Announcements

- Reading
  - Today: Chapter 2 (2.1-2.2)
How to Design in Performance

- **CPU Speed is more important than link speed**
  - protocol processing time is the critical time for most networks
  - use simple algorithms for your network

- **Reduce packet count**
  - there is a large per packet cost in most levels
  - big packets amortize this overhead over more bytes

- **Minimize Context Switches**
  - user/kernel boundary crossings are expensive
    - require many cache misses, pipeline stalls, etc.
  - send large units of data

- **Minimize Copying**
  - each copy is extra time
  - memory operations are often 10 times slower than other insns
How To Design In Performance (cont.)

- Bandwidth is growing, but latency isn’t shrinking as fast
  - fundamental limits of how many rounds trips are possible
  - need to design to transfer large requests
- Congestion Avoidance beats Recovery
  - getting the network out of a bad state will take time
  - better to prevent getting it there in the first place
- Avoid Timeouts
  - use NACKs to get info back
  - use long values for timeouts
  - timeouts result in:
    - interrupts (slow for the processor)
    - re-transmission (slow for the link)
- Make The Common Case Run Fast
  - data transmission is more common than connect
Sending Information

- **data is sent by varying a value over time**
  - can model this as a single valued function f(t)
  - the physical property that is changed could be
    - current
    - voltage
- **goal is to analyze the properties of this function**
  - how much energy is required?
  - how does the physical media affect the signal
Fourier Analysis

- Any periodic function $g(t)$ can be represented by
  - a constant term
  - a series (possibly infinite) of sines and cosines
    • a signal has a fundamental frequency $f=1/T$
    • each term is called a harmonic
      \[
      G(t) = \frac{1}{2} c + \sum_{n=1}^{\infty} a_n \sin(2\pi nft) + \sum_{n=1}^{\infty} b_n \cos(2\pi nft)
      \]
  - finite functions can be repeated forever
    • effectively any signal is finite so it has a Fourier transform
How many Harmonics do we need?

- **Adding Harmonics**
  - reduce error in regenerated signal
  - requires additional bandwidth

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Importance of Harmonics

- **Bandwidth limits**
  - physical circuits often only pass up to a cutoff frequency
  - sometimes limit bandwidth (it costs money)

- **Non-Uniform Attenuation**
  - not all frequencies pass equally well
    - 60 Hz is a bad frequency due to electrical circuits
  - try to ensure that the “important” parts get through
  - this is called distortion
    - exactly like bad sound when you turn up the stereo amp
Why baud may not equal bits/sec

- **baud is number of changes per second**
  - if the signal has 0/1 volts then bits/baud == 1
  - but if 0, 1, 2, 3, 4, 5, 6, and 7 volts used then 3 bits/baud

- **limit on baud per second over a phone line**
  - phone lines are limited to about 3khz
    - so only harmonics less than 3,000 will get sent
  - for 9600Bps the first harmonic is at 1,200
    - only two harmonics will be sent
  - not possible to send past 38.4kBps
    - but Baud is not bit/sec
Max Data Rates Over A Channel

- **Shannon/Nyquist limit**
  - max data rate is $2H \log_2 V$ bits/sec
    - $H$ - bandwidth of the channel
    - $V$ - number of levels used to encode data
  - for example, a noiseless 3khz channel can carry
    - 6,000 bps for binary traffic but
    - 12,000 pbs for quadary (4 level) traffic

- **What about noise?**
  - noise is measured as the ratio of signal to noise power
  - normally measured in db or $10 \log_{10}(S/N)$
  - Shannon limit:
    - max bits/sec = $H \log_2 (1+S/N)$
    - 3khz, 30dB channel limited to 30,0000 bps
Transmission Media

- **Magnetic Media**
  - tapes hold 40GB today
  - a van can carry 2,000 tapes (or 80 TB)
  - want to move data from DC to Baltimore
    - 80 TB/hour = 166 Gb/sec
  - what about latency?
    - get all 80TB at once
    - need to read/write all of these tapes

- **Twisted Pair**
  - copper wires (1.5 Mbps long hall)
  - 100Mbps with two pairs for short distances
    - some experimental versions go to 1Gbps