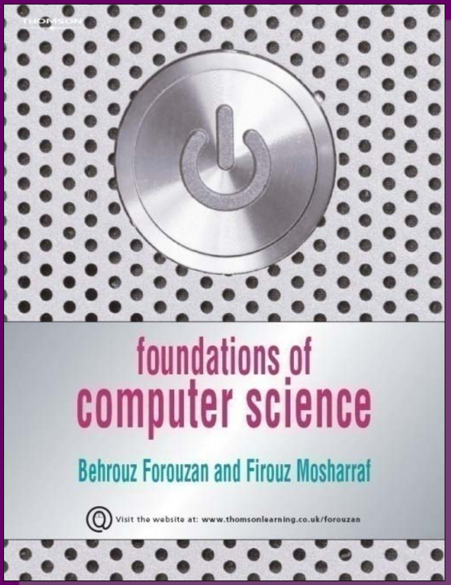


6
Computer Networks

Objectives

After studying this chapter, the student should be able to:

- ❑ **Describe network criteria, physical structures and categories of networks.**
- ❑ **Describe the TCP/IP protocol suite as the network model in the Internet.**
- ❑ **Define the layers in the TCP/IP protocol suite and their relationship.**
- ❑ **Discuss the client-server architecture of the Internet.**
- ❑ **Describe the three early applications of the Internet:**
- ❑ **Understand the World Wide Web as the most common application of the Internet and its components.**
- ❑ **Distinguish between three Internet document types: static, dynamic and active.**

6-1 INTRODUCTION

A **network** is a combination of hardware and software that sends data from one location to another.

The hardware consists of the physical equipment that carries signals from one point in the network to another.

The software consists of instructions that make the services that we expect from a network possible.

Network criteria

A network must be able to meet a number of criteria. The most important of these are performance, reliability, and security.

1. **Performance** can be measured in many ways, including transit time and response time.

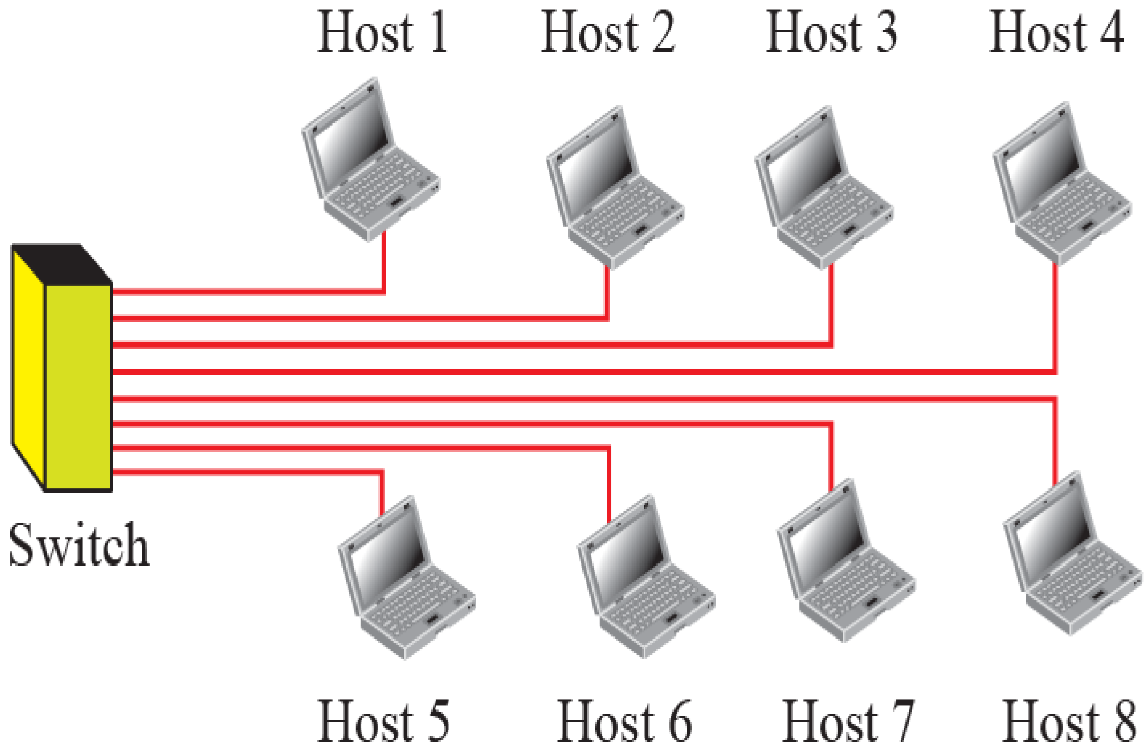
2. **Reliability** is measured by the frequency of failure, the time it takes to recover from a failure, and the network's robustness in a catastrophe.

3. **Network security** issues include protecting data from unauthorized access, damage and change, and implementing policies and procedures for recovery from breaches and data losses.

Local area network (LAN)

A **LAN** is usually privately owned and connects some hosts in a single office, building, or campus.

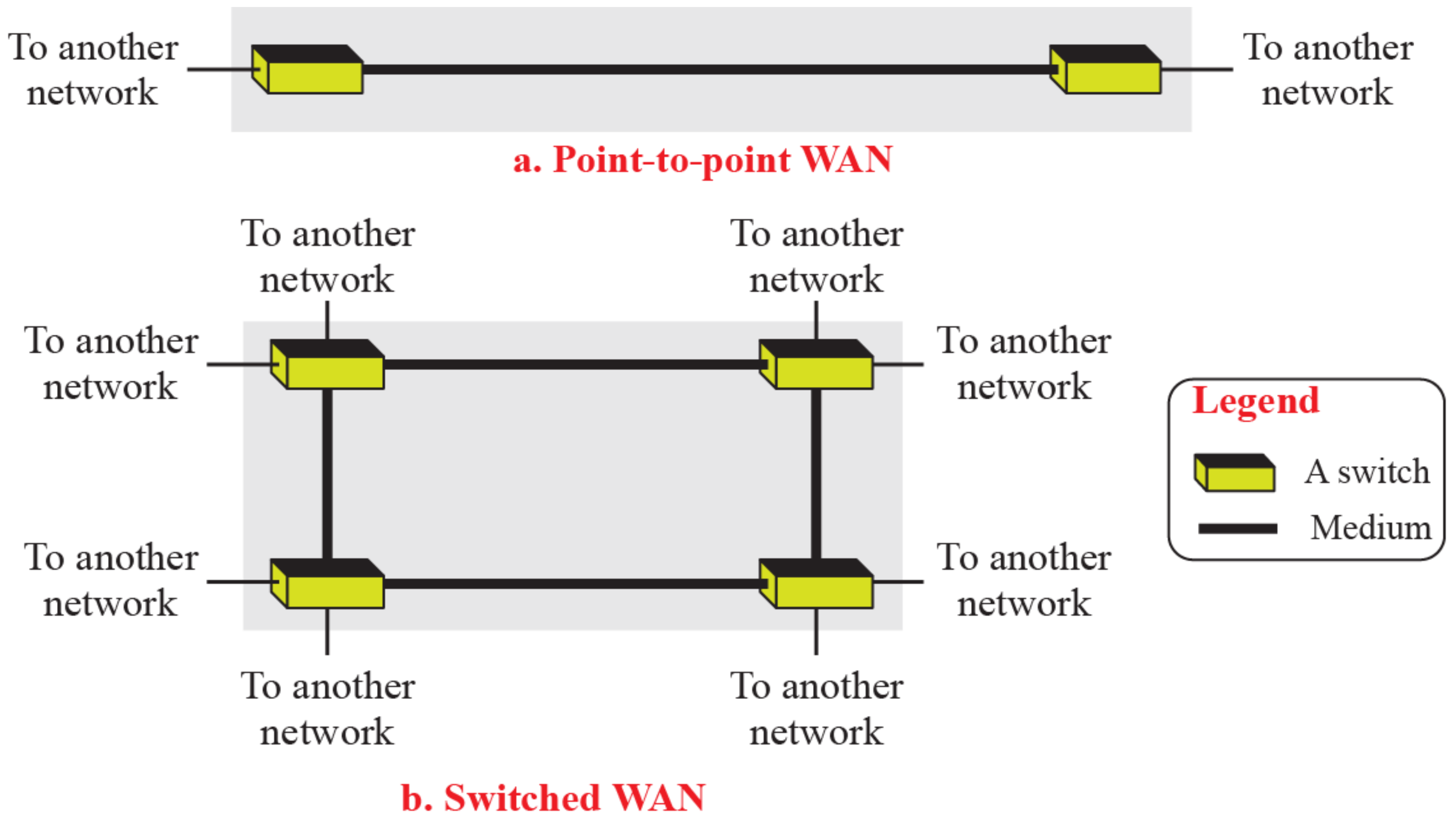
Figure 6.1: Example of a LAN



Wide area network (WAN)

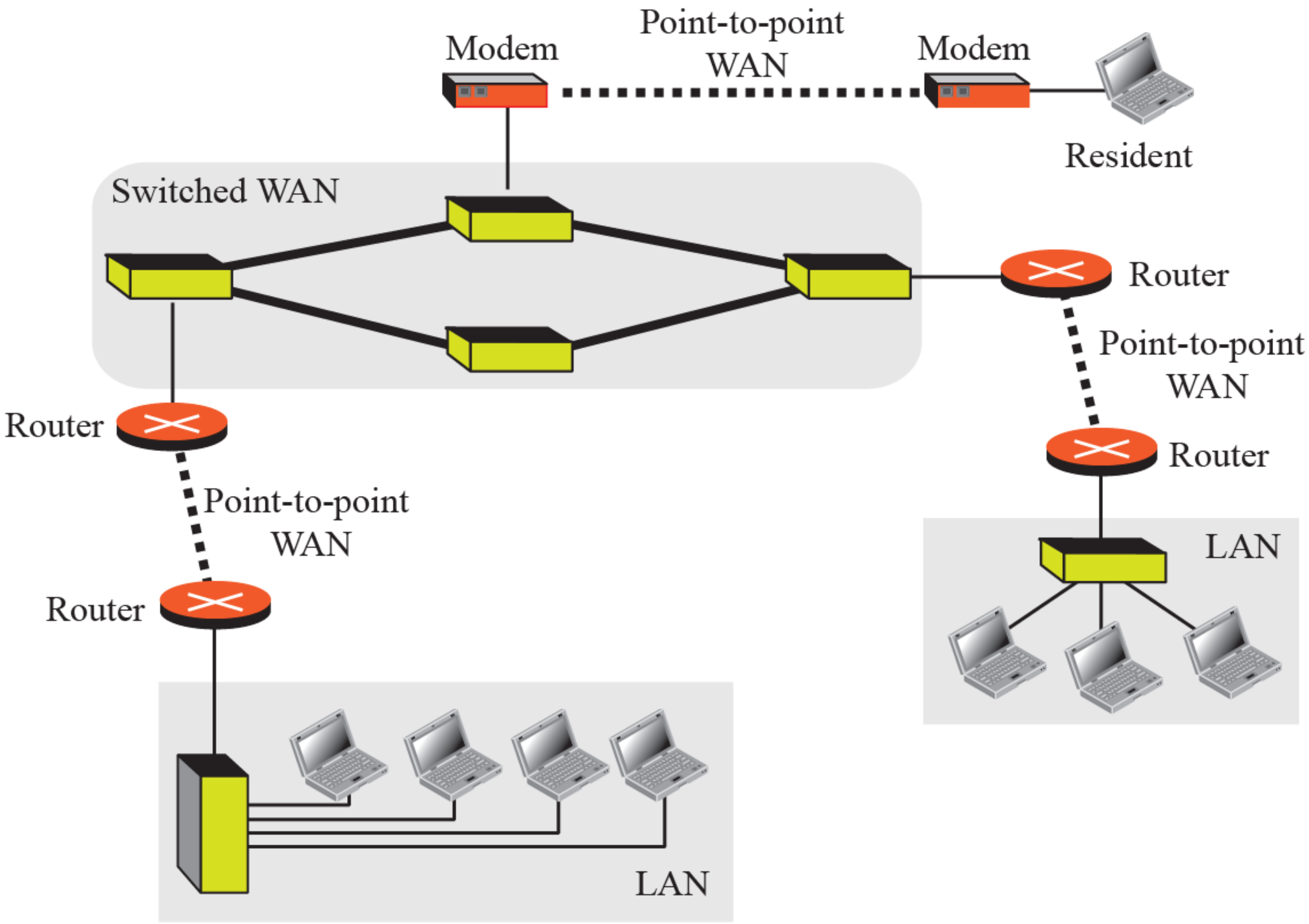
Point-to-point WANs and switched WANs as shown in Figure 6.2.

Figure 6.2: A point-to-point and a switched WAN



Internetwork

Figure 6.3: An Internetwork made of LANs and WANs



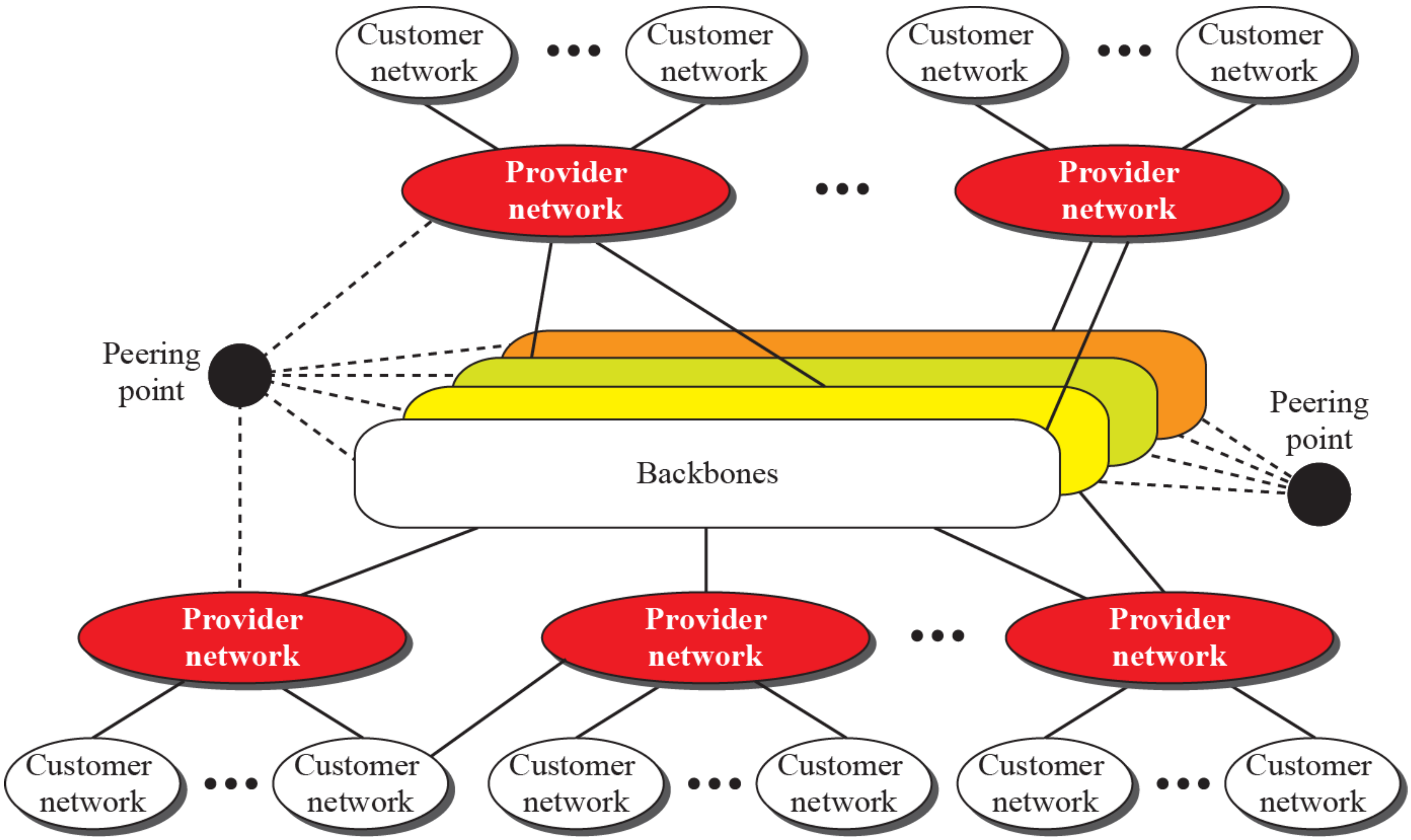
The Internet

The most notable internet is the **Internet** (uppercase "I"), a collaboration of hundreds of thousands of interconnected networks.

Private individuals, as well as various organizations such as government agencies, schools, research facilities, corporations and libraries in more than 100 countries use the Internet.

Today, most end users who want an Internet connection use the services of **Internet service providers (ISPs)**.

Figure 6.4: The Internet today

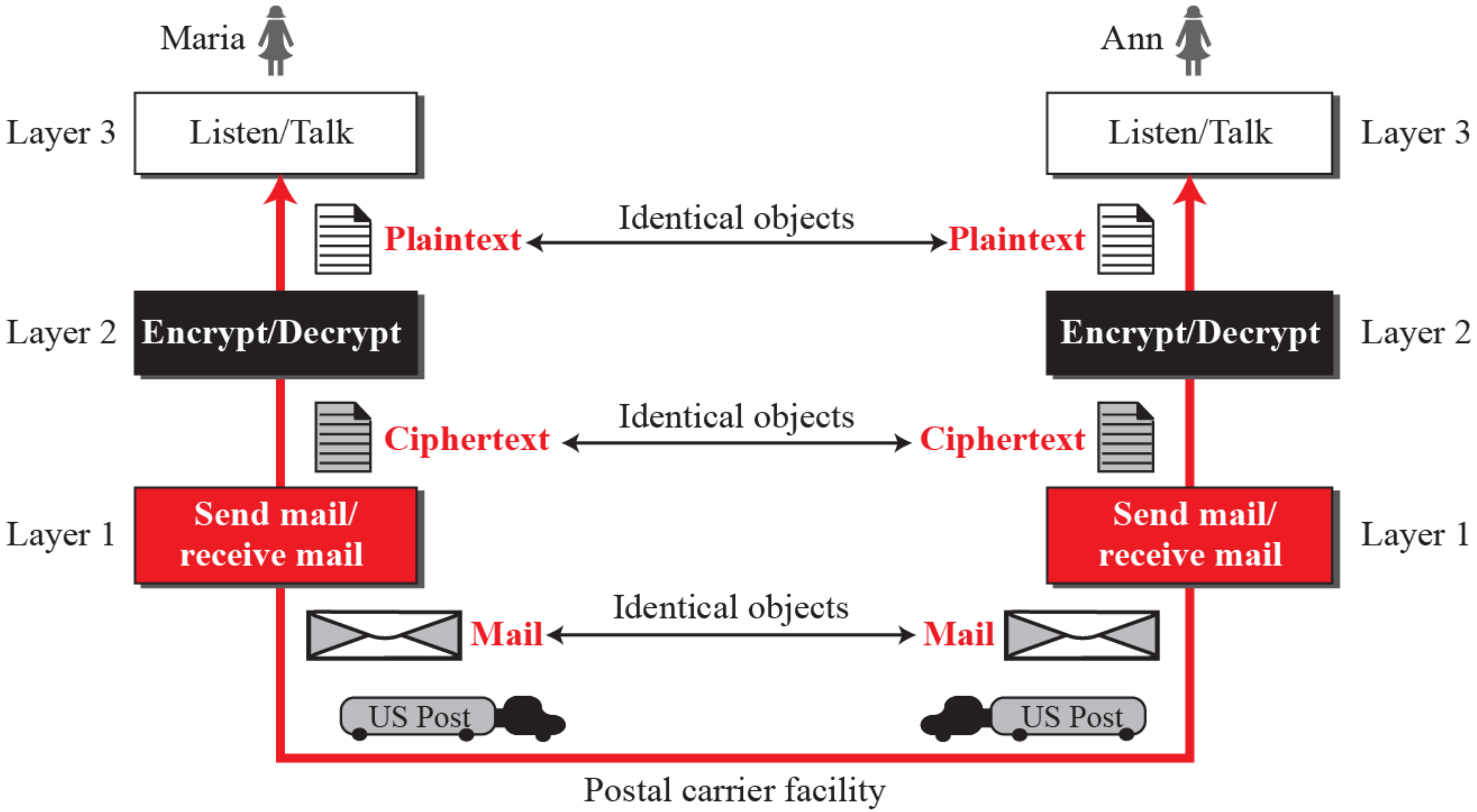


Protocol layering

A **protocol** defines *the rules* that both the sender and receiver and all intermediate devices need to follow to be able to communicate effectively.

