CENG 422

Design and Managment of Computer Networks Lecture Notes

Ege Özkan

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Chapter 1

Data and Signals - October 20, 2020

To be transmittedd, data must be transofrmed to electronic signals. Data can be *analog* or it could be *digital*.

Analog Data is the information that is continious. It may have a range of infinite values. They tend to be periodic.

Digital Data is the information that has discrete states. It can only have a limited number of values. They tend to be non-periodic.

1.1 Signal Types

1.1.1 Periodic Analog Signals

Periodic analog signals can be classified as *simple* or *composite*. Two signals may have the same phase and frequency but different amplitudes. The frequency determines the amount of repeats a signal has in a time period.

A period is the amount of time (in seconds) a signal needs to complete 1 cycle, given as $T = \frac{1}{f}$ where f is the frequency.

Frequency is the rate of change with respect to time. Change in a short span of time means high fequency. Otherwise a low frequency. If a frequency does not change at all, its frequency is zero. If the change is instantenious, it is infinite.

The wavelength describes the distance a signal can travel during a period.

The waves may be represented using only their frequency domains, simplifying their graphs significantly.

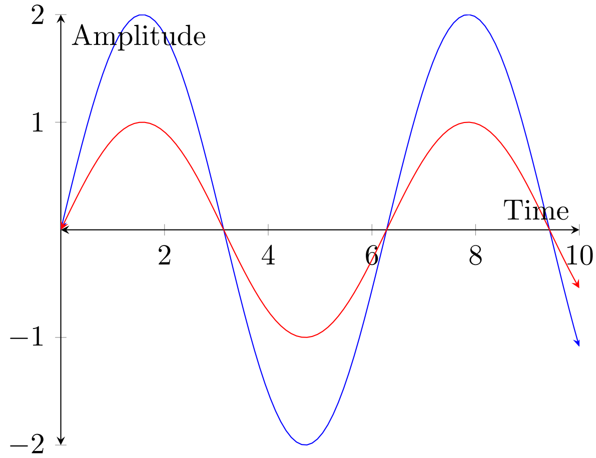

Figure 1.1: Two waves with sample phase and frequency but different amplitude.

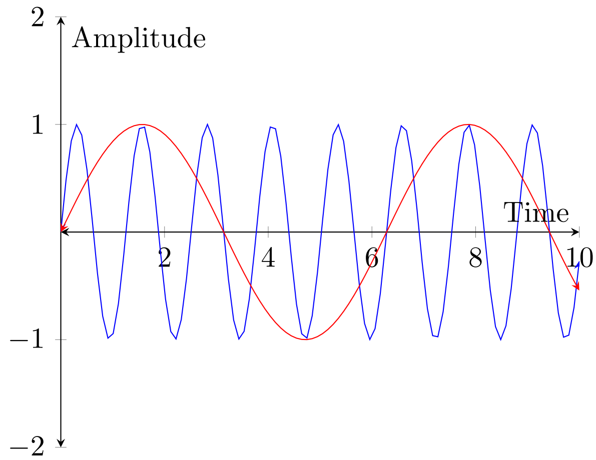

Figure 1.2: Two waves with sample amplitude and phase but different frequency.

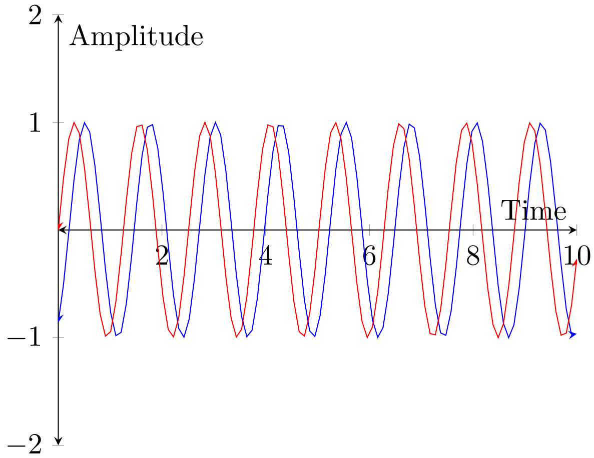

Figure 1.3: Two waves with sample amplitude and frequency but different phase.

Composite Signals

According to Fourier analysis, any composite signal consists of simpler simple signals. If the composite signal is periodic, the decomposition gives a series of signals with discrete frequencies. If the composite signal is nonperiodic, the decomposition gives a combination of sine waves with continuous frequencies.

The *bandwith* of a signal is the difference between the maximum frequency and the minimum frequency it consists of.

$$B = f_h - f_l \tag{1.1}$$

1.1.2 Digital Signals

In digital signals, the amplitude is divided into levels, as the number of levels increase, so does the speed of the transmittion. The **bitrate** represents the number of bits sent per second. Number of bits that can fit in a number of levels if the number of levels are n_L is:

$$n_B = \log_2 n_L \tag{1.2}$$

A **bit length** is the distance that a bit occupies on the transmission medium. Tranmission speed times bitrate.

$$L_B = v \times r_b \tag{1.3}$$

A periodic digital signal occupies an infinite amount of discreate freuqiencies. Whereas non-periodic digital signals (which most of them are.) occupy a continous range of infinite frequencies.

Baseband transmission is sending a signal through a channel.
A digital signal necessitates a low-pass channel, a channel that starts from 0Hz.

In general, any transmission losses *some* information with regards to the wave form of the signal, to preserve the shape of the signal completely, one needs a low-pass channel with an infinite or very wide bandwith. Sometimes, the digital signal may have to be convert to correspodning analog signals to preserve information.

The required bitrate for a bandwith of b is at minimum $\frac{b}{2}$. To acquire better result, once can multiply this number with harmonic sequences.

Bandpass is a channel with a limited range of frequencies $f_1 < f < f_2$. A digital signal cannot pass through a bandpass, as it is not a lowpass channel, therefore, the signal is first converted to analog, sent through the channel and then converted back to the digital. These include telephone lines.

1.2 Tranmission Impairment

Attenuation is the lose of amplitue in the medium, and amplifier can be used to mitigate this issue. The lose and gain can be calculated with the dB unit.

Distortion Due to the difference of behaviour of the medium for difference frequiences, parts of the composite signal may arrive out of phase, or different.

Noise They may be **Thermal Noise** due to the random motiof of electrons in the wire. **Induced Noise** is noise due to motors or appliences in the environment. **Crosstalk Noise**, effect of one wire on the other and **Impulse Noise** is a sudden spike in electricity in the wire. The quality of the medium can be calculated via the SNR (Signal-to-Noise Ratio), higher the SNR, higher the quality of the signal.

1.3 Data Rate Limits

A very important considiration in communication is how fast the data can be sent, in bits per second, over a channel. Keep in mind that, increasing the levels of a signal may reduce the reliability of the system.

1.3.1 Formulas

Maximum data rate of a channel for a noiseless channel is the Nyquist formula $L \times n_B \times \log_2 L$?*and for a noisy channel is the Shannon Formula, Capacity $=$ bandwith $+ \log_2(1 + \mathrm{SNR})$

1.4 Performance

The bandwith can be calculated in hertz or in bits per second. **Bandwith delay** is the number of bits that can fit into a channel.