# DATA LINK LAYER

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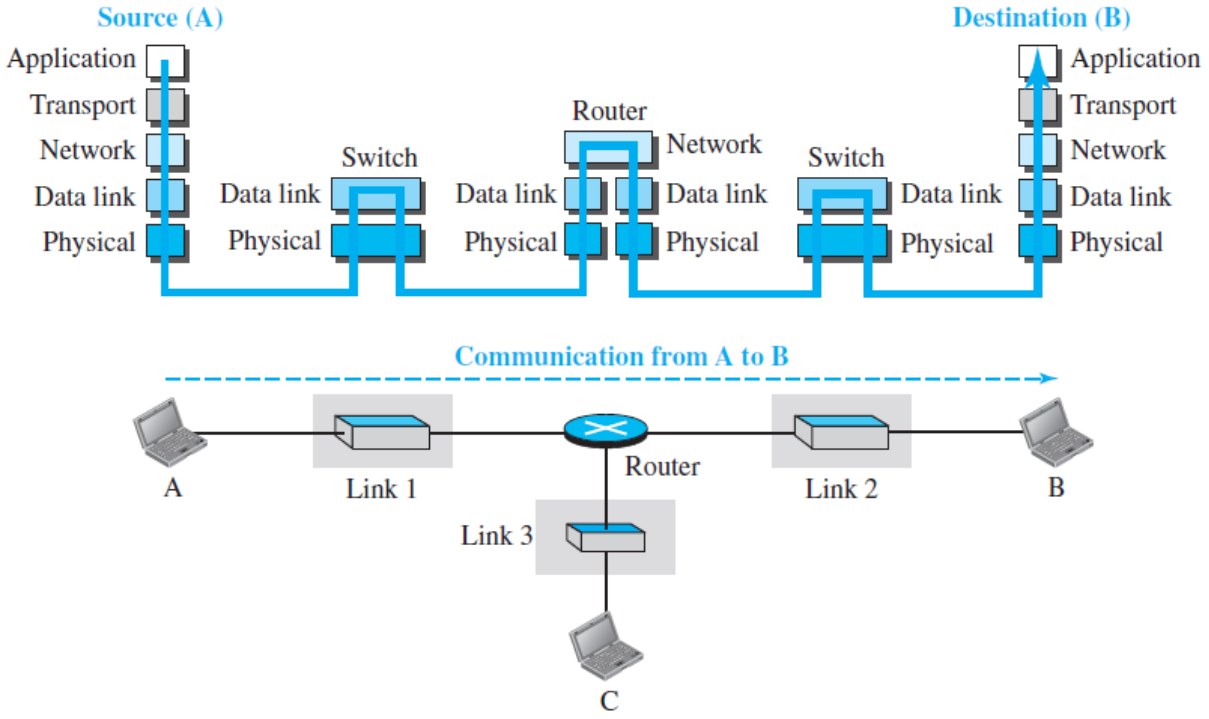
# INTRODUCTION

- Only one data-link layer is involved at the source or the destination, but two data-link layers are involved at each router. The reason is that source and destination computers are each connected to a single network, but each router takes input from one network and sends output to another network.

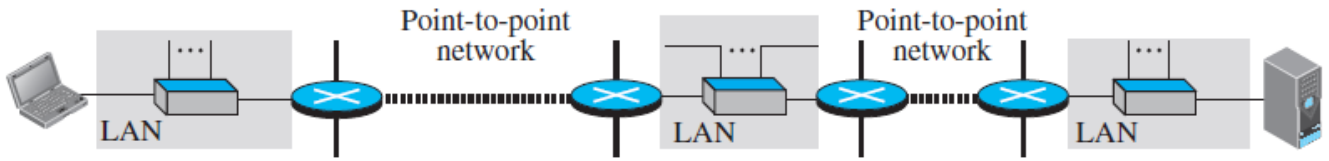
**Figure 2.5** *Communication through an internet*



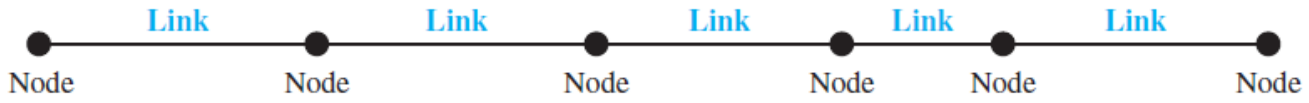
# NODES AND LINKS

- Communication at the data-link layer is node-to-node. A data unit from one point in the Internet needs to pass through many networks (LANs and WANs) to reach another point. These LANs and WANs are connected by routers. It is customary to refer to the two end hosts and the routers as nodes and the networks in between as links.

