COMP 3721
Introduction to Data Communications

06b - Week 6 - Part 2

Learning Outcomes

- By the end of this lecture, you will be able to
  - Explain the services of the data-link layer.
  - Explain how the link-layer addressing work as well as being familiar with types of addresses.
  - Explain the purpose and functionality of ARP.

Introduction

- The Internet
  - Combination of **networks glued together** by connecting devices (routers or switches).
  - A packet traveling from a host to another host needs to **pass through these networks**.

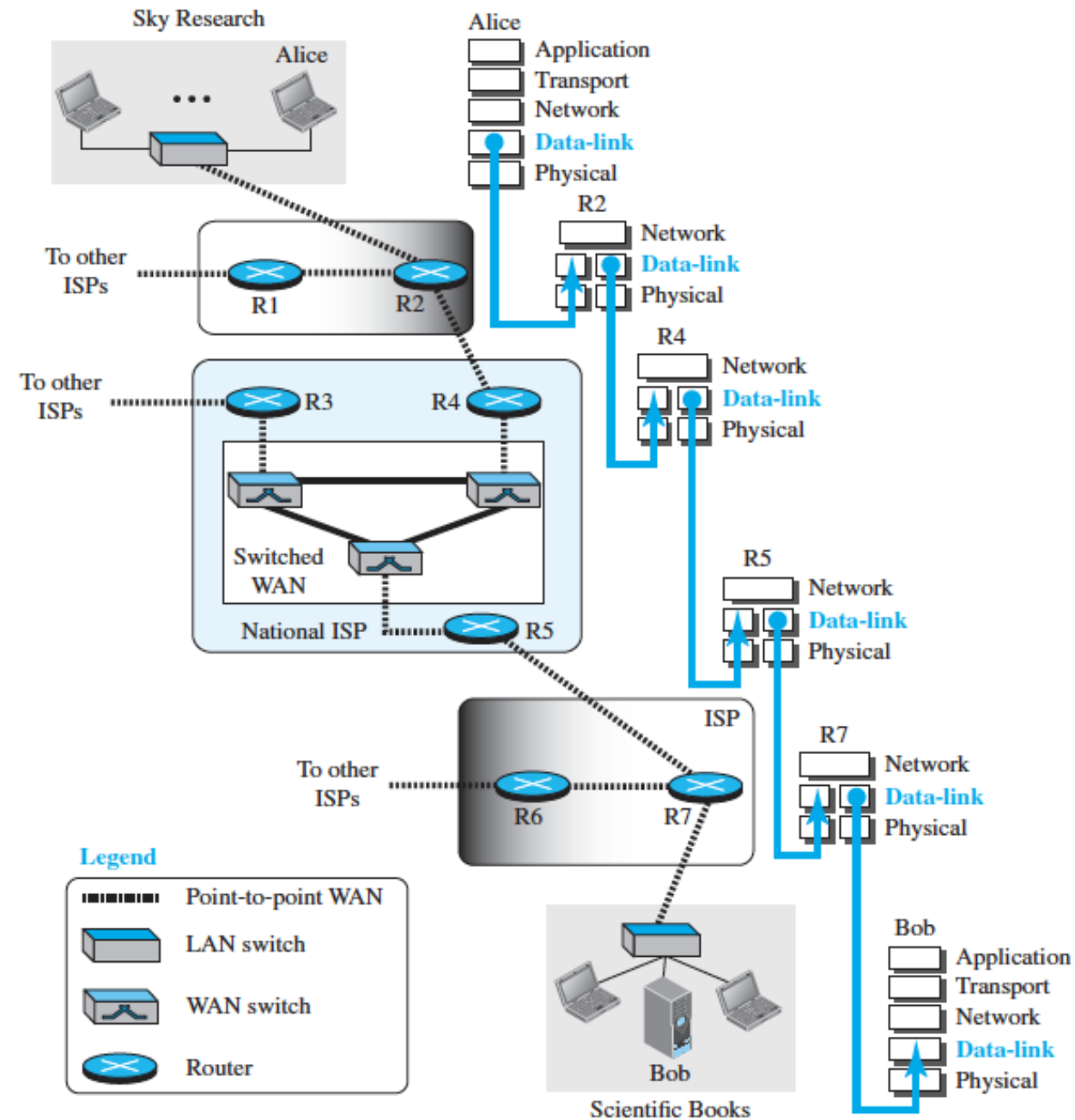# Node-to-Node Communication at the Data-Link Layer

