CHAPTER 6
Computer Networks and Internet

Objectives

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

- ❑ **Describe local and wide area networks (LANs and Wans).**
- ❑ **Distinguish an internet from the Internet.**
- ❑ **Describe the TCP/IP protocol suite as the network model in the internet.**
- ❑ **Describe some application at the application layer.**
- ❑ **Describe the services provided by the transport-layer protocols**
- ❑ **Describe the services provided by the network-layer protocol.**
- ❑ **Describe different protocols used at the data-link layer.**

Objectives

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

- ❑ **Describe local and wide area networks (LANs and Wans).**
- ❑ **Distinguish an internet from the Internet.**
- ❑ **Describe the TCP/IP protocol suite as the network model in the internet.**
- ❑ **Describe some application at the application layer.**
- ❑ **Describe the services provided by the transport-layer protocols**
- ❑ **Describe the services provided by the network-layer protocol.**
- ❑ **Describe different protocols used at the data-link layer.**
- ❑ **Describe the duties of the physical layer.**
- ❑ **Describe different transmission media used in networking.**

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.

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

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.

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

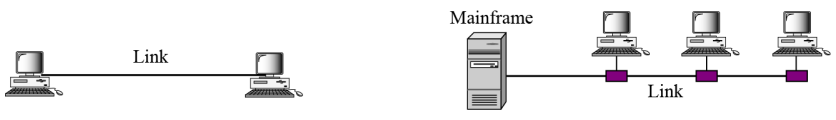
6.5

Physical structures

Before discussing networks, we need to define some network attributes.

Types of Connection: A network consists of two or more devices connected through **links**. A link is a communications pathway that transfers data from one device to another. There are two possible types of connections: **point-to-point** and **multipoint**..

Figure 6.1 **Types of connections: point-to-point and multipoint**

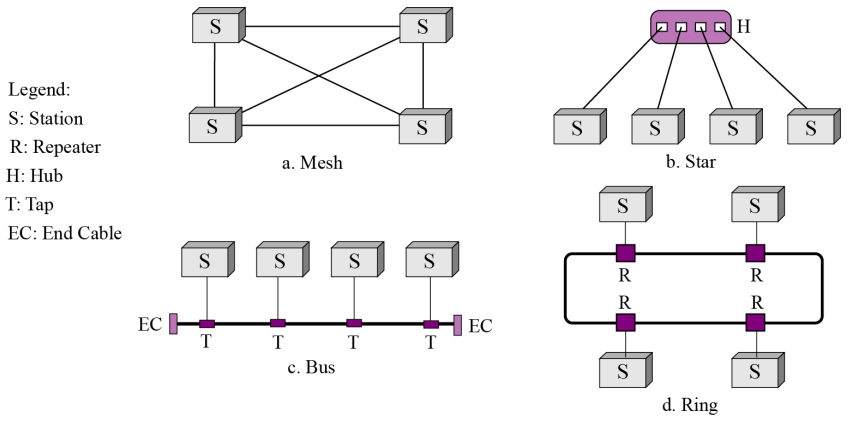


a. Point-to-point

b. Multipoint

The term **physical topology** refers to the way in which a network is laid out physically. There are four basic topologies possible: mesh, star, bus, and ring.

Figure 6.2 **Four physical topologies**



Categories of networks

Today networks can be divided into three broad categories: **local-area networks (LANs), wide-area networks (WANs),** and **metropolitan area networks (MANs).**

Figure 6.3 **An isolated LAN connecting eight computers to a hub**

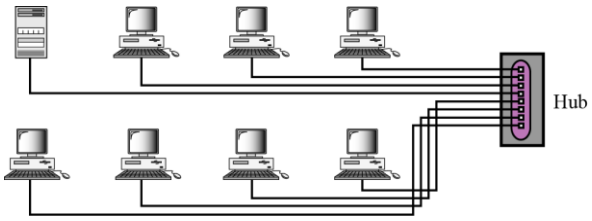
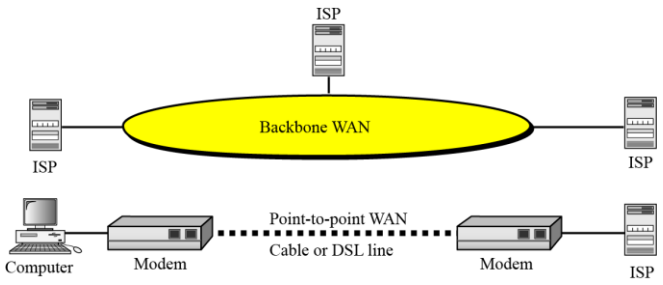


