Cell Phone Working Knowledge

John Marsh
Telecommunications, SUNYIT
Why Learn About Cell Phones?

• Understanding technology is important!
Course Outline

• Two afternoons, 4 sessions
  – Day 1: Session 1 – Introduction and Overview
  – Day 1: Session 2 – Communications Basics
  – Day 2: Session 1 – The Phone
  – Day 2: Session 2 – The Network
Introduction and Overview

- Why learn about how cell phones work?
  - iPhone as motivation

- Communications Basics
  - Information
  - Transmitter
Cell Phones – Names around the world

• “Cell phone”
• “Mobile phone”
• “Hand phone”
• “GSM”
• “Cellular”
• “Pocket phone”
• “Travel phone”
• “Wonder phone”
• “portable”

http://en.wikipedia.org/wiki/Mobile_phone_terms_across_the_world

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Example: The iPhone

• The “hottest” cell phone out there these days
• The 3G version was just released July 2008
• What’s inside?
Inside the iPhone

• Several detailed dissections available online!

http://www.anandtech.com
iPhone Circuitry

- What is all this electronics doing?
- What technical advances make today’s cell phones work so much better than yesterday’s?

http://arstechnica.com/

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Communications Basics

• Understanding the basics of communications helps to understand everything else about the phones and the networks
Communications Basics

• Basic communications model:
  – Transmitter + Channel + Receiver

• This model fits a wide variety of examples:
  – Telephones
  – Computers on the internet
  – Writing data to a CD, then reading it later
Information

- Types of information:
  - Analog
  - Digital

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Analog Information

- Analog Data – continuously varying data values
  - Sound – speech, music
  - Photo on film
  - Video on film
  - Temperature over a 24 hour period
Analog Data: WAVE File Example

• “This is a test”
• Duration: 1.2 s, File size: 500 kB

http://audacity.sourceforge.net/

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WAVE File Example

• View of WAVE file using a hex editor
Digital Information

- Digital – data take on only certain values
  - Data values drawn from an *alphabet*
    - All alphabets can be reduced to binary values
  - Examples:
    - Text
    - Digitized sound, images, or video

```
100100110100111001111101001111010011000011101100
```
ASCII Text Standard

• ASCII is a standard way to represent text as numbers

• Numerical value can be expressed in *decimal* or *binary* formats

• ANY alphabet can be reduced to BINARY – “base 2”

```
72 = 1*64 + 0*32 + 0*16 + 1*8 + 0*4 + 0*2 + 0*1
```

```
<table>
<thead>
<tr>
<th>Binary</th>
<th>Oct</th>
<th>Dec</th>
<th>Hex</th>
<th>Glyph</th>
<th>Binary</th>
<th>Oct</th>
<th>Dec</th>
<th>Hex</th>
<th>Glyph</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 0000</td>
<td>100</td>
<td>64</td>
<td>40</td>
<td>@</td>
<td>110 0000</td>
<td>140</td>
<td>96</td>
<td>60</td>
<td>`</td>
</tr>
<tr>
<td>100 0001</td>
<td>101</td>
<td>65</td>
<td>41</td>
<td>A</td>
<td>110 0001</td>
<td>141</td>
<td>97</td>
<td>61</td>
<td>a</td>
</tr>
<tr>
<td>100 0010</td>
<td>102</td>
<td>66</td>
<td>42</td>
<td>B</td>
<td>110 0010</td>
<td>142</td>
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<td>62</td>
<td>b</td>
</tr>
<tr>
<td>100 0011</td>
<td>103</td>
<td>67</td>
<td>43</td>
<td>C</td>
<td>110 0011</td>
<td>143</td>
<td>99</td>
<td>63</td>
<td>c</td>
</tr>
<tr>
<td>100 0100</td>
<td>104</td>
<td>68</td>
<td>44</td>
<td>D</td>
<td>110 0100</td>
<td>144</td>
<td>100</td>
<td>64</td>
<td>d</td>
</tr>
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<td>100 0101</td>
<td>105</td>
<td>69</td>
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<td>E</td>
<td>110 0101</td>
<td>145</td>
<td>101</td>
<td>65</td>
<td>e</td>
</tr>
<tr>
<td>100 0110</td>
<td>106</td>
<td>70</td>
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<td>F</td>
<td>110 0110</td>
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<td>f</td>
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<td>100 0111</td>
<td>107</td>
<td>71</td>
<td>47</td>
<td>G</td>
<td>110 0111</td>
<td>147</td>
<td>103</td>
<td>67</td>
<td>g</td>
</tr>
<tr>
<td>100 1000</td>
<td>110</td>
<td>72</td>
<td>48</td>
<td>H</td>
<td>110 1000</td>
<td>150</td>
<td>104</td>
<td>68</td>
<td>h</td>
</tr>
</tbody>
</table>
```

