Wireless Networks

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Wireless Communication Systems are one of the key enabling technologies of the mobile revolution. They allow a seamless integration with the Internet, providing users with access to rich information content and data services anytime, and practically anywhere.

But mobile applications are just the tip of the iceberg. Beyond the 5 billion cellular subscribers, wireless communication is today pervasive bridging the physical and cyber-worlds. Wireless communication is present in transportation systems, the smart-grid, implantable devices, structural monitoring bridges and tunnels, car-to-car communication, and airplanes engines.

This course aims at providing a good understanding of today's wireless technologies and standards, the fundamental underlying constraints and mechanisms, and finally a practical experience with several key wireless and mobile systems technologies (i.e., wireless sensor networks, cellular systems, wireless local area networks, mobile applications).

Lectures plan:

- Overview
- Standards & Systems I: IEEE802.11, ZigBee, Cellular
- Fundamentals: Propagation, Antennas, Modulation, Capacity, Coding, MIMO
- Standards & Systems II: Mobile IP, ad hoc networks, Wireless TCP, LTE, GPS
- Recent breakthroughs, challenges, and directions e.g., WiTricity

The course has a major project integrating the conceptual and practical aspects. Wireless communication is one of the rare areas where theoretical advances (e.g., information theory, coding theory, cryptography) converged to characterize and achieve optimality!

Small Projects:

- WiFi performance measurement
- ZigBee sensor node communication
- Mobile application
- Wireless router application

Final Projects:

- Smart Home
- Quadcopter control with brain signals
- Security of SCADA systems

Grading policy:

- Assignments: 30%
- Midterm: 20%
- Quizzes: 10%
- Final Project: 40%

Notes of overview of wireless networks

Wireless Networks Architectures:

- Infrastructure networks: cellular, WLAN
- Ad hoc networks: PAN, disaster recovery
- Hybrid networks: typical architecture of today's and future systems

Typical Systems:

- Cellular: GSM-> EDGE -> WCDMA -> HSPA -> LTE; IS-95 -> CDMA2000 -> 1xEvDO -> LTE/(WiMax)
- PAN: Bluetooth;
- WLAN: IEEE802.11abgn
- WSN: ZigBee
- Vehicular: DSRC
- Satellite: Iridium; GPS

Application Areas:

- Internet access
- Health
- Smart homes
- Cyber-physical
- Energy
- Vehicular
- Localization
- Outdated/converged: paging, voice, etc.

Wireless Communication Systems Characteristics:

- Wireless:
  - Limited bandwidth: frequencies have to be coordinated, useful frequencies are almost all occupied
  - Broadcast medium: requires efficient access mechanisms
  - Link quality (noise, disconnection, interference)
  - Security: eavesdropping, denial of service

- Mobility:
  - user and terminal location is a dynamic system variable
  - speed of mobile impact wireless bandwidth
  - Security: tracking, spoofing

- Portability:
  - limited battery capacity
  - limited computing
  - limited storage memory
  - small dimensions (limited user interfaces)

Fundamental Mechanisms:

- Antennas and Signal Propagation [Physics, Electromagnetic Waves]; RF Front Ends

[Electronics]

- Channel Capacity (single/multi-hop, single/multi-antenna, single/multi-user) [Information Theory]
- Modulation, coding [Communication Theory]
- Medium Access Control [Information Theory, queuing theory]
- Routing [Information Theory, Network Flows, Network Coding]

Anatomy of a Wireless Link:

- Channel:
  - RF spectrum (freq vs. wavelength lambda = c/f; KHz – THz, IR, Optical, ISM vs. licenced, etc.),
  - signal $g(t) = A_t \sin(2\pi f_t t + \phi_t)$,
  - power (Watts, dBW, dBm, dB),
  - propagation (free space d^2, impact of matter e.g., water => weather/rain app), attenuation related to the frequency, free space attenuation, transmission/detection/interference ranges, multi-path (shadowing, reflection, refraction, scattering, diffraction),
- Antenna:
  - transducer guided RF to radiated RF signal,
  - radiation patterns (ideal istropic, dipole, directional antennas, parabolic, sectorized),
  - multi-antenna systems, diversity, combining, [example of beam forming])
- RF Front End: up-conversion, filtering
- Baseband processor: modulation, coding, spreading
- MAC processor: TDMA, FDMA, CDMA, OFDMA, Power Conservation
- Network stack: routing (ad hoc, cellular [HLR, VLR], mobile IP), transport