CSIS 625 Week 4

Overview

- Transmission of Digital Data
  - Serial & Parallel transmission
  - Serial interfaces - DTE & DCE - Modems
- Transmission Media
  - Wired - Twisted Pair, Coax, Fiber
  - Wireless
  - Impairments
- Multiplexing
  - Space, Frequency, Wave, Time

Parallel Transmission of Data

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

Serial Transmission of Data

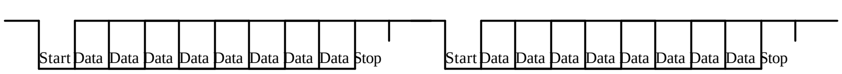
- Sends all bits from node to node over a single media link.
- Bits are sent one after another - or “serially”
- May or may not have additional media links for clock, frame, or flow control.
- Need some method of keeping track of when a byte starts and ends.
  - Asynchronous or Synchronous

Serial - Asynchronous transmission

- Bits are grouped together into characters
- Start and stop bits frame the data bits
  - – A start bit is sent first
  - – Followed by the data bits
  - – Followed by a stop bit or bits
- Variable number of idle bits between characters

Serial - Asynchronous transmission

- At best - 80% efficient
  - – 8 data bits
  - – 1 start bit
  - – 1 stop bit
- Allows for about a lot of timing error
- Example:



Serial - Synchronous transmission

- Each byte of data is sent with no extra gaps between bytes.
- Data is grouped into frames
  - Frame contains
- Between frames, special idle patterns used
- Much less overhead that asynchronous
- Can achieve faster bit rates than asynchronous
- Requires synchronization method

Data transparency on serial links

- Data transparency - the ability of a link to send any data pattern
- Bit stuffing - insertion of extra bits to change a flag pattern so that data transparency is achieved
- Byte stuffing - insertion of extra bytes to change a flag pattern so that data transparency is achieved
- Flag character - special bit pattern to show start or end of a frame

Serial - Synchronous transmission

- Bit-oriented synchronous transmission
  - Uses a special bit pattern at the start and end of the frame (flag character)
  - Data may be any number of bits
  - Uses bit stuffing to replace flag pattern in data
  - Bit stuffing is slightly more efficient than byte stuffing
  - Easier to implement in hardware

Serial - Synchronous transmission

- Character oriented synchronous transmission
  - Uses a special byte at the start and end of the frame
  - Data must be an even number of 8-bit bytes
  - Uses byte stuffing to replace flag byte in data
  - Byte stuffing makes this slightly less efficient
  - Easier to implement in software

DTE-DCE interface

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

RS-232 Interface

- Specifies the mechanical, electrical & functional characteristics of DTE-DCE interface
- EIA-232 is now the official name
- Tailored to Computer to modem interface
- Limited to about 20 Kbps
- Mechanical
  - less than 50 feet long cable
  - DB-25 connector original standard
  - DB-9 connector now standardized

RS-232 Interface

- Electrical - Uses NRZL
  - 0 = +3 to +15 volts
  - 1 = -3 to -15 volts
- 3 pins are all that are necessary
  - Receive Data
  - Transmit Data
  - Ground
- Other pins are often ignored
- Null modem - a device that flips receive and transmit lines

Other serial interfaces

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

Balanced transmission

- Uses two wires with a positive or negative voltage put on the line
- Compared to unbalanced which using two wires, one as ground and the other as signal.
- Better noise resistance than unbalanced

Transmission media - Twisted Pair

- UTP - Unshielded Twisted pair
  - two wires twisted together in a cable
- STP - Shielded Twisted pair
  - two wires twisted together in a cable with extra metal casing around the wires.
  - Extra metal casing is grounded to prevent noise from entering (or leaving) wire pair.
  - Extra metal makes cable more expensive
  - At connectors the metal shield must be grounded (more cost)

Twisted pair cables

- An electrical noise source gives more noise into those wires that are closer
- With un-twisted wires, one of the wires gets more noise.
- With twisted wires, both wires get roughly equal amount of noise, so the noise offsets itself.
- The more twists per inch, the better the noise immunity

Twisted pair cables

- The more twists per inch, the more copper (and cost) in a cable.
- When multiple pairs are in a single cable, each of the pairs should be twisted at a slightly different number of twists per inch.
  - To prevent one pair creating noise in another pair.

EIA categories of cables

- Category 1
  - – Unspecified cabling - used for analog POTs connections
- Category 2
  - – 22 or 24 gauge wires, with 1 MHz bandwidth
  - – Used in 4 Mbps Token ring LANs
- Category 3
  - – 22 or 24 gauge wires with 16 MHz bandwidth
  - – Used for 10Base-T, ISDN, T1
  - – about 3-4 twists per foot

EIA categories of cables

- Category 4
  - – 20 MHz bandwidth
  - – Used for 16 Mbps Token Ring
- Category 5
  - – 100 MHz bandwidth
    - about 3-4 twists per inch
  - – Used for 100Base-T
- Category 5E
  - – 100 MHz bandwidth, but 3 dB better S/N
  - – Used for 1000Base-T