http://en.wikipedia.org/wiki/Ascii

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ASCII Text Example

- Text file size: 15 B

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ASCII Text Example

- View of the text file using a “hex editor”

http://www.pspad.com/
Network Evolution: Analog to Digital

• Bell Telephone System pre-1970’s:
  – Voice network: used analog transmission

• Starting in the 1970’s:
  – Entire voice network, except for the “local loop”, transitioned to a digital system
  – Data communications networks connecting computers began to proliferate

• Today:
  – Standard “local loop” phone line (i.e., from your house to your local central office) is still analog!
  – Many customers buy data communication links for home Internet access: cable modem or DSL
  – Many customers moving to using data communications links for voice (“triple-play services”) or to using cell phones for home phone service.
  – Corporate users and home users moving towards VoIP – voice directly onto the Internet!
Why Digital?

1. Noise buildup on analog lines can be eliminated when digital signals are regenerated
2. Analog signals can be converted to digital easily
3. Digital signals can be compressed
4. Often our communications needs involve digital data from computers
5. Can provide privacy: Easy to encrypt digital data
Noise Buildup on Analog Lines

• Two facts:
  – Every transmission line has LOSS – the signal gets weaker the farther you go
  – Every transmission line adds NOISE to the signal

• Analog transmission over a short distance is successful

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![Analog Transmission: Short Distance](image)

- **Tx**: Transmitter
- **Rx**: Receiver
- **Strong Signal**
- **Weaker Signal + Weak Noise**

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Noise Buildup on Analog Lines

• Analog transmission over a long distance requires AMPLIFIERS
  — BUT the amplifier amplifies the noise also, leading to a buildup of noise, which is eventually stronger than the signal itself!

Analog Transmission: Long Distance

<table>
<thead>
<tr>
<th>Signal Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weak Signal + Weak Noise</td>
<td>Strong Signal + More Noise</td>
</tr>
<tr>
<td>Weak Signal + More Noise</td>
<td>Strong Signal + Strong Noise</td>
</tr>
<tr>
<td>Weak Signal + Strong Noise</td>
<td>Strong Signal + Strong Noise</td>
</tr>
</tbody>
</table>

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Digital Signal Regeneration

• Digital signals are sent as binary data
  – Recall ANY alphabet can be reduced to binary 0s and 1s

• Even digital signals get noise added to them
  – BUT as long as the noise is smaller than the difference between a 0 and a 1, the regenerator can recreate the signal without any noise in it
Digital Signal Regeneration

- Example: Binary signal of the word “Digital” using ASCII representation → 7 letters * 7 bits/letter = 49 bits
- Most bit values are not destroyed by added noise
- Sampling:
  - Signal > 0.5 → bit = 1; Signal < 0.5 → bit = 0

ASCII text: 'Digital'

Original digital signal with noise level 0.15
Digital Signal Regeneration

• Regeneration steps:
  1. Sampling incoming signal
  2. Creating new outgoing signal

