ECE 435 – Network Engineering Lecture 3

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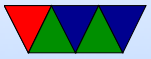
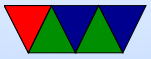
Announcements

- Homework was due
- Don't forget the IEEE picnic immediately following

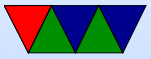


Question from Last time: Cable Differences

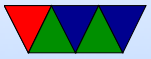
- Plenum (fire resistant) and shielded cables
- Can have solid or stranded wires. Stranded bends around corners better.
- Cat5 the four different pairs have differing numbers of twists to avoid crosstalk.
- Cat6 originally had "spline" to separate cables but now most don't



- 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.

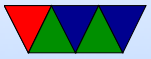


More Physical Layer

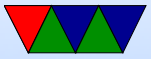


Wireless

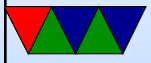
- Speed of light in vacuum $3 \times 10^8 m/s$ (foot/ns)
- In wire/fiber more like 2/3 of value, freq dependent
- $\lambda f = c$
- Include chart? Radio, microwave, infrared, visible, UV, X-ray, gamma ray why aren't UV, x-ray and gamma rays used much?
- bandwidth calc



Rough table, based on one found on Wikipedia

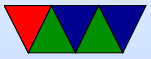


Type	Name	Freq	Wavelength
Ionizing	Gamma	300EHz	1pm
	Hard X	30EHz	10pm
		3EHz	100pm
	Soft X	300PHz	1nm
	Extreme UV	30PHz	10nm
Visible	Near UV	3PHz	100nm
	Visible	300THz	1μm
	Near IR	30THz	10μm
	Mid IR	3THz	100μm
	Far IR	300GHz	1mm
Radio/Microwave	EHF	30GHz	1cm
	SHF	3GHz	10cm
	UHF		
	VHF	300MHz	1m
	HF	30MHz	10m
		3MHz	100m
	MF	300kHz	1km
	LF	30kHz	10km
	VLF	3kHz	100km
	ULF	300Hz	1Mm
	SLF	30Hz	10Mm
	ELF	3Hz	100Mm

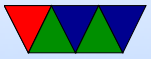


Radio Transmission

- Radio from 3kHz to 1GHz. VLF (3-30kHz) LF (30-300kHz) MF (300kHz-3MHz) HF (3-30MHz) VHF (30MHz-300MHz) UHF (300MHz-3GHz)
- Even lower? ELF (3Hz) submarines?
- Can travel long distances, omni-directional (go in all directions)
  why is omni bad? interference, everyone can hear
- Inverse square law

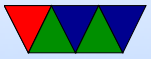


- High frequencies go in straight lights and bounce off things and absorbed by rain
- Government regulated
- VLF, LF and MF follow ground
- MF (AM radio) pass through buildings easily, but low bandwidth
- VHF can bounce off ionosphere

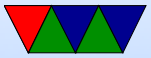


Microwaves

- 1GHz to 300GHz (overlap with UHF)
- GPS at 1.2-1.6Hz, Wifi 2.4GHz and 5GHz
- Microwaves, above 100MHz travel in nearly straight lines, can be focused. Before fiber optics transmitted across country like this. Multipath fading. Up to 10GHz used, but above 4GHz absorbed by water (only few inches long)
- Absorbed by water, as in microwave oven.

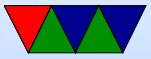


- Benefits: no need to dig up right of way (MCI, microwave towers. Sprint Southern Pacific railroad fiber)



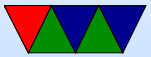
Infrared

- 300GHz-400THz, cannot penetrate walls



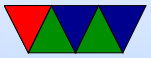
Visible Light

- Networks that modulate the lightbulbs in a room?
- Laser links between roofs of buildings (cannot penetrate fog well)



Electromagnetic Spectrum

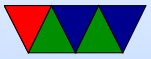
- Government regulated
- Hard to decide to allocate. Recently auction, lead to crazy large fees but then companies can't actually pay them
- alternative is "spread spectrum" frequency hop until find one that's free. Unregulated bands, 900MHz, 2.4GHz, 5GHz.



Communications Satellites

- geostationary – 35,800km. Need to be at least 2 degrees apart to avoid interference, so only 180 slots. But can use tricks to avoid this (different frequencies, polarization). ITU regulates slots

- Certain frequencies allocated to avoid microwave interference L (1.5Ghz), S (1.9GHz) C (4.0GHz) Ku (11GHz) Ka (20GHz). Higher bands have problems with rain.

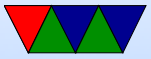


- Originally just transponders, signals that wait on a certain frequency, amplify, rebroadcast at another. Modern ones can do more processing

- geostationary 250 to 300ms latency

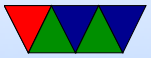
- medium-earth-orbit – closer than GEO (between the radiation belts). drift though. Not widely used, but GPS is here

- LEO – low Garth orbit. Only few ms latency, low power. Iridium



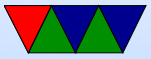
Satellite vs Fiber

- Fiber: point to point. Satellite anyone with a dish can tap in anywhere
- Mobile: airplanes and such
- Broadcast: send once, receive by many
- Difficult landscape. Uneconomical to lay fiber to every house in distant regions