Point-to-point network

Point-to-point network

LAN

LAN

LAN
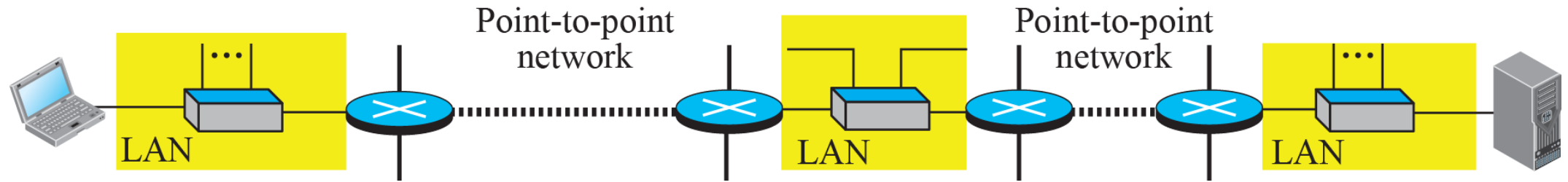
a. A small part of the Internet

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

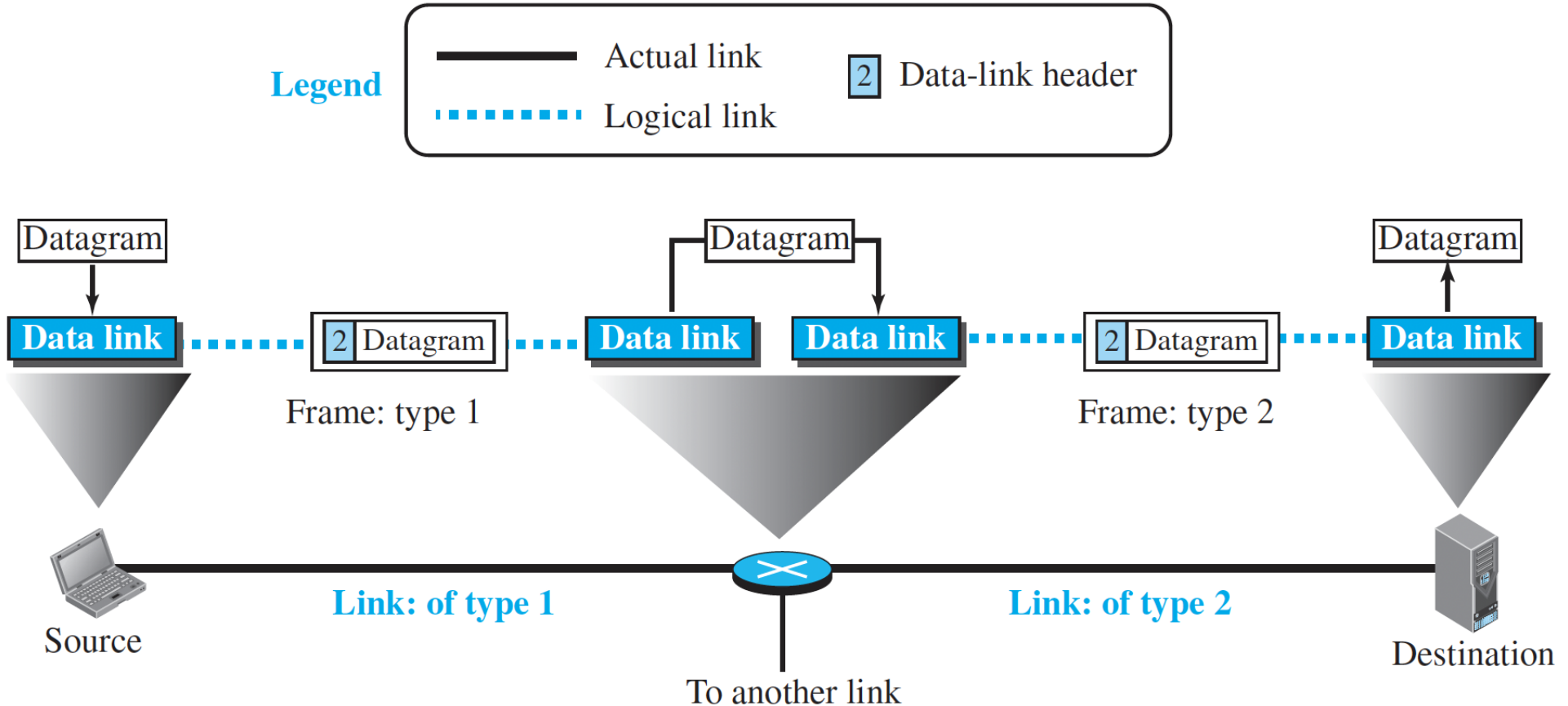Node Node Node Node Node Node

b. Nodes and links

Communication at the Data-Link Layer

Encapsulation and Decapsulation at the Data-Link Layer

A packet at the data-link layer is called a **frame.**

Encapsulation and Decapsulation at the Data-Link Layer

- Why we need encapsulation and decapsulation at each **intermediate node**?

Encapsulation and Decapsulation at the Data-Link Layer

- Why we need encapsulation and decapsulation at each **intermediate node**?

- **Two reasons**:
    1. Each link may be using a **different protocol** with a **different frame format**.
    2. Even if one link and the next are using the same protocol, encapsulation and decapsulation are needed because the link-layer **addresses are normally different**.

Services

- The data-link layer is located between the physical layer and the network layer.
  - Provides services to the network layer
  - Receives services from the physical layer

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  - Receives services from the physical layer
- Services **provided** by the data-link layer
  1. **Framing** → Encapsulating the datagram in a frame before sending it to the next node
  2. **Flow control** → Controlling the rate of producing frames w.r.t. the rate of consumed frames
  3. **Error control** → Error detection and correction
  4. **Congestion control**

Two Sublayers

- We can divide the data-link layer into two sublayers:

1. **Data Link Control** (**DLC**)
   - Deals with issues common to both **point-to-point** (dedicated) and **broadcast** (shared) links.
   - Services: framing, flow control, and error control.

2. **Media Access Control** (**MAC**)
   - Deals only with issues specific to **broadcast** (shared) links.

a. Data-link layer of a broadcast link
b. Data-link layer of a point-to-point link
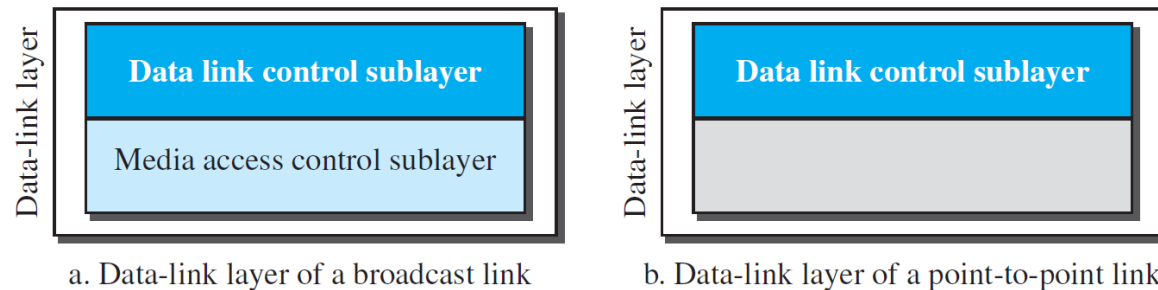
Link-Layer Addressing

- Why do we need link-layer addressing?

Link-Layer Addressing

- Why do we need link-layer addressing?

- The source and destination **IP addresses** in the header of a datagram **define the two ends** but cannot define which links the datagram should pass through.

- The datagram (coming from the network layer) 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 (Cont.)

- **Link-layer address** = **Physical address** = **MAC** (**Media Access Control**) **address**

- In the most common LAN, Ethernet, MAC addresses are **48 bits** (6 bytes) and are presented as **12 hexadecimal digits** separated by colons.

MAC
Media Access Control Address

| 00 | 1A | 3F | F1 | 4C | C6 |
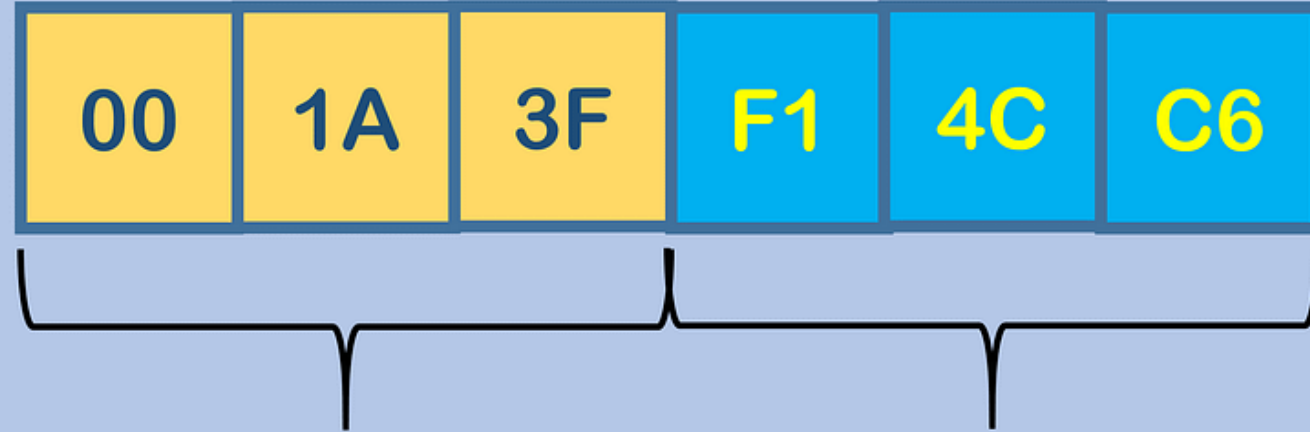
Organizationally Unique Identifier   Universally Administered Address

MAC Address Lookup

Find the vendor name of a device by entering an OUI or a MAC address

| MAC | F01FC7 | 🔍 |

Check an OUIs or a MAC address and display details like vendor name, location, MAC details, and more...

Search by Vendor Name?

Apple, Inc.

Vendor | Details

OUI: **F0:1F:C7**

Vendor name: **Apple, Inc.** 🔗

Address:

1 Infinite Loop
Cupertino CA 95014
US.

Assignment Type **MA-L**

Mac Address Block Large (previously named OUI). Number of address 2^24 (~16 Million)

Initial registration: **28 April 2022**

Switch as a Layer 2 Device

- A **link-layer switch** is involved only in two layers, data-link and physical.

- A switch connects devices within a network. Unlike a router, a **switch** only sends data **to the single device it is intended for** (which may be another switch, a router, or a user's computer), not to networks of multiple devices.