Histogram showing 1 bit errors out of 49 bits, or 2.04 %

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Converting Analog to Digital

• Process performed by a ADC (Analog to Digital Converter)
• The analog signal is sampled
• Quality of digital signal determined by:
  1. Sampling rate
  2. Sampling depth
Sampling Rate

• Analog signals are converted to digital by sampling the signal at equally spaced time intervals
  – Higher sample rate $\rightarrow$ better quality reproduction of original signal
  – Higher sample rate $\rightarrow$ more data, larger digital file

• Sampling rate measured in Hertz (Hz)
  – 1000 samples/sec = 1000 Hz sampling rate
Example: Decreased Sample Rate

- Blue: original analog signal
- Red: high quality sampling

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Example: Decreased Sample Rate

- Blue: original analog signal
- Red: Sample rate decreased one step
Example: Decreased Sample Rate

- Blue: original analog signal
- Red: Sample rate decreased two steps
Example: Decreased Sample Rate

- Blue: original analog signal
- Red: Sample rate decreased three steps
Sampling Depth

• Value of each sample can only take on a certain number of values
  – Higher sample depth → better quality reproduction of original signal
  – Higher sample depth → more data, larger digital file

• Number of values is usually a power of 2
  – $2^8 = 256$ → “8-bit sample depth”
  – $2^{16} = 65,536$ → “16-bit sample depth”

• Note: number of bits in sampling depth also equals number of bits needed to specify one sampled value

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Example: Decreased Sample Depth

- Blue: original analog signal
- Red: high quality sampling
Example: Decreased Sample Depth

- Blue: original analog signal
- Red: Sample depth decreased one step
Example: Decreased Sample Depth

- Blue: original analog signal
- Red: Sample depth decreased two steps

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Example: Decreased Sample Depth

- Blue: original analog signal
- Red: Sample depth decreased three steps
Digital Audio Quality

• Traditional standard for digitized voice:
  – 8-bit sample depth (i.e., 8-bits are required to specify the sampled value)
  – 8 kHz = 8000 samples per second
  – Data Rate:
    \[\left(\frac{8 \text{ bits}}{\text{sample}}\right) \left(\frac{8000 \text{ samples}}{\text{second}}\right) = 64000 \frac{\text{bits}}{\text{second}} = 64 \text{kbps}\]

• Traditional standard for CD quality audio (“hi-fi”):
  – 16-bit sample depth, 44.1 kHz sample rate, 2 channels
  – Yields a data rate of about 700 kbps
  – For a 5 minute song: 50 MB/song (WAV file)
  – 1 CD: holds 700 MB, or about 14 songs
Demonstrate Digital Audio

- <<Matlab demos of sampling rate and sampling depth effects on sound quality>>
Compressing Digital Signals

• Redundancy in digital data can be eliminated, yielding a smaller file size
  — Lossless compression: allows original data to be recovered
  — Lossy compression: throws away information not noticed by humans

• Compression in computers and handheld devices provided by CODECs
  — CODEC = coder/decoder
  — Computations can be handled by software, but it is much faster if it is in hardware – i.e., there is a special computer chip that does the calculations
Compressing Digital Signals

• For cell phones: advanced voice CODECs are used to compress your voice
  – Hardware compression/decompression used
  – Variety of voice CODECs available for use by different phones and cellular networks

• Specs include:
  – Bit rate – measured in kbps (traditional standard telephone voice 64 kbps)
  – Perceptual voice quality (Mean Opinion Score – MOS)
Voice CODECs

- A feature of modern voice CODECs is “Silence Suppression”
  - Saves bandwidth by recognizing pauses in voice, and stops sending data
  - Sometimes makes it sound like you’ve lost the connection
  - Often causes choppy “on hold” music