**Figure 9.2** *Nodes and Links*




a. A small part of the Internet



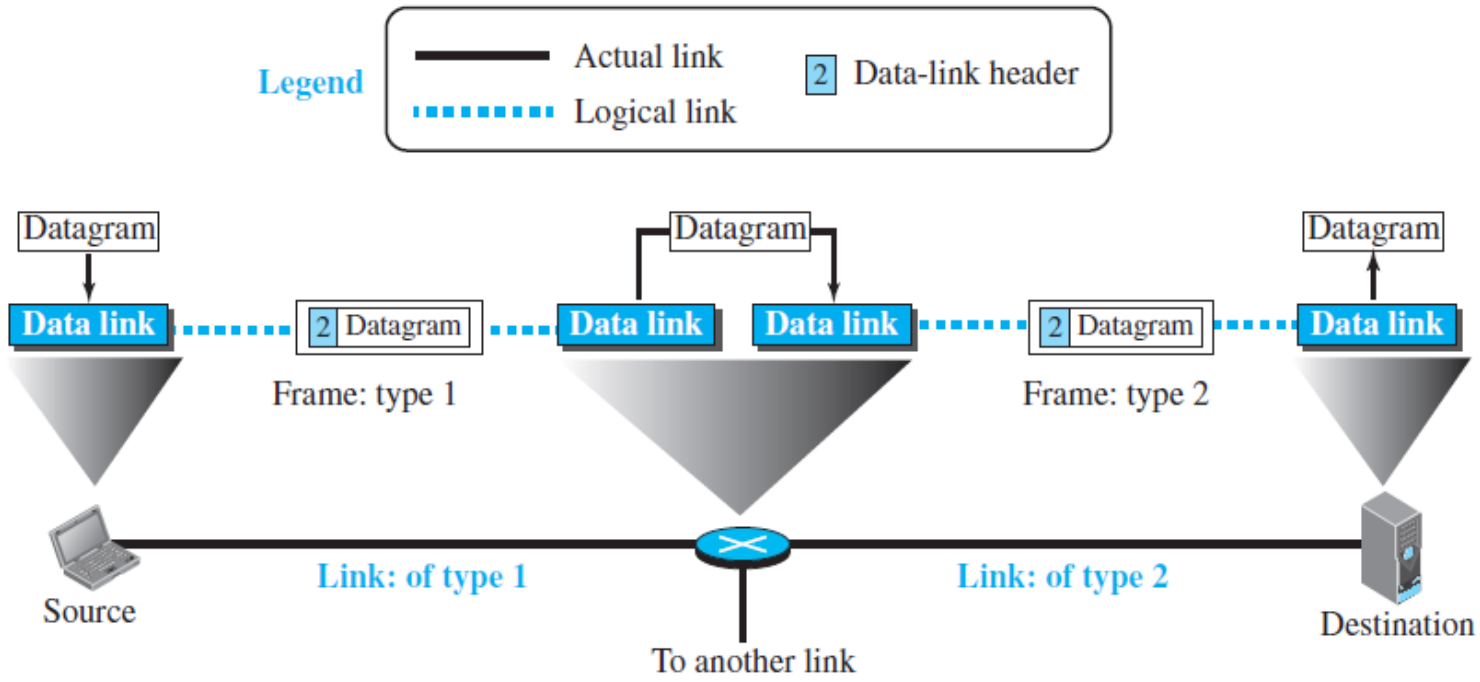

b. Nodes and links

# SERVICES

- The data-link layer is located between the physical and the network layers.
- The datalink layer provides services to the network layer; it receives services from the physical layer.
- The duty scope of the data-link layer is node-to-node. When a packet is travelling in the Internet, the data-link layer of a node (host or router) is responsible for delivering a datagram to the next node in the path.
- For this purpose, the data-link layer of the sending node needs to encapsulate the datagram received from the network in a frame, and the data-link layer of the receiving node needs to decapsulate the datagram from the frame.
- In other words, the data-link layer of the source host needs only to encapsulate, the data-link layer of the destination host needs to decapsulate, but each intermediate node needs to both encapsulate and decapsulate. The reason is that each link may be using a different protocol with a different frame format.