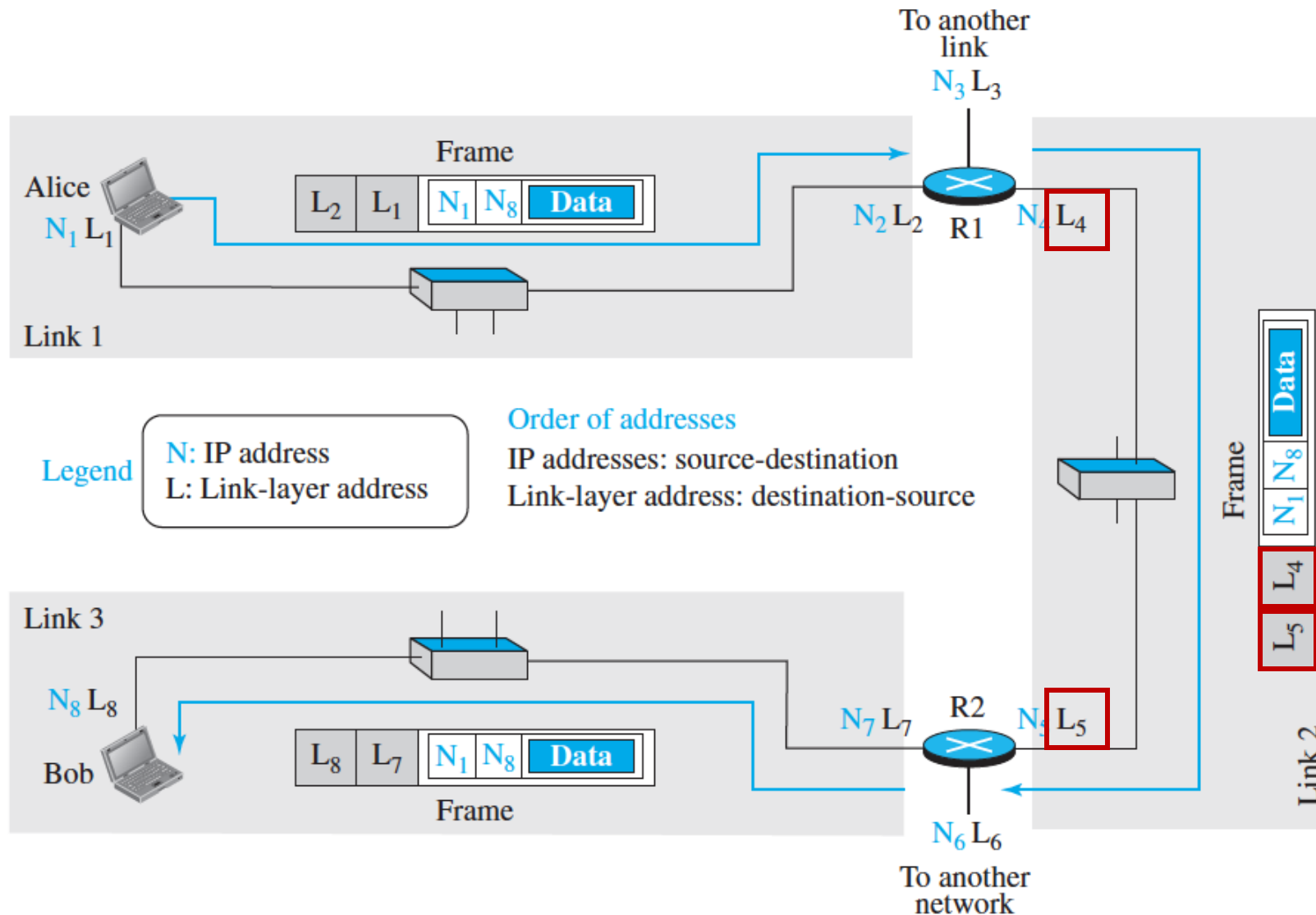- Most switches, are layer 2 switches (we also have layer 3 switches, but they are less common).
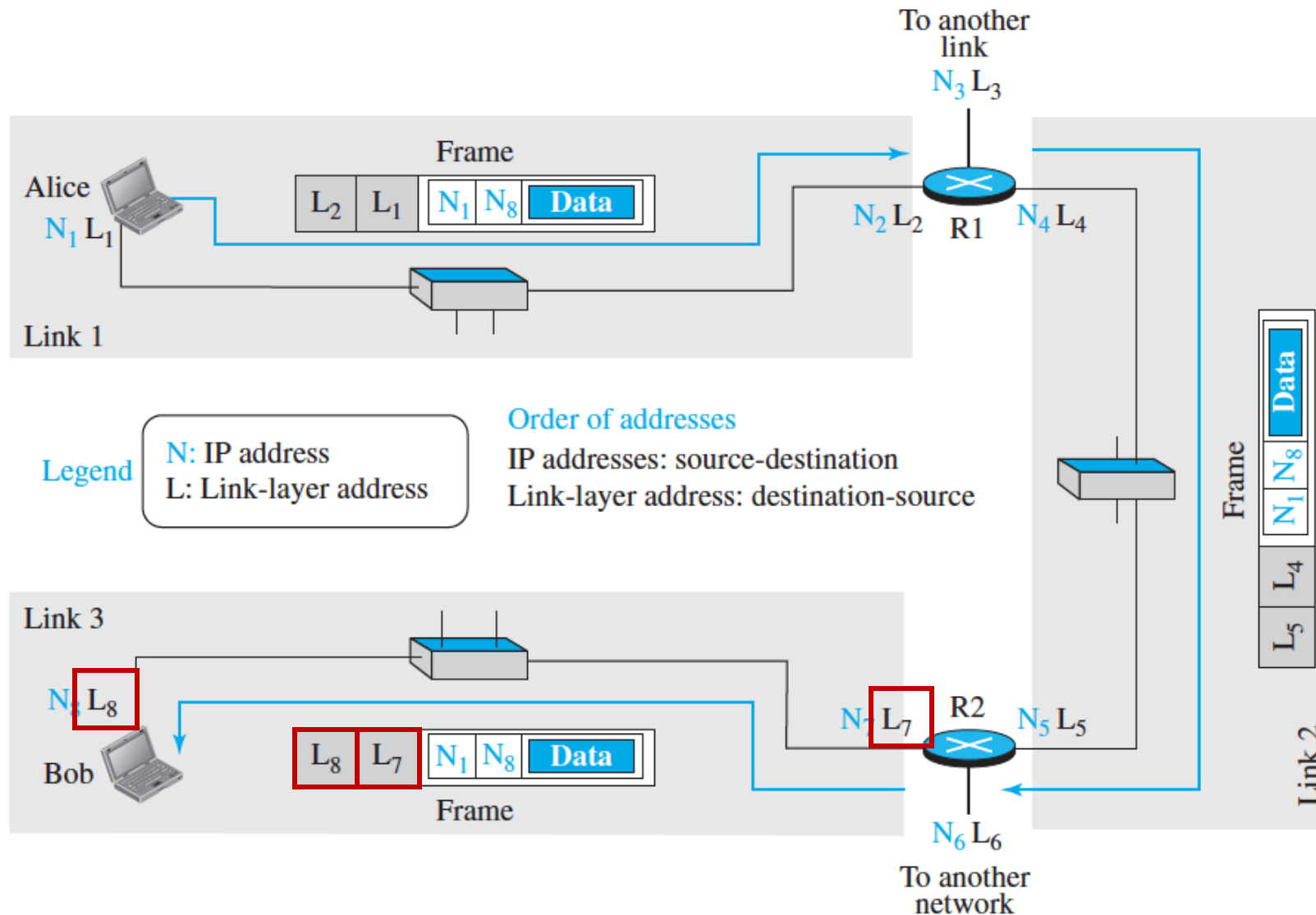
IP Addresses and Link-Layer Addresses in a Small Internet
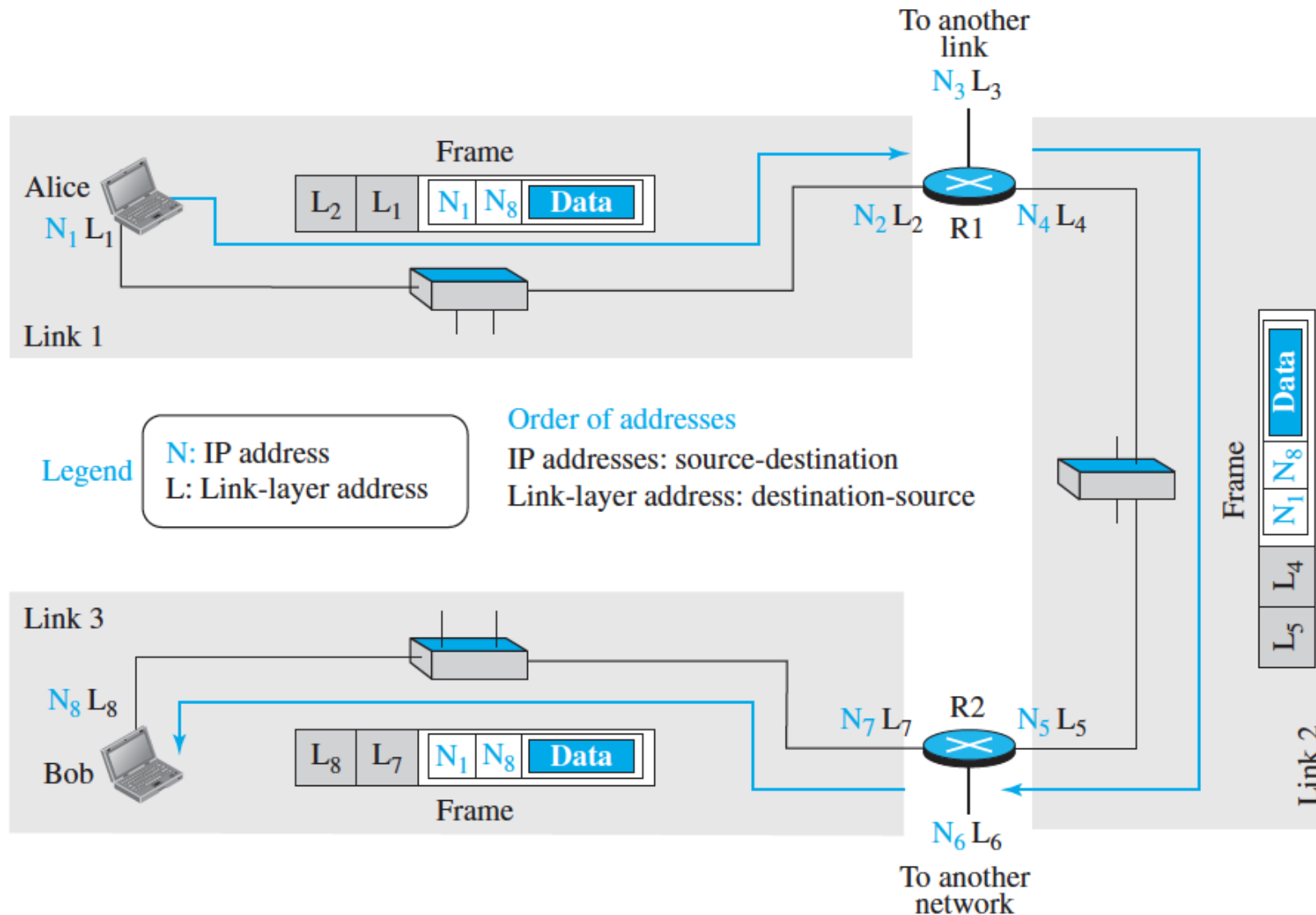
IP Addresses and Link-Layer Addresses in a Small Internet
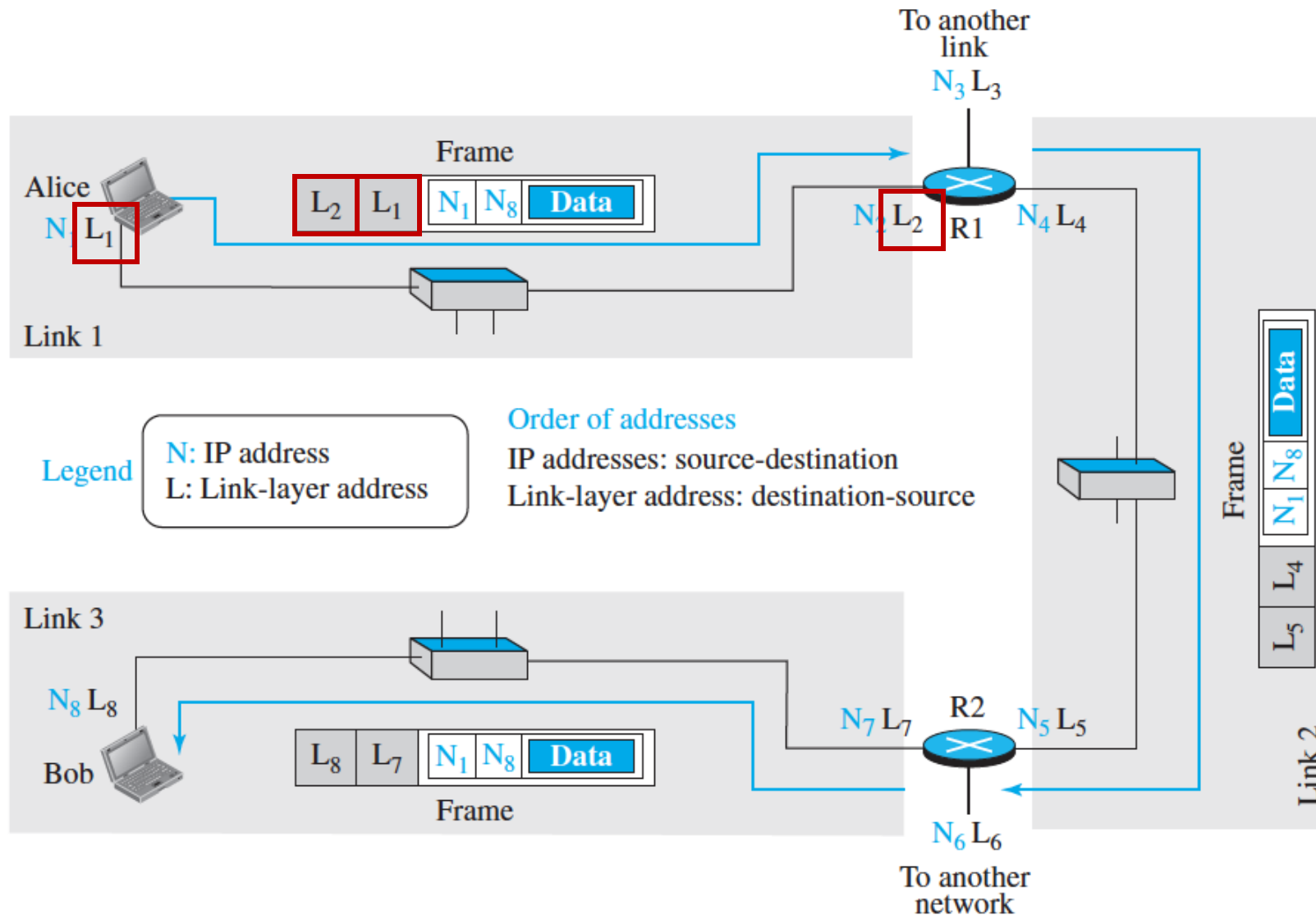
IP Addresses and Link-Layer Addresses in a Small Internet