<table>
<thead>
<tr>
<th>Voice Codecs</th>
<th>Bit Rate (kbps)</th>
<th>Codec Sample Size (Bytes)</th>
<th>Codec Sample Interval (ms)</th>
<th>Mean Opinion Score (MOS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>G.711</td>
<td>64 kbps</td>
<td>80 Bytes</td>
<td>10 ms</td>
<td>4.1</td>
</tr>
<tr>
<td>G.726</td>
<td>32 kbps</td>
<td>20 Bytes</td>
<td>5 ms</td>
<td>3.85</td>
</tr>
<tr>
<td>G.728</td>
<td>16 kbps</td>
<td>10 Bytes</td>
<td>5 ms</td>
<td>3.61</td>
</tr>
<tr>
<td>G.729</td>
<td>8 kbps</td>
<td>10 Bytes</td>
<td>10 ms</td>
<td>3.92</td>
</tr>
<tr>
<td>G.723.1</td>
<td>6.3 kbps</td>
<td>24 Bytes</td>
<td>30 ms</td>
<td>3.9</td>
</tr>
<tr>
<td>G.723.1</td>
<td>5.3 kbps</td>
<td>20 Bytes</td>
<td>30 ms</td>
<td>3.8</td>
</tr>
</tbody>
</table>

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Compressing Digital Signals

• Familiar examples of data compression:
  – ZIP, StuffIt for any computer file
  – JPEG, GIF for pictures
  – MP3, WMA for audio files
  – MPEG, QuickTime for movies

• Recent advances in video compression (in particular “H.264”) have enabled YouTube and Internet TV
Streaming Media Bitrates

- iTunes radio shows the bit rate available for each station
  - Higher bit rate stations sound best
Voice Coding Examples

• <<online demo of CODEC sound files>>
Data Encryption

• Encryption makes signals look random
• Encrypted data can only be read if you have the “key”
• Simplest method:
  1. Choose a random starting “key” value
  2. Use your “key” to seed a random number generator to generate random bits
  3. Add your message bits to the random bits
  4. Only someone else with the key can decrypt the message, by generating the same random bit sequence

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• The transmitter prepares information for and puts a signal on the channel
The Transmitter

• Main functions of the Transmitter:
  – Signal processing to prepare the data for the modulator
  – Modulates a carrier wave
  – Filters the modulated wave
  – Amplifies the carrier wave as needed
  – Launches the modulated carrier wave onto/into the transmission medium
Transmitter Block Diagram

- Simplified block diagram

- Information

- Transmitter

- Signal Processing:
  - ADC
  - Compression
  - Scrambling
  - Line Coding
  - FEC

- Modulator

- Filter

- Amplifier

- Antenna

- Channel

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Transmitter Signal Processing

- Analog to Digital Conversion
  - Already covered
- Compression
  - Already covered
- Scrambling
  - Helps protect against burst errors
- Forward Error Correction (FEC)
  - Adds redundancy to data to make it robust against bit errors

Signal Processing:
- ADC
- Compression
- Scrambling
- FEC

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Data Scrambling

• Scrambling is used to deal effectively with burst errors
  – Burst errors are bit errors occurring sequentially due to a “noise event” – e.g., a lightening strike
  – Unfortunately are very common

• Spreads out the effect of a burst error by spreading out the data

• Used on CDs so that a scratch on the plastic doesn’t cause a noticeable “skip”
Data Scrambling

• Example:

111111112222222233333333444444445555555566666666

SCRAMBLED

123456123456123456123456123456123456123456

DESCRAMBLED

111111112222222233333333444444445555555566666666

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Data Scrambling

• Example:

1111111122222222233333333344444444555555555666666666

SCRAMBLED

123456123456123456123456123456123456123456

BURST ERROR

123456123456123456123456123456123456

DESCRAMBLED

110111112202222230033333404444445055555556066666666

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Line Coding

- Line coding techniques describe how the 0s and 1s of a binary sequence are represented in the signal.
- Various flavors:
  - NRZ: nonreturn-to-zero
  - NRZI: NRZ Inverted
  - Etc.
Forward Error Correction

