جامعة المعارف - كلية العلوم- قسم علوم الحاسوب

Data Communication and Networks

Chapter 1: Computer Networks Overview

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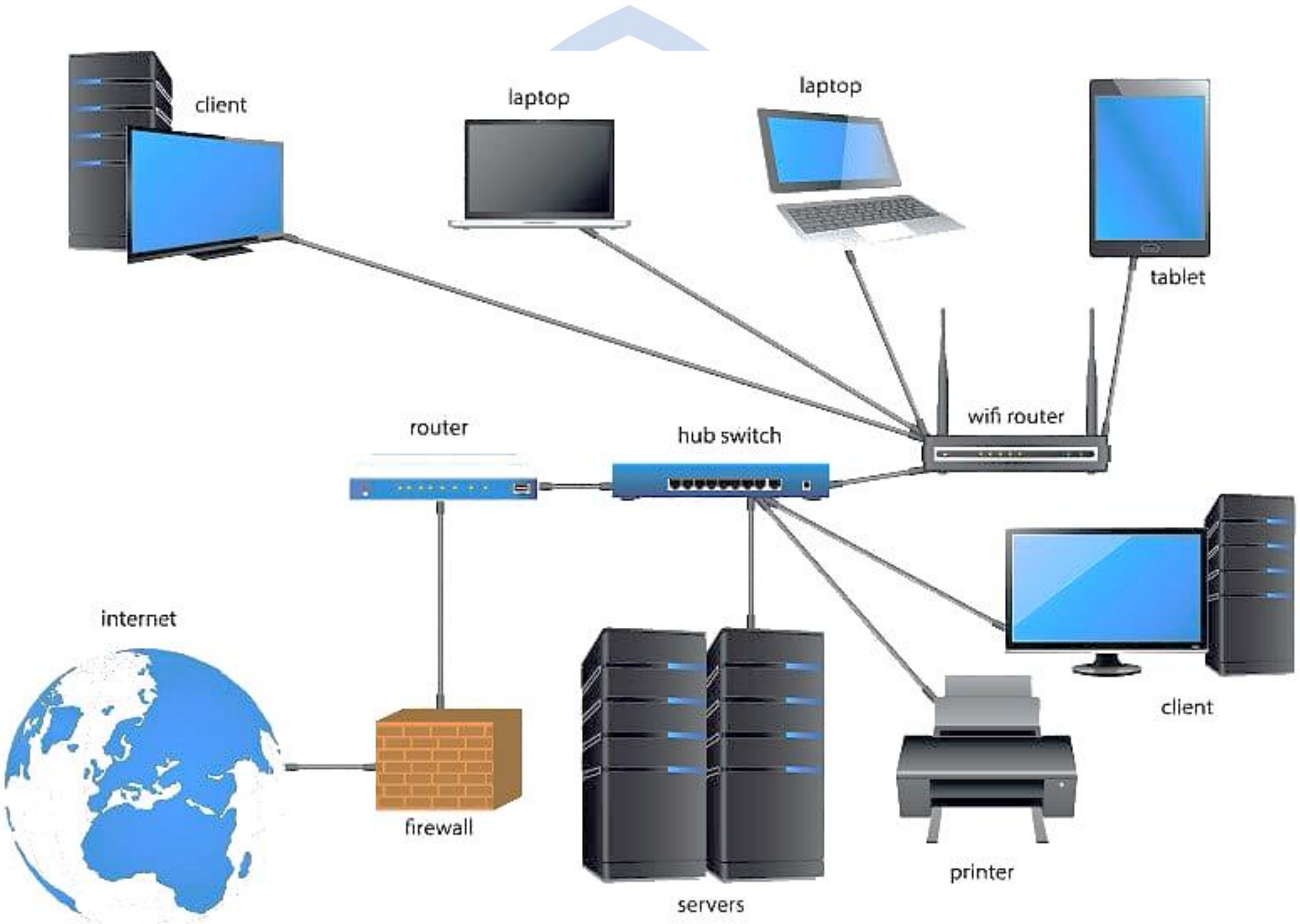

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Let us start our lectures with the following question:

Why wait a week for that letter from Germany to arrive by regular mail when it could appear almost instantaneously through computer networks?

Data communications and ***networking*** are changing the way we do business and the way we live. Businesses today rely on computer networks and internetworks (e.g., Internet).

Data communications and ***networking*** enable to exchange data such as text, audio, and video from all points in the world. We want to access the Internet to download and upload information quickly and accurately and at any time.

1.1 Data Communication

When we communicate, we are sharing information. This sharing can be local or remote. Between individuals, local communication usually occurs face to face, while remote communication takes place over distance.

The term *telecommunication*, which includes telephony, telegraphy, and television, means communication at a distance (tele is Greek for "far").

