ECE 435 – Network Engineering
Lecture 22

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Announcements

- HW#10 – has been posted, Wireless and Physical Layer
- HW#11 – will still be coming
- Project presentations – 13 groups
  Will send n e-mail with proposed schedule.

Cellphone – 0G

- 1946 at first, more common in 70s+80s
- Only a few per city, more similar to a 2-way radio that an operator used to connect you to the phone network

Cellphone 1G

- Analog – has since been decommissioned
- 1977 Japan / 1981 Scandinavia / 1983 US (Chicago)
- 1982 AMPS – Advanced Mobile Phone System
- Cells
  - 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.
- Protocol
  - 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

- Security – none. Plain analog, could listen on scanner (government made it illegal to sell scanners that could listen on those frequencies)
- Cloning – could listen and capture phone ID when it sends to tower. Then reprogram your own phone to steal the phone's account, make calls for free, etc.

Cellphone 2G

- Roughly 1991
- Digital, Encrypted, Data+SMS, Voice
- Being decommissioned, though T-mobile in the US not until 2020
- D-AMPS, GSM, CDMA, (PDC, D-AMPS in Japan)
- D-AMPS
  - 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
  - Global System for Mobile
  - everywhere but US and Japan.
  - 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 2.5/2.75G

- 2.5G
  - GPRS
  - General Packet Radio Service
  - Packet vs Switched
  - Speed 50kbps (40kbps achievable)
- 2.75G
  - EDGE in 2003
  - 8PSK encoding
  - 500kbps

Cellphone 3G

- 1998 - 2001
- Digital Voice and Data
- IMT-2000 standard
- W-DCMA
- Spread Spectrum
- 200kbps (3.5 and 3.75G provide “broadband” speed)
- Security, more secure than 2G, better ciphers (KASUMI)
- Mix of connection and packet based

Cellphone 4G

- 2008
- Digital Voice and Data
- The "G" has become a marketing term
- 3.9G
  - First implementations declared not really 4G
  - Mobile WiMax (Sprint)
  - LTE (Long Term Evolution)
- Only real 4G is LTE advanced and mobile WiMaX advanced

- Requirements: 100Mbps for mobile, 1Gbps stationary (walking)
  Why is it harder for mobile?
- Packet switching – IPv6 based, not connection based
- OFDMA

Cellphone 5G

- Under development

WiMax

- IEEE 802.16
- Worldwide Interoperability for Microwave Access
- Fixed or mobile. Originally designed for “last mile” setup, (metropolitan area network) but used as 4G phone (mobile wi-max)
- Distance of miles
- Base station allocates a time slot, good for VOIP and

QoS

- Licenses spectrum from 2-11GHz and 10GHz-66GHz High frequency has more bandwidth, but blocked by obstacles
- can run in mesh mode where nodes can act as relays
- OFDM and OFDMA

WiMax mobile

- 802.16e-2005
- handoffs and roaming
- Lower freq, 2.3 - 2.5Ghz
- up to 75Mbps, can cover 30 mile radius
- soft and hard handoff

WiMax Scheduling

- Unsolicited Grant Service (UGS) – voip w/o silence suppression
- Real-time Polling Service (rtPS) – video, voip w silence suppression
- Non-real-time Polling (nrtPS) – web browsing
- Best Effort (BE) – e-mail, message based
- Extended Real-Time Polling (ertPS) – video, voip w silence suppression

LtE

- TODO?

Line Coding

- Goals of line coding:
  - prevent baseline wandering
  - eliminate DC components (waste energy)
  - self-synchronization: (Synchronization: what if send long stream of zeros)
  - error detection/correction
  - avoid noise/interference

Transmission Impairments

- Attenuation: gradual loss of energy. How to fix? Amplification
- Fading: time varying source of attenuation (varies with time, location, etc). Multipath fading (reflections), shadow fading (obstacle)
- Distortion: different frequency components have different propagation delay
- Interference: unwanted signals added to desired signal
- Noise: random fluctuations of an analog signal

- “white”, that is uniformly distributed
- “pink”, each octave has equal amount of energy
- Also red, brown(ian), blue, violet, grey, etc.

