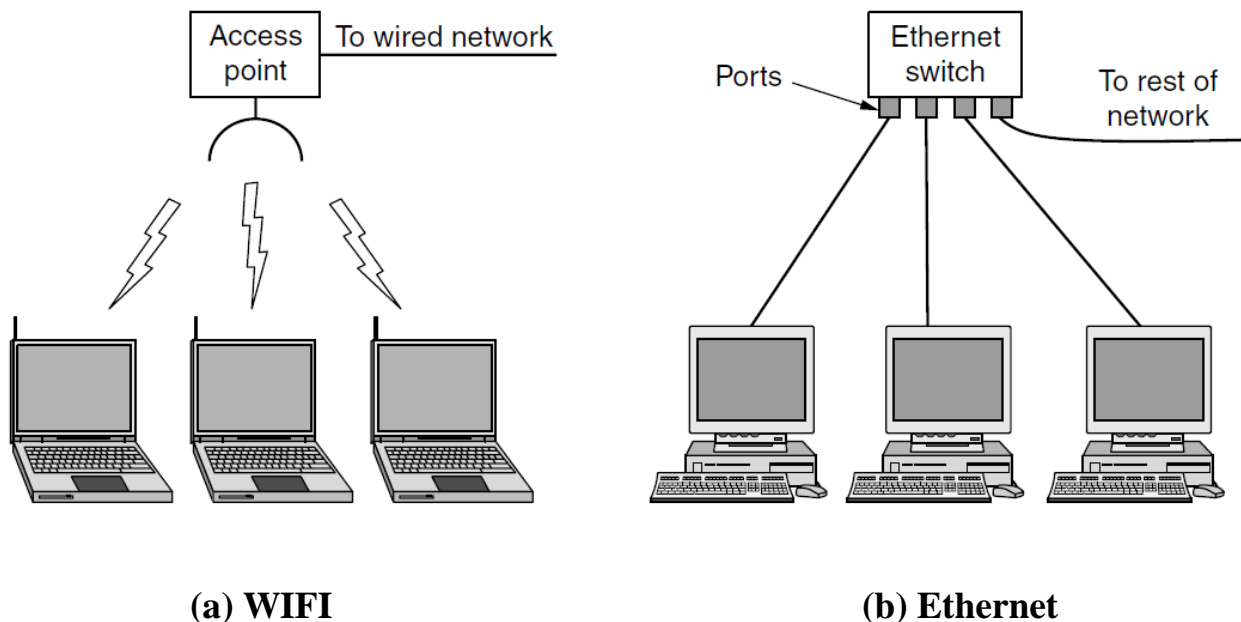


## Local area networks (LANs)

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.

✚ **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.

