CSE/EE 461 – Lecture 3

Bits, Encoding and Framing

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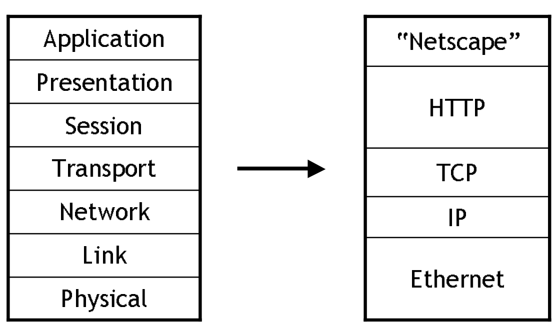
Last Time …

- Protocols, layering and reference models

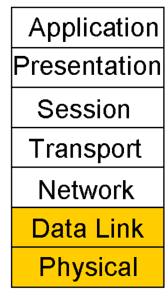


The OSI Model　　Sample Protocol Stack

This Lecture

- A look at the physical/link layers:
  1. Different kinds of Media
  2. Encoding bits with signals
  3. Framing messages

- Key Focus: How do we send a message across a wire?

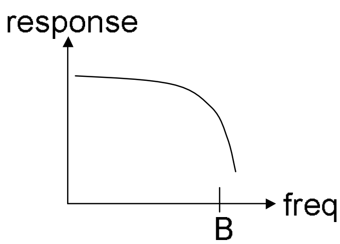


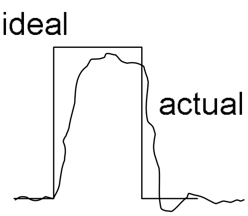
1. Different Kinds of Media

- Wire
  - Twisted pair, e.g., CAT5 UTP, 10 → 100Mbps, 100m
  - Coaxial cable, e.g, thin-net, 10 → 100Mbps, 200m
- Fiber
  - Multi-mode, 100Mbps, 2km
  - Single mode, 100 → 2400 Mbps, 40km
- Wireless
  - Infra-red, e.g., IRDA, ~1Mbps
  - RF, e.g., 802.11 wireless LANs, Bluetooth (2.4GHz)
  - Microwave, satellite, cell phones, …

Wires

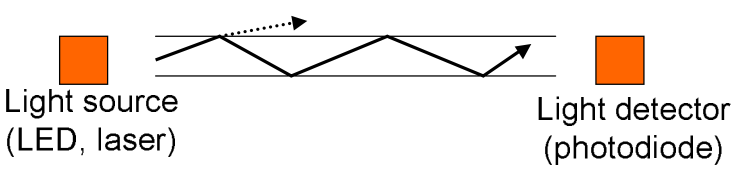
- Signal subject to:
  - Attenuation (repeaters)
  - Distortion (frequency and delay)
  - Noise (thermal, crosstalk, impulse)





Fiber

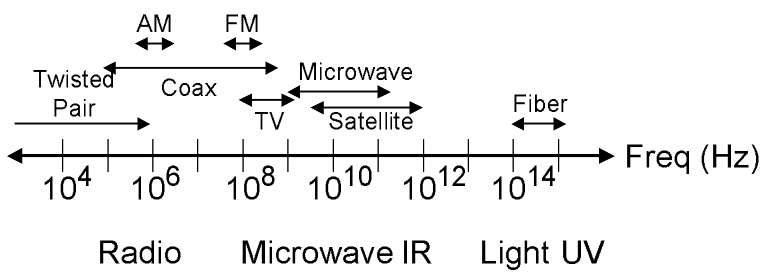
- Long, thin, pure strand of glass
  - Enormous bandwidth available (terabits)



- Multi-mode allows many different paths, dispersion
- Chromatic dispersion if multiple frequencies

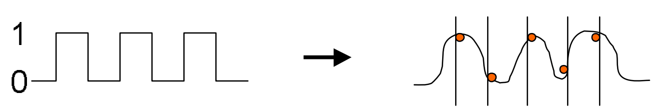
Wireless

- Different frequencies have different properties
- Signals subject to atmospheric/environmental effects



2. Encoding Bits with Signals

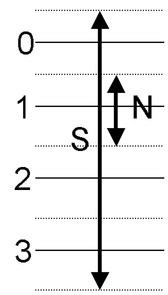
- Generate analog waveform (e.g., voltage) from digital data at transmitter and sample to recover at receiver



- We send/recover symbols that are mapped to bits
  - Signal transition rate = baud rate, versus bit rate
- This is baseband transmission … take a signals course!

Aside: Bandwidth of a Channel

- EE: Bandwidth (B) (Hz) is the width of the pass-band in the frequency domain
- CS: "Bandwidth" (bps) is the information carrying capacity (C) of the channel
- Shannon showed how they are related by noise, which limits how many signal levels we can safely distinguish.



