1 Preliminaries

1.1 Course Information

Course Outline

- To establish the terminology and concepts of Computer Networks and the associated Communication environment.
- Understand the finer details of data communications for digital transmission of information.
- Identify and appreciate the physical layer, data link layer concepts in efficient communication system.

At the end ..

- Understand and describe the concepts related to exchange of data between coupled interconnect devices with emphasis on transmission, interfacing, link control and multiplexing.
- Understand and describe the internal mechanisms of different network topologies and architectures and their relevance to data transmission systems.

Course Outline

- The electrical interface: Media, impairments, physical layer standards.
- Data transmission: transmission methods, error detection and correction, compression for transmission.
- Protocol basics for the data link layer: ARQ, link management.
- Application environments: Character na bit oriented protocols.

Course Outline
Main Text:

- Data Communications, Computer Networks and Open Systems/4e Fred Halsall, Pearson Education Inc. 1996.

Supplementary Text:

- Communication Networks: Fundamental concepts and key architectures/2e, Alberto Leon-Garcia and Indra Widjaja, Tata McGraw-Hill 2004.

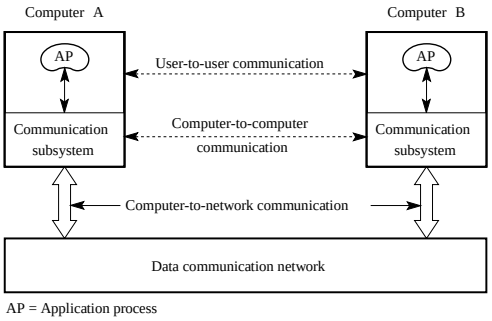
Course Outline

- Continuous assessment (50%)
  - Home work assignments
  - Other independent work
- Final examination (50%)
  - Comprehensive.
  - Open book.

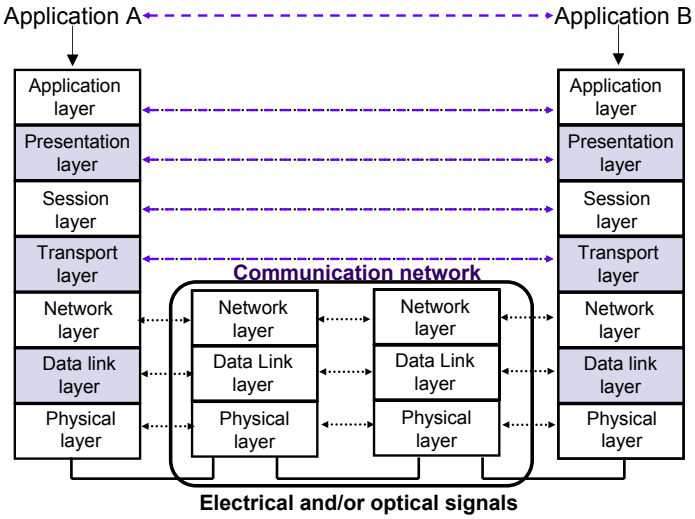
1.2 Introduction

Network Background

- We are concerned with the issues that have to be considered when two or more computers communicate with each other.

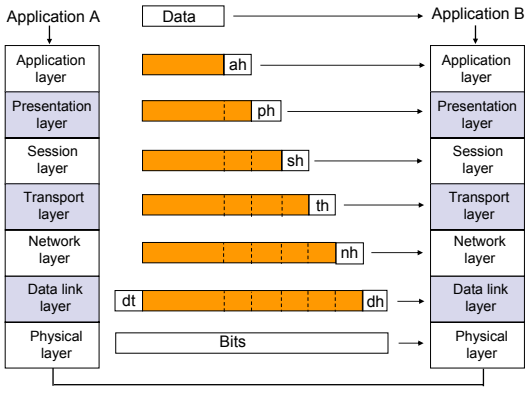


Our Concentration



Our Concentration ...