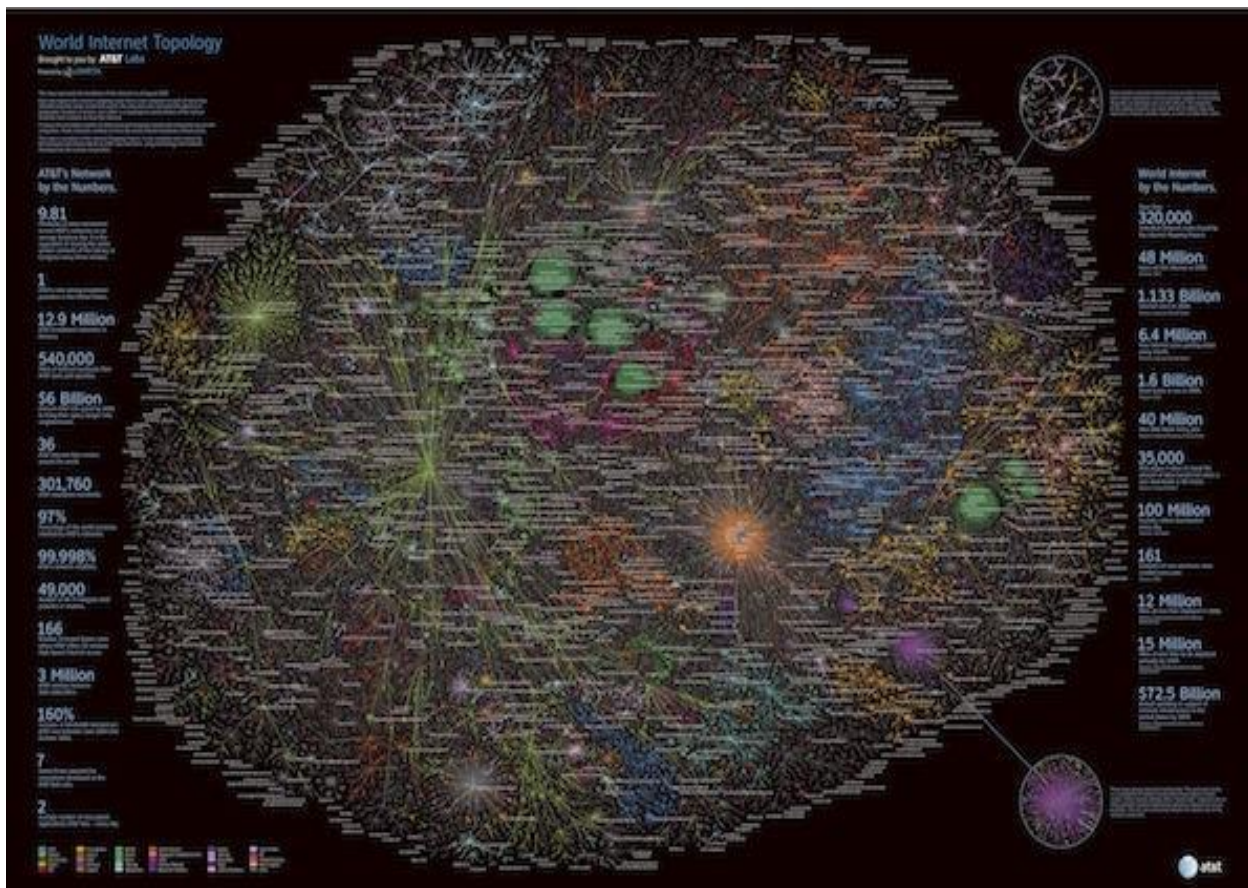


## Interconnection of Networks: Internetwork

Today, it is very rare to see a LAN, a MAN, or a WAN 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.

## 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 the Internet service provider (ISP) networks to connect enterprise networks, home networks, and many other networks.



## Throughput and Bandwidth

Throughput is the measure of how much data is transmitted during a given period of time. It may also be called capacity or bandwidth (though as you will learn, bandwidth is technically different from throughput). Throughput is commonly expressed as a quantity of bits transmitted per second. As an example, a typical modem connecting a home PC to the Internet would probably be rated for a maximum throughput of 56.6 Kbps. A fast LAN might transport up to 10 Gbps of data. Modern networks commonly achieve throughputs of 10 Mbps, 100 Mbps, or 1 Gbps.

Often, the term “bandwidth” is used interchangeably with throughput, bandwidth is a measure of the difference between the highest and lowest frequencies that a medium can transmit. This range of frequencies, which is expressed in Hz, is directly related to throughput.

## Analog and Digital Signaling

On a data network, information can be transmitted via one of two signaling methods: **analog** or **digital**. Both types of signals are generated by electrical current, which is measured in volts. The strength of an electrical signal is directly proportional to its voltage. Thus, when network engineers talk about the strength of an analog or digital signal, they often refer to the signal’s voltage.

The essential difference between analog and digital signals is the way voltage creates the signal. **In analog signals**, voltage varies continuously and appears as a wavy line when graphed over time, as shown in Figure 3-1. Your speech, and live music are all examples of analog waves.

