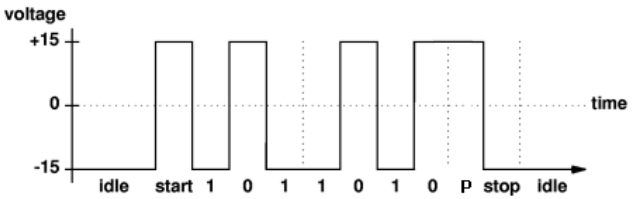
Communication Limits

COMP467 Networked Computer Systems

Goals

- Be able to calculate the maximum possible transmission rate
- Be able to calculate the maximum transmission rate in the presence of noise

RS-232 Format



- Each byte starts with a special 0 bit called a start bit. This is not a data bit.
- Each byte ends with a non-data 1 bit called the stop bit.
- There may be a parity bit at the end of the data

Parity

- An extra bit is added to each byte transmitted to detect transmission errors.
- The parity bit is the XOR of the data bits.
- The transmitter computes the parity and sends it at the end of the data byte.
- The receiver computes the parity as the bits are received.
- If the parity the receiver calculates is different from the parity received, then an error has occurred.

Parity Examples

- XOR can be calculated as addition without carry.
- Even parity adds a bit to make the number of one bits an even number.

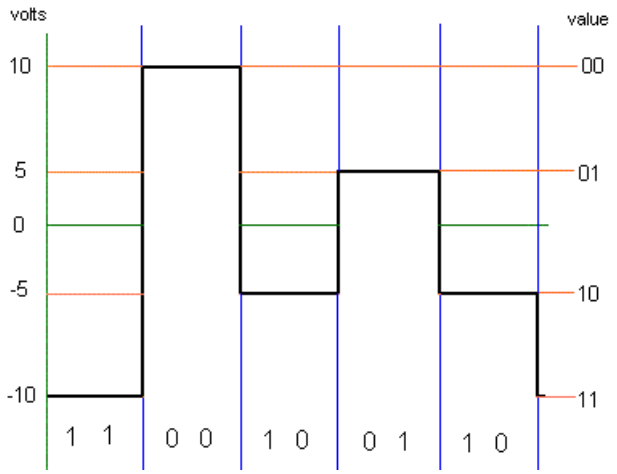
Data	Parity
01100100	1
01101100	0
01101110	1

Multiple Signals

- If there are **V** possible signal values, then each signal can represent $\mathbf{\log_2 V}$ bits.
- Each transmission of one of 4 values would send 2 bits.
- The receiver has to be able to distinguish each of the different states.
- The Baud rate is the number of states or signals sent every second.

Bit rate = Baud rate * $\log_2 V$

Four Possible Transmission States



Bandwidth

- Bandwidth is the range of frequencies that can be sent and received.
- Traditional telephone system provide a bandwidth of 3KHz.
- Modern digital telephone systems may provide a bandwidth of 4 KHz.

Nyquist Formula

- The Nyquist formula gives the maximum data rate for perfect noiseless channels.

$$\text{max data rate(bits/sec)} = 2 * B * \log_2 V$$

where:

- B = bandwidth
- V = number of different values that can be sent.

Nyquist Formula Example

If a telephone modem can transmit 56K bits/sec over a modern phone system, how many different states must it be able to send?

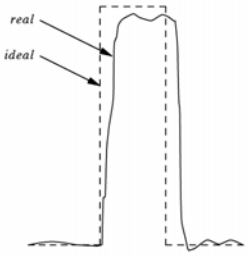
$$V = 2^{\frac{transrate}{2B}}$$

V = 128 states

Max Transmission Question

- Each television channel has 6.0 MHz of bandwidth. If you use a transmission scheme that sends 16 different possible values, what is the maximum possible transmission rate over a single TV channel?

Noise



- In the real world, transmissions are subject to noise and distortion.
- You can hear noise on a weak radio channel.
- Noise makes it difficult to distinguish different states.

Noise

- Noise is represented as a signal/noise ratio (S/N) or the ratio of the strength (energy) of the noise to the strength (energy) of the noise.
- If someone whispers (low signal strength) in a noisy room, it is difficult to hear them.
- Noise reduces the rate at which data can be transmitted.

Shannon Formula

- In 1948 Shannon derived an equation for channels with random noise.

max data rate(bits/sec) = $B * \log_2 (S/N+1)$

- This is a physical law that applies to all communication systems.
- Space probes that transmit very weak signals send only a few bits / second.

Decibels

- Noise is often measured in decibels (dB)

$$dB = 10 * \log_{10} S/N$$

$$S/N = 10^{dB/10}$$

- Note that the decibel scale is exponential.
- A good telephone connection has a noise level of about 34 - 38 dB.

Shannon Formula with dB

- We can simplify calculations using decibels by combining the equations

maxrate = $B * \log_2 (S/N+1)$
maxrate = $B * \log_2 (S/N)$ ignore +1 if S/N > 1000
maxrate = $B * \log_2 (10^{dB/10})$ substitute $S/N = 10^{dB/10}$
maxrate = $B * \log_{10} (10^{dB/10})/\log_{10} 2$ change log base
maxrate = $B * \log_{10} (10^{dB})/(10*\log_{10} 2)$ pull out /10
maxrate = $B * dB /(10*\log_{10} 2)$ log & power cancel
maxrate = $B * dB / 3.0103$ convert constant

Shannon Formula with dB

$$\text{maxrate} = \frac{B * dB}{3.01}$$

Shannon Formula Example

If a telephone line has a signal to noise ratio of 34dB, how fast can it transmit data?

$$\max rate = \frac{B * dB}{3.01} = \frac{4000 * 34}{3.01} = 45.2K$$

56K modems do not really work at 56,000 bits per second and are subject to the Shannon formula limitations.

Homework Due Wednesday

- The first homework assignment is due Wednesday, January 16, at the beginning of class.