A scenario

Figure 6.5: A three-layer protocol

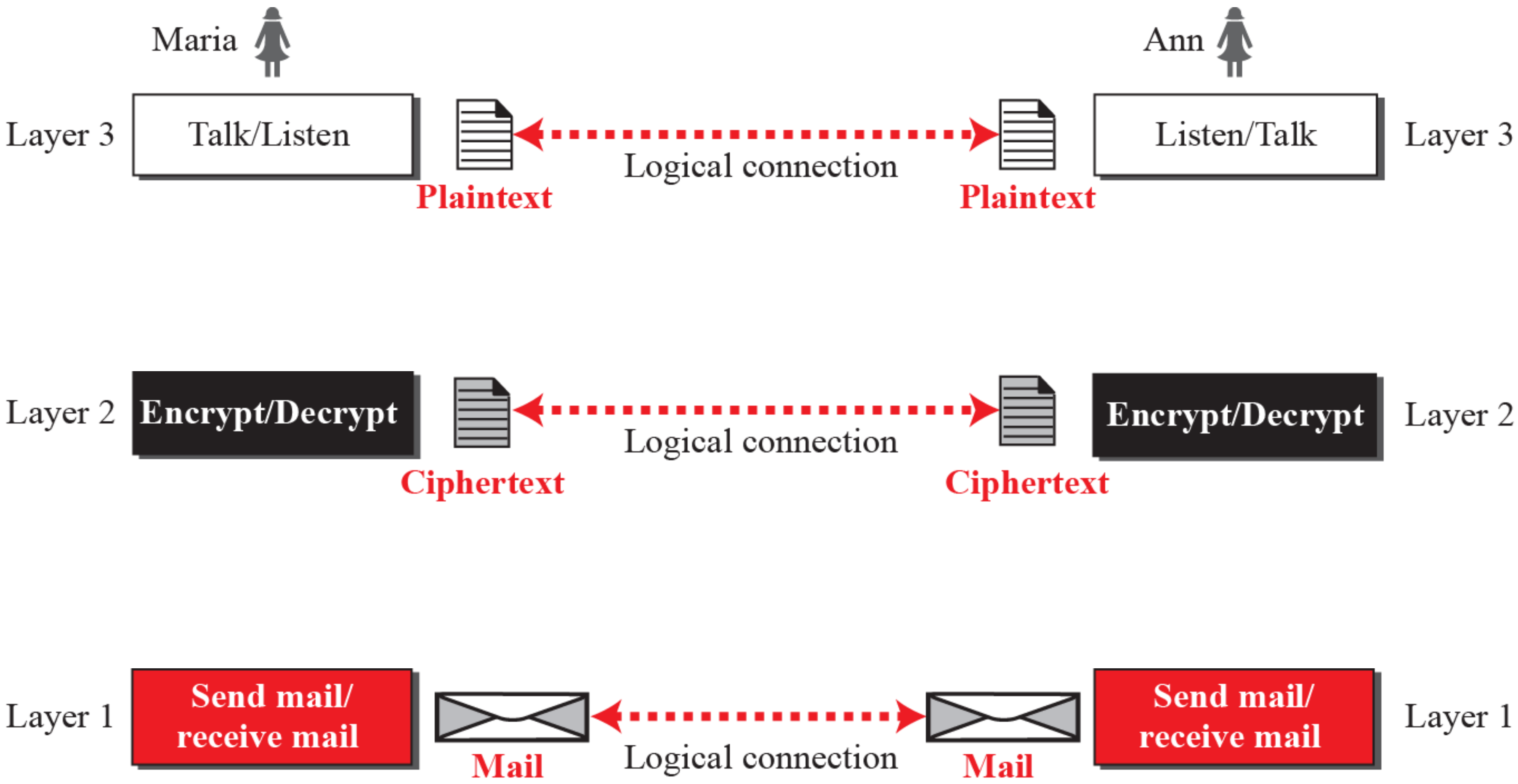


Principles of protocol layering

Logical connections

About logical connection between each layer as shown in Figure 6.6. This means that we have layer-to-layer communication.

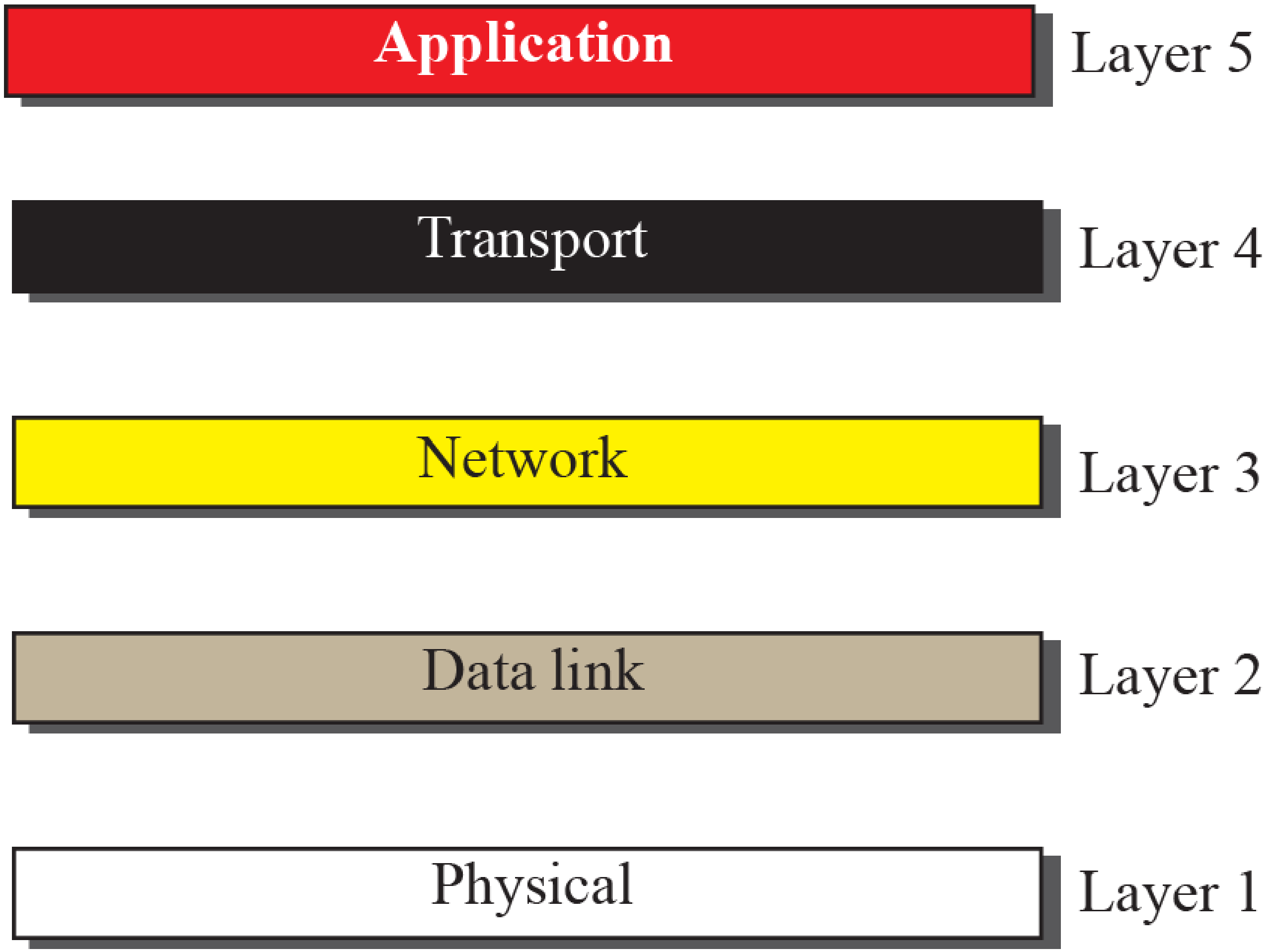
Figure 6.6: Logical connection between peer layers



TCP/IP (Transmission Control Protocol/Internet Protocol) protocol suite

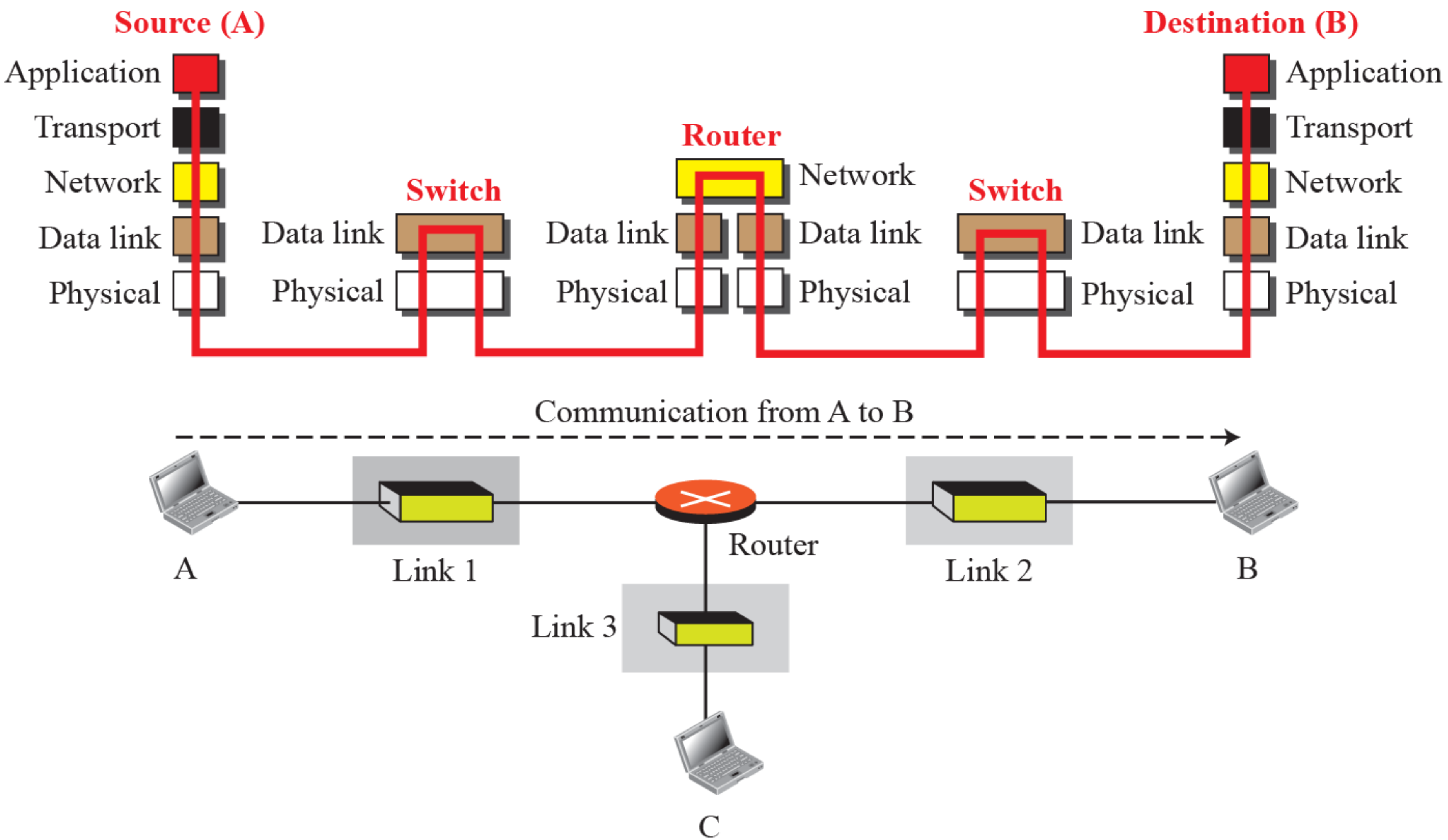
TCP/IP is a protocol suite (a set of protocols organized in different layers) used in the Internet today.

Figure 6.7: Layers in the TCP/IP protocol suite



Layered architecture

Figure 6.8: Communication through an internet

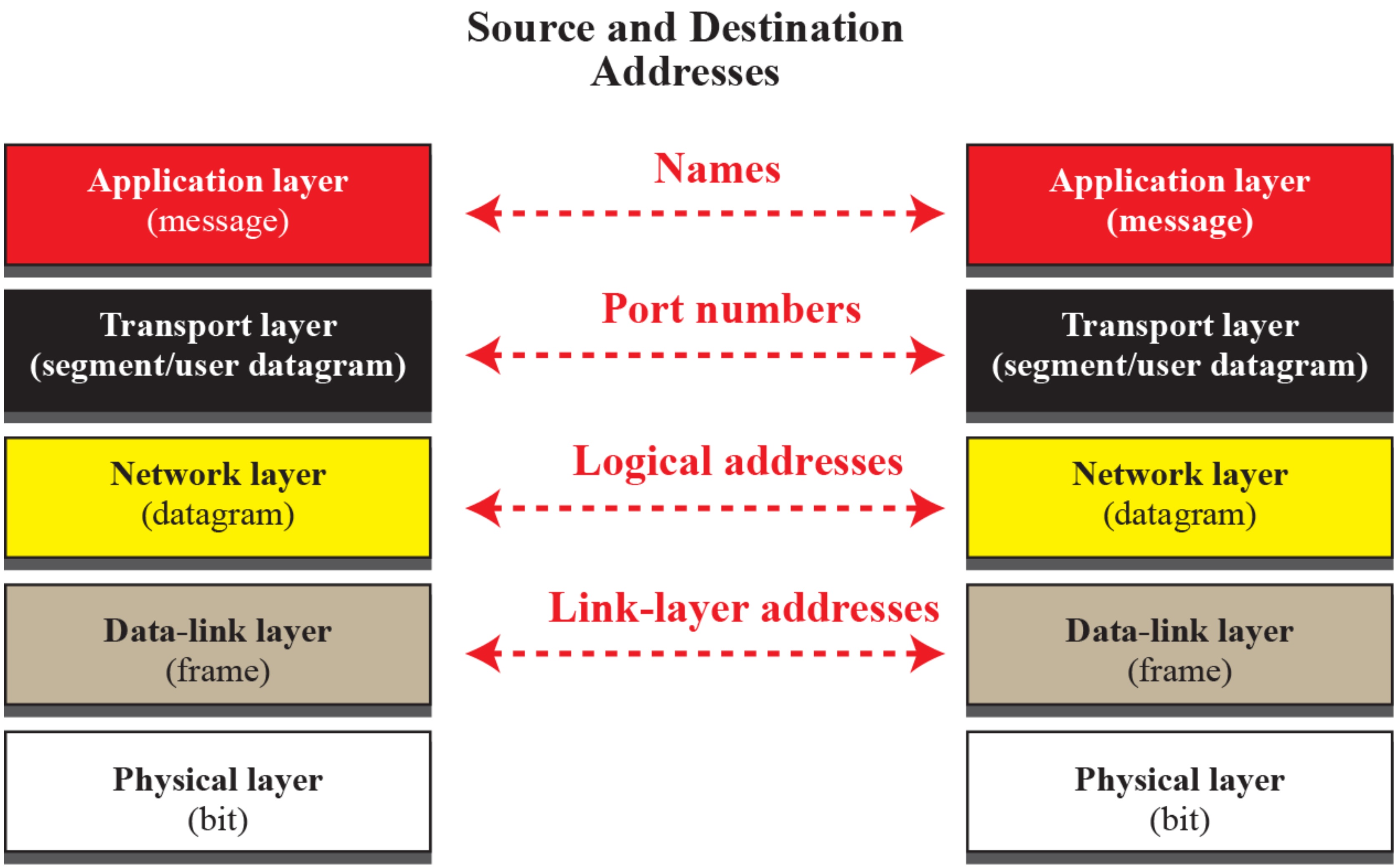


Addressing and packet names

It is worth mentioning another two concepts related to protocol layering in the Internet, addressing and packet names.

Any communication that involves two parties needs two addresses: *source address* and *destination address*.

Figure 6.9: Addressing and packets names in TCP/IP

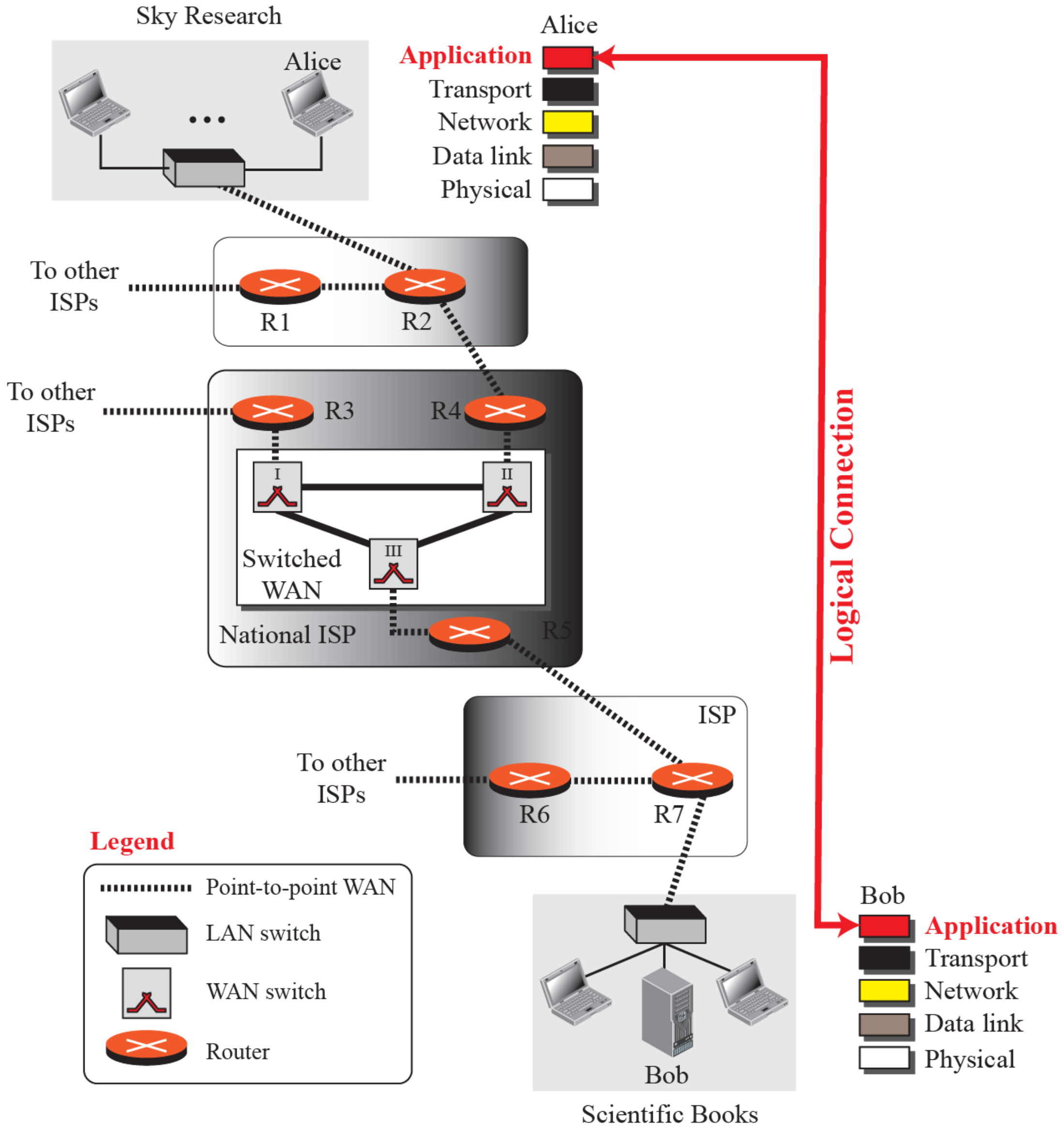


6.2 APPLICATION LAYER

The fifth layer of the TCP/IP protocol is called the application layer.

The application layer provides services to the user. Communication is provided using a logical connection.

Figure 6.10: Logical connection at the application layer



Providing services

The application layer is somehow different from other layers in that it is the highest layer in the suite.

The protocols in this layer do not provide services to any other protocol in the suite; they only receive services from the protocols in the transport layer.

This means that protocols can be removed from this layer easily. New protocols can be also added to this layer as long as the new protocol can use the service provided by one of the transport-layer protocols.