# SERVICES

**Figure 9.3** *A communication with only three nodes*



# FRAMING

- Definitely, the first service provided by the data-link layer is framing. A packet at the data-link layer is normally called a frame.
- The data-link layer at each node needs to encapsulate the datagram (packet received from the network layer) in a frame before sending it to the next node. The node also needs to decapsulate the datagram from the frame received on the logical channel.

# FLOW CONTROL

- The sending data-link layer at the end of a link is a producer of frames; the receiving data-link layer at the other end of a link is a consumer.
- If the rate of produced frames is higher than the rate of consumed frames, frames at the receiving end need to be buffered while waiting to be consumed (processed).
- Definitely, we cannot have an unlimited buffer size at the receiving side. We have two choices. The first choice is to let the receiving data-link layer drop the frames if its buffer is full. The second choice is to let the receiving data-link layer send feedback to the sending data-link layer to ask it to stop or slow down.

# ERROR CONTROL

- At the sending node, a frame in a data-link layer needs to be changed to bits, transformed to electromagnetic signals, and transmitted through the transmission media.
- At the receiving node, electromagnetic signals are received, transformed to bits, and put together to create a frame.
- Since electromagnetic signals are susceptible to error, a frame is susceptible to error.
- The error needs first to be detected. After detection, it needs to be either corrected at the receiver node or discarded and retransmitted by the sending node.

# CONGESTION CONTROL

- Although a link may be congested with frames, which may result in frame loss, most data-link-layer protocols do not directly use a congestion control to alleviate congestion, although some wide-area networks do.
- In general, congestion control is considered an issue in the network layer or the transport layer because of its end-to-end nature.

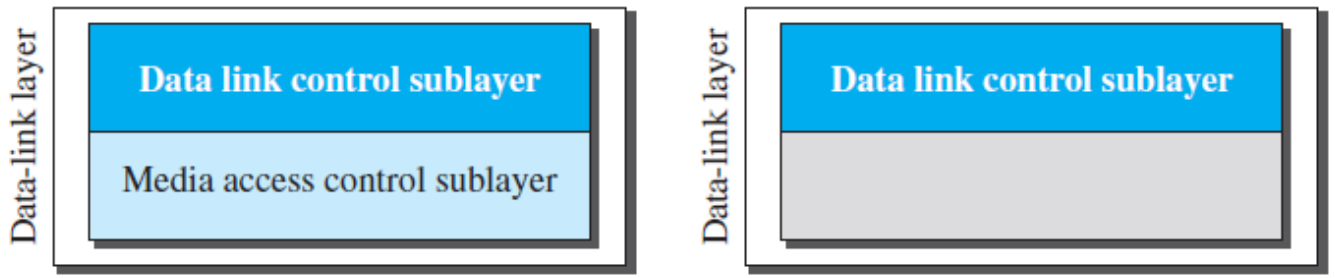
# TWO CATEGORIES OF LINKS

- We can have a data-link layer that uses the whole capacity of the medium; we can also have a data-link layer that uses only part of the capacity of the link. In other words, we can have a point-to-point link or a broadcast link.
- In a point-to-point link, the link is dedicated to the two devices; in a broadcast link, the link is shared between several pairs of devices.
- For example, when two friends use the traditional home phones to chat, they are using a point-to-point link; when the same two friends use their cellular phones, they are using a broadcast link.

# TWO SUBLAYERS

- We can divide the data-link layer into two sublayers: data link control (DLC) and media access control (MAC).
- The data link control sublayer deals with all issues common to both point-to-point and broadcast links; the media access control sublayer deals only with issues specific to broadcast links.

