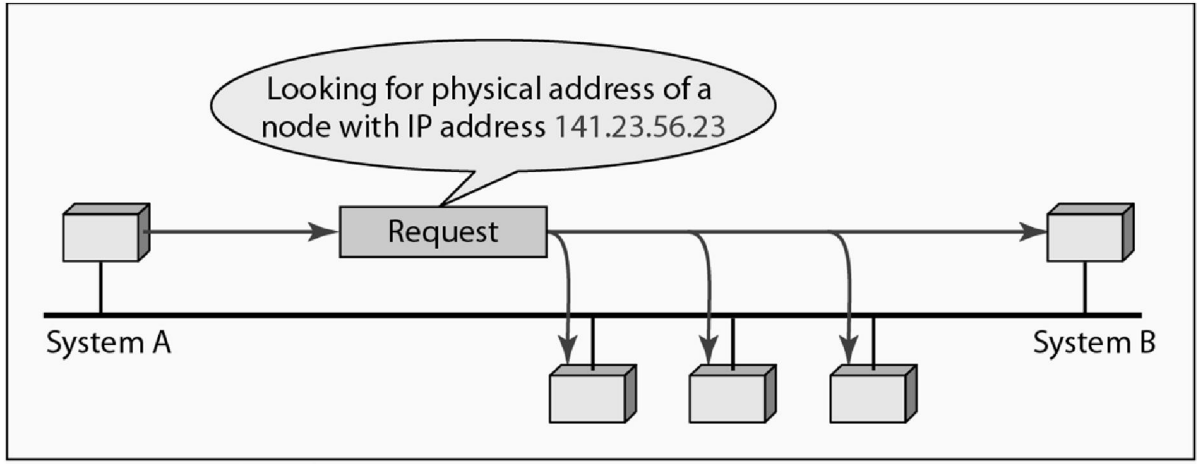
ARP Message Structure



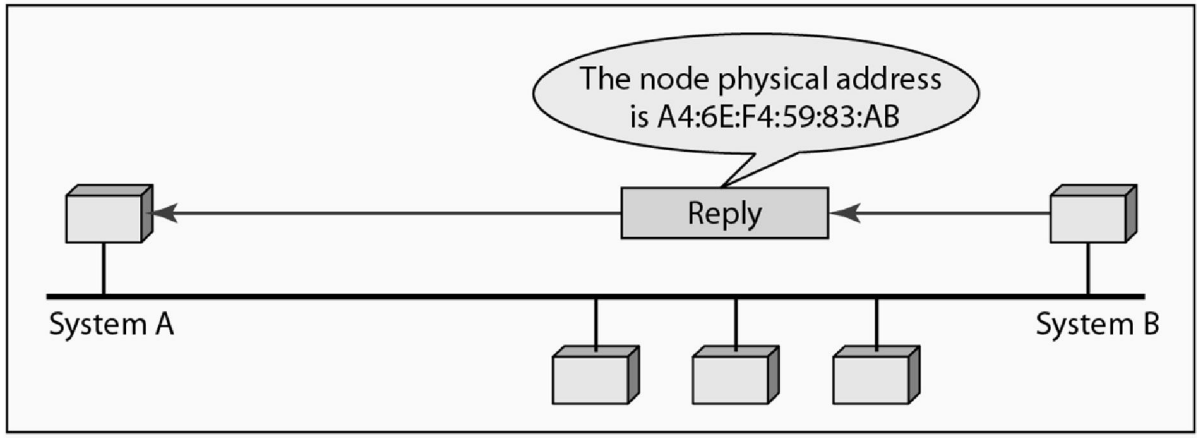
Address Resolution With Message Exchange

- *ARP request messages* are **Broadcast** to all computers on the network inside a *frame*:
  - The frame's DEST MAC address is the network's broadcast address.
  - The **ARP Request Message** contains:
    - SRC MAC/SRC IP Addresses and DEST MAC (unknown - all zeroes) and DEST IP Address (to be resolved).
- *ARP response messages* are not broadcast
  - The ARP response message contains :
    - SRC MAC (now resolved) and SRC IP Addresses and DEST MAC/DEST IP Addresses. (Note the SRC and DEST addresses are switched).

