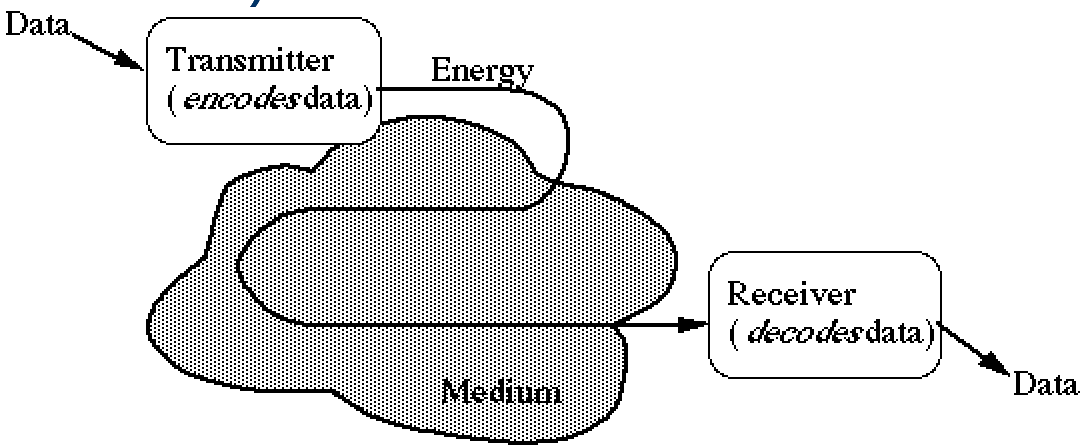
Data Communications 101

- How do computers *really* communicate?

1. They need a physical connection.
2. Data is encoded and transmitted as energy.
3. Energy is decoded at the destination back into data.
4. Each form of energy has different properties and requirements for transmission.

Transmission Media

- Energy is carried through a medium
  - Copper: twisted pair
  - Glass: optical
  - Air : radio (many portions of the frequency spectrum can be used)

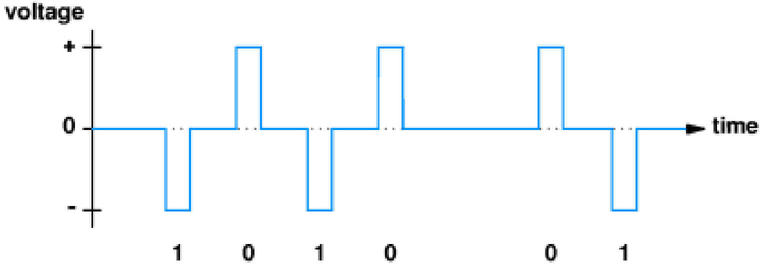


Choosing a Medium

- Copper wire (traditional wired network) is mature technology, rugged and inexpensive; maximum transmission speed is limited.
- Glass fiber (optical network):
  - Higher speed
  - More resistant to electro-magnetic interference
  - Spans longer distances
  - Requires only single fiber
  - More expensive; less rugged
- Radio and microwave (wireless network) don't require physical connection and can be used for mobile connections.

Data Communications

- Simplest approach - use varying voltages to represent 1s and 0s
- One common encoding use negative voltage for 1 and positive voltage for 0
- In following figure, transmitter puts positive voltage on line for 0 and negative voltage on line for 1

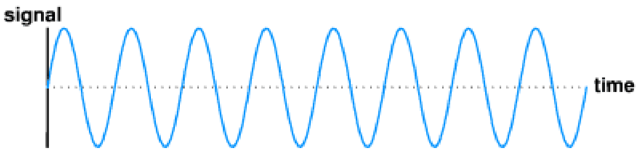


Data Communications

- Encoding scheme leaves several questions unanswered:
  - How long will voltage last for each bit?
  - How soon will next bit start?
  - How will the transmitter and receiver agree on timing?
- Standards specify operation of communication systems
  - Devices from different vendors that adhere to the standard can interoperate
  - Example organizations:
    - International Telecommunications Union (ITU)
    - Electronic Industries Association (EIA)
    - Institute for Electrical and Electronics Engineers (IEEE)

Data Communications

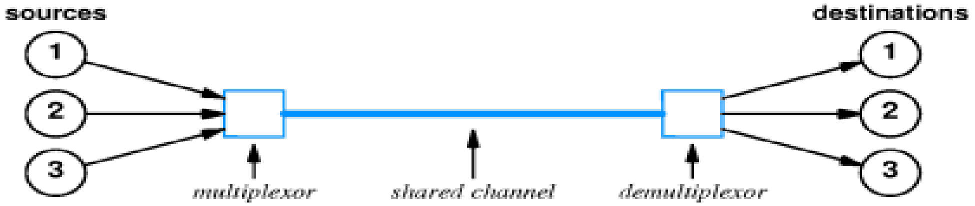
- Digital signals can't travel very far.
- Continuous, oscillating signal will propagate farther than digital signal
- Long distance communication uses such a signal, called a *carrier*
- Waveform for carrier looks like:



- Various methods used to 'modulate' data using a carrier

Multiplexing

- Modulation allows a medium to be shared by separate signals by using carriers of different frequencies.
  - F*requency division multiplexing* (FDM) achieves multiplexing by using different carrier frequencies.
  - Allows multiple sources to simultaneously share a single medium without interference
- Receiver can "tune" to specific frequency and extract modulation for that one channel
  - Frequencies must be separated to avoid interference
  - Only useful in media that can carry multiple signals with different frequencies - high-bandwidth required



Multiplexing

- *Time division multiplexing* uses a single carrier and sends data streams sequentially
  - Allow multiple sources to share a medium by 'taking turns'
- Transmitter/receiver pairs share single channel
- Basis for most computer networks used shared media
- *Statistical multiplexing* is similar to TDM except if a source does not have data to send, the multiplexor skips the source

Wrapup Comments

- Physical layer impairments (e.g., noise on the wire) lead to bit errors.
  - We will see next time how this impacts the higher layers
- The physical layer can become unusable (e.g., construction crews destroy fiber lines).
  - The higher layers needs to handle this.

Wrapup Comments

- The communications channel along with the modulation technique determines the bandwidth:
  - Channel bandwidth: Measured in cycles per second or Hertz (hz), is the fastest continuously oscillating signal that can be sent over the channel.
    - Can also refer to bandwidth as the width of the spectrum available to the signal.
    - A transmitter's maximum signal rate (i.e., baud rate) is limited by the channel bandwidth.

Wrapup Comments

- Nyquist thereom:
  - Provides a theoretical bound on the maximum rate at which data can be sent over a channel (i.e., gives the channel capacity).

$$D = 2B\log_2 K$$

D: maximum data rate over a channel
B: channel bandwidth
K: number of signal levels available

Example: Television channels are allocated 6Mhz of spectrum. How many bits / second can be sent over a 6Mhz channel if four-level signals are used (assuming a noiseless channel?)