Data communications are the exchange of data between two devices via some form of transmission medium such as a wire cable. The communicating devices must be part of a communication system which is made up of a combination of **hardware** (physical equipment) and **software** (programs).

The effectiveness of a data communications system depends on four fundamental characteristics:

1. **Delivery**. The system must deliver data to the correct destination.

2. **Accuracy**. The system must deliver the data accurately, without errors.

3. **Timeliness**. The system must deliver data in a timely manner. Data delivered late is useless. In the case of video and audio, timely delivery means delivering data as they are produced, without significant delay (*real-time transmission*).

4. **Jitter**. Jitter refers to the variation in the packet arrival time. It is the uneven delay in the delivery of audio or video packets. For example, let us assume that video packets are sent every 3D-ms. If some of the packets arrive with 3D-ms delay and others with 4D-ms delay, an **uneven quality** in the video is the result.

1.2 Components of data communications system

A data communications system has five components (see Figure 1.1).

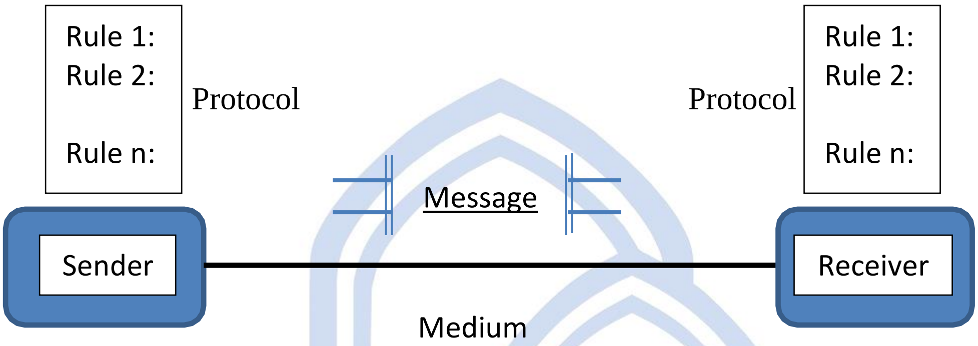


Figure 1.1 *Five components of data communication system*

1. **Message**. It is the information (data) to be communicated. Popular forms of information include text, numbers, pictures, audio, and video.

2. **Sender**. It is the device that sends the data message. It can be a computer, workstation, telephone handset, video camera, and so on.

3. **Receiver**. It is the device that receives the message. It can be a computer, workstation, telephone handset, television, and so on.

4. **Transmission medium**. It is the physical path by which a message travels from sender to receiver. Some examples of transmission media include twisted-pair wire, coaxial cable, fiber-optic cable, and radio waves.

5. **Protocol**. It is a set of rules that govern data communications. It represents an agreement between the communicating devices. Without a protocol, two devices *may be connected but not communicating*, just as a person speaking French cannot be understood by a person who speaks only Japanese.

1.3 Data Representation

Information today comes in different forms such as:

Text In data communications, text is represented as a bit pattern, a sequence of bits (0s or 1s). Different sets of bit patterns have been designed to represent text symbols, for example, the ***A**merican **S**tandard **C**ode for **I**nformation **I**nterchange* (**ASCII**) which uses 32 bits to represent a symbol or character used in any language in the world. Each set is called a code, and the process of representing symbols is called coding.

Numbers are also represented by bit patterns. However, a code such as ASCII is not used to represent numbers; the number is directly converted to a binary number.

Images are also represented by bit patterns. In its simplest form, an image is composed of a matrix of pixels (picture elements), where each pixel is a small dot. The size of the pixel depends on the *resolution*.

Audio refers to the recording or broadcasting of sound or music. Audio is by nature different from text, numbers, or images. It is continuous, not discrete.

Video refers to the recording or broadcasting of a picture or movie. Video can either be produced as a continuous entity (e.g., by a TV camera), or it can be a combination of images.

1.4 Data Flow

Communication between two devices can be simplex, half-duplex, or full-duplex as shown in Figure 1.2.

Simplex In simplex mode, the communication is unidirectional, as on a one-way street. For example, the keyboard can only introduce input; the monitor can only accept output.

Half-Duplex In half-duplex mode, each station can both transmit and receive, but not at the same time. When one device is sending, the other can only receive, and vice versa, for example, the Walkie-talkies devices.

Full-Duplex In full-duplex mode (also called duplex), both stations can transmit and receive simultaneously, for example, the telephone network.