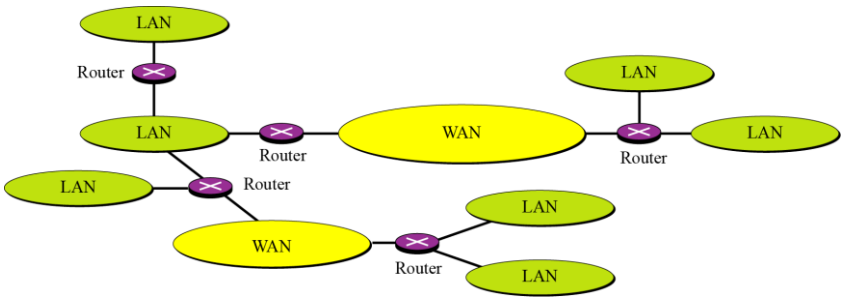
Figure 6.4 A point-to-point WAN and a backbone WAN



An internet

Today, it is very rare to see a network in isolation: networks are connected to one another. When two or more networks are connected, they become an **internetwork**, or an **internet** (lowercase "i").

Figure 6.5 An internet made of WANs, LANs, and routers

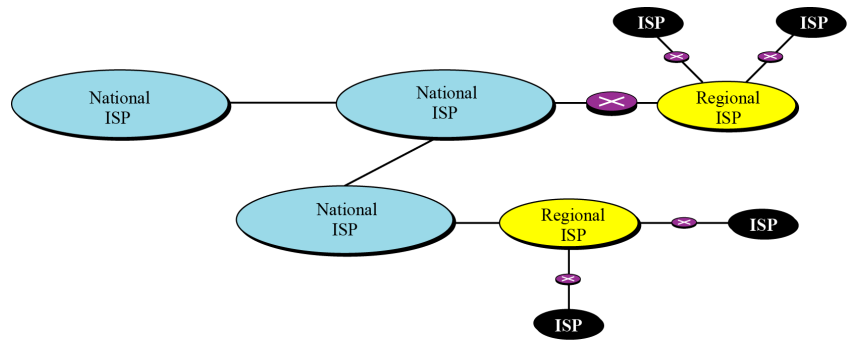


The Internet

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. Millions of people are users.

It is difficult to give an accurate representation of the Internet, because it is continually changing. Today most end users who want an Internet connection use the services of **Internet service providers (ISPs).**

Figure 6.6 Hierarchical organization of the Internet



6-2 TCP/IP PROTOCOL SUITE

To divide the services required to perform a task, the Internet has created a set of rules called protocols. These allow different local and wide area networks, using different technologies, to be connected together and carry a message from one point to another. The set, or suite, of protocols that controls the Internet today is referred to as the **TCP/IP protocol suite**. The abbreviations (TCP and IP) will become clear as we explain different protocols.

The original TCP/IP protocol suite was defined as having four layers: host-to-network (or link), internet (network), transport, and application. However, the TCP/IP protocol suite today is normally considered as a five-layer model, as shown in Figure 6.7.

Figure 6.7 **The TCP/IP protocol suite**

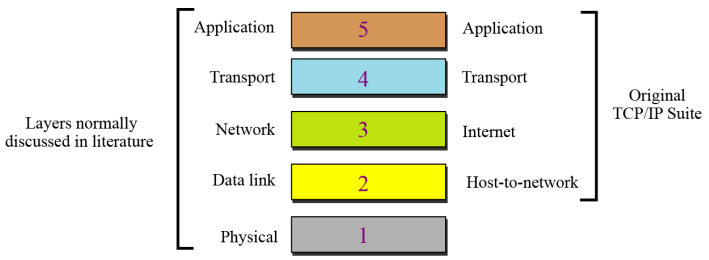
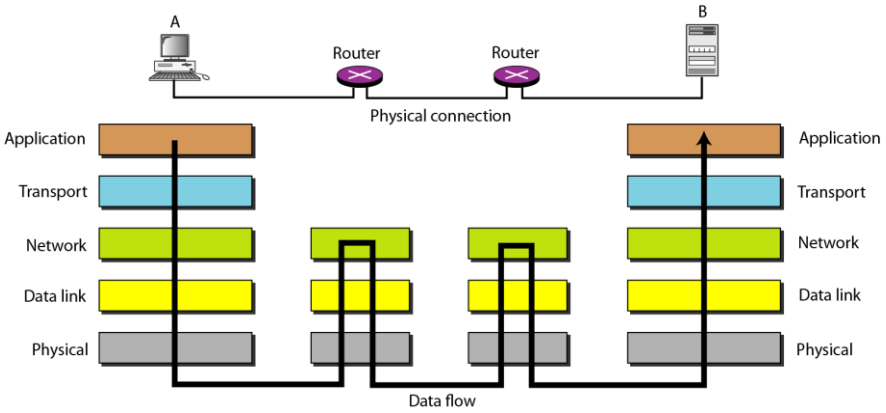


Figure 6.8 shows the layers involved when a message is sent from device A to device B. As the message travels from A to B, it may pass through many routers. Routers use only the first three layers.

