ECE 435 – Network Engineering
Lecture 16

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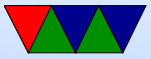
Announcements

- Reminder HW#7 done and graded
- Remember project topics are due 28th (next Tues)
- Demo of infiniband / fiber / ethernet cables

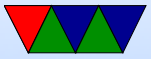


HW#7 Review – IPv4

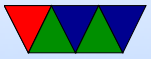
- Header:

```
0x000e:  4500 = version(4), header length(5)=20 bytes
                ToS=0
0x0010:  0038 = packet length (56 bytes)
0x0012:  572a = identifier
0x0014:  4000 = fragment 0100 0000 0000 0000 =
                do not fragment, offset 0
0x0016:  40 =   TTL = 64
0x0017:  06 =   Upper layer protocol (6=TCP)
0x0018:  69cc = checksum
0x001a:  c0a80833 = source IP 192.168.8.51
0x001e:  826f2e7f = dest IP 130.111.46.127
```

- Valid IPs

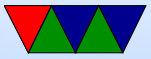


  - 123.267.67.44 = N
  - 8.8.8.8 = Y
  - 3232237569 = 192.168.8.1
  - 0xc0a80801 = 192.168.8.1
- A class-A allocation is roughly $2^{24}/2^{32}$ which is 0.39%
- 192.168.13.0/24. subnet 255.255.255.0, lowest ip 192.168.13.1, highest 192.168.13.254 (traditionally can't use the host values with all 0 or 1s (so .0 and .255 on a /24). There's a push to allow .0 on Linux
- First hop not local (how to tell?) goes to router



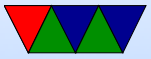
Otherwise go direct (can you go direct? how).

- Ping google. 1e100.net?
- Traceroute. Some routers block?
  Used to pass through Neville hall
- Interesting, people tracerouting umaine from spectrum have packets going via chicago and boston bngrme/sebgme/rochny/chgil



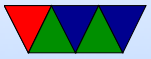
HW#7 Review – NAT/IPV6

- NAT questions:
  - No 192.168.8.x should not be able to connect to outside directly.
  - NAT is happening.
  - Why is nat showing UNREPLIED? TCP vs UDP difference. Can you detect when TCP connection is closed? Yes. Can you detect when UDP connection is done? No. Must keep port open a bit in case reply. How long. Forever? What goes wrong with that?

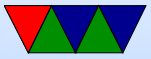


- IPv6 addresses
  - 2607:f8b0:4009:0801:0000:0000:0000:200e – OK
  - 2607:f8b0:4009:801::200e – OK
  - 2607:f8b0::4009:801::200e – can you have two colons?
  - 123.45.67.18 – ipv4
- IPv6 packet

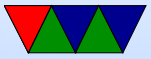
```
0x000e:  6002 2618 :
6 = IPv6
00 = traffic class
2618 = flow label
0x0012:  0031 =       payload length, 49
0x0014:  11 =         next header = 0x11, UDP
0x0015:  40 =         hop limit 0x40, 64
0x0016:  2610 0048 0100 08da 0230 18ff feab 1c39
                        source address
0x0026:  2001 4860 4860 0000 0000 0000 0000 8844
                        destination address
```



- traceroute:
  - internet2
  - bost/hart/newy probably boston, hartford, new york
  - lon2.uk London
  - janet is british academic network
  - 6→7 across ocean
  - 80ms = ?? speed of light
  - 80e-3s 3e8m/s = 24000km? 5500km = 1/4 speed of light?
- traceroute6
  - different hops? IP6 different? random chance

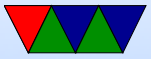


- hop 5→6
- Washington? internet 2?
- Abilene was the predecessor to internet2
- fra.de Frankfurt Germany probably not France
- latency 133ms rather than 106ms



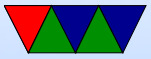
The Physical Layer

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



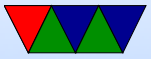
Physical Layer Limitations

- Fourier analysis – (see diagram from Tanenbaum, Figure 2-12 (p112)
- Transmit an ASCII binary signal down the line, made up of harmonics
- The various harmonics attenuate differently, causing noise



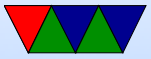
Physical Layer – Bandwidth

- Note: EEs measure bandwidth in Hz, CEs in bits/s
- 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 channels.
- Starting at 0 is the `baseband`, shifted to another channel `passband`