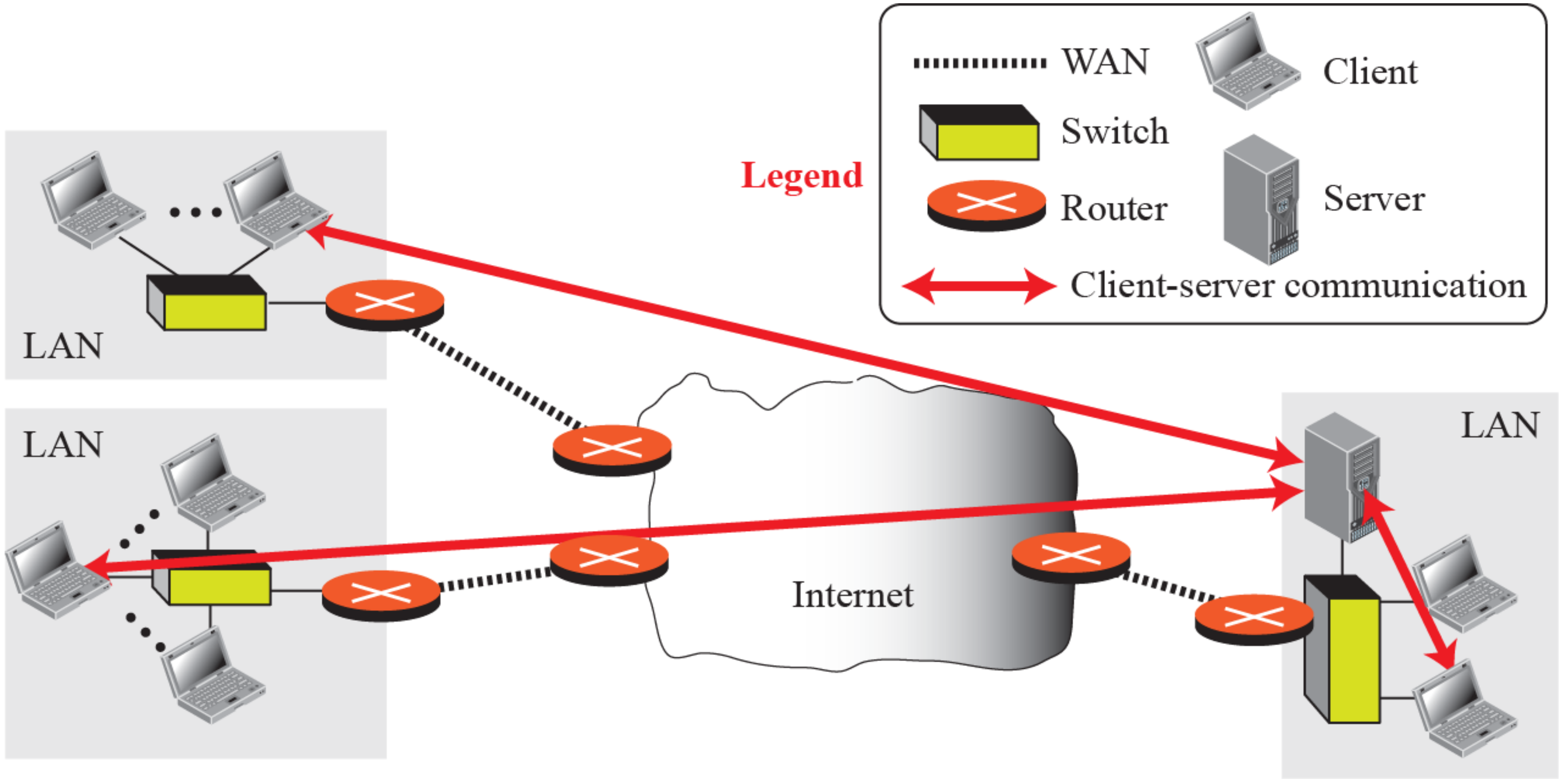
Application-layer paradigms

Traditional paradigm: client-server

The traditional paradigm is called the **client-server paradigm**.

The service provider is an application program, called the server process; it runs continuously, waiting for another application program, called the client process, to make a connection through the Internet and ask for service.

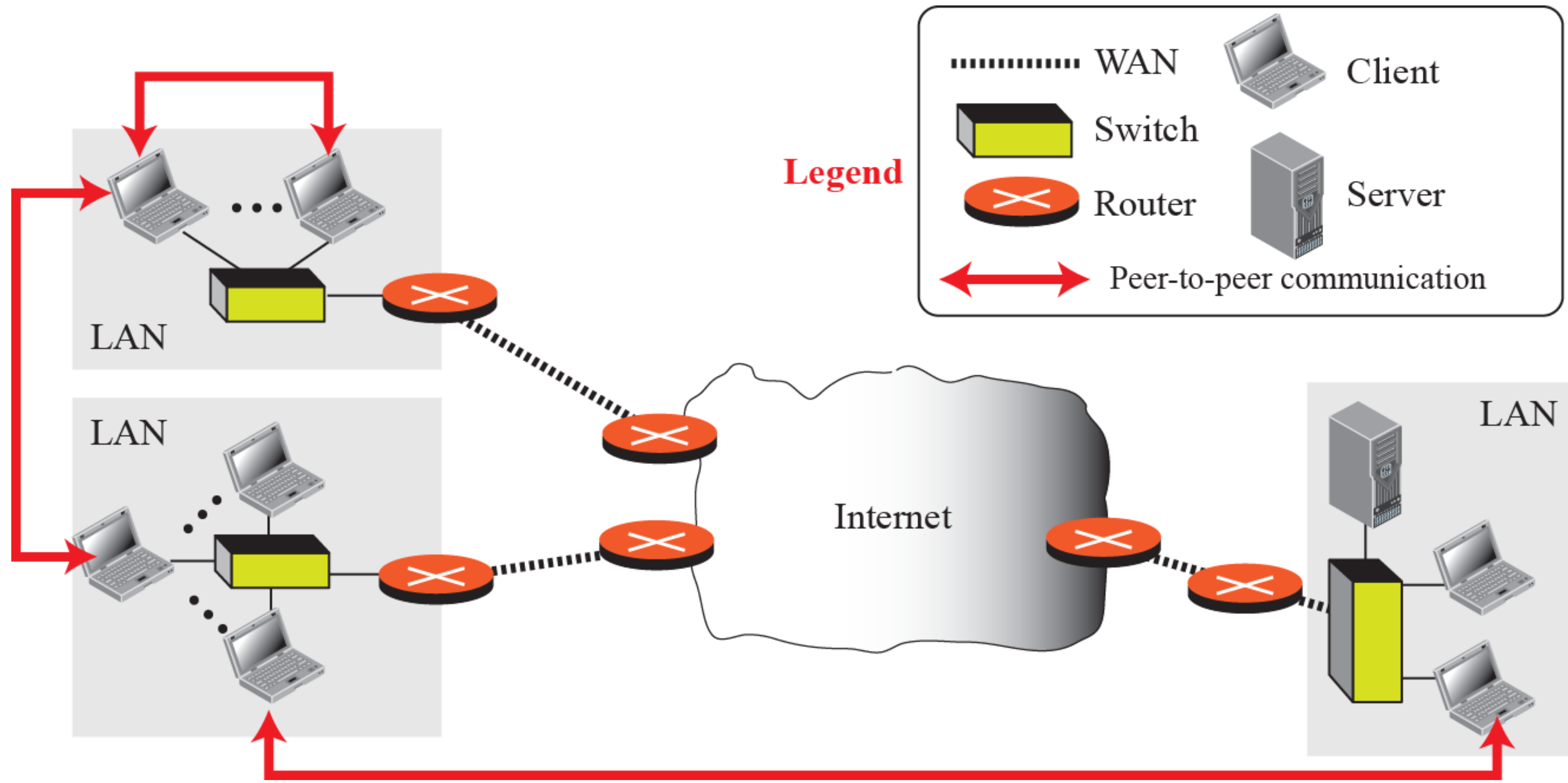
Figure 6.11: Example of a client-server paradigm



New paradigm: peer-to-peer

A new paradigm, called the **peer-to-peer paradigm** (often abbreviated P2P paradigm) has emerged to respond to the needs of some new applications.

Figure 6.12: Example of a peer-to-peer paradigm



Standard client-server applications

During the lifetime of the Internet, several client-server application programs have been developed.

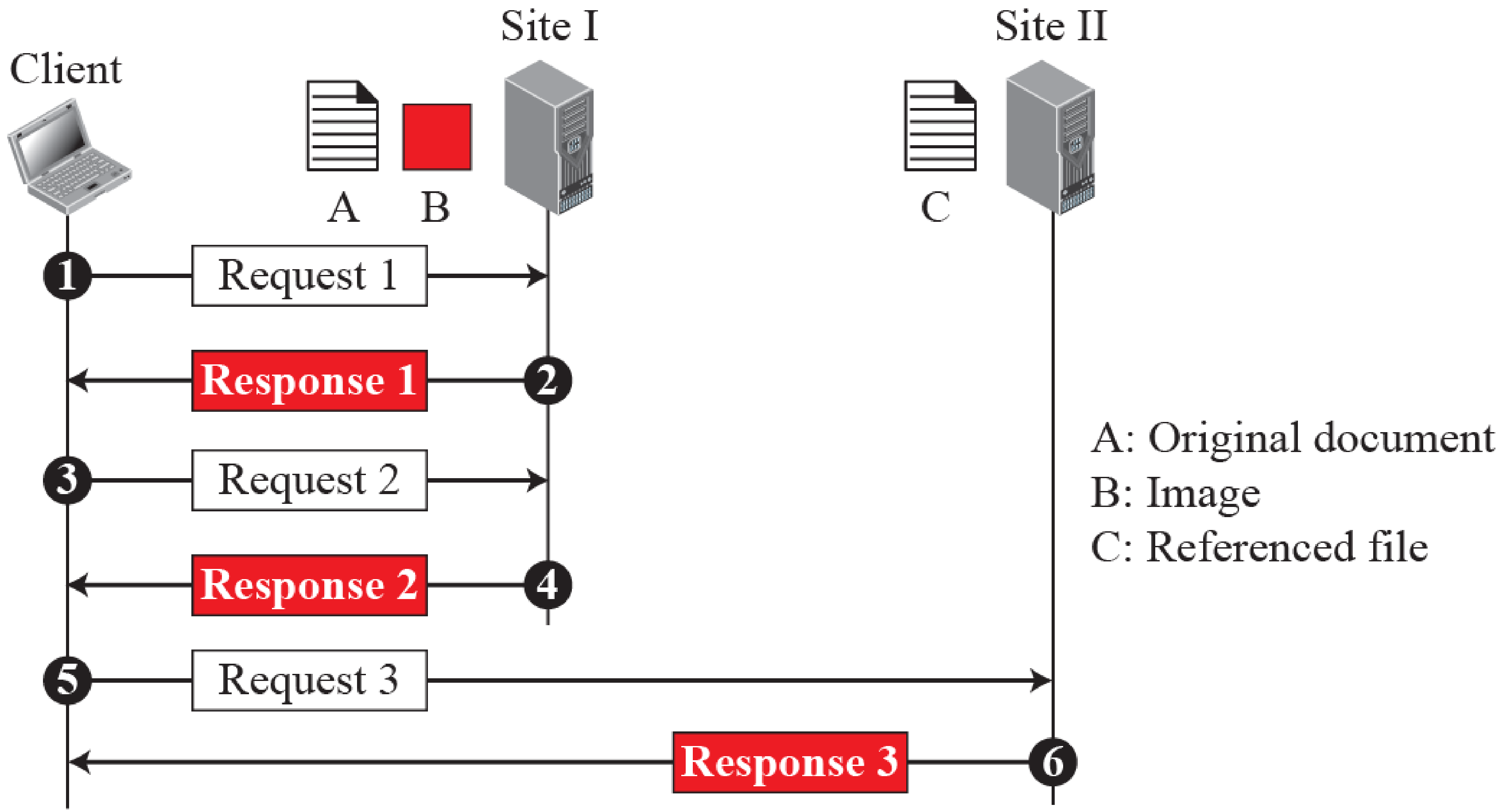
World Wide Web

The WWW today is a distributed client-server service, in which a client using a browser can access a service using a server.

However, the service provided is distributed over many locations called sites. Each site holds one or more documents, referred to as web pages.

Each web page, however, can contain some links to other web pages in the same or other sites.

Figure 6.13: Example 6.1



Example 6.1

Assume we need to retrieve a scientific document that contains one reference to another text file and one reference to a large image. Figure 6.13 shows the situation.

Web client (browser)

A variety of vendors offer commercial **browsers** that *interpret* and *display* a web page, and all of them use nearly the same architecture.

Each browser usually consists of three parts:

- a controller
- client protocols
- interpreters

Uniform resource locator (URL)

The first is the type of vehicle to be used to fetch the web page; the last three make up the combination that defines the destination object (web page).

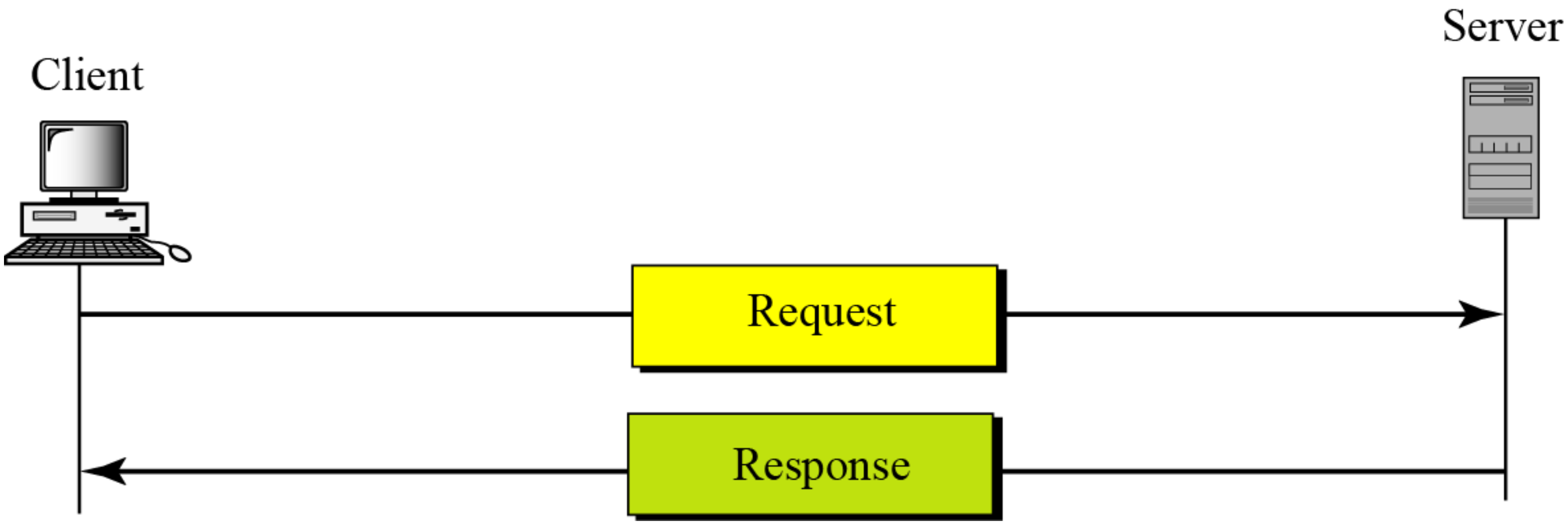
- **Protocol**
- **Host.**
- **Port.**
- **Path.**

http://www.nchu.edu.tw 連接中興大學WWW Server

protocol://host/path	Used most of the time
protocol://host:port/path	Used when port number is needed

http://www.yahoo.com.tw:80/

Hypertext Transfer Protocol (HTTP) is a protocol used mainly to access data on the World Wide Web.



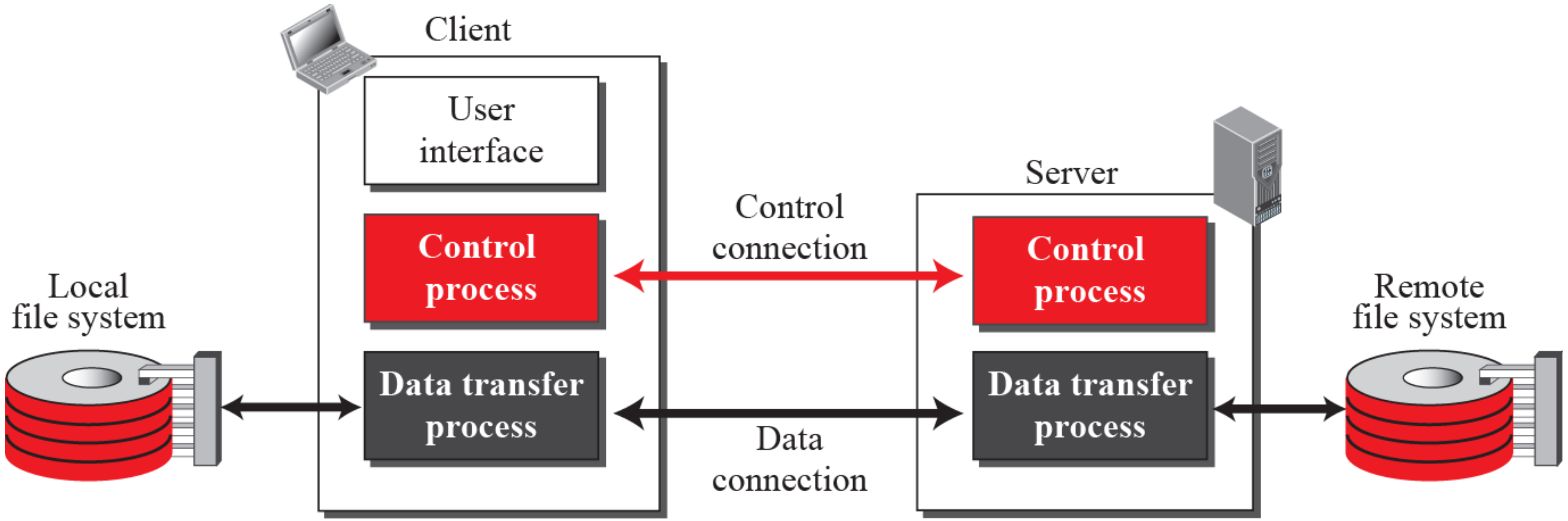
File Transfer Protocol (FTP)

FTP is the standard protocol provided by TCP/IP for copying a file from one host to another.

Two systems may use different file name conventions, different ways to represent data, and different directory structures.

All of these problems have been solved by FTP in a very simple and elegant approach.

Figure 6.14: FTP

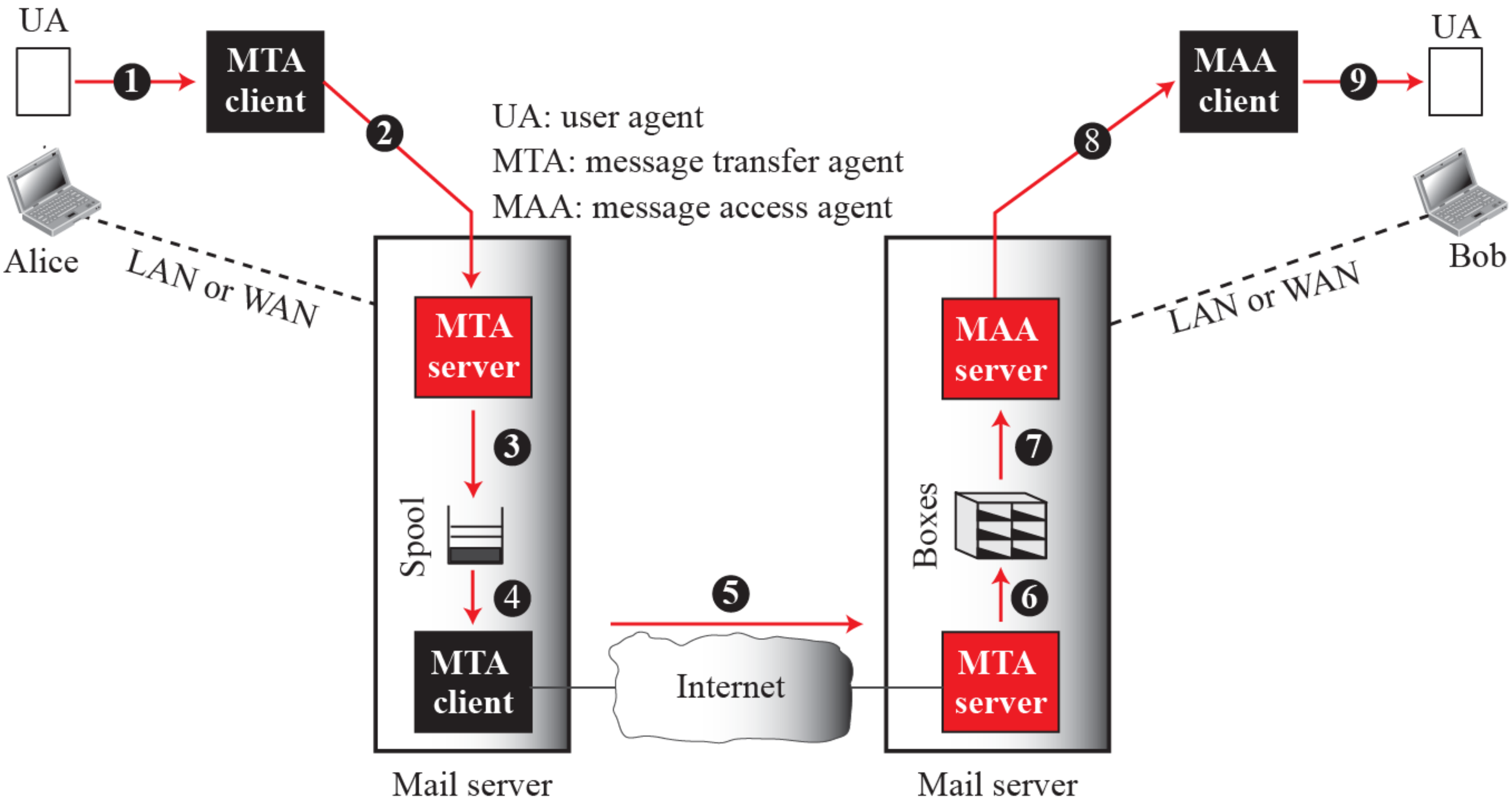


Electronic-mail

E-mail is exchange of messages between two entities. Although the sender of the e-mail can be a client program, the receiver cannot be the corresponding server, because that implies that the receiver must let their computer run all the time, as they do not know when an e-mail will arrive.

