Chapter 9

Introduction To Data-Link Layer

FIFTH EDITION

Data Communications AND Networking

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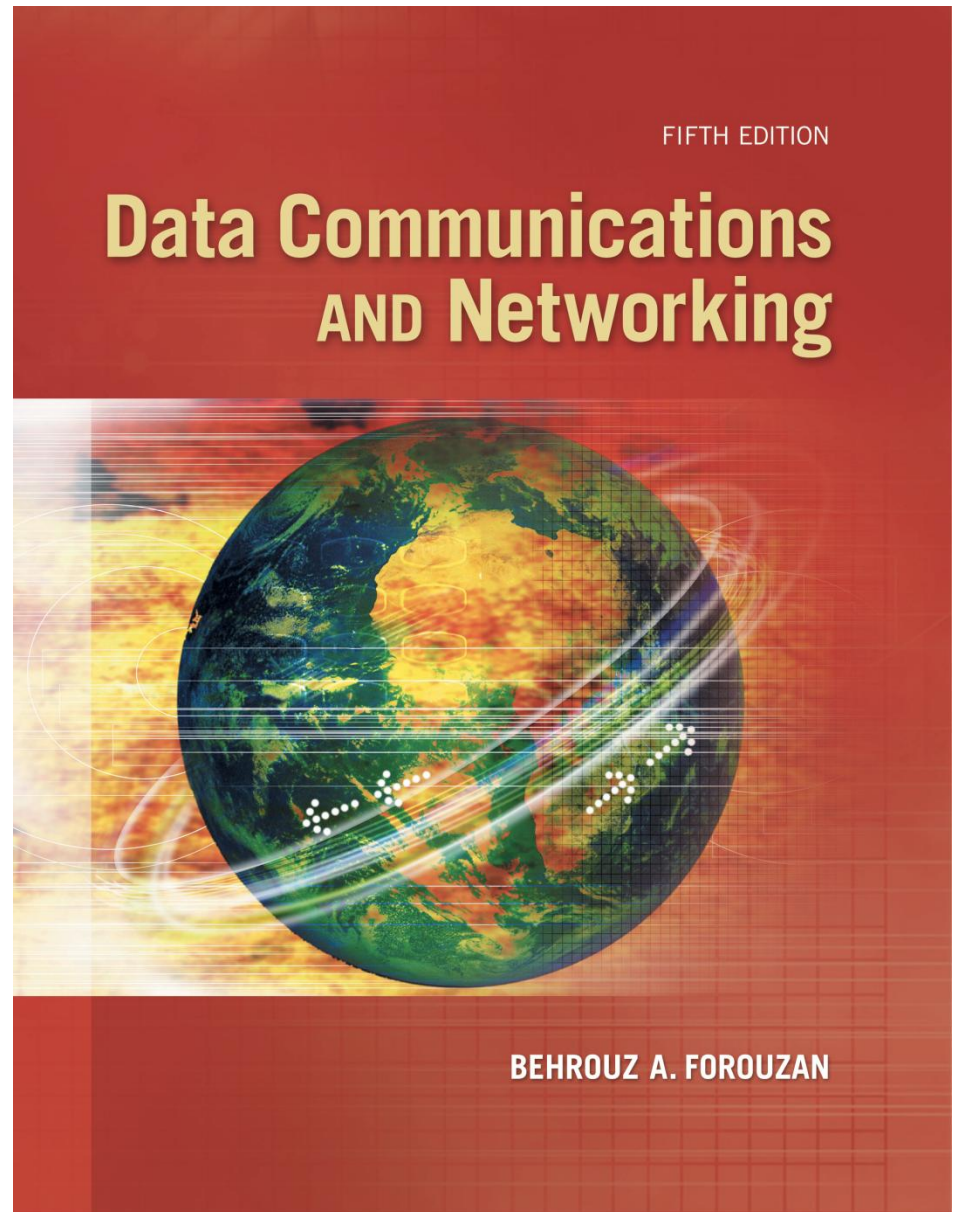
Chapter 9: Outline

9.1 INTRODUCTION

9.2 LINK-LAYER ADDRESSING

❑ *The first section introduces the* **data-link layer**. *It starts with defining the concept of links and nodes. The section then lists and briefly describes the services provided by the data-link layer. It next defines two categories of links: point-to-point and broadcast links. The section finally defines two sub-layers at the data-link layer that will be elaborated on in the next few chapters.*

❑ *The second section discusses* **link-layer addressing**. *It first explains the rationale behind the existence of an addressing mechanism at the data-link layer. It then describes three types of link-layer addresses. The section discusses the Address Resolution Protocol (ARP), which maps the addresses at the network layer to addresses at the data-link layer.*