An ARP Message Exchange

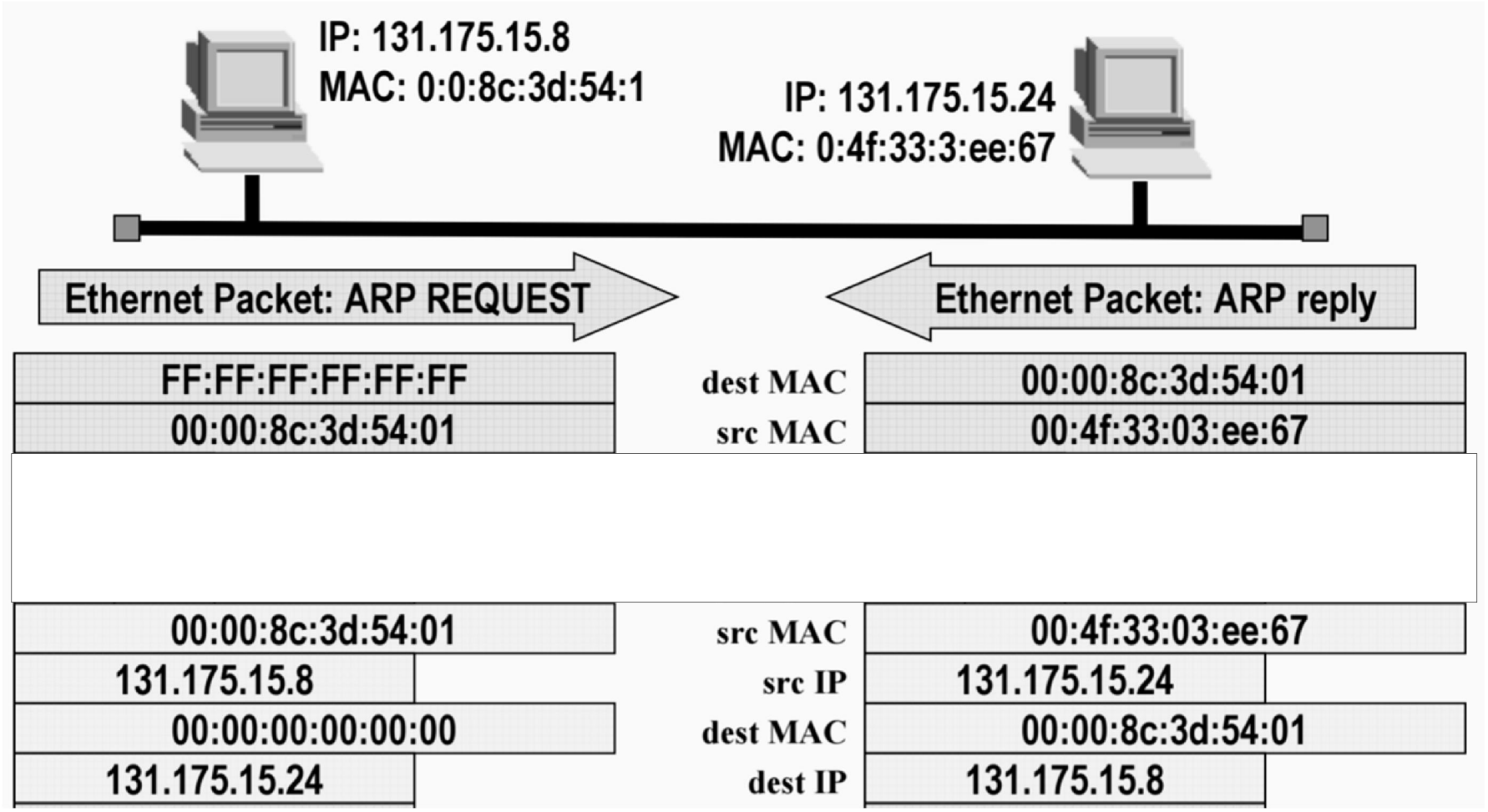


a. ARP request is broadcast



b. ARP reply is unicast

An ARP Message Exchange



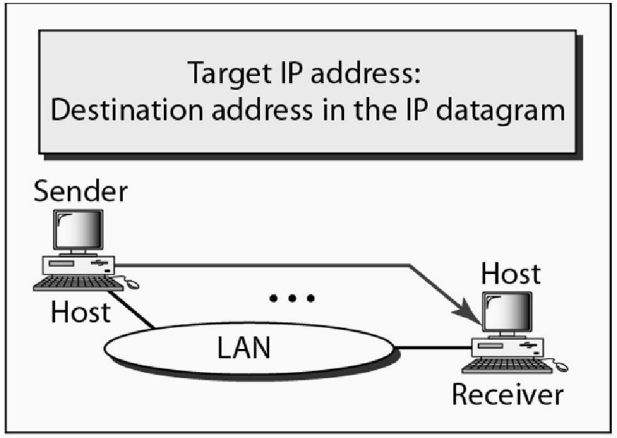
Address Resolution Protocol (ARP)

- Sending request messages for each binding is very inefficient.
- Most computer communication involve the exchange of *multiple packets*. This is likely to require multiple *binding requests.*
- To reduce network traffic, ARP software *caches* address bindings.
- Both the *sender* and *receiver* cache address bindings from the *request/response* messages.