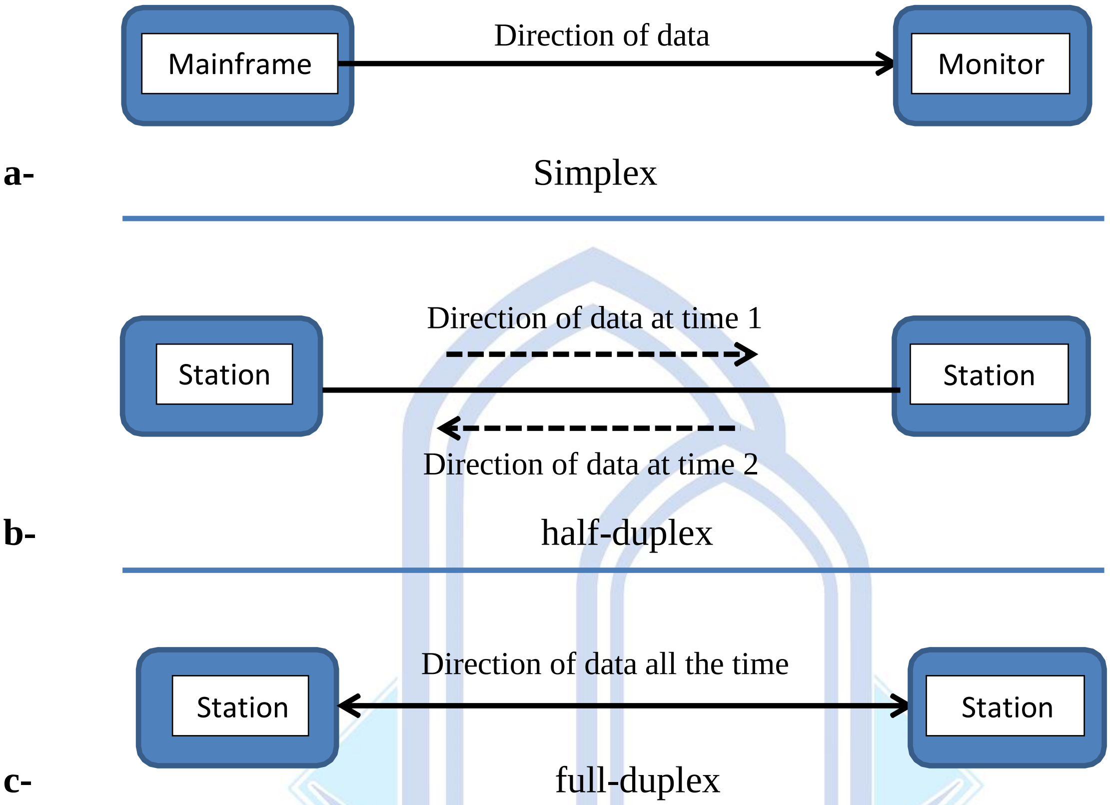


Figure 1.2 *Data flow (simplex, half-duplex, and full-duplex)*

1.5 Networks

A network is a set of devices (often referred to as *nodes)* connected by communication links. A *node* can be a computer, printer, or any other device capable of sending and/or receiving data generated by other nodes on the network.

1.5.1 Distributed Processing

Most networks use distributed processing, in which a task is divided among multiple computers. Instead of one single large machine being responsible for all aspects of a process, separate computers (usually a personal computer or workstation) handle a subset.