9-1   INTRODUCTION

The Internet is a combination of networks glued together by connecting devices (routers or switches). If a packet is to travel from a host to another host, it needs to pass through these networks. Figure 9.1 shows the same scenario we discussed in Chapter 3, but we are now interested in *communication at the data-link layer.*
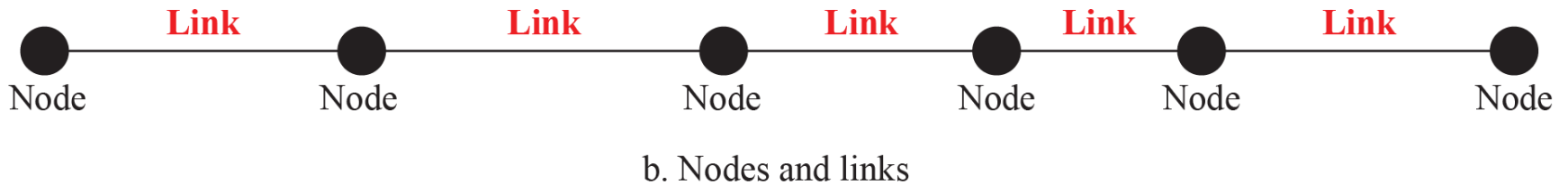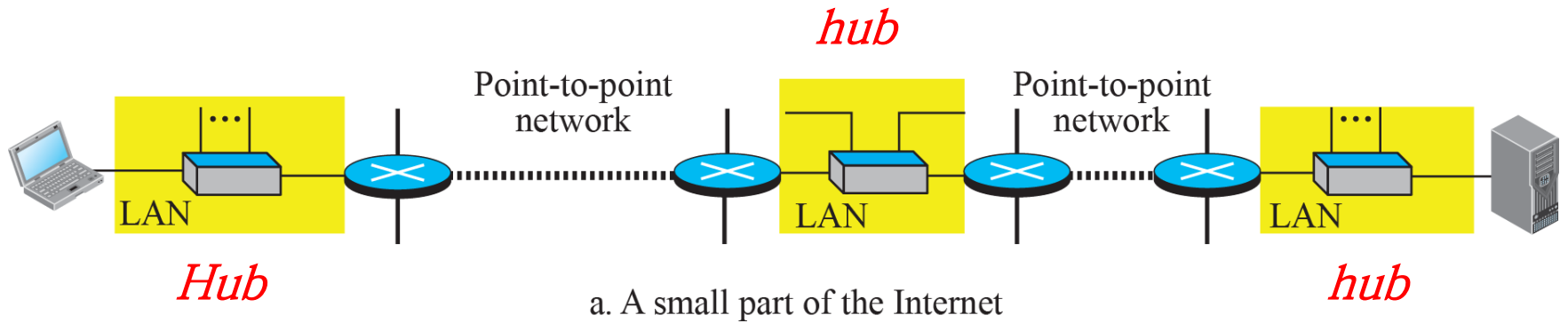
Figure 9.1: Communication at the data-link layer
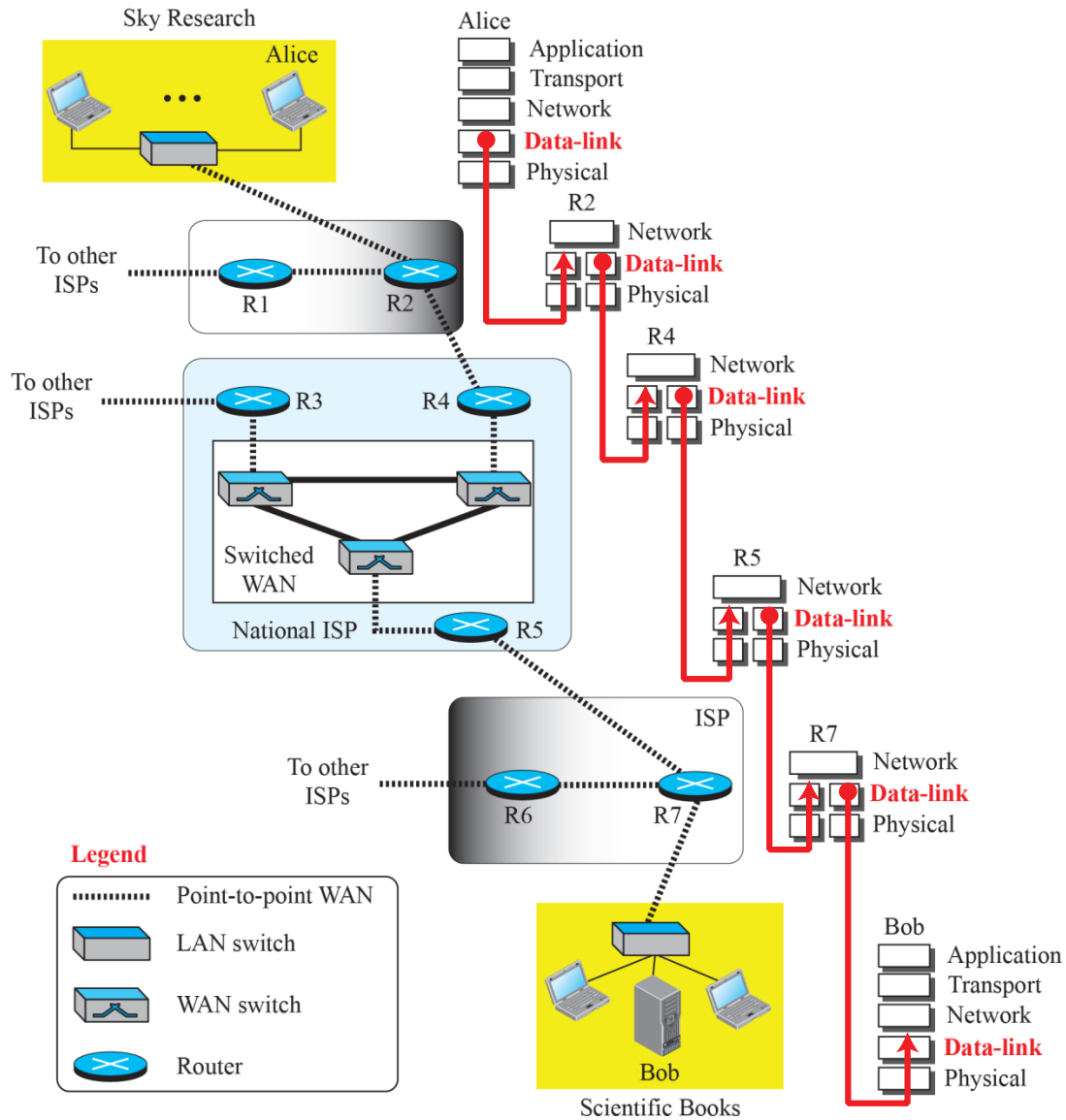
9.9.1 Nodes and Links

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. Theses 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 is a simple representation of links and nodes when the path of the data unit is only six nodes.