For this purpose, e-mail architecture is designed as shown in Figure 6.20.

Figure 6.15: Common scenario (Email)



Remote login – TELNET

TELNET is a general-purpose client-server program that lets a user access any application program on a remote computer.

In other words, it allows the user to log onto a remote computer. After logging on, a user can use the services available on the remote computer and transfer the results back to the local computer.

Although TELNET requires a logging name and password, it is vulnerable to hacking because it sends all data including the password in plaintext (not encrypted).

Secure Shell (SSH) is used in the TELNET.

Domain Name System (DNS)

The following **six steps** map the host name to an IP address:

1. The user passes the host name to the file transfer client.
2. The file transfer client passes the host name to the DNS client.
3. Each computer, after being booted, knows the address of one DNS server. The DNS client sends a message to a DNS server with a query that gives the file transfer server name using the known IP address of the DNS server.
4. The DNS server responds with the IP address of the desired file transfer server.
5. The DNS client passes the IP address to the file transfer server.
6. The file transfer client now uses the received IP address to access the file transfer server.

Purpose of DNS

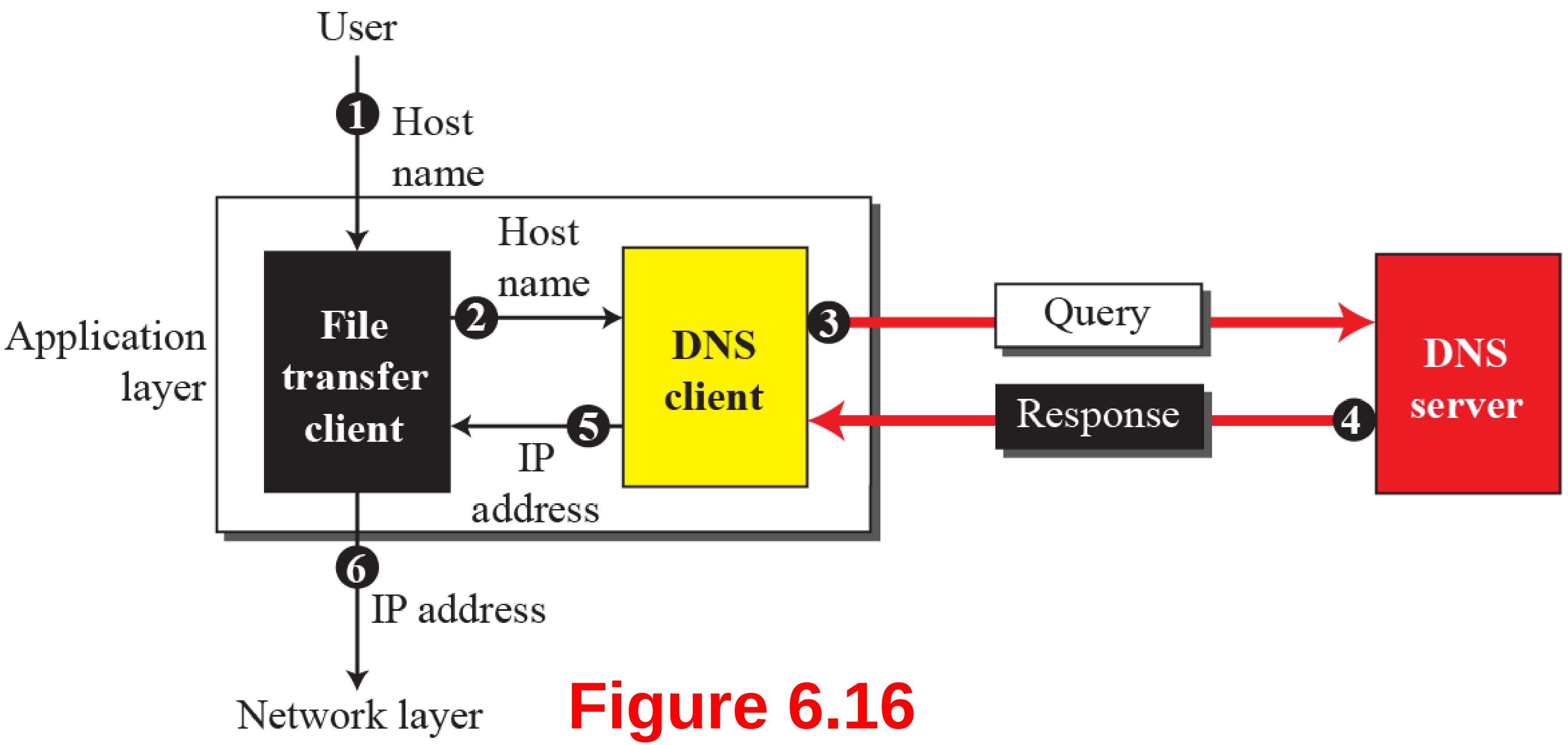


Figure 6.16

Name space

The management of the organization need not worry that the prefix chosen for a host is taken by another organization because, even if part of an address is the same, the whole address is different.

For example, two organizations call one of their computers caesar. The first organization is given a name by the central authority, such as first.com, the second organization is given the name second.com. When each of these organizations adds the name caesar to the name they have already been given, the end result is two distinguishable names: ceasar.first.com and ceasar.second.com.

DNS in the Internet

Generic domains

The **generic domains** define registered hosts according to their generic behavior. Each node in the tree defines a domain, which is an index to the **domain name** space database (see Figure 6.17).

Figure 6.17: Generic domains

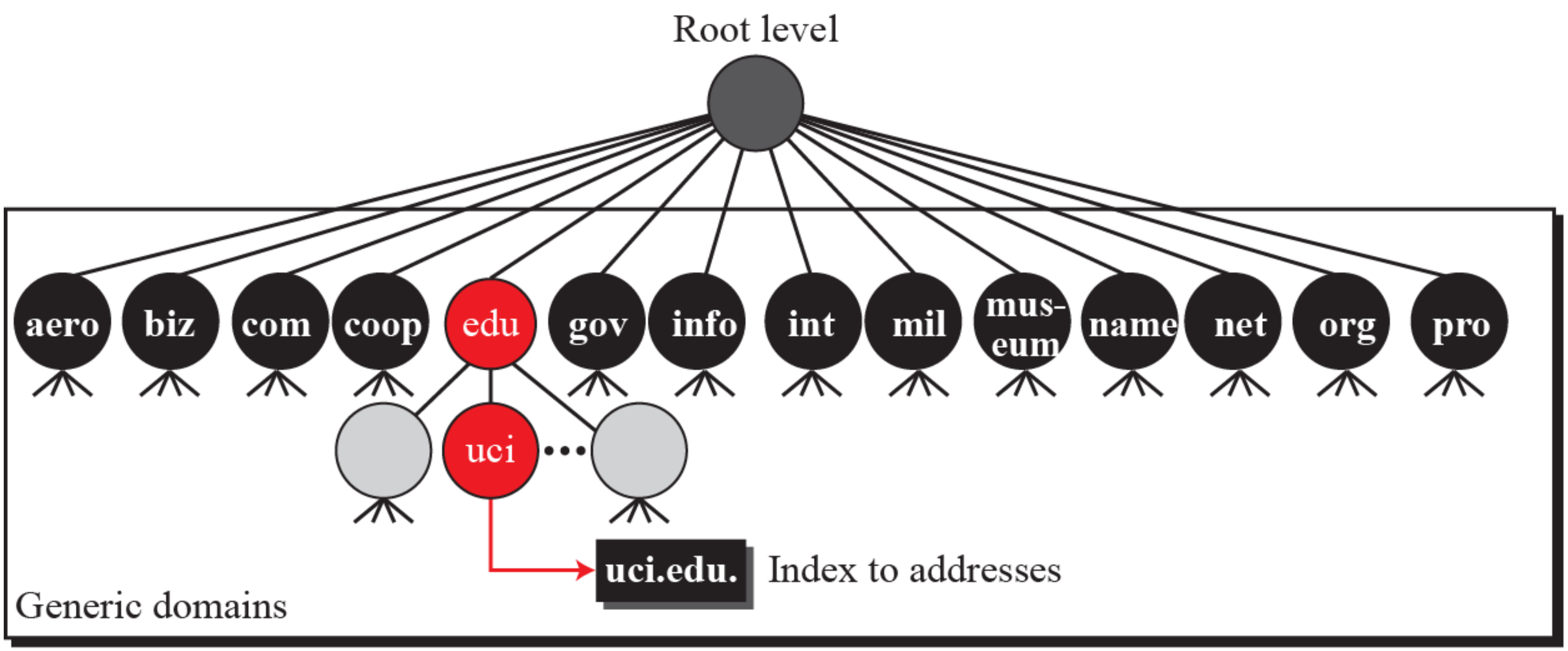


Table 6.1: Generic domain labels

Label	*Description*	*Label*	*Description*
aero	Airlines and aerospace	int	International organizations
biz	Businesses or firms	mil	Military groups
com	Commercial organizations	museum	Museums
coop	Cooperative organizations	name	Personal names (individuals)
edu	Educational institutions	net	Network support centers
gov	Government institutions	org	Nonprofit organizations
info	Information service providers	pro	Professional organizations

Country domains

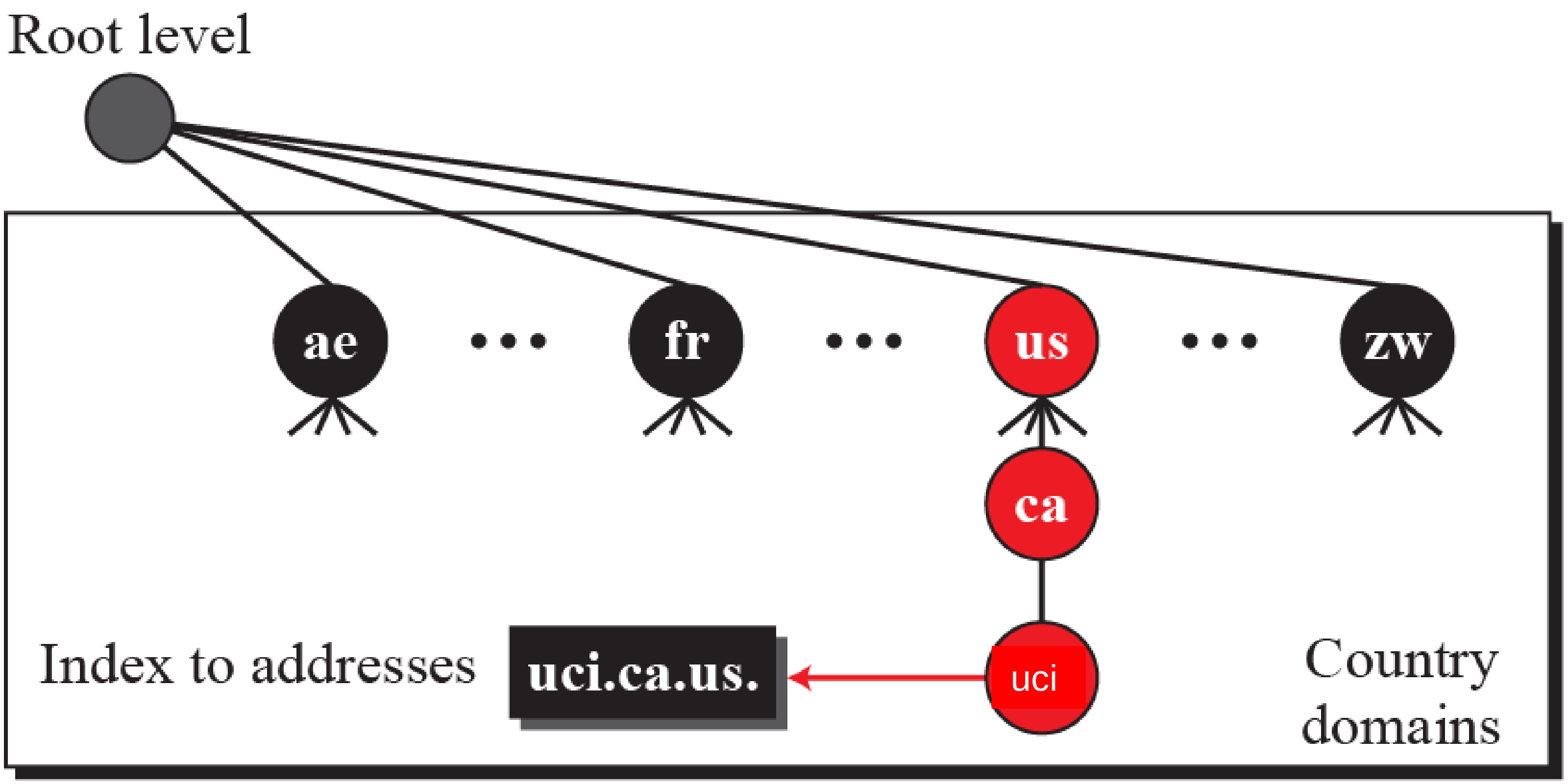


Figure 6.18

Peer-to-peer paradigm

The first instance of peer-to-peer file sharing goes back to December 1987 when Wayne Bell created WWIVnet, the network component of WWIV (World War Four) bulletin board software.

In July 1999, Ian Clarke designed Freenet, a decentralized, censorship-resistant distributed data store, aimed to provide freedom of speech through a peer-to-peer network with strong protection of anonymity.

Centralized networks

The peer then provides its IP address and a **list** of files it has to share. To avoid system collapse, Napster used several servers for this purpose, but we show only one in Figure 6.18.

Decentralized network

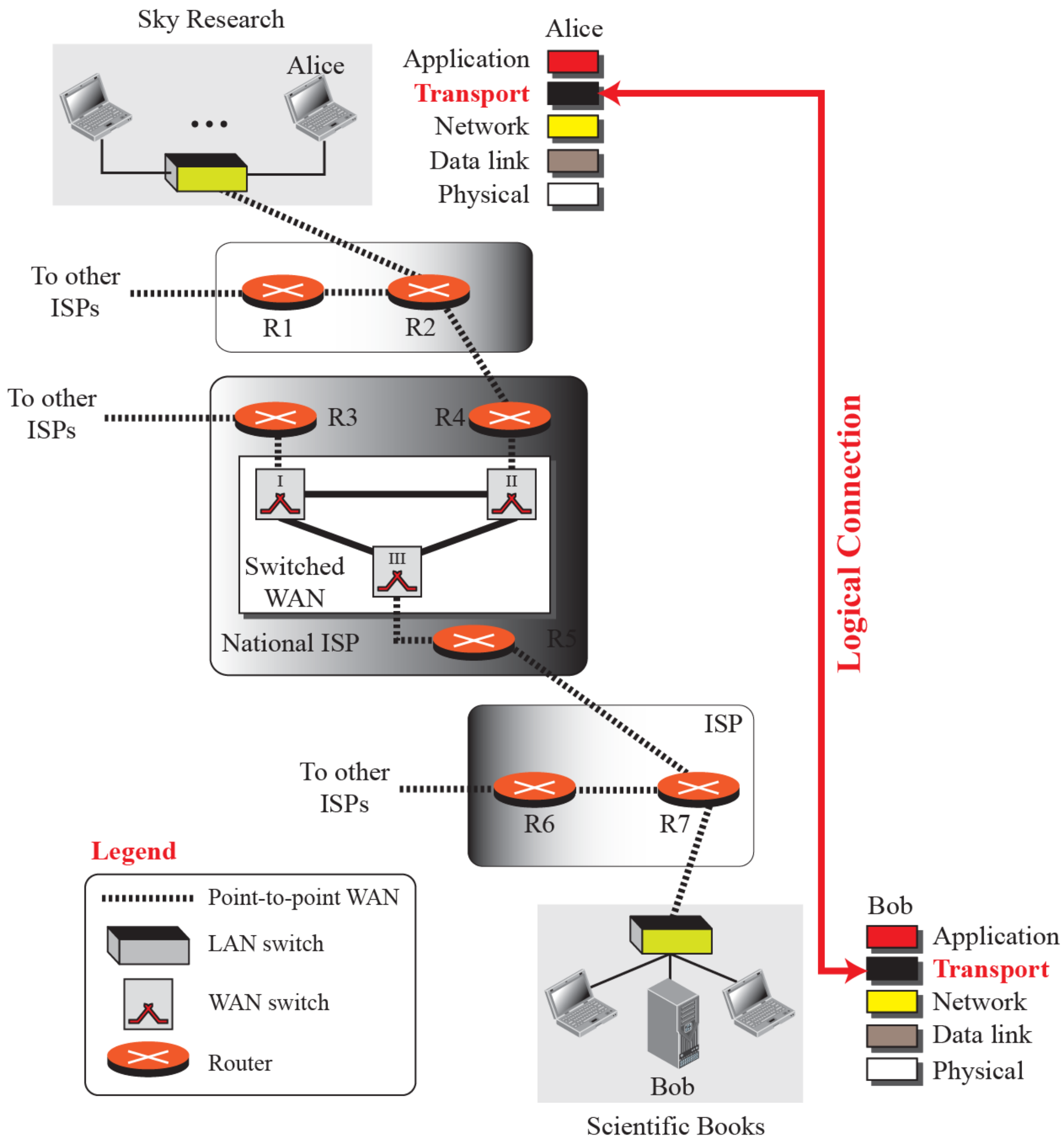
A structured network uses a predefined set of rules to link nodes so that a query can be effectively and efficiently resolved.
The most common technique used for this purpose is the Distributed Hash Table (DHT).

Transport layer

The transport layer is responsible for process-to-process delivery of the entire message: logical communication is created between the transport layer of the client and the server computer.

The transport layer is responsible for the logical delivery of a message between client and server processes.

Figure 6.19: Logical connection at the transport layer



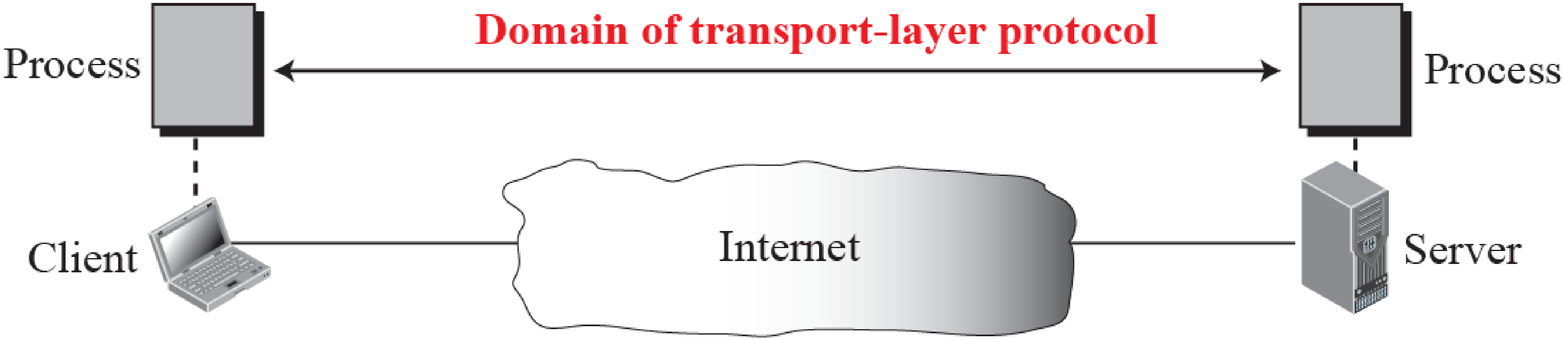
Transport-layer services

Process-to-process communication

The first duty of a transport-layer protocol is to provide **process-to-process communication**.

A process is an application-layer entity (running program) that uses the services of the transport layer.