- The following figure illustrates the protocols and information that we are going to consider in this course.



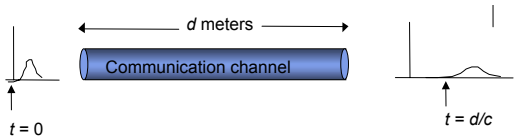
The Justification

- Signals converted to electrical signals travel in the physical layer as a bit stream.
- The transmitted signals undergo attenuation and distortion. This can be acceptable untill the receiver is unable to discriminate between the binary 1 and 0 in the bit stream.
- The above is influenced by
  - Transmission medium.
  - Bit rate of transmission.
  - Physical separation of the source and destination.
- Hence it is necessary to learn
  - Choosing transmission media.
  - Types of impairments.
  - Signaling and modulation.

2 Transmission Media

Fundamental Issues in Transmission Media

- The information bearing capacity is based on the following
  - The amplitude response function and the phase response function of the medium and the associated BW. This is dependent on the distance.
  - The susceptibility of the medium to noise and interference from other sources. This will result in error rates and SNRs.



- The speed of propagation is dependent on the relative permittivity of the channel ($v = c/\sqrt{\epsilon}$). It is 2.3E8 m/s for Cu and 2E8 m/s for optical fiber.

Fundamental Issues in Transmission Media ...

- The amount of energy used at the source for transmission is dependent on the type of media. i.e. cost is associated with the choice of media.
- The media has certain properties that limits the affective distance. Hence the additional infrastructure used in the system is directly related to the choice of media.
- The choice between guided and unguided media has a direct relationship to the network topology.
- The attenuation is also dependent on the media type.

$$\text{attenuation for guided media} = kd \text{ dB}$$
$$\text{attenuation for unguided media} = n \log_{10} d \text{ dB}$$

- For the former the relationship between attenuation and frequency is of the form 10^{kd} where k is dependent on the frequency. Attenuation increases linearly with distance.
- For the latter the relationship is d^n where n is the path loss.
- signal level in a unguided media can be maintained over much longer distance than over guided media.

Transmission Media - Guided

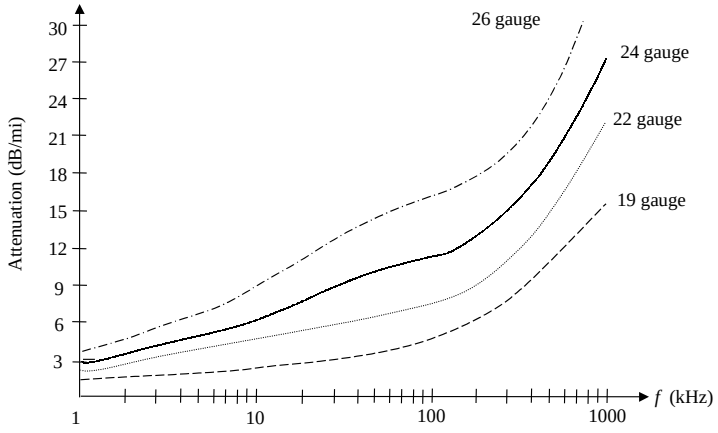
- Simplest transmission medium.
- Good for a separation of up to 50m apart and moderate data rates (less than 19.2 kb/s).
- Cross coupling of electrical signals, electromagnetic interference limits the data rate.
- Applications: TP line connection. Direct communication links over short distances.

Transmission Media - Guided

- Reduces capacitive cross coupling leading to higher data rates.
- Interference effects are reduced since now both wires pick up the interference equally.
- Skin effect can reduce the available BW. Hence sophisticated electronics have to be used at higher frequencies to recognize received information.
- Bit rates up to around 1 Mbps over distances less than 100m.
- Bit rates can be increased by using UTP and STP cables.
- Applications: Intra net. TP subscriber loops. Sme data rates for 24-gauge twisted pair.