EIA categories of cables

- Category 6
  - Proposed 250 MHz
- Category 7
  - Proposed 500-700 MHz
- Question if Category 5E cable is standards compliance
  - Many companies were selling it before the standard was finished. (Feb 2000)

Coax Cable

- Construction
  - Solid wire down center
  - Insulator around that
  - Foil or mesh around that
  - Final outer insulator
- Thin Ethernet
  - 50-Ohm, 0.2 inch diameter
  - Connector - BNC
  - Max Length: 185 Meters
  - Minimum distance between nodes - 0.5 meters

Coax Cable

- Thick Ethernet cable
  - 50-Ohm, 0.4 inch diameter
  - Connector - N-series
  - Vampire tap for nodes
  - Max length - 500 meters
  - Minimum distance between nodes - 2.5meter
- Broadband coax (aka Cable TV)
  - 75-Ohm, 0.2 inch diameter
  - 860MHz relatively flat
  - Up to 2 GHz with more attenuation

Fiber optics primer

- Angle of refraction
  - aka - How to be a good lifeguard
  - aka - why does a diamond sparkle
  - Light travels faster in some mediums than others - this causes refraction
    - Light in vacuum is 3.0+E8 m/s
    - Light in glass is about 2.0+E8 m/s
  - When light hits at less than critical angle, total reflection occurs.

Fiber

- Core - center of a fiber optic strand. Where the light travels.
- Cladding - material of different refractive index wrapped around the core of a fiber
- Fibers propagate all light that enters them at less than the critical angle.
- Fibers typically have about 1% difference in refractive index between core and cladding
- This results in a critical angle of about 8°

Fiber

- Getting lots of light in is good.
  - Choose a “big” fiber
  - Refractive index between air and fiber end makes all light with about a 12° acceptance angle.
- Typical “big” is 125 micron diameter cladding and 50 or 62.5 micron core
- Waves of light tend to make reflection occur only at certain “modes”

Fiber - multi-mode fiber

- Big core fiber will allow multiple modes to propagate down the fiber.
- Modal Dispersion - Multiple modes result in light that travels different distances
  - creates "mush" out of signals
- Step index fiber
  - Step function for refractive index
- Graded index fiber
  - Curved function for refractive index
  - Light travels faster near edges

Multi-mode fiber

- Graded index fiber allows for much farther distances at higher bit rates to be achieved

Fiber - single-mode fiber

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

Fiber light sources - Raleigh Scattering

- aka Why are sunsets red and the sky blue.
- Raleigh Scattering
  - Blue light is about 400nm wavelength
  - Red light is about 700nm wavelength
  - Blue is about 9.4 times more likely to be scattered than red
  - From this, we want longer wavelengths to avoid scattering and keep light headed towards destination

Fiber light sources

- Light absorption of glass
  - Around 1600 nm wavelength, silica glass light starts to absorb light
- Water is a common impurity in glass
  - OH tends to absorb light at various parts
- Graph of loss vs. wavelength
  - From graph we see that around 1550nm and around 1310nm are best spots for transmitting
  - 850nm is also used because of ease of creating light source

Fiber Dispersion types

- Dispersion - All light does not travel at the same speed down a fiber. This results in sloped edges of optical pulses
- Modal Dispersion -
  - Different modes of light travel different distances in multi-mode fiber
- Material Dispersion
  - Differences in the refractive index in the core
    - Careful quality control fixes this

Fiber Dispersion types

- Waveguide Dispersion
  - Light acts like a big wave in a small tube
  - Can be minimized by choice in glass
- Chromatic Dispersion
  - Different wavelengths of light travel at different speeds
  - Dependant on the type of glass
  - Dependant on width of light source

Fiber Dispersion types

- Polarization mode Dispersion
  - Different refractive indexes in a material based on the polarization of light.
    - Different refractive indexes means different speeds of light.
  - Smallest effect
    - Increases with square root of transmission distance

Fiber's advantages

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

Wireless media

- Wireless communication - using free space or the air as your media. (i.e. not using wire or fiber)
- Radio waves can be modulated using FM, AM, PM, or QAM
- Often used for broadcast applications - TV, Radio, etc.
- Some frequencies bounce off layers in atmosphere allowing for greater distance
- Higher frequencies = line of sight

Frequency Bands

– 0-300 Hz	ELF - Extremely low Freq
– 300-3000 Hz	ILF - Infra Low Freq
– 3-30 kHz	VLF - Very Low Frequency
– 30-300 kHz	LF - Low Frequency
– 300-3000 kHz	MF - Medium Frequency
– 3-30 MHz	HF - High Frequency
– 30-300 MHz	VHF - Very High Frequency
– 300-3000 MHz	UHF - Ultra High Frequency
– 3-30 GHz	SHF - Super High Frequency
– 30-300 GHz	EHF - Extremely High Frequency
– 300-3000 GHz	THF - Tremendously High Frequency

Wireless Applications

- TV and Radio
- Cellular Telephone
- Satellite Television
- Satellite Telephony and Data
- Wireless LANs
- Much more on this in a future lecture

Transmission impairments

- Attenuation
  - Signal loses strength as it goes through medium
- Distortion
  - Signal changes form or shape as it goes through medium
- Noise
  - Additional signal merged in

Signal Strength

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

Multiplexing

- Multiplexer - (Mux) a device to combine multiple signals to go over one media link
- Demultiplexer - (Demux) a device to separate the multiple signals from a multiplexer

Space division multiplexing

- Use of multiple paths between one source and one destination
- Not really multiplexing because it doesn’t use one media link
- Inverse-Multiplexing - Use of multiple paths between two points for one signal to get greater bandwidth.

