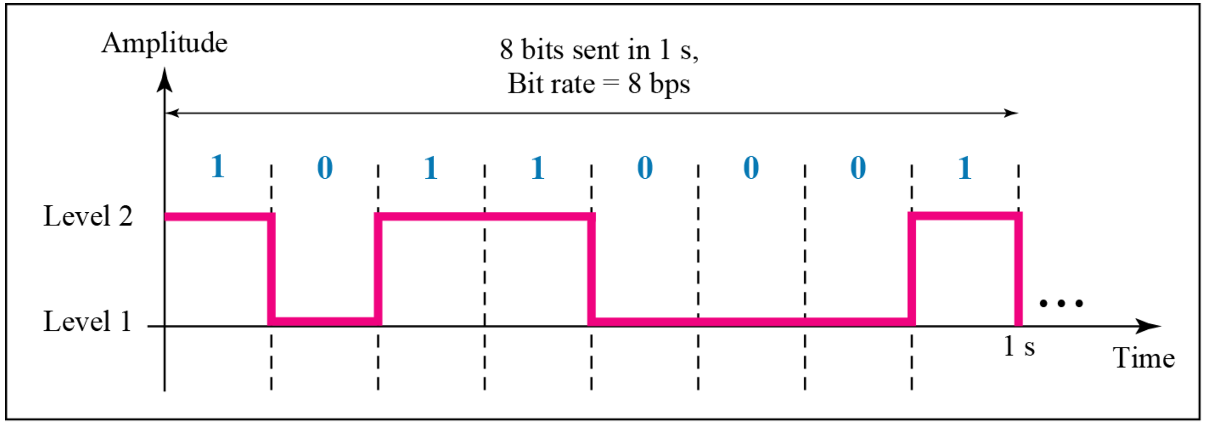
Digital Signal

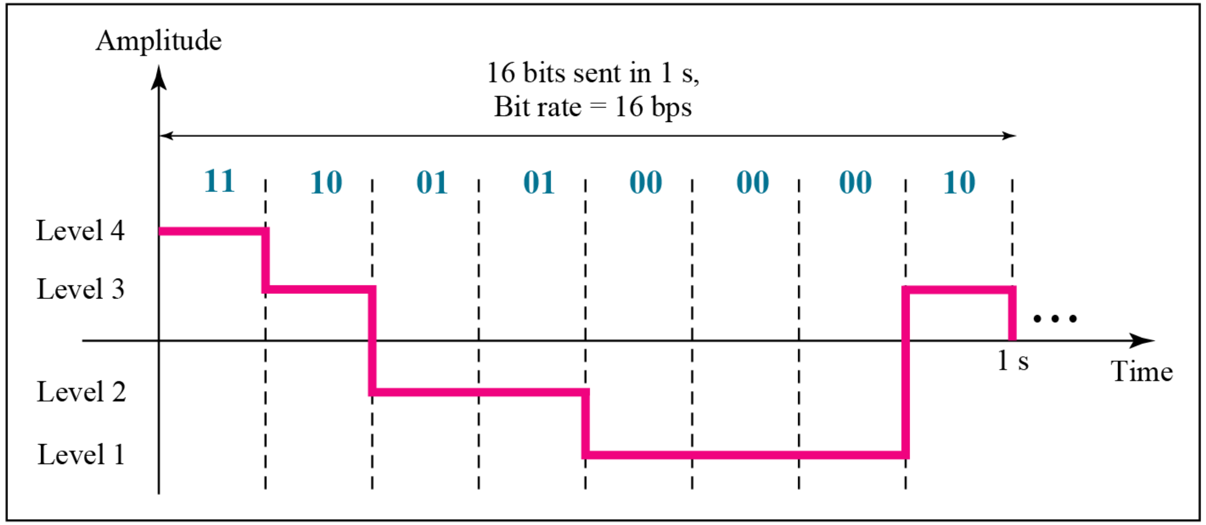
DIGITAL SIGNALS

- In addition to being represented by an analog signal, information can also be represented by a digital signal.
- For example, a 1 can be encoded as a positive voltage and a 0 as zero voltage.
- A digital signal can have more than two levels. In this case, we can send more than 1 bit for each level.

Figure Two digital signals: one with two signal levels and the other with four signal levels



a. A digital signal with two levels



b. A digital signal with four levels

Example

A digital signal has eight levels. How many bits are needed per level? We calculate the number of bits from the formula

$$\boxed{\text{Number of bits per level} = \log_2 8 = 3}$$

Each signal level is represented by 3 bits.

Example

A digital signal has nine levels. How many bits are needed per level?

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We calculate the number of bits by using the formula. Each signal level is represented by 3.17 bits. However, this answer is not realistic.

The number of bits sent per level needs to be an integer as well as a power of 2.

For this example, 4 bits can represent one level.

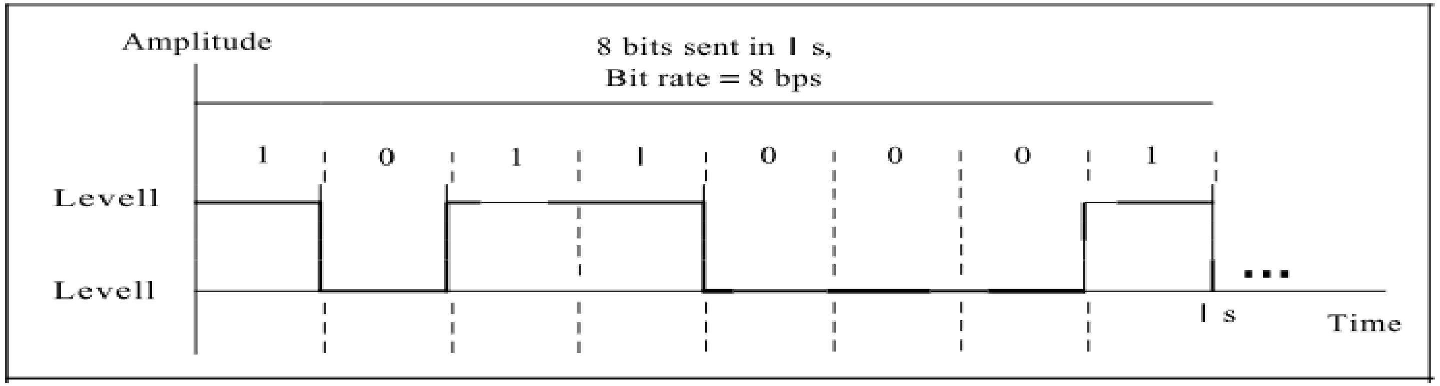
Digital Signal (non periodic signal)

Digital signals are nonperiodic, and thus period and frequency are not appropriate characteristics.