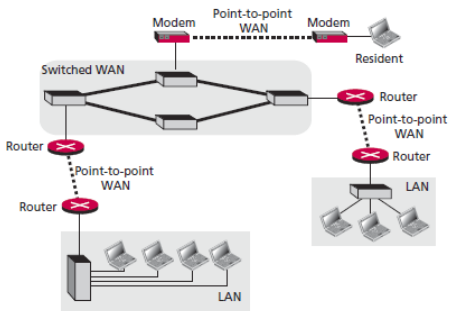
Figure 6.8 **The interaction between layers in the TCP/IP protocol suite**



6-3 LAYERS

This section briefly describes the function of each **layer** in the TCP/IP protocol suite. We show how a message travels through the different layers until it reaches the physical layer and is sent by the transmission media.

Figure 6.3 *An internetwork made of two LANs and three WANs*



6.16

Application layer

The application layer enables a user, whether human or software, to access the network. It provides support for services such as electronic mail, remote file access and transfer, browsing the World Wide Web, and so on.

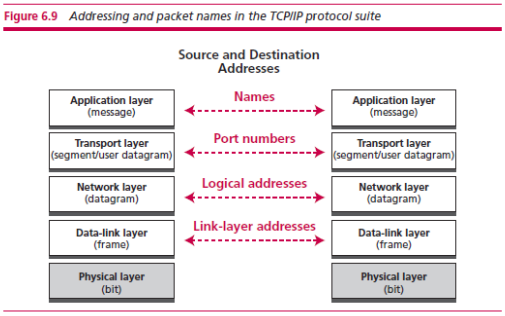
The application layer is responsible for providing services to the user.

6.17

Client-server architecture

Although there are two architectures (designs) that allow two application programs, running on two remote computers, to communicate with each other, **client-server architecture** is more common.

Figure 6.9 Communication at the application layer



Application-layer address

When a client needs to send a request to a server, it needs the server application-layer address. For example, to identify one particular site, the client uses a Uniform Resource Locator (URL). As we will see later, the server application-layer address is not used for delivery of messages, it only helps the client to find the actual address of the server computer.

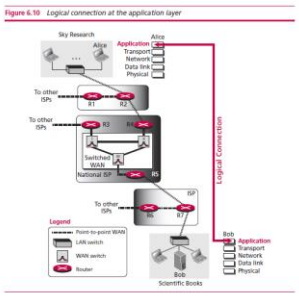


Figure 6.10 **Addresses at the application layer**

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. In other words, although physical communication is between two physical layer (through many possible links and routers), the two application layers consider the transport layer as the agent that takes responsibility for delivering the messages.

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

Figure 6.11 *Example of a client–server paradigm*

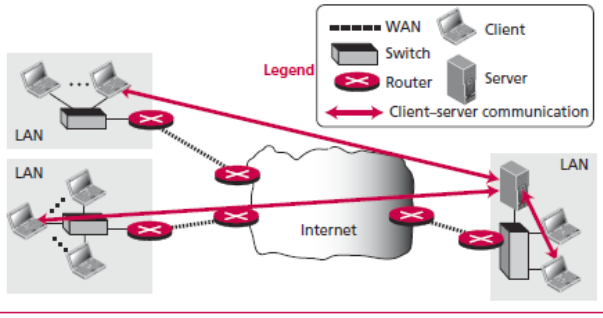


Figure 6.11 **Communication at the transport layer**

6.21

Transport-layer addresses (port numbers)

The server computer may be running several processes at the same time, for example an FTP server process and an HTTP server process. When the message arrives at the server, it must be directed to the correct process. We need another address for server process identification, called a port number.

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

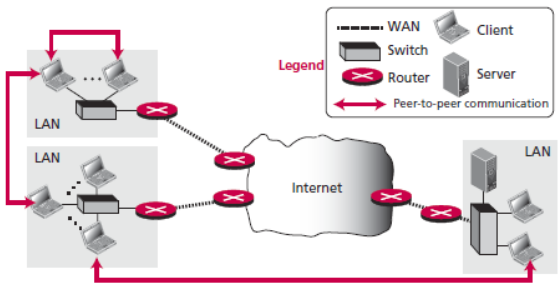


Figure 6.12 **Addresses at the transport layer**

6.22

Transport-layer protocols

During the life of the TCP/IP protocol suite three transport layer protocols have been designed: **UDP**, **TCP**, and **SCTP**.