**Figure 9.4** *Dividing the data-link layer into two sublayers*

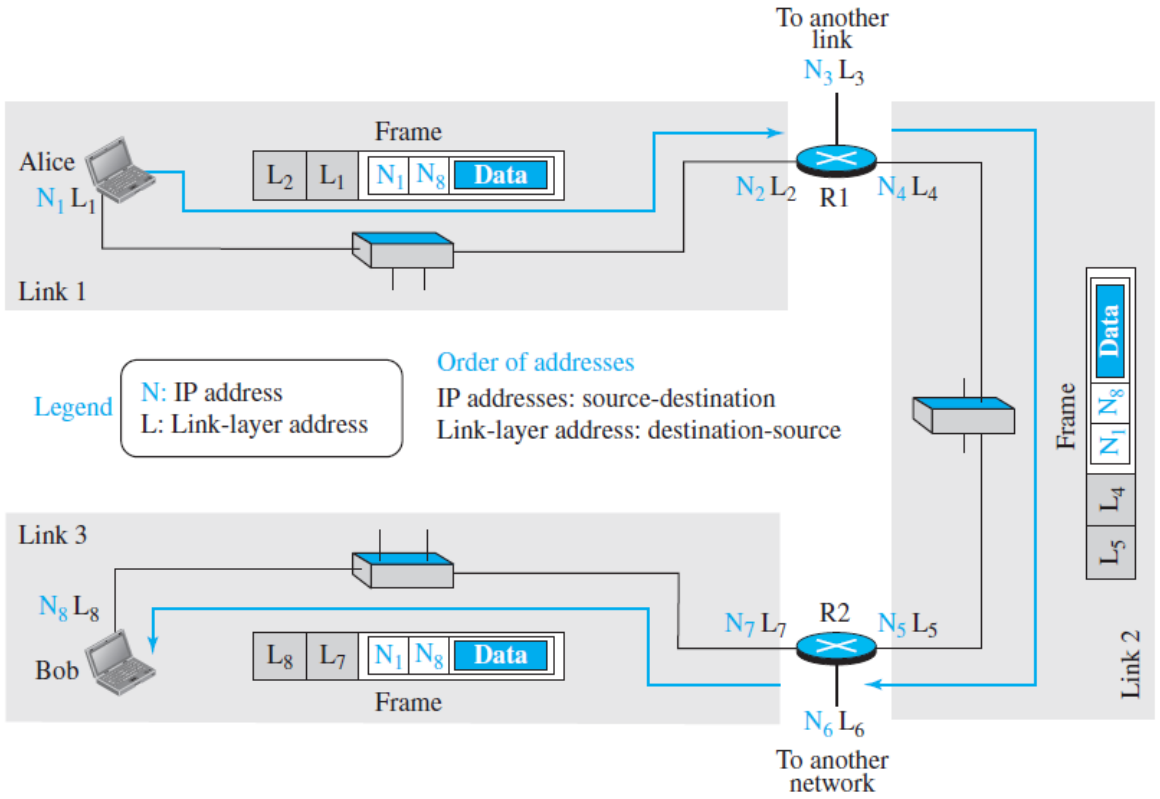


# LINK-LAYER ADDRESSING

- A link-layer address is sometimes called a link address, sometimes a physical address, and sometimes a MAC address.
- Since a link is controlled at the data-link layer, the addresses need to belong to the data-link layer. When a datagram passes from the network layer to the data-link layer, the datagram will be encapsulated in a frame and two data-link addresses are added to the frame header. These two addresses are changed every time the frame moves from one link to another.

# LINK-LAYER ADDRESSING

**Figure 9.5** *IP addresses and link-layer addresses in a small internet*



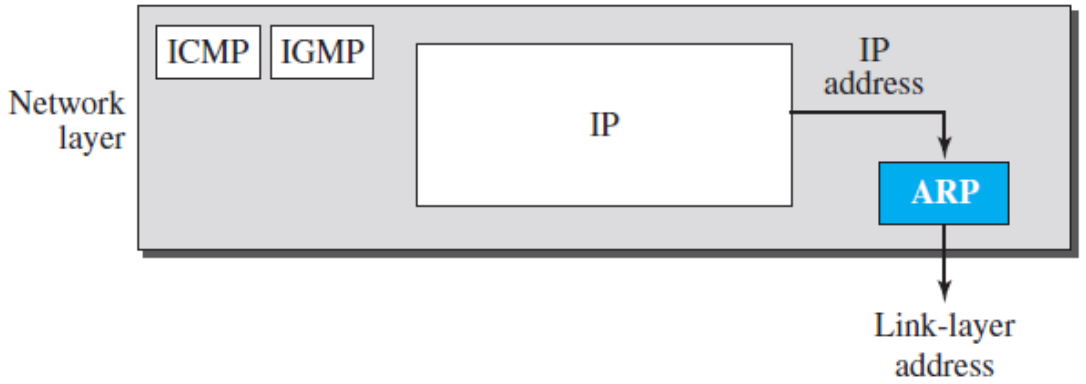
# THREE TYPES OF ADDRESSES

- Some link-layer protocols define three types of addresses: unicast, multicast, and broadcast.
- **Unicast Address**: Each host or each interface of a router is assigned a unicast address. Unicasting means one-to-one communication. A frame with a unicast address destination is destined only for one entity in the link. Ex - A3:34:45:11:92:F1 - (48 bits/six bytes that are presented as 12 hexadecimal digits separated by colons)
- **Multicast Address**: Some link-layer protocols define multicast addresses. Multicasting means one-to-many communication. Ex - A2:34:45:11:92:F1 – (The second digit even)
- **Broadcast Address**: Some link-layer protocols define a broadcast address. Broadcasting means one-to-all communication. A frame with a destination broadcast address is sent to all entities in the link. Ex - FF:FF:FF:FF:FF:FF (all bits are 1)