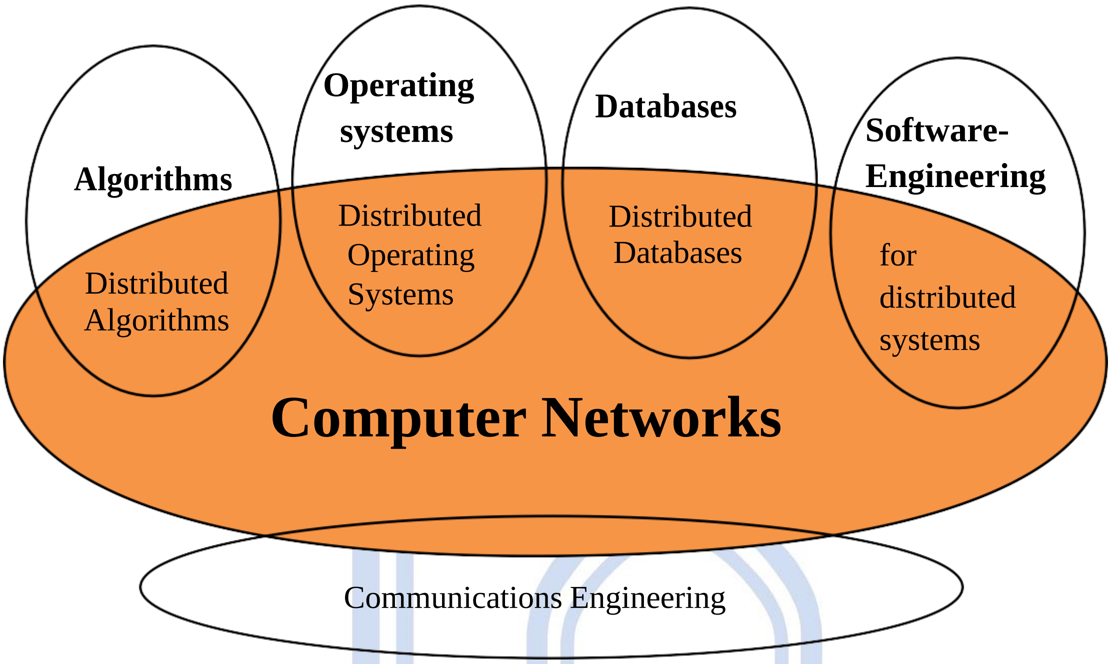


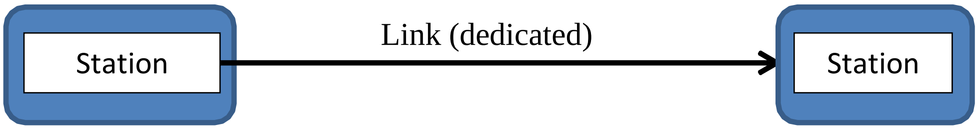
Figure 1.3 Distributed processing in computer networks vs. otherComputer Science Classes

1.5.2 Types of Network Connections

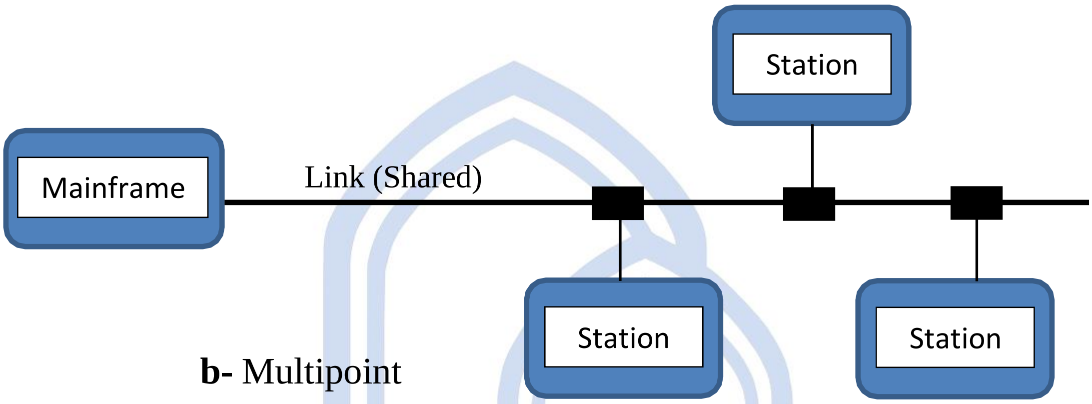
There are two possible types of connections:

Point-to-Point This connection provides a dedicated link between two devices. The entire capacity of the link is reserved for transmission between those two devices, (see Figure 1.3a). For example: establishing a point-to-point connection between the remote control and the television's control system.

Multipoint In this connection, more than two specific devices share a single link (see Figure 1.3b). The capacity of the channel is shared, either spatially or temporally. If several devices can use the link simultaneously, it is a ***spatially shared*** connection. If users must take turns, it is a ***timeshared*** connection.



a- Point-to-Point connection



b- Multipoint

Figure 1.3 *Types of connections: point-to-point and multipoint*

1.5.3 Physical Network Topology

The term *physical topology* refers to the way in which a network is laid out physically. The topology of a network is the geometric representation of the relationship of all the links and linking devices (usually called nodes) to one another.
There are four possible basic topologies:

1. Mesh In a mesh topology, every device has a dedicated point-to-point link to every other device.
Advantages: 1) Eliminating the traffic problems, 2) it does not incapacitate the entire system, If one link becomes unusable, and 3) High privacy or security.
Disadvantages: 1) amount of cabling and 2) the number of I/O ports are required.

2. Star Topology In a star topology, each device has a dedicated point-to-point link only to a central controller, usually called a ***hub***. The devices are not directly linked to one another. For example, the star topology is used in local-area networks (LANs).
Advantages: 1) each device needs only one link and one I/O port to connect it, 2) easy to install and reconfigure.

