- Computer Networks
- Al-Mustansiryah University
- Elec. Eng. Department College of Engineering
  Fourth Year Class

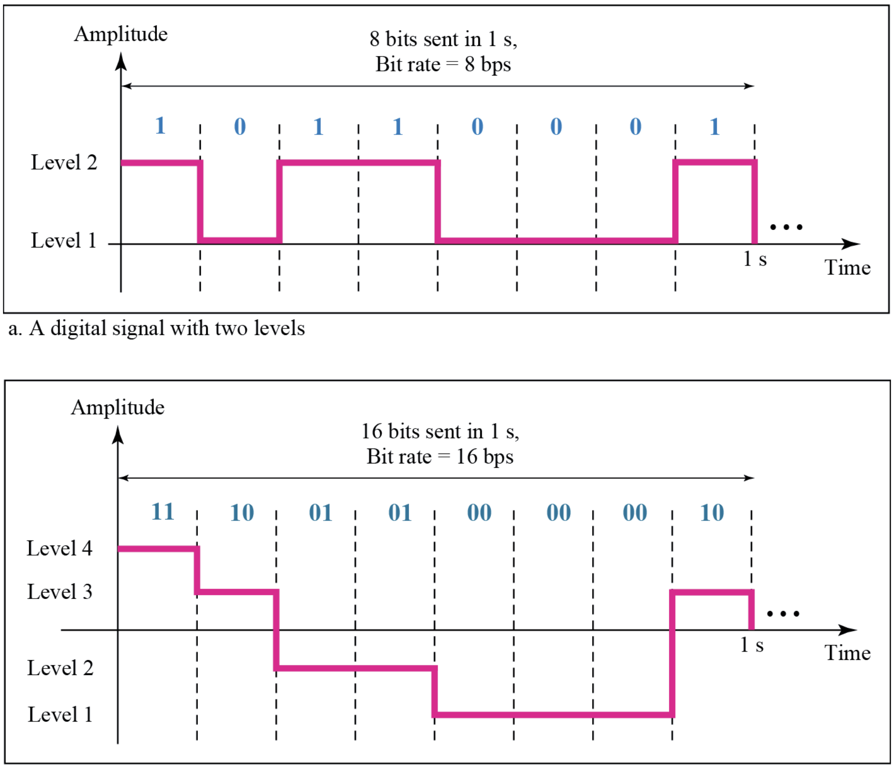
Chapter 3

Data and Signals

3-3 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 3.1 *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 3.1

Assume we need to download text documents at the rate of 100 pages per sec. What is the required bit rate of the channel (page is an average of 24 lines with 80 characters in each line)?

Solution

If we assume that one character requires 8 bits (ascii), the bit rate is

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

Example 3.2

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

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

Example 3.3

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.

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

The TV stations reduce this rate to 20 to 40 Mbps through compression.

3-4 PERFORMANCE

One important issue in networking is the performance of the network—how good is it? We discuss quality of service, an overall measurement of network performance, in greater detail in Chapter 24. In this section, we introduce terms that we need for future chapters.

Topics discussed in this section:

- **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**
- **Bandwidth-Delay Product**

Note

In networking, we use the term bandwidth in two contexts.

- The first, bandwidth in **hertz**, refers to the range of frequencies in a composite signal or the range of frequencies that a channel can pass.
- The second, bandwidth in **bits per second**, refers to the speed of bit transmission in a channel or link. Often referred to as Capacity.

Example 3.6

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

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

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

Propagation & Transmission delay

- **Propagation speed** - speed at which a bit travels though the medium from source to destination.
- **Transmission speed** - the speed at which all the bits in a message arrive at the destination. (difference in arrival time of first and last bit)

Propagation and Transmission Delay

- Propagation Delay = Distance/Propagation speed
- Transmission Delay = Message size/bandwidth bps
- Latency = Propagation delay + Transmission delay + Queueing time + Processing time

Example 3.7

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.

Solution

We can calculate the propagation time as

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

The example shows that a bit can go over the Atlantic Ocean in only 50 ms if there is a direct cable between the source and the destination.

Example 3.8

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 3.8 (continued)

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

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

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 3.9

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.

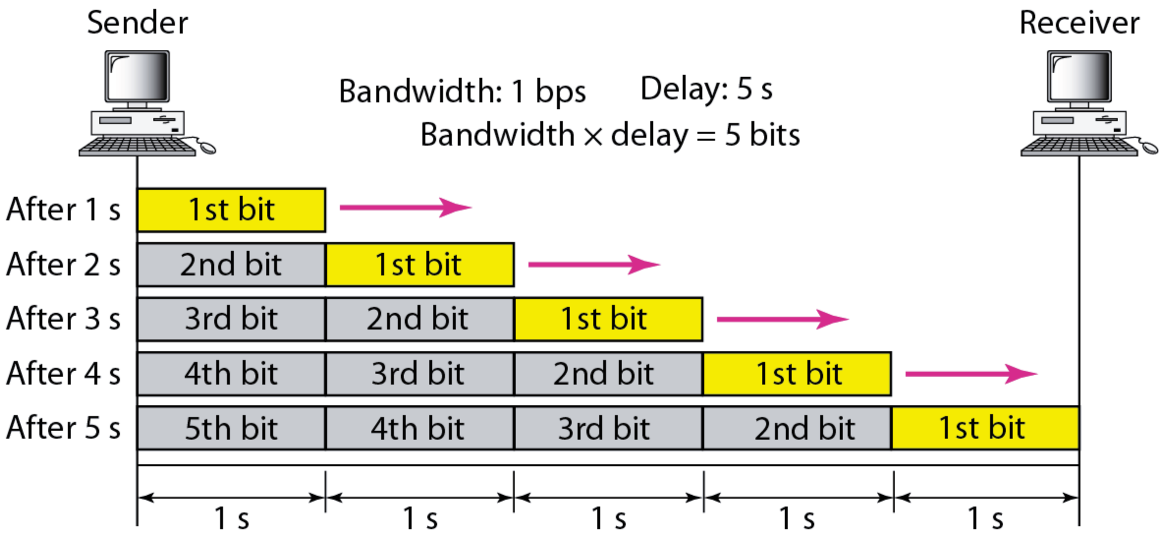
Example 3.10 (continued)