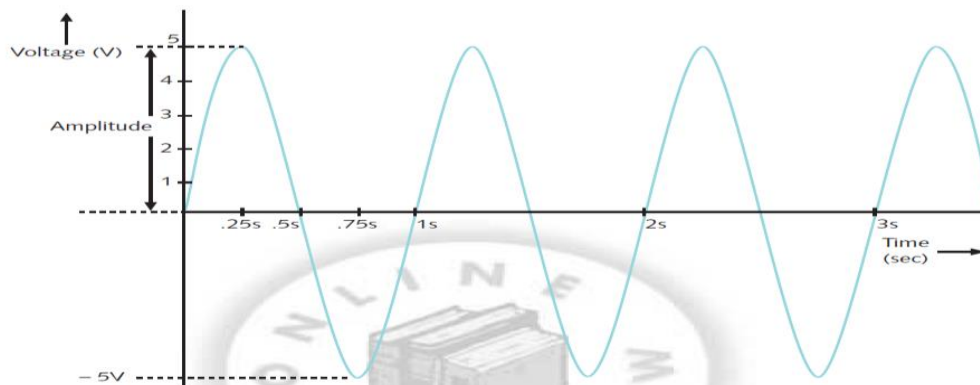


Figure 3-1 An example of an analog signal

An analog signal, like other waveforms, is characterized by four fundamental properties: amplitude, frequency, wavelength, and phase.

**1. Amplitude:** Is a measure of its strength at any given point in time.

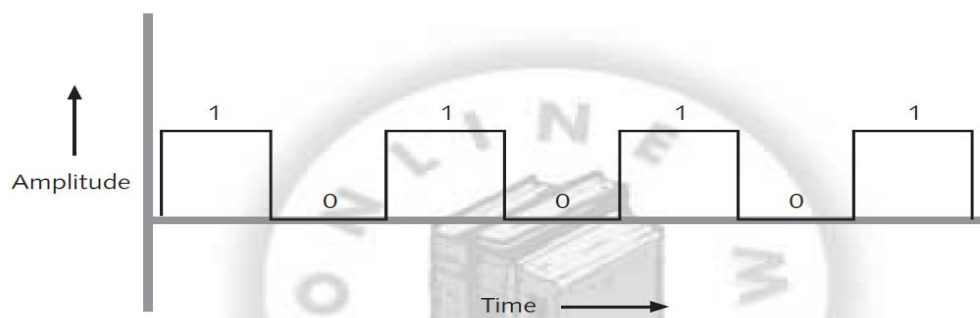
**2. Frequency hertz (Hz):** Is the number of times that a wave's amplitude cycles from its starting point, through its highest amplitude and its lowest amplitude, and back to its starting point over a fixed period of time.

**3. Wavelength:** The distance between corresponding points on a wave's cycle is called its wavelength.

Wavelengths can be expressed in meters or feet. A wave's wavelength is inversely proportional to its frequency. In other words, the higher the frequency, the shorter the wavelength.

**4. Phase:** The term phase refers to the progress of a wave over time in relationship to a fixed point.

**Digital signals** are composed of pulses of precise, positive voltages and zero voltages. A pulse of positive voltage represents a 1. A pulse of zero voltage (in other words, the lack of any voltage) represents a 0. Because digital transmission involves sending and receiving only a pattern of 1s and 0s, represented by precise pulses, it is more reliable than analog transmission, which relies on variable waves. In addition, noise affects digital transmission less severely. On the other hand, digital transmission requires many pulses to transmit the same amount of information that an analog signal can transmit with a single wave. In the end, digital transmission is more efficient than analog transmission because it results in fewer errors.



