Announcements

- project #1 is due on Wed. at 6:00 PM
  - submit a tar file with
    - source
    - typescript file
  - use submit program from ~jh01/bin/submit

ATM

- Asynchronous Transfer Mode
  - not tied to a single central clock
  - proposed by telco's to replace their network
- Fixed size packets called cells (53 bytes)
  - 5 bytes for header (not big enough for end-to-end id)
    - use hop by hop Virtual Circuit Ids (VCI)
  - 48 bytes for data
    - telcos wanted 32, packet switching wanted 64
- Physical Media
  - copper at T-3 speeds (45 Mbps)
  - fiber at OC-3 to OC-48 (155 Mbps and up)
- Designed to carry
  - constant rate applications: voice and video
  - variable rate applications: email, www, etc.

ATM Reference Model

OSI Layer	ATM Layer	Function
3 and 4	AAL	Segmentation Reassembly
2 and 3	ATM	Flow control Cell header Virtual circuit Cell mux/demux
1 and 2	Physical	Header sums Frame generation

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

Fourier Analysis (cont.)

- can solve for a_n,b_n, and c to get:

$$a_n = \frac{2}{T}\int_0^T g(t)\sin(2\pi nft)dt$$

$$b_n = \frac{2}{T}\int_0^T g(t)\cos(2\pi nft)dt$$

$$c = \frac{2}{T}\int_0^T g(t)dt$$

Bandwidth Limits

- Consider sending 01100010 (ascii b):

$$a_n = \frac{1}{\pi n}[\cos(\pi n/4) - \cos(3\pi n/4) + \cos(6\pi n/4) - \cos(7\pi n/4)]$$

$$b_n = \frac{1}{\pi n}[\sin(3\pi n/4) - \sin(\pi n/4) + \sin(7\pi n/4) - \sin(6\pi n/4)]$$

$$c = \frac{3}{8}$$

- how much power is required to send the signal ?
  - height of a_n and b_n dictate power requirements
  - (rms) $\sqrt{a^2 + b^2}$ indicates the power required

How many Harmonics do we need?

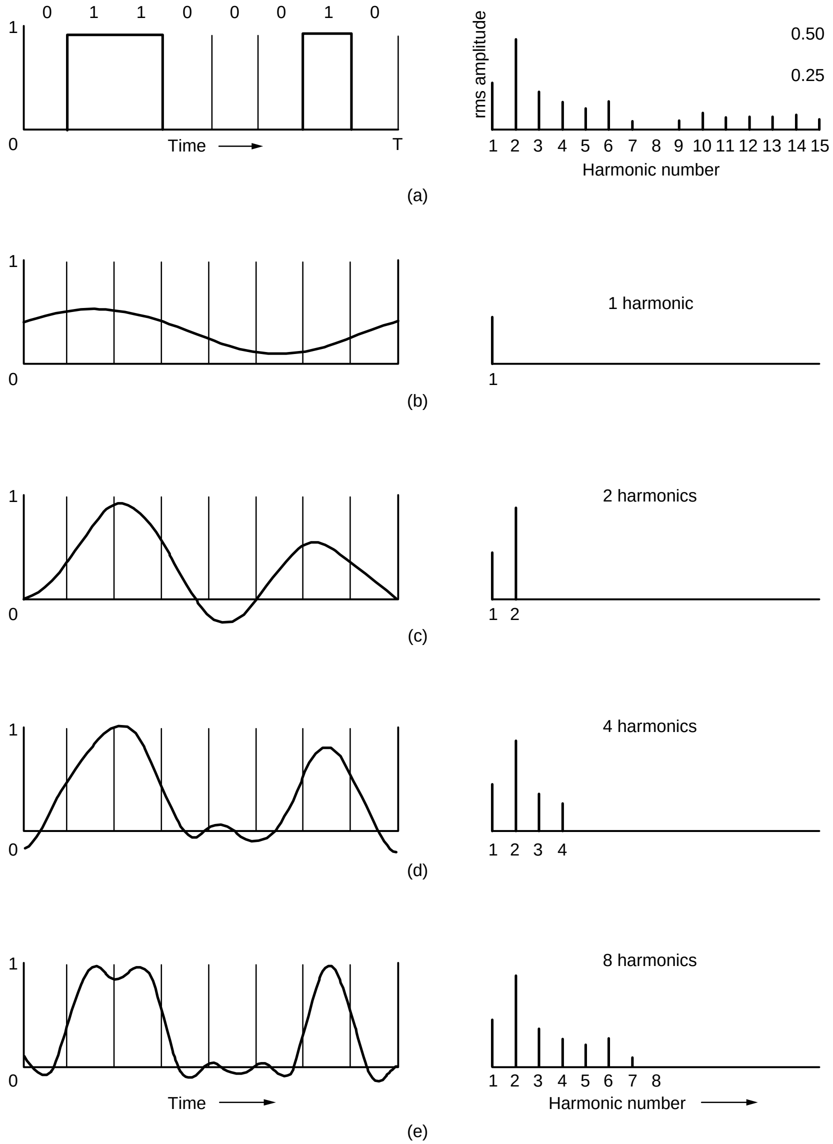

figure copyright , 1996, Andrew S. Tanenbaum

- Adding Harmonics
  - reduce error in regenerated signal
  - requires additional bandwith

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 Hz will get sent
  - for 9600Bps the first harmonic is at 1,200
    - only two harmonics will be sent

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 bps 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 30,000 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