Bit rate is used to describe digital signals.

The bit rate is the number of bits sent in 1 second, expressed in bits per second (bps).

Two digital signals: one with two signal levels and the other with four signal levels



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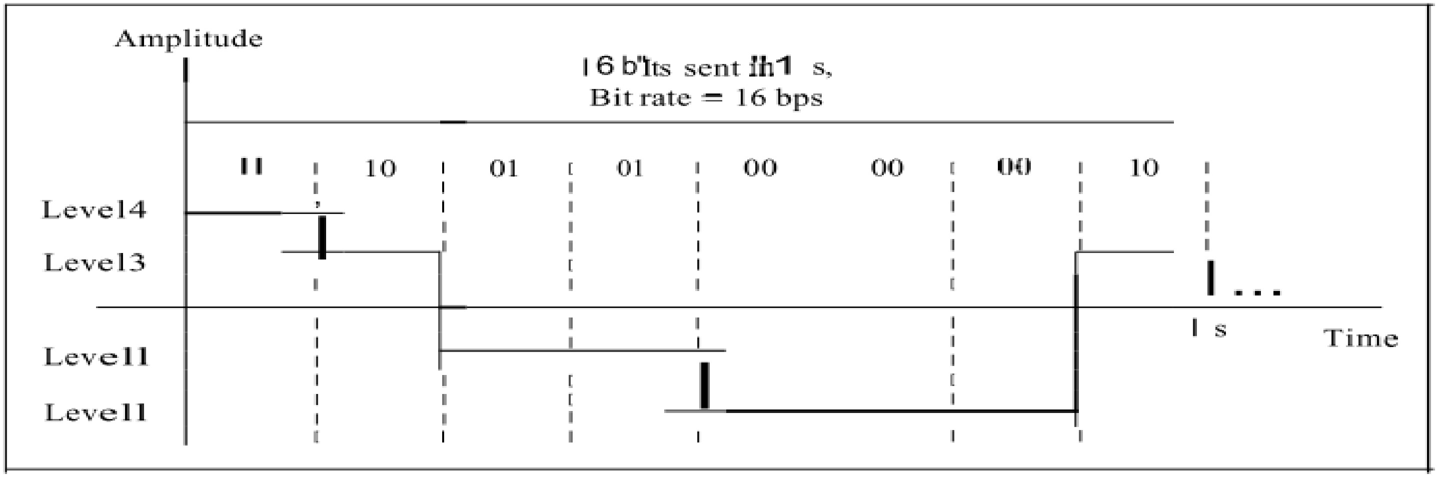

b. A digital signal with four levels

Example

Assume we need to download text documents at the rate of 100 pages per sec. What is the required bit rate of the channel?

Solution

A page is an average of 24 lines with 80 characters in each line. If we assume that one character requires 8 bits (ascii), the bit rate is

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$$\boxed{100 \times 24 \times 80 \times 8 = 1{,}636{,}000 \text{ bps} = 1.636 \text{ Mbps}}$$

Example

A digitized voice channel is made by digitizing a 4-kHz bandwidth analog voice signal. We need to sample the signal at twice the highest frequency (two samples per hertz). We assume that each sample requires 8 bits.

What is the required bit rate?

Solution

The bit rate can be calculated as

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Solution

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$$\boxed{2 \times 4000 \times 8 = 64{,}000 \text{ bps} = 64 \text{ kbps}}$$

Example

What is the bit rate for high-definition TV (HDTV)?

Solution

HDTV uses digital signals to broadcast high quality video signals. The HDTV screen is normally a ratio of 16 : 9. There are 1920 by 1080 pixels per screen, and the screen is renewed 30 times per second. Twenty-four bits represents one color pixel.

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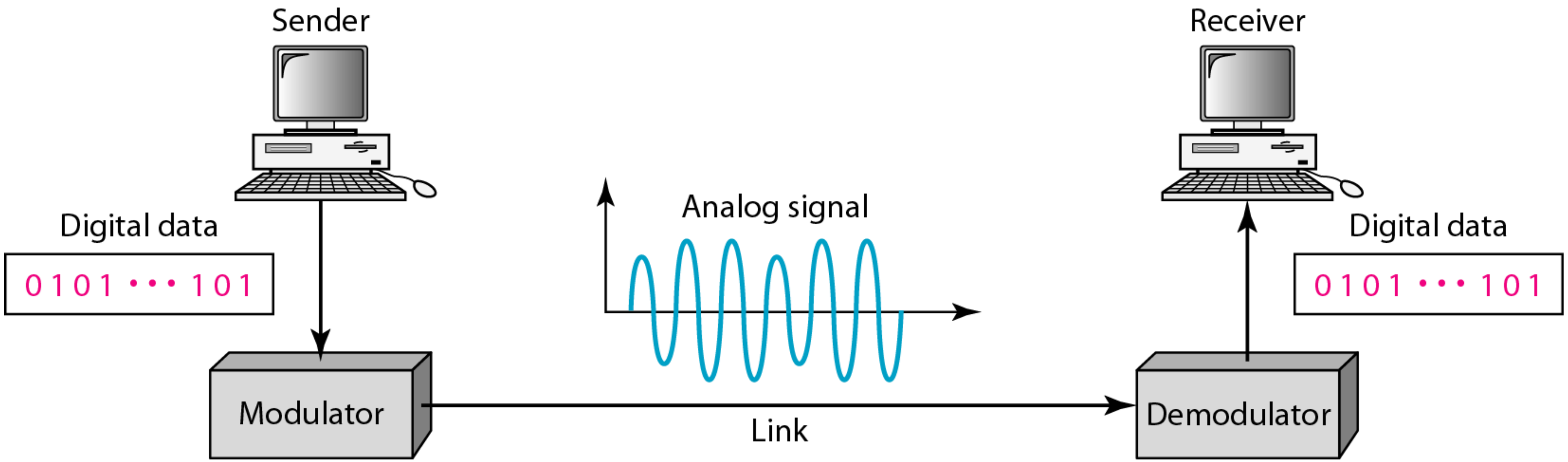
$$\boxed{1920 \times 1080 \times 30 \times 24 = 1{,}492{,}992{,}000 \text{ or } 1.5 \text{ Gbps}}$$