The **User Datagram Protocol (UDP)** is the simplest of all three protocols. UDP does multiplexing and de-multiplexing It also does a type of error control by adding a checksum to the packet.

Transmission Control Protocol (TCP) is a protocol that supports all the duties of a transport layer. However, it is not as fast and as efficient as UDP. TCP uses sequence numbers, acknowledgment numbers, and checksums. It also uses buffers at the sender's site. This combination of provisions provides multiplexing, de-multiplexing, flow control, congestion control, and error control.

6.23

Stream Control Transmission Protocol (SCTP) is a new protocol that is designed for new services expected from the Internet, such as Internet telephony and video streaming. This protocol combines the advantages of both UDP and TCP. Like UDP, it is suitable for real-time transmission of audio and video, but like TCP, it
provides error and flow control.

6.24

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.

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

Network-layer addresses

The packet traveling from the client to the server and the packet returning from the server need network-layer address. The server address is provided by the server, as discussed above, while the client address is known by the client computer.

Figure 6.13 *Example 6.1*

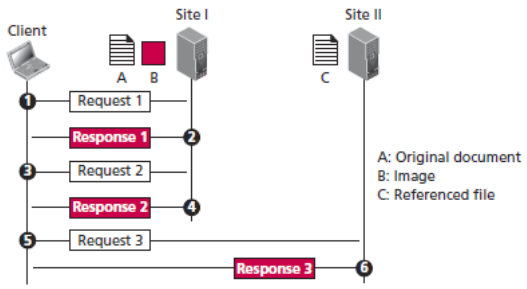


Figure 6.13 Addresses at the network layer

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.

6.27

Figure 6.14 *FTP*

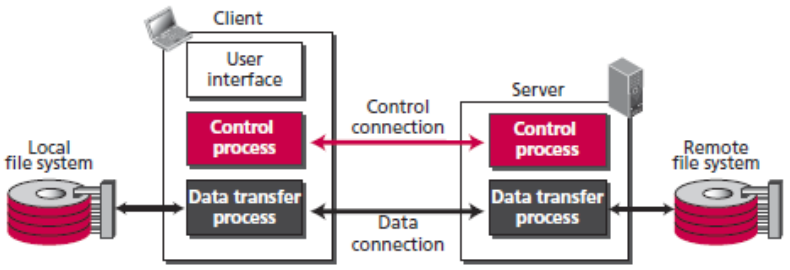


Figure 6.14 **Routing at the network layer**

6.28

Network-layer protocols

The TCP/IP protocol suite supports one main protocol (IP) and several auxiliary protocols to help IP to perform its duties.

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.

The notation divides the 32-bit address into four 8-bit sections and writes each section as a decimal number between 0 and 255 with three dots separating the sections. For example, an IPv4 address

00001010 00011001 10101100 00001111

is written as

10.25.172.15

Dotted-Decimal Notation

Data link layer

As we saw in the previous section, the network layer packet may pass through several routers in its journey from its source to its destination. 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.

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

6.31

Figure 6.15 *Common scenario*

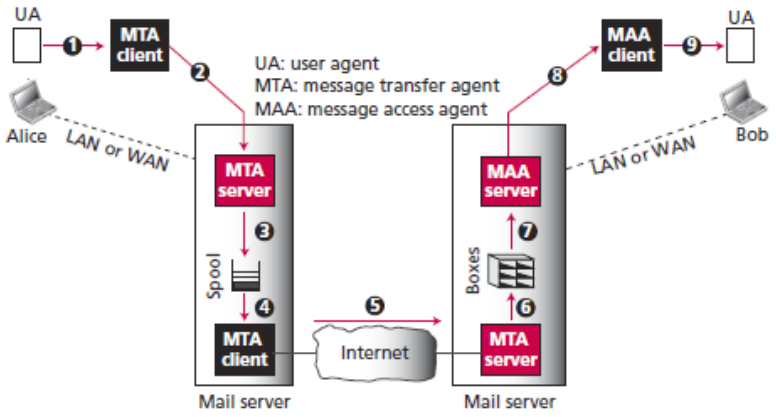


Figure 6.15 Communication at the data-link layer

6.32

Data-link layer addresses

Two questions that come to mind are how computer A knows the data-link layer address of router R_1, or router R_1 knows the data-link layer address of router R_4. A device can find the data-link address of another device either **statically** or **dynamically**.