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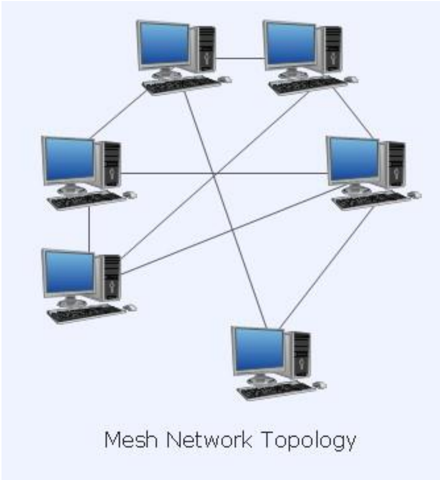
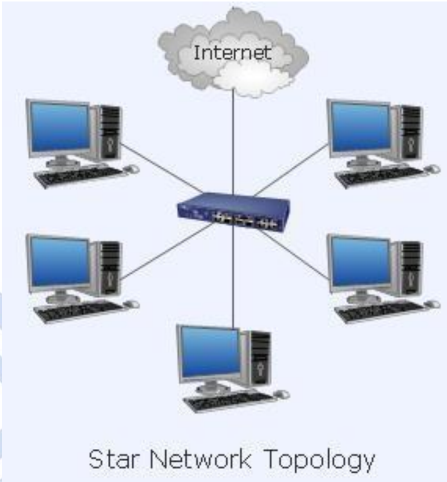
Disadvantages: the dependency of the whole topology on one single point, the hub. If the hub goes down, the whole system is dead.

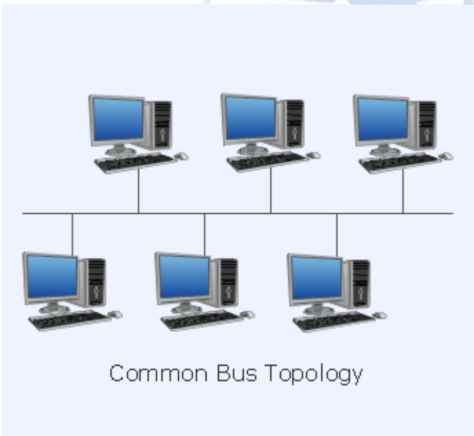


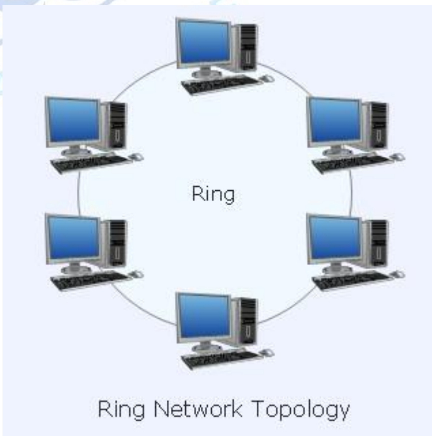


3. Bus Topology This topology is multipoint. One long cable acts as a backbone to link all the devices in a network. Nodes are connected to the bus cable by drop lines and taps. For example, Ethernet LANs can use a bus topology, but they are less popular now.
Advantages: 1) ease of installation and 2) less cabling than mesh or star topologies.
Disadvantages: difficult reconnection and fault isolation.

4. Ring Topology Each device has a dedicated point-to-point connection with only the two devices on either side of it. A signal is passed along the ring in one direction, from device to device, until it reaches its destination.

Advantages: easy to install and reconfigure. Each device is linked to only its immediate neighbours (either physically or logically).
Disadvantages: unidirectional traffic i.e., a break in the ring (such as a disabled station) can disable the entire network.





5. Hybrid Topology A network can be hybrid. For example, we can have a main star topology with each branch connecting several stations in a bus topology.

1.5.4 Categories of Networks

The category of networks is determined by its ***size*** and ***connection type.*** Figure 5 classifies the networks by their rough physical *size*.

Distance	*Location*	*Network category*
1 m	Square meter	Personal area network
10 m	Room	
100 m	Building	Local area network
1 km	Campus	
10 km	City	Metropolitan area network
100 km	Country	
1000 km	Continent	Wide area network
10,000 km	Planet	The Internet

Figure 1.5 *Classification of networks by size*

1. Personal Area Networks (PANs) let devices communicate over the range of a person. A common example is a wireless network that connects a computer with its peripherals: monitor, keyboard, mouse, and printer.

In the simplest form, Bluetooth networks use the master-slave paradigm of Figure 6. The system unit (the PC) is normally the master, talking to the mouse, keyboard, etc., as slaves. The master tells the slaves what addresses to use, when they can broadcast, how long they can transmit, what frequencies they can use, and so on.

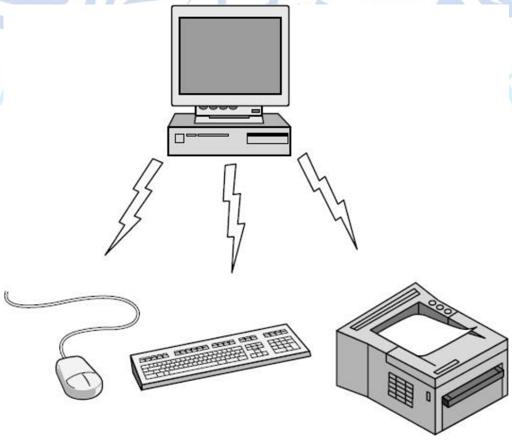


Figure 1.6 *Bluetooth PAN Configuration*

2. Local area networks (LANs) link the devices in a single office, building, or campus (see Figure 1.7). LANs can be as simple as two PCs and a printer in someone's home office; or it can extend throughout a company, they are called *enterprise networks*.