• FEC makes the stream of data resistant to bit errors caused by noise or other factors

• Simplest type of FEC: Redundant bits
  – Repeat each bit 3 or more times
  – Receiver then decides on what bit was sent using a “voting scheme” – whichever bit value has 2 out of 3 wins
  – This scheme is OK if bit errors are not coming in bursts and it two bit errors in a row are highly unlikely
FEC Example

011010011101001111

FEC

0001111110001110000001111111000111000000111111111111

NOISE

0001011110011110000000111011110000111010000101111111010

RECEIVER VOTE

0001011110011110000000111011110000111010000101111111010

0 0 1 1 0 0 0 1 1 1 1 0 1 1 1 1 0 0 1 1 1 0 1 0 0 0 0 1 1 1 1 1 0 0 1 1 0
Modulation

• Modulation: Imparting the data signal onto a carrier wave that travels through the channel

• Familiar communications channels:
  – copper wire → carrier wave is an AC current
  – optical fiber → carrier wave is a light beam
  – Air → carrier wave is a radio or microwave signal

• Radio waves have frequencies in the range 10 kHz – 100 GHz
Radio Frequency Transmission

• Familiar uses of radio transmission:
  – AM/FM radio broadcast
  – TV broadcast
  – Satellite feeds for commercial distribution systems
  – Consumer satellite TV/data systems
  – Wireless entry systems
    • car keys, garage doors, etc.
  – Cell phones
  – Wireless computer networks
  – Personal area networks (Bluetooth, Zigby, etc)
Radio Frequency Transmission

• Broadcast radio carrier frequencies:
  – “AM band” – 530 – 1710 kHz
  – “FM band” – 88 – 108 MHz
  – Various shortwave bands
Radio Frequency Transmission

• Broadcast TV carrier frequencies:
  – VHF (Very High Frequency): 30 – 300 MHz
  – UHF (Ultra High Frequency): 300 MHz – 3 GHz

• TV channels in US:
  – VHF Ch 1 - 6 occupy 44 – 88 MHz
  – VHF Ch 7 – 13 occupy 174 – 216 MHz
  – UHF Ch 14 – 83 occupy 470 – 890 MHz
Digital TV and Feb 17, 2009

• Standard broadcast AM/FM radio and TV modulates an analog signal onto the carrier wave

• Digital radio in the US:
  – XM/Serius Radio: via satellite transmission
  – HD Radio: terrestrial broadcast as a “side channel” to normal FM

• Digital TV in the US:
  – Feb 17, 2009: “analog switchoff” – no more analog TV broadcast
  – Many cable systems will still send TV as an analog signal, on coax or fiber, as part of “triple play” services (voice/video/data)
Modulation

• Analog signals modulated onto carrier waves
  – AM – Amplitude modulation
  – FM – Frequency modulation

• Digital signals modulated onto carrier waves
  – ASK – Amplitude shift keying
  – FSK - Frequency shift keying
  – PSK – Phase shift keying
  – QAM – Quadrature amplitude modulation
ASK Modulation

- Digital 0s and 1s change the amplitude of the carrier wave
  - The scheme illustrated is called OOK (On-Off Keying)
FSK Modulation

- Digital 0s and 1s change the frequency of the carrier wave
  - Less susceptible to noise than ASK
PSK Modulation

- Digital 0s and 1s change the phase of the carrier wave
  - The scheme illustrated is called Binary Phase Shift Keying (BPSK)
Modulation

• << Matlab demo of ASK, FSK, and PSK modulated ASCII text>>
A Note About the Demos

• Note: we modulated an audio carrier in these examples
  – In wireless communications we modulate RF (Radio Frequency) carriers, which operate at a much higher frequency
  – The ratio of frequencies is roughly equal to the ratio of information carrying capacities
    • Audio: typically 5kHz
    • RF: typically 1 GHz
    • Ratio: 200,000!
Filtering and Amplification

