Impairments and Concerns
Transmission Media

- the physical path between transmitter and receiver

- design factors
  - bandwidth
  - attenuation: weakening of signal over distances
  - interference:
  - number of receivers
Impairments and Capacity

- Impairments exist in all forms of data transmission
- Analog signal impairments result in random modifications that impair signal quality
- Digital signal impairments result in bit errors (1s and 0s transposed)
Transmission Impairments

- Attenuation
  - loss of signal strength over distance
- Attenuation Distortion
  - different losses at different frequencies
- Delay Distortion
  - different speeds for different frequencies
- Noise
Attenuation

- Attenuation refers to the loss of signal strength as the signal travels further along a cable.
Types of Noise

- Thermal (aka “white noise”)
  - Uniformly distributed, cannot be eliminated
- Intermodulation
  - when different frequencies
- Crosstalk
- Impulse noise
  - Less predictable
Transmission Media

- two major classes
  - conducted or guided media
    - use a conductor such as a wire or a fiber optic cable to move the signal from sender to receiver
  - wireless or unguided media
    - use radio waves of different frequencies and do not need a wire or cable conductor to transmit signals
Guided Transmission Media

- the transmission capacity depends on the distance and on whether the medium is point-to-point or multipoint
  - e.g.,
    - twisted pair wires
    - coaxial cables
    - optical fiber
Twisted Pair Wires

- Consists of two insulated copper wires arranged in a regular spiral pattern to minimize the electromagnetic interference between adjacent pairs.

- Often used at customer facilities and also over distances to carry voice as well as data communications.

- Low frequency transmission medium.
Twisted Pair Wires

- two varieties
  - STP (shielded twisted pair)
    - the pair is wrapped with metallic foil or braid to insulate the pair from electromagnetic interference
  - UTP (unshielded twisted pair)
    - each wire is insulated with plastic wrap, but the pair is encased in an outer covering
UTP Categories

- **Category 1** - traditional telephone cable; can carry voice but not data
- **Category 2** - consists of 4 twisted-pairs and is rated for data transmissions up to 4 Mbps.
- **Category 3** - consists of 4 twisted-pairs and 3 twists per foot; rated for 10 Mbps
- **Category 4** - 4 TP, rated for 16 Mbps
- **Category 5** - 4 TP, rated for 100 Mbps
Beyond Category 5

- Category 5 – 4 TP, 100 MHz, 100 Mbps
- Category 5e – 4 TP, 100 MHz, can be used for 1000 Mbps
- Category 6 – 4 TP, 250 MHz, can be used for 10000 Mbps
- Category 7 – 4 TP, 600 MHz, can be used for 100000 Mbps
Shielded Twisted Pair (STP)

- STP uses a foil wrap between and around the wire pairs.
- In addition, the woven copper braid jacket is of higher quality and offers better protection than what UTP uses.
- This provides STP with much better shielding from interference.
- More expensive, harder to work with
Twisted Pair Advantages

- inexpensive and readily available
- flexible and light weight
- easy to work with and install
Twisted Pair Disadvantages

- susceptibility to interference and noise
- attenuation problem
- relatively low bandwidth (3000Hz)
Coaxial Cable (or Coax)

- has an inner conductor surrounded by a braided mesh
- both conductors share a common center axial, hence the term “co-axial”
Coax Layers

- **outer jacket** (polyethylene)
- **shield** (braided wire)
- **insulating material**
- **copper or aluminum conductor**
Coaxial Cable Shielding

- Dual shielded - one layer of foil insulation and one layer of braided metal shielding

- Quad shielding - two layers of foil insulation and two layers of braided metal shielding (used in environments that are subject to higher interference)
Types of Coaxial Cable

- Thin (thinnet)
- Thick (thicknet)
Thinnet is a flexible coaxial cable about 0.25 inch thick. Thinnet coaxial cable can carry a signal up to approximately 185 meters. At 2 Mbps.
Thicknet

- Thicknet is relatively rigid coaxial cable about 0.5 inch in diameter. The copper core is thicker than a thinnet core.

- Because of the thicker copper core, thicknet can carry a signal for up to 500 meters. At 10 Mbps.
Coaxial Connection Hardware

- BNC (Bayonet Neill-Concelman) connector
- BNC T connector
- BNC barrel connector
- BNC terminator
Coaxial Cable Grades and Fire Codes

- Polyvinyl chloride (PVC) - flexible, for use in the exposed areas of office

- Plenum - more expensive and less flexible but are certified to be fire resistant; used in the plenum
Coax Advantages

- high bandwidth
  - up to 10,800 voice conversations
- can be tapped easily (pros and cons)
- much less susceptible to interference than twisted pair
Coax Disadvantages

- high attenuation rate makes it expensive over long distance
- bulky
- lower data rate (10 Mbps for LANs)
Fiber Optic Cable

- Relatively new transmission medium used by telephone companies in place of long-distance trunk lines

- Also used by private companies in implementing local data communications networks

- Require a light source with injection laser diode (ILD) or light-emitting diodes (LED)
Fiber Optic Layers

- consists of three concentric sections
Fiber Optic Signals

- Glass or plastic core
- Laser or light emitting diode
- Specially designed jacket
- Small size and weight

Light at less than critical angle is absorbed in jacket
Angle of incidence
Angle of reflection

(c) Optical Fiber
Fiber Optic Types

- **multimode step-index fiber**
  - the reflective walls of the fiber move the light pulses to the receiver

- **multimode graded-index fiber**
  - acts to refract the light toward the center of the fiber by variations in the density

