

# CSIS 625 Week 3

## Transmission of Data, Transmission Media

Copyright 2001, 2002, 2003 – Daniel R. Oelke

For use by students of CSIS 625 for purposes of this class only.

## I. Overview

### A. Wrap up Encoding

1. Analog to Analog Conversion

### B. Transmission of Data

1. Serial vs. Parallel Transmission

### C. Transmission Media

1. Impairments
2. Wired - Twisted Pair, Coax, Fiber
3. Wireless

## II. Wrap up Encoding from last week

### A. Analog to Analog Encoding

1. AM - Amplitude Modulation
  - a. The amplitude of the carrier is modified
  - b. Bandwidth = 2x Bandwidth of modulating signal
  - c. More susceptible to noise
  - d. Most common example is AM radio.
2. FM- Frequency Modulation
  - a. The frequency of the carrier is modified
  - b. Bandwidth = 10x Bandwidth of modulation signal
  - c. Less susceptible to noise
  - d. Most common example is FM radio
3. Phase Modulation
  - a. The phase of the carrier is modified
  - b. Phase Modulation and FM are a special case of Angle modulation
  - c. Observing the signal, it is impossible to tell apart FM and phase modulation

## III. Parallel/Serial Transmission of Data

### A. Parallel Transmission of Data

1. Send several bits of data at the same time, each one over a separate media link.
  - a. Typically 8 bits of data sent over 8 wires
  - b. Examples: Parallel Printer cables, SCSI, PCI bus, Memory Bus
2. Allows faster transmission of data, but at the cost of multiple wires, multiple transmitters, and multiple receivers
3. Must keep all bits in sync
4. Typically uses a separate clock line

### B. Serial Transmission of Data

1. Definition:
  - a. Sends all bits from node to node over a single media link.
  - b. Bits are sent one after another - or “serially”

- c. May or may not have additional media links for clock, frame, or flow control.
  - d. Need some method of keeping track of when a byte starts and ends.
- 2. Data transparency on serial links
  - a. Data transparency - the ability of a link to send any data pattern
  - b. Bit stuffing - insertion of extra bits to change a flag pattern so that data transparency is achieved
  - c. Byte stuffing - insertion of extra bytes to change a flag pattern so that data transparency is achieved
  - d. Flag character - special bit pattern to show start or end of a frame
- 3. Serial - Asynchronous transmission
  - a. Bits are grouped together into characters
  - b. Start and stop bits frame the data bits
    - 1. A start bit is sent first
    - 2. Followed by the data bits
    - 3. Followed by a stop bit or bits
  - c. Variable number of idle bits between characters
  - d. At best - 80% efficient
    - 1. 8 data bits + 1 start bit + 1 stop bit
    - 2.  $8 \text{ data bits} / 10 \text{ bits sent} = 80 \%$
  - e. Allows for about a lot of timing error
    - 1. Clock difference of 4-5% will still work if edges of signal are sharp
- 4. Serial - Synchronous transmission
  - a. Each byte of data is sent with no extra gaps between bytes.
  - b. Data is grouped into frames
  - c. Between frames, special idle patterns used
  - d. Much less overhead than asynchronous
  - e. Can achieve faster bit rates than asynchronous
  - f. Requires synchronization method
- 5. Bit-oriented synchronous transmission
  - a. Uses a special bit pattern at the start and end of the frame (flag character)
  - b. Data may be any number of bits
  - c. Uses bit stuffing to replace flag pattern in data
  - d. Bit stuffing is slightly more efficient than byte stuffing
  - e. Easier to implement in hardware
- 6. Character oriented synchronous transmission
  - a. Uses a special byte at the start and end of the frame
  - b. Data must be an even number of 8-bit bytes
  - c. Uses byte stuffing to replace flag byte in data
  - d. Byte stuffing makes this slightly less efficient
  - e. Easier to implement in software

### C. DTE-DCE interface

- 1. DTE - Data Terminal Equipment
  - a. A device that is a source or destination for binary digital data
- 2. DCE - Data Circuit-terminating Equipment
  - a. A device that interfaces between a DTE and a network
  - b. Modem is classic DCE example
- 3. Lots of standards specify DTE to DCE interface
- 4. Lots of standards specify DCE to DCE interface

#### D.RS-232 Interface

1. Specifies the mechanical, electrical & functional characteristics of DTE-DCE interface
2. One of the most common serial interfaces
3. EIA-232 is now the official name
4. Tailored to Computer to modem interface
5. Limited to about 20 Kbps
6. Mechanical
  - a. less than 50 feet long cable
  - b. DB-25 connector original standard
  - c. DB-9 connector now standardized
7. Electrical - Uses NRZL
  - a. 0 = +3 to +15 volts
  - b. 1 = -3 to -15 volts
8. 3 pins are all that are necessary
  - a. Receive Data
  - b. Transmit Data
  - c. Ground
9. Other pins are often ignored
10. Null modem - a device that flips receive and transmit lines