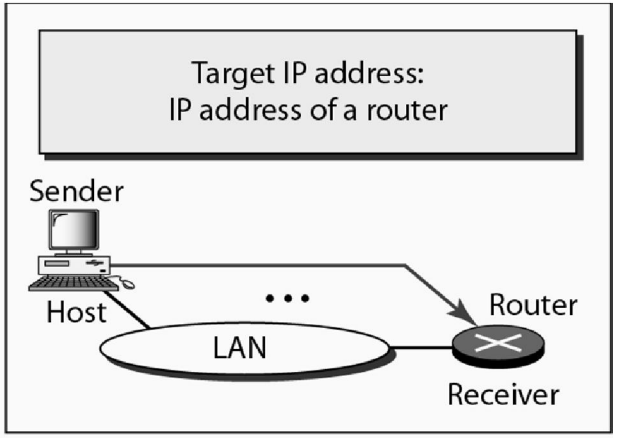
Address Resolution Protocol (ARP)

- The following outlines a number of scenarios which require **Address Resolution**:
  - These will be explored in class.

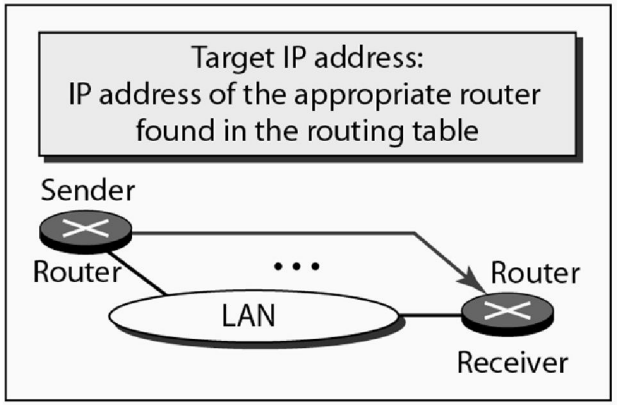
ARP Scenarios



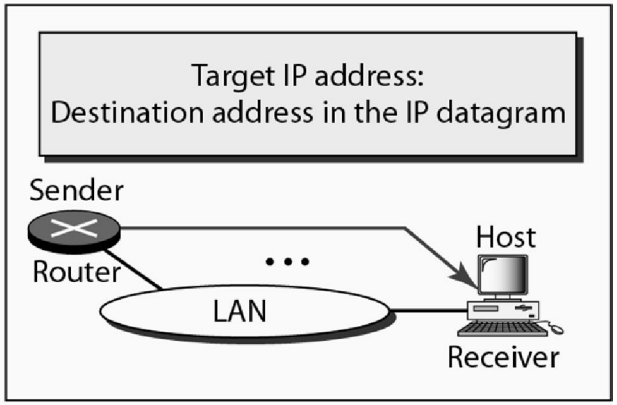
Case 1. A host has a packet to send to another host on the same network.



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



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.



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