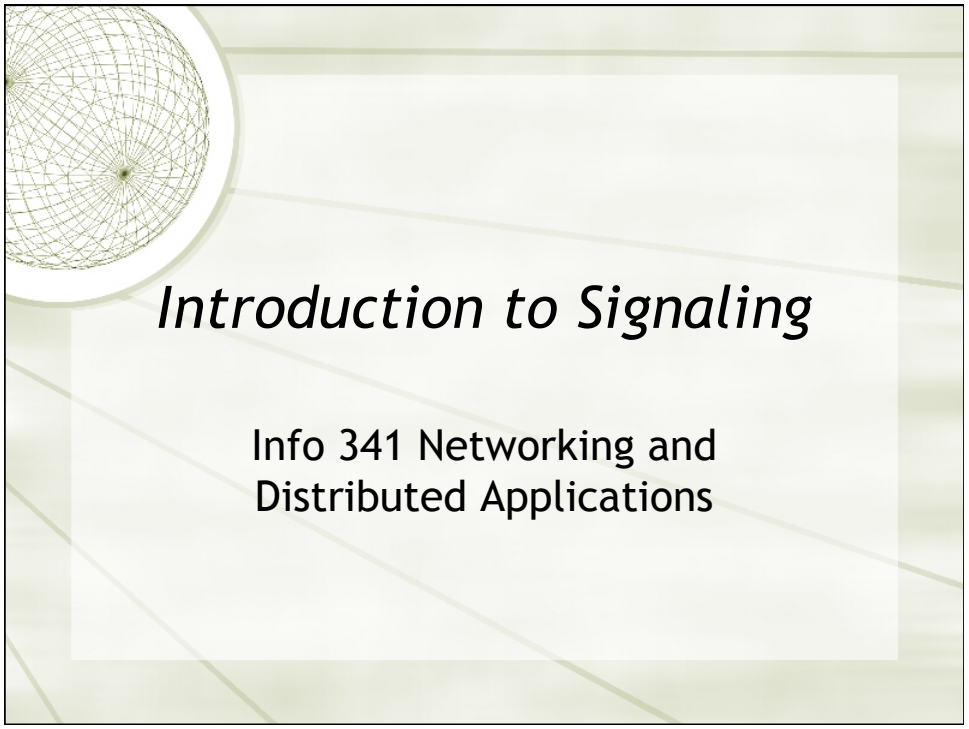


Signaling

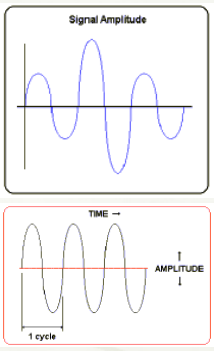
- We have wires, and we said these wires need to carry bits (0's and 1's)
- How exactly do you put a 1 or a 0 on a wire?

Analog Signaling

- Three characteristics:
  - Amplitude
  - Frequency
  - Phase

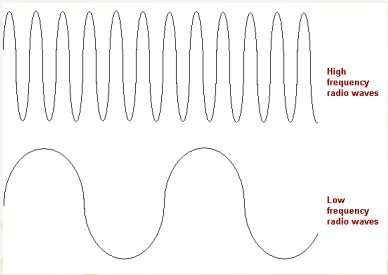
Three Characteristics …

- Amplitude
  - This is the "height" of a wave.
  - This is the strength of the signal.
  - It can be expressed a number of different ways (as volts, decibels).
  - The higher the amplitude, the stronger (louder) the signal.



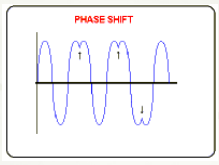
Three Characteristics …

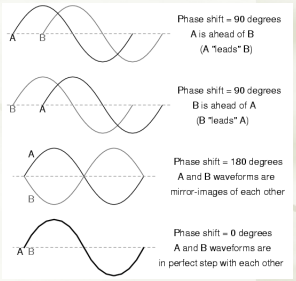
- Three characteristics:
  - Frequency
    - This is the rate of change in a signal
    - expressed in Hertz (Hz), or cycles per second.



Three Characteristics …

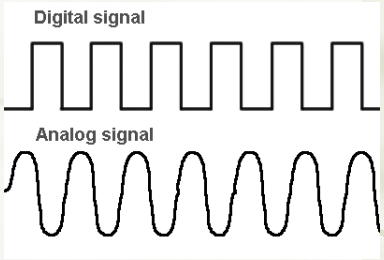
- Three characteristics:
  - Phase
    - This is the rate at which the signal changes its relationship to time
    - Expressed as degrees
    - Phase shift occurs when the cycle does not complete, and a new cycle begins before the previous one has fully completed.





