1

Basic Concepts

1.1 Introduction

The input of a communication system is a sound, image, or text file to be transmitted to the other end. The output is naturally this original information signal, which goes through many processes (modulation, coding, multiplexing, etc.) until it reaches the end. This section explains the layers through which the information passes from where it enters the system to where it leaves.

1.2 Main Components of Communication Systems

The main components of an end-to-end communication system are the transmitter, transmission medium, and receiver (Figure 1.1). Any factor that negatively affects the operation of the system is called noise.

- **Information source:** The first step in sending a message is to convert it into an electronic form suitable for transmission. For voice messages, a microphone is used to convert the sound into an electronic audio signal. For TV, the camera converts the light information in the scene into a video signal. In computer systems, the message is typed on the keyboard and converted into binary codes that can be stored in memory or transmitted in serial. Transducers convert physical properties (temperature, pressure, light intensity, etc.) into electrical signals.
- **Transmitter:** The transmitter is a collection of electronic components and circuits designed to convert the electrical signal into a signal suitable for transmission over a given communication medium. Transmitters consist of oscillators, amplifiers, tuned circuits and filters, modulators, mixers, frequency synthesizers, and

Evolution of Wireless Communication Ecosystems, First Edition. Suat Seçgin.

Published 2023 by John Wiley & Sons, Inc.

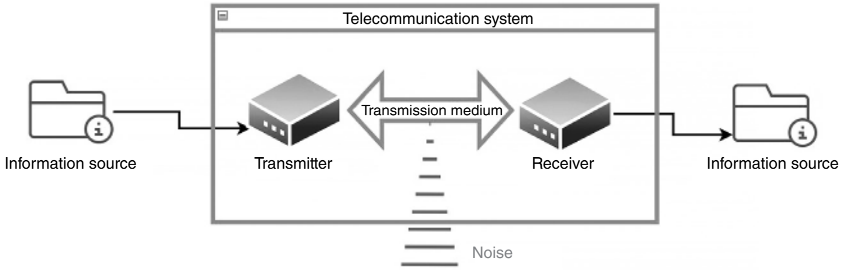

Figure 1.1 Block schema of a communication system.

other circuits. The original signal is usually modulated with a higher frequency carrier sine wave produced by the transmitter and amplified by power amplifiers. Thus, the information signal is rendered transmittable in the transmission medium.

- **Communication channel:** The communication channel is the medium in which the electronic signal is sent from one place to another. Many media types are used in communication systems, including wire conductors, fiber optic cable, and free space. Of these, electrical conductors can be a pair of wires that carry an audio signal from the microphone to the headphone. It could be a coaxial cable similar to that used to have signals. Or it could be a twisted-pair cable used in a local area network (LAN). The communication medium may also be a fiber optic cable or “light pipe” that carries the message on a light wave. These are used today to carry out long-distance calls and all Internet communications. The information is converted into a digital form that will be used to turn a laser diode on and off at high speeds. Alternatively, audio or video analog signals can be used to vary the amplitude of the light. When space is media, the resulting system is known as radio. Radio, also known as wireless, is the general term applied to any form of wireless communication from one point to another. Radio makes use of the electromagnetic spectrum. Information signals are converted into electric and magnetic fields that propagate almost instantly in space over long distances.
- **Receiver:** The receiver is a collection of electronic components and circuits that accepts the message transmitted through the channel and converts it back into a form that can be understood. Receivers include amplifiers, oscillators, mixers, tuned circuits and filters, and a demodulator or detector that retrieves the original information signal from the modulated carrier. The output is the initial signal that is then read or displayed. It can be an audio signal sent to a speaker, a video signal fed to an LCD screen for display, or binary data received by a computer and then printed or displayed on a video monitor.