Figure 9.2: Nodes (Core and Edge) and Links

hub

Point-to-point network

Hub

Point-to-point network

hub

LAN

LAN

LAN

a. A small part of the Internet

Link   **Link**   **Link**   **Link**   **Link**

Node   Node   Node   Node   Node   Node

b. Nodes and links

9.9.2 Services

The data-link layer is located between the physical and the network layers. The data-link layer provides services to the network layer; it receives services from the physical layer. Let us discuss services provided by the data-link layer.
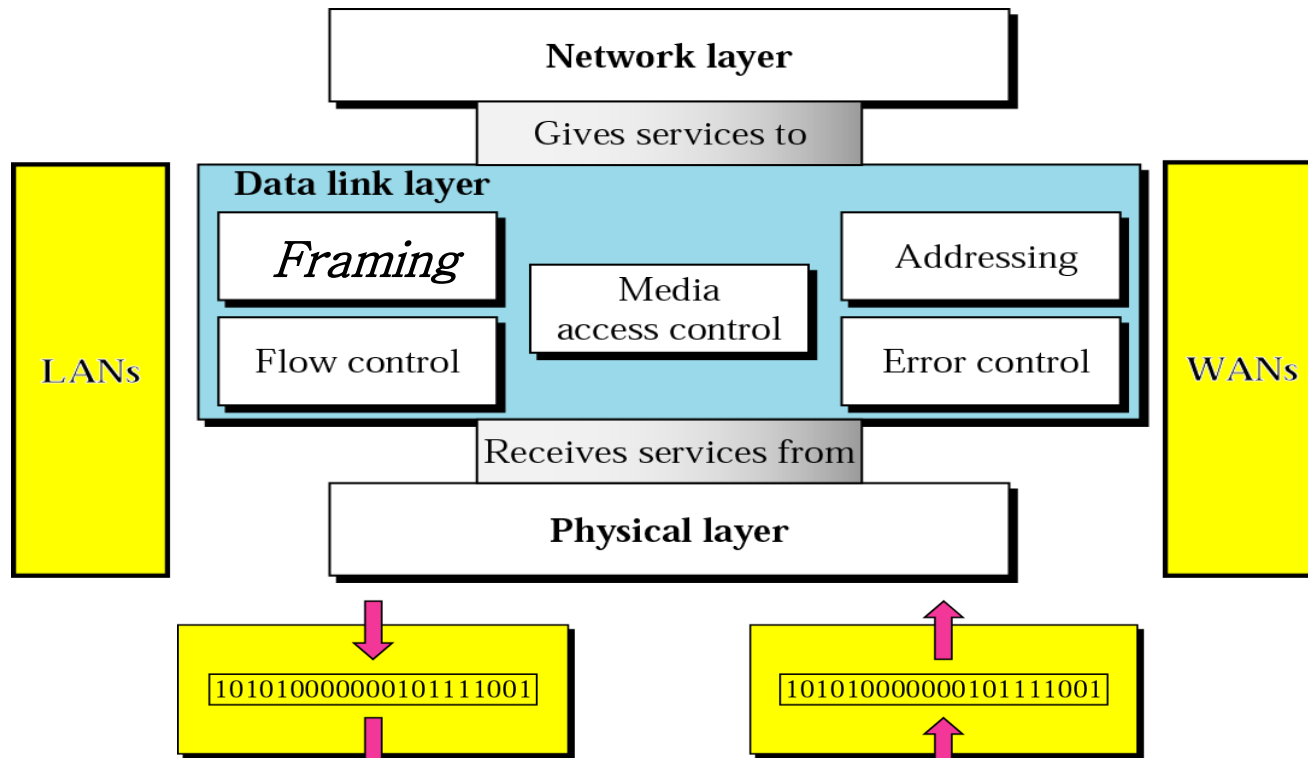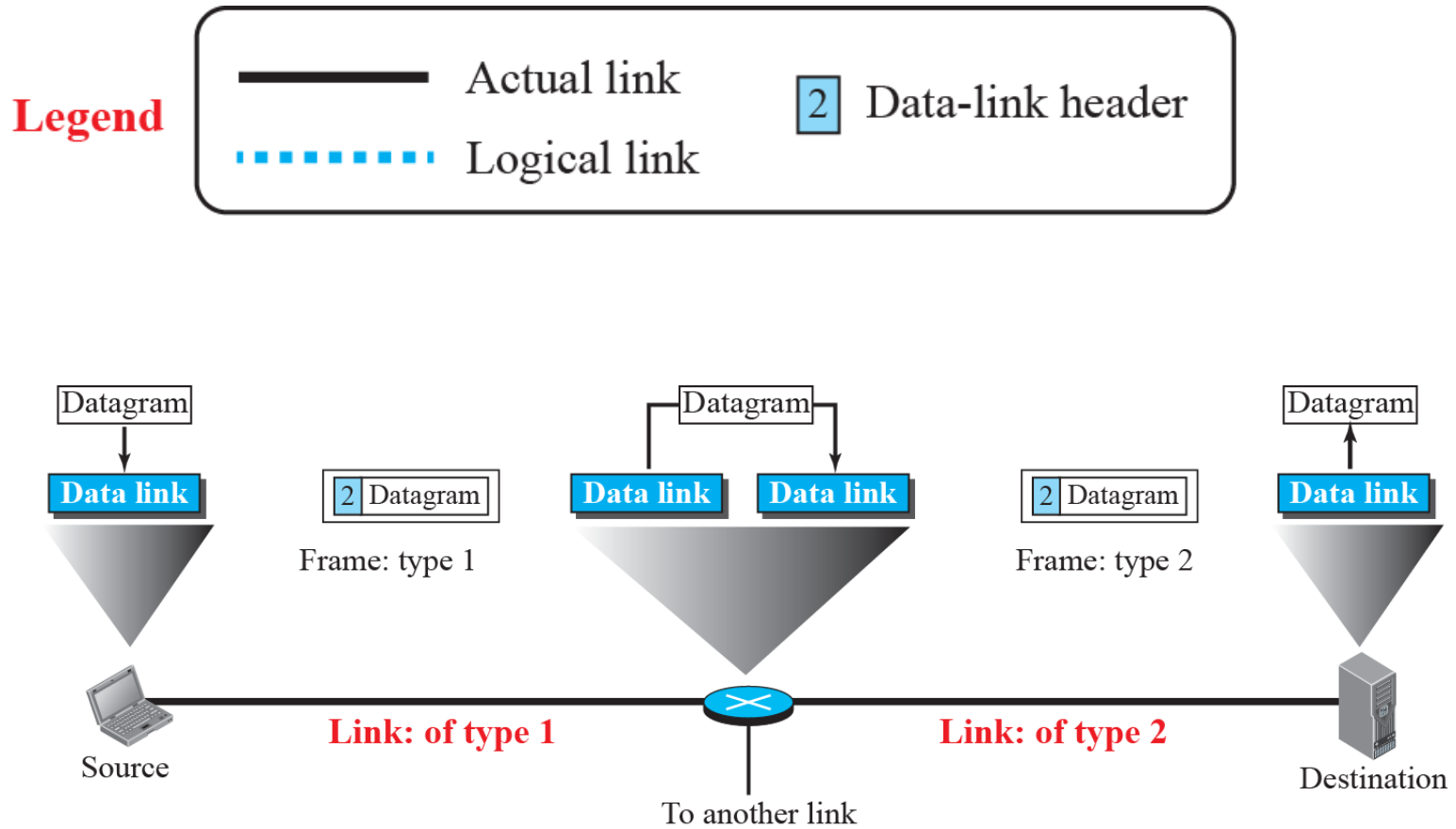
# Figure 9.3: A communication with only three nodes

9.9.3 Two Categories of Links

Although two nodes are physically connected by a transmission medium such as cable or air, we need to remember that the data-link layer controls how the medium is used. 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.

9.9.4 Two Sublayers

To better understand the functionality of and the services provided by the link layer, we can divide the data-link layer into two sublayers: data link control (DLC) and media access control (MAC). This is not unusual because, as we will see in later chapters, LAN protocols actually use the same strategy.