Figure 6.16 *DNS usage*

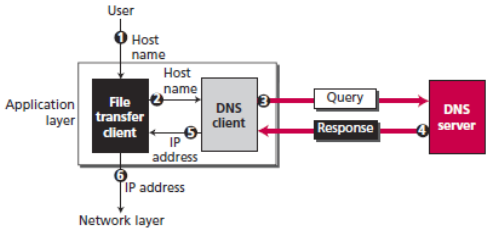


Figure 6.16 Addresses at the data link layer

Unlike IP addresses, addresses at the data-link layer cannot be universal. Each data link protocol may have a different address format and size. The Ethernet protocol, the most prevalent local area network in use today, uses a 48-bit address, which is normally written in hexadecimal format (grouped in six sections, each with two hexadecimal digits) as shown below:

```
07:01:02:11:2C:5B
```

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 6.17 *Generic domains*

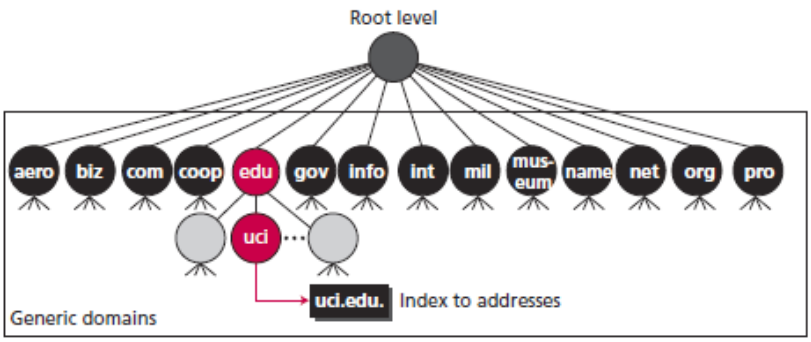


Figure 6.17 Duty of the physical layer

Summary of layers

Figure 6.18 summarizes the duties of each layer in the TCP/IP protocol and the addresses involved in each layer.

Figure 6.18 *Country domains*

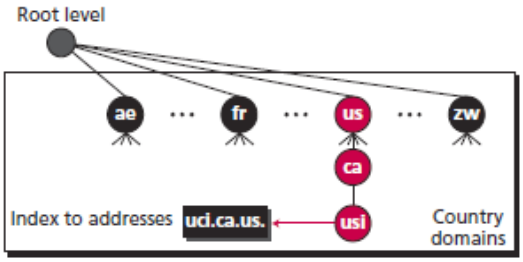


Figure 6.18 Four levels of addressing in the Internet

Figure 6.19 *Logical connection at the transport layer*

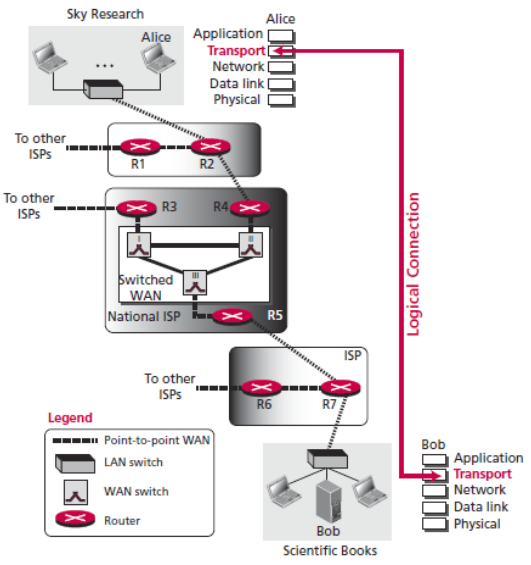


Figure 6.19 An exchange using the TCP/IP model

6-4 INTERNET APPLICATIONS

The main task of the Internet is to provide services for users. Among the most popular applications are **electronic mail**, **remote login**, **file transfer**, and accessing the **World Wide Web (WWW).** We briefly discuss these applications in this section.

Electronic-mail

Let us first discuss electronic mail (e-mail). Ironically, this first application that we discuss in this section cannot be supported by one client process and one server process. The reason is that 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.