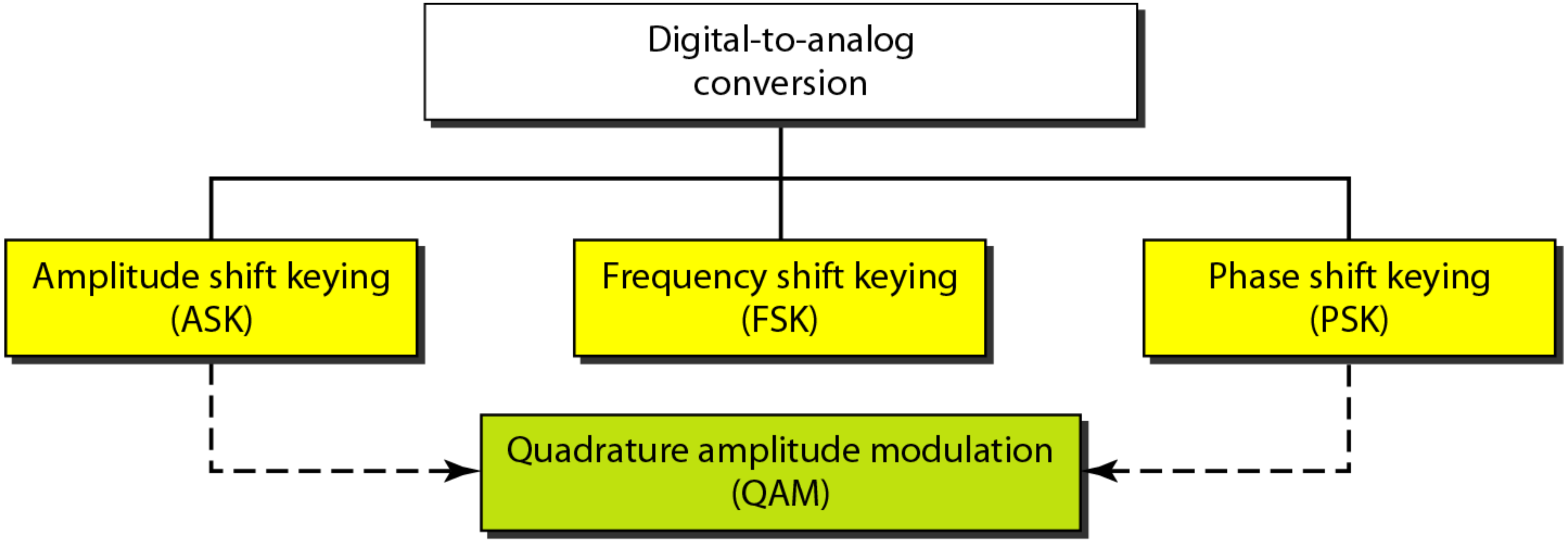
Figure *Digital-to-analog conversion*



Types of digital-to-digital conversion

- Line Coding
- Block Coding
- Scrambling

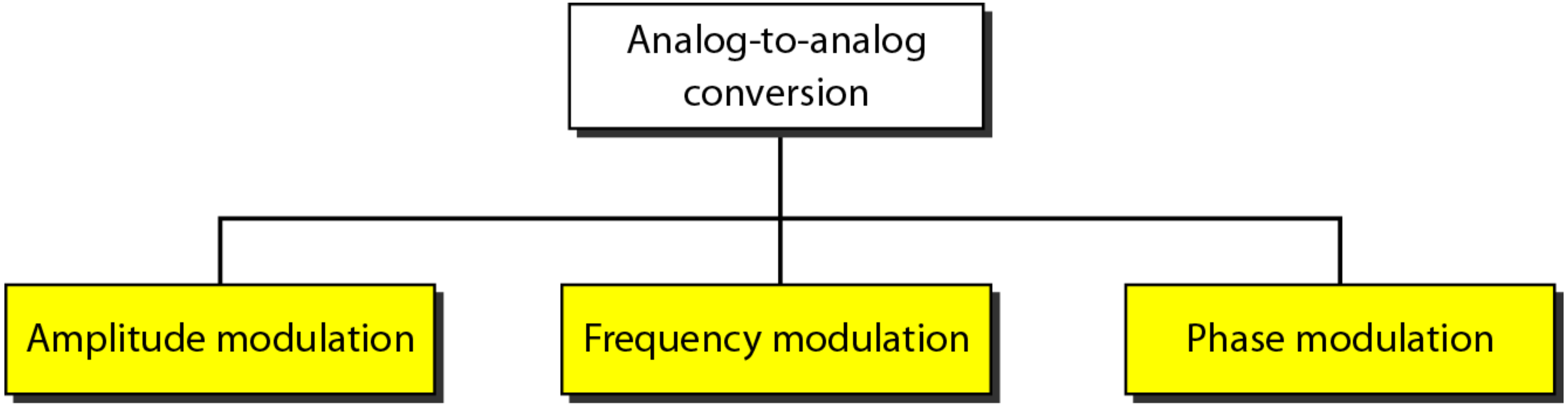
Types of digital-to-analog conversion



Types of analog-to-digital conversion

- Pulse Code Modulation (PCM)
- Delta Modulation (DM)