Figure 9.3: Dividing the data−link layer into two sublayers

a. Data-link layer of a broadcast link

b. Data-link layer of a point-to-point link
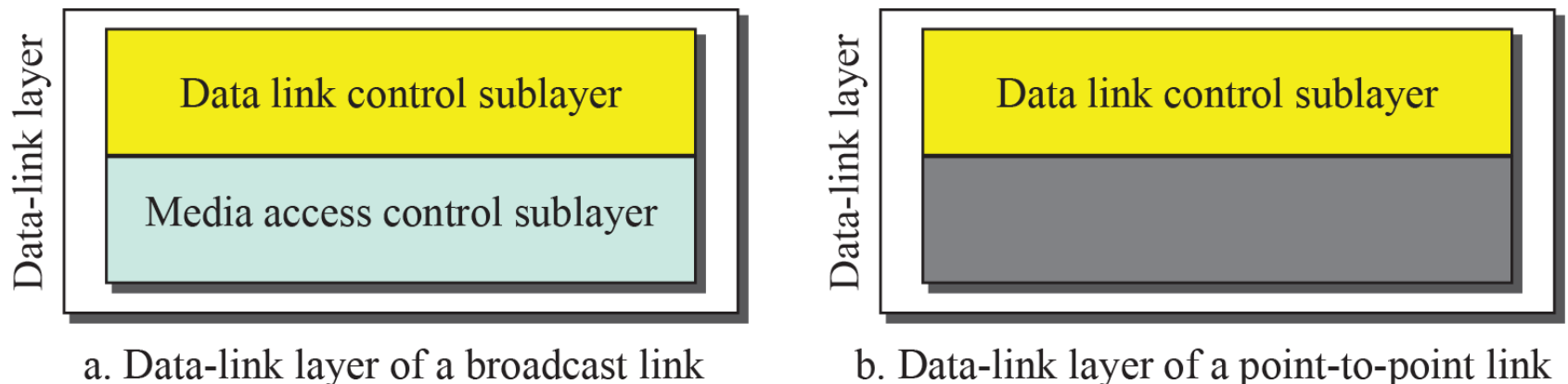
5-4 LINK-LAYER ADDRESSING

In Chapter 18, we will discuss IP addresses as the identifiers at the network layer. However, in a internetwork such as the Internet we cannot make a datagram reach its destination using only IP addresses. The source and destination IP addresses define the two ends but cannot define which links the packet should pass through.

Figure 9.5: IP addresses and link-layer addresses in a small internet
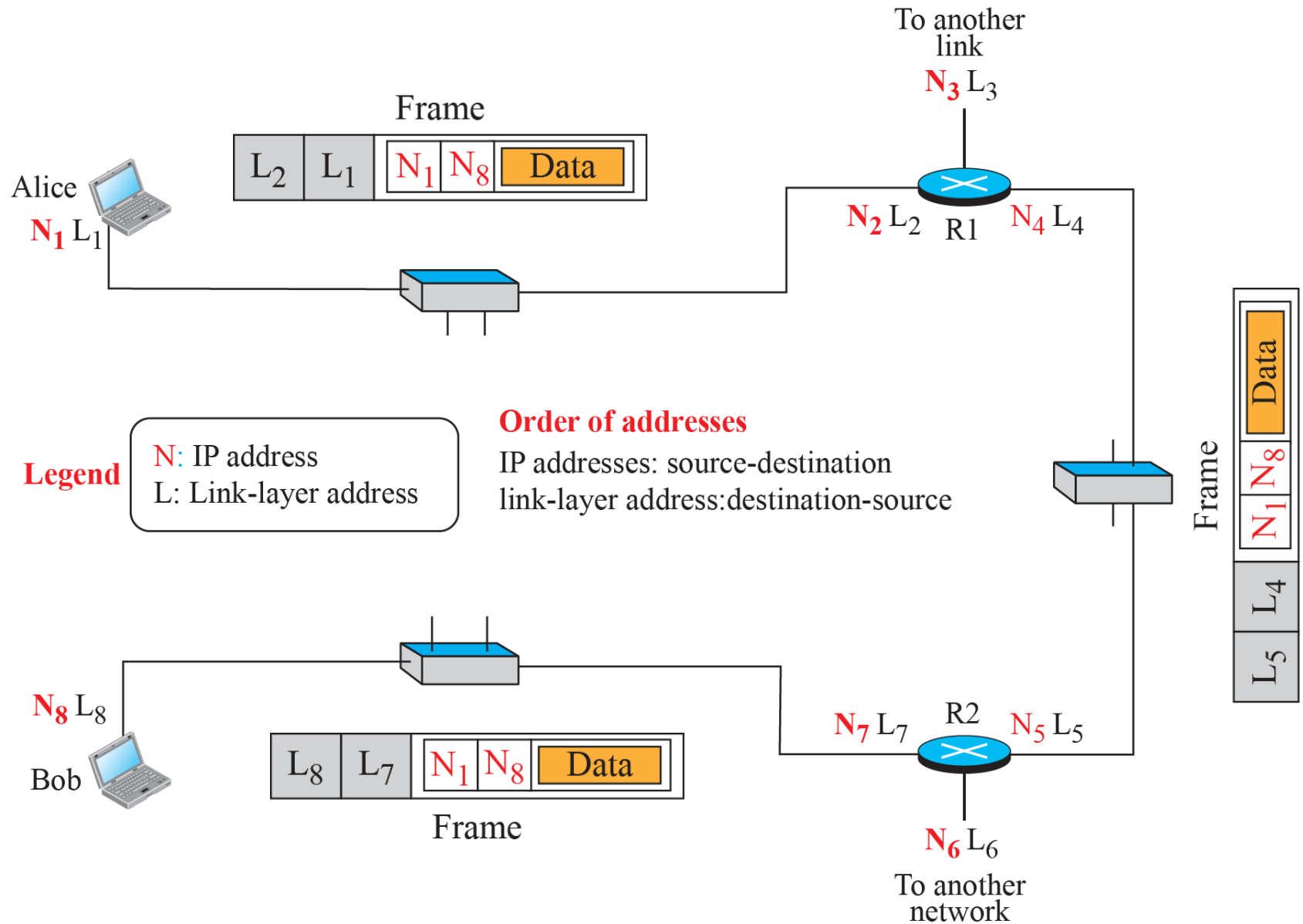
9.2.1 Three Types of addresses

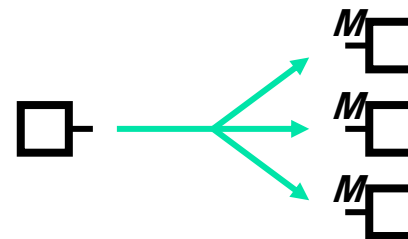*Some link-layer protocols define three types of addresses: unicast, multicast, and broadcast.*
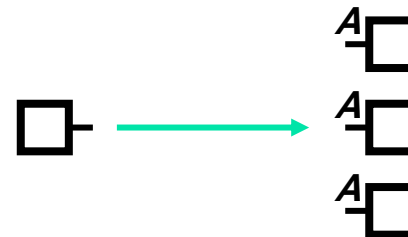
unicast:
    for one-to-one communication

multicast:
    for one-to-many communication

anycast:
    for one-to-nearest communication

Example 9.1

As we will see in Chapter 13, the unicast link-layer addresses in the most common LAN, Ethernet, are 48 bits (six bytes) that are presented as 12 hexadecimal digits separated by colons; for example, the following is a link-layer address of a computer. The second digit needs to be an odd number.

A3:34:45:11:92:F1

Example 9.2

As we will see in Chapter 13, the multicast link-layer addresses in the most common LAN, Ethernet, are 48 bits (six bytes) that are presented as 12 hexadecimal digits separated by colons. The second digit, however, needs to be an even number in hexadecimal. The following shows a multicast address:

A2:34:45:11:92:F1

Example 9.3

As we will see in Chapter 13, the broadcast link-layer addresses in the most common LAN, Ethernet, are 48 bits, all 1s, that are presented as 12 hexadecimal digits separated by colons. The following shows a broadcast address:

FF:FF:FF:FF:FF:FF

9.2.2 ARP

Anytime a node has an IP datagram to send to another node in a link, it has the IP address of the receiving node. However, the IP address of the next node is not helpful in moving a frame through a link; we need the link-layer address of the next node. This is the time when the Address Resolution Protocol (ARP) becomes helpful.