**Figure 3-3** An example of a digital signal

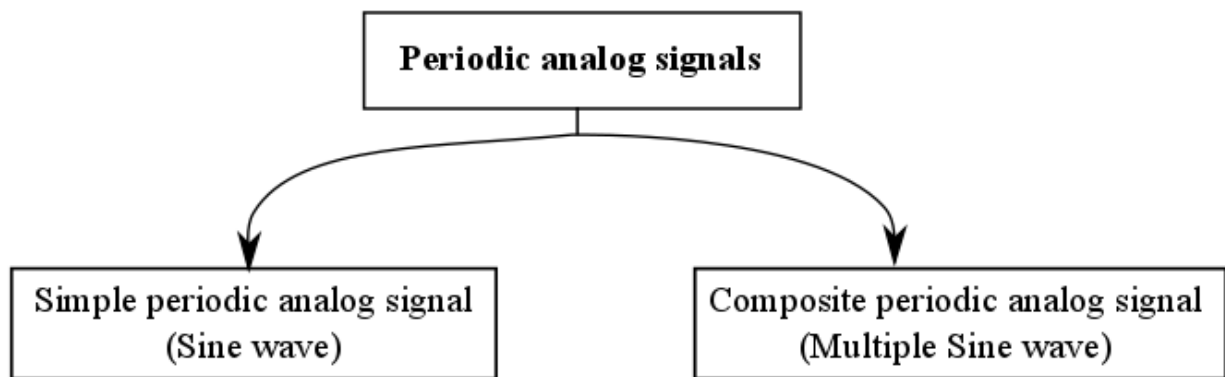
## 🚦 Periodic and Non-periodic Signals

A periodic signal completes a pattern within a measurable time frame, called a period, and repeats that pattern over identical periods. The completion of one full pattern is called a cycle.

A nonperiodic signal changes without exhibiting a pattern or cycle that repeats over time. Both analog and digital signals can be periodic or nonperiodic.

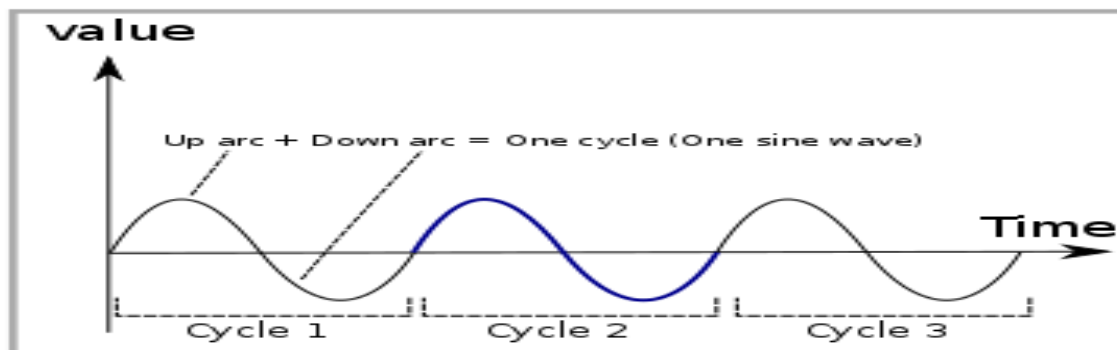
In data communications, we commonly use periodic analog signals (because they need less bandwidth) and nonperiodic digital signals (because they can represent variation in data).

Periodic analog signals can be classified as simple or composite.