Wireless LANs are very popular these days in which every computer has a radio modem (e.g., wireless LAN card) to communicate with other computers. Each computer talks to an *Access Point* or *wireless router* (see Figure 1-7a) to relay data packets between the wireless computers and also with the Internet. There is a standard for wireless LANs called ***IEEE 802.11***, popularly known as ***WiFi***. It runs at speeds from 11 to hundreds of Mbps[1].

Wired LANs use a range of different transmission technologies. Most of them use copper wires, but some use optical fibre. Typically, wired LANs run at speeds of 100 Mbps to 1 Gbps, have low delay (microseconds or nanoseconds), and make very few errors. Compared to wireless networks, wired LANs exceed them in all dimensions of performance. ***IEEE 802.3***, popularly called ***Ethernet***, is the most common type of wired LAN. Figure 1-7(b) shows a sample topology of switched Ethernet.

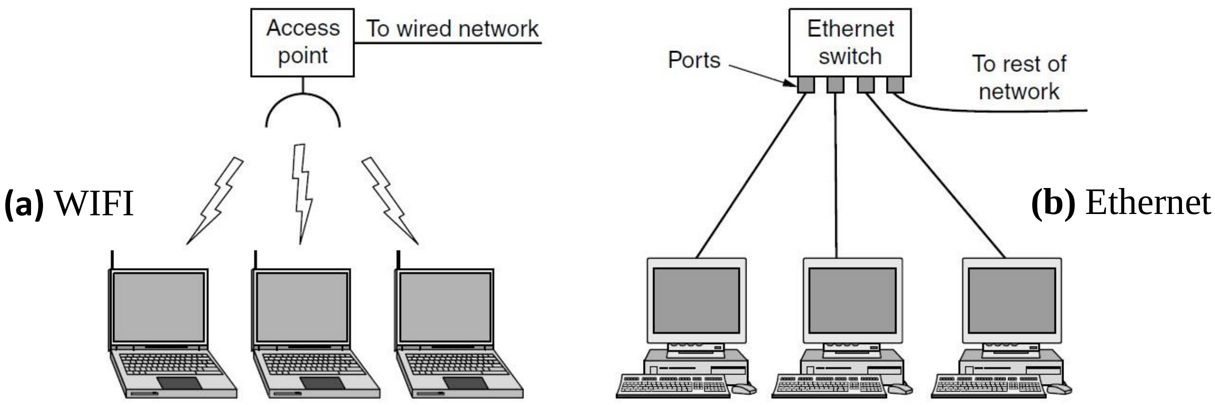


Figure (1.7): Wireless and wired LANs

LANs are designed to allow *resources* to be shared between personal computers or workstations. The resources to be shared can include *hardware* (e.g., a printer), *software* (e.g., an application program), or *data* (files). One of the computers may be given a large capacity disk drive and may become a server to clients. Software can be stored on this central server and used as needed by the whole users group.

[1] The 1 Mbps (Megabits/sec) is 1,000,000 bits/sec, and the 1 Gbps (gigabits/sec) is 1,000,000,000 bits/sec.)

3. Metropolitan Area Network (MAN) covers a city. The best-known examples of MANs are the cable television networks available in many cities. These systems grew from earlier community antenna systems. A MAN might look something like the system shown in Figure 1-8. In this figure we see both television signals and Internet being fed into the centralized cable head-end for subsequent distribution to people's homes.