# ADDRESS RESOLUTION PROTOCOL (ARP)

- The ARP protocol is one of the auxiliary protocols defined in the network layer. It maps an IP address to a logical-link address.
- ARP accepts an IP address from the IP protocol, maps the address to the corresponding link-layer address, and passes it to the data-link layer.

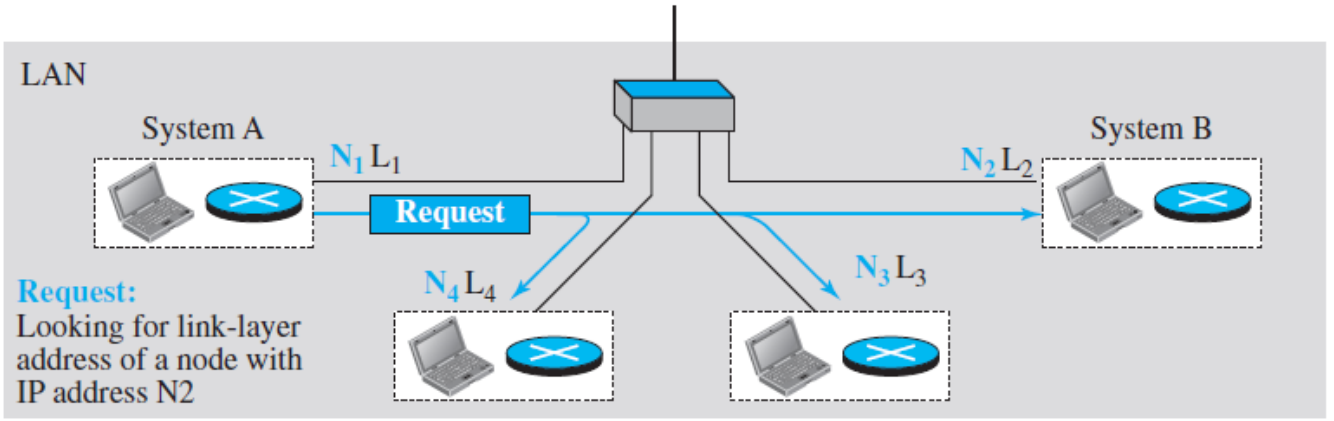
**Figure 9.6** *Position of ARP in TCP/IP protocol suite*



# ADDRESS RESOLUTION PROTOCOL (ARP)

- Anytime a host or a router needs to find the link-layer address of another host or router in its network, it sends an ARP request packet. The packet includes the link-layer and IP addresses of the sender and the IP address of the receiver. Because the sender does not know the link-layer address of the receiver, the query is broadcast over the link using the link-layer broadcast address.

