Nyquist Theorem

How can the data rate be predicted if you know the bandwidth of the medium across which you're transmitting?

The rate of signal changes is twice the rate of the bandwidth, or

$$R = 2B$$

Where R is the rate of signal changes and B is the bandwidth.

When using multilevel signaling:

$$R = 2B\log_2 m$$

Where *m* is the number of levels in the signal.

$$56k = 2 \cdot 4KHz \log_2 m$$
$$56k = 8K \log_2 m$$
$$7 = \log_2 m$$
$$m = 2^7 = 128$$

Decibel

$$decibels = 10\log_{10}\frac{P_2}{P_1}$$

Noise

Usually noise is specified by a **signal to noise ratio**. The higher this value, the better. This is often given in decibels.

For a typical telephone line, the signal to noise ratio is 30 dB.

Shannon Capacity Theorem

Accounts for white noise. Specifies the number of bits per second you can get through a medium.

$$c = B\log_2\left(1 + \frac{S}{N}\right)$$

c is a value in bits / second
B is the bandwidth in cycles / second
The SNR is not in decibels.

Example:
Find the minimum signal to noise ratio in dB that will allow transmission data rate of 6000 bps through a medium that has a bandwidth of 3000 Hz.

$$6000 = 3000\log_2(1+SNR)$$
$$2 = \log_2(1+SNR)$$
$$4 = 1+SNR$$
$$SNR = 3$$

In dB:

$$dB = 10\log_{10}(3)$$
$$dB = 4.77$$

Example 2:
Given a bandwidth of 3000 Hz and a signal to noise ratio of 30 dB, calculate the maximum bit rate.

$$c = 3000Hz\log_2(1+1000)$$
$$c = 29,901kbps$$

Example 3:
Given a channel with 1MHz bandwidth

Types of Media

Unguided

- Air

Guided
Has a physical path for the signal to pass through.

- Copper wire
  - Twisted Pair
    - Cat 3, 4, 5, 5e, 6
- Coax
- Fiber

Twisted Pair

Types: Shielded, unshielded

Unshielded twisted pair (UTP) is the most common type of cabling used when using copper wires.

Single ended signal – there is one wire that carries that signal. The voltage on the wire is measured with respect to ground.

Ethernet uses **differential signaling**. There are two wires that carry the signal – one has the signal, the other has the complement. T_x^+, and T_x^-.

Common mode rejection – since the difference between the two signals is calculated by the differential amplifier, any noise induced on both wires will get canceled out.

The main distinction between cat 3, 4, 5, 5e, and 6 is the number of twists per inch. This more closely approximate the same wire occupying the same space, thus improving the common mode rejection.

Bandwidths

Cat 3	16 MHz
Cat 4	20 MHz
Cat 5	
Cat 5e	100 MHz
Cat 6	250 MHz