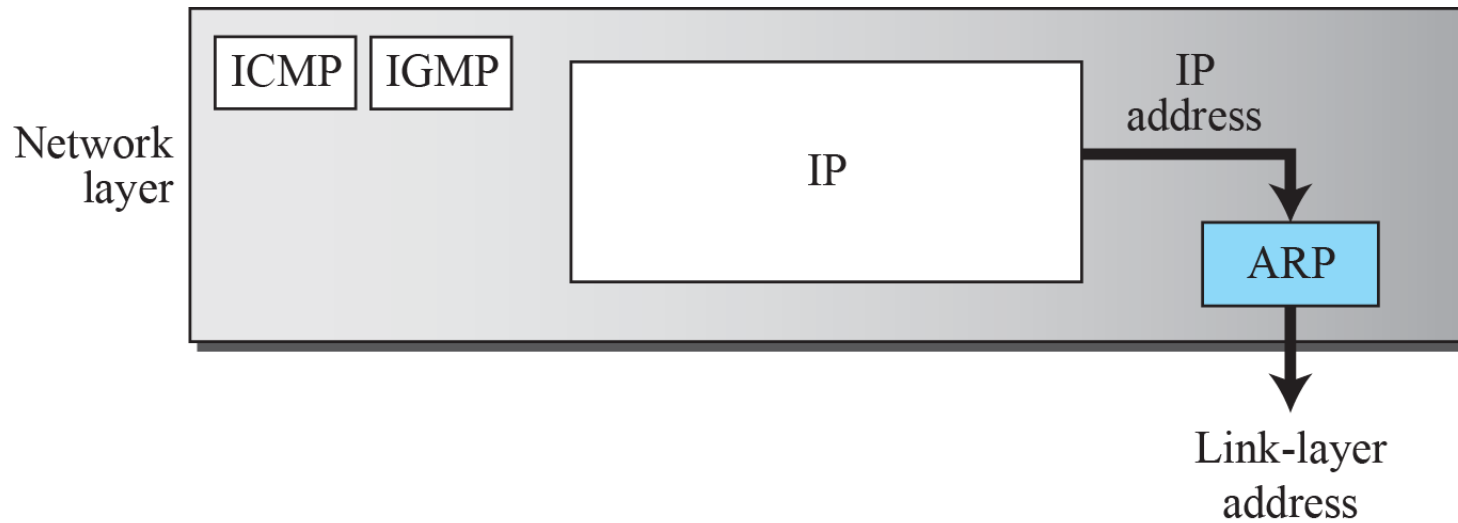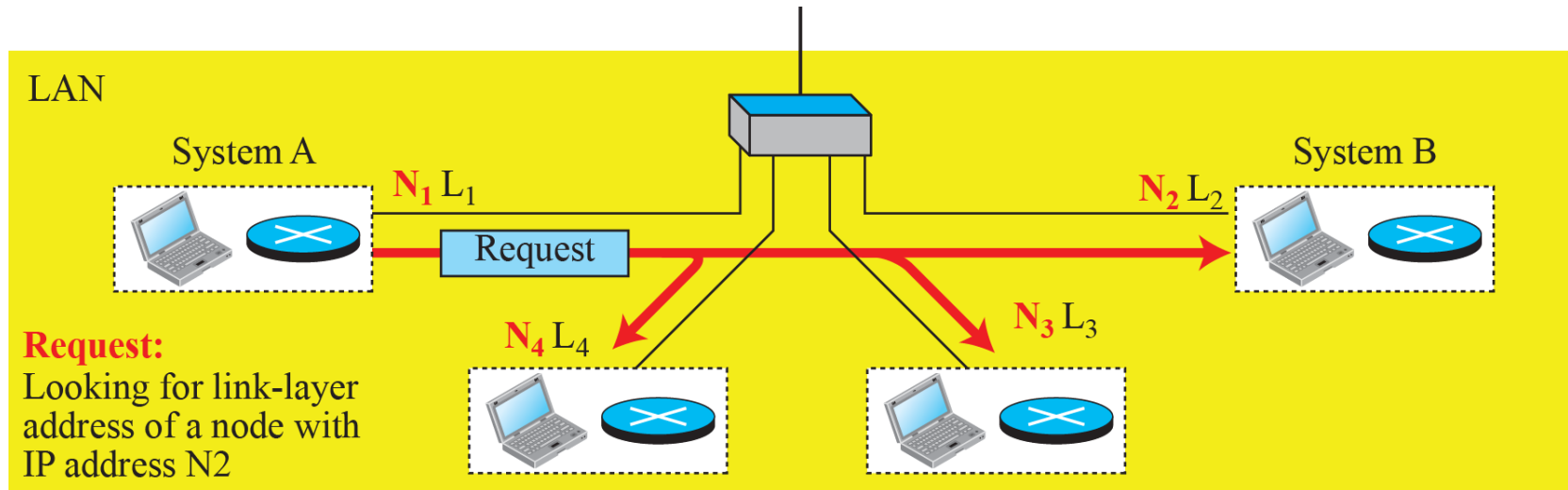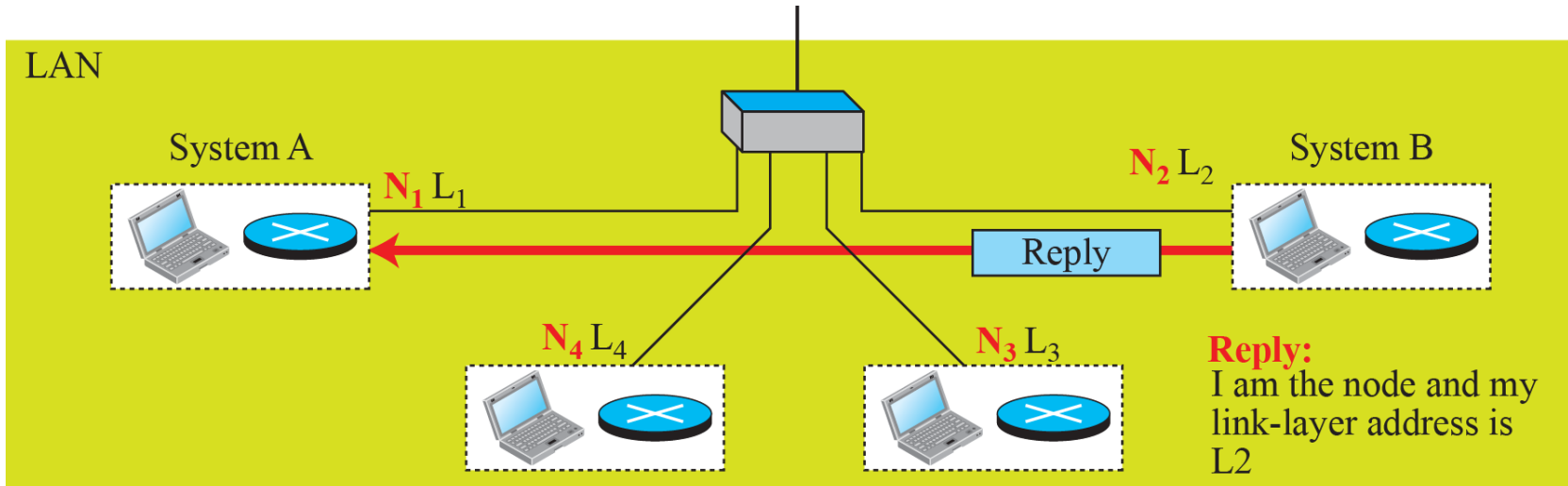# Figure 9.6: Position of ARP in TCP/IP protocol suite

