

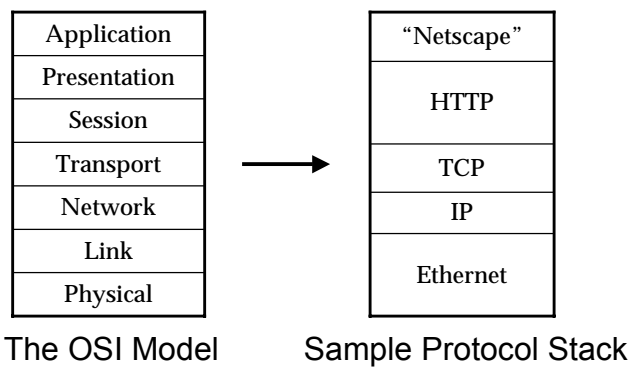
CSE/EE 461 – Lecture 3

Bits, Links and Frames

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Last Time ...

- Protocols, layering and reference models



This Lecture

- Focus: How do we send a message across a wire?
- The physical/link layers:
 1. Different kinds of media
 2. Encoding bits
 3. Model of a link
 4. Framing messages

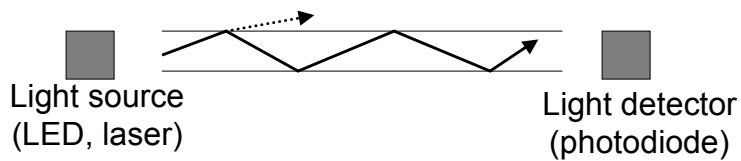
Application
Presentation
Session
Transport
Network
Data Link
Physical

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, ...

Fiber

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



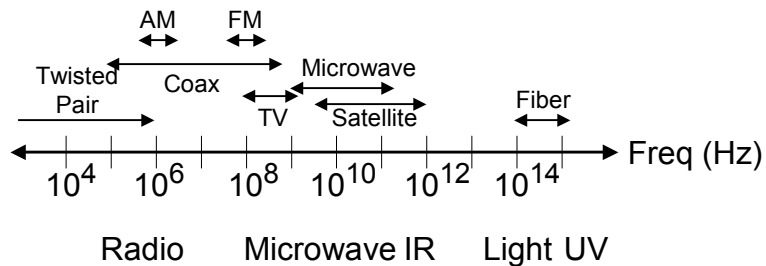
- Multi-mode allows many different paths, dispersion
- Chromatic dispersion if multiple frequencies

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Wireless

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

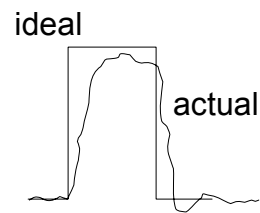
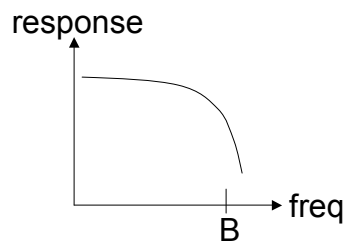


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Wires

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



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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.

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2. Encoding Bits with Signals

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



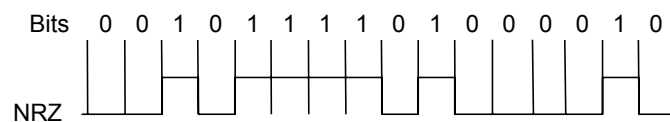
- We send/recover symbols that are mapped to bits
 - Signal transition rate = baud rate, versus bit rate
- This is baseband transmission ... take a signals course!

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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



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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

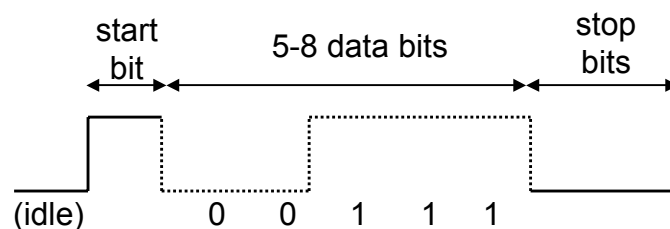
- Possible solutions:
 - Send separate clock signal → expensive
 - Keep messages short → limits data rate
 - Embed clock signal in data signal → other codes