- **Transceiver:** Most electronic communications are two-way. Therefore, both parties must have a transmitter and a receiver. As a result, most communications equipment contains both sending and receiving circuits. These units are often called transceivers. All transmitter and receiver circuits are packaged in a single enclosure and often share some common circuitry, such as the power supply. Telephones, walkie-talkies, mobile phones, and computer modems are examples of transceivers.
- **Attenuation:** Regardless of the transmission medium, signal attenuation or degradation is inevitable. The attenuation is proportional to the square of the distance between the transmitter and receiver. Media is also frequency selective because a particular medium acts as a low-pass filter for a transmitted signal. Thus, digital pulses will be distorted, and the signal amplitude will significantly reduce over long distances. Therefore, a significant amount of signal amplification is required at both the transmitter and receiver for successful transmission. Any medium also slows signal propagation to a slower-than-light speed.
- **Noise:** Noise is mentioned here because it is one of the most important problems of all electronic communication. Its effect is experienced in the receiving part of any communication system. Therefore, we consider noise in Chapter 9 as a more appropriate time. While some noise can be filtered out, the general way to minimize noise is to use components that contribute less noise and lower their temperature. The measure of noise is usually expressed in terms of the signal-to-noise ratio (SNR), which is the signal power divided by the noise power and can be expressed numerically or in decibels (dB). A very high SNR is preferred for the best performance.

1.3 Circuit, Packet, and Cell Switching

A circuit, packet, or cell switching technique is used on the communication line established to communicate two terminals at two opposite endpoints.

1.3.1 Circuit Switching

Circuit switching is the first method used in communication systems. When you somehow pull a cable (or establish a wireless link) between the two opposite ends that will communicate, we establish a circuit between the two terminals. A one-to-one connection between the terminals in the matrix structure and connected to the switching center (switchboard) with a circuit is established between the terminals that require connection by the switching center. Thus, a circuit is established (switched) that can only be used by those two terminals at the communication time. Since packet-switched communication is widely used in today's

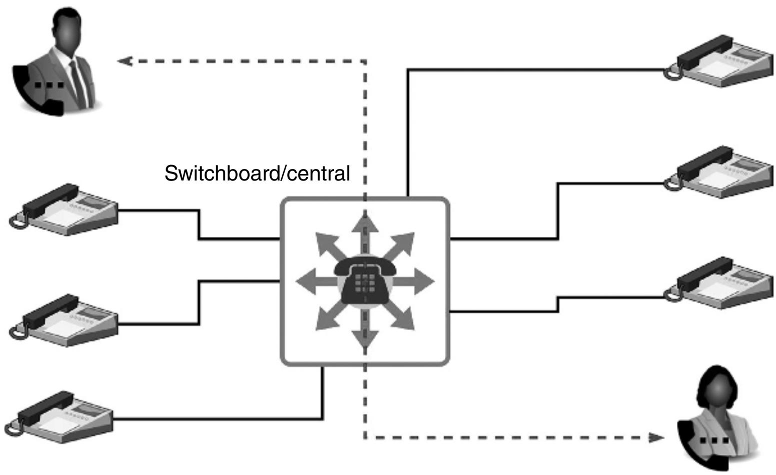

Figure 1.2 Circuit switching.

communication, virtual circuits specific to end terminals can be established by defining virtual paths on packet-based circuits (Figure 1.2).

In circuit switching, a link is established between both terminals, which is used only by these terminals. As long as the link connection is used, other terminals cannot use this line. As we mentioned earlier, only two terminals can use the virtual circuits established on the packet-switched circuits (for example, an IP network). A virtual private network (VPN) can be given as an application example. Unlike packet-switched circuits, the capacities of unused circuits cannot be transferred to currently used circuits. In this sense, circuit switching is insufficient for the efficient use of transmission lines.

1.3.2 Packet Switching

We have mentioned that in the circuit switching technique, a "dedicated" circuit is installed on the terminals at the opposite ends, which is used only by these two terminals at the time of communication. The circuit switching technique is insufficient due to limited bandwidths and increasing communication speed needs. Even if the connected terminals do not exchange information over the circuit, other terminals cannot use this circuit. The packet switching technique divides the data to be transmitted into packets. Each of these packets contains the address of the sender (IP) and the receiver's addresses. These packets are left to the transmission medium and delivered to their destination via packet switching devices (switch, router, etc.). Thus, a transmission medium can be used by hundreds of terminals (millions if we consider the Internet environment) instead of being divided into only two terminals (Figure 1.3).