#### E. Other serial interfaces

1. RS-449 - uses 37 pin connector
2. RS-423 - uses 2-6 volt levels
  - a. 40 feet - 100 Kbps
  - b. 4000 feet - 1 Kbps
3. RS-422 - 2-6 Volt balanced transmission
  - a. 40 feet - 10 Mbps
  - b. 4000 feet - 1 Kbps

### IV. Balanced / Unbalanced transmission

#### A. Balanced

1. Uses two wires with a positive or negative voltage put on the line

#### B. Unbalanced

1. Using two wires, one as ground and the other as signal.

#### C. Balanced provides better noise resistance than unbalanced

### V. Transmission impairments

#### A. Attenuation

1. Signal loses strength as it goes through medium
2. All devices that handle a signal cause some attenuation

#### B. Distortion

1. Signal changes form or shape as it goes through medium
2. Dispersion in fiber optic systems is a prime example

#### C. Noise

1. Additional signal merged in
2. The static heard on a radio is one example
3. The ghost images on a TV are an example of a reflection of the original being noise.

## D. Signal Strength Measurement

1. Decibel (dB) is a measure of the relative strengths of two signals.
  - a.  $\text{dB} = 10 * \log_{10} (P_2/P_1)$
  - b.  $P_1$  = Power of signal at point 1
  - c.  $P_2$  = Power of signal at point 2
2. dB are used because it allows end-to-end signal strength to be determined by adding up attenuation and amplification
3. Signal-Noise Ratio - a dB measurement of signal strength to noise strength

## VI. Transmission Performance

### A. Throughput

1. How many bits you can put through the system in a unit of time – typically bps (bits per second)

### B. Latency

1. How long it takes for bits to get through a system
2. Affected by:
  - a. The speed of bits through the system
  - b. The distance the bits travel
  - c. The processing time at various stops

### C. Error Rate

1. How many bits get changed as they go through the system

## VII. Transmission media - Twisted Pair

### A. Shielded or Unshielded

1. UTP - Unshielded Twisted pair
  - a. two wires twisted together in a cable
2. STP - Shielded Twisted pair
  - a. two wires twisted together in a cable with extra metal casing around the wires.
  - b. Extra metal casing is grounded to prevent noise from entering (or leaving) wire pair.
  - c. Extra metal makes cable more expensive
  - d. At connectors the metal shield must be grounded (more cost)
  - e. Must be careful to not ground at both ends if they are in different buildings (or different electrical systems) as this may create a “ground loop” which causes current to flow through the cable.
    1. This may cause cable to overheat and start fire

### B. Characteristics of twisted pair cables.

1. An electrical noise source gives more noise into those wires that are closer
2. With un-twisted wires, one of the wires gets more noise.
3. With twisted wires, both wires get roughly equal amount of noise, so the noise offsets itself.
4. The more twists per inch, the better the noise immunity
5. The more twists per inch, the more copper (and cost) in a cable.
6. When multiple pairs are in a single cable, each of the pairs should be twisted at a slightly different number of twists per inch.
  - a. To prevent one pair creating noise in another pair.

### C. EIA categories of cables

1. Category 1
  - a. Unspecified cabling - used for analog POTs connections
2. Category 2
  - a. 22 or 24 gauge wires, with 1 MHz bandwidth
  - b. Used in 4 Mbps Token ring LANs
3. Category 3
  - a. 22 or 24 gauge wires with 16 MHz bandwidth
  - b. Used for 10Base-T, ISDN, T1
  - c. about 3-4 twists per foot
4. Category 4
  - a. 20 MHz bandwidth
  - b. Used for 16 Mbps Token Ring
5. Category 5
  - a. 100 MHz bandwidth
    1. about 3-4 twists per inch
  - b. Used for 100Base-T
6. Category 5E
  - a. 100 MHz bandwidth, but 3 dB better S/N
  - b. Used for 1000Base-T
7. Category 6
  - a. Proposed 250 MHz
8. Category 7
  - a. Proposed 500-700 MHz
9. Question if Category 5E cable is standards compliance
  - a. Many companies were selling it before the standard was finished. (Feb 2000)

## VIII. Transmission Media - Coax Cable

### A. Construction

1. Solid wire down center
2. Insulator around that
3. Foil or mesh around that
4. Final outer insulator

### B. Thin Ethernet

1. 50-Ohm, 0.2 inch diameter
2. Connector - BNC
3. Max Length: 185 Meters
4. Minimum distance between nodes - 0.5 meters