• Once the carrier wave has been modulated, it is filtered to remove unused “sidebands” that result from the modulation process

• Before sending the signal to the antenna, it is amplified using an RF (radio frequency) power amplifier

• Finally, this amplified signal is sent to an antenna to be transmitted through the air!
Antennas

• What a variety...
Antennas

• Simplest case: a single straight piece of metal hooked to the amplifier output
• Antennas used for both transmit and receive
• Omni-directional antennas: radiate and receive signals to/from all directions equally
• Directional antennas: have a preferred direction
The Wireless Channel

- The wireless channel = the AIR
  - Actually includes the air, the fog, the rain, the layers of the atmosphere, the ground, and all types of obstacles (foliage, buildings, cars, people, etc.)
The Wireless Channel

• The “air channel” is characterized by how radio waves propagate
  – Radio wave propagation is complex!

•
The Electromagnetic Spectrum

- Short wavelength part of EM spectrum: visible light, invisible light, x-rays, ionizing radiation

Frequency | Wavelength
--- | ---
Gamma-rays | 0.1 Å
X-rays | 1 Å
Ultraviolet | 0.1 nm
Visible | 1 nm
Near IR | 100 nm
Infrared | 1 μm
Thermal IR | 10 μm

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The Electromagnetic Spectrum

• Radio and microwaves are long wavelength portion of the EM spectrum
Radio Wave Propagation

• Radio waves are attenuated as they propagate
  – They lose strength with distance
  – In general, longer wavelengths propagate farther with a given transmitter power (measures in Watts)

• Three main modes of propagation
  1. Ground wave
  2. Sky wave
  3. Line-of-sight
Radio Wave Propagation

1. Ground Wave Propagation
   - Very long wavelengths $> 150$ m are guided around the earth by the atmospheric layers
   - AM radio

2. Skywave Propagation
   - Wavelengths between 10m and 150 m bounce off the Ionosphere – can travel around the earth at night
   - International and short wave radio

3. Line-of-Sight Propagation
   - Wavelengths shorter than about 10 m
   - FM radio, TV, and microwave radio

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Radio Wave Propagation

• Radio waves bounce off objects and layers of the atmosphere and interfere with each other
  – Constructive interference
  – Destructive interference

• Interfering signals give rise to multipath fading
  – Two or more copies of the signal arrive at different times
    • Familiar as ghosting on TV sets when using air antenna
  – When these signals add up out of phase, you have “a fade”
  – Fading depends on position in space – can change dramatically over a distance of about half a wavelength
    • Familiar with FM radio at red light: inch forward a few inches and you get out of the fade
Day 1: Session 2 – The Phone

- Review of yesterday
- Cell phones
- Cell phone networks
Review

• Session 1, Part 1:
  – Communication system overview
  – Information: Analog and Digital
  – Evolution of the Network
Review

• Session 1 Part 2:
  – Why digital?
    1. **Regeneration**: Digital signals can be regenerated to avoid noise buildup.

    ![Graph of Original Digital Signal with Noise](image)

    2. **ADC**: Analog to digital conversion (ADC): sample rate, sample depth.

    ![Graph of ADC](image)

    3. **Compression**: Digital signals can be compressed. Lossy compression used for analog data like photos, music and video.

    ![Graph of Compression](image)

    4. **Encryption**: Cryptography works on digital data.

