Wireless Networking

Low-Power Computing
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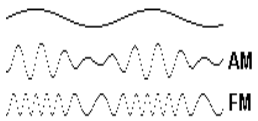
Projects!

- Start thinking!
- Start finding partners!
- Idea proto-list will be on Wiki after SIGCOMM deadline (by next Monday)
- Proposals will be due in about 1.5-2 weeks.

Wireless Background

- Digital signals sent in analog medium
- How to encode data?
  - Amplitude differences
  - Frequency differences
  - Phase differences



- Also called "X shift keying" - PSK, Q-PSK, FSK, etc. BPSK = "Binary Phase Shift Keying", QAM = "Quadrature Amplitude Modulation", etc.

Decibels

- Recall:
  - db = 10 $\log_{10}(P_1/P_2)$
- It's a relative value - power 1 is *x* db stronger than power 2...
- Can make absolute by using a reference point (decibel-watt -- power relative to 1W, etc.)

Capacity

- Recall Shannon
  - $C = B * \log_2 (1 + SNR)$
    B = bandwidth
- SNR? Signal to noise ratio.
- Noise??
  - Interference, etc;
  - Thermal noise in circuitry & environment

How we use the capacity

- AM - on/off? 4 levels? 8 levels? ("QAM") -- requires less noise to distinguish levels.
- How do we increase SNR?
  - Reduce noise: Better technology / lower noise circuitry
  - Increase signal: Higher power transmission
- Increase bandwidth (uses more spectrum...)
- Remember - Shannon is limit, takes cleverness to get near.

Energy vs. Bandwidth Efficiency

- Shannon again...
- $C < B \log_2 (1 + P / N_0 B)$
- Energy per bit = P / C
- Eb/N0 in dB = propto bits per Hz
  IN dB! ... in other words, exponential.
  technically: Eb/N0 > (2^(C/B) -)1 / (C/B)
  But at that point, who's counting?

Sad Reality: Fixed B

- In many apps, don't have luxury to trade bandwidth (spectrum) efficiency for energy efficiency
- There are practical challenges to wideband, but UWB is interesting for exactly this reason (Ouch: frequency-specific attenuation and shifting.)
- If you want higher rate, at some point, you boost the SNR. And you only get a log improvement in capacity from it, vs. a linear improvement with boosting B.

Next issue: Radiation pattern

- How do signals propagate?
  - In a wire: Linearly along the wire.
  - With a "perfect" isotropic antenna: In a sphere around the antenna.
  - Most of that energy does NOT go to the receiver...
  - With other antennas: Various patterns: donuts around antenna (dipole), more focused (parabolic; pringles can), etc.
- Path loss exponent - how much signal degrades with distance. Varies from 2 (free space) to 4 (earth loss)
- Consequence: Energy increases with ^2 - ^4 th power of distance. (!)

Making a transmitter

- Or - how to understand those weird diagrams in the papers...
- AM example: Local signal, say, 1Mhz
- Modulated onto carrier wave @ 5Ghz
  - LO provides that carrier
- Result: 5Ghz wave that varies in 1Mhz bumps (picture)

- Cabletron 802.11 (2Mbps) (old!)
  Tx: 1400 Rx: 1000 Idle: 830 Sleep: 130
- Enterasys 802.11 10Mbps (still old!)
  Tx: 750 Rx: 750mw Sleep: ~50
  (Estimates...)

Paper 1.

- Look similar to anything we've hit before? :)

Paper 2.

- Putting the network to sleep cannot be done unilaterally
  - "I want to send you a packet." "ZZZZ"
  - "Dude, I really want to send you a packet." "ZZZ".
  - "Ah, forget it."
  - "Hey, I wanted those packets!"