Types of analog-to-analog conversion

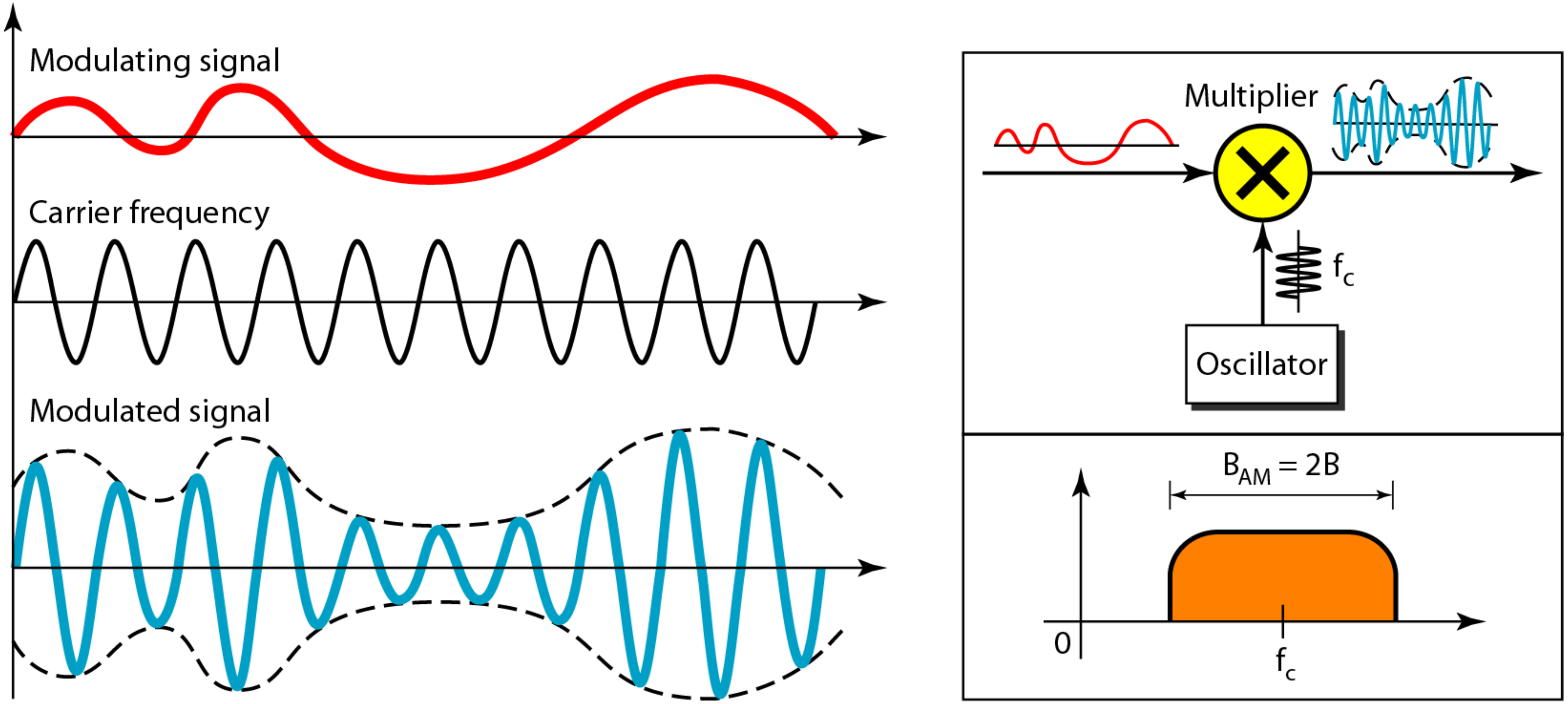


Amplitude Modulation

In AM transmission, the carrier signal is modulated so that its amplitude varies with the changing amplitudes of the modulating signal.

The frequency and phase of the carrier remain the same; only the amplitude changes to follow variations in the information