- **single mode fiber**
  - the light is guided down the center of an extremely narrow core
Fiber Optic Signals

- **Step index fiber**
  - Index of refraction
  - Input pulse
  - Output pulse

- **Graded index fiber**
  - Index of refraction
  - Input pulse
  - Output pulse

- **Singlemode fiber**
  - Index of refraction
  - Input pulse
  - Output pulse

Image by Merzeon, Wikipedia under CC
Fiber Optic Advantages

- greater capacity (bandwidth of up to 2 Gbps)
  - Theoretically unlimited (limited by electrical equipment at ends)
- smaller size and lighter weight
- lower attenuation
- immunity to environmental interference
- highly secure due to tap difficulty and lack of signal radiation
Fiber Optic Disadvantages

- expensive over short distance
- requires highly skilled installers
- adding additional nodes is difficult
Cable Comparison Summary

- Cable cost
- Usable length
- Transmission Rates
- Flexibility
- Ease of installation
- Susceptibility to interference
Selecting Cabling

- Cabling depends on the particular site. Among the considerations which affect cabling price and performance include:
  - installation logistics (how easy to install?)
  - shielding (what level?)
  - noise and crosstalk (any power lines? motors?)
  - transmission speed (how fast?)
  - cost (how much?)
  - attenuation
Selecting Cabling

- The more the cable protects against internal and external electrical noise, the farther the cable will carry a clear signal.

- The better the speed, clarity and security, the higher the cost.
Unguided or Wireless Media
Sharing the Airwaves
Wireless (Unguided Media) Transmission

- Transmission and reception are achieved by means of an antenna

- **directional**
  - Transmitting antenna puts out focused beam
  - Transmitter and receiver must be aligned

- **omnidirectional**
  - Signal spreads out in all directions
  - Can be received by many antennas
Wireless Examples

- Cellular Mobile
- Terrestrial microwave transmission
- Satellite transmission
- Broadcast radio
- Infrared
Terrestrial Microwave Transmission

- Alternatively referred to as **P2P microwave**
- Uses the radio frequency spectrum, commonly from 2 to 40 Ghz
- Transmitter is a parabolic dish, mounted as high as possible
- Used by common carriers as well as by private networks
- Requires unobstructed line of sight between source and receiver
- Curvature of the earth requires stations (called repeaters) to be ~30 miles apart
Microwave Transmission Applications

- long-haul telecommunications service for both voice and television transmission
- short point-to-point links between buildings for closed-circuit TV or a data link between LANs
- bypass application
Microwave Transmission Advantages

- no cabling needed between sites
- wide bandwidth
- multichannel transmissions
Microwave Transmission Disadvantages

- line of sight requirement
- expensive towers and repeaters
- subject to interference such as passing airplanes and rain
Satellite Microwave Transmission

- a microwave relay station in space
- can relay signals over long distances
- geostationary satellites
  - remain above the equator at a height of 22,300 miles (geosynchronous orbit)
  - travel around the earth in exactly the time the earth takes to rotate
 Satellite Transmission Links

- Earth stations communicate by sending signals to the satellite on an uplink.
- The satellite then repeats those signals on a downlink.
- The broadcast nature of the downlink makes it attractive for services such as the distribution of television programming.
Satellite Transmission Process

- **uplink station**
- **dish**
- **22,300 miles**
- **satellite transponder**
- **downlink station**
- **dish**
Sample geostationary satellite coverage

- Earth radius = 6,370 km
- Typical shuttle orbit = 225 – 250 km
- Hubble Space Telescope = 600 km
- Polar Orbiting Satellite 850 km altitude
- Orbital positions of the 165 geostationary satellites orbit Earth today
Satellite Transmission Applications

- television distribution
  - a network provides programming from a central location
  - direct broadcast satellite (DBS)
- long-distance telephone transmission
  - high-usage international trunks
- private business networks
Principal Satellite Transmission Bands

- **C band**: 4(downlink) - 6(uplink) GHz
  - The first to be designated
  - Dishes tend to be big

- **Ku band**: 12(downlink) - 14(uplink) GHz
  - Rain interference is the major problem

- **Ka band**: 19(downlink) - 29(uplink) GHz
  - Equipment needed to use the band is still very expensive
Satellite Advantages

- can reach a large geographical area
- high bandwidth
- cheaper over long distances
Satellite Disadvantages

- high initial cost
- susceptible to noise and interference
- propagation delay
Long Haul?
### Table 4-7 Comparison of Optical Fiber and Satellite Transmission

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Optical Fiber</th>
<th>Satellite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bandwidth</td>
<td>Theoretical limit of 1 terahertz; currently 1-10 GHz</td>
<td>Typical transponder has a bandwidth of 36-72 MHz</td>
</tr>
<tr>
<td>Immunity to interference</td>
<td>Immune to electromagnetic interference</td>
<td>Subject to interference from various sources, including microwave</td>
</tr>
<tr>
<td>Security</td>
<td>Difficult to tap without detection</td>
<td>Signals must be encrypted for security</td>
</tr>
<tr>
<td>Multipoint capability</td>
<td>Primarily a point-to-point medium</td>
<td>Point-to-multipoint communications easily implemented</td>
</tr>
<tr>
<td>Flexibility</td>
<td>Difficult to reconfigure to meet changing demand</td>
<td>Easy to reconfigure</td>
</tr>
<tr>
<td>Connectivity to customer site</td>
<td>Local loop required</td>
<td>With antenna installed on customer premises, local loop not required</td>
</tr>
</tbody>
</table>
Review