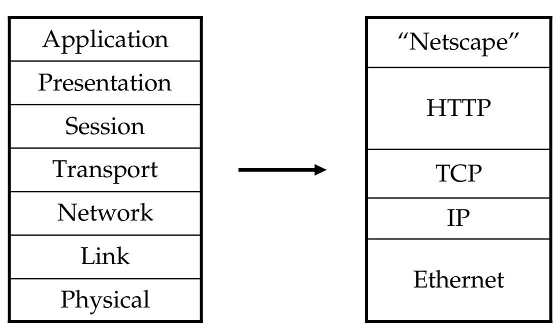
CSE/EE 461 – Lecture 3

Bits and Bandwidth

Last Time …

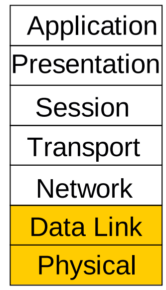
- Protocols, layering and reference models



The OSI Model Sample Protocol Stack

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



L3.3

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, …

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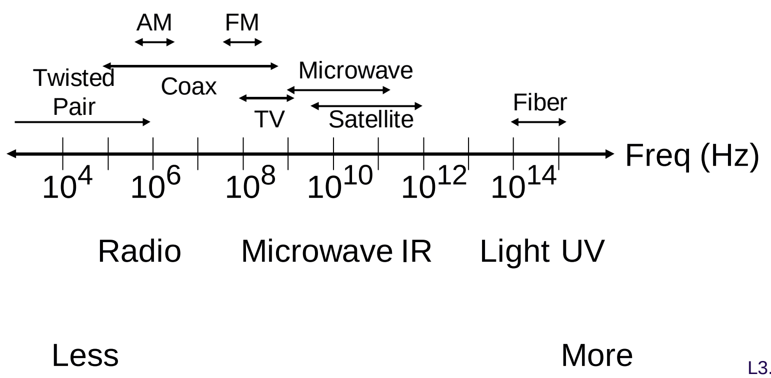
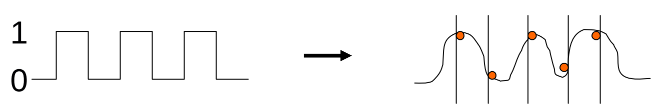
Media and Frequencies

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



2. Encoding Bits with Signals

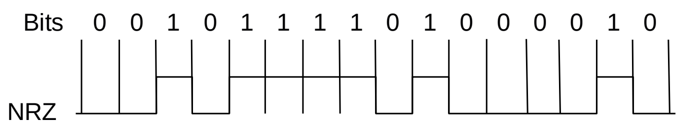
- Generate analog waveform (e.g., voltage) from digital data at transmitter and sample to recover at receiver



- 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!

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

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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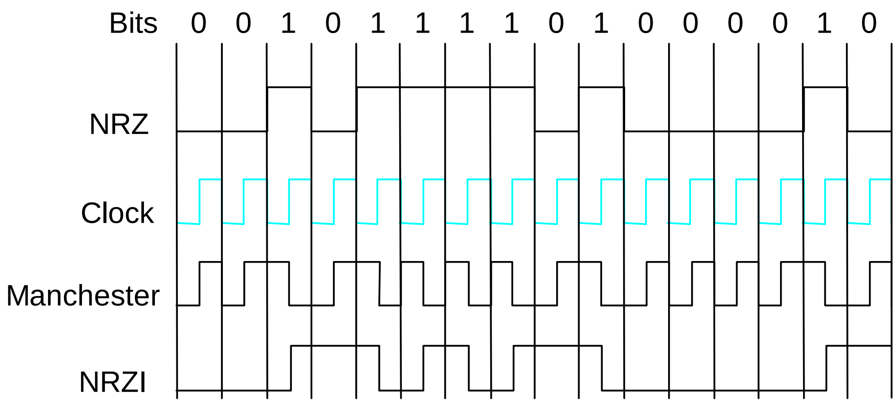
Coding Examples



L3.10

4B/5B Codes

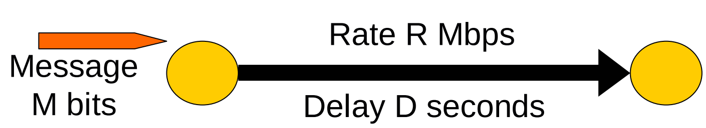
- We want transitions *and* efficiency …
- Solution: map data bits (which may lack transitions) into code bits (which are guaranteed to have them)

- 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

L3.11

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

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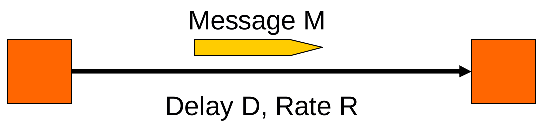
Message Latency

- How long does it take to send a message?



