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

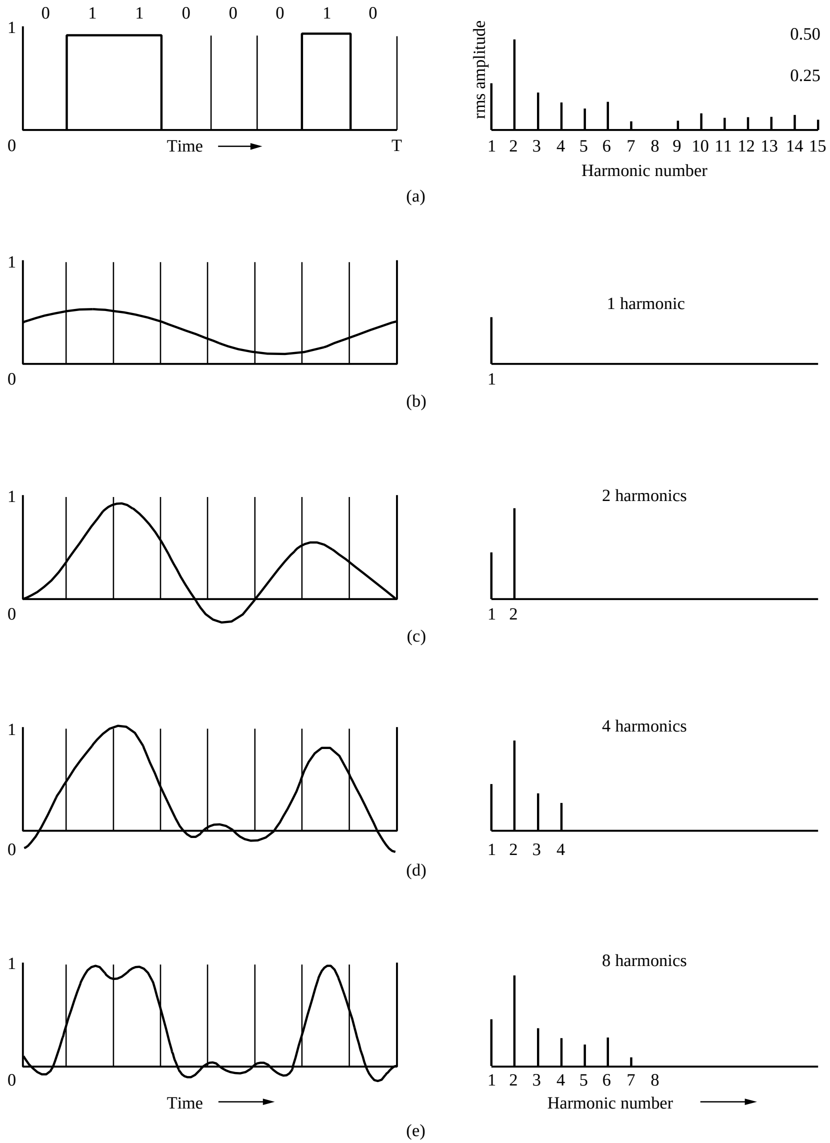
Fourier Analysis

- 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

$$G(t) = \frac{1}{2}c + \sum_{n=1}^{\infty} a_n \sin(2pnft) + \sum_{n=1}^{\infty} b_n \cos(2pnft)$$

  - 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

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 - bandwith 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