Figure 6.20: Network layer versus transport layer

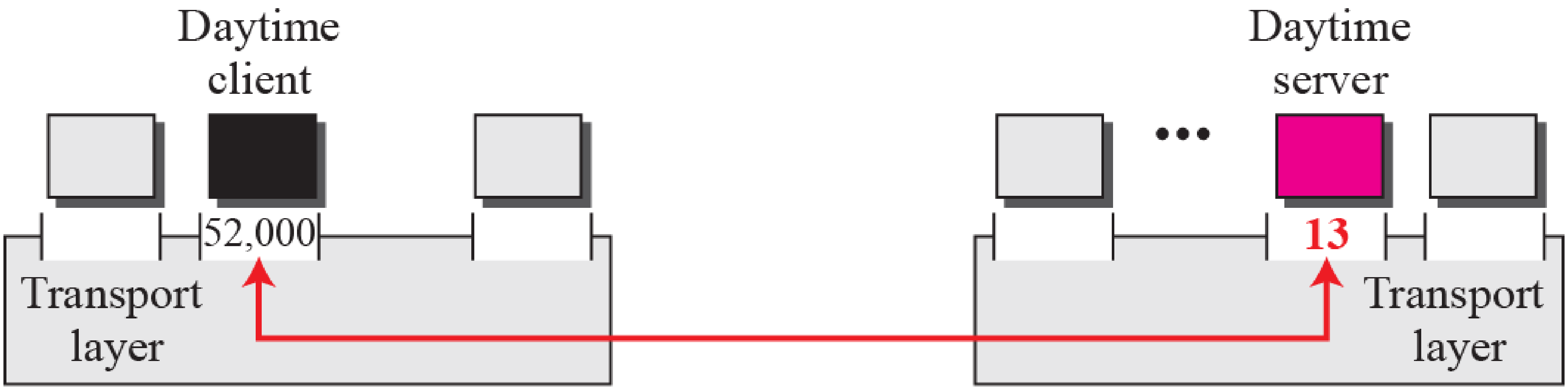


Addressing: port numbers

A process on the local host, called a client, needs services from a process usually on the remote host, called a server. Both processes (client and server) have the same name.

The client program defines itself with a port number, called the **ephemeral port number**.
The word ephemeral means short-lived and is used because the life of a client is normally short.

Figure 6.21: Port numbers



User Datagram Protocol (UDP)

User datagrams

UDP packets, called **user datagrams**, have a fixed-size **header** of 8 byte.

However, the total length needs to be less because a UDP user datagram is stored in an **IP datagram** with the total length of 65,535 bytes.

User datagram packet format

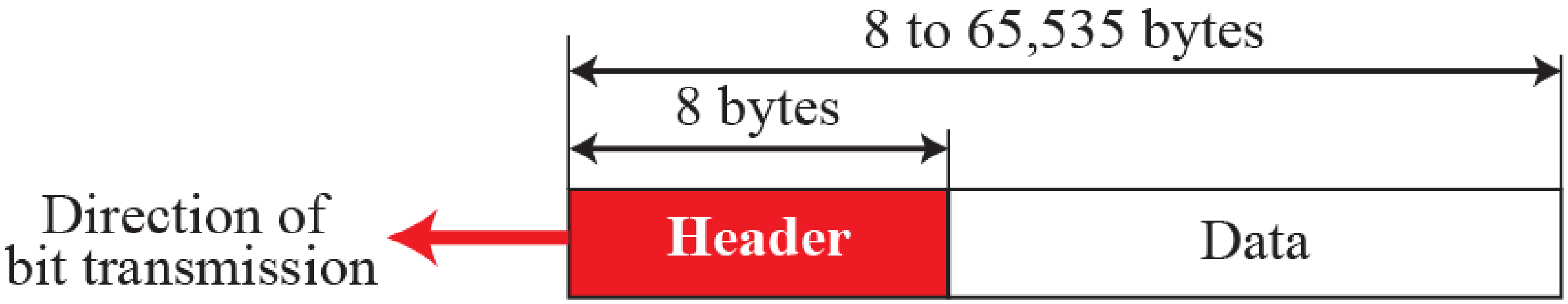


Figure 6.22

Transmission Control Protocol (TCP)

Segments

At the transport layer, TCP groups a number of bytes together into a packet called a **segment**.
TCP adds a header to each segment (for control purposes) and delivers the segment to the network layer for transmission.
The segments are encapsulated in an IP datagram and transmitted as shown in Figure 6.23.

TCP segments

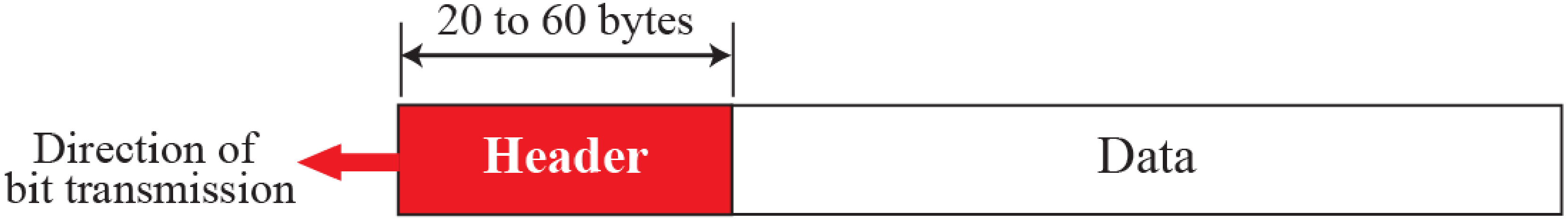


Figure 6.23

The network layer

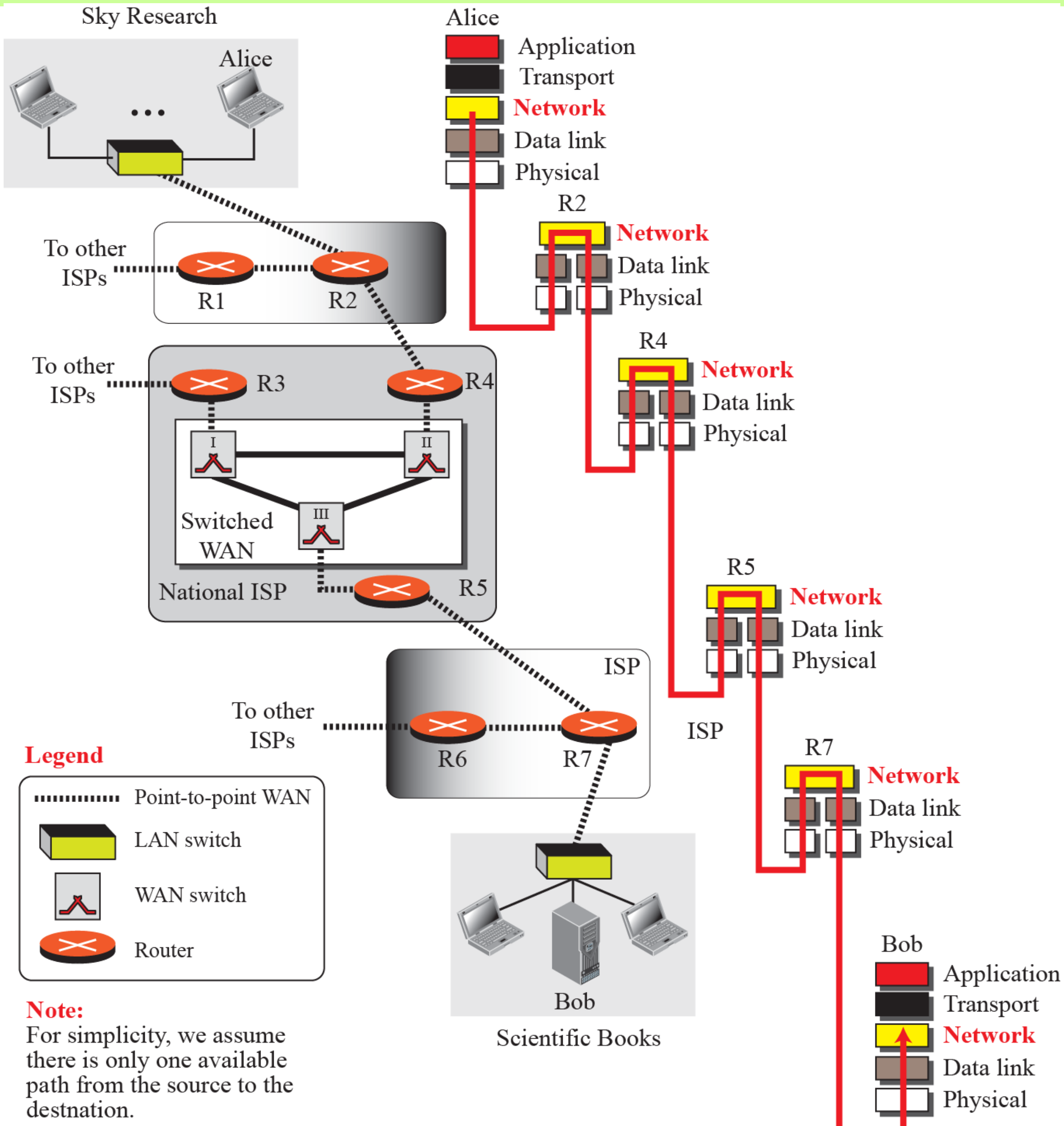
The network layer is responsible for the source-to-destination (computer-to-computer or host-to-host) delivery of a packet, possibly across multiple networks (links).

The network layer ensures that each packet gets from its point of origin to its final destination.

i

The network layer is responsible for the delivery of individual packets from the source host to the destination host.

Figure 6.24: Communication at the network layer



Note:
For simplicity, we assume there is only one available path from the source to the destnation.

Services Provided by network layer

1.Packetizing

Encapsulating the payload (data received from upper layer) in a network-layer packet at the source and decapsulating the payload from the network-layer packet at the destination.

This is done in three steps as shown in Figure 6.25.

Packetizing at the network layer

Note:
A transport-layer payload may become several network-layer packets

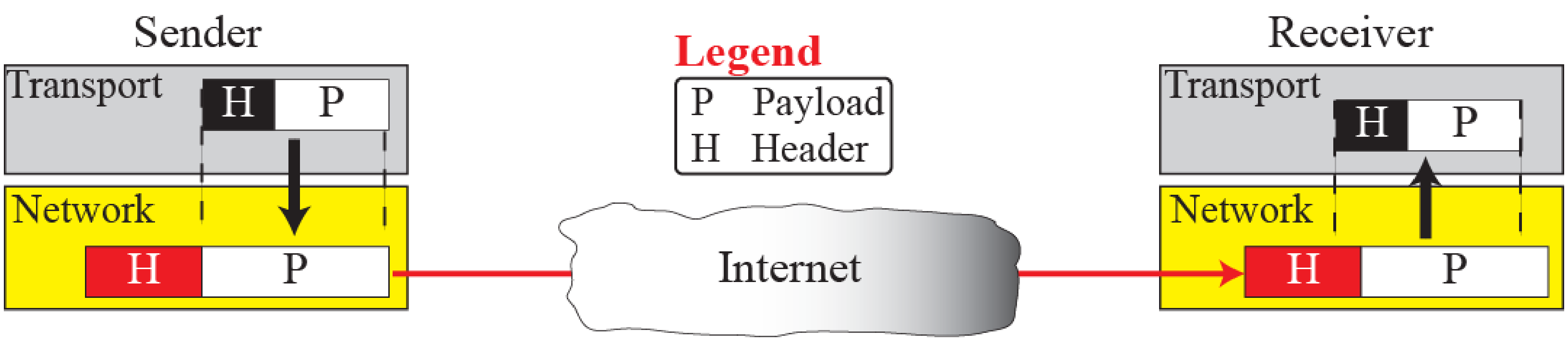


Figure 6.25

2.Packet delivery

Unreliable delivery

The delivery of packets at the network layer is unreliable. This means that the packets can be corrupted, lost, duplicated.
The network layer provides a best-effort delivery, but there is no guarantee that a packet reaches the destination as we expect.

Connectionless delivery

The delivery at the network layer is also connectionless, but the word *connectionless* here does not mean that there is no physical connection between the sender and receiver.

Packets travelling different paths

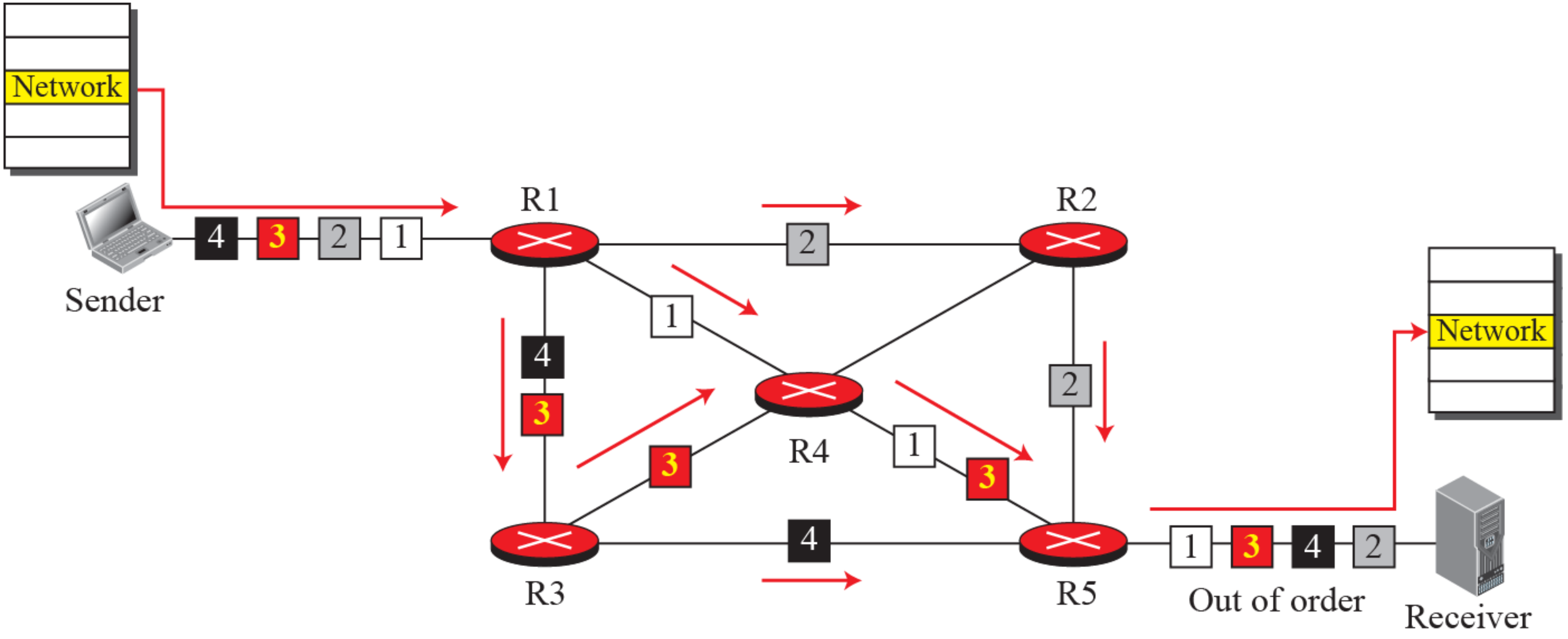


Figure 6.26

3.Routing

The network layer has a specific duty: routing.

Routing means determination of the partial or total path of a packet.

As the Internet is a collection of networks (LANs, WANs, and MANs), the delivery of a packet from its source to its destination may be a combination of several deliveries: a source-to-router delivery, several router-to-router delivery, and finally a router-to-destination delivery.

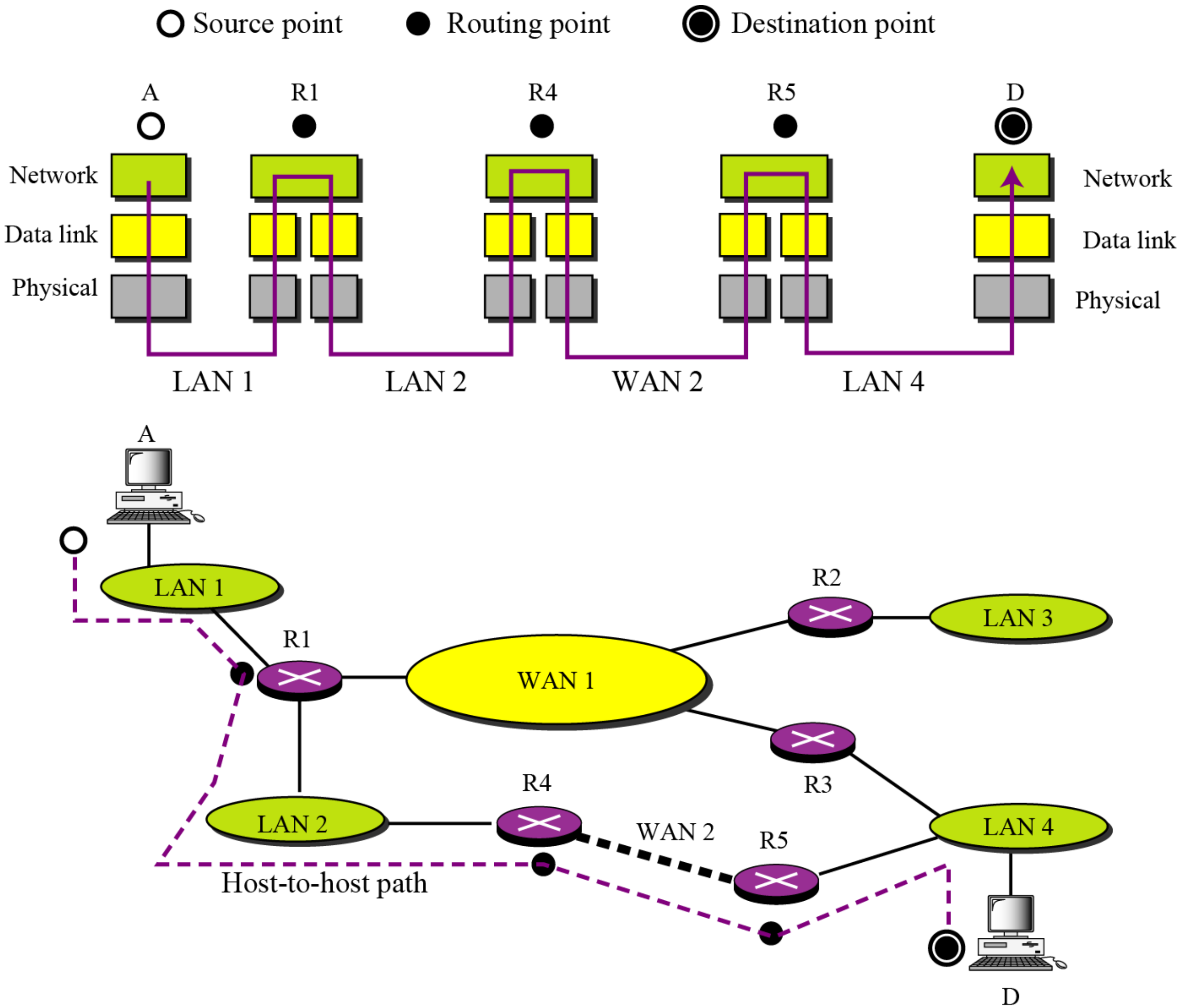


Figure 6.14 **Routing at the network layer**

Network-layer protocols

In the TCP/IP protocol suite, the main protocol at the network layer is **Internet Protocol (IP)**.

The current version is IPv4 (version 4) although IPv6 (version 6) is also in use, although not ubiquitously. IPv4 is responsible for the delivery of a packet from the source computer to the destination computer.

For this purpose, every computer and router in the world is identified by a 32-bit IP address, which is presented in dotted decimal notation.

