ECE 435 – Network Engineering Lecture 16

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Announcements

- Reminder: no homework due this week.
- Use of .0 as unicast address (HW6) in news
- 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

Physical Layer Limitations

- Fourier analysis – diagram from Tanenbaum
- Transmit an ASCII binary signal down the line, made up of harmonics
- The various harmonics attenuate differently, causing noise

Physical Layer – Bandwidth

- Range of frequencies that can be transmitted w/o attenuation is the bandwidth (usually quoted as power by 1/2)
- For example, telephone wire might have bandwidth of 1MHz but limited by filter to 3.1kHz
- Bandwidth often artificially limited to provide more channels.

  Starting at 0 is the `baseband`, shifted to another channel `passband`

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:
  $maximumrate = 2Hlog_2 V bits/sec$
- This assumes noiseless channel
- Thermal noise is 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?

Medium

Media Types

- Guided (copper wire, fiber)
- Unguided (radio, microwaves)
- Persistant Storage (magnetic media)

Magnetic Media

- To quote AST: *Never underestimate the bandwidth of a station wagon full of tapes hurtling down the highway.*
- Sneakernet
- See xkcd comic about sd-cards `https://what-if.xkcd.com/31/` “Those thumbnail-sized flakes have a storage density of up to 160 terabytes per kilogram, which means a FedEx fleet loaded with MicroSD cards could transfer about 177 petabits per second, or two

zettabytes per day — a thousand times the internet's current traffic level."

- High bandwidth but high latency

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

Twisted Pair Cabling

- Cat3 = phone lines (16MHz)
- Cat4 = up to 20MHz
- Cat5 = more twists (up to 100MHz)
- Cat6 and higher (250MHz) gigabit
- Cat7 = up to 600MHz (pairs shielded)
- Cat8 = ????

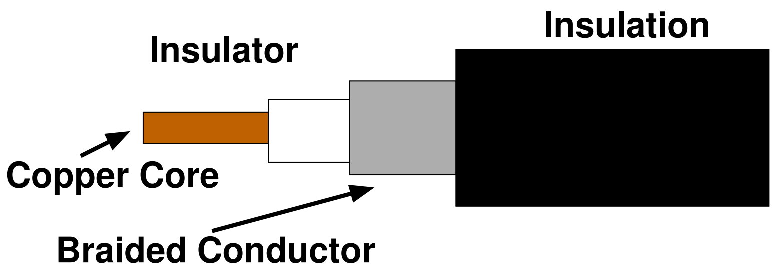
More Twisted Pair Cabling

- 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



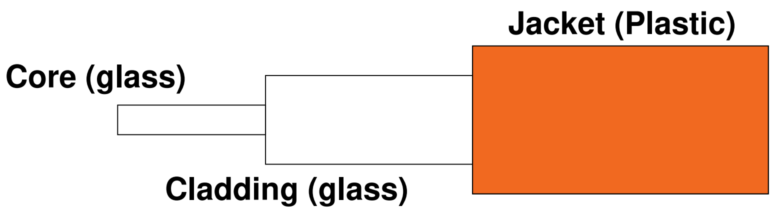
- 50 ohm (computer) or 75 ohm (TV, but also cable modem)
- copper core, insulating material, outer conductor, outer insulator
- Bandwidth close to 1GHz - 6GHz

- Used in old Ethernet, as well as cable modems

Power Line internet

Infiniband

Fiber Optics



- 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
- Single mode (narrow, more like wave guide, faster) vs multimode (lots bouncing around) fibers

Fiber Optics – Background

- 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

Fiber Optics – Practical

- 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

Fiber Optics – Implementation

- Maine 3-ring binder
- Network, a ring. Passive tap (no regeneration) active (reads and re-sends)
- Dark fiber?
- Multiplexing vs multiple colors

Long-distance Fiber

- Fascinating to read up on
- How do they do sub-sea cables? Pump recharge lasers down

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)