S=signal
N=noise

The Shannon Limit (1948)

- Define Signal to Noise Ratio (SNR):

  SNR = $10\log_{10}$(signal / noise) decibels (dB)

  e.g, 30 dB means signal 1000 times noise

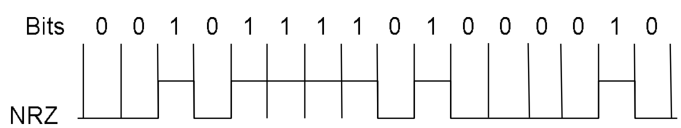
- For a noisy channel with bandwidth B (Hz) and given SNR, the maximum rate at which it is possible to send information, the channel capacity, is:

  $C = B \log_2(1 + SNR)$ (bits/sec)

  e.g 3KHz and 30dB SNR → 30Kbps

NRZ and NRZI

- Simplest encoding, NRZ (Non-return to zero)
  - Use high/low voltages, e.g., high = 1, low = 0
- Variation, NRZI (NRZ, invert on 1)
  - Use transition for 1s, no transition for 0s



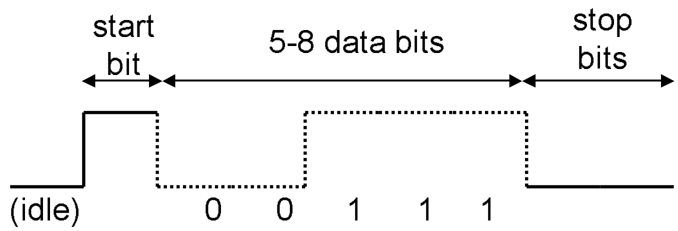
Clock Recovery

- Problem: How do we distinguish consecutive 0s or 1s?
- If we sample at the wrong time we get garbage …
- If sender and receiver have exact clocks no problem
  - But in practice they drift slowly
- This is the problem of clock recovery

- Possible solutions:
  - Send separate clock signal → expensive
  - Keep messages short → limits data rate
  - Embed clock signal in data signal → other codes

"Asynchronous" Transmission

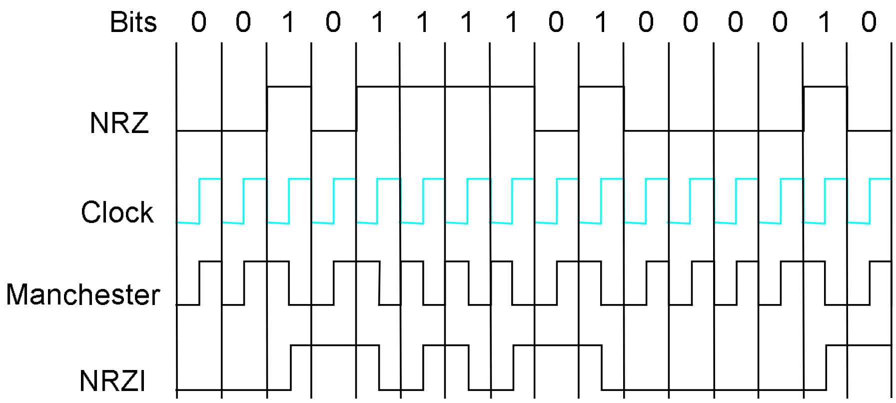
- Avoid timing problem by sending short, delimited data
  - E.g., UARTs (typically used to connect your keyboard)



Manchester Coding

- Make transition in the middle of every bit period
  - Low-to-high is 0; high-to-low is 1
  - Signal rate is twice the bit rate
  - Used on 10 Mbps Ethernet
- Advantage: self-clocking
- Disadvantage: 50% efficiency

Coding Examples



4B/5B Codes

- We want transitions *and* efficiency …
- Solution: map data bits (which may lack transitions) into code bits (which are guaranteed to have them)
- 4B/5B code:
  - 0000 → 11110, 0001 → 01001, … 1111 → 11101
  - Never more than three consecutive 0s back-to-back
  - 80% efficiency
- This code is used by LANs such as FDDI

3. Framing

- Need to send message, not just bits
  - Even if we know where the bits are we still need to synchronize on the start of the message
  - Complete Link layer messages are called frames
- Common approach: Sentinels
  - Look for special control code that marks start of frame

Point-to-Point Protocol (PPP)

- IETF standard, used for dialup and leased lines

Flag 01111110	(header)	Payload (variable)	(trailer)	Flag 01111110

- Flag indicates start/end of frame
- Occurrences of flag inside payload must be "stuffed"
  - Replace "flag" with "flag flag"
  - Length of payload is data-dependent!

Other Approaches

- Use explicit byte count after preamble
  - More susceptible to errors?
- Use "invalid" codeword
  - E.g., pick non-data 4B/5B symbol, used for FDDI
- SONET: "clock"-based framing
  - Periodic sync bits plus very accurate clock
  - Used extensively in the telecommunications industry

Key Concepts

- Different media have different properties that affect higher layer protocols
- To send messages in practice we must solve the problems of clock recovery and framing