Digital Signaling

- Comprised of discrete pulses of voltage



Signaling Methods

- Broadband transmission
  - One cable carries multiple signals simultaneously
- Baseband transmission
  - Only one signal per cable

Broadband Transmission

- The signal capacity of the cable is split into multiple analog channels
  - Frequency division multiplexing
  - Data, Voice and Video channels on a single wire
  - Distances of 10 - 30 kilometers
- Common to coaxial cable
  - Example: Cable television
- Expensive hardware & maintenance
- Disruptions impact entire communications system

Baseband Transmission

- Entire bandwidth of the cable is devoted to one signal
- Typical to digital networks
  - Digital signals can't be multiplexed
  - Distances of 3-5 kilometers max.
- Common to most LANs
- Cheaper and easier to maintain
- Disruptions are limited to a single communication channel

Signaling Errors

- Attenuation
- Reflections
- Noise

Attenuation

- The strength (voltage) of signals decay over distance, due mainly to absorption by the transmission medium
- As the frequency of a signal increases, attenuation occurs more quickly
- Amplifiers & repeaters are used to compensate for attenuation
- Attenuation affects analog signals more drastically than digital signals

Reflections

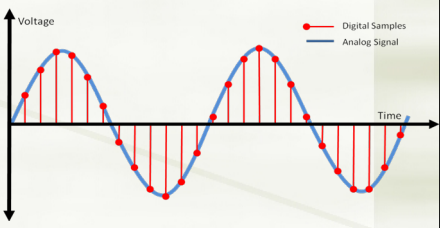
- Caused by changes in the transmission media
  - e.g. Hubs introduce echoes when the signal bounces off the connector at the end of the cable
- Devices detect multiple echoes of varying strength
- Most reflections are filtered out by the signaling hardware

Noise

- Ambient noise
  - Electrical interference inherent in electrical devices
- Crosstalk
  - Electrical interference due to external electro-magnetic sources

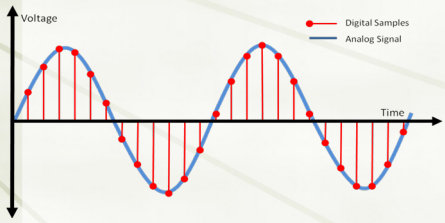
Converting Analog to Digital

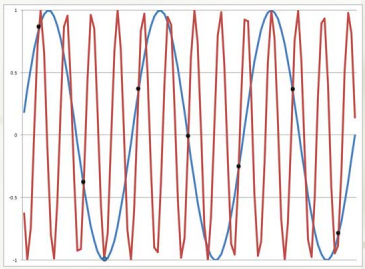
- Often signals start in analog
  - Sounds, music
- Sample to convert



Converting Analog to Digital

- How much to sample?





Converting Analog to Digital

- How much to sample?
- Nyquist Rate (2B), where B is the bandwidth of the analog signal

$\mathcal{F} = 2B$

basically, sample at least twice the frequency

Nyquist Theorm

- The theoretical upper bound (max) transmission
  - Maximum bits per second D is:

$D = 2B \log_2 K$

- B = bandwidth, K the number of encoding values

Example with Wi-Fi

- What are the common stated data speeds for Wi-Fi?

Example with Wi-Fi

- What are the common stated data speeds for Wi-Fi?
  - 802.11b 11Mbps
  - 802.11g 52Mbps
  - 802.11n 102Mbps
- What is the theoretical capacity of Wi-Fi?

Example with Wi-Fi

- What are the common stated data speeds for Wi-Fi?
  - 802.11b 11Mbps
  - 802.11g 52Mbps
  - 802.11n 102Mbps
- What is the theoretical capacity of Wi-Fi?
  - 2400000 Hz = 2400 Mhz = 2.4 Ghz
  - $2 * 2.4 \log_2 2 = 4.8$Gbps
- Where is all that bandwidth going?

Noise/Interference

- Networks often encounter noise
  - Electromagnetic spectrum is everywhere
  - Magnetic fields induce current on a wire causing noise/interference
- Shannon's Theorem
  - $C = B \log_2 (1 + S/N)$
  - C is capacity, B is bandwidth, S/N is signal to noise ratio (SNR)
  - Decibels (dB) = $10 \log_{10} S/N$ -- often used instead of SNR

Wi-Fi Example

- What capacity of Wi-Fi accounting for Noise?
  - 2400000 Hz = 2400 Mhz = 2.4 Ghz
  - Signal listed at 40%

$C = B \log_2 (1 + S/N)$

$= 2.4 \text{ Gbps} \log_2 (1.4)$

$= 2.4 \text{ Gbps } 0.48$

$= 1.53 \text{ Gbps}$