Announcements

- **Reading**
  - Chapter 2 (2.1 & 2.2)

- **Project #4 will be out next week**

- **Homework #1**
  - Due 11/6/01
    - Chapter 6: 4, 12, 24, 37
Performance Issues

- **Broadcast storms**
  - response to a broadcast packet sent by many hosts
  - caused by:
    - bad parameter resulting in an error message
    - asking a question everyone has the answer to

- **Reboot storms**
  - RARP queries
  - file servers responding to page requests

- **Delay-bandwidth product**
  - need to buffer at least as many bytes as can be “in flight”

- **Jitter**
  - keep standard deviation of packet arrivals low
  - important for continuous media traffic
How to Measure Performance

- Ensure sample size is large
  - repeat experiments for several iterations

- Make sure samples are representative
  - consider time of day, location, day of week, etc.

- Watch for clock resolution/accuracy
  - don’t use two clocks at opposite ends of the network
  - if the clock resolution is poor, aggregate over multiple iterations

- Know what you are measuring
  - is a cache going to distort results?
  - is the hardware, OS, device driver, compiler the same?

- Careful not to extrapolate too far
  - results generally hold for an operating region, not all values
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

\[
G(t) = \frac{1}{2}c + \sum_{n=1}^{\infty} a_n \sin(2\pi n ft) + \sum_{n=1}^{\infty} b_n \cos(2\pi n ft)
\]

- 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

![Diagram of Harmonic Numbers and Rms Amplitude](image_url)
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