We can compare the packet switching circuit to highways where hundreds of vehicles (packages) are present simultaneously. Each vehicle proceeds on the

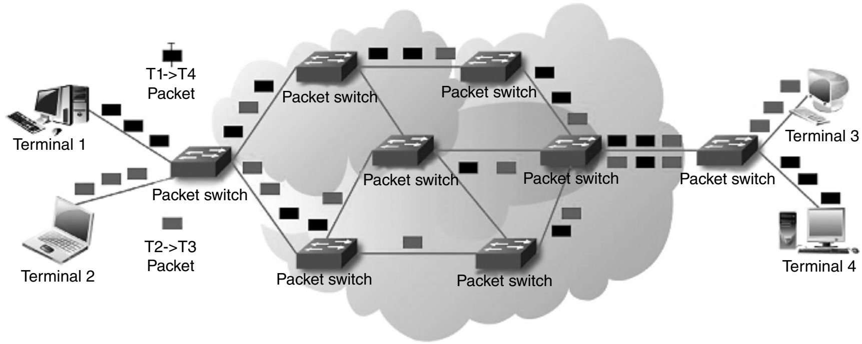

Figure 1.3 Packet switching.

same road (backbone) and reaches its destination by entering secondary roads when necessary. The critical limitation is the slowdowns due to increased vehicle (package) traffic. In this case, traffic engineering methods come into play and make essential optimizations on the network to prevent jams.

1.3.3 Cell Switching

We can describe cell-switched systems as a mixture of the circuit and packet-switched systems. What is decisive here is that the packet lengths are divided into tiny packets of 53 bytes in size. A circuit is then virtually allocated between opposing terminals (physically on a single line). These small packets are exchanged extremely quickly over these dedicated virtual circuits (Figure 1.4).

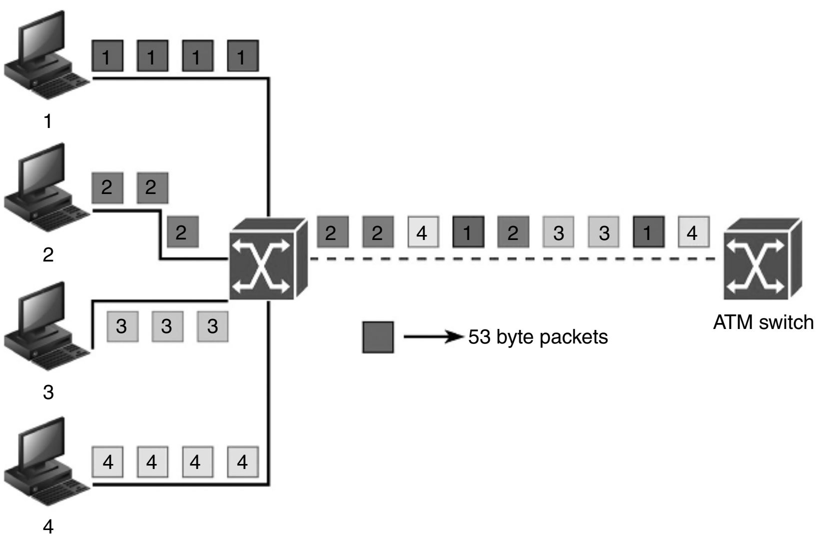

Figure 1.4 Cell switching.

Virtual circuits not transmitting packets for a certain period are closed and re-established when necessary.

1.4 Duplexing in Communication

In communication systems, information can be exchanged in three different ways between two mutual communication terminals. In simplex communication (Figure 1.5a), the transmitter is broadcasting continuously. Classical radio broadcasting can be given as an example of this type of communication.

On the other hand, simultaneous telephone conversations are a good example of full-duplex communication (Figure 1.5b). In this type of communication, the terminals perform both the receiving and transmitting functions at the same time.

Finally, the type of communication in which one of the terminals acts as a receiver and the other as a transmitter at a given time interval is called half-duplex communication (Figure 1.5c). While one terminal transmits information, the other is in a listening state, and these roles change according to the need during the conversation. Conversations made from police radio devices can be given as an example of this type of communication.

In wireless communication systems, one channel should be reserved for upload/ transmit and one for download (receive) for the terminal in connection with the base station. Two doubling techniques create this simultaneous transmission

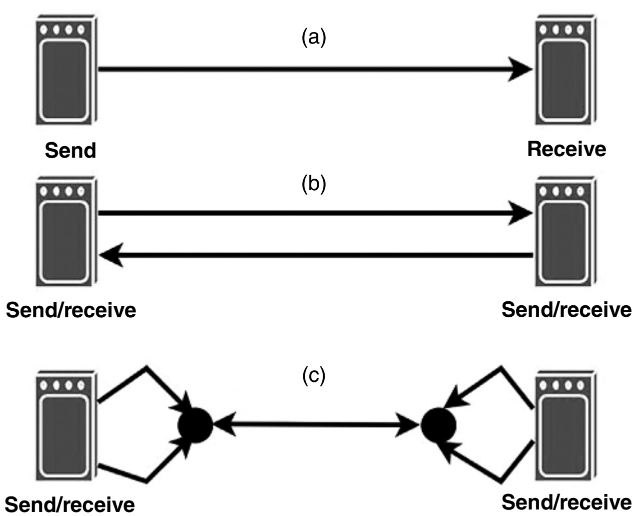

Figure 1.5 Duplexing methods. (a) Simplex; (b) full-duplex; (c) half-duplex.