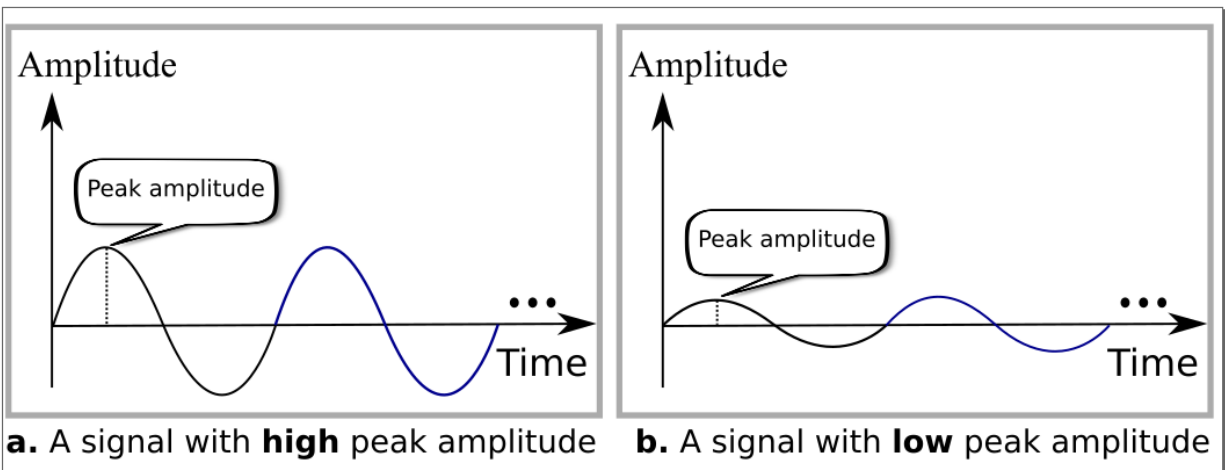
### 1. Sine Wave

Figure 4.3 shows a sine wave. Each cycle consists of a single arc above the time axis followed by a single arc below it. A sine wave can be represented by three parameters: the 1) peak amplitude, 2) the frequency, and 3) the phase.



## 1) Peak amplitude

The peak amplitude of a signal is the absolute value of its highest intensity (the energy). Figure 4.4 shows two signals and their peak amplitudes. For electric signals, peak amplitude is normally measured in volts. The power in your house can be represented by a sine wave with a peak amplitude of 220 to 240 V, whereas the peak value of an AA battery is normally 1.5 V.



## 2) Period and Frequency

Period refers to the amount of time, in seconds, a signal needs to complete 1 cycle. Frequency refers to the number of periods in 1 s. Formally expressed in Hertz (Hz), which is cycle per second. Note that period and frequency are just one characteristic defined in two ways. Period is the inverse of frequency, and frequency is the inverse of period, as the following formulas show.  $F=1/T$  and  $T=1/f$

(f: frequency T: time)

Units of period and frequency are shown in Table 4.1.

<i>Unit</i>	<i>Equivalent</i>
Seconds (s)	1 s
Milliseconds (ms)	$10^{-3}$ s
Microseconds ( $\mu$ s)	$10^{-6}$ s
Nanoseconds (ns)	$10^{-9}$ s
Picoseconds (ps)	$10^{-12}$ s

Units of period

<i>Unit</i>	<i>Equivalent</i>
Hertz (Hz)	1 Hz
Kilohertz (kHz)	$10^3$ Hz
Megahertz (MHz)	$10^6$ Hz
Gigahertz (GHz)	$10^9$ Hz

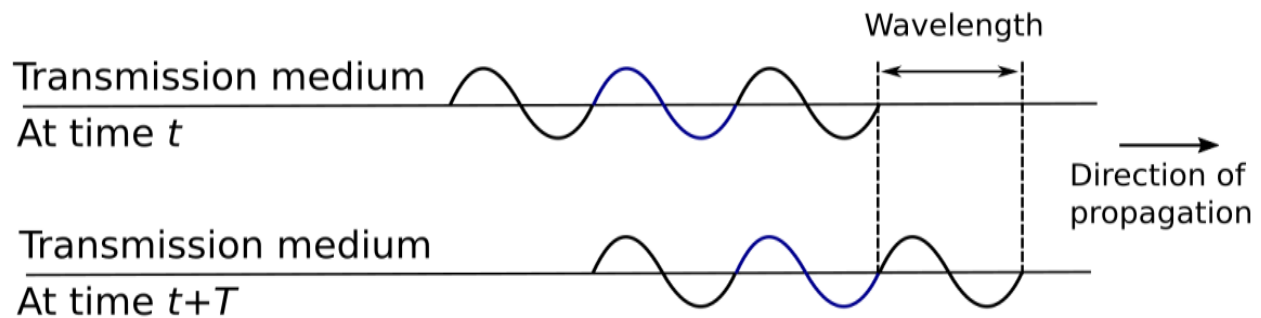
Units of frequency

### 3) Phase

The term phase describes the position of the waveform relative to time 0. It indicates the status of the first cycle (how much the wave is shifted from 0 on the time axis).

### 4) Wavelength

Wavelength is another characteristic of a signal traveling through a transmission medium. Wavelength binds the period or the frequency of a simple sine wave to the propagation speed of the medium (see Figure 4.6).



