Lecture 1 - EE 359: Wireless Communications - Winter 2009

Overview of Wireless Communications

Lecture Outline

- **Course Basics**
- **The Wireless Vision**
- **Technical Challenges**
- **Current Wireless Systems**
- **Emerging Wireless Systems**
- **Spectrum Regulation**
- **Standards**

1. The Wireless Vision: Ubiquitous Communication between People and Devices
    - Nth generation cellular
    - WLANs
    - Wireless Adhoc and Sensor networks
    - Smart homes/appliances
    - Remote learning and telemedicine
    - Automated vehicles and robots

2. **Design Challenges:**
    - Wireless channels are a difficult and capacity-limited communications media.
    - Traffics patterns, user locations, and network conditions change constantly.
    - Applications are heterogeneous with hard constraints.
    - Hard energy, delay, and rate constraints change fundamental design principles.

3. **Evolution of Current Systems:**
    - Evolution based on pushing each layer of protocol stack harder.
    - Leads to diminishing returns in performance.
    - Most advances are on the link technology, little new in wireless networking technology.
    - Important tradeoffs often not even considered.
    - Systems mostly tailored to one specific application (voice or data).

4. **Multimedia Requirements:**

	Voice	Data	Video
Delay	<100ms	-	< 100ms
Packet Loss	<1%	0	<1%
BER	10^{-3}	10^{-6}	10^{-6}
Data Rate	8-32 Kbps	1-100 Mbps	20 Mbps
Traffic	Continuous	Bursty	Continuous

5. **Quality-of-Service (QoS):**

   - QoS refers to the requirements associated with a given application, typically rate and delay requirements.
   - It is hard to make a one-size-fits all network that supports requirements of different applications.
   - Wired networks often use this approach with poor results, and they have much higher data rates and better reliability than wireless systems.
   - Supporting QoS for all applications requires a cross-layer design approach.

6. **Cross-Layer Design:**

   - Cross-layer design involves designing and operating different layers of the OSI protocol stack jointly.
   - The joint design can merely incorporate information exchange and adaptation across layers, or layer design can be truly integrated.
   - Diversity and scheduling can help reduce uncertainty across different layers.
   - Tremendous performance gains are possible under cross layer design, especially for systems with delay or energy constraints.

7. **Cellular Systems:**

   - Exploits frequency reuse to maximize capacity.
   - Timeslots/codes/frequencies/antennas reused in spatially separate cells.
   - Shrinking cell size increases capacity and network burden.
   - Handoff and control coordinated by basestations and their MTSOs.
   - Cellular system uses telephone backbone network.
   - 3G systems support voice, data, and multimedia, with data rates up to 384 Kbps.
   - 3G popular in Asia and Europe, less so in the US.
   - Dual mode (Wifi + 3G) cell phone use growing.

8. **Wireless LANs:**

   - Uses packetized transmission for better sharing of the network resources.
   - Channel access is shared and typically random.
   - Backbone Internet provides best-effort service.
   - Not good enough for demanding applications (e.g. video).
   - First generation WLANs flopped.
   - 802.11b standard based on DSSS dated but widely available and used.
   - 802.11g standard based on OFDM, in same band (2.4 GHz) as 802.11b, has better performance and is widely used. Only 3 channels in the 2.4 GHz band, so it can get crowded.
   - 802.11a is in 5 GHz band and has 10 channels. Still not widely used due to 5 GHz propagation being worse than 2.4 GHz. 802.11a expected to be used for video with 802.11g for data. New 802.11n is a new standard which will be finalized next year, already have products on the market with this standard. Utilizes MIMO technology and OFDM. Operates in both 2.4 and 5 GHz bands with data rates up to 600 Mbps depending on bandwidth 920 or 40 MHz) and number of antennas.

9. **Wide Area Wireless Data Systems:**

   - Initial systems (Motient, Bell South, Ram Mobile Data, Metricom) very low rates (20-70 Kbps).
   - Cellular digital packet data uses FDMA voice channels of analog cellular at rates of 19.2 Kbps.
   - 2nd and 3rd generation celluar services provide higher data rates.
   - WiMax, based on the 802.16 standard, targeting data rates of 15Mbps (mobile) and 70 Mbps (fixed). Uses 2.5 and 3.5 MHz spectrum with bