CSIS 4222

Chapter 5 - 6

Data Communications

Data Communications Essentials

Three main ideas help define the scope of data communications

1. The sources of information can be of arbitrary types
2. Transmission uses a physical system
3. Multiple sources of information can share the underlying medium

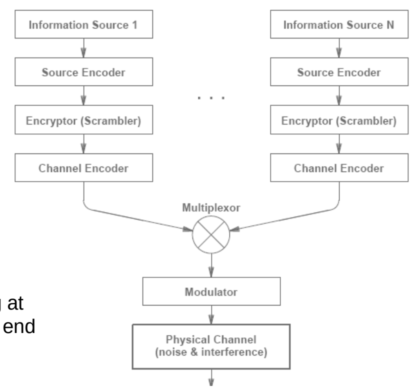
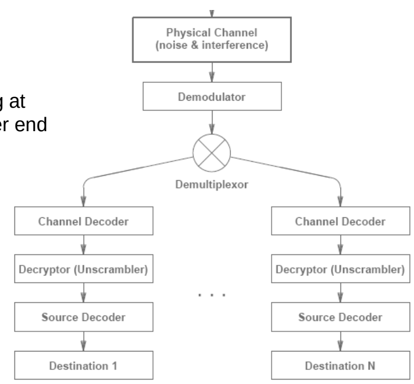


Figure 5.3

Processing at the sender end

Figure 5.3

Processing at the receiver end



Source Encoder / Decoder
- Transforming and converting the representation of digitized information (compress, etc.)

Encryptor / Decryptor
- To keep information private

Channel Encoder / Decoder
- Detect and correct transmission errors

Multiplexor / Demultiplexor
- How information from multiple sources is combined for transmission across a shared medium

Modulator / Demodulator
- How electromagnetic radiation is used to send information on the physical channel

Data Communications

Data communications theory concentrates on low-level communications systems from arbitrary sources of information

- Keyboards, mice, etc.
- Microphones, sensors, thermometers, …

Information can be *analog* or *digital*

Data and Signaling

- Data is encoded as strings of *bits*
- For transmission, the sender must convert bits into signals that represent the bits
- Simple signaling:
  - Divide time into *clock cycles* (short periods of time)

    1-bit: Turn signal *on* during a clock cycle

    0-bit: Turn signal *off* during a clock cycle

Analog and Digital Signals

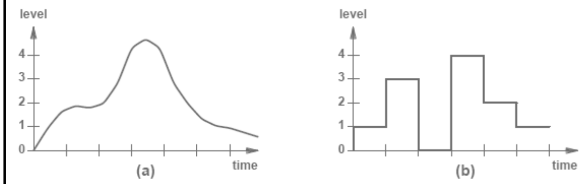


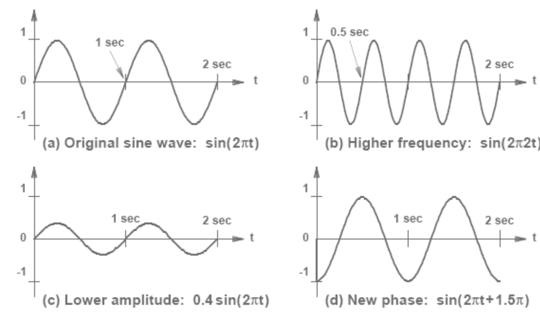
Figure 6.1 Illustration of (a) an analog signal, and (b) a digital signal.

Sine Waves and Signals

Much of data communications analysis involves sinusoidal trigonometric functions

- Many natural phenomena produce sine waves
- Electromagnetic radiation can be represented as a sine wave

Sine Waves and Signal Characteristics



Composite signals are a combination of these

Figure 6.3 Illustration of frequency, amplitude, and phase characteristics.

Bandwidth of an Analog Signal

What is network bandwidth?

In networking and communication, there are multiple definitions

- The bandwidth of an analog signal is the difference between the highest and lowest frequencies of the constituent parts (highest and lowest frequencies obtained by Fourier analysis)

These frequencies are in the range audible of the human ear.

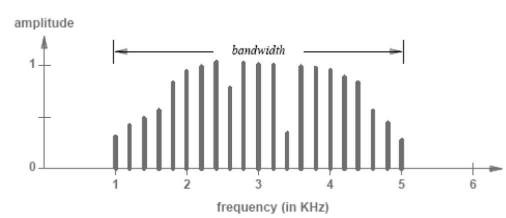


Figure 6.7 A frequency domain plot of an analog signal with a bandwidth of 4 KHz.