### C. Thick Ethernet cable

1. 50-Ohm, 0.4 inch diameter
2. Connector - N-series
3. Vampire tap for nodes
4. Max length - 500 meters
5. Minimum distance between nodes - 2.5meter

### D. Broadband coax (aka Cable TV)

1. 75-Ohm, 0.2 inch diameter
2. 860MHz relatively flat
3. Up to 2 GHz with more attenuation

## IX. Eye Diagrams

- A. Diagram that shows how well a digital signal is transported on a medium.
- B. Shows amplitude and timing noise
- C. Wide open eye is better than mostly closed one.
- D. Standards often have exclusion zones in the center and above and below

## X. Fiber optic cables

### A. Angle of refraction – Why light stays in fiber

- 1. aka - How to be a good lifeguard
- 2. aka - why does a diamond sparkle
- 3. Light travels faster in some mediums than others - this causes refraction
  - a. Light in vacuum is  $3.0 \times 10^8$  m/s
  - b. Light in glass is about  $2.0 \times 10^8$  m/s
- 4. When light hits at less than critical angle, total reflection occurs.

### B. Cable Constructions

- 1. Core - center of a fiber optic strand. Where the light travels.
- 2. Cladding - material of different refractive index wrapped around the core of a fiber
- 3. Fibers propagate all light that enters them at less than the critical angle.
- 4. Fibers typically have about 1% difference in refractive index between core and cladding
- 5. This results in a critical angle of about  $8^\circ$
- 6. Getting lots of light in is good.
  - a. Choose a “big” fiber
  - b. Refractive index between air and fiber end makes all light with about a  $12^\circ$  acceptance angle.
- 7. Typical “big” is 125 micron diameter cladding and 50 or 62.5 micron core
- 8. Waves of light tend to make reflection occur only at certain “modes”

### C. Multi-mode fiber

- 1. Big core fiber will allow multiple modes to propagate down the fiber.
- 2. Modal Dispersion - Multiple modes result in light that travels different distances
  - a. creates “mush” out of signals
- 3. Step index fiber
  - a. Step function for refractive index
- 4. Graded index fiber
  - a. Curved function for refractive index
  - b. Light travels faster near edges
- 5. Graded index fiber allows for much farther distances at higher bit rates to be achieved

### D. Fiber - single-mode fiber

- 1. To avoid Modal dispersion - use a smaller fiber where only one mode can travel down the fiber
- 2. Harder to get light in - BUT results in much longer distances being obtainable.
- 3. Single mode fiber is typically 125 micron diameter cladding and 8 micron core.

### E. Fiber light sources

- 1. Raleigh Scattering
  - a. aka Why are sunsets red and the sky blue.

- b. Blue light is about 400nm wavelength
  - c. Red light is about 700nm wavelength
  - d. Blue is about 9.4 times more likely to be scattered than red
  - e. From this, we want longer wavelengths to avoid scattering and keep light headed towards destination
2. Light absorption of glass
    - a. Around 1600 nm wavelength, silica glass light starts to absorb light
  3. Water is a common impurity in glass
    - a. OH tends to absorb light at various parts
  4. Graph of loss vs. wavelength
    - a. From graph we see that around 1550nm and around 1310nm are best spots for transmitting
    - b. 850nm is also used because of ease of creating light source

## F. Fiber Dispersion types

1. Dispersion - All light does not travel at the same speed down a fiber. This results in sloped edges of optical pulses
2. Modal Dispersion -
  - a. Different modes of light travel different distances in multi-mode fiber
3. Material Dispersion
  - a. Differences in the refractive index in the core
    1. Careful quality control fixes this
4. Waveguide Dispersion
  - a. Light acts like a big wave in a small tube
  - b. Can be minimized by choice in glass
5. Chromatic Dispersion
  - a. Different wavelengths of light travel at different speeds
  - b. Dependant on the type of glass
  - c. Dependant on width of light source
6. Polarization mode Dispersion
  - a. Different refractive indexes in a material based on the polarization of light.
    1. Different refractive indexes means different speeds of light.
  - b. Smallest effect
    1. Increases with square root of transmission distance

## G. Fiber's Advantages & Disadvantages

1. Advantages
  - a. Minimal interference
  - b. Best bandwidth and distance
2. Disadvantages
  - a. Slightly more costly
    1. But may be offset by speed up
  - b. Harder to do a splice
3. Security - slight advantage
  - a. Contrary to the myth - You can tap a fiber
  - b. Not cheap or easy to do it though.