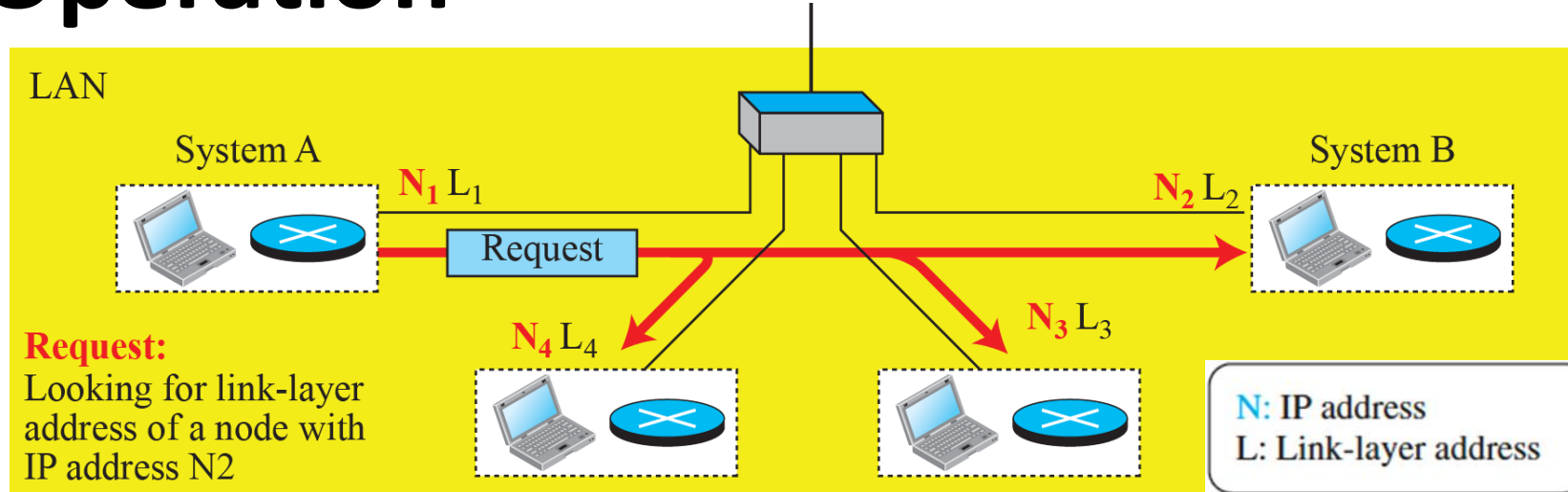# IP Addresses and Link-Layer Addresses in a Small Internet

