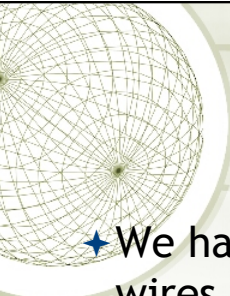


# *Introduction to Signaling*

Info 341 Networking and Distributed Applications



# *Signaling*

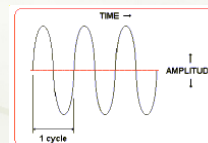
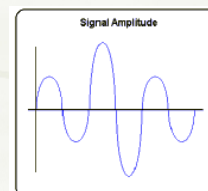
- ★ We have wires, and we said these wires need to carry bits (0's and 1's)
- ★ How exactly do you put a 1 or a 0 on a wire?

## 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.

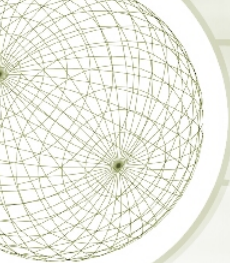


## Three Characteristics ...

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

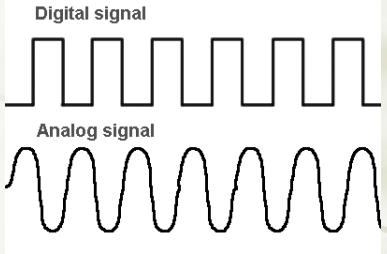
## Three Characteristics ...

- ★ 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



The diagram shows two signal waveforms. The top waveform, labeled 'Digital signal', is a square wave with five pulses. The bottom waveform, labeled 'Analog signal', is a smooth sine wave with five cycles.



## 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



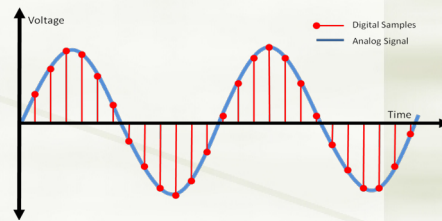
## *Noise*

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

## Converting Analog to Digital

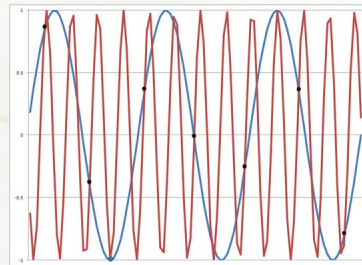
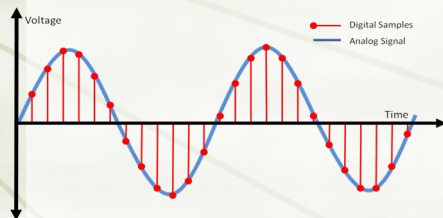
- ★ Often signals start in analog
  - ◆ Sounds, music

- ★ 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

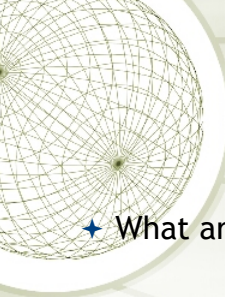
$$f_s = 2B$$

basically, sample at least twice the frequency



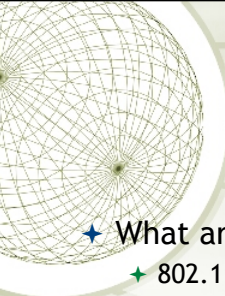
## Nyquist Theorem

- ★ 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?



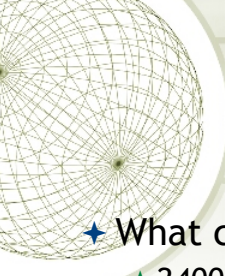
## Example with Wi-Fi

- ★ 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?
  - ★  $2400000 \text{ Hz} = 2400 \text{ Mhz} = 2.4 \text{ Ghz}$
  - ★  $2 * 2.4 \log_2 2 = 4.8\text{Gbps}$
  
- ★ 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%

$$\begin{aligned}C &= B \log_2 (1 + S/N) \\ &= 2.4 \text{ Gbps} \log_2 (1.4) \\ &= 2.4 \text{ Gbps} 0.48 \\ &= 1.53 \text{ Gbps}\end{aligned}$$