DATA COMMUNICATION AND NETWORKING

Software Department – Fourth Class

Data Transmission II

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Introduction

With any communications system, the signal that is received may differ from the signal that is transmitted, due to various transmission impairments. For analog signals, these impairments introduce various random modifications that degrade the signal quality. For digital signals, bit errors may be introduced, such that a binary 1 is transformed into a binary 0 or vice versa. In this section, we examine the various impairments and how they may affect the information-carrying capacity of a communication link. Moreover, we have discussed the tools of transmitting data (signals) over a network and how the data behave. One important issue in networking is the performance of the network—how good is it? In this section, also, we introduce terms that we need in this part.

Transmission Impairments

Signals travel through transmission media, which are not perfect. The imperfection causes signal impairment. This means that the signal at the beginning of the medium is not the same as the signal at the end of the medium. What is sent is not what is received. Three causes of impairment are attenuation, distortion, and noise (see Figure 1).

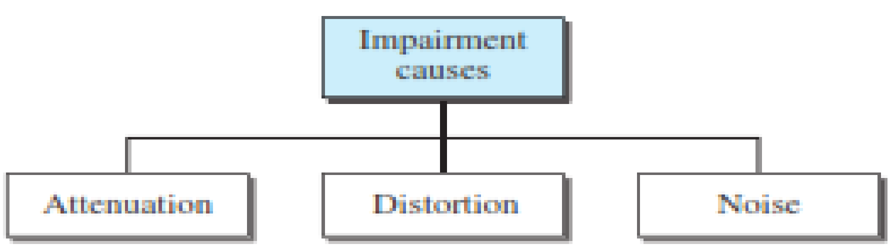

Figure 1. Causes of impairment

❖ Attenuation

Attenuation means a loss of energy. When a signal, simple or composite, travels through a medium, it loses some of its energy in overcoming the resistance of the medium. That is why a wire carrying electric signals gets warm, if not hot, after a while. Some of the electrical energy in the signal is converted to heat. To compensate for this loss, ***amplifiers*** are used to amplify the signal. Figure 2 shows the effect of attenuation and amplification.

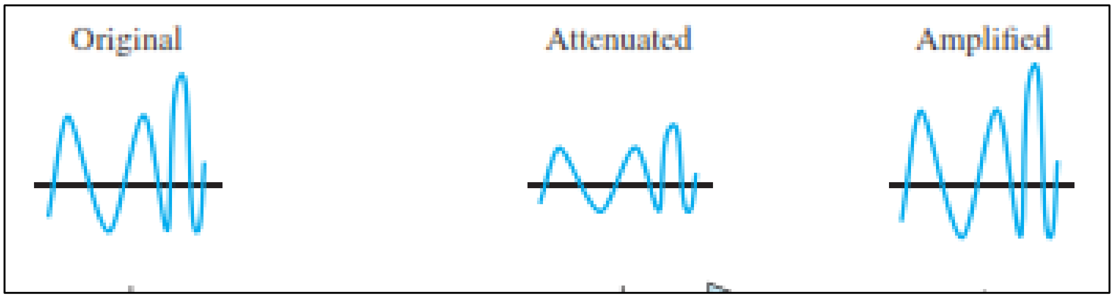

Figure 2. Attenuation

❖ Distortion

Distortion means that the signal changes its form or shape. Distortion can occur in a composite signal made of different frequencies. Each signal component has its own propagation speed (see the next section) through a medium and, therefore, its own delay in arriving at the final destination. Differences in delay may create a difference in phase if the delay is not exactly the same as the period duration. In other words, signal components at the receiver have phases different from what they had at the sender. The shape of the composite signal is therefore not the same. Figure 3 shows the effect of distortion on a composite signal.

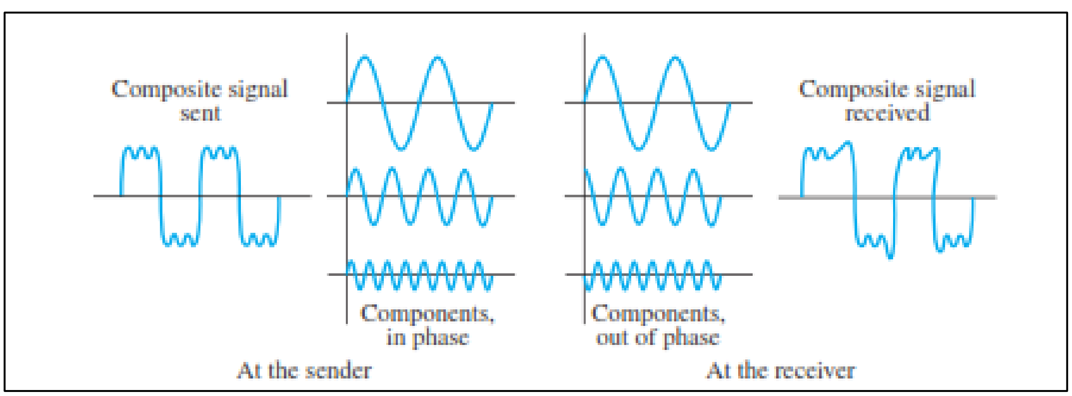

Figure 3. Distortion

❖ Noise

Noise is another cause of impairment. Several types of noise, such as ***thermal noise, induced noise, crosstalk,*** and ***impulse noise***, may corrupt the signal.

- Thermal noise is the random motion of electrons in a wire, which creates an extra signal not originally sent by the transmitter.
- Induced noise comes from sources such as motors and appliances. These devices act as a sending antenna, and the transmission medium acts as the receiving antenna.
- Crosstalk is the effect of one wire on the other. One wire acts as a sending antenna and the other as the receiving antenna.
- Impulse noise is a spike (a signal with high energy in a very short time) that comes from power lines, lightning, and so on.

Figure 4 shows the effect of noise on a signal.

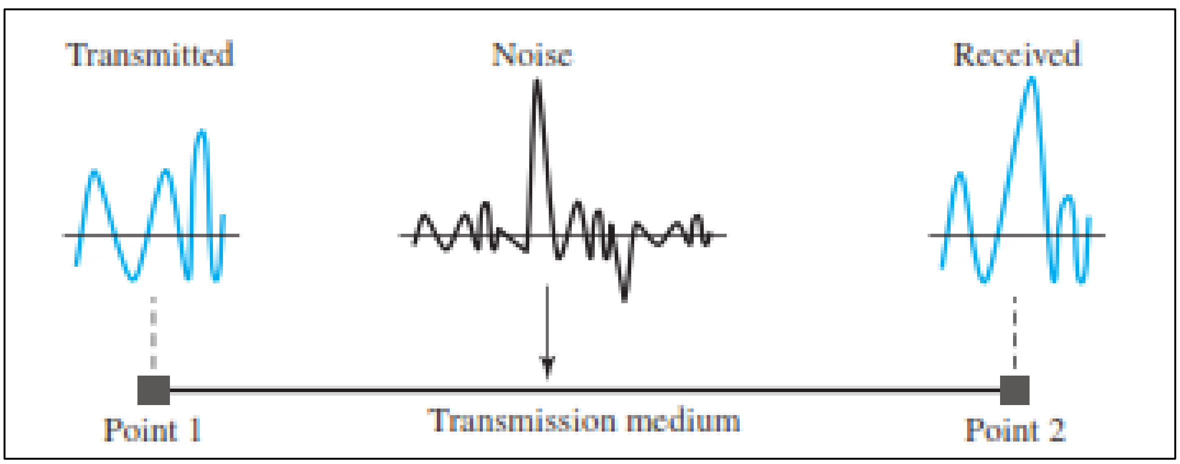

Figure 4. Noise

Performance

Performance refers to measures of service quality of a network as seen by the customer. Also, it is the analysis and review of collective network statistics, to define the quality of services offered by the underlying computer network. It is a qualitative and quantitative process that measures and defines the performance level of a given network. There are many different ways to measure the performance of a network, as each network is different in nature and design.

Bandwidth

One characteristic that measures network performance is bandwidth. However, the term can be used in two different contexts with two different measuring values: bandwidth in ***hertz*** and bandwidth in ***bits per second***.

Bandwidth in Hertz

It is the range of frequencies contained in a composite signal or the range of frequencies a channel can pass. For example, we can say the bandwidth of a subscriber telephone line is 4 kHz.

Bandwidth in Bits per Seconds

The term bandwidth can also refer to the number of bits per second (speed of bit) transmission in a channel or link. 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.