Address notation

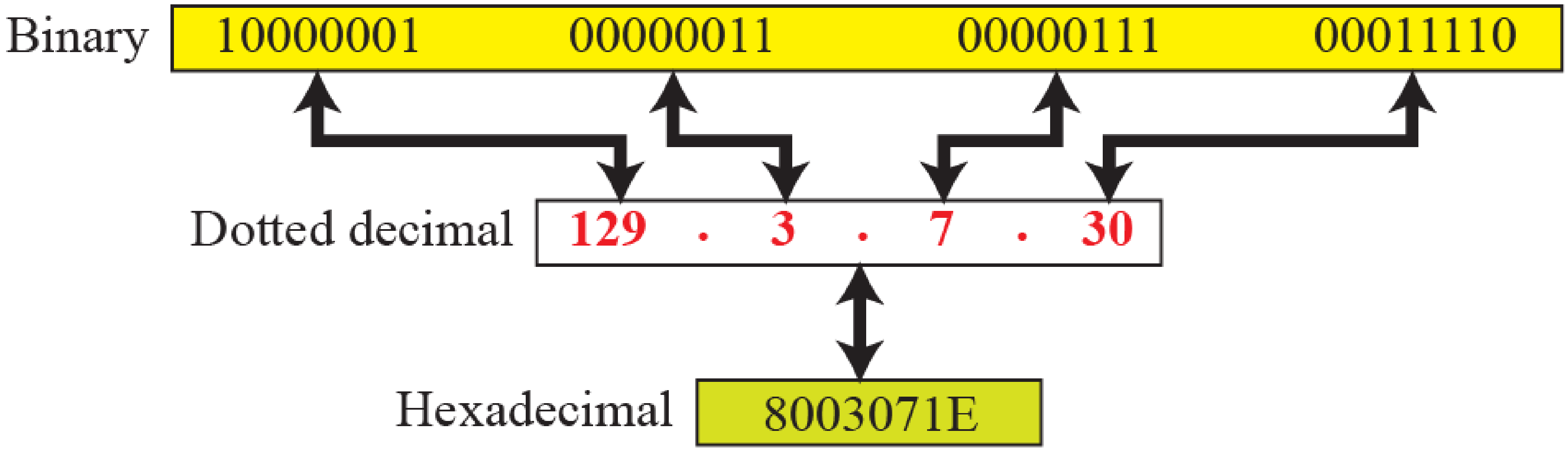


Figure 6.27

Hierarchy in IPv4 addressing

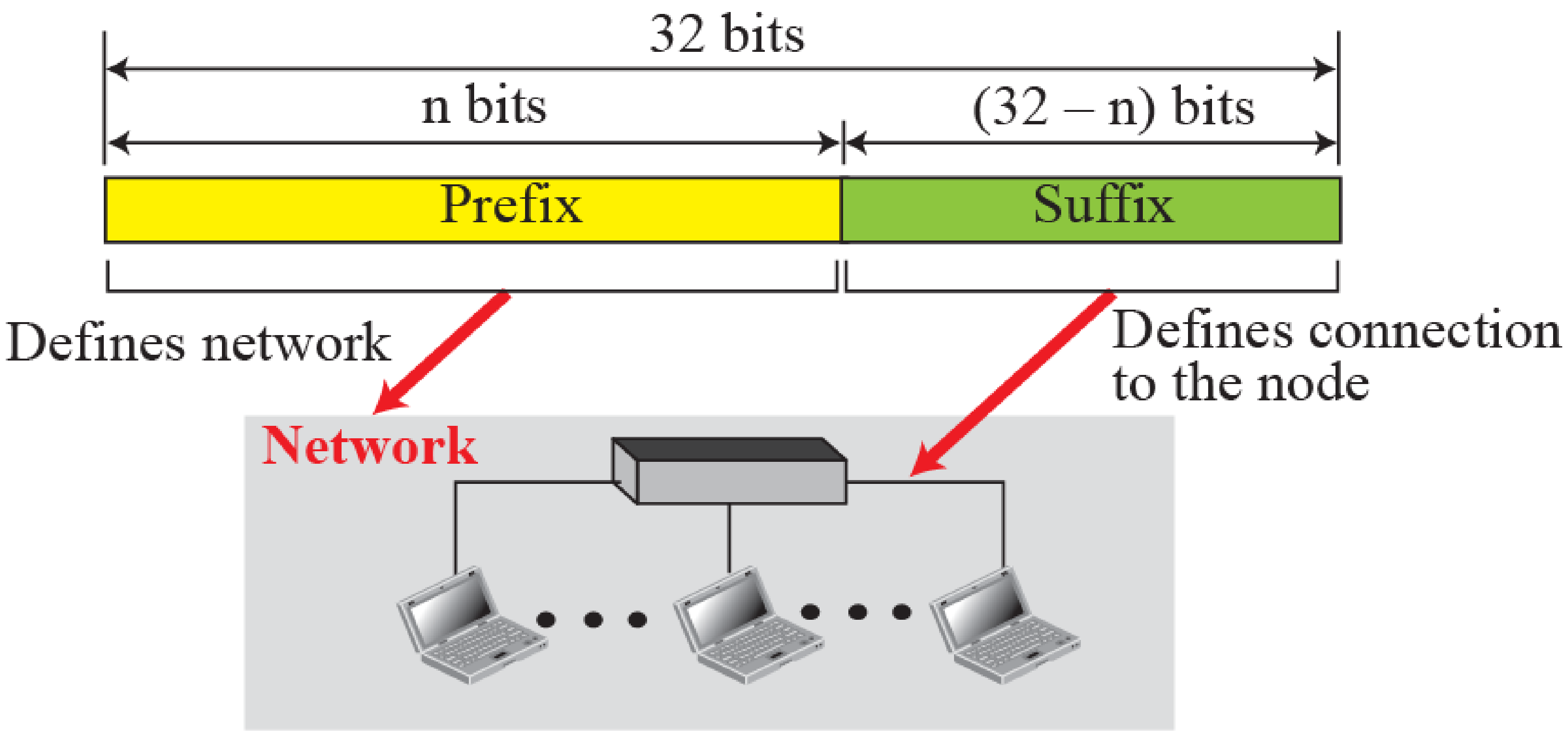


Figure 6.28

IPv4 datagram

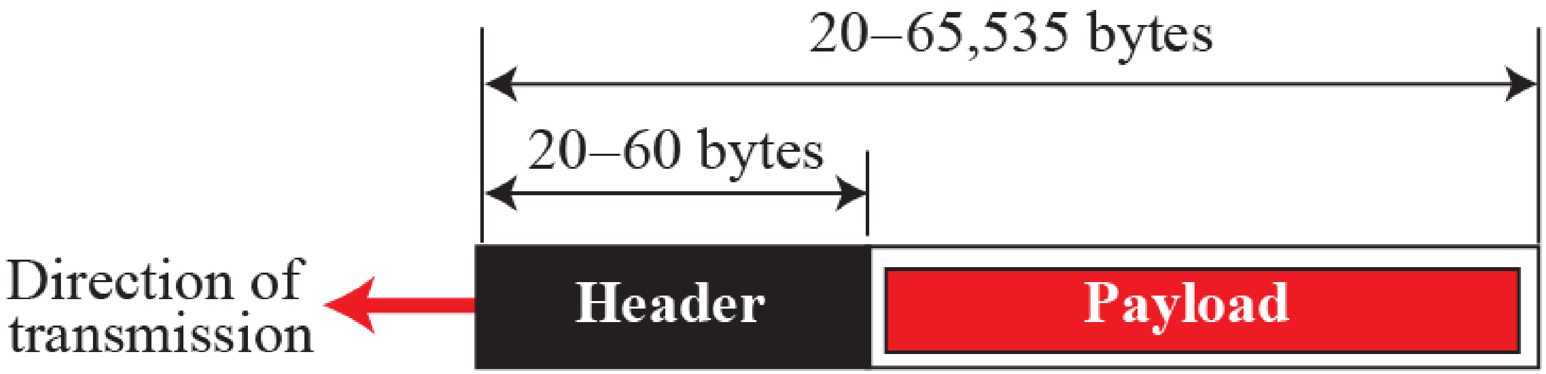


Figure 6.29

Internet Protocol Version 6 (IPv6)

The new version, which is called **Internet Protocol version 6 (IPv6)** or **IP new generation (IPng)** was a proposal to augment the address space of IPv4 and at the same time redesign the format of the IP packet and revise some auxiliary protocols.

IPv6 address notations

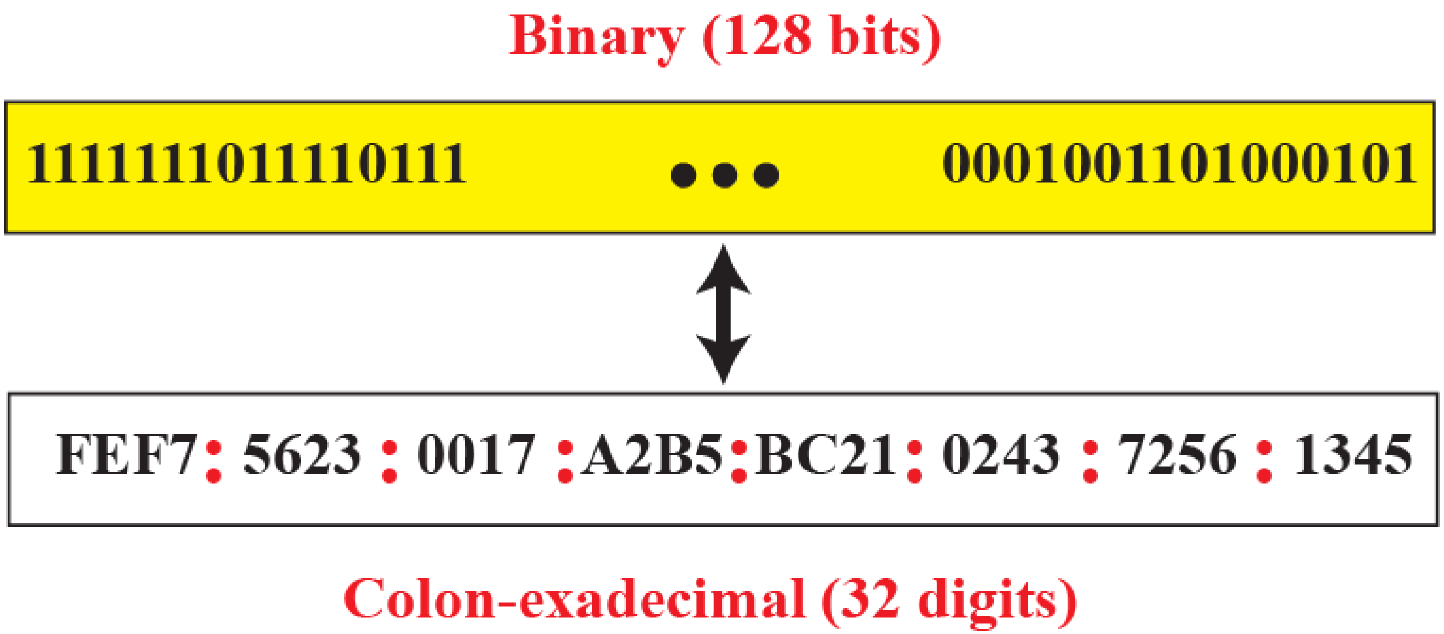


Figure 6.30

Hierarchy in IPv6 addressing

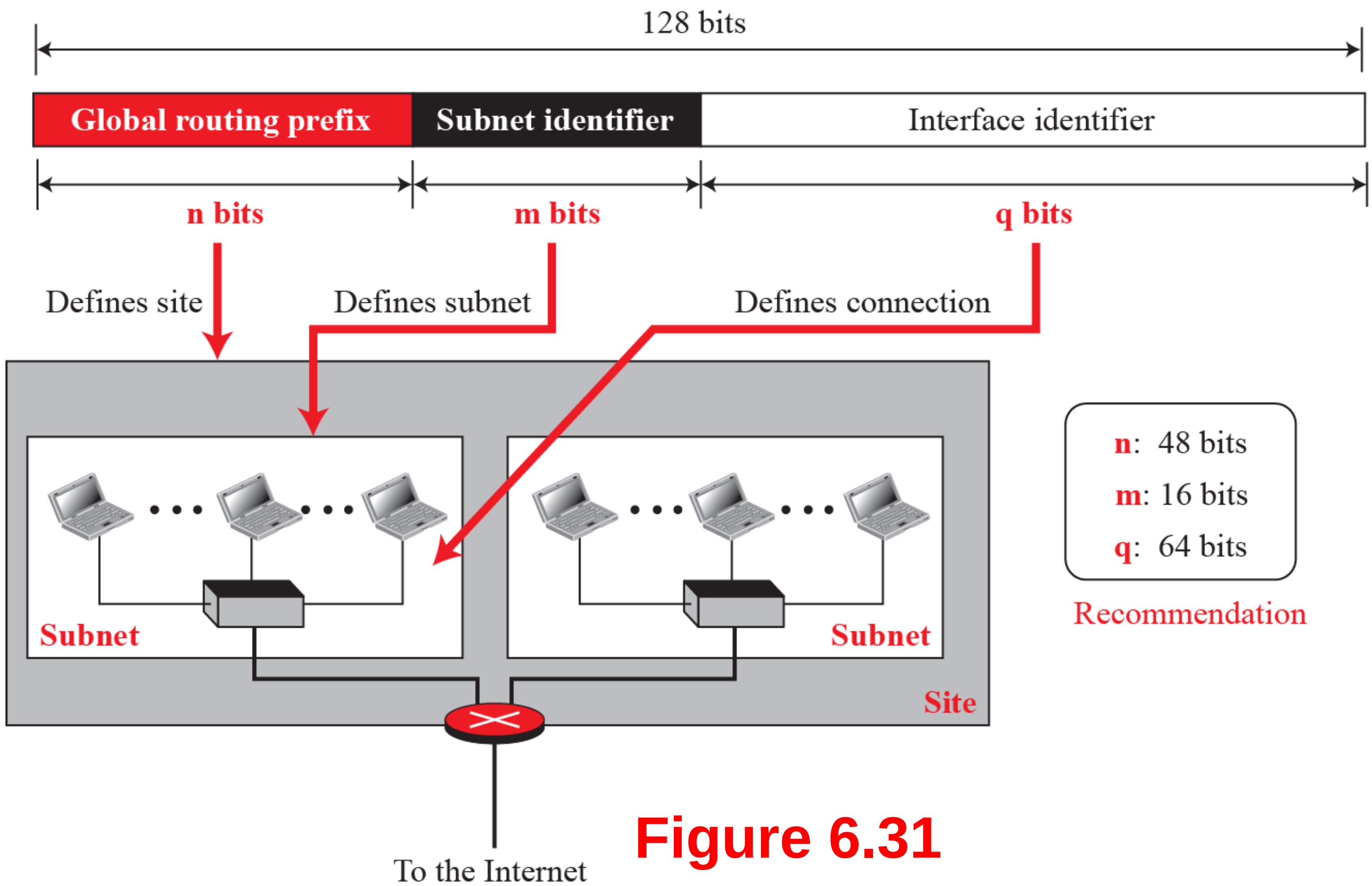


Figure 6.31

IPv6 datagram

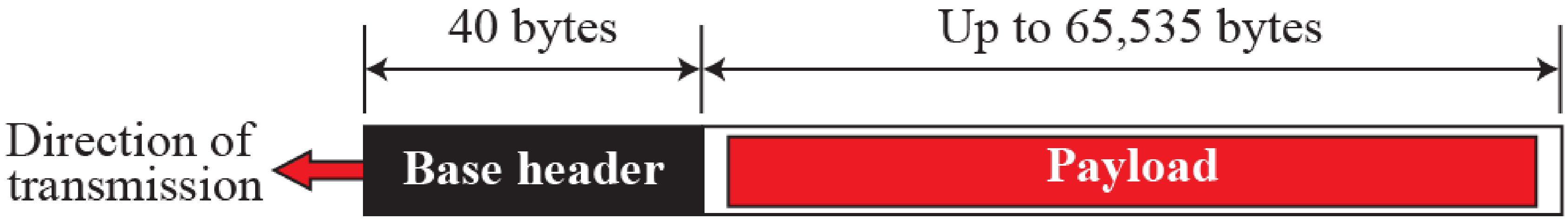


Figure 6.32

Data link layer

Carrying the packet from one node to another (where a node can be a computer or a router) is the responsibility of the data link layer.

i

The data link layer is responsible for node-to-node delivery of frames.

Figure 6.33: Communication at the data-link layer

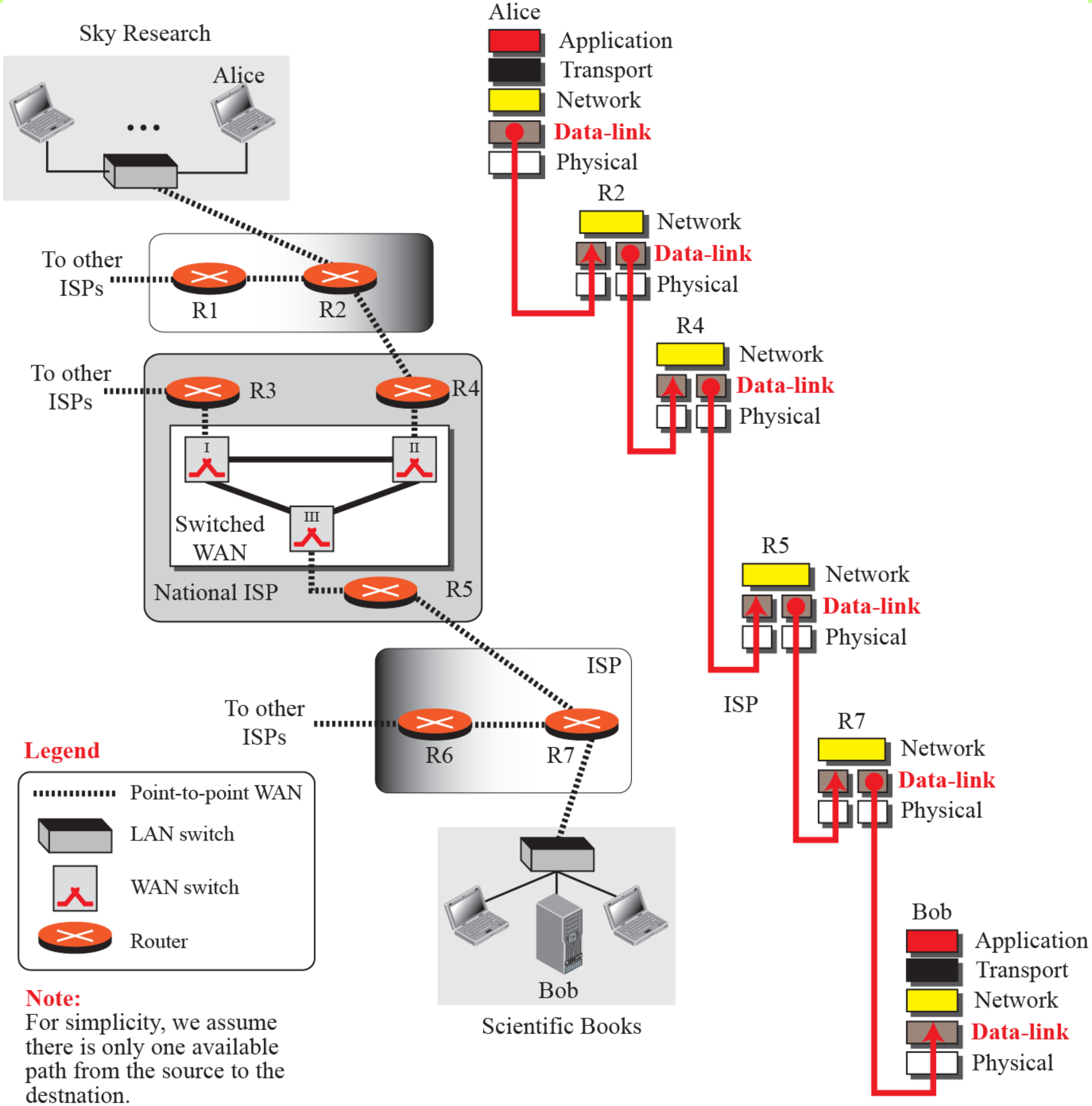
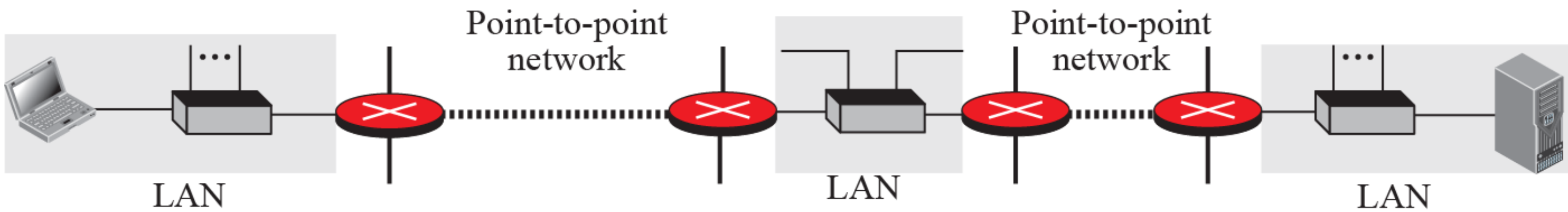


Figure 6.34: Nodes and links



a. A small part of the Internet

b. Nodes and links

Local area networks (LANs)

LANs can be wired or wireless networks.

In the first group, the stations in the LANs are connected by wired; in the second group the stations are logically connected by air.

Wired LANS: Ethernet

The Ethernet LAN was developed in the 1970s by Robert Metcalfe and David Boggs. Since then, it has gone through four generations: **Standard Ethernet** (10 Mbps), **Fast Ethernet** (100 Mbps), **Gigabit Ethernet** (1 Gbps), and **10 Gigabit Ethernet** (10 Gbps).The data rate, the speed in which bits are sent in each second, has been increased ten times in each generation.