Figure 9.7: ARP operation

LAN

System A

$N_1 L_1$

System B

$N_2 L_2$

Request

Request:
Looking for link-layer
address of a node with
IP address N2

$N_4 L_4$

$N_3 L_3$

a. ARP request is broadcast

LAN

System A

$N_1 L_1$

$N_2 L_2$

System B

Reply

$N_4 L_4$

$N_3 L_3$

Reply:
I am the node and my
link-layer address is
L2

b. ARP reply is unicast

Figure 9.8: ARP packet

Hardware: LAN or WAN protocol
Protocol: Network-layer protocol

0	8	16	31

Hardware Type		Protocol Type	
Hardware length	Protocol length	Operation **Request:1, Reply:2**	
Source hardware address			
Source protocol address			
Destination hardware address (Empty in request)			
Destination protocol address			

Example 9.4

A host with IP address N1 and MAC address L1 has a packet to send to another host with IP address N2 and physical address L2 (which is unknown to the first host). The two hosts are on the same network. Figure 9.9 shows the ARP request and response messages.
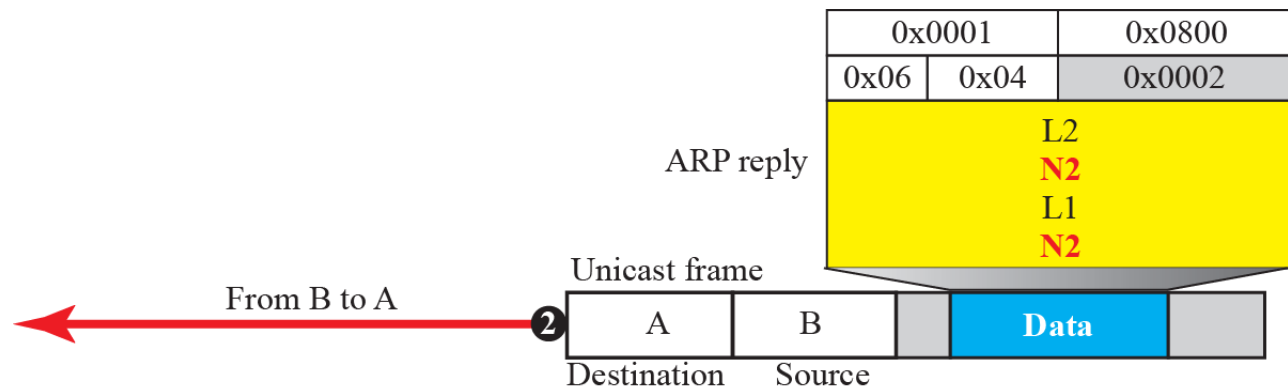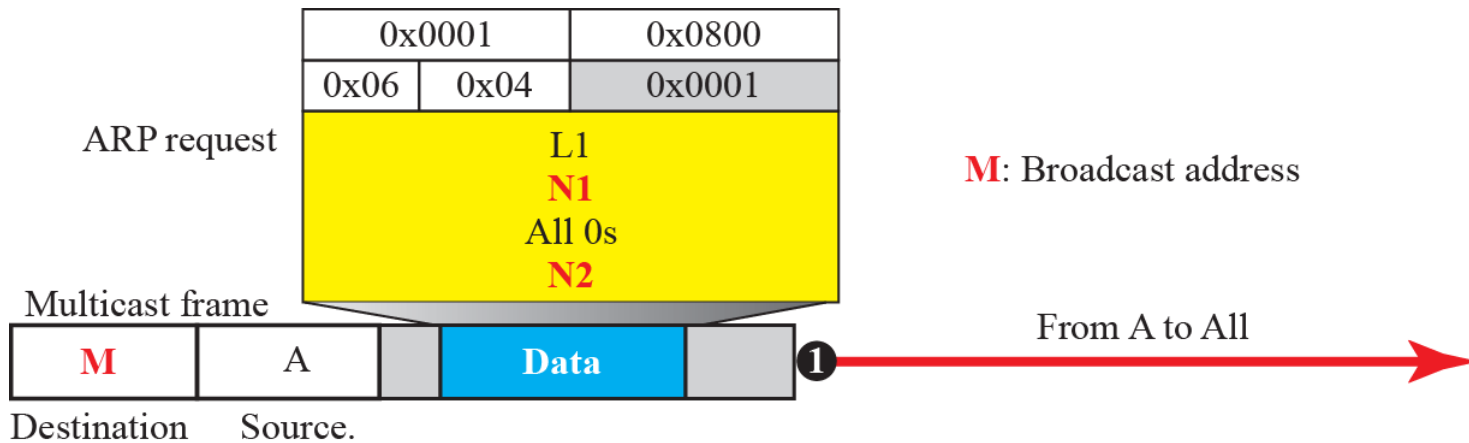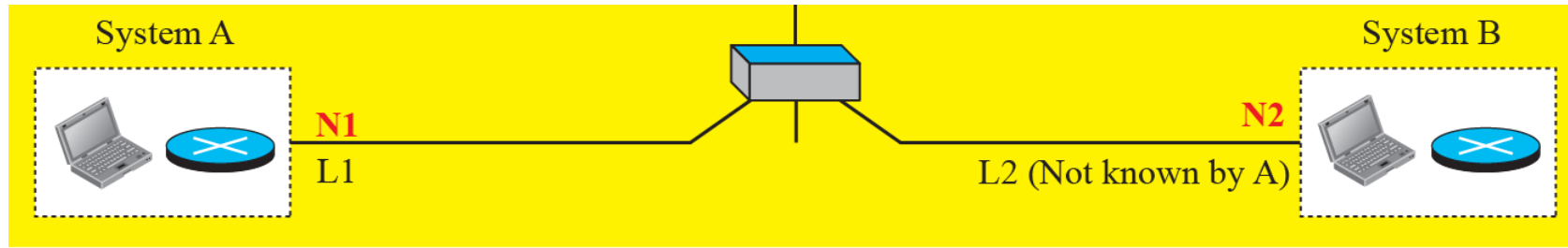
Figure 9.9: Example 9.4

0x0001		0x0800
0x06	0x04	0x0001

ARP request

L1
N1
All 0s
N2

M: Broadcast address

Multicast frame

M	A		Data	

Destination Source.