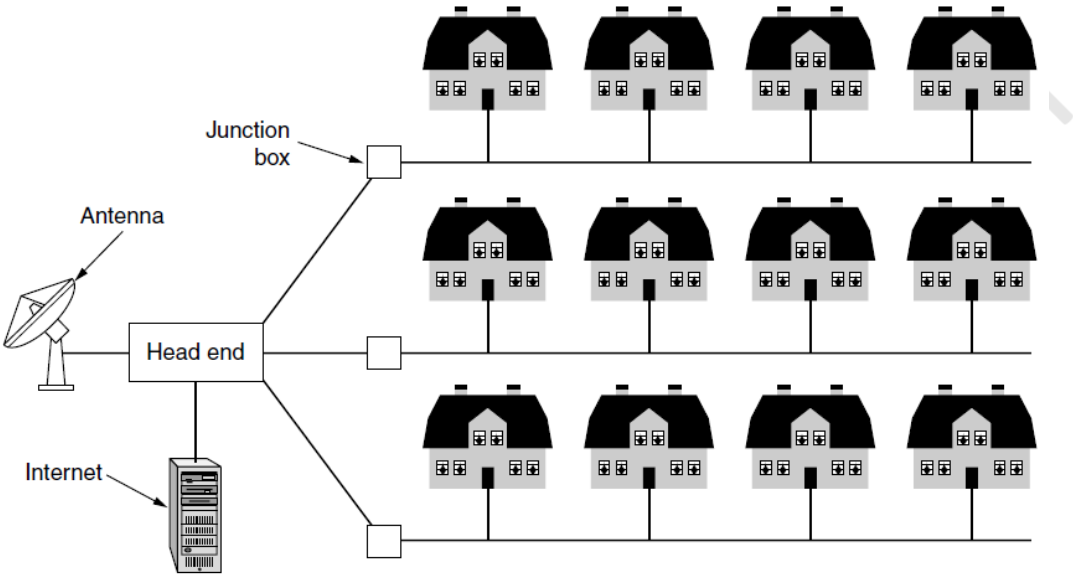


Figure 1.8 A metropolitan area network based on cable TV

4. A wide area network (WAN) provides long-distance transmission of data over large geographic areas that may comprise a country, a continent, or even the whole world.

The WAN in Figure 1-9 is a network in Australia that connects offices in Perth, Melbourne, and Brisbane. Each of these offices contains computer machines intended for running user (i.e., application) programs. Each of these machines are called host. The rest of the network that connects these hosts is then called the **communication subnet**, or just **subnet**[2] for short.

The subnet consists of two distinct components: *transmission lines* and *switching* elements. Transmission lines move bits between machines. They can be made of copper wire, optical fiber, or even radio links. Switching elements are specialized computers that connect two or more transmission lines. When data arrive on an incoming line, the switching element must choose an outgoing line on which to forward them. These switching computers are called the ***router.***

[2] There is second meaning for the word: ***subnet*** in conjunction with network addressing. We will discuss that meaning in next lecture.

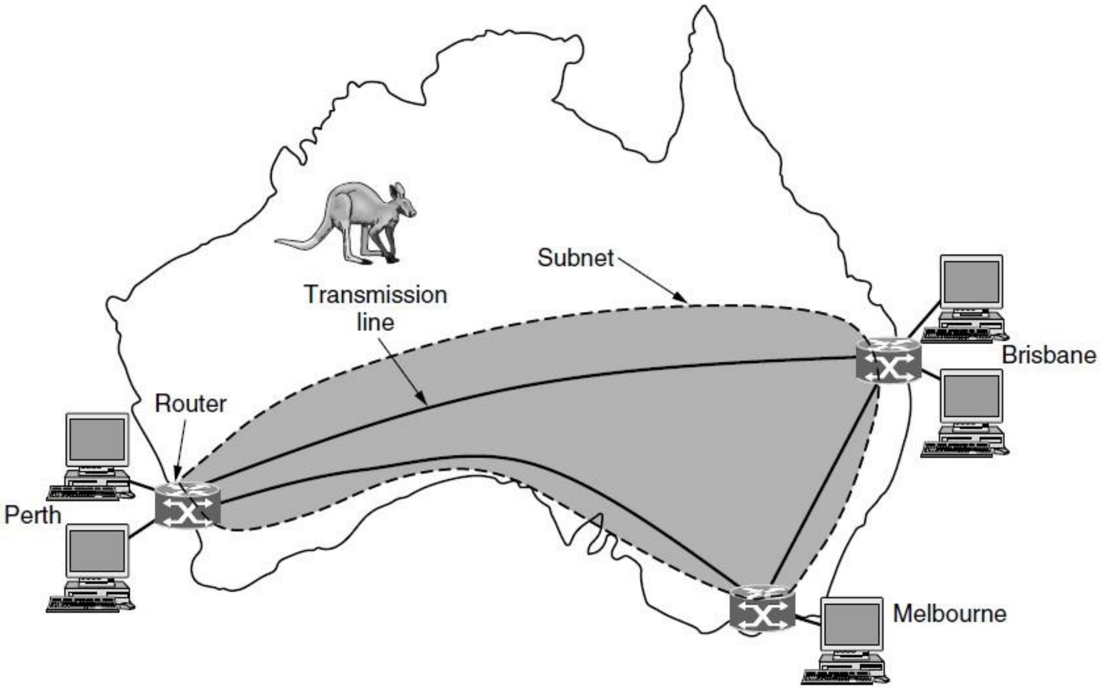


Figure 1.9: WAN that connects three branch offices in Australia

5. Interconnection of Networks: Internetwork

Today, it is very rare to see a LAN, a MAN, or a LAN in isolation; they are connected to one another. When two or more networks with different hardware and software are connected, they become an ***internetwork***, or ***internet***. (i.e., it is a collection of interconnected networks). These terms is used in a generic sense, in contrast to the worldwide **Internet** (*which is one specific* ***internet***), which we will always capitalize.

