

PHY layer

- Key question: How do we send a message across a wire?
- Mediums used for data transfer
 - Coaxial cables
 - Fiber optics
 - Satellite
 - Wireless

Application	5000 ft
Transport	4000 ft
Network	...
Data Link	
Physical	Sea level

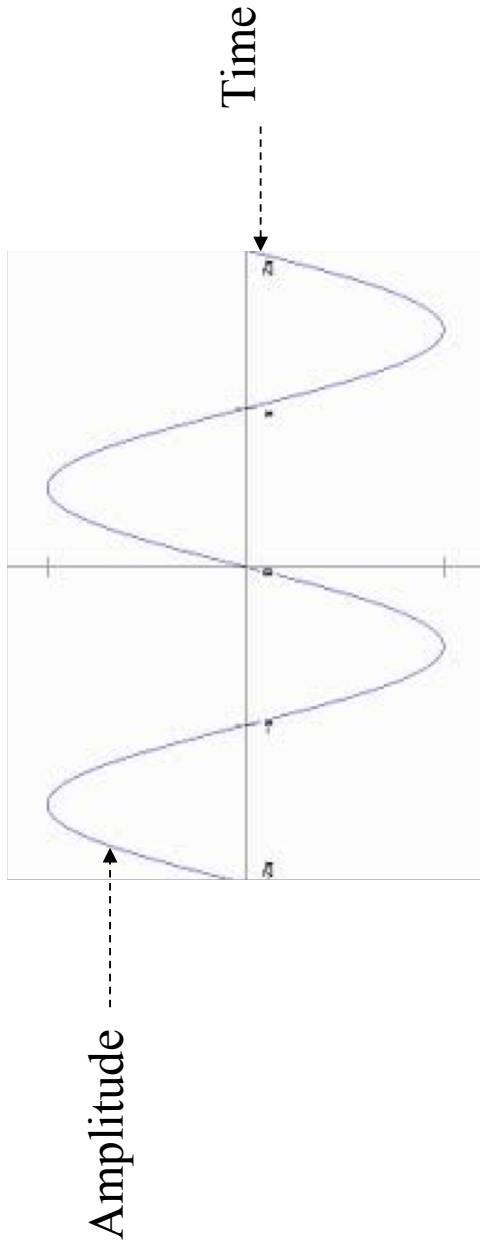
How is data sent on the medium



Network interface cards (NICs)

1. Digital information is converted to an analog signal
2. Analog signal is then sent on the wire

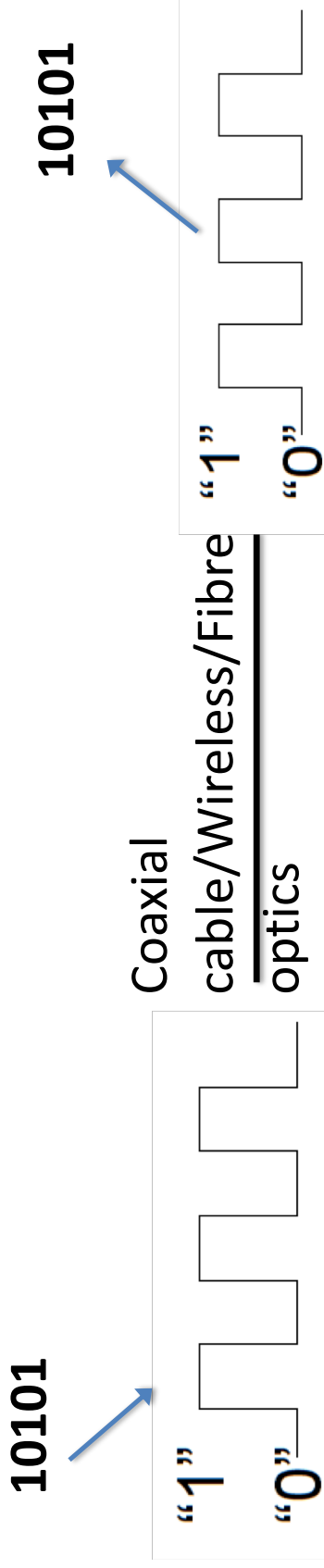
How is data sent?



- High amplitude $\rightarrow 1$
- Low amplitude $\rightarrow 0$
- Can also be done in frequency scale

How exactly are bits sent?

- Ideal world



- But....
 - Infinitely many points to send.
 - How do you decide how many points to sample at the receiver?

Sampling

- How many samples are needed to reconstruct a signal?
- **Nyquist formula: It is sufficient to get $2B$ samples of the signal to reconstruct the entire signal**
 - B is the bandwidth(Hz) : Width of the frequency band

A bit of signal processing background

- Frequency is the number of cycles per second.
 - Example: (Human) voice signal has a maximum frequency of 30Hz
- A signal can have multiple frequencies:
- Bandwidth (in Hertz) is the difference between the largest and the smallest frequency in the signal
 - Physically it tells you how much data can be encoded in the signal

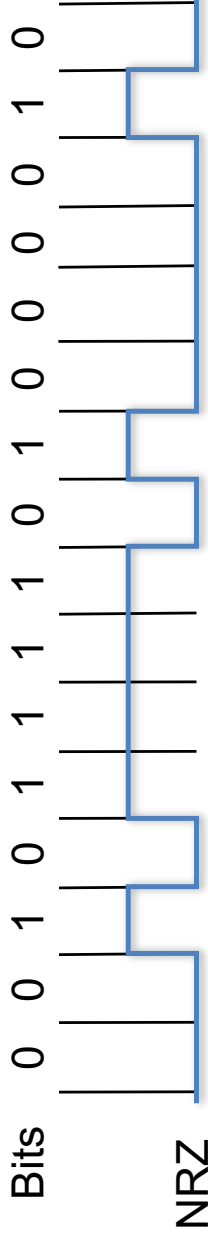
Back to Nyquist

- The sampling rate can be converted to the maximum data rate
 - Maximum data rate = $2B$ bits/sec;
 - but only if the channel has no noise
- A channel can deteriorate in the medium because of
 - attenuation
 - distortion
 - noise
- Shannon's formula includes noise,
 - Maximum data rate = $B \log (1+S/N)$