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Review

• Session 1, Part 3: Receivers

Transmitter

Signal Processing:
• ADC
• Compression
• Scrambling
• Line Coding
• FEC

Modulator

Filter

Amplifier

Antenna

Channel

Information

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Today

• Cell Phones
• Cell Phone Networks
• Cell Phone Operators
• Cell Phone Teardowns

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Cell Phone Components

- Radio Transceiver (Transmitter/Receiver)
- Signal processing chips
- Control electronics
- Battery
- Buttons
- Screen
- Microphone
- Speaker
- Camera
- Antenna
- Input/Output connectors
Example: The iPhone

• High end cell phone – called a “smartphone”!
• Lots of functionality
  – Cellular phone
  – Music playback
  – Mobile web
  – WiFi web access
  – Location services
  – Email
  – Chat

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Mobile Phone Manufacturers

• Handset manufacturers:
  – Nokia: 40%
  – Samsung: 14%
  – Motorola: 14%
  – Sony Ericsson: 9%
  – LG: 7%

http://en.wikipedia.org/wiki/Mobile_phone

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Mobile Phone Batteries

• Nickel metal-hydride (NiMH)
  – 2-3X capacity as NiCd batteries
  – Energy per weight: 70 W·h/kg
  – Not used in cell phones any more

• Lithium-Ion (Li-Ion)
  – Energy per weight: 160 W·h/kg
  – Very popular!

• Lithium-polymer
  – Newest technology!
  – Energy per weight: 130-200 W·h/kg
  – Advantage over Li-Ion is ability to be reshaped to fit non-rectangular spaces

http://en.wikipedia.org
Battery Guidelines

- Tips for prolonging battery life:
  - Nickel metal-hydride (NiMH)
    - Frequent “deep cycle” needed: full discharge/charge
  - Lithium-Ion (Li-Ion) and Lithium-polymer
    - No deep cycle
    - Charge often
    - Don’t let sit unused for too long
Mobile Phone Displays

• Usually LCDs (Liquid Crystal Displays)
  – Use a liquid crystal whose molecules line up when a small voltage is applied
  – Lined up molecules only allow certain polarization of light to pass
  – Electrodes placed on pixels
  – Placing LCD panel between two polarizing sheets with a mirror in the back creates the display
  – No voltage: Mirror reflects light - light
  – Voltage: No light makes it to the mirror – dark

http://en.wikipedia.org/wiki/Lcd_display

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Mobile Phone Displays

- LCD (Liquid Crystal Display)
- TFT-LCD (Thin Film Transistor)
  - Provides an “active matrix”
  - Also used in TVs, flat panel displays
  - Usually provide 16-bit color ($2^{16} = 65535$ colors)
- <<Demo: Wikipedia page on LCD Displays>>
Mobile Phone Specifications

• Online resources for mobile phone specs and search:
  – [www.phonescoop.com](http://www.phonescoop.com)
    • GO to phone finder
    • Click on “Show All Options” if you want to search by manufacturer
    • Click on the “FCC ID” spec to get photos of the phone taken apart!
Cellular Network History

- **First generation system:**
  - AMPS – Analog Mobile Phone System
  - Analog transmission, lots of limitations
- **Second generation (2G) systems:** mostly voice
  - TDMA flavor: “GSM”
  - CDMA flavor: “CDMA-one”
- **Third generation (3G) systems:** full data network
  - TDMA flavor: “UMTS”
  - CDMA flavor: “CDMA2000”
- **Fourth generation (4G) systems:** FAST data network, part of the Internet
  - 3GPP LTE (Long Term Evolution)
  - WiMax
Cellular Network Operation

- Cell towers arranged in a hexagonal grid for complete area coverage
  - Shows cell tower locations on Google maps

T. Dean, “Guide to Telecommunications”, Thompson
2008 John A. Marsh, SUNYIT
Frequency Reuse in Cells

- Frequency plans determine level of interference

T. Dean, “Guide to Telecommunications”, Thompson
2008 John A. Marsh, SUNYIT
Cellular Phone Networks

- Base stations connected to MTSO (Mobile Telephone Switching Office), then to telephone network (Local Exchange Carrier Central Office)