Figure *Amplitude modulation*

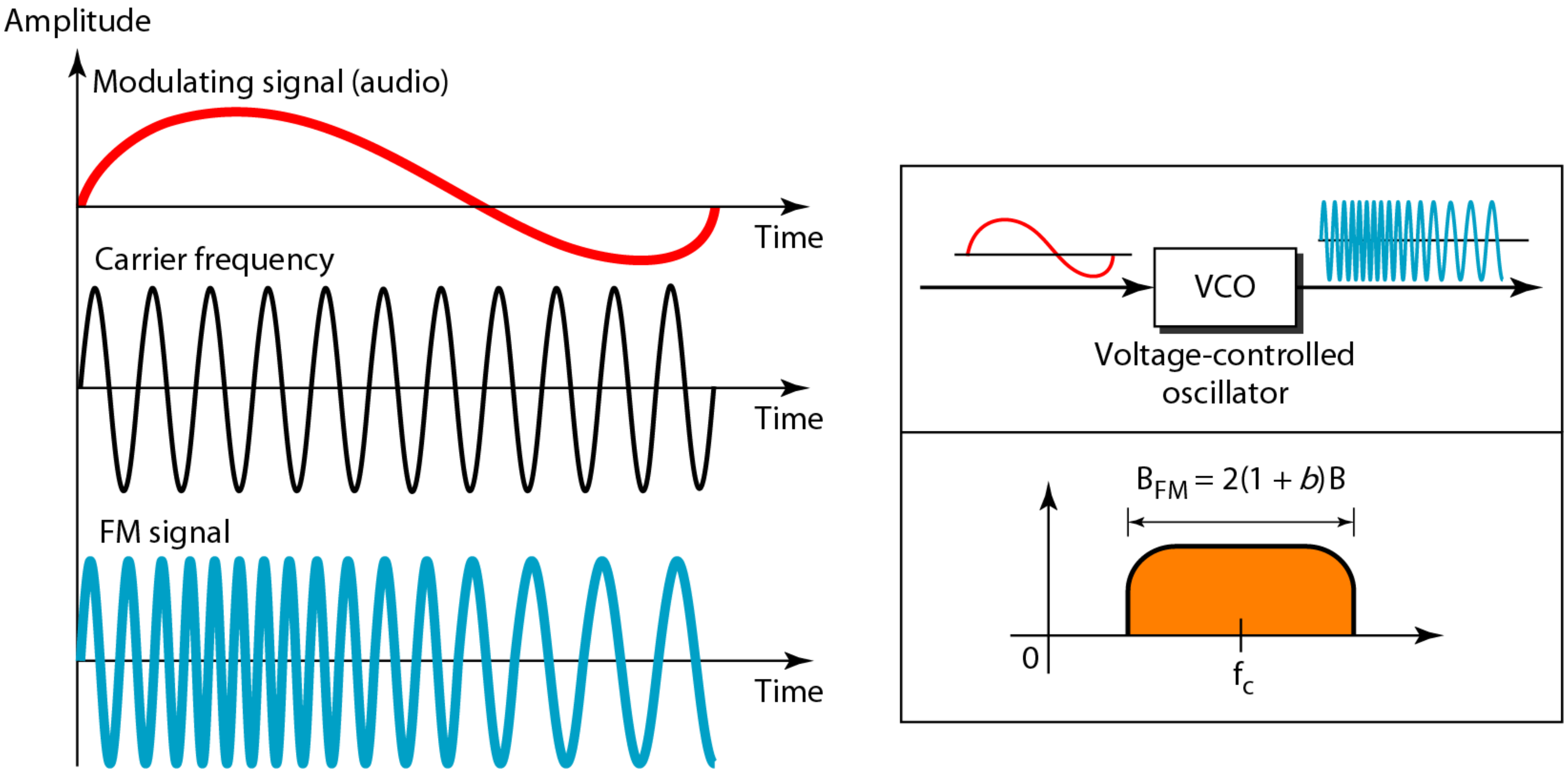


Frequency Modulation

In FM transmission, the frequency of the carrier signal is modulated to follow the changing voltage level (amplitude) of the modulating signal.

The peak amplitude and phase of the carrier signal remain constant, but as the amplitude of the information signal changes, the frequency of the carrier changes correspondingly

Figure *Frequency modulation*

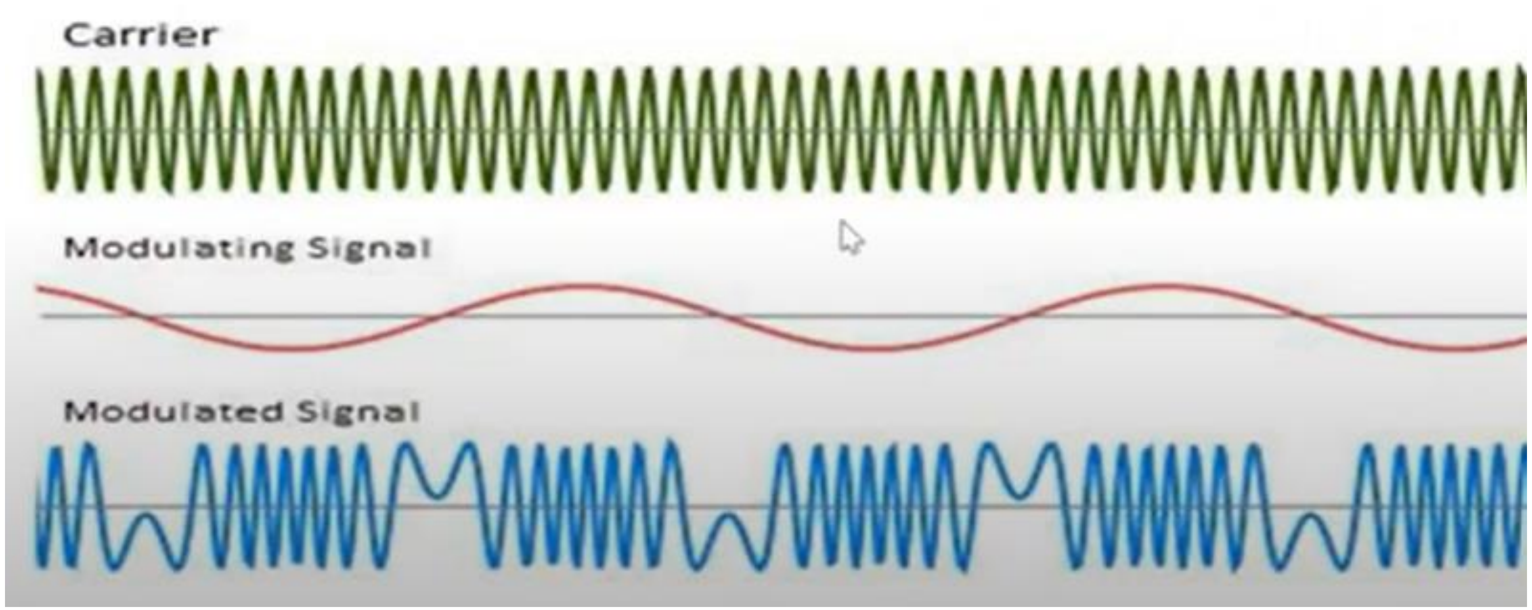


Phase Modulation (PM)

The modulating signal only changes the phase of the carrier signal.

The peak amplitude and frequency of the carrier signal remain constant, but as the amplitude of the information signal changes, the phase of the carrier changes correspondingly.

Figure *Phase modulation*



TRANSMISSION MODES

- The transmission of binary data across a link can be accomplished in either parallel or serial mode.

- Parallel mode, multiple bits are sent with each clock tick.

- Serial mode, 1 bit is sent with each clock tick.