Standard	Data rate	Distance
T1	1.544 Mbps	5.5 km
STS1	51.840 Mbps	300 m

Attenuation Vs. Frequency for Twisted Pair



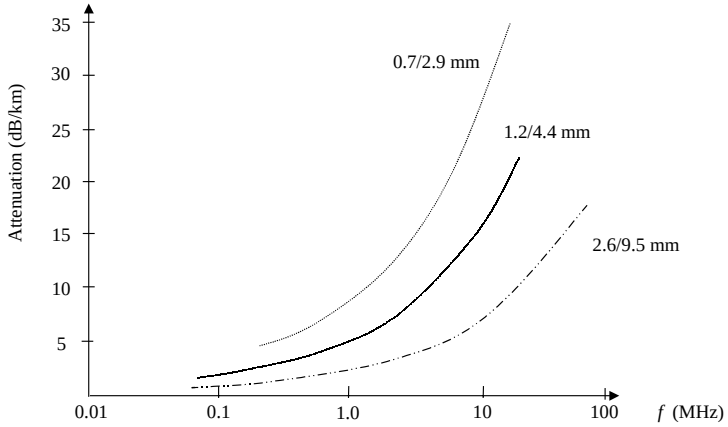
Twisted Pair Applications

- Cat3 UTP: Ordinary TP cables.
- Cat5 UTP: Tighter twist to improve signal quality.
- STP can be used to minimize interference: costly.
- 10BASE-T Ethernet
  - 10 Mbps baseband Twisted pair.
  - Two Cat 3 pairs.
  - 100m for Manchester coding (may change for different types).
- Cat3 up to 16 MHz, Cat4 up to 20 MHz, Cat5 up to 100 MHz.

Transmission Media - Guided

- Interference shielded leading to higher bit rates.
- Capacitive coupling eliminated for the most part.
- Can be used for bit rates of typically over 10 Mbps over several 100 meters.
- Techniques of modulation can be used to increase the distance.
- Applications: Cable TV, long distance TP transmission, original Ethernet LAN medium.

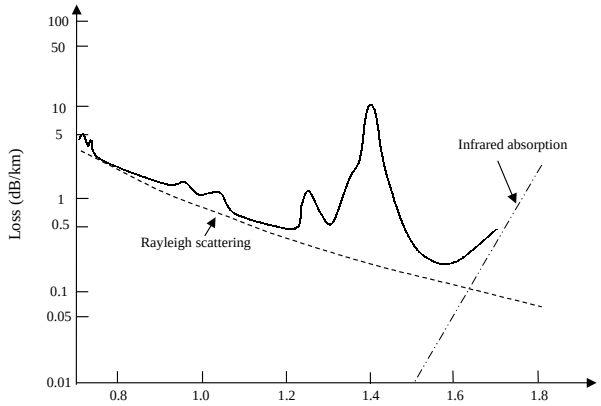
Attenuation Vs. Frequency for Coaxial Cable



Transmission Media Guided

- Getting away from the restrictions of the Cu cables. Optical fiber has very high bandwidth. Nearly error free transmission.
- Light waves are immune to EM waves and is good for industrial environments.
- High BW and high bit rates. Also good for transmitting lower bit rates in noisy environments.
- High security since it cannot be tapped.
- Limiting factor is dispersion. Multi mode fibers can be used to narrow the pulse width when traveling which can increase the BW. Mechanical vibration can become signal noise.
- Dominates long distance transmission.

Attenuation Vs. Wavelength for Optical Fiber



Transmission Media - Unguided

- A collimated microwave beam onto which the data is modulates is used for communication.
- High BW can be achieved (> 500MHz) and can carry many hundreds of high bit rate data using multiplexing.
- Requires line of sight.
- The degree of collimation determines the receivers. Very small aperture terminals (VSATs) are used if highly collimated.

Transmission Media - Unguided

- Replacement for transmission lines up to 50 km.
- Line of sight is required.
- Adverse weather conditions determines the reliability of transmission.