Address Resolution Protocol (ARP)

- Consider the previous example for communication between Alice and Bob.

- How does each node acquire the MAC address of the next node on the path from source to destination?

Address Resolution Protocol (ARP)

- Useful when moving a frame through a link.

- One of the auxiliary protocols defined in the network layer.

- It maps an **IP address** to a **logical-link address**.

- A host or a router need to run the ARP program all of the time in the background.
  - A host does not know when another host sends an ARP request; it needs to be ready all of the time to respond to an ARP request.
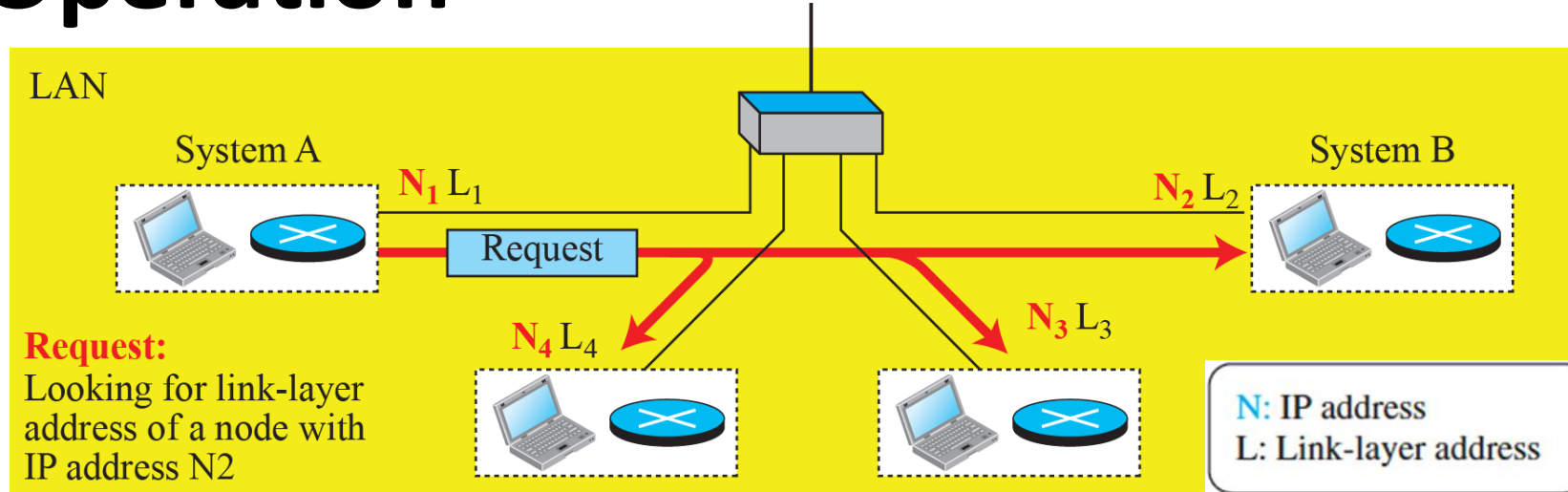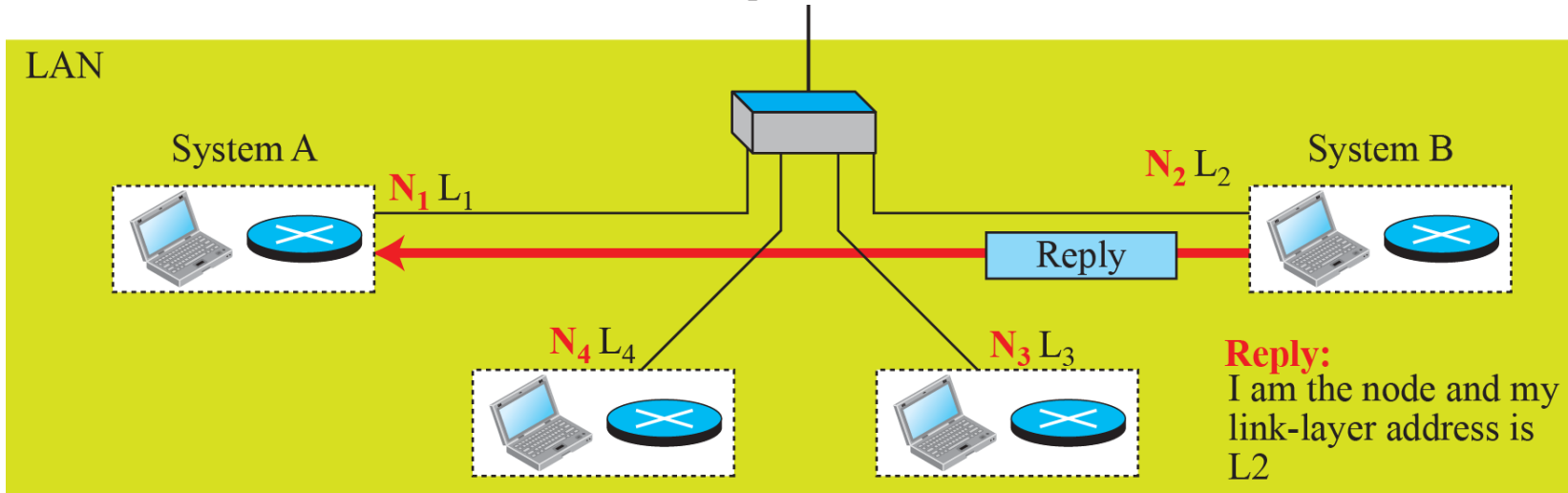
ARP Operation