$t$  = specific time e.g., 11:15:40:115

$T$  = Period e.g., 100 ms

The wavelength is normally measured in micrometres (microns) instead of meters. For example, the wavelength of red light in air is  $0.75 \mu\text{s}$ . But In a Coaxial or fibre-optic cable the wavelength is shorter ( $0.5 \mu\text{s}$ ) because the propagation speed in the cable is decreased.

### Composite Signals

The previous section focused on simple sine waves which have many applications in daily life. We can send a single sine wave to carry electric energy from one place to another. For example, the power company sends a single sine wave with a frequency of 50 Hz to distribute electric energy to houses and businesses.

If we had only one single sine wave to convey a conversation over the phone, it would make no sense and carry no information. We would just hear a buzz. Therefore, we need to send a composite signal to communicate data; a single frequency sine wave is not useful in data communications.

The composite signal is a combination of simple sine waves with different frequencies, amplitudes, and phases.

A composite signal can be periodic or non-periodic as shown in the following:

- ✓ **A periodic composite signal can be decomposed into a series of simple sine waves with discrete frequencies (the frequencies that have integer values: 1, 2, 3, and so on).**
  
- ✓ **A nonperiodic composite signal can be decomposed into a combination of an infinite number of simple sine waves with continuous frequencies (the frequencies that have real values: 0.1, 0.2, 0.3, and so on).**

## **Data Modulation**

Data relies almost exclusively on digital transmission. However, in some cases the type of connection your network uses may be capable of handling only analog signals. For example, telephone lines are designed to carry analog signals. If you dial into an ISP's network to surf the Internet, the data signals issued by your computer must be converted into analog form before they get to the phone line. Later, they must be converted back into digital form when they arrive at the ISP's access server. A modem accomplishes this translation. The word modem reflects this device's function as a modulator/demodulator that is, it modulates digital signals into analog signals at the transmitting end, then demodulates analog signals into digital signals at the receiving end.

Data modulation is a technology used to modify analog signals to make them suitable for carrying data over a communication path. In modulation, a simple wave, called a carrier wave, is combined with another analog signal to produce a unique signal that gets transmitted from one node to another. The carrier wave has preset properties (including frequency, amplitude, and phase). Its purpose is to help convey information; in other words, it is only a messenger. Another signal, known as the information or data wave, is added to the carrier wave. When the information wave is added, it modifies one property of the carrier wave (for example, the frequency, amplitude, or phase). The result is a new, blended signal that contains properties of

both the carrier wave and added data. When the signal reaches its destination, the receiver separates the data from the carrier wave.

Modulation can be used to make a signal conform to a specific pathway, as in the case of FM (frequency modulation) radio, in which the data must travel along a particular frequency. In frequency modulation, the frequency of the carrier signal is modified by the application of the data signal. In AM (amplitude modulation), the amplitude of the carrier signal is modified by the application of the data signal. Modulation may also be used to issue multiple signals to the same communications channel and prevent the signals from interfering with one another. Figure 3-5 depicts an unaltered carrier wave, a data wave, and the combined wave as modified through frequency modulation. Later in this book, you will learn about networking technologies, such as DSL, that make use of modulation.