Transmission Media - Unguided

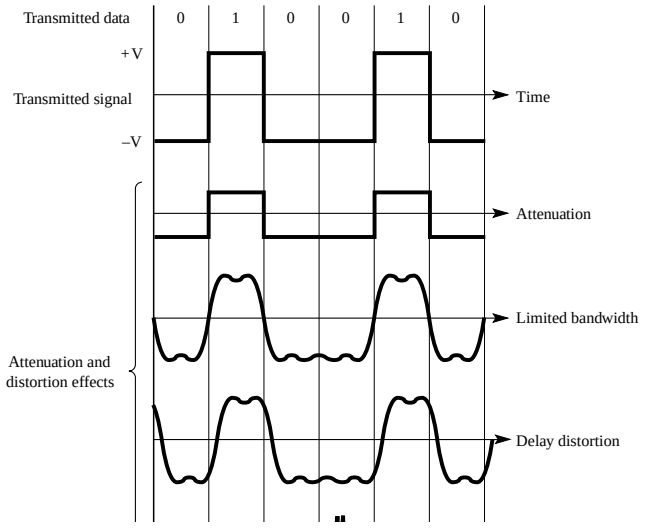
- Low frequency radio waves can also be used for replacement for guided media.
- Wireless distributed connections.
- Usable data rate is generally lower than the fixed wiring system.

Assignment

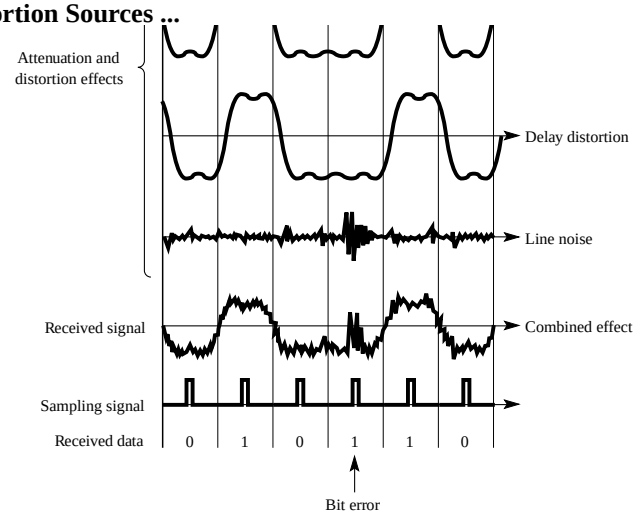
- Use the attenuation vs. frequency graphs for twisted pair and coaxial cables and explain why the bandwidth decreases with distance.
- Suppose we wish to delay an optical signal by 1ns. How long a length of optical fiber is needed to do this? How much is the signal attenuated? Repeat for 1ms.

3 Transmission Line Impairments

Attenuation and Distortion Sources



Attenuation and Distortion Sources ...



Attenuation

- Decrease of amplitude oer a distance during transmission is known as attenuation.
- Both hardware and media will determine the correct transfer of information. Repeaters/amplifiers may have to be used.
- Signal attenuation increases as a function of frequency. Hence a signal with a large frequency content will be distorted due to disparate nature of attenuation for each frequency.
- Quantitatively

$$\text{Attenuation} = 10 \log_{10} \frac{\text{transmitted signal power}}{\text{received signal power}} \text{ dB}.$$

- Amplitude distortion can be eliminated by using an equalizer after the amplifier. This will provide differential amplifications
- Amplitude distortion affects analog systems more than digital systems since in analog systems we require faithful reproduction at all frequencies.
- The attenuation becomes a bigger issue for multilevel signaling.