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

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

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.

Figure 3.6 *Filling the link with bits for case 1*

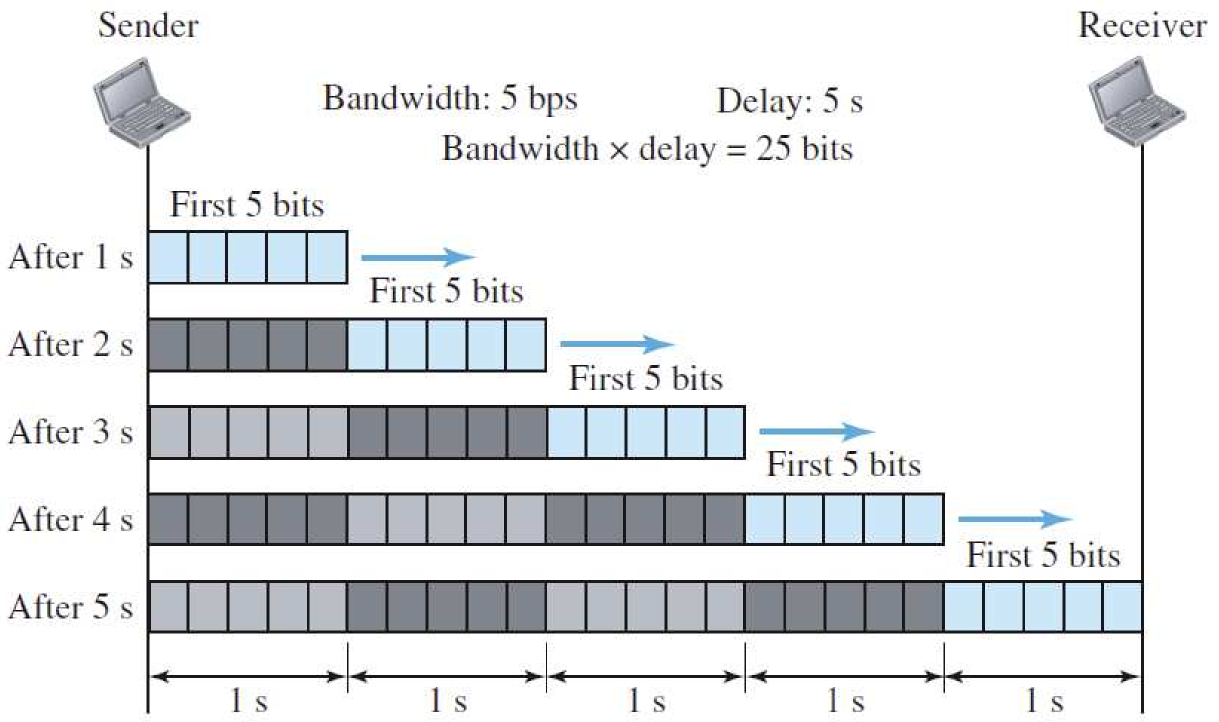


Example 3.11

We can think about the link between two points as a pipe. The cross section of the pipe represents the bandwidth, and the length of the pipe represents the delay. We can say the volume of the pipe defines the bandwidth-delay product, as shown in Figure 3.7.

The bandwidth-delay product defines the number of bits that can fill the link.

Figure 3.7 *Filling the link with bits in case 2*

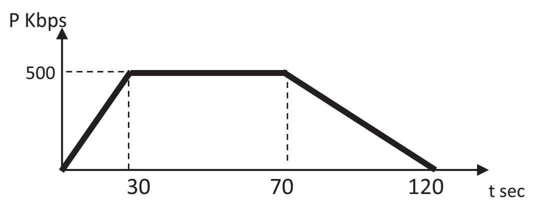


Example 3.11

A network link is transferring a data file in two minutes period. The figure shown below shows the throughput vs. time. Use this figure to calculate the following:

1) Average data transfer rate for this whole time.

2) Amount of data transferred between second 70 and second 120 ?



Solution

Size of data=0.5*30*500+40*500+0.5*50*500= 40000 KB

1) Average data transfer =S/T=40000/120= 333.3333 Kbps

2) Amount of data transferred =0.5*50*500= 12500 bit

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