Note:- *There is an explicit relationship between the bandwidth in hertz and bandwidth in bits per second. Basically, an increase in bandwidth in hertz means an increase in bandwidth in bits per second. The relationship depends on whether we have baseband transmission or transmission with modulation.*

Throughput

The throughput is a measure of how fast we can actually send data through a network. Although, at first glance, bandwidth in bits per second and throughput seem the same, they are different. 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. For example, we may have a link with a bandwidth of 1 Mbps, but the devices connected to the end of the link may handle only 200 kbps. This means that we cannot send more than 200 kbps through this link. Imagine a highway designed to transmit 1000 cars per minute from one point to another. However, if there is congestion on the road, this figure may be reduced to 100 cars per minute. The bandwidth is 1000 cars per minute; the throughput is 100 cars per minute.

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?

We can calculate the throughput as:

$$\text{Throughput} = (12000 * 10000)/60 = 2000000 \text{ bps} = 2 \text{ Mbps}$$

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. We can say that latency is made of four components: ***propagation time, transmission time, queuing time*** and ***processing delay***.

Latency = propagation time + transmission time + queuing time + processing delay

- ***Propagation time***: measures the time required for a bit to travel from the source to the destination. The propagation time is calculated by dividing the distance by the propagation speed.

Propagation time = Distance / (Propagation Speed)

The propagation speed of electromagnetic signals depends on the medium and on the frequency of the signal. For example, in a vacuum, light is propagated with a speed of 3×10^8 m/s. It is lower in air; it is much lower in cable.

Example: What is the propagation time if the distance between the two points is 12,000 km? Assume the propagation speed to be 2.4×10^8 m/sin cable.
We can calculate the propagation time as

$$\text{Propagation time} = (12000 * 1000) / (2.4 \times 10^{8)} = 50 \text{ ms}$$

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.

- ***Transmission Time***: In data communications we don't send just 1 bit, we send a message. The first bit may take a time equal to the propagation time to reach its destination; the last bit also may take the same amount of time. However, there is a time between the first bit leaving the sender and the last bit arriving at the receiver. The first bit leaves earlier and arrives earlier; the last bit leaves later and arrives later. The transmission time of a message depends on the size of the message and the bandwidth of the channel.

Transmission time = (Message size) / Bandwidth

Example: What are the propagation time and the transmission time for a 2.5-KB (kilobyte) message (an email) 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 $2.4 * 10^8$ m/s.

We can calculate the propagation and transmission time as:

$$\text{Propagation time} = (12000 * 1000) / (2.4 * 10^8) = 50 \text{ ms}$$

$$\text{Transmission time} = (2500 * 8) / 10^9 = 0.02 \text{ ms}$$

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-MB (megabyte) 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.

We can calculate the propagation and transmission times as:

$$\text{Propagation time} = (12000 * 1000) / (2.4 * 10^8) = 50 \text{ ms}$$

$$\text{Transmission time} = (5000000 * 8) / 10^6 = 40 \text{ s}$$

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 third component in latency is the 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; it changes with the load imposed on the network. When there is heavy traffic on the network, the queuing time increases. An intermediate device, such as a router, queues the arrived messages and processes them one by one. If there are many messages, each message will have to wait.
- ***Processing Delay:*** processing delay is the time it takes nodes to process the packet header. Processing delay is a key component in network delay. During processing of a packet, nodes may check for bit-level errors in the packet that occurred during transmission as well as determining where the packet's next destination is.

Jitter

Another performance issue that is related to delay is jitter. Jitter is defined as a variation in the delay of received packets (see Figure 5). The sending side transmits packets in a continuous stream and spaces them evenly apart. Because of network congestion, improper queuing, or configuration errors, the delay between packets can vary instead of remaining constant. This variation causes problems for audio playback at the receiving end. Playback may experience gaps while waiting for the arrival of variable delayed packets. If the delay for the first packet is 20 ms, for the second is 45 ms, and for the third is 40 ms, then the real-time application that uses the packets endures jitter.

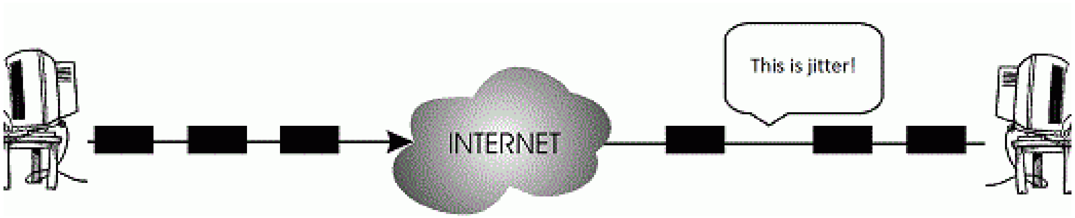

Figure 5. Jitter

Good Luck