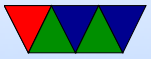
Sampling

- 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

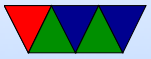


Nyquist/Shannon Theorem

- Harry Nyquist, 1932, based on earlier work by Whittaker. Shannon wrote it up, often Nyquist gets most credit.
- 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 is always present

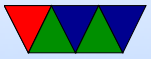


- Example: binary signal (2-level), 3kHz channel, max 6000bps
  $2(3000)log_2 2 = 6000bits/sec$



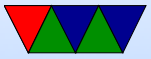
Signal-to-Noise Ratio

- 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

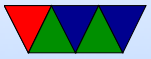


Shannon

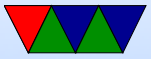
- Max data rate of a noisy channel with bandwidth H Hz and S/N is
  $maxbps = Hlog_2(1 + S/N)$
- Example 1: 3000Hz bw with 30dB (typical of old POTS, limited to 30kbps)
  $30dB = 10log(S/N)$, $S/N = 10^3$
  $3000 * log_2(1 + 10^3) = 29.9kbps$
  Why is this different from previous example? Previous limited to two voltages.



- 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?

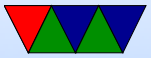


Medium



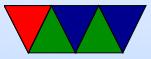
Media Types

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



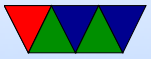
Magnetic Media

- 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

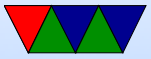


zettabytes per day — a thousand times the internet's current traffic level."

- High bandwidth but high latency

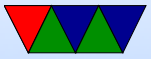


Guided Media



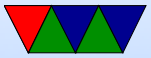
Twisted Pair

- 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



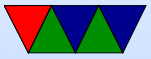
Twisted Pair Cabling

- 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 = ????



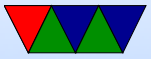
More Twisted Pair Cabling

- 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

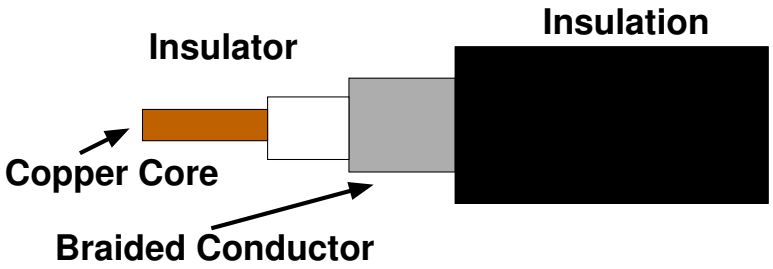


most don't

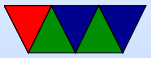
- Mostly there are specifications that you have to meet (resistance, cross-talk, inductance, delay) and as long as you test to that you are fine. Standards documents but have to pay to see.



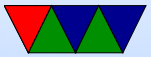
Coaxial Cable



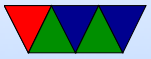
- 50 ohm (computer) or 75 ohm (TV, but also cable modem)
- copper core, insulating material, outer conductor, outer insulator
- Bandwidth close to 1GHz - 6GHz



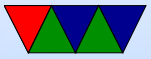
- Used in old Ethernet, as well as cable modems



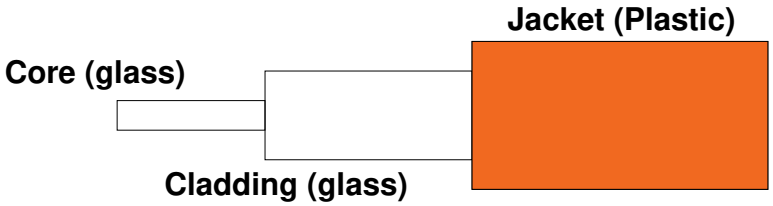
Power Line internet



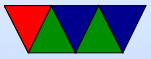
Infiniband



Fiber Optics

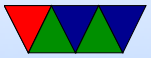


- Light source, transmission medium, detector
- Total internal reflection/refraction. Bend too much and light will leak out. Straight can go for kilometers with no loss



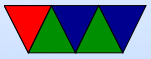
Fiber Optic Types

- Single mode
  - narrow, more like wave guide
  - faster
  - more expensive
- Multimode
  - lots of bouncing around
  - cheaper, but shorter distances



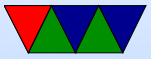
Fiber Optics – Background

- 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



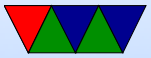
Fiber Optics – Practical

- 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



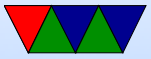
Fiber Optics – Implementation

- 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)