



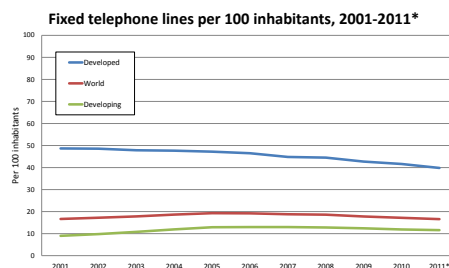
University of
Massachusetts
Amherst

Lecture 3–Wireless Communication

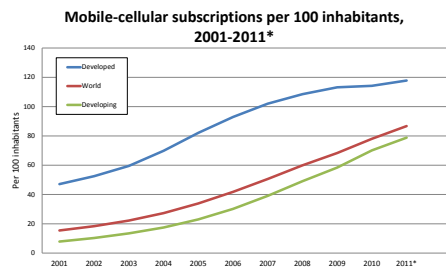
ECE 197SA – Systems Appreciation

Cell Phone

- Cell phone (vs. landline)
 - Mobile wireless access to telephone network
- Extremely widely used
 - 4.6 billion subscribers worldwide
- What interesting trend can be observed?
 - (from International Telecommunication Union)



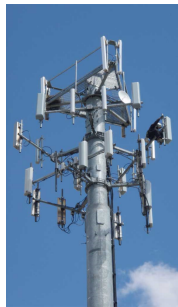
* Estimate.
The developed/developing country classifications are based on the UN M49, see:
<http://www.itu.int/ITU-D/ict/definitions/regions/index.html>
Source: ITU World Telecommunication /ICT Indicators database



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Cell Phones Everywhere

- Cell phones are replacing fixed phones
- Infrastructure more easily deployed
- Important to remember: recycling of old phones



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Cell Phone

- How does it work?
 - How does it communicate wirelessly?
- First: How does a wired telephone network work?
 - What happens when you make a phone call?

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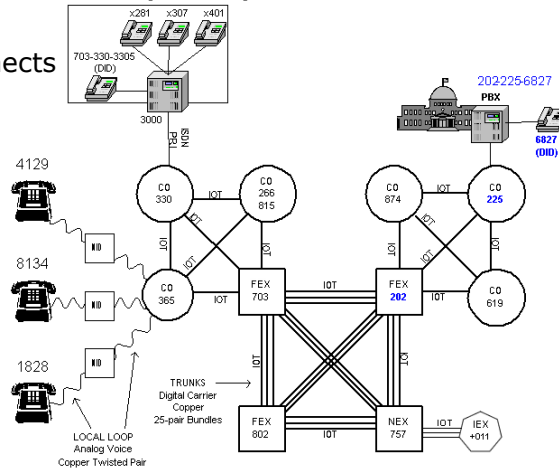
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Telephone Network

- Plain Old Telephone Service (POTS)

- Central office types

- Local exchange connects local subscriber
- Foreign exchange connects beyond local calling area
- National exchange connects long-distance providers
- International exchange connects to other countries



- Communication

- Local loop is analog
- Most links digital (which requires sampling!)

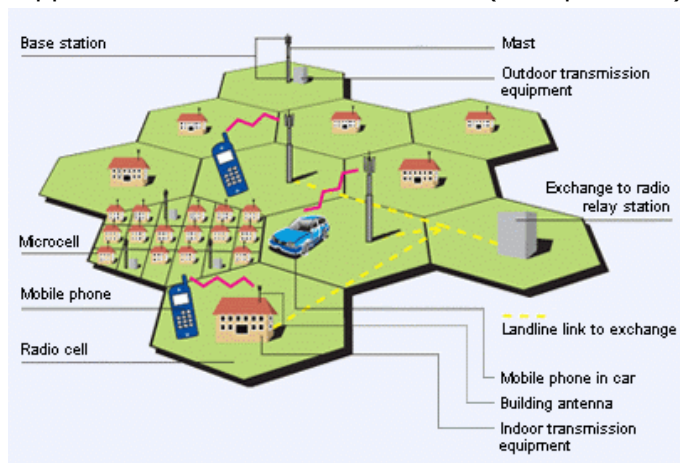
- How do DSL and VoIP relate?

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Cellular Telephone Network

- Cellular network extends telephone network
 - Support for mobile wireless devices ("cell phones")



- How does the network direct a call to a cell phone?

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Side Note

- Cell phone system does not involve satellites!
 - Satellite phones exist, but are not common



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Cellular Telephone Network

- How does the network direct a call to a cell phone?
 - Mobile users move around...
- Turning on cell phone
 - Cell phone registers with base station
 - Information recorded at Mobile Telephone Switching Office (MTSO)
- Calling cell phone
 - Call directed to MTSO
 - MTSO redirects call to cell recorded in database
- Moving between cells
 - MTSO monitors signal strength
 - MTSO coordinates "handoff" to new cell
- Many more details in practice
- Important note: no satellites involved!
 - Satellite phones exist, but are rarely used