a. ARP request is broadcast

ARP Operation

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

N: IP address
L: Link-layer address

a. ARP request is broadcast

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

b. ARP reply is unicast

ARP Packet Format

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			

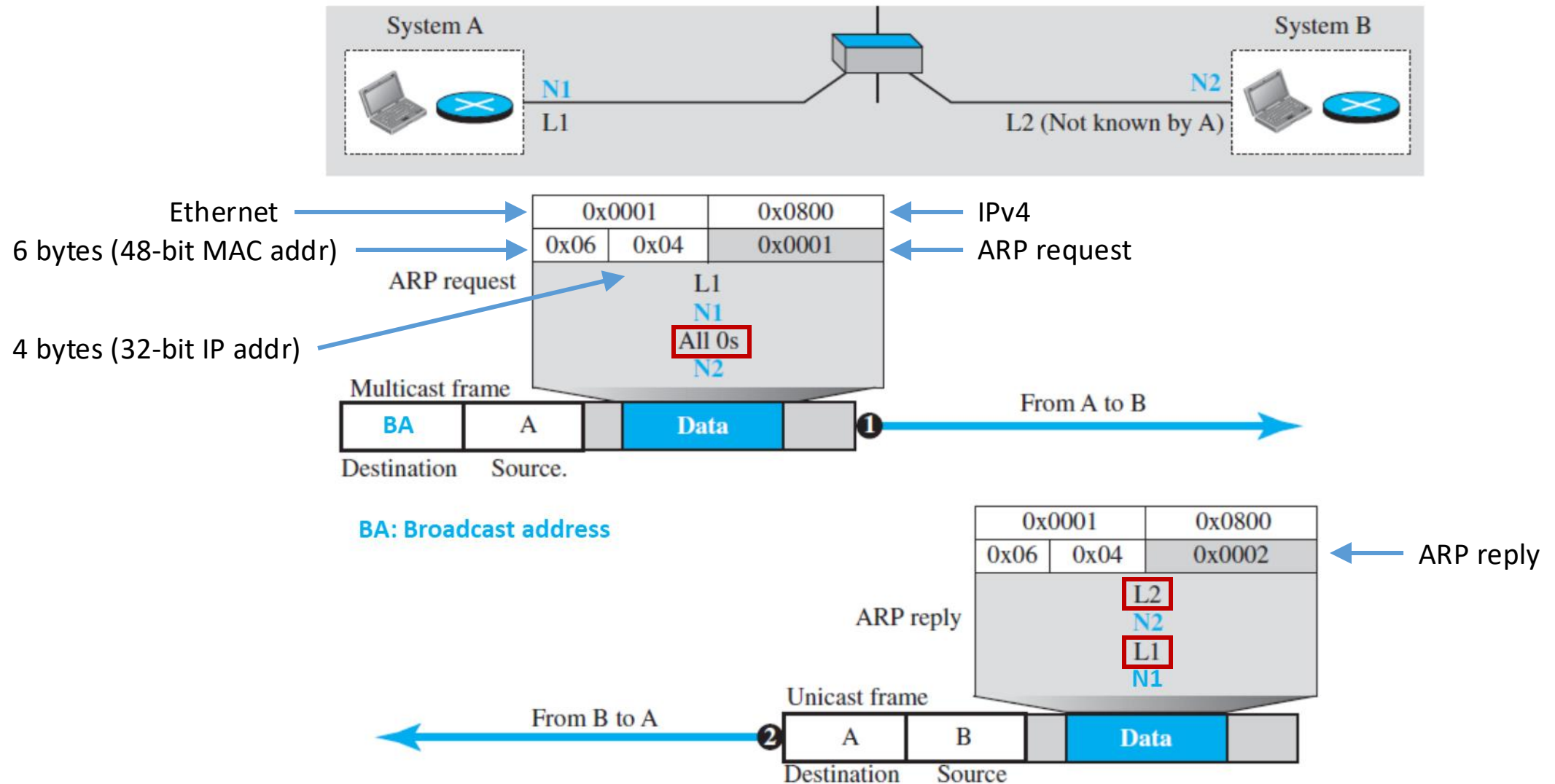# Example of ARP Request and Response Messages
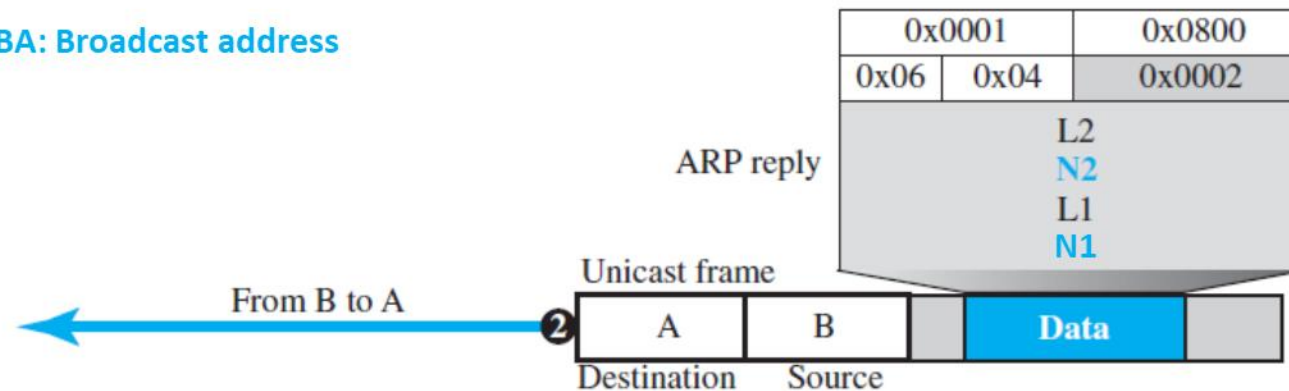
# Example of ARP Request and Response Messages