Frequency Division multiplexing - FDM

- Use of different carrier frequencies
- Must make sure that the carriers do not overlap
- Guard Band - unused bandwidth between signals that provides protection against overlap
- TV and Radio are most common examples

Telephony FDM

- Telephony before the digital time, used FDM heavily
- AT&T and CCITT came up with slightly different standards
- Lower groups multiplex to higher groups

# Voice Channels	Bandwidth	Spectrum	AT&T	CCITT
12	48kHz	60-108kHz	Group	Group
60	240kHz	312-552kHz	Supergroup	Supergroup
300	1.232MHz	812-2044kHz		Mastergroup
600	2.52MHz	564-3084kHz	Mastergroup	
900	3.872MHz	8.516-12.388MHz		Supermastergroup
3600	16.984MHz	0.564-17.548MHz	Jumbogroup	
10800	57.442MHz	3.124-60.566MHz	Jumbogroup Multiplex	

Wave Division multiplexing (WDM)

- Use of multiple wavelengths of light over a fiber optic system (optical form of FDM)
- CDWM - Coarse WDM
  - Typically use of 850, 1310nm and 1550nm wavelengths
  - Sometimes use of 4 or 8 wavelengths around 1550nm
- DWDM - Dense WDM
  - Use of many (16-100+) wavelengths around the 1550nm wavelength.

Synchronous Time Division Multiplexing (TDM)

- Multiple signals are carried by interleaving portions of each signal in time.
- Each input signal has exactly the same time slot that occurs repeatedly
- A group of time slots are grouped into a frame
- May occur at bit level, byte level, or blocks of data
- May be done in analog systems as well as digital, but typically seen in digital systems

Synchronous TDM

- The incoming signals must have big enough timeslots so that they never have to buffer data for more than one frame.
- The outgoing bit rate of a MUX must be ? the sum of the incoming bit rates.
  - If the incoming bit rates are equal, then typically each source gets one timeslot per frame.
  - If the incoming bit rates are not equal then each source gets a different number of timeslots per frame (but the same in every frame)

Synchronous TDM

- So that the DEMUX knows when the timeslots are and who gets which data, there is some framing overhead.
  - Typically some extra bytes of data at the start of each frame.
- If the data rate of the incoming signals does not divide evenly into a timeslot, then extra bits may be inserted by the MUX and discarded by the DEMUX.
  - This is sometimes called bit-stuffing

Telephony TDM

- Telephony uses Synchronous TDM heavily as it always has a constant data rate
- Named DS or T in North America
  - – DS-1 == T1, DS-3 == T3, etc

North America				CCITT	
Digital Signal Number	# Voice Channels	Data Rate	Level Number	# Voice Channels	Data Rate
DS-0	1	64kbps	0	1	64kbps
DS-1/T1	24	1.544Mbps	E1	30	2.048Mbps
DS-1C	48	3.152Mbps	E2	120	8.448Mbps
DS-2/T2	96	6.312Mbps	E3	480	34.368Mbps
DS-3/T3	672	44.736Mbps	E4	1920	139.264Mbps
DS-4/T4	4032	274.176Mbps	E5	7680	565.148Mbps

DS1 circuit

- The DS1 circuit is the most common digital telephony signal
- Breakdown of 1.544Mbps
  - 24 voice timeslots per frame - one byte per timeslot
  - 1 bit per frame for framing information
  - 24 timeslots/frame * 8 bits/timeslot + 1 bit/frame = 193 bits/frame
  - 193 bits/frame * 8000 frames/sec = 1.544Mbps
- Fractional T1 - a T1 where only some of the timeslots are in use.

Statistical Time Division Multiplexing

- With Synchronous TDM, if an input has nothing to send, that timeslot is wasted.
- With Statistical TDM you are betting that at any given time only some of the inputs want to send data
- The sum of the input bit rates to the MUX may exceed the output bit rate of the MUX
- If you are “unlucky” some data may be delayed or discarded by the MUX

Statistical TDM

- Delaying data because others are using the line requires additional buffers at the MUX
- A burst of high speed data at the DEMUX may require the DEMUX to buffer data until the lower speed output can accept it
- Timeslots can be borrowed
- Some inputs can have priority over others
- Some systems have variable length timeslots

Statistical TDM

- Additional framing overhead required
  - Just knowing the timeslots is not enough
  - Each packet of data in a statistical TDM system must have overhead labeling its source or destination
  - It is best to have relatively large timeslots to minimize overhead relative to data carried
- Almost all data systems today use statistical TDM at some point.