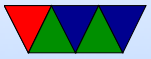
Wired Phone Network

- Originally all analog. Point-to-point
- Switching offices, operator manually jumper
- Later automatic dialing involved (story of that, Stowager gear)
- Wires connecting to your house "local loop"



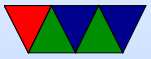
Data over Phone lines

- Rent your own local loop
- Modems on both ends. Before 1984 not allowed to, acoustic couplers
- Modem doesn't send raw binary, it uses sine wave carrier Max a perfect phone line can do about 3000Hz, so max is 2400bps. Instead change the "baud" which is *symbols* per second. Say four different voltages. Also say different phase shifts. Quadrature Phase Shift



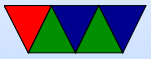
Keying

- Interesting to me as I used to do all of this
- Duplex – simplex or full duplex
- Hit Shannon limit about 33.6kbps
- how do you hit 56k? need ISP equipment at the exchange, can bypass some restrictions. Also different rates up/down



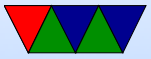
DSL

- Normal phone lines have a filter from 300 – 4000Hz or so
- For DSL they remove the filter
- You need to put own filter on your actual phones in house
- Speed depends on distance to the facility
- Often asymmetric. Could split 50/50, but people usually



download more so make it favor download

- 250 channels of data coming down. Modem has a DSP to convert this to data



Cellphone

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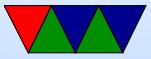
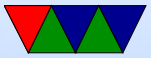


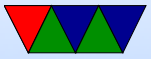
Cellphone 1G

- Analog
- 1982 AMPS (previous systems existed but were impractical)
- Divide landscape up into cells
- Smaller cells better, need less power. Need more towers though.
- Frequency reuse, have a number of frequencies, try to



keep them a few cells apart to avoid interference

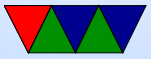
- Phone only in one cell. As it leaves cell, surrounding asked which has strongest signal, and that one gets it
  "handoff" switch channels, take 300ms.
  soft handoff: connects to new before switching off old.
  no loss, but needs to be able to receive two freq
  hard handoff, old drops before new. If something goes wrong, lose connection.
  832 full duplex channels 824MHz to 849MHz, 869MHz to 894MHz
  40cm, straight lines but blocked by trees and plants and



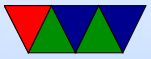
bounce
Since adjacent cells cannot use same freq, only maybe 40 or so freq available at each tower.

- Phone had 32-bit serial number and 10-digit phone number. On power it scans the list of 21 control channels and picks strongest . The tower gets this, logs it. Phone re-registers every 15 mins. Press send, tries to send. If collision wait. Tower finds idle channel for call, then notifies phone which one.

- Incoming, constantly monitors to paging channel to see

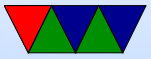


if one is incoming. It says call for certain phone on certain freq, and if it can it picks up



Cellphone 2G

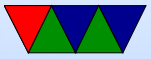
- Digital Voice
- D-AMPS, GSM, CDMA, (PDC, D-AMPS in Japan)
- D-AMPS – digital. CO-exist with AMPS, 1G and 2G could operate in same cell. Same freq, can change on fly which channels digital, which analog. Freq in 1800-1900 waves are 16cm, 0.25 wave antenna 4cm so can have smaller phones.
  Compression of signal, so much that typically 3 can use



same channel via TDMA
Control is complicated

- GSM – everywhere but US and Japan.
  Global System for Mobile
  FDM used. GSM channels wider, higher data rate.
  Standard 5000 pages long.
  In theory up to 900 channels available
  Simplex, cannot send and receive at same time.
  33kbps, but after overhead only 13kbps

- CDMA – code division multiple access



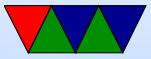
Qualcomm

At first people thought it was crazy

Instead of having channels, tower broadcast throughout the spectrum. Coding theory.

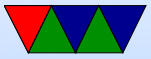
Noisy room analogy: TDM is people taking turns talking. FDM, people in clumps talking to each other. CDMA everyone talking at once, but different language

Chips. Complicated

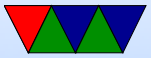


Cellphone 3G

- Digital Voice and Data
- 1998
- 200kbps (3.5 and 3.75G provide “broadband” speed)
- IMT-2000 standard
- W-DCMA
- Security, more secure than 2G

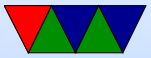


- Mix of connection and packet based



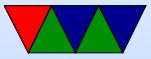
Cellphone 4G

- Digital Voice and Data
- 2008
- Mobile WiMax (Sprint)
- LTE (Long Term Evolution)
- 100Mbps for mobile, 1Gbps stationary
- Packet switching



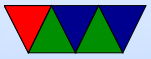
Cellphone 5G

- Under development

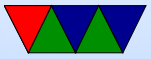


Cable Modems

- Cable typically a broadcast medium
- Single cable shared by many users; download a large file and you slow everyone else (not a problem with DSL)
- Bandwidth of co-ax higher than twisted pair
- TV stations up to 550MHz, data down above to 750MHz, data up 5-42MHz. Smaller so asymmetric
- QAM-256, QPSK



- encrypted



FIOS

- Fiber to the home. One fiber line sent to neighborhood, split for 32 subscribers
- 50Mbps-500Mbps symmetric
- VOIP