environment: frequency division duplexing (FDD) and time division duplexing (TDM). In the FDD mechanism, two-way communication is carried out by defining different frequency ranges (carriers) for each of the transmit/receive channels. In the TDM mechanism, two-way communication is provided by sending at a given moment of t_1 and receiving at a consecutive moment of t_2 [1].

1.5 Historical Developments of Wireless Communication Systems

Starting with 1G systems (1980), we will talk about communication systems at tera hertz levels with spectrum efficient modulation techniques and advances in electronic circuits. Additionally, users can receive services at high bandwidths using three-dimensional multiplexing techniques.

Wireless mobile communication systems, which started with only voice calls (1G) in the 1980s, were introduced into our lives with the 2G short message service (SMS) in the 1990s. In both generations, communication was carried out using circuit switching techniques. On the other hand, the third-generation (3G) systems have been a turning point. With this generation, packet-switched (data) services have been used in the wireless communication ecosystem. With 3G, multimedia content started to be used among users in the 2000s. With 4G, communication was carried out entirely with packet switching; thus, users could operate 24/7 Internet access. Although machine-to-machine communication exists, we have now met the Internet of things (IoT) concept with 4G (Figure 1.6).

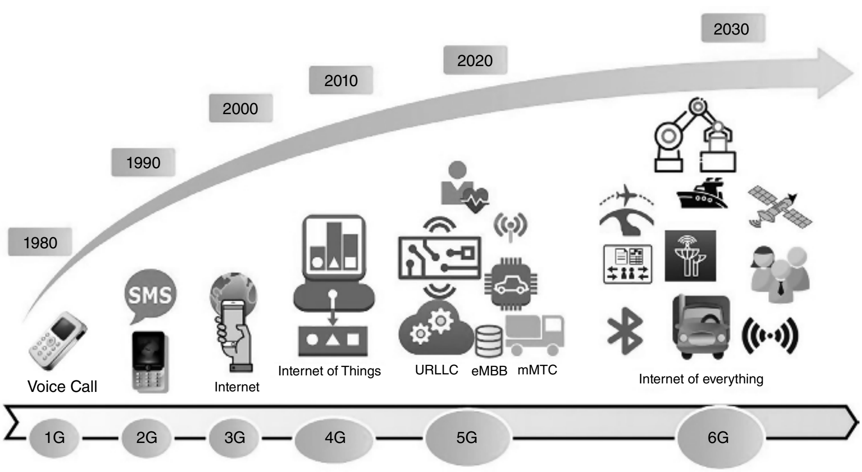

Figure 1.6 Evolution of wireless communication systems.

Wireless communication systems, which continue to progress without slowing down, have evolved into the fifth-generation communication systems as of the 2020s. Communication speeds up to 20 GHz with 5G, and thanks to these speeds, the concepts of ultra-reliable low latency communication (uRLLC), enhanced mobile broadband (eMBB), and massive machine type communication (mMTC) entered our lives. The transition phase from the IoT to the Internet of everything occurred at this stage. Communication systems, applications, and services have become much more intelligent using topics such as artificial intelligence, blockchain, and big data in the software field. Smart homes, smart cities, intelligent health systems, and autonomous vehicles are now inseparable parts of our lives.

In the years when the book was written (2021/2022), 5G applications entered our lives, and the sixth-generation communication systems, which will be put into use starting from the 2030s, became talked about and fictionalized. Concepts such as 6G and 3D networks, intelligent networks, quantum communication, blockchain technologies, deep learning, and programmable surfaces are designed together with communication infrastructures.

With the wireless communication systems enabling high-speed connection anytime and anywhere, the concept of IoT has started to take more place in our lives.

Reference

1 Frenzel, L.E. (2016). *Principles of Electronic Communication Systems*. New York: McGraw-Hill Education.