ECE 250 - Wireless Communication and Networking
Fall 2013
Professor Yasamin Mostofi
Lecture#1
Outline

- Course Information
- Course Syllabus
- The Wireless Vision
- Current and Emerging Wireless Systems
- Technical Challenges
- Spectrum Regulation
Course Information

- **Instructor:** Yasamin Mostofi
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  - Office: HFH 5121
  - Office hours: Mondays 4-5pm

- **Class WebPage:**
  [http://www.ece.ucsb.edu/~ymostofi/TeachingFall13.html](http://www.ece.ucsb.edu/~ymostofi/TeachingFall13.html)

- All handouts, homework, and announcements are posted on the website

- **Prerequisites:** basic understanding of probability, random processes & Fourier techniques
Course Information (cont.)

- **Grading:**
  - Homework/quiz-20%, Midterm-20%, Final 40%
  - HW grading loses 25% credit per day late
  - HWs include paper reading/presentation

- **Textbook:**
  - *Wireless Communications* by Andrea Goldsmith

- **Class Involvement**
Course Information (cont.)

- Supplementary Readings:
  - Microwave Mobile Communications, W. C. Jakes, Wiley, 1974
  - Wireless Communications - Principles and Practice by T. Rappaport, 2nd Ed. Prentice Hall, 2001
Course Syllabus

- Overview of Wireless Communications (today)
- Channel impairment modeling:
  - Path Loss, Shadowing, and Fading
  - Narrowband and wideband channels
- Digital modulation and its performance
- Performance improvement techniques:
  - Diversity, adaptive modulation
  - Equalization
  - Multi-Carrier, OFDM, Spread Spectrum
  - MIMO
Course Syllabus (cont.)

- Multiple access techniques
- Capacity of wireless channels
- Examples of wireless networks:
  - Cellular systems
  - Wireless data networks
  - Sensor networks
  - networked control systems
  - Robotic networks
- Emerging applications: cognitive radios, device-free localization, RF-based energy harvesting
History of Wireless Comm.

- Wireless communication in old times: Smoke Signals
- Radio invented by Marconi in the 1880s
  - From Isle of Wight to a tugboat 18 miles away
- Many radio systems were developed during WW2
- Several existing examples today
- Cellular systems have enjoyed exponential growth since 1988
  - around 6 billion users worldwide today according to the UN telecom agency
Wireless Vision

- Access to any form of information any time at any place conveniently

- Constitute of
  - Advanced wireless voice and data access
  - Wireless Ad Hoc Networks
  - Sensor Networks
  - Distributed control systems
  - Smart Homes
  - Automated Highways
  - and more
Current Wireless Systems

- Cellular Systems
- Wireless LANs
- Satellite Systems
- Cordless Phones
- Paging Systems
- Short Range Data Systems: Bluetooth & ZigBee
First Mobile Radio Phone, 1924

Courtesy of www.bellsystemmemorial.com/oldphotos_1.html
Pre-Cellular Wireless Voice

- One highly-elevated antenna
- Small number of channels

Very low capacity
Cellular Concept: Reuse Channels

- First proposed at Bell Labs by D. Ring, 1947
- Geographic areas divided into cells
- Resources like frequencies, timeslots or codes are reused at spatially-separated locations
- Co-channel interference
- MTSOs handle handoff and control functions
- Smaller cell size increases capacity
Cellular Phone Networks

Drawing courtesy of Dr. Andrea Goldsmith, wireless communications
World Telecom Statistics

Graph courtesy of Dr. Homayoun Hashemi wireless comm. class

Crossover in 2002
US Growth

U.S. Cell Phone Subscriber Growth 1990-2015

- Subscribers
- Tot US Pop
- Poly. (Subscribers)

© Bridge Ratings LLC
Multiple Access Techniques

FDMA

TDMA

CDMA

Courtesy of Petri Possi, UMTS World
Code Division Multiple Access

- Originally developed for the military
- Resists jamming and interference
- All users share the same spectrum
- All accepted 3G radio standards are based on CDMA
  - CDMA2000, W-CDMA and TD-SCDMA
Uplink and Downlink Separations

- Uplink and Downlink should be separated as well
- FDD: Frequency Division Duplex
- TDD: Time Division Duplex
- Can not be separated in codes, interference too strong
The Wireless Evolution

- Cellular: was fastest growing sector of communication industry
- exponential growth since 1982, with 6 billion users worldwide today
- Four generations of cellular systems
- First Generation (1980s): Analog 30 KHz FM, voice only
  - AMPS in USA, TACS in Europe
- Second Generation (1990s): Digital voice and low bit-rate data, portable units, 30-70 kbps
  - Unified GSM in Europe, TDMA, slow frequency hopping, FSK
  - In US:
    - 900 MHz: IS-136 (TDMA), IS-95 (CDMA)
    - 1.9 GHz: IS-136, IS-95, GSM
  - 2.5G increased data transmission capabilities
- Third Generation: Wideband CDMA, CDMA 2000, voice and high bit-rate data, portable units, data rate from 144 kbps to a few Mbps, development slow (in practice peak around 380kbps)
- 4th Generation: FDMA, adaptive modulation, MIMO, IP-based
  - Verizon and Att LTE (Long Term Evolution), first publicly-available LTE 2009 (50-100 Mbps)
Digital vs. Analog Communication

- Encryption and security
- Compression
- Channel coding
- Signal processing
Wireless Local Area Networks

- Data applications not delay-sensitive and bursty
- Short range wireless data transfer
- Breaks data into packets
- Random channel access
Wireless Data Standards

- **802.11b**
  - 2.4GHz ISM band
  - Spread spectrum
  - 11 Mbps
  - around 100 m range