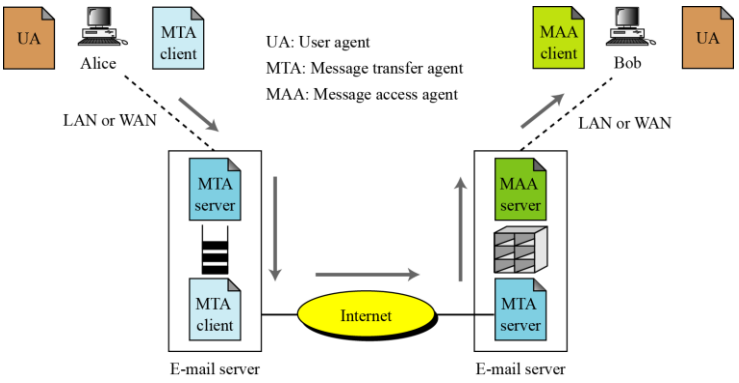


Figure 6.20 **E-mail architecture**

Mail access protocols

Stored e-mail remains on the mail server until it is retrieved by the recipient through an access protocol. Currently two e-mail access protocols are in common use: **Post Office Protocol, Version 3 (POP3)** and **Internet Mail Access Protocol (IMAP).**

Addresses

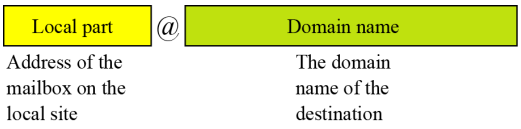


Figure 6.21 **E-mail address**

Multi-purpose Internet Mail Extension (MIME)

Multipurpose Internet Mail Extension (MIME) is a supplementary protocol that allows non-ASCII data to be sent through SMTP. MIME is not an e-mail protocol and cannot replace SMTP, it is only an extension to SMTP.

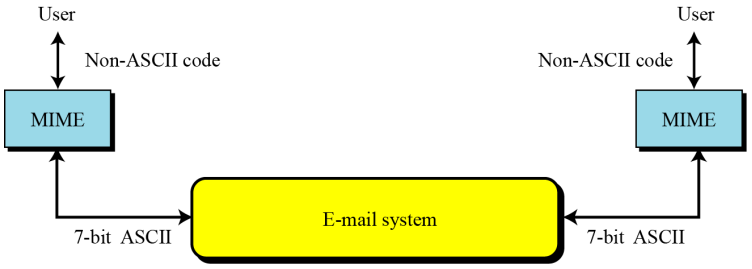


Figure 6.22 **Multi-purpose Internet Mail Extension (MIME)**

File Transfer Protocol (FTP)

File Transfer Protocol (FTP) is the standard mechanism for one of the most common tasks on the Internet, copying a file from one computer to another.

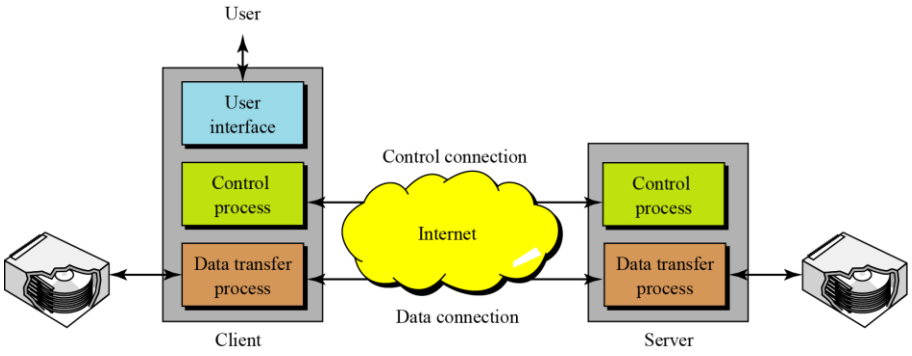


Figure 6.23 **File Transfer Protocol (FTP)**

Remote login – TELNET

The main task of the application layer is to provide services for users. One way to satisfy these demands is to create different client-server application programs for each desired service. Programs such as file transfer programs (FTP and SMTP), and so on are already available. However, it would be impossible to write a client-server program for each specific application.

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.