From A to All ❶

0x0001		0x0800
0x06	0x04	0x0002

ARP reply

L2
N2
L1
N2

Unicast frame

From B to A ❷

A	B		Data	

Destination Source

System A

System B

N1
L1

N2
L2 (Not known by A)

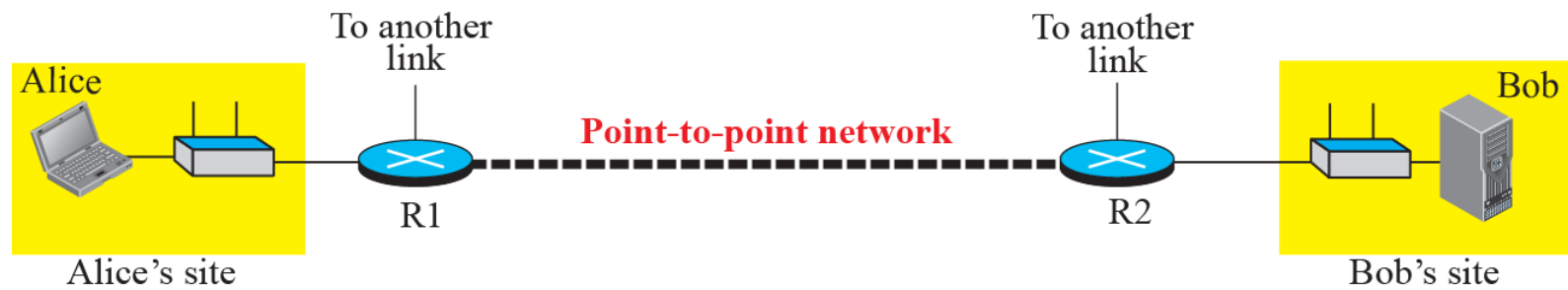# Figure 9.10: The internet for our example

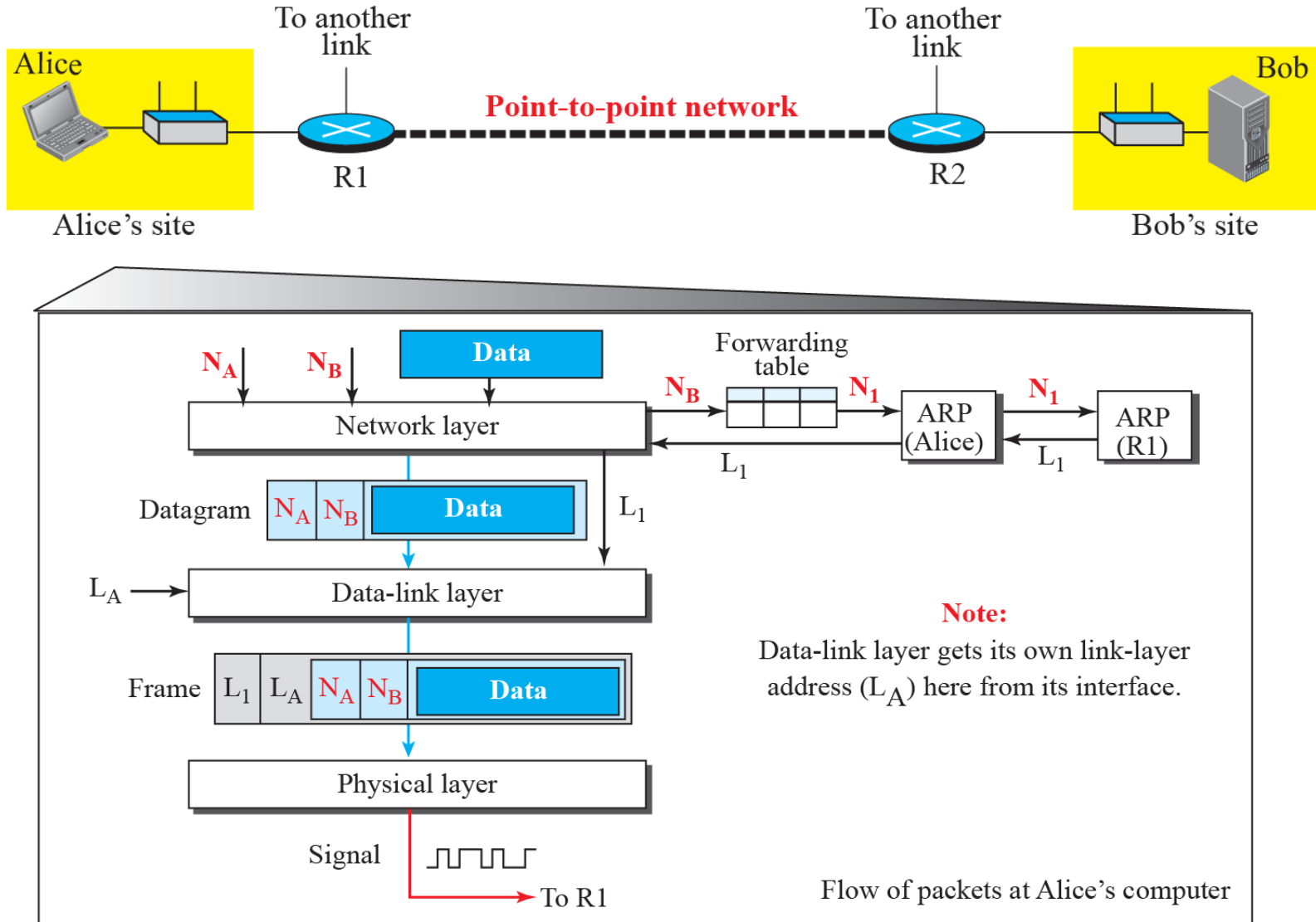# Figure 9.11: Flow of packets at Alice site