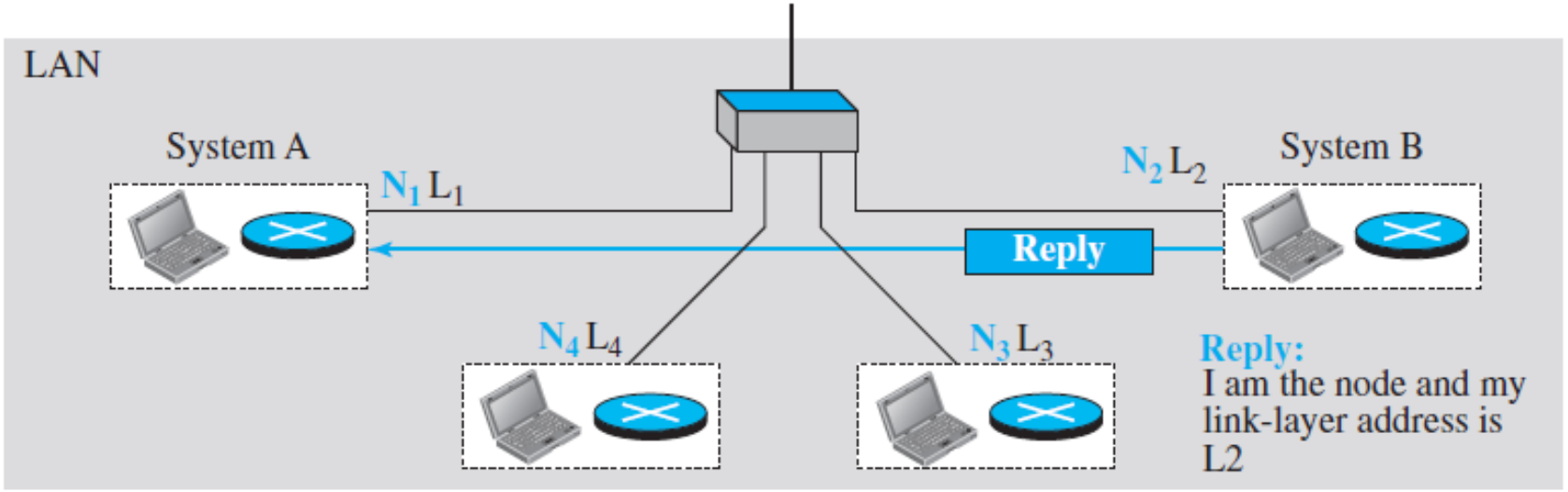
**Figure 9.7** *ARP operation*




a. ARP request is broadcast

# ADDRESS RESOLUTION PROTOCOL (ARP)

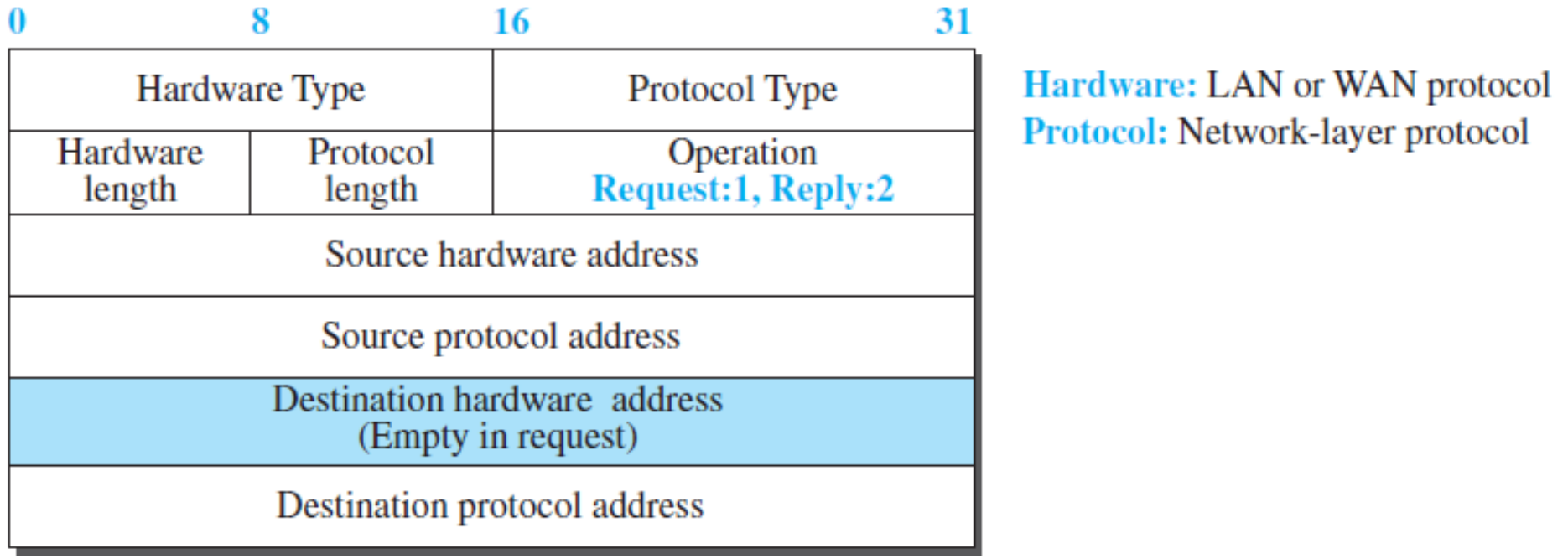
- Every host or router on the network receives and processes the ARP request packet, but only the intended recipient recognizes its IP address and sends back an ARP response packet. The response packet contains the recipient's IP and link-layer addresses. The packet is unicast directly to the node that sent the request packet.




b. ARP reply is unicast

# PACKET FORMAT

**Figure 9.8** *ARP packet*



# EXAMPLE

**Figure 9.9** *Example 9.4*