Figure *Data transmission and modes*

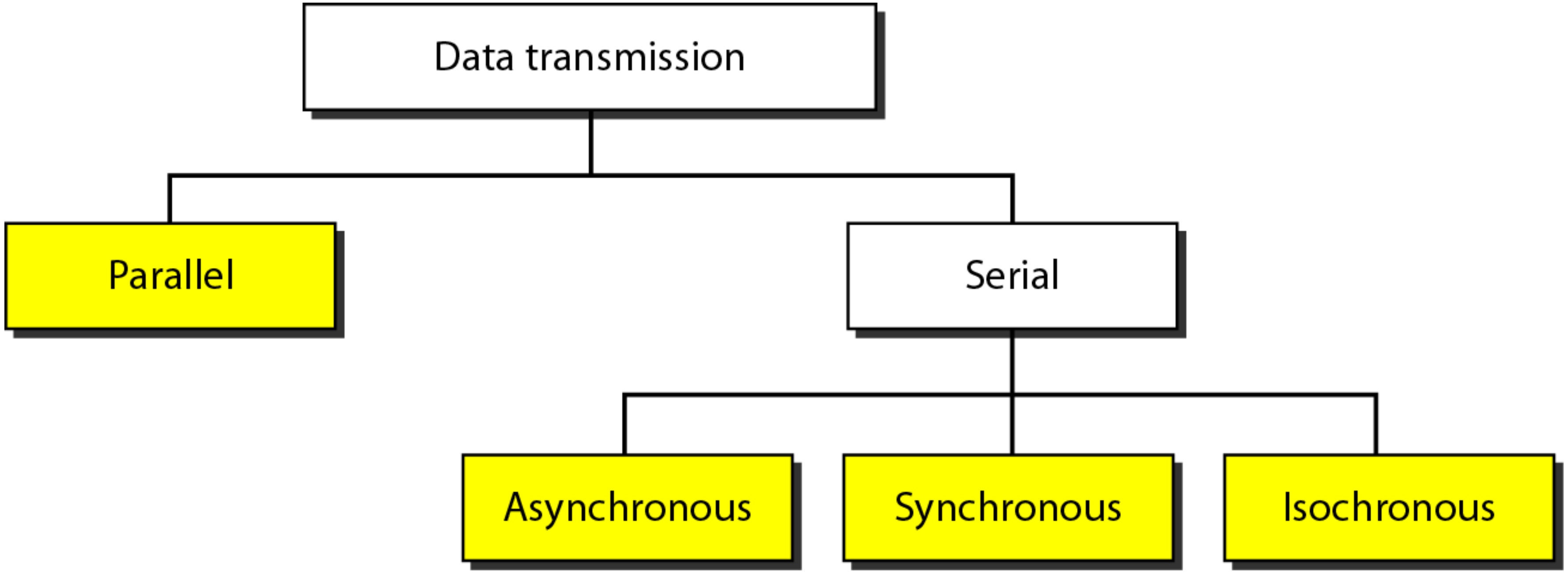


Figure *Parallel transmission*

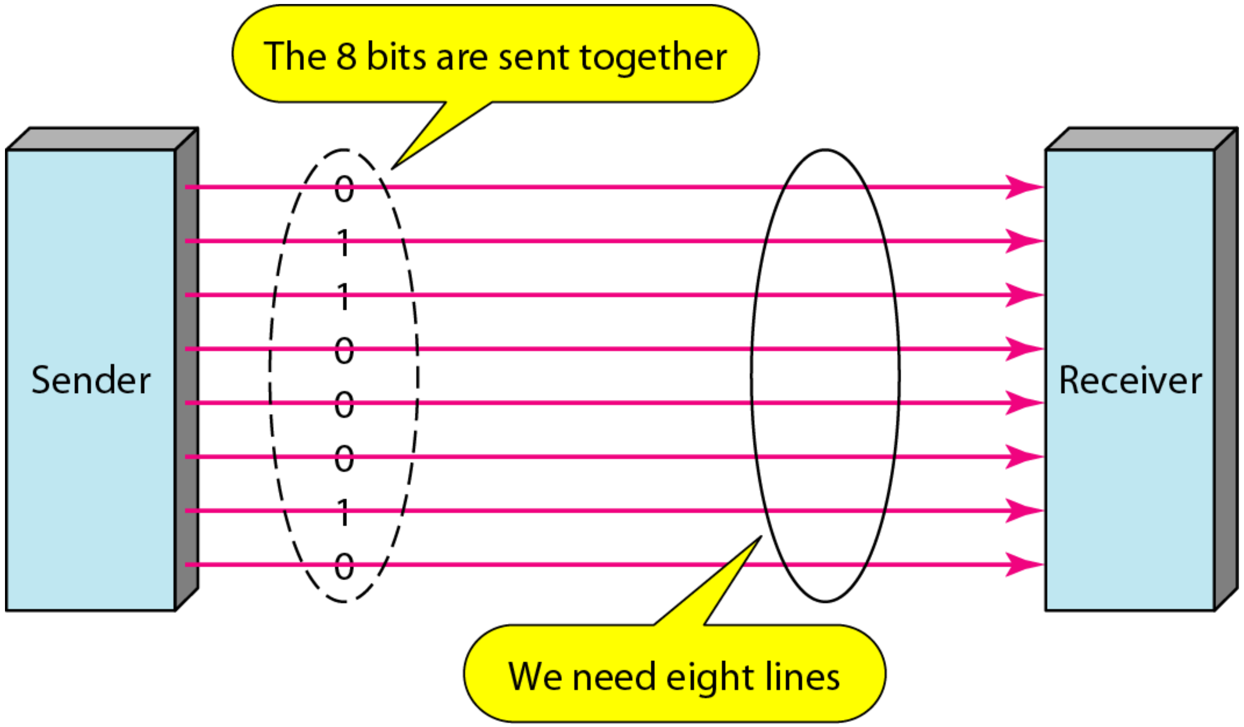
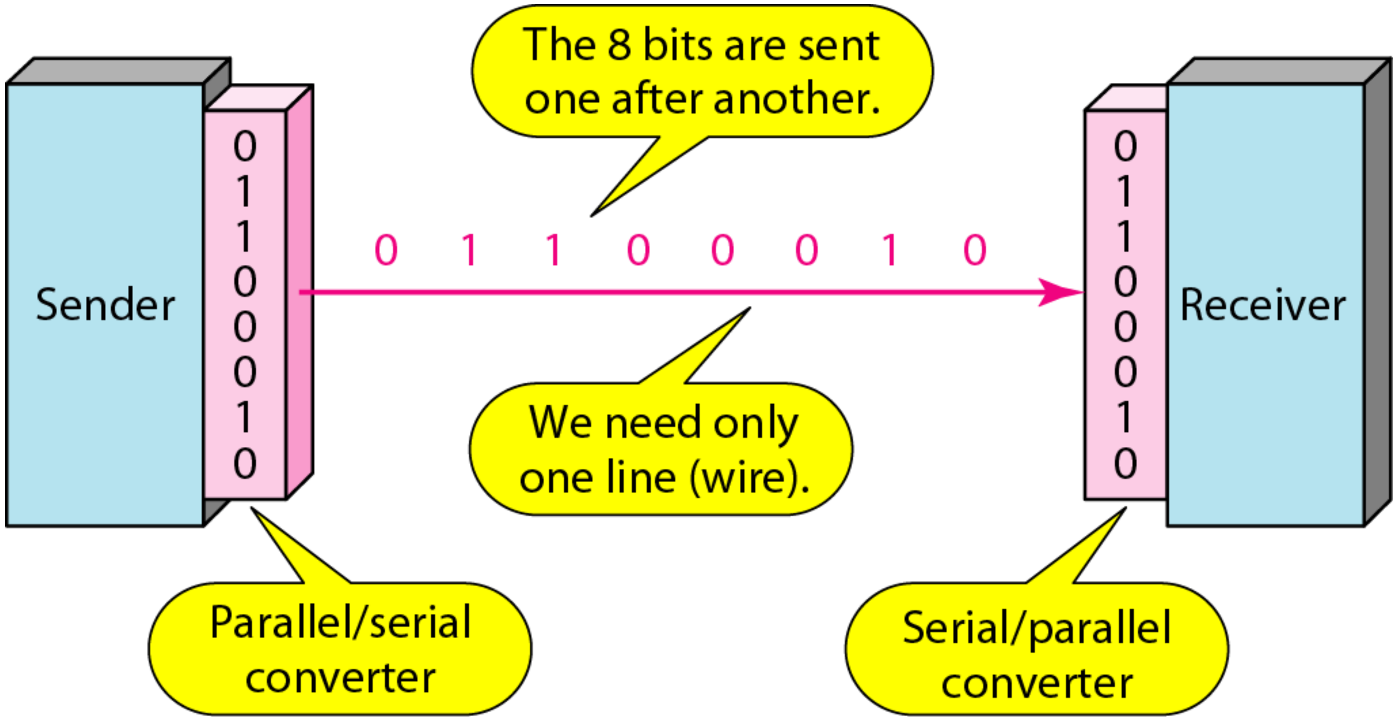