## XI. Wireless media

### A. Wireless communication

1. Using free space or the air as your media. (i.e. not using wire or fiber)
2. Radio waves can be modulated using FM, AM, PM, or QAM

3. Often used for broadcast applications - TV, Radio, etc.
4. Some frequencies bounce off layers in atmosphere allowing for greater distance
5. Higher frequencies = line of sight

## B. Frequency Bands

1. 0-300 Hz ELF - Extremely low Freq
2. 300-3000 Hz ILF - Infra Low Freq
3. 3-30 kHz VLF - Very Low Frequency
4. 30-300 kHz LF - Low Frequency
5. 300-3000 kHz MF - Medium Frequency
6. 3-30 MHz HF - High Frequency
7. 30-300 MHz VHF - Very High Frequency
8. 300-3000 MHz UHF - Ultra High Frequency
9. 3-30 GHz SHF - Super High Frequency
10. 30-300 GHz EHF - Extremely High Frequency
11. 300-3000 GHz THF - Tremendously High Frequency

## C. Wireless Applications

1. TV and Radio
2. Cellular Telephone
3. Satellite Television
4. Satellite Telephony and Data
5. Wireless LANs

## D. Cell Phone Technology

1. Based on the idea of offering mobile phone service
2. Reference:
  - a. Much of this material taken from:
  - b. <http://www.ee.washington.edu/class/498/sp98/final/marsha/final.html>
  - c. [http://www.iec.org/online/tutorials/cell\\_comm/](http://www.iec.org/online/tutorials/cell_comm/)
  - d. <http://www.iec.org/online/tutorials/tdma/>
3. There were early radio to telephone type systems, but cellular technology didn't start until the early 1980's.
  - a. Limited number of channels in a large area
  - b. 1981 the FCC approved the use of a larger number channels.
4. Based on the idea of using radio frequencies in small areas called cells.
  - a. 806-890 MHz and 1850-1990 MHz
5. Cells are often laid out in a honeycomb type of topology.
  - a. Frequencies can then be re-used in non-adjacent cells.
  - b. A cell is 1-2 miles in radius in urban areas
  - c. up to 20 miles in radius in rural area.
  - d. Micro-Cell and Pico-Cell are used in very small very high density areas
    1. Such as inside a sports stadium
6. Cellular system components
  - a. PSTN - Public Switched Telephone System
    1. The "normal" phone system
  - b. MTSO - Mobile Telephone Switch Office
    1. The switch that controls all of the cell sites
    2. This switch coordinates handoffs between cells
  - c. Mobile Base Station - The cell site
    1. The antenna, radios, interface equipment, etc.
  - d. MSU - Mobile Subscriber Units

1. The cell phone you carry around.
7. Cell phone - Analog vs. Digital
  - a. Analog technology uses FDM with FM analog modulation
    1. call uses a fixed frequency in its cell for the duration
    2. Older scheme - more coverage in united states than digital technology
    3. Any scanner can listen in on these conversations
      1. Newt Gingrich knows this well
      2. Congress made it illegal to listen in on these conversations, but it is very difficult to enforce unless you come out with a tape
  - b. Digital technology
    1. Uses PCM to get a digital stream
    2. Then uses various audio compression techniques to get voice down to rates as low as 8kbps.
      1. Compression may reduce the quality of the voice
    3. Newer technology with good coverage in high population density areas.
    4. Allows many more calls for a given bandwidth
    5. May use "silence suppression" to further increase capacity
      1. Silence suppression - not sending data when there is no-one talking
      2. Effectively doubles the amount of data that can be sent.
      3. Need to have comfort noise added
8. Cell - Modulation techniques
  - a. FDMA - Frequency Division Multiple Access
    1. used for analog phones
    2. The same thing as Frequency Division Multiplexing
  - b. TDMA - Time Division Multiple Access
    1. Divides a frequency into multiple timeslots
    2. Each call uses one timeslot in one frequency
    3. Increases the number of calls that may be present
    4. Used with digital technology
  - c. CDMA - Code Division Multiple Access
    1. Use of entire time and frequency
    2. Each call has minimal interference with one another.
    3. Not a hard limit on the number of calls possible
      1. Each call just adds a little more interference
  - d. GSM - Global System for Mobile Communications
    1. TDMA based system used in Europe.
    2. Voice compressed to 13kbps
  - e. PCS - Personal Communications Services
    1. use of 1900 MHz frequencies
9. Cell handoff
  - a. As a phone moves from one cell to another, the call must be handed off with minimal interruption.
    1. When signal strength decreases sufficiently, base station notifies switch

2. The switch queries the other base stations to determine which has the strongest signal from the phone.
  3. The switch then notifies the new base station to take over the call
  4. Normally less voice is dropped for only 10-100ms
- b. CDMA can use a “soft” handoff with no interruption
1. The use of the entire frequency spectrum means that there is no other channel to use