- Two terms:
  - Propagation delay = distance / speed of light in media
    - How quickly a message the wire
  - Transmission delay = message (bits) / rate (bps)
    - How quickly you can inject the message onto the wire
- Later we will see queuing delay …

L3.13

Relationships

- Latency = Propagation + Transmit + Queue
- Propagation Delay = Distance/SpeedOfLight
- Transmit Time = MessageSize/Bandwidth

L3.14

One-way Latency

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

L3.15

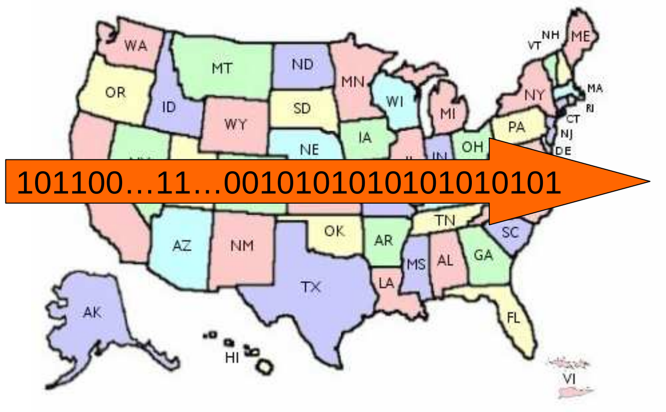
Messages Occupy "Space" On the Wire

- Consider a 1b/s network.
- How much space does 1 byte take?
- Suppose delay is 16 seconds.
- How many bits can the network "store"
- This is the BANDWIDTH-DELAY product
  - Measure of "data in flight."
  - 1b/s * 16s = 16b
- Tells us how much data can be sent before a receiver sees any of it.
- Twice B.D. tells us how much data we could send before hearing back from the receiver something related to the first bit sent.
  - Implications?

L3.16

A More Realistic Example

BD = 50ms * 45Mbps = 2.25 * 10^6 = 280KB



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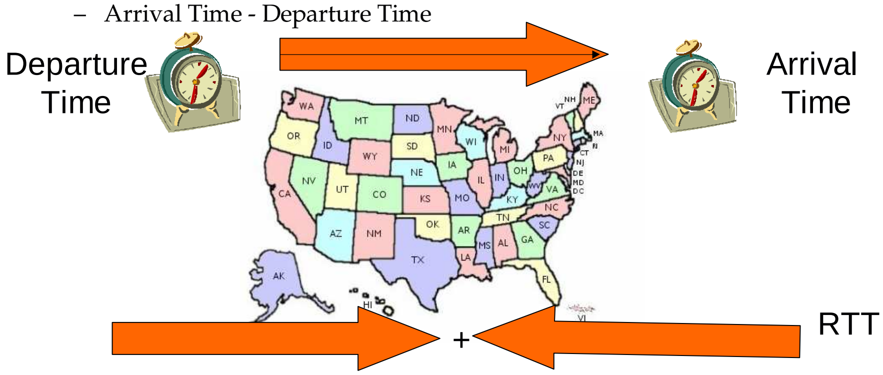
Throughput

- Measure of system's ability to "pump out" data
- NOT the same as bandwidth
- Throughput = Transfer Size / Transfer Time
  - Eg, "I transferred 1000 bytes in 1 second on a 100Mb/s link"
    - BW?
    - Throughput?
- Transfer Time = SUM OF
  - Time to get started shipping the bits
  - Time to ship the bits
  - Time to get stopped shipping the bits
- What's the best we can do to "get started?"
  - Put something, get something
- Always more efficient to move big things

L3.18

Latency and RTT

- Latency is typically the one way delay over a link
  - Arrival Time - Departure Time



- The round trip time (RTT) is twice the one way delay
  - Measure of how long to signal and get a response

L3.19

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 <u>frames</u>

- Common approach: Sentinels
  - Look for special control code that marks start of frame
  - And escape or “stuff” this code within the data region

L3.20

Example: Point-to-Point Protocol (PPP)

- IETF standard, used for dialup and leased lines

Flag 0x7E	(header)	Payload (variable)	(trailer)	Flag 0x7E

- Flag is special and indicates start/end of frame
- Occurrences of flag inside payload must be “stuffed”
  - Like an “escape” character:
    - \.\.\”\\ --> ..”\
  - Replace 0x7E with 0x7D, 0x5E
  - Replace 0x7D with 0x7D, 0x5D

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