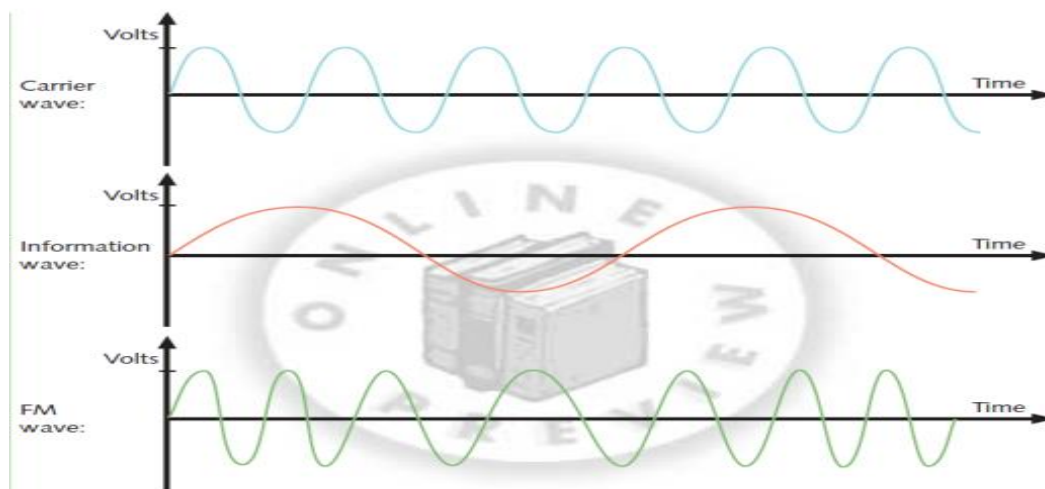


Figure 3-5 A carrier wave modified through frequency modulation

## Multiplexing

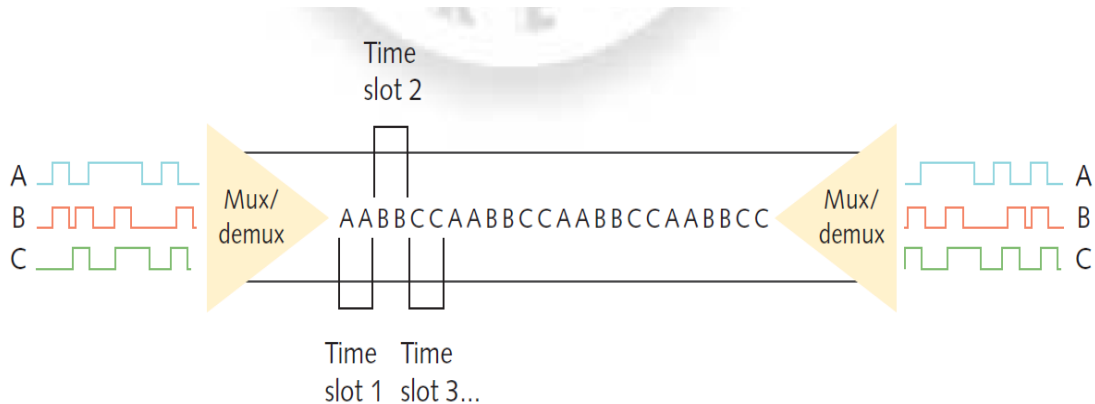
A form of transmission that allows multiple signals to travel simultaneously over one medium is known as **multiplexing**. To carry multiple signals, the medium's channel is logically separated into multiple smaller channels, or **subchannels**. Many different types of multiplexing are available, and the type used in any given situation depends on what the media, transmission, and reception equipment can handle. For each type of multiplexing, a device that can combine

many signals on a channel, a **multiplexer (mux)**, is required at the sending end of the channel. At the receiving end, a **demultiplexer (demux)** separates the combined signals and regenerates them in their original form.

Multiplexing is commonly used on networks to increase the amount of data that can be transmitted in a given time span.

➤ **Types of multiplexing:**

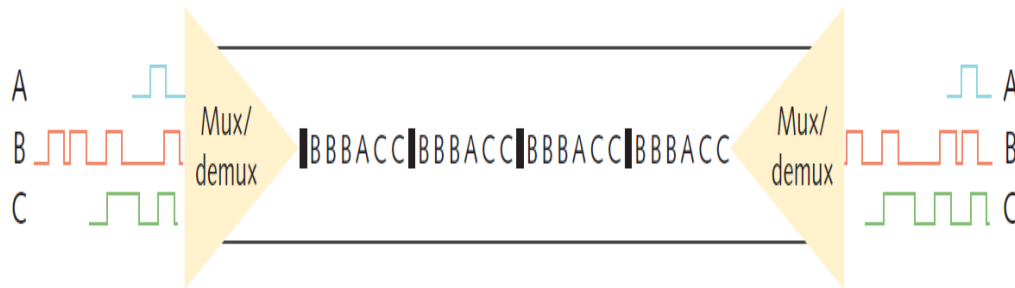
**1. Time Division Multiplexing (TDM)**, it is divides a channel into multiple intervals of time, or time slots, then assigns a separate time slot to every node on the network and, in that time slot, carries data from that node. For example, if five stations are connected to a network over one wire, five different time slots are established in the communications channel. Workstation A may be assigned time slot 1, workstation B time slot 2, workstation C time slot 3, and so on. Time slots are reserved for their designated nodes regardless of whether the node has data to transmit. If a node does not have data to send, nothing is sent during its time slot. This arrangement can be inefficient if some nodes on the network rarely send data. Figure 3-7 shows a simple TDM model.