6. Internet

The Internet is a communication system that has brought a wealth of information to our fingertips and organized it for our use. The Internet today is not a simple hierarchical structure. It is made up of many wide- and local-area networks joined by connecting lines and switching devices (see Figure 1.10). The Internet uses ISP networks to connect enterprise networks, home networks, and many other networks.

The Internet has revolutionized many aspects of our daily lives. It has affected the way we do business as well as the way we spend our time. Perhaps you've sent electronic mail (e-mail) to a business associate, paid a utility bill, read a newspaper from a distant city, or looked up a local movie schedule-all by using the Internet.

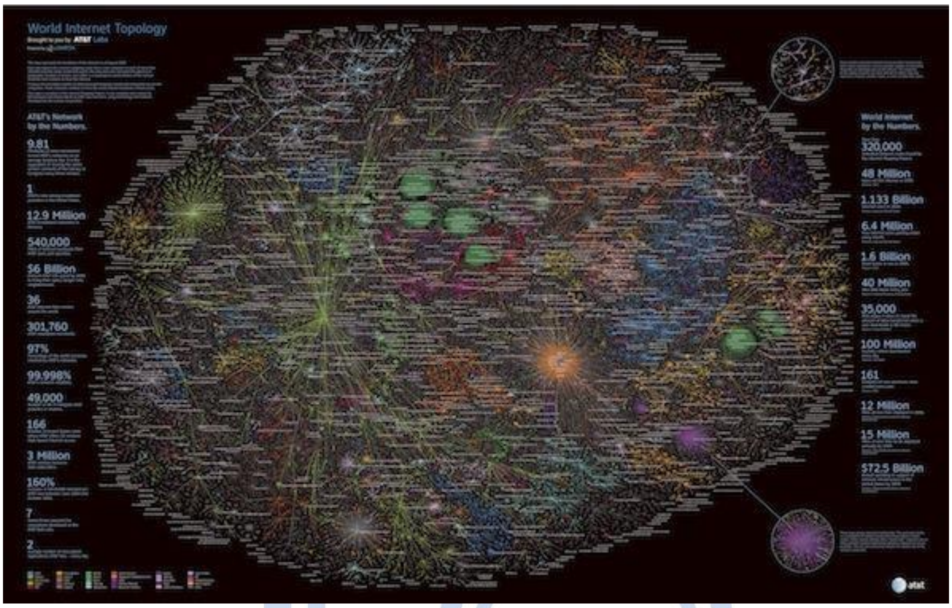
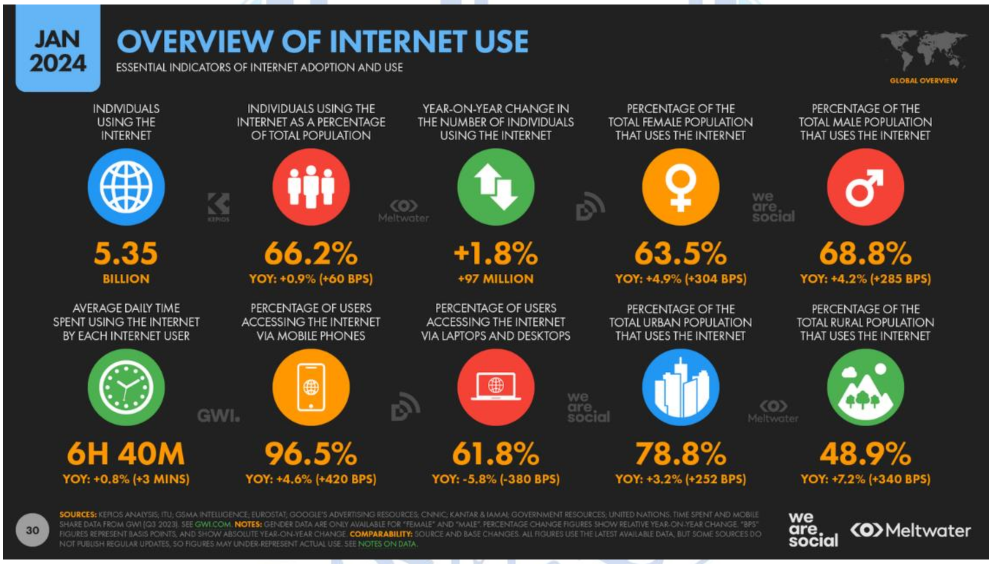


Figure 1.10 Internet Map



- **Internet usage in 2024**

The number of Internet users is expected to reach 5.35 billion by 2024, equivalent to 66.2% of the world's total population. The number of internet users grew by 1.8% over the past year, with 97 million new users entering the internet for the first time in 2023.

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