ECE 435 – Network Engineering Lecture 16

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Announcements

- No homework this week.
- Demo of infiniband / fiber / ethernet cables

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, $maximum rate = 2H log_2 V bits/sec$

- 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
  $33dB = 10log(S/N)$, $S/N = 1995$

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

- 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 $= 10 log_{10} \frac{transmitted power}{received power}$
- 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)