Where S/N is the signal to noise ratio

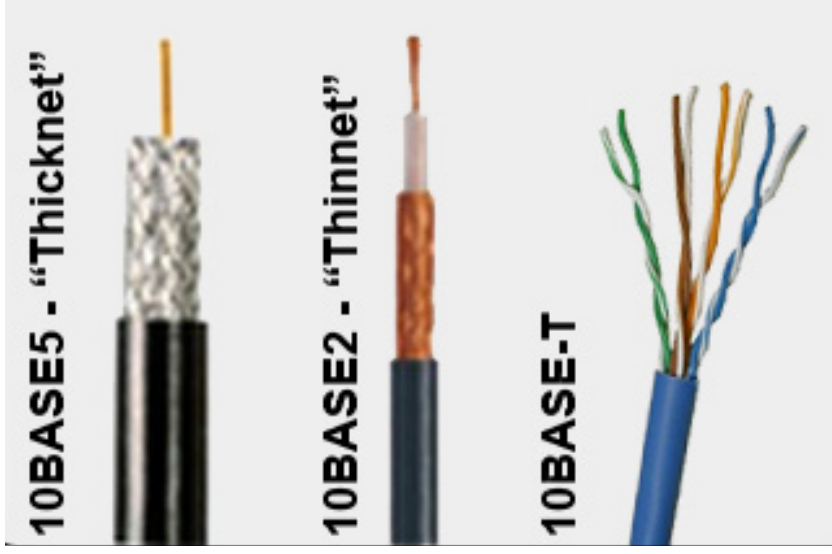
Encoding bits with signals

- Simplest encoding, NRZ (Non-return to zero)
 - Use high/low voltages, e.g., high = 1, low = 0



- The maximum bit rate = $2B$ bits/sec
 - Can we increase this?
 - Nyquist formula really is
 - Maximum bit rate = $2B (\log v)$ bits/sec, where v is the number of levels.

Wires



- Twisted pairs: twists reduce RF emission / crosstalk; also shielding can be added
- Coaxial cable: inner and outer ring conductor for superior noise immunity

Now Cat 6, Cat 7 for

GigE, four pairs

arunab, SBU // CSE 310, Spring

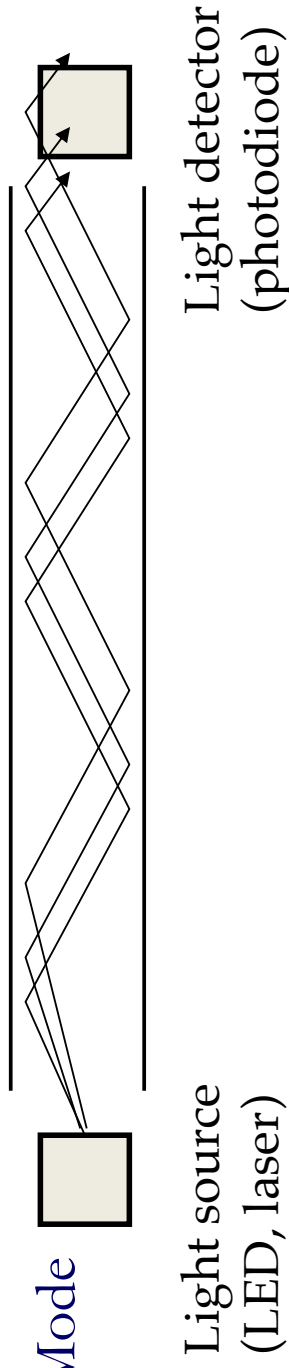
2019:Physical Layer

Fiber Optic Cable

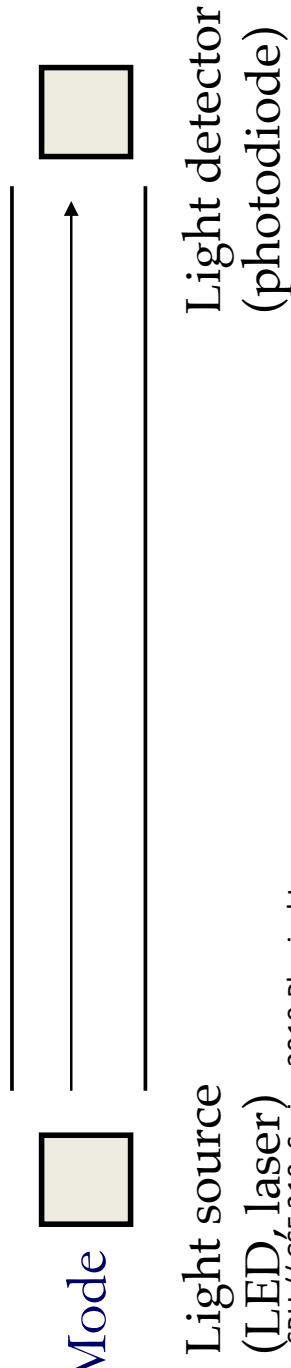
- Long, thin, pure strand of glass
 - light propagated with total internal reflection
 - enormous bandwidth available (terabits)



Multi-Mode



Single-Mode



Light source
(LED, laser)

Light detector
(photodiode)