Limited Bandwidth

- Each type of cable used for data transmission has a particular bandwidth associated with it. Generally one has to choose the appropriate type of medium depending on the maximum frequency of transmission.
- Fourier analysis can be used to decompose a binary waveform into its frequencies.
- Even though the binary waveform can consists of randomly varying sequences, the worst case sequence of 101010... is considered for computations.
- **Example**: If a signal 500bps is transmitted over a communication channel, what is the minimum bandwidth required if it should not attenuate up to the fifth harmonic.
- *Definitions*: The absolute BW of a signal is the width of the spectrum while the effective BW is the band within which most of the signal energy is concentrated.

Limited Bandwidth ...

- The coding of the signal for transmission is also important to determine the effective BW required to transmit it (bipolar/unipolar RZ/NRZ etc).
- For a signal
$$v(t) = a_1\{\cos 2\pi f_0 t - \frac{1}{3}\cos 6\pi f_0 + \frac{1}{5}\cos 10\pi f_0 - ...\}$$
corresponding to a bipolar square wave, the following is true.
  - If $f_0 = 1MHz$ then the BW of the above signal which has up to the 5th harmonic is 4MHz. The bit rate is 2Mbps.
  - If $f_0 = 2MHz$ (effectively increasing the BW) then the BW of the above signal which has up to the 5th harmonic is 8MHz. Further the data rate is 4Mbps.
  - If $f_0 = 2MHz$, however now if the signal has only up to the third harmonic, the BW is 4MHz while the data rate is still 4Mbps.

Limited Bandwidth ...

- Multilevel signaling is one way to improve bandwidth usage.
- If the number of signal levels is M, the number of bits per signal element m is given by
$$m = \log_2 M.$$
- Data rate (R, measured in bps) and the signaling rate (R_s, measured in Baud) are related by
$$R = mR_s.$$
- Now the maximum information transfer rate in a noiseless channel is given by $C = 2Wm$.
- In the absence of noise, the bit rate can be increased without limit by increasing m.
- With the introduction of transmission protocols, the effective information transmission rates decrease. Hence three terms, namely, bit rate, data rate and signaling rate. All of these can mean the same or different as the case maybe.

Limited Bandwidth ...

- The bit rate (R) indicates the actual number of bits that are transmitted
$$R = m\frac{1}{T_b}.$$
where T_b is the duration of the bit.
- Signaling rate R_s (measured in baud, pulses per second) is given by
$$R_s = \frac{R}{m}$$
- Data rate (R_i) is the actual information content in the signal.
$$R_i = R - \text{ overhead bits/s.}$$
- Higher the bandwidth efficiency $B = R/W$, the stricter are the design parameters of the associated equipment and hence higher cost.

Delay Distortion

- Similar to amplitude distortion, the delay experienced by different frequencies vary in a channel. Hence delay distortion occurs at the receiver.
- Can be reduced by using an equalization process.
- For higher bit rates the delay distortion increases leading to inter symbol interference and thus limits the bit rate. Measured using eye diagrams.
- The transmission delay is different from the propagation delay. For example if the input signal $x(t)$ to a channel with amplitude response $A(kf_0)$ and phase response $\phi(kf_0)$ is given by

$$x(t) = \sum a_k \cos(2\pi k f_0 t).$$

- The output from channel

$$y(t) = \sum a_k A(kf_0) \cos(2\pi k f_0 t + \phi(kf_0)).$$

- If $A(kf_0)$ is constant no amplitude distortion will occur. If $\phi(kf_0)$ is constant no delay distortion will occur.

Delay Distortion ...

- The compounded delay for a block of data can be written as

$$\begin{aligned} \text{Delay} &= t_{\text{prop}} + t_{\text{tr}} \\ &= \frac{d}{c} + \frac{L}{R}. \end{aligned}$$

  where L is the number of bits in the block.
- Use data compression techniques to reduce L.
- Use higher speed DTEs to increase R.
- Place the DTEs closer to reduce d.
- Since in the data link we handle frames within the protocols it is better to look at the information as a frame. Then

$$a = \frac{t_{\text{prop}}}{t_{\text{tr}}}$$

  determines which part dominates.