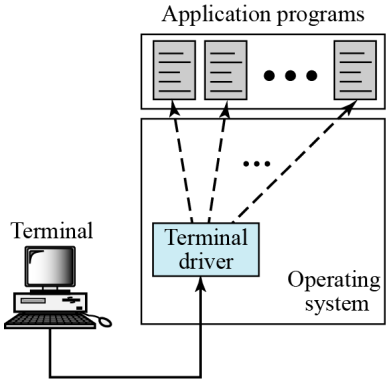


Figure 6.24 **Local login**

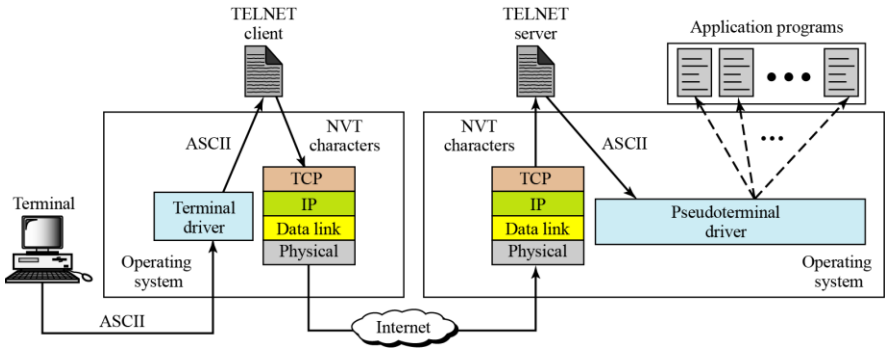


Figure 6.25 **Remote login**

The World Wide Web (WWW)

The **World Wide Web (WWW)**, or just "the Web", is a repository of linked information spread all over the world. The WWW has a unique combination of flexibility, portability, and user-friendly features that distinguish it from other services provided by the Internet. 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 web sites.

Hypertext and hypermedia

The WWW uses the concept of hypertext and hypermedia. In a hypertext environment, information is stored in a set of documents that are connected together using the concept of links.

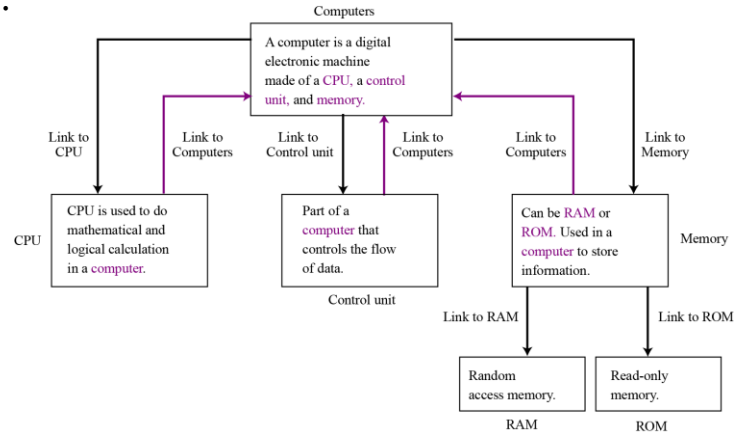


Figure 6.26 **Hypertext**

6.49

Components of WWW

To use the WWW we need three components: a **browser**, a **web server**, and a protocol called **Hypertext Transfer Protocol (HTTP)**.

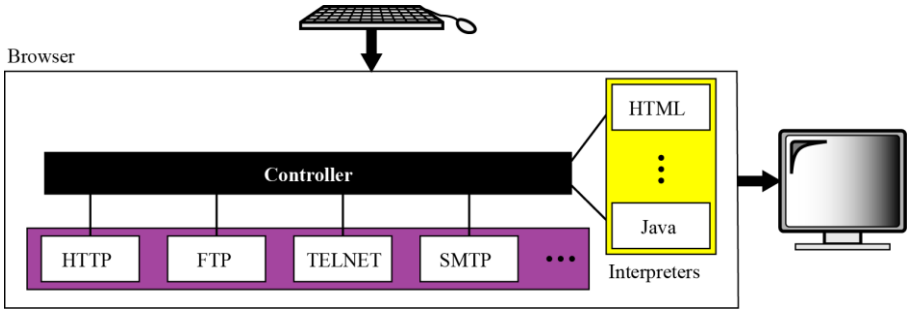


Figure 6.27 **Browser structure**

6.50

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

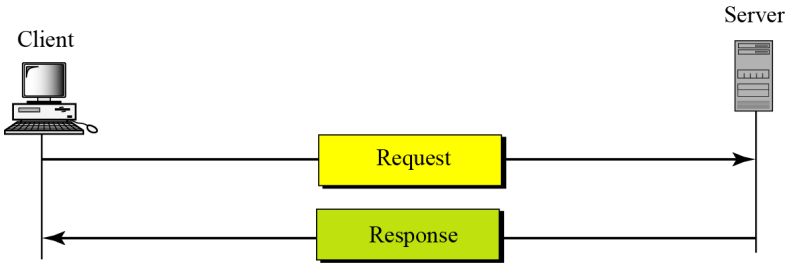


Figure 6.28 **HTTP transaction**

A client that wants to access a document needs an address. To facilitate the access of documents distributed throughout the world, HTTP uses the concept of locators. The **uniform resource locator (URL)** is a standard for specifying any kind of information on the Internet.