Example

- Assume Alice needs to send a datagram to Bob, who is three nodes away on the Internet. Assume that Alice knows the network-layer (IP) address of Bob (i.e., N_B). Also, Alice's host knows its own IP address (i.e., N_A) and its MAC address (i.e., L_A). Explain/show the activities for communication at the data link layer at each node.
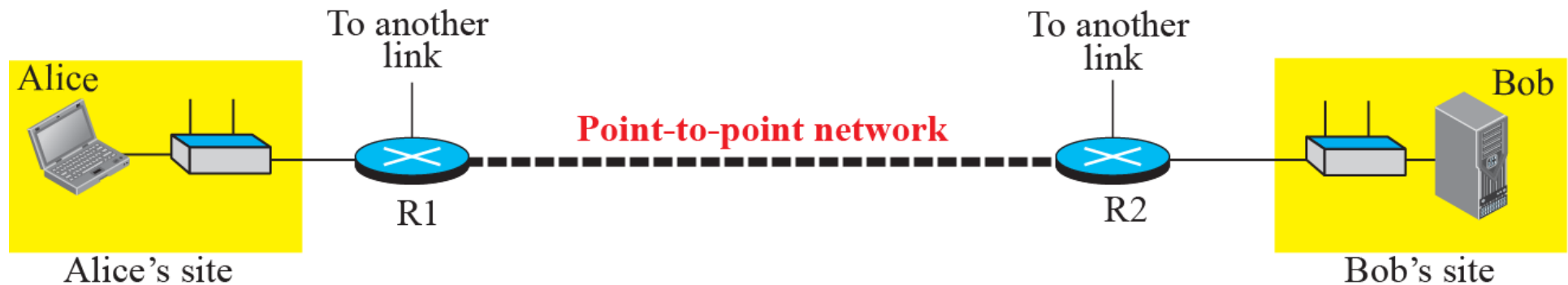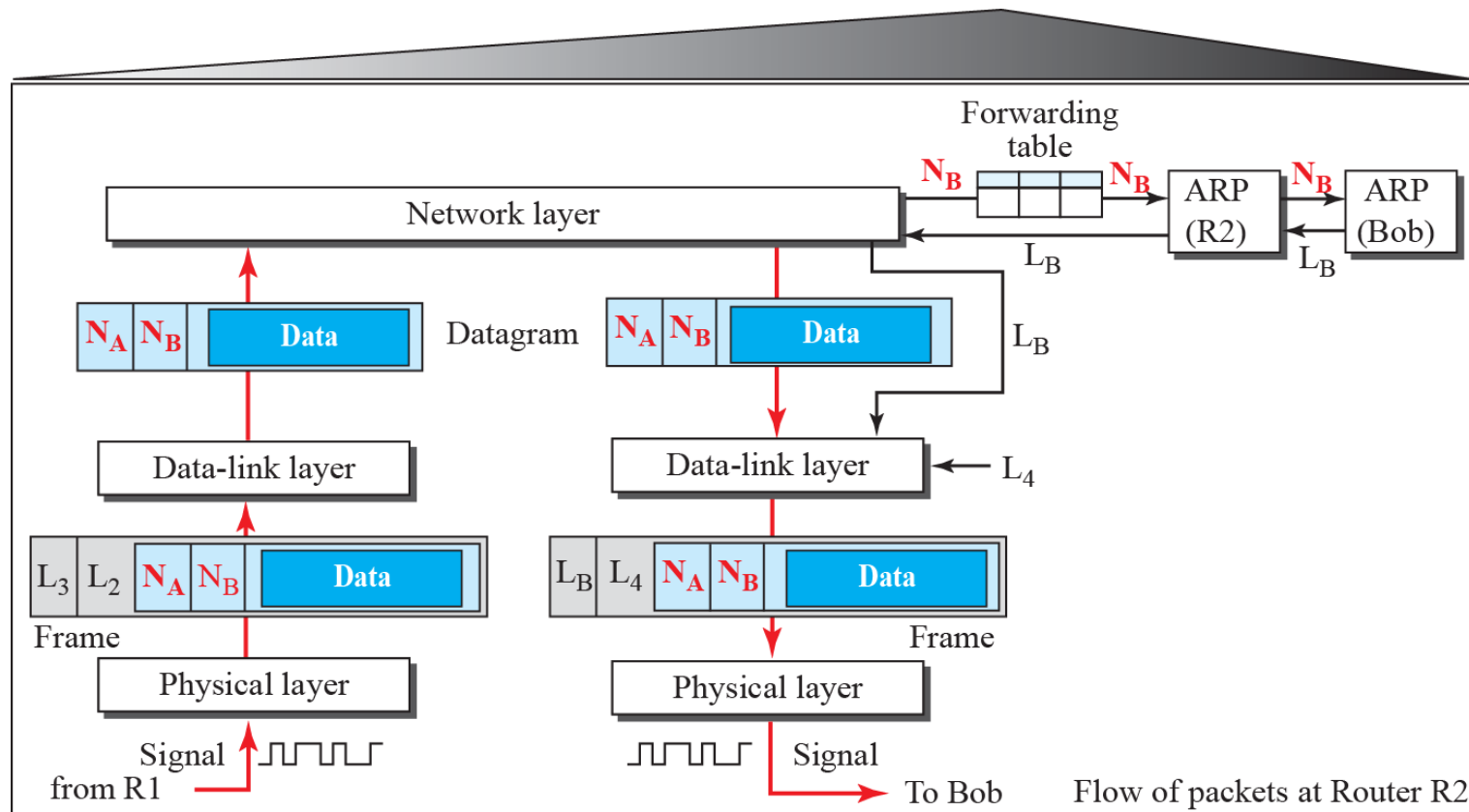
Activities at Alice's Site
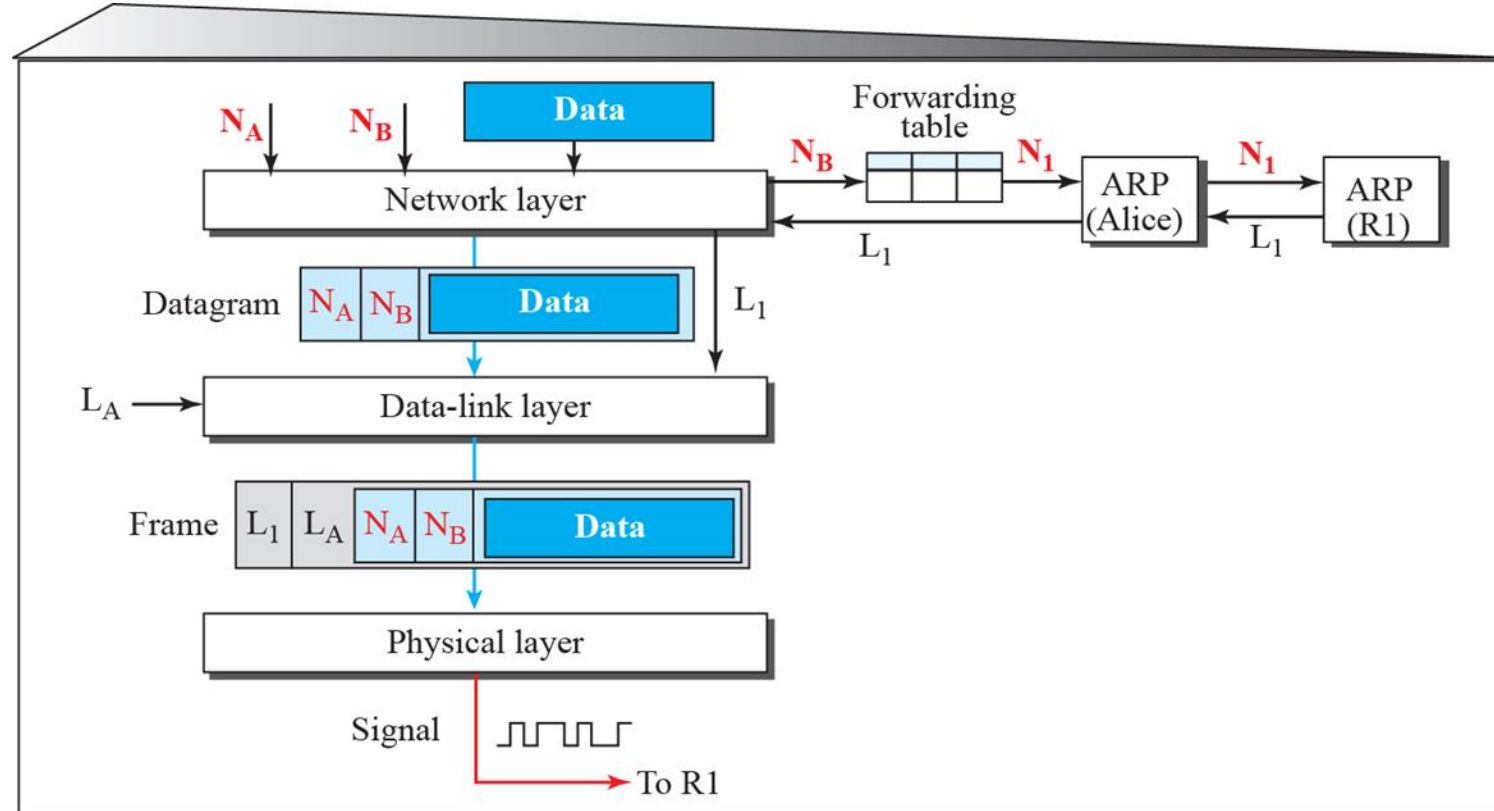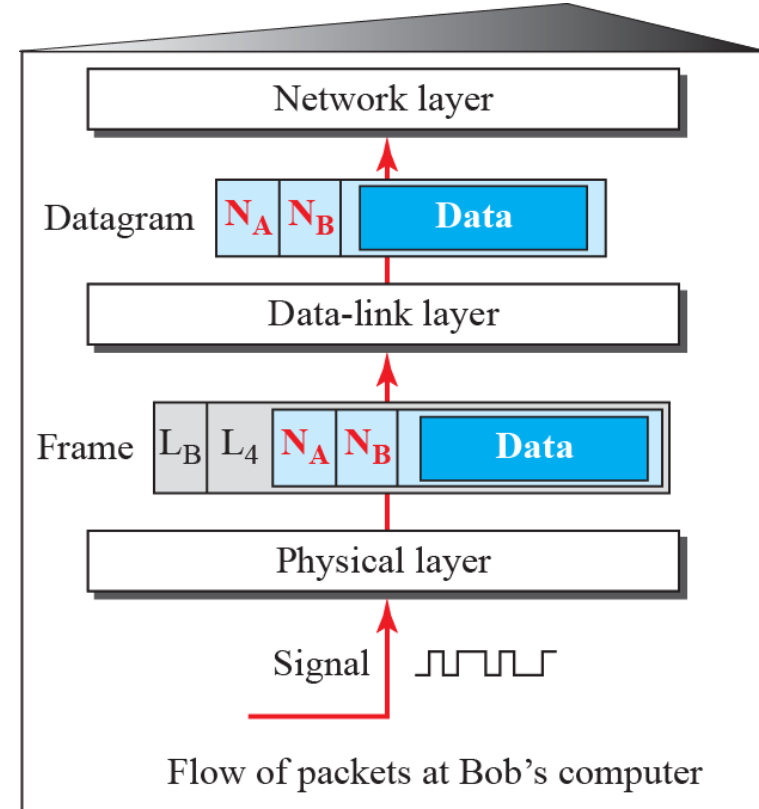
Activities at Router R1
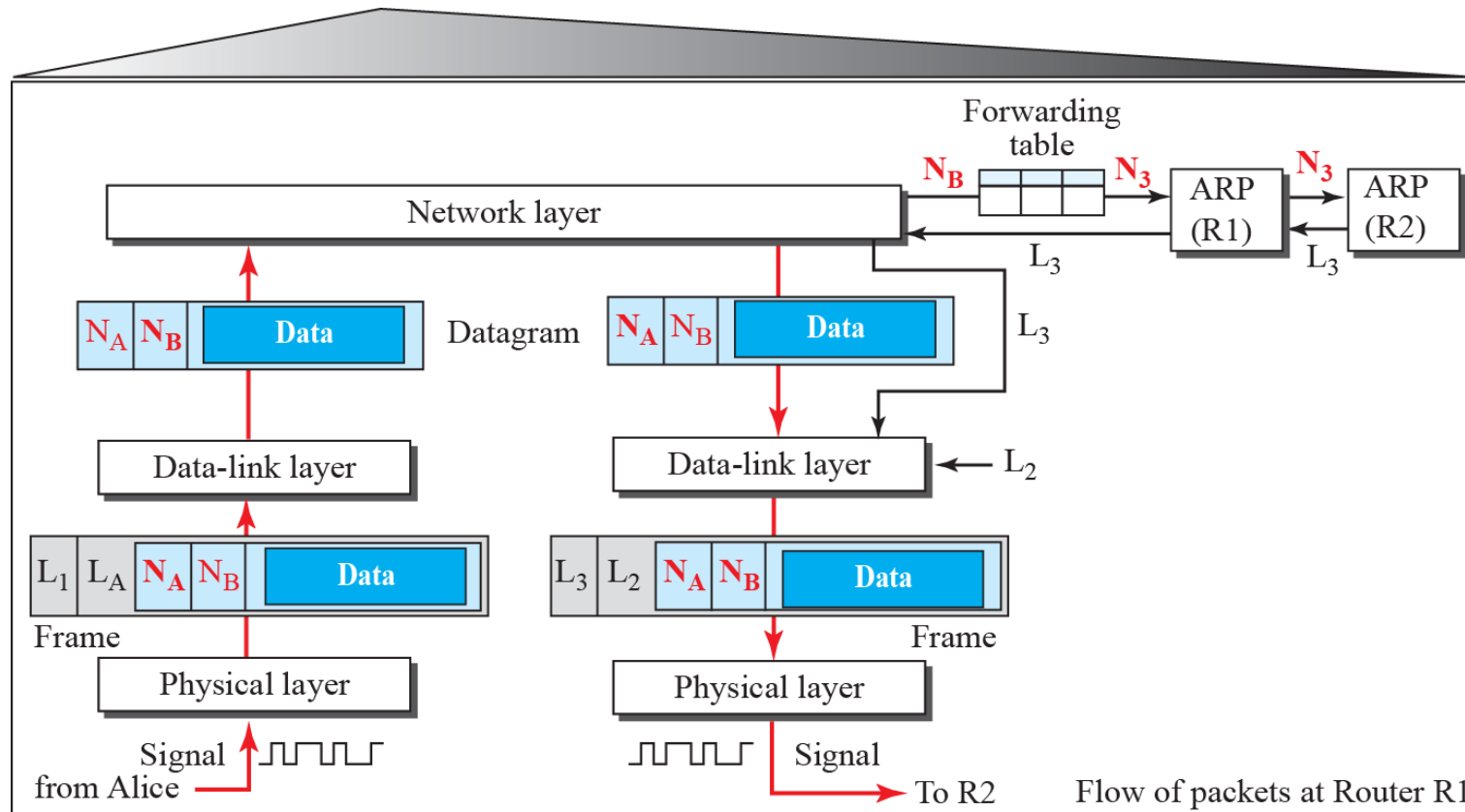
Activities at Router R2

Activities at Bob's Site

Note that the source and destination **network-layer addresses**, N_A and N_B, have **not been changed** during the whole journey.

Summary

- The data-link layer is responsible for:
  - The creation and delivery of a frame to another node, **along the link**
  - Packetizing (framing)
  - Flow control and error control **along the link**
  - Controlling access to the link
- Link-layer addressing
- ARP to map IP addresses to MAC addresses

References

[1] Behrouz A.Forouzan, Data Communications & Networking with TCP/IP Protocol Suite, 6th Ed, 2022, McGraw-Hill companies.

Reading

- Chapter 3 of the textbook, sections 3.1 and 3.4
- Chapter 3 of the textbook, section 3.6 (Practice Test)