ECE 435 – Network Engineering
Lecture 20

Vince Weaver

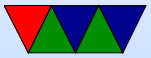
http://web.eece.maine.edu/~vweaver

vincent.weaver@maine.edu

16 November 2017

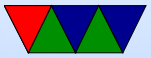
Announcements

- SC'17 takeaway
  - Lots of network stuff there, the network being important for a supercomputer
  - SCInet with their own Class Cs, 56 miles of fiber, 200+ wireless access points, 3.15 Tbps bandwidth, 206 volunteers
  - Cable connector vendors
  - Newark Airport wireless
- Demo of infiniband / fiber / ethernet cables



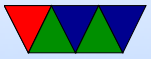
Hw8 Wrapup

- Ethernet header: MAC/MAC/IPv4
  Note not size, as it's 2048 and size must be smaller than 1500
- Speed Dragon – macbookair with USB-ethernet / Pi Foundation
- ARP / maps IP addresses (or other) to MAC
- 100MB or gigabit
  some drivers not report in dmesg
- Collision count low? Most likely you're connected to a



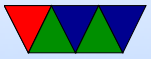
switch so there aren't any collisions

- Questions
  - Ethernet was cheaper
  - 64 bytes ensured a collision could happen
  - Maximum size of 1500 was due to cost of RAM, but also the larger it is the more likely an error can happen
  - Ethernet drops things on floor



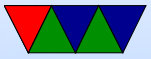
The Physical Layer

- Deals with "transmission media"
- Digital signal into a waveform
- Modulation/Demodulation
- Sometimes referred to as "PHY" in device drivers



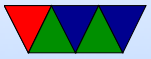
The Physical Layer

- Fourier analysis – draw diagrams from Tannenbaum
- Transmit an ASCII binary signal down the line, made up of harmonics
- The various harmonics are attenuated differently, causing noise
- Range of frequencies that can be transmitted w/o attenuation is the bandwidth
- For example, telephone wire might have bandwidth of 1MHz but limited by filter to 3.1kHz



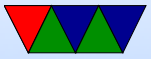
Sampling

- Digital signal converted to analog
- Sometimes modulate carrier for long distance
- How to get back digital signal? Sample
- How often do you need to sample?
- Quantization: A/D conversion. Can add noise
- Reconstruction is interpolation

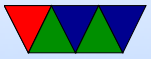


Nyquist Theorem

- If arbitrary signal run through low-pass filter of bandwidth H, can be reconstructed with 2H samples. Sampling faster pointless, as higher frequencies already gone. If V discrete levels, $maximumrate = 2Hlog_2Vbits/sec$
- This assumes noiseless channel
- Thermal noise always present
- Signal-to-noise ratio
- Signal power = S, N power =N, S/N

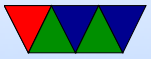


- Usually logarithmic, presented in dB
  S/N of 10 = 10dB, S/N of 100 = 20dB, S/N of 1000 = 30dB
- Shannon: max data rate of a noisy channel with bandwidth H Hz and S/N is $maxbps = Hlog_2(1+S/N)$
- Example 1: 3000Hz bw with 30dB (typical of old POTS, limited to 30kbps)
  $30dB = 10log(S/N)$, $S/N = 10^3$
  $3000 * log_2(1+10^3) = 29.9kbps$
- Example 2: 3000Hz bw with 33dB
  $33dB = 10log(S/N)$, $S/N = 1995$



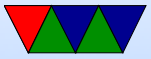
$$3000 * log_2(1 + 1995) = 32.9kbps$$

- Bonus question: Why are CDs 44.1kHz?

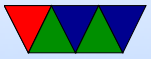


Baseband vs Broadband

- Baseband is a digital signal that can be put directly on the wire
- Broadband requires modulation. Often modulated to use a higher frequency so that multiple channels can share same medium (cable TV, radio, etc)

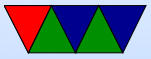


Medium

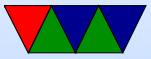


Media Types

- Guided (copper wire, fiber)
- Unguided (radio, microwaves)

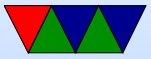


Guided Media

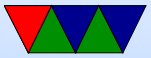


Twisted Pair

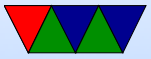
- Two wires, twisted together
- Can be shielded too, usually isn't due to expense
- Why twisted? Parallel wires make antenna
- POTS
- Several kilometers, several Mb/s over such distances
- Cat3 = phone lines (16MHz)



- Cat4 = up to 20MHz
- Cat5 = more twists (up to 100MHz)
- Cat6 and higher (250MHz) gigabit
- Cat7 = up to 600MHz
- Not only faster cables, but use more than one set of twisted pairs. 8 wires in typical Ethernet. Two pairs used 10/100, four pairs for gigabit
- Plenum (fire resistant) and shielded cables

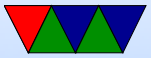


- Can have solid or stranded wires. Stranded bends around corners better
- Cat5 the four different pairs have differing numbers of twists to avoid crosstalk
- Cat6 originally had “spline” to separate cables but now most don’t
- Mostly there are specifications that you have to meet (resistance, cross-talk, inductance, delay) and as long as you test to that you are fine. Standards documents but have to pay to see.

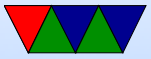


Coaxial Cable

- TODO: diagram?
- 50 or 75 ohm
- copper core, insulating material, outer conductor, outer insulator
- Bandwidth close to 1GHz - 3GHz
- Used in old Ethernet, as well as cable modems

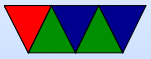


Infiniband

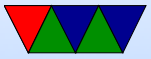


Fiber Optics

- TODO: diagram
- Light source, transmission medium, detector
- Total internal reflection/refraction. Bend too much and light will leak out. Straight can go for kilometers with no loss
- How do they do sub-sea cables? Pump recharge lasers down
- Single mode (narrow, more like wave guide, faster) vs multimode (lots bouncing around) fibers

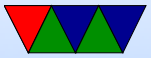


- attenuation in dB $= 10log_{10}\frac{transmittedpower}{receivedpower}$
- Three common wavelength bands, 0.05, 1.30 and 1.44 microns
- chromatic dispersion. pulse spreads out as it travels. special cosh solitons to avoid this
- Often packed with fiber, glass with different index of refraction, plastic protection
- Often dug up by backhoes. How to fix? Sockets, lost 20% of light. Mechanical splice, 10%. Can fuse and melt for smaller
- Sources: LED or laser. LEDs worse at rate, and distance,



but are cheaper and last longer

- Receiver: photo-diode
- Maine 3-ring binder
- Network, a ring. Passive tap (no regeneration) active (reads and re-sends)
- Dark fiber?
- Multiplexing vs multiple colors
- Underseas cables and how they work



Fiber vs Copper

- Fewer repeaters
- No power surges or power failures
- No corrosion
- Thin and lightweight: more room in ducts
- Difficult to wiretap
- Downside (often one-way, can't bend too sharp, more skills to make)