T. Dean, “Guide to Telecommunications”, Thompson
2008 John A. Marsh, SUNYIT
Cellular Network Connections

- MTSOs talk to each other using the public telephone network

T. Dean, “Guide to Telecommunications”, Thompson
2008 John A. Marsh, SUNYIT
Multiple Access Technologies

- **FDMA** – Frequency Division Multiple Access
  - Each user gets a frequency channel
  - Used in original analog cellular networks
- **TDMA** – Time Division Multiple Access
  - Each user gets a timeslot using a shared narrow frequency band
- **CDMA** – Code Division Multiple Access
  - Users share wide frequency band
  - Helps prevent multipath fading effects
CDMA Frequency Sharing

• Online info at www.cdg.org
  – Technology, → CDMA Technology Resources, →
    Welcome to the World of CDMA, → CDMA Revolution
Major Cellular Networks

- Verizon: CDMA2000
- AT&T: GSM
- Sprint/Nextel: CDMA2000
- T-Mobile: GSM
- Alltel: CDMA20

Listings at:

Also see: [http://www.cdg.org/worldwide/index.asp](http://www.cdg.org/worldwide/index.asp)
TDMA vs CDMA

- TDMA
  - See www.3gamericas.org

- CDMA
  - See www.cdg.org
Verizon Coverage
Verizon Coverage

Select Coverage Type

- **Voice & Messaging**
  - Includes:
    - Voice Calls
    - Text Messaging

- **Voicemail**
  - Includes:
    - Mobile TV

- **Enhanced Services**
  - Includes:
    - NationalAccess
    - Push to Talk
    - Mobile Email
    - Picture/Video Messaging
    - Mobile Web
    - VZNavigator
    - Call Forwarding

- **Broadband & V CAST**
  - Includes:
    - BroadbandAccess
    - V CAST

- **Prepay**
  - Includes:
    - Inpulse

Map Legend:
- Green: Enhanced Services
- Green: Extended
- Green: Enhanced Services
- Green: Roaming
- No Coverage

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Verizon Coverage
Verizon Coverage in NY
Verizon Coverage in NY

Select Coverage Type

- **Voice & Messaging**
  Includes:
  - Voice Calls
  - Text Messaging

- **V CAST Mobile TV**
  Includes:
  - Mobile TV

Enhanced Services
Includes:
- NationalAccess
- Push to Talk
- Mobile Email
- Picture/Video Messaging
- Mobile Web
- V7 Navigator
- Checkpoint

Broadband & V CAST
Includes:
- broadbandAccess
- V CAST

Prepay
Includes:
- Impulse

Map Legend
- Broadband & V CAST
- Enhanced Services
- Extended Enhanced Services
- No Coverage

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AT&T

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Cell Phone Teardown

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Apple iPhone Teardown

• Step by step...

http://www.anandtech.com

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Apple iPhone Teardown

http://www.anandtech.com

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Apple iPhone Teardown

• Camera

http://www.anandtech.com

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Apple iPhone Teardown

• The screen

http://www.anandtech.com
Apple iPhone Teardown

- Battery
- Boards
- Casework

http://arstechnica.com/

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Apple iPhone Teardown

- Main processing board

http://arstechnica.com/

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Apple iPhone Teardown

- Main processing board

Apple branded ARM Processor - Possibly Samsung 6C36400 or S5L8900. ARM1176 Series.

Wolfson Audio Processor

Samsung 4GB Flash Memory

Unknown Apple-branded chip

http://arstechnica.com/

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Apple iPhone Teardown

- Daughter board

http://arstechnica.com/

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Apple iPhone Teardown

• Daughter board

Intel Wireless Flash Memory + 8-Mbit SRAM. Similar to 38F1020W0Y7Q1

CSR Bluetooth

Skyworks GSM/EDGE power amplifier

Infineon Multimedia Engine (S-GOLD2) with advanced EDGE modem functionality.

Marvell WiFi chip (802.11b/g)

http://arstechnica.com/

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THANKS!
I hope you enjoyed the course!

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