Ethernet frame

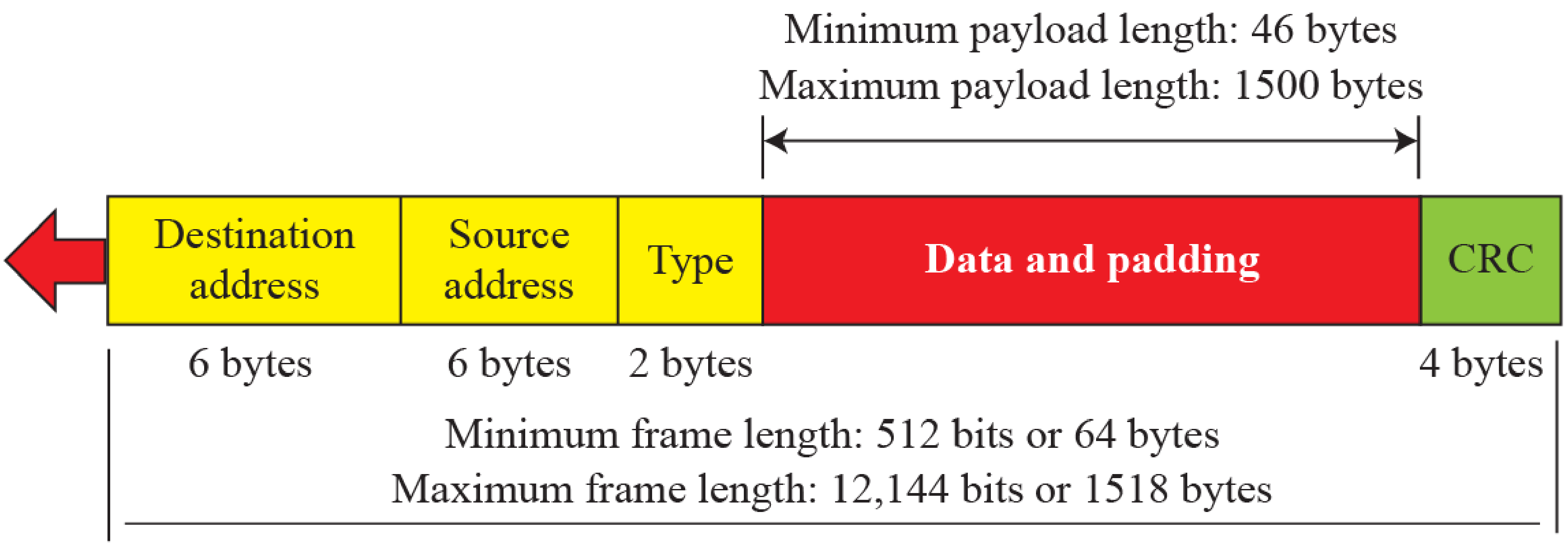


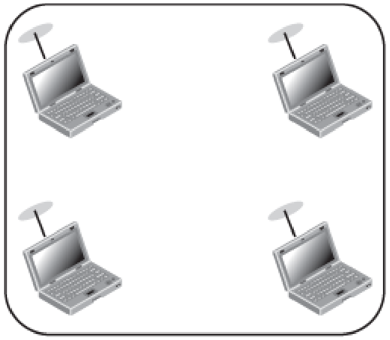
Figure 6.35

Wireless LANs

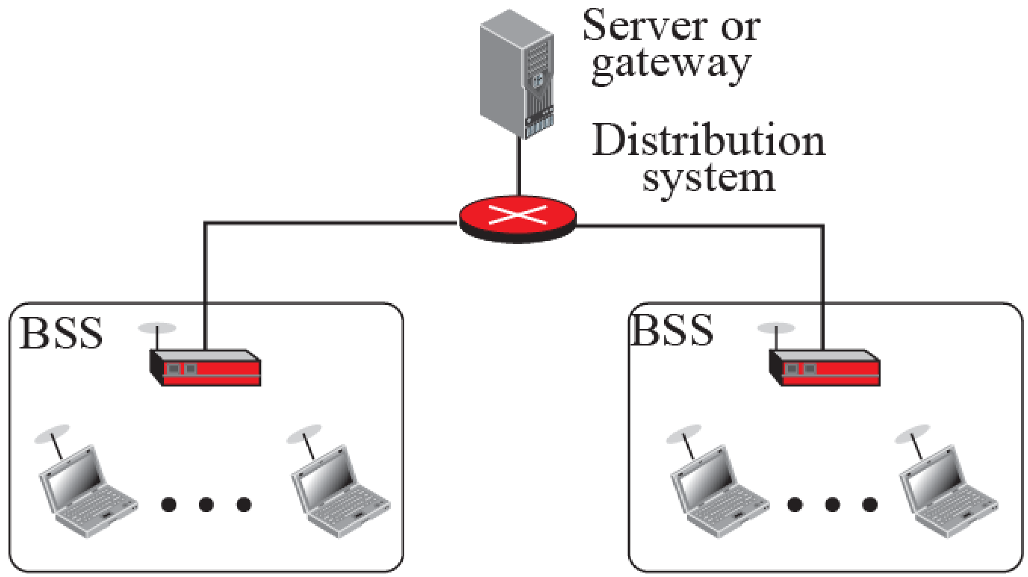
Wireless communication is one of the fastest-growing technologies. The demand for connecting devices without the use of cables is increasing everywhere.

When hosts in a wireless LAN communicate with each other, they are sharing the same medium (multiple access). Two technology have been in this area: Wireless Ethernet and Bluetooth.

BSSs and ESSs



Basic Servic set (BSS)



Extended Service Set (ESS)

Figure 6.36

Bluetooth

Bluetooth is a wireless LAN technology designed to connect devices of different functions such as telephones, notebooks, computers (desktop and laptop), cameras, printers, and even coffee makers when they are at a short distance from each other.
A Bluetooth LAN is an ad hoc network, which means that the network is formed spontaneously; the devices, sometimes called gadgets, find each other and make a network called a piconet.

A Bluetooth LAN can even be connected to the Internet if one of the gadgets has this capability.
A Bluetooth LAN, by nature, cannot be large. If there are many gadgets that try to connect, there is chaos.

Wide area networks (WANs)

Wired WANs

Dial-up service

The term **modem** is a composite word that refers to the two functional entities that make up the device: a signal modulator and a signal demodulator.

1. A **modulator** creates signal from data.
2. A **demodulator** recovers the data from the modulated signal.

Dial-up network to provide Internet access

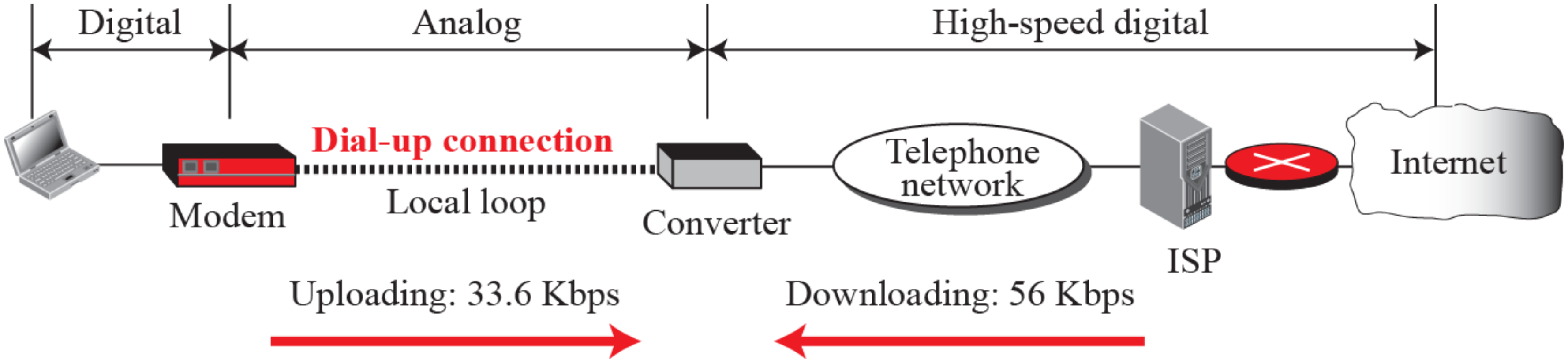


Figure 6.37

ASDL point-to-point network

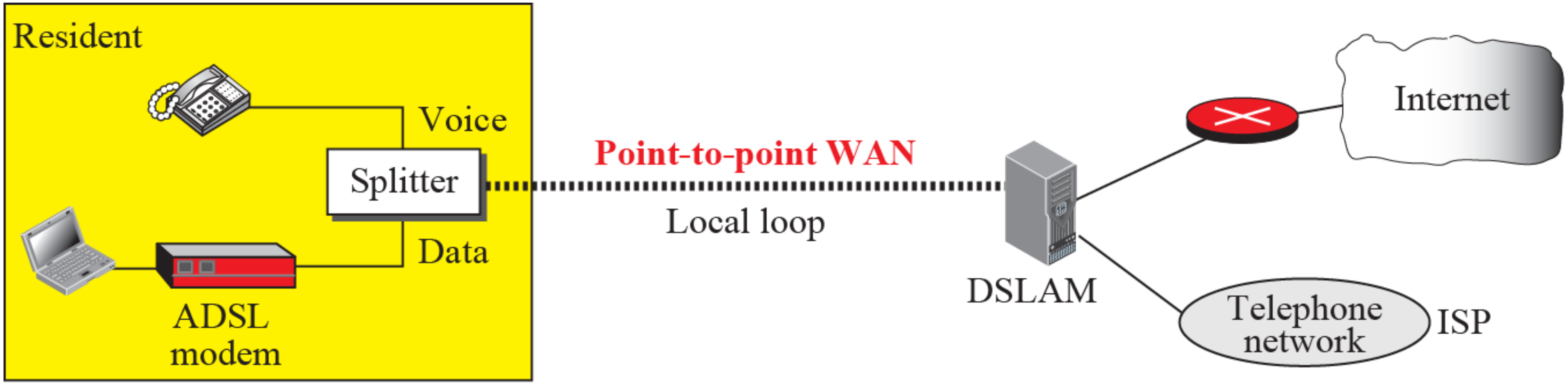


Figure 6.38

Cable service

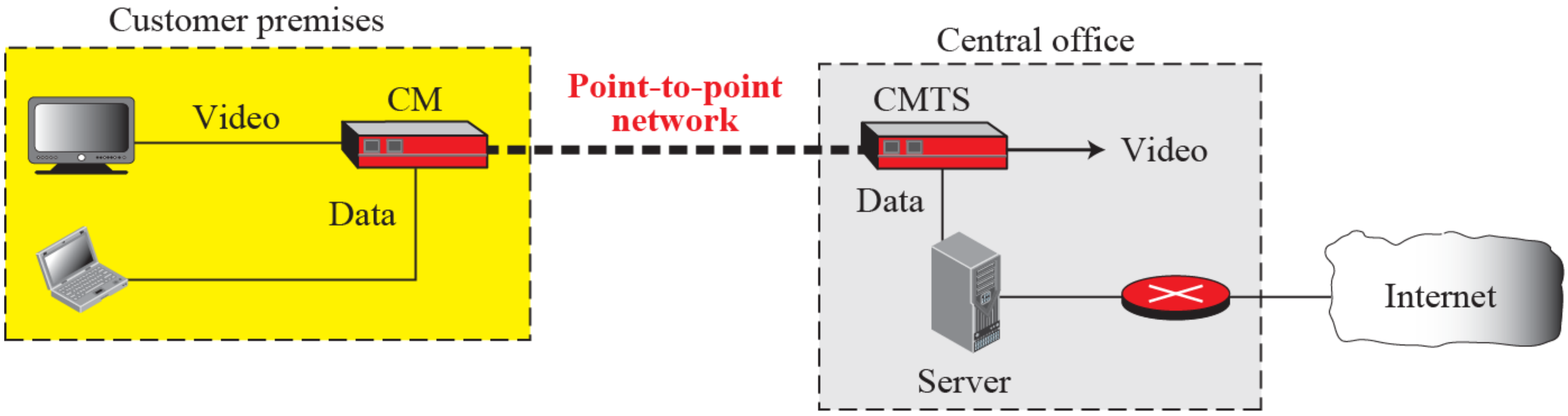


Figure 6.39

Wireless WANs

WiMAX

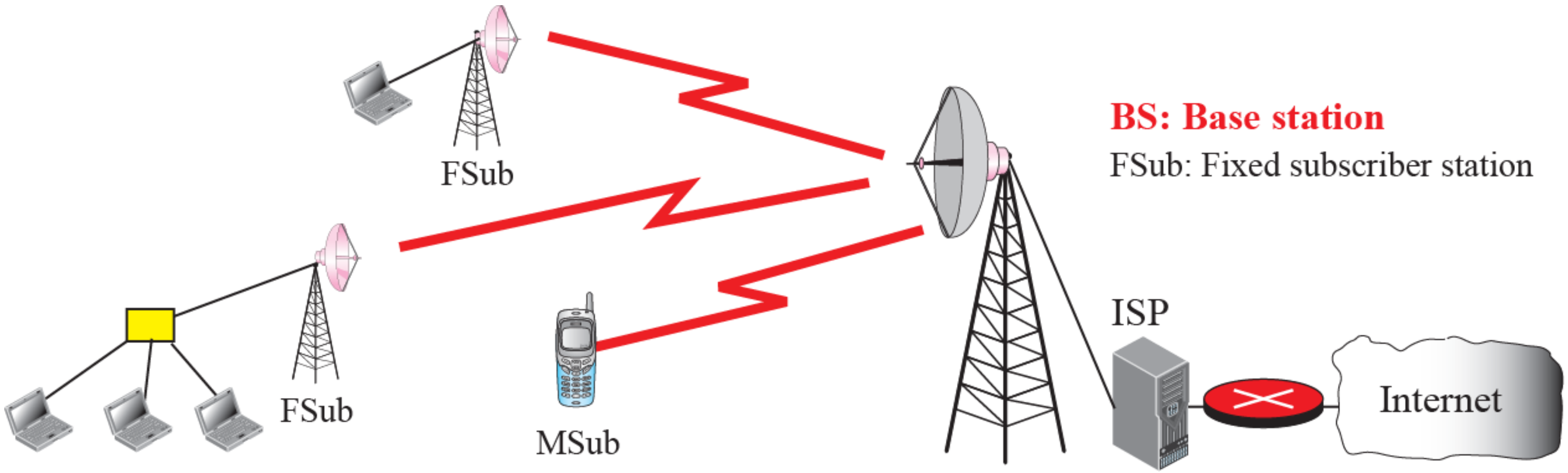


Figure 6.40

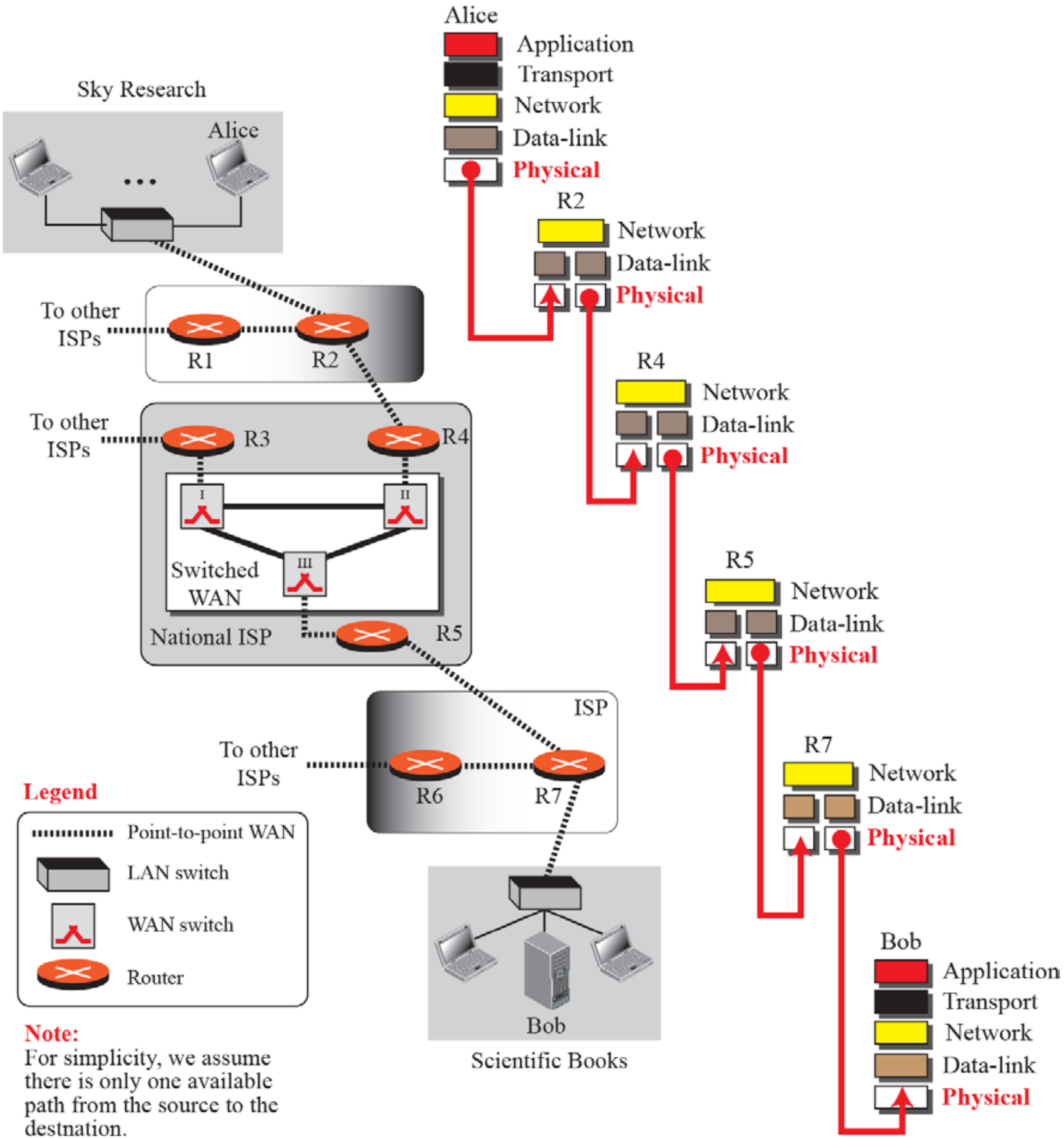
Physical layer

The physical layer coordinates the functions required to carry a bit stream over a physical medium. Although the data link layer is responsible for moving a **frame** from one node to another, the physical layer is responsible for moving the **individual bits** that make up the frame to the next node.

In other words, the unit of transfer in the data link layer is a frame, while the unit of transfer in the physical layer is a bit.

The physical layer is responsible for node-to-node delivery of bits

Figure 6.41: Communication at the physical layer



Data and signals

Analog and digital

Like the data they represent, signals can be either analog or digital. An **analog signal** has infinitely many levels of intensity over a period of time. As the wave moves from value A to value B, it passes through and includes an infinite number of values along its path.

A **digital signal**, on the other hand, can have only a limited number of defined values.