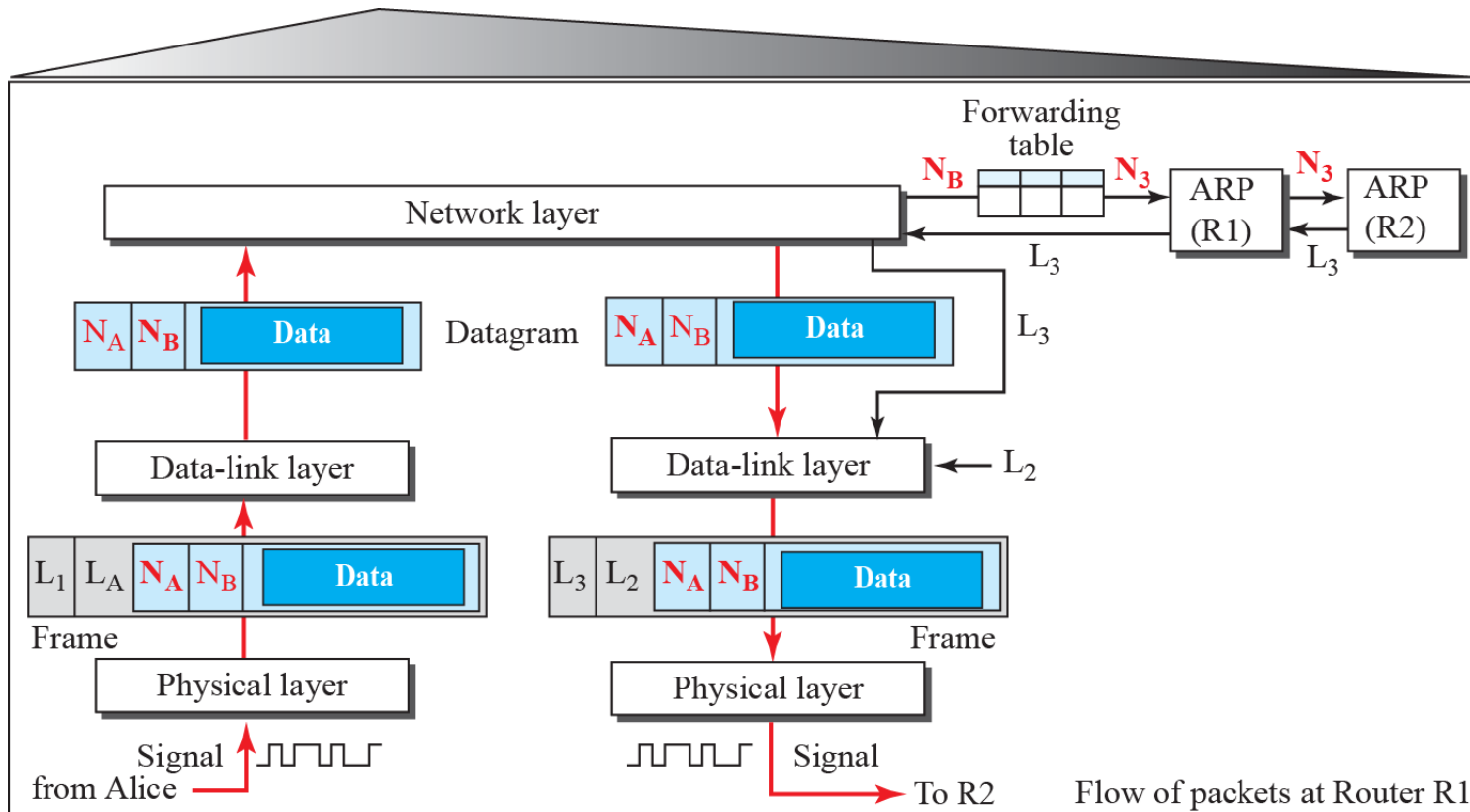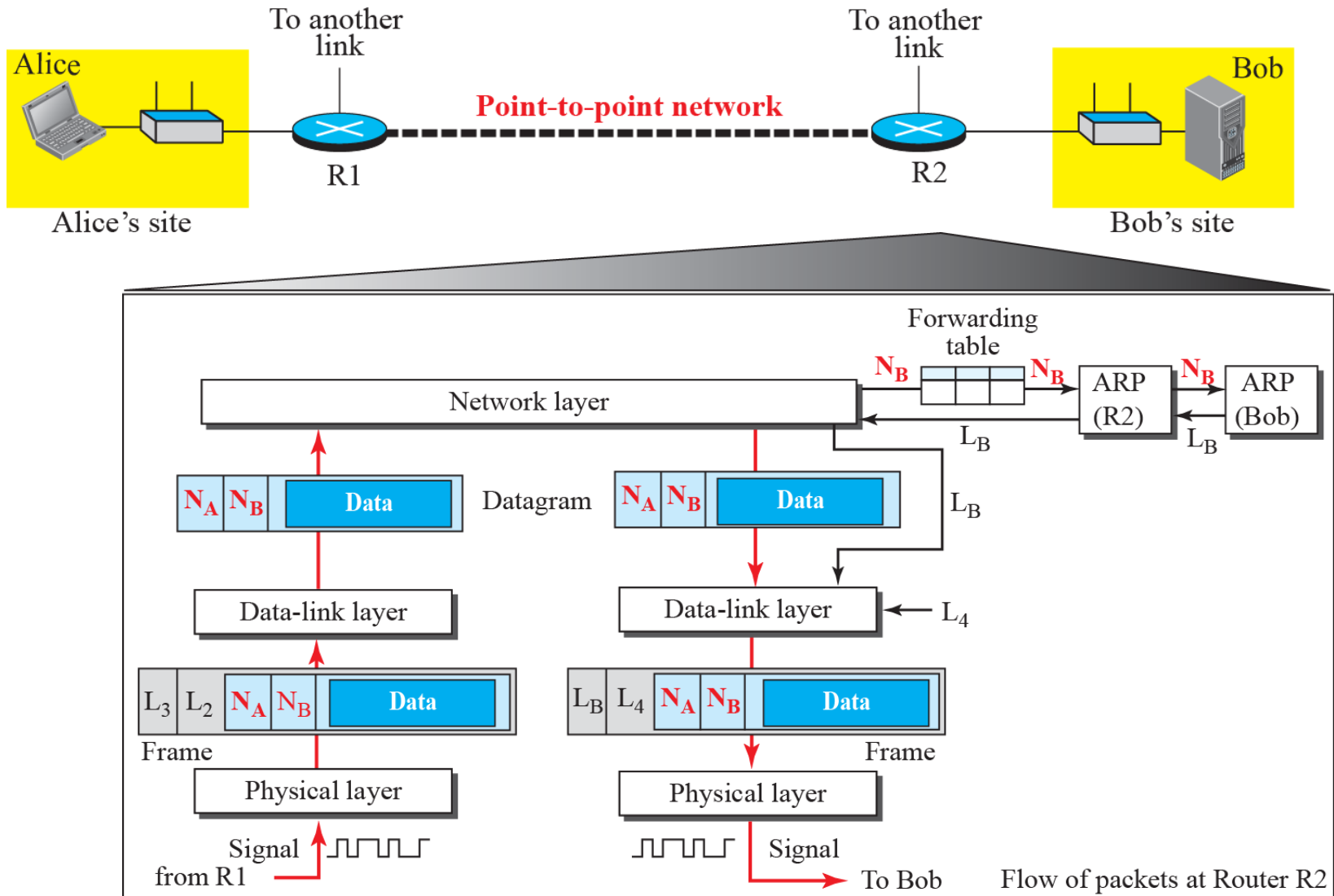# Figure 9.12: Flow of activities at router R1

Figure 9.13: Flow of activities at router R2

Figure 9.14: Activities at Bob's site

Flow of packets at Bob's computer