Digital Signals and Signal Levels

- Some systems use voltage levels to represent digital values. For example,
  - ***+5*** volts to represent a logical ***one***
  - ***0*** volts to represent a logical ***zero***
- With only two levels of voltage, each level corresponds to one data bit (0 or 1).
- When multiple levels are used, each level can represent multiple bits.
  - For example, using four levels of voltage:
    - -5 volts, -2 volts, +2 volts, and +5 volts
    - (Each level corresponds to two bits of data)

Digital Signals and Signal Levels

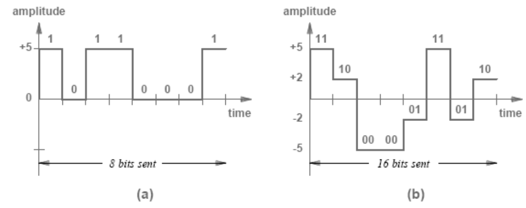


Figure 6.8 (a) A digital signal using two levels, and (b) a digital signal using four levels.

Digital Signals and Signal Levels

There must be a signal level for each possible combination of bits
- A communication system must use 2^n levels to represent n bits

- An arbitrary numbers of levels can be obtained by dividing voltage into arbitrarily small increments
- Practical electronic systems are restricted to a few signal levels because they can't distinguish between signals that differ by very small amounts

Baud and Bits Per Second

- How much data can be sent in a given time?
- The rate at which data can be sent depends on
  - the number of signal levels
  - the amount of time the system remains at a given level before moving to the next

Baud and Bits Per Second

- Halve the time per bit = twice as many bits sent in the same time
- *Baud*: The number of times the signal can change per second,
  - If a system requires the signal to remain at a given level for .001 seconds, the system operates at 1000 baud

Baud and number of signal levels control bit rate

Baud and Bits Per Second

Suppose a system operates at 1000 baud

- With two signal levels it can transfer 1000 bps
- With four signal levels it can transfer 2000 bps

$$\textit{bits per second} = \textit{baud} \times \left\lfloor \log_2(\textit{levels}) \right\rfloor$$

Converting Digital Signals to Analog

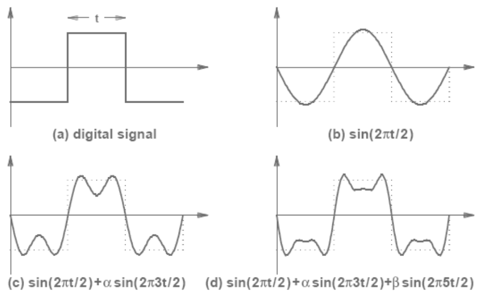


Figure 6.9 Approximation of a digital signal with sine waves.

Synchronization

A fundamental problem in data representation is synchronization of sender and receiver

– Suppose a receiver misses the first bit that arrives, and starts interpreting data at the second bit

Both ends of a physical medium must have circuitry to measure time precisely

– The high speeds used in modern networks makes this extremely difficult

Timing

- Transmitter and receiver must agree on timing of each bit
- Agreement accomplished by choosing *transmission rate*
- Measured in *bits per second*
- Detection of start bit indicates to receiver when subsequent bits will arrive

Line Coding

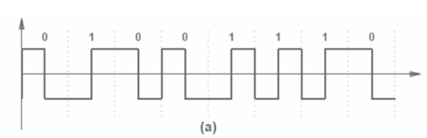
- There are several techniques that can help avoid synchronization errors
- Manchester Encoding is important for networks (used with Ethernet)
  - It uses transitions in signal level to define bits because its easier to detect transitions than it is to measure signal levels

Manchester Encoding

1 = a transition from negative voltage level to a positive voltage level

0 = a transition from a positive voltage level to a negative level

The transitions occur in the “middle” of the time slot of a bit



Encoding Details

- ➢ How long will voltage last for each bit?
- ➢ How soon will next bit start?
- ➢ How will the transmitter and receiver agree on timing?
- Details are specified by *standards*
- Several organizations produce networking standards
  - IEEE, ITU, EIA
- Hardware that adheres to the standard can *interoperate*