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“Asynchronous” Transmission

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



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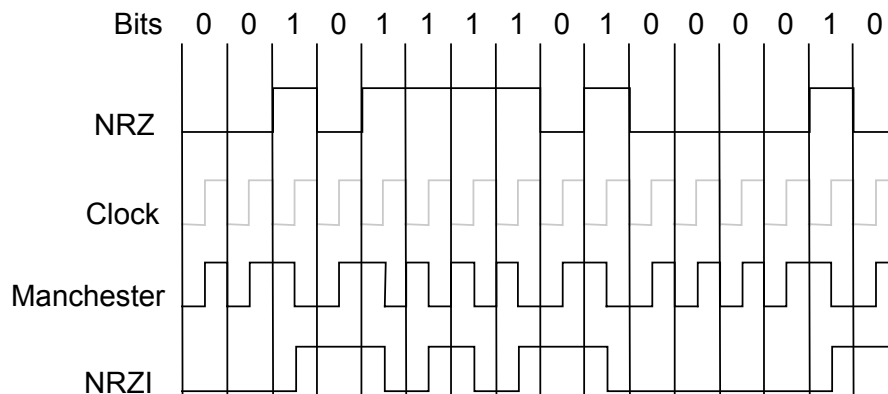
Manchester Coding

- 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
 - clock is embedded in signal, and we re-sync with a phase-locked loop every bit
- Disadvantage: 50% efficiency

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Coding Examples



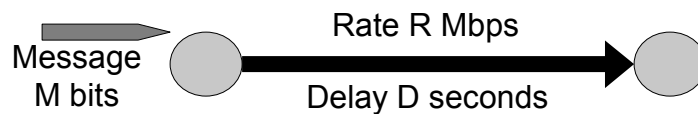
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4B/5B Codes

- 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

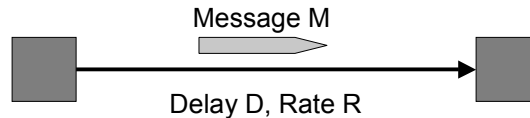
3. Model of a Link



- Abstract model is typically all we will need
 - What goes in comes out altered by the model
- Other parameters that are important:
 - The kind and frequency of errors
 - Whether the media is broadcast or not

Message Latency

- How long does it take to send a message?



- Two terms:
 - Propagation delay = distance / speed of light in media
 - Transmission delay = message (bits) / rate (bps)
- In effect, slow links stretch bits out in time/space
- Later we will see queuing delay ...

One-way Latency examples

- Either a slow link or long wire makes for large latency
- Dialup with a modem:
 - $D = 10\text{ms}$ (say), $R = 56\text{Kbps}$, $M = 1000$ bytes
 - Latency = $10\text{ms} + (1024 \times 8) / (56 \times 1024)$ sec = 153ms!
- Cross-country with T3 (45Mbps) line:
 - $D = 50\text{ms}$, $R = 45\text{Mbps}$, $M = 1000$ bytes
 - Latency = $50\text{ms} + (1024 \times 8) / (45 \times 1000000)$ sec = 50ms!

Terminology

- Latency is typically the one way delay over a link
 - But latency and delay are generic terms
- The round trip time (RTT) is twice the one way delay
 - Measure of how long to signal and get a response
- An important metric is the bandwidth-delay product
 - Measure of how much data can be in-flight at a time

4. Framing

- Need to send message, not just bits
 - Requires that we synchronize on the start of message reception at the far end of the link
 - Complete Link layer messages are called frames
- Common approach: Sentinels
 - Look for special control code that marks start of frame
 - And escape or “stuff” this code within the data region

Point-to-Point Protocol (PPP)

- IETF standard, used for dialup and leased lines

Flag 0x7E	(header)	Payload (variable)	(trailer)	Flag 0x7E
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- Flag is special and indicates start/end of frame
- Occurrences of flag inside payload must be “stuffed”
 - Replace 0x7E with 0x7D, 0x5E
 - Replace 0x7D with 0x7D, 0x5D

Alternatives that avoid stuffing

- “Invalid” signal from physical layer
 - Just trust me. Used in Ethernet and FDDI (later).
- Explicit byte count after flag
- SONET: “clock”-based framing
 - Periodic sync information plus very accurate clock
 - Used extensively in the telecommunications industry
- What are the pros and cons?
 - Efficiency (in terms of bandwidth)
 - Robustness (with respect to errors)

Key Concepts

- We typically model links in terms of bandwidth and delay, from which we can calculate message latency
- Different media have different properties that affect their performance as links
- We need to encode bits into signals so that we can recover them at the other end of the channel.
- Framing allows complete messages to be recovered at the far end of the link