Coding

- Source Coding – reduce data needed to be send. Compression (JPEG, MPEG, audio, etc)
  lossy, lossless, discuss kinds

- Channel Coding – protect data through noisy medium, adds extra info. error correcting code, hamming codes, reed-solomon codes, turbo codes

- Line Coding – pulse modulation (PCM) to transmit binary signal

- PAM (pulse-amplitude modulation)
- PWM (pulse-width modulation)
- PCM (pulse-code modulation)
- PWM/PDM (pulse-width/duration modulation)

- PCM most popular because easier to pick on/off then to measure time or amplitude

- self-synchronization

Line Coding

- self-synchronization. Need to keep transmitter and receiver synchronized (why?) how, usually a certain number of 0/1 transitions, can resync on those
- signal-to-data ratio (SDR). data rate is number of data bits sent in second, signal rate is number of signal elements in a second (baud)
- unipolar signaling: 1 is positive voltage, 0 is ground
- polar signaling: 1 is positive volt, negative is negative

volt

- bipolar 1 is positive or negative volt, 0 is ground
- unipolar require more power, DC-unbalanced, not used much
- NRZ (non return to zero, return to zero mid-bit)
- NRZ-L (level) positive for 1, negative for 0
- NRZI, NRZ-M, NRZ-S a transition means change from 0s to 1s

NRZ-S (space) 1 means no change in signal, 0 means transition

- HLDC and USB are non-return-to-zero-space (NRZ-S) long strings of zeros (synchronization?) disks use RLL (coded to at least so many transitions), USB uses bit-stuffing (inserting extra bits)

- PRZ return to zero returns to zero halfway through bit. synchronized but at expense of half of bandwidth

- Manchester encoding

- AMI, alternate mark inversion, pseudoternary

Block Coding

- a smaller chunk of bits encoded with larger,
- 4B/5B: i.e. user 5B to encode 4B. Then if something goes wrong can no, also can send control info along. also can ensure that when grouped together the pattern has no more than three consecutive zeros
- 8B/10B widely used. PCI Express, firewire, serial ATA, DVI/HDMI, gigabit Ethernet. same number of 0s/1s for a data stream (charge building up?) maximum run

length

Modulation

- passband modulation. Convert digital signal to analog, then multiple by much higher carrier frequency.
- ASK amplitude shift keying
  usually two levels of amplitude, one for 0 one for 1
- FSK frequency shift keying – two distinct frequencies
  bandwidth concerns
- PSK phase shift keying – two phases, 0degree for 0 and 180deg for 1

- ASK is limited by noise (reduces amplification). FSK needs two freq, more complex. PSK considered better.
- QPSK (four phases)
- Differential phase shift keying (DPSK)
- QAM hybrid quadrature amplitude modulation – amplitude *and* phase

Multiplexing

- Most of the cost of a line is digging the cable. So avoid at all cost

- FDM (frequency division multiplexing). Multiple channels on same cable. AM radio analogy. 1MHz total bandwidth, but many channels within
  twelve 4kHz channels in 60-108kHz band. Some overlap (non-perfect filters) so noise can escape
  1G cellphone

- WDM (Wavelength division multiplexing) fiber – basically multiple colors down same fiber

- TDM (time division multiplexing)
  FDM is analog.
  T1 line – 1.544Mbps. PCM, 8-bit at 8000Hz (why?)
  24 channels, round robin
  56kbps (7bits*8Hz) plus 1 bit control
  GSM cellphone

- SS spread spectrum – spread across frequency band. pseudo-noise, barker and willard codes. harder to jam

3G cell phone

- DSSS (direct sequence SS)
  802.11b/g/n
- FHSS (frequency hopping SS) – hop among different frequencies, so if one blocked still eventually get through. best for short bursts, hard to synchronize when high-speed transmissions
  bluetooth
- SM (spatial multiplexing)
  802.11n, LTE, WiMAX

- STC (space time coding)
  802.11n,LTE,WiMAX

TDM encoding Tricks

- Differential pulse code modulation – trying to reduce bits. Assume amplitude not going to change more than +/-16 so only include difference.
- Four T1 lines into T2 line (6.312 Mbps)
- Seven T2 lines into T3 line (44.7 Mbps)
- Six T3 lines into T4 line (274 Mbps)