Comparison of analog and digital signals

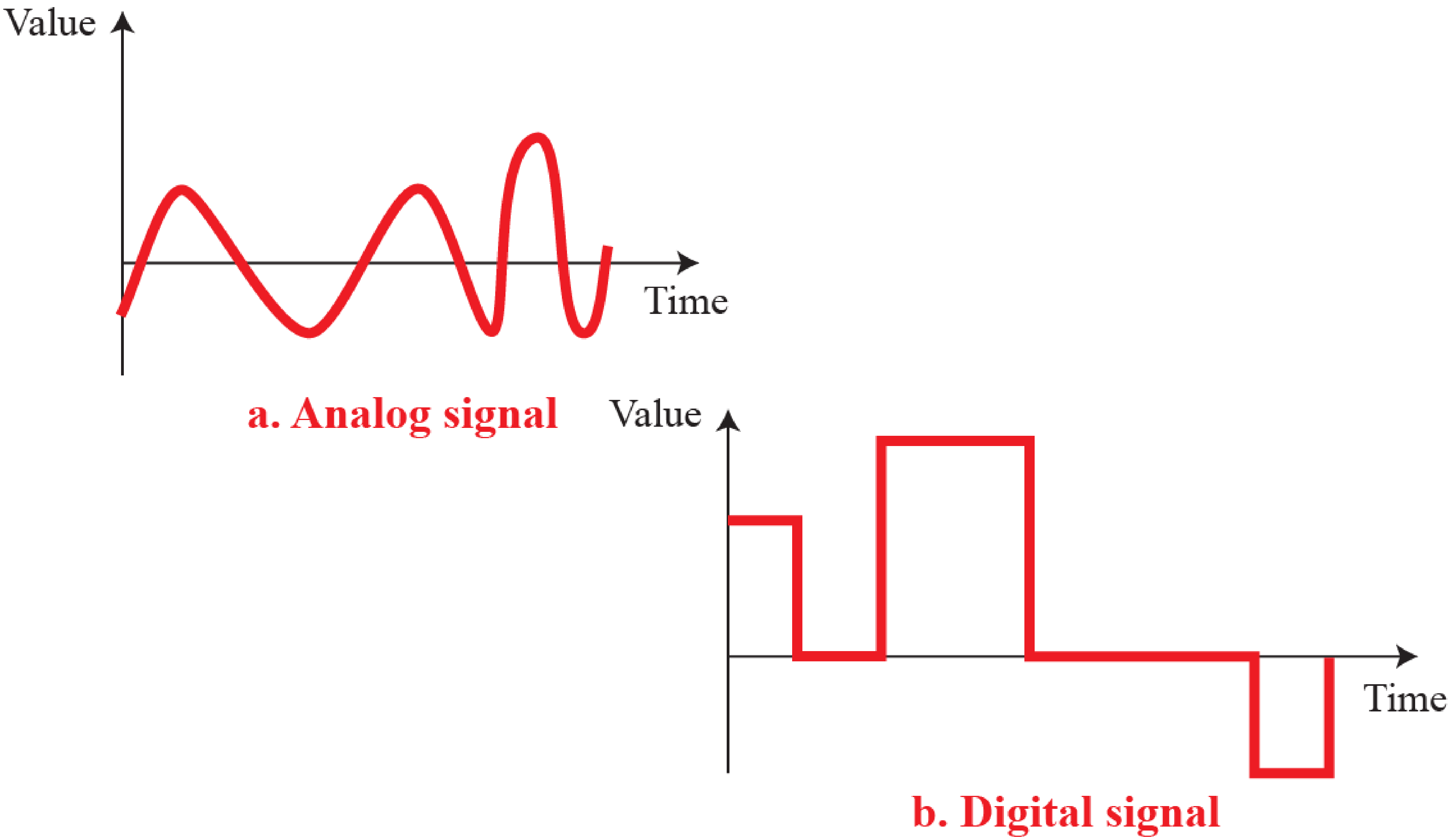


Figure 6.42

Digital transmission

Digital to digital conversion

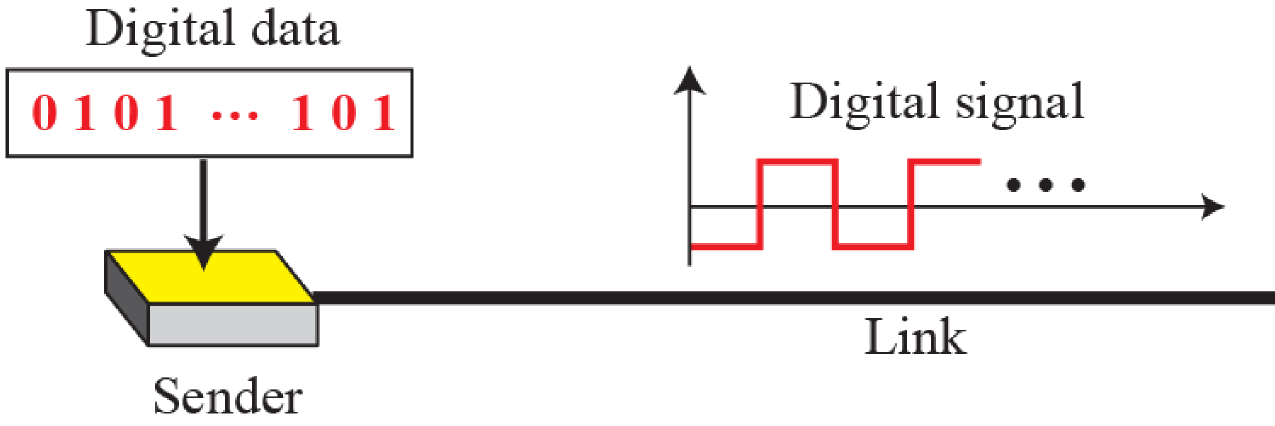


Figure 6.43

Analog to digital conversion

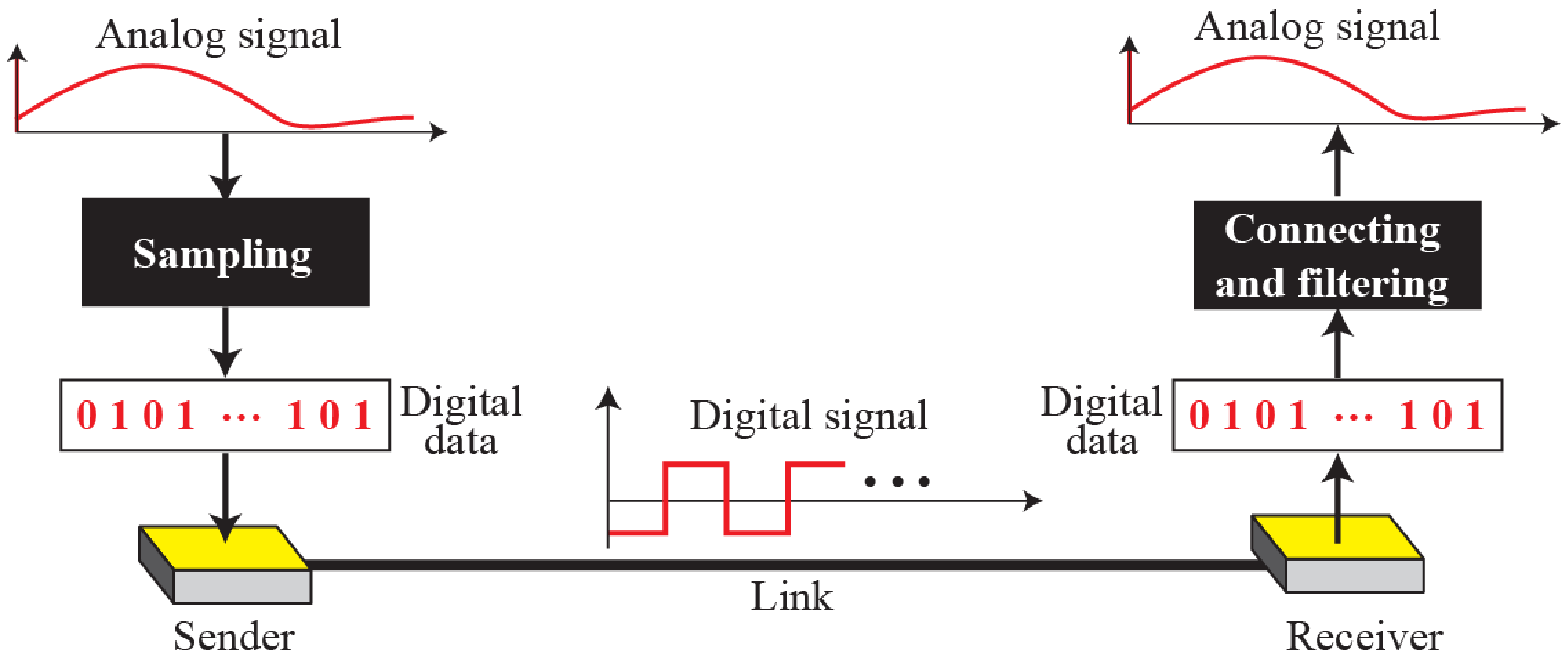


Figure 6.44

Analog transmission

Digital-to-analog conversion

Digital-to-analog conversion is the process of changing one of the characteristics of an analog signal based on the information in digital data.

Figure 6.45 shows the relationship between the digital information, the digital-to-analog conversion process, and the resultant analog signal.

Digital-to-analog conversion

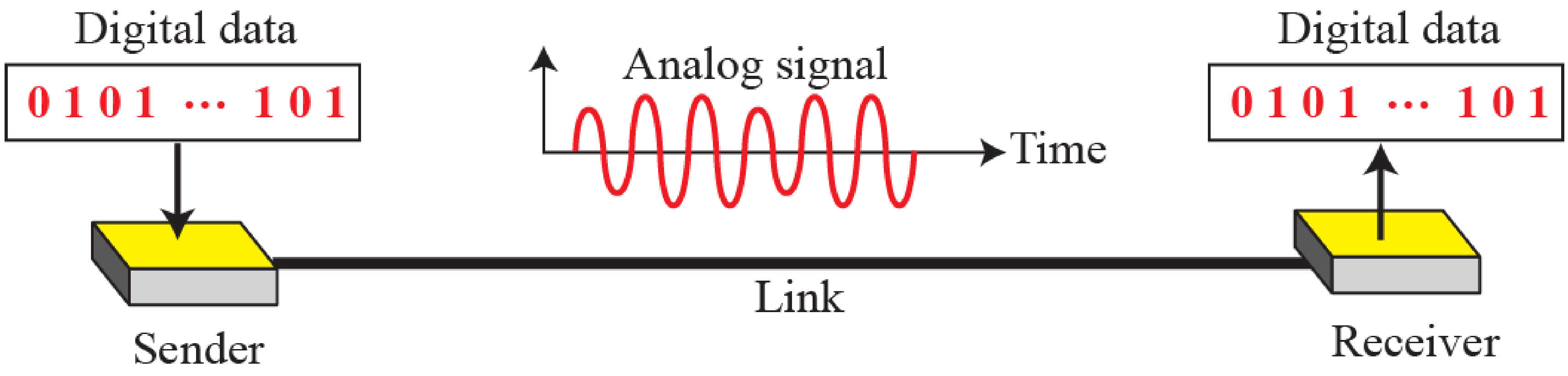


Figure 6.45

Analog-to-analog conversion

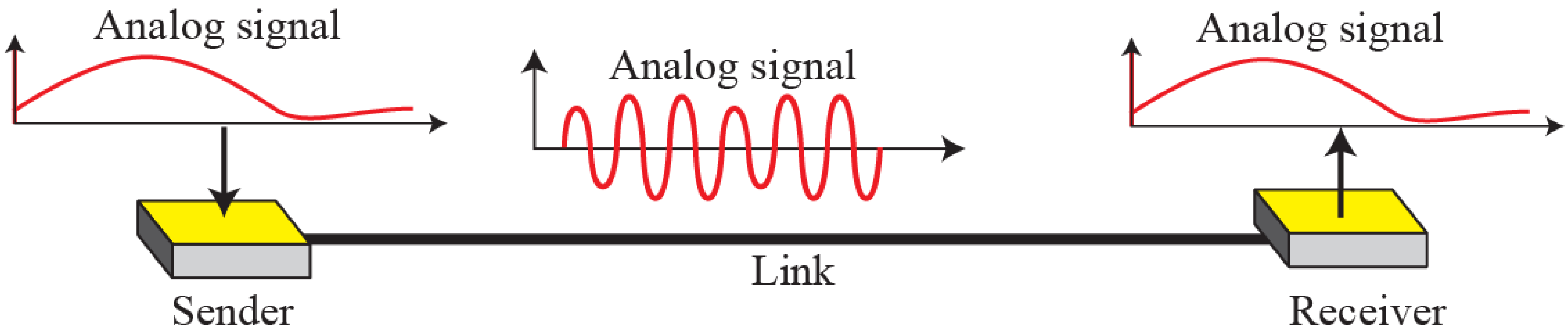


Figure 6.46

6.7 TRANSMISSION MEDIA

Electrical signals created at the physical layer need transmission media to go from point to another. Transmission media are actually located below the physical layer and are directly controlled by the physical layer. We could say that transmission media belong to layer zero.

Guided media

Guided media

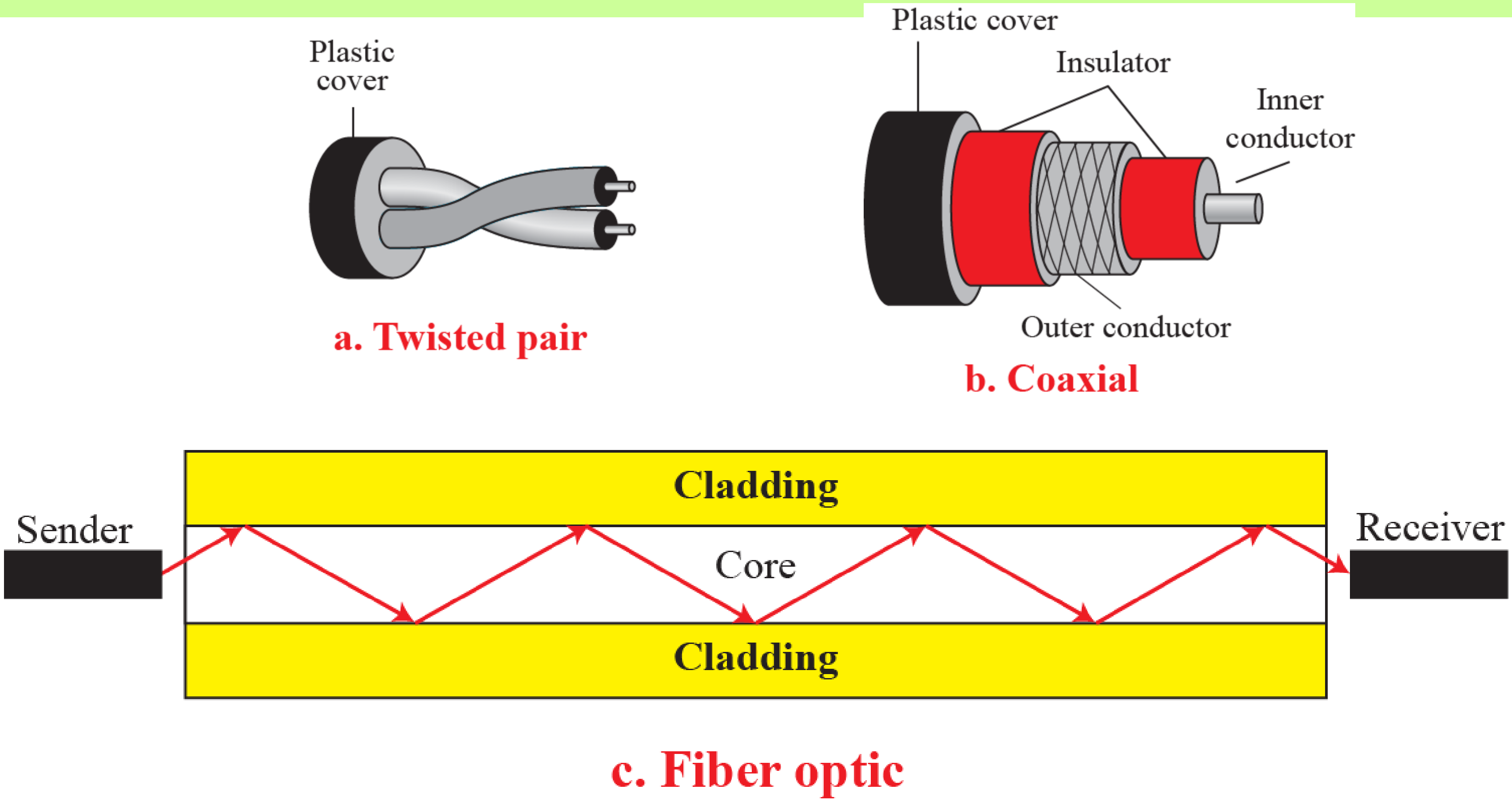
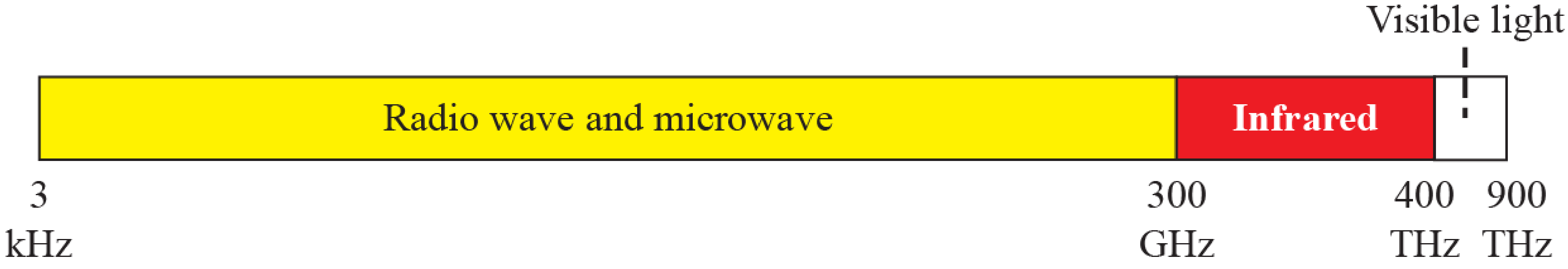


Figure 6.48

Unguided media: wireless

Figure 6.49 shows the part of the electromagnetic spectrum, ranging from 3 kHz to 900 THz, used for wireless communication.

Figure 6.49: **Electromagnetic spectrum**



Radio waves

Microwaves

Infrared

Infrared waves, with frequencies from 300 GHz to 400 THz (wavelengths from 1 mm to 770 nm), can be used for short-range communication. Infrared waves, having high frequencies, cannot penetrate walls.

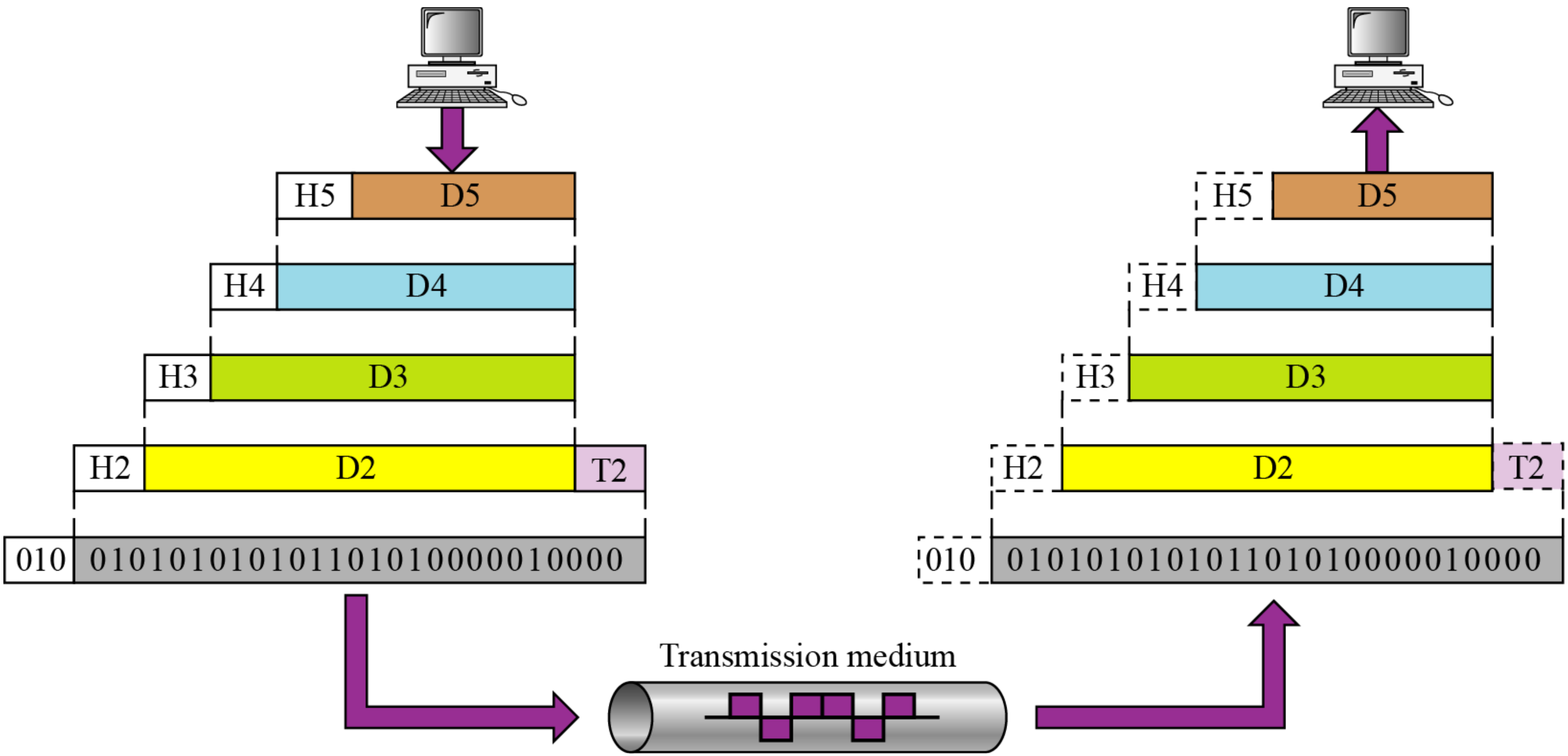


Figure 6.19 **An exchange using the TCP/IP model**