- **802.11a**
  - 5GHz
  - OFDM
  - 54 Mbps, around 30m range

- **802.11g**
  - Standard in 2.4 GHz
  - OFDM
  - Speeds up to 54 Mbps

- **802.11n**
  - 2.4 and 5 GHz
  - OFDM/MIMO
  - 600Mbps

- **WiMAX (802.16)**
  - Worldwide Interoperability for Microwave Access
  - Metropolitan area Network
  - OFD/MIMO, 15Mbps, 1-2mile
Satellite Systems

- Like a base station with a large coverage area
- Different orbit heights
  - GEO (40,000 Km), MEO (9000km), LEOs (2000 Km)
- Best suited for one-way transmission
  - Digital Audio Broadcast (DAB), Digital Video Broadcasting (DVB)
- Most two-way attempts did not make it
  - Example: Iridium, launched on November 1, 1998 and went into Chapter 11 bankruptcy on August 13, 1999
  - Causes: high cost, bulky handheld units, competition from terrestrial service providers
Cordless Phones

- Appeared in late 70s
- Range less than 100m
- Use ISM bands
- Co-channel interference due to neighboring homes
- Has multiple voice channels to scan
Paging Systems

- Suitable for short messaging
- Broadcast from all base stations
- Optimized for 1-way transmission
Short Range Communication: Bluetooth

- RF technology for cable replacement
- Short range, around 10m
- 2.4 GHz ISM band
- Supported by consumer electronics
- Applications beyond cable replacement
Short Range Communication: IEEE 802.15.4 / ZigBee

- Low-Rate short range data communication
- Data rates of 20, 40, 250 kbps
- Shorter range and rate than Bluetooth
- CSMA-CA channel access
- Very low power consumption
- Operate in ISM bands
- Possible sensor network applications like factory monitoring
Ultrawideband Radio (UWB)

- UWB sends pulses of 10^{-12}s to nanoseconds
  - 10^{-9}s
- Uses a lot of bandwidth (GHz)
- Low probability of detection
- Multipath highly resolvable
- Need new channel characterizations
Compare Data Rates

Courtesy of Dr. Andrea Goldsmith Wireless Comm. Class
Compare Range

10 km
1 km
100 m
10 m
1 m
0 GHz 1 GHz 2 GHz 3 GHz 4 GHz 5 GHz 6 GHz

3G
802.11b,g
802.11a
ZigBee
Bluetooth
UWB

Courtesy of Dr. Andrea Goldsmith Wireless Comm. Class
Compare Power Consumption

- 3G
- 802.11bg
- 802.11a
- Bluetooth
- ZigBee
- UWB

Courtesy of Dr. Andrea Goldsmith Wireless Comm. Class
What is a Future Cell?

- Fast growth in data usage, not so fast in generating revenue
- Current research directions
- Heterogeneous cells
  - Have macro/pico/femto cells
  - Cooperating smart nodes to limit interference
  - MIMO
  - Relays
  - Adaptive antennas and beam forming
- What is a cell?
- Convergence of cellular and WIFI
Cognitive Radios

- Spectrum sensing to allow secondary users use idle bands
- Considerable research interest in recent years
- True benefits and applicability yet to be seen
Green Cellular Networks

- Redesign base station location optimization with an emphasis on energy efficiency
Other Emerging Systems

- Sensor networks
- Networked control systems and robotic networks
- Smart homes
- Automated highways
- In-body networks
- RF-based localization
- RF-based energy harvesting
Sensor Networks

- Examples:
  - Environmental monitoring
  - Machine health monitoring

- Goal: Non-real time information gathering

- Constraint: battery life time, non-rechargeable baterries

- Typically short-range

- Require routing and multihop optimization

- Typically adhoc, no center node

- Data can be correlated in time and space

- Cooperative data processing is beneficial

- Cross-layer design is beneficial
Networked Control Systems

- **Examples:**
  - Target tracking
  - Vehicle formation/swarming
  - Emergency response

- **Constraint:** Real-time nature

- Send and receive control commands over wireless links

- Estimation & control over Wireless

- **Decentralized** decision & control
Robotic Networks

- Channel impairments impact controller
- Cross-layer design can be beneficial
- Not clear what the right design strategy is
- Packet loss, channel noise and delay can ruin the performance or result in instability
- Distributed decision making that results in certain group goals
RF-based Localization

- Use RF to localize, track or image
- Applications: surveillance, health monitoring, entertainment
RF-based Energy Harvesting

- Use ambient RF to recharge smart objects
- Examples: TV signals, existing cellular signals
Technical Challenges

- Wireless channel degrades the signal: path loss, shadowing, fading, ....
- Limited bandwidth results in interference
- Different applications have different requirements
- Mobility makes it more challenging
- Two major constraints: delay, energy
Application Requirements

- **Voice:**
  - delay-sensitive (can tolerate less than 100ms)
  - Can tolerate bit error rate of up to .001
  - Does not require large bandwidth
  - Traffic is continuous => originally circuit switching

- **Data:**
  - Not real-time, hence no delay-sensitivity
  - Requires low bit error rate (less than $10^{-6}$)
  - Requires larger bandwidth
  - Traffic bursty => packet switching
Application Requirements

- Emerging applications
- Networked control systems:
  - Deals with dynamical systems
  - Delay-constrained
  - Different from both voice and data
  - Needs new design principles
- Sensor networks:
  - Energy-constrained
- No single design works
Spectrum Regulation

- FCC controls commercial spectral allocation in US through auctioning parts of the spectrum
- ISM band:
  - Industrial Scientific Medical
  - Unrestricted
  - Restriction on transmission power, crowded
- ETSI controls commercial spectral allocation in Europe
- ITU controls worldwide spectrum