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Cell Phone Standards

- First generation (1G):
 - Analog, FDMA,
 - Frequencies: 450/900 MHz
- Second generation (2G):
 - Digital, better sound quality, more secure, data service
 - Frequencies: 900/1800 MHz (Europe), 850/1900 MHz (US)
 - » Time-division multiple access (TDMA) (GSM, Europe)
 - » Code-division multiple access (CDMA) (CDMA, US)
- Third generation (3G)
 - Higher bandwidth, simultaneous data and voice
 - Many standards (UMTS, EDGE, CDMA2000, ...)
- Fourth generation (4G)
 - Higher bandwidth, mobile broadband
 - Can be all-IP based
- Large number of standards and details

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Wireless Communication

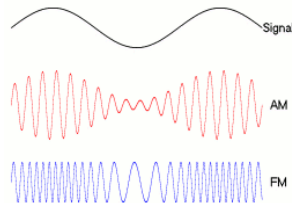
- How to get analog signal (or binary data) from handset to cell tower?

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Wireless Communication

- How to get analog signal (or binary data) from handset to cell tower?
- Sender modulates signal
 - Overlay signal (or coded data) onto baseband signal
- Example:



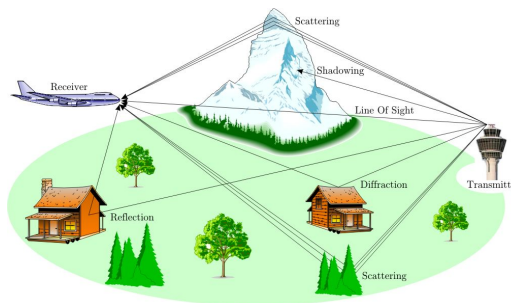
- Receiver demodulates signal
 - Retrieves original signal (incl. potential errors)
 - Interprets signal (or binary data)
- Amplification before transmitting and after receiving
- What could go wrong?

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Transmission Problems

- Attenuation
 - Loss of signal intensity with distance
 - When time-dependent: "fading"
- Noise
 - Fluctuations in signal
- Interference
 - RF interference from electromagnetic source
 - Other transmitter on same (or neighboring) channel
 - Multipath interference
- Received signal may be different from sent signal
 - Digital data transmission: bit errors



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Error-Correcting Codes

- Simple error correction code
 - Repeat each bit odd number of time (3, 5, 7, ...) [why odd?]
 - Use "majority vote" to determine original bit
- Example:
 - 3-bit sequence: 101
 - 3-bit sequence with error correction code: 111000111

Activity

- Coin toss
 - Heads: correct transmission of bit
 - Tails: bit error
- Transmit 3-bit sequence with error correcting code



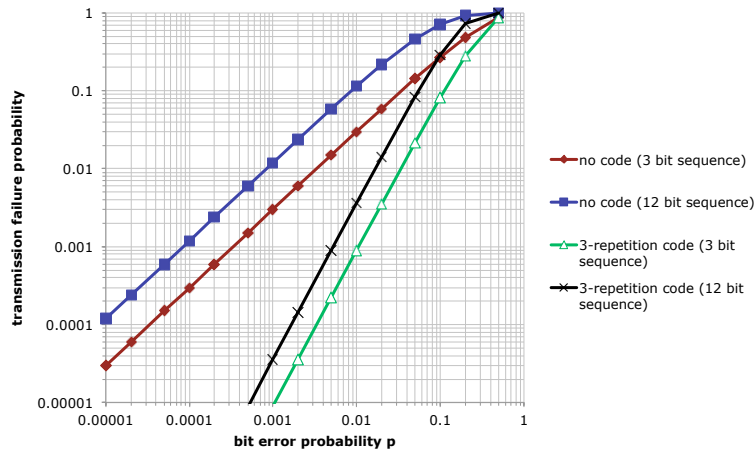
First bit:	First bit:	First bit:
First toss:	First toss:	First toss:
Second toss:	Second toss:	Second toss:
Third toss:	Third toss:	Third toss:

Error-Correcting Codes

- What is the probability of transmission error
 - Assume: bit error probability p
 - Length of transmitted sequence n
- No code:
 - Success needs n consecutive error-free bit transmissions
 - » Probability: $(1-p)^n$
 - Anything else is failed transmission
 - » Probability: $1-(1-p)^n$
- With code (3 repetitions per bit)
 - Successful transmission of single bit
 - » No error: $(1-p)^3$
 - » One error: $p(1-p)^2$ (3 possible positions, can be corrected)
 - Successful transmission of sequence
 - Probability $((1-p)^3+3p(1-p)^2)^n$
 - Anything else is failed transmission
 - » Probability: $1-((1-p)^3+3p(1-p)^2)^n$

Error-Correcting Codes

- Example
 - No code vs. 3-repetition code
 - 3-bit sequence and 12-bit sequence



Courses in ECE Curriculum

- Communication
 - ECE 563 – Communication and Signal Processing
 - ECE 564 – Digital Communication Systems
 - ECE 645 – Digital Communication
- Probability
 - ECE 314 – Intro Probability and Random Processes
 - ECE 603 – Probability and Random Processes
- Networking
 - ECE 374 – Computer Networks and the Internet
 - ECE 671 – Computer Networks

Upcoming...

- Next Wednesday: Computers
 - Microprocessors
- Moodle quiz

