Lecture 23 Overview

- Signaling
  - Channel characteristics
  - Types of physical media

- Modulation
  - Narrowband vs. Broadband
  - Encoding schemes

- A lot of this material is not in the book
  - Caveat: I am not an EE Professor
Morse Code Message

Let man have dominion over the fish of the sea and over the fowl of the air and over every living thing that moves upon the earth.
Binary signaling with Voltage

- Encode 1’s and 0’s on a wire
  - +5 volts = 1
  - -5 volts = 0
Signals and Channels

- **A signal** is some form of energy (light, voltage, etc)
  - Varies with time (on/off, high/low, etc.)
  - Can be continuous or discrete

- **A channel** is a physical medium that conveys energy
  - Any real channel will distort the input signal as it does so
  - How it distorts the signal depends on the signal
Channel Challenges

- Every channel degrades a signal
  - Distortion impacts how the receiver will interpret signal
Channel Properties

- **Bandwidth-**limited
  - Range of frequencies the channel will transmit
  - Means the channel is slow to react to change in signal

- **Power** *attenuates* over distance
  - Signal gets softer (harder to “hear”) the further it travels
  - Different frequencies have different response (*distortion*)

- **Background** *noise* or interference
  - May add or subtract from original signal

- **Different physical characteristics**
  - Point-to-point vs. shared media
  - Very different price points to deploy
Copper

- Typical examples
  - Category 5/6 Twisted Pair: 10M-10Gbps, 50-100m
  - Coaxial Cable: 10-100Mbps, 200m

### Twisted Pair
- Copper core
- Insulation
- Braided outer conductor
- Outer insulation

### Coaxial Cable (coax)
- Center Conductor
- Dielectric
- Aluminum Tape
- Braid
- Jacket
Fiber Optics

- Typical examples
  - Multimode Fiber
    - 100Mbps-10Gb
    - 500-2000m

  - Single Mode Fiber
    - 1-100Gbps
    - 100m-40km

Cheaper to drive (LED vs laser) & terminate

Longer distance (low attenuation)
Higher data rates (low dispersion)
Wireless

- Widely varying channel bandwidths/distances
- Extremely vulnerable to noise and interference
Spectrum Allocation

- Policy approach forces spectrum to be allocated like a fixed spatial resource (e.g. land, disk space, etc)
- Reality is that spectrum is time and power shared
- Measurements show that fixed allocations are poorly utilized

Hot topic: Whitespace communication

CSE 123 – Lecture 23: Links and Signaling
Two Main Tasks

- First we need to transmit a signal
  - Determine how to send the data, and how quickly

- Then we need to receive a (degraded) signal
  - Figure out when someone is sending us bits
  - Determine which bits they are sending

- A lot like a conversation
  - “WhatintheworldamI saying” – needs punctuation and pacing
  - Helps to know what language I’m speaking
The Magic of Sine Waves

- All periodic signals can be expressed as sine waves
  - Component waves are of different frequencies

- Sine waves are “nice”
  - Phase shifted or scaled by most channels

- “Easy” to analyze
  - Fourier analysis can tell us how signal changes
  - But not in this class…
Carrier Signals

- **Baseband** modulation: send the “bare” signal
  - E.g. +5 Volts for 1, -5 Volts for 0
  - All signals fall in the same frequency range

- **Broadband** modulation
  - Use the signal to modulate a high frequency signal (**carrier**).
  - Can be viewed as the product of the two signals
Forms of Digital Modulation

Input Signal

Amplitude Shift Keying (ASK)

Frequency Shift Keying (FSK)

Phase Shift Keying (PSK)

Phase changes
Why Different Schemes?

- Properties of channel and desired application
  - AM vs FM for analog radio

- Efficiency
  - Some modulations can encode many bits for each symbol (subject to Shannon limit – more on this next class)

- Aiding with error detection
  - Dependency between symbols… can tell if a symbol wasn’t decoded correctly

- Transmitter/receiver Complexity
Sampling

- To reconstruct a signal, we need to sample it.
Intersymbol Interference

- Bandlimited channels cannot respond faster than some maximum frequency $f$
  - Channel takes some time to settle
- Attempting to signal too fast will mix symbols
  - Previous symbol still “settling in”
  - Mix (add/subtract) adjacent symbols
  - Leads to intersymbol interference (ISI)

- OK, so just how fast can we send symbols?
Speed Limit: Nyquist

- In a channel bandlimited to $f$, we can send at maximum symbol (baud) rate of $2f$ without ISI
For Next Class

- Read 2.2