Figure 6.29 **URL structure**

Static documents

The documents on the WWW can be grouped into three broad categories: static, dynamic, and active. This categorization is based on the time at which the contents of the document are determined. Static documents are fixed-content documents that are created and stored on a server.

6.53

Hypertext Markup Language (HTML) is a language for creating Web pages.

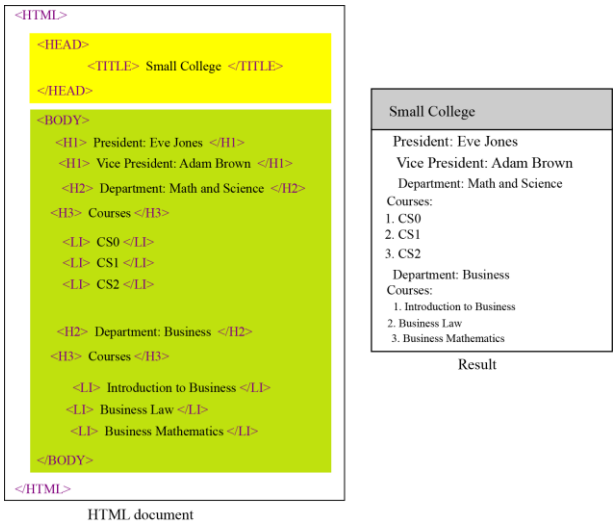


Figure 6.30 HTML example

6.54

HTML adds formatting capability to a document, but it does not define the type of data. **Extensible Markup Language (XML)** is a language in which tags can be used to define the content (type) of the text between two tags.

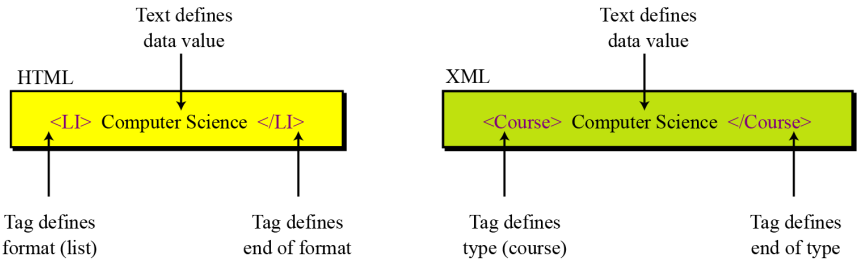


Figure 6.31 **Comparing HTML and XML**

6.55

Dynamic documents

A dynamic document is created by a Web server whenever a browser requests the document. When a request arrives, the Web server runs an application program that creates the dynamic document. The server returns the output of the program as a response to the browser that requested the document.

6.56

Active documents

For many applications we need to be able to run a program or a script at the client site. These are called active documents. For example, suppose we want to run a program that creates animated graphics on the screen, or a program that interacts with the user. The program definitely needs to be run on the client computer where the animation or interaction takes place. When a browser requests an active document, the server sends a copy of the document or a script. The document is then run under the control of the client's browser.

Other Internet applications

During the last decades other applications have been developed on the Internet. These applications are not as popular as those discussed above, but they are gaining ground. We discuss a few of them here.

Videoconferencing

Videoconferencing can eliminate the cost of traveling, and save time and energy, by providing communication between two or more groups of participants or a set of individual participants.

Figure 6.32 *IPv6 datagram*

Figure 6.32 Videoconferencing

Group discussion Listservs

Another popular class of applications is **listservs**, which allow a group of users to discuss a common topic of interest.

Figure 6.33 *Communication at the data-link layer*

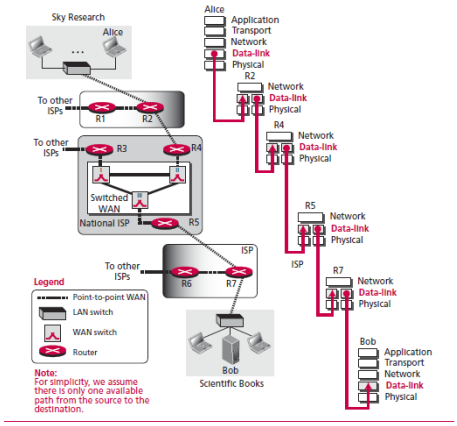


Figure 6.33 Listserv organization

Chat

Another populate class of Internet application is **chat**. This is a real-time application like videoconferencing, in which two or more parties are involved in an exchange of text and optionally audio and video. The two parties can send text to each other, talk to each other (the same way as they might talk on the phone), and even see each other with suitable cameras.