**Figure 3-7** Time division multiplexing

**2. Statistical multiplexing** is similar to time division multiplexing, but rather than assigning a separate slot to each node in succession, the transmitter assigns slots to nodes according to priority and need. This method is more efficient than TDM, because in statistical multiplexing time slots are unlikely to remain empty. To begin with, in statistical multiplexing, as in TDM, each node is assigned one time slot. However, if a node doesn't use its time slot, statistical

multiplexing devices recognize that and assign its slot to another node that needs to send data. The contention for slots may be arbitrated according to use or priority or even more sophisticated factors, depending on the network. Most importantly, statistical multiplexing maximizes available bandwidth on a network. Figure 3-8 depicts a simple statistical multiplexing system.



**Figure 3-8** Statistical multiplexing

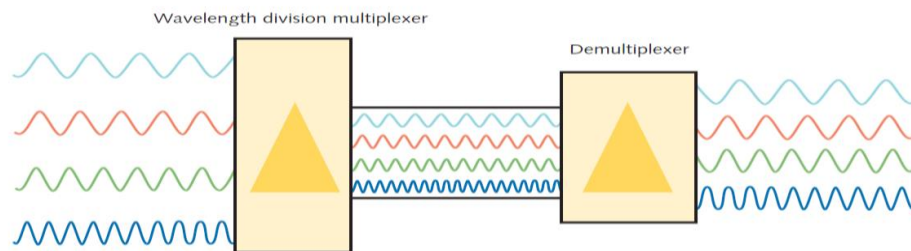
### 3. Wavelength Division Multiplexing (WDM)

Is a technology used with fiber-optic cable, In fiber-optic transmission, data is represented as pulses of light, rather than pulses of electric current. WDM enables one fiber-optic connection to carry multiple light signals simultaneously. Using WDM, a single fiber can transmit as many as 20 million telephone conversations at one time. WDM can work over any type of fiber-optic cable.

In the first step of WDM, a beam of light is divided into up to 40 different carrier waves, each with a different wavelength (and, therefore, a different color). Each wavelength represents a separate transmission channel capable of transmitting up to 10 Gbps. Before transmission, each carrier wave is modulated with a different data signal. Then, through a very narrow beam of light, lasers issue the separate, modulated waves to a multiplexer. The multiplexer combines all of the waves, in the same way that a prism can accept light beams of different wavelengths and concentrate them into a single beam of white light. Next, another laser issues this multiplexed beam to a strand of fiber within a fiber-optic cable. The fiber carries the multiplexed signals to a receiver, which is connected to a demultiplexer. The demultiplexer acts as a prism to separate the combined signals according to their different wavelengths (or colors). Then, the separate waves are sent to their destinations on the network. If the signal risks losing strength between the

multiplexer and demultiplexer, an amplifier might be used to boost it. Figure 3-9 illustrates WDM transmission.

The form of WDM used on most modern fiber-optic networks is DWDM (dense wavelength division multiplexing). In DWDM, a single fiber in a fiber-optic cable can carry between 80 and 160 channels. It achieves this increased capacity because it uses more wavelengths for signaling. In other words, there is less separation between the usable carrier waves in DWDM than there is in the original form of WDM. Because of its extraordinary capacity, DWDM is typically used on high-bandwidth or long-distance WAN links, such as the connection between a large ISP and its (even larger) network service provider.



**Figure 3-9** Wavelength division multiplexing