Figure *Serial transmission*



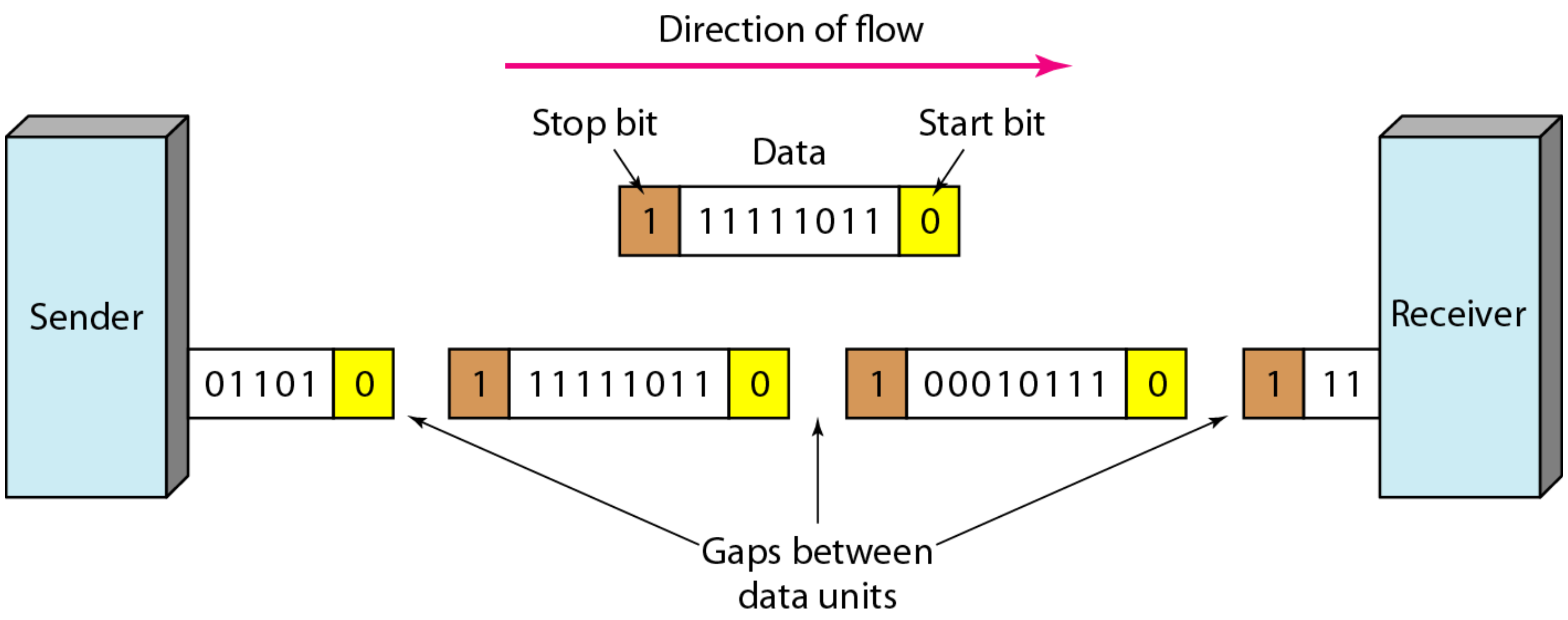
Note

In asynchronous transmission, we send 1 start bit (0) at the beginning and 1 or more stop bits (1s) at the end of each byte. There may be a gap between each byte.

Note

Asynchronous here means "asynchronous at the byte level," but the bits are still synchronized; their durations are the same.

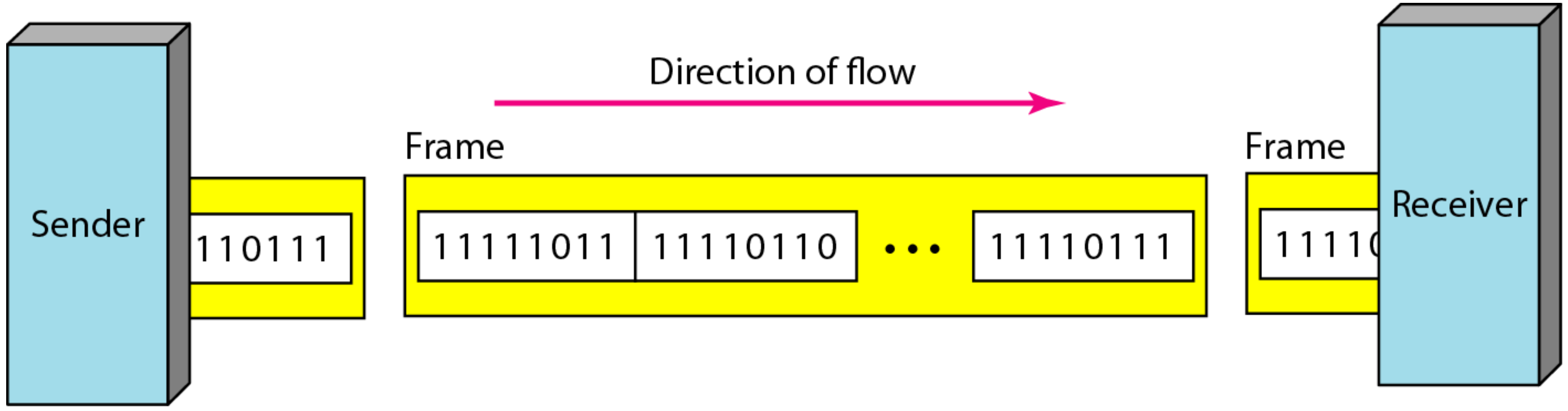
Figure *Asynchronous transmission*



Note

In synchronous transmission, we send bits one after another without start or stop bits or gaps. It is the responsibility of the receiver to group the bits. The bits are usually sent as bytes and many bytes are grouped in a frame. A frame is identified with a start and an end byte.

Figure *Synchronous transmission*



Isochronous

- In isochronous transmission we cannot have uneven gaps between frames.

- Transmission of bits is fixed with equal gaps.

PERFORMANCE

One important issue in networking is the performance of the network—how good is it?.

- Bandwidth - capacity of the system
- Throughput - no. of bits that can be pushed through
- Latency (Delay) - delay incurred by a bit from start to finish

Note

Bandwidth

- Bandwidth in bits per second, refers to the speed of bit transmission in a channel or link. Often referred to as Capacity.

For example, one can say the bandwidth of a Fast Ethernet network (or the links in this network) is a maximum of 100 Mbps. This means that this network can send 100 Mbps.

Throughput

The throughput is a measure of how fast we can actually send data through a network.

Bandwidth and Throughput

A link may have a bandwidth of B bps, but we can only send T bps through this link with T always less than B.

In other words, the bandwidth is a potential measurement of a link; the throughput is an actual measurement of how fast we can send data.

Example

A network with bandwidth of 10 Mbps can pass only an average of 12,000 frames per minute with each frame carrying an average of 10,000 bits. What is the throughput of this network?

Solution

We can calculate the throughput as

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$$\boxed{\text{Throughput} = \frac{12{,}000 \times 10{,}000}{60} = 2 \text{ Mbps}}$$

The throughput is almost one-fifth of the bandwidth in this case.

Latency (Delay)

The latency or delay defines how long it takes for an entire message to completely arrive at the destination from the time the first bit is sent out from the source

Latency = Propagation delay + Transmission delay + Queueing time + Processing time

Propagation Delay

Propagation Delay measures the time required for a bit to travel from the source to the destination

Propagation Delay = Distance/Propagation speed

Propagation speed - speed at which a bit travels though the medium from source to destination

For example, in a vacuum, light is propagated with a speed of 3 x 10 8 mbps

Transmission delay

Transmission Delay :The time required for transmission of a message depends on the size of the message and the bandwidth of the channel.

Transmission Delay = Message size/bandwidth bps

Example

What is the propagation time if the distance between the two points is 12,000 km? Assume the propagation speed to be 2.4 × 108 m/s in cable.

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We can calculate the propagation time as

$$\text{Propagation time} = \frac{12{,}000 \times 1000}{2.4 \times 10^8} = 50 \text{ ms}$$

Example

What are the propagation time and the transmission time for a 2.5-kbyte message (an e-mail) if the bandwidth of the network is 1 Gbps? Assume that the distance between the sender and the receiver is 12,000 km and that light travels at 2.4 × 108 m/s.

Solution

We can calculate the propagation and transmission time as shown on the next slide:

Example

$$\text{Propagation time} = \frac{12{,}000 \times 1000}{2.4 \times 10^8} = 50 \text{ ms}$$

$$\text{Transmission time} = \frac{2500 \times 8}{10^9} = 0.020 \text{ ms}$$

Note that in this case, because the message is short and the bandwidth is high, the dominant factor is the propagation time, not the transmission time. The transmission time can be ignored.

Example

What are the propagation time and the transmission time for a 5-Mbyte message (an image) if the bandwidth of the network is 1 Mbps? Assume that the distance between the sender and the receiver is 12,000 km and that light travels at 2.4×10^8 m/s.

Solution

We can calculate the propagation and transmission times as shown on the next slide.

Example

$$\text{Propagation time} = \frac{12{,}000 \times 1000}{2.4 \times 10^{8}} = 50 \text{ ms}$$

$$\text{Transmission time} = \frac{5{,}000{,}000 \times 8}{10^{6}} = 40 \text{ s}$$

Note that in this case, because the message is very long and the bandwidth is not very high, the dominant factor is the transmission time, not the propagation time. The propagation time can be ignored.

Queuing Time

- The time needed for each intermediate or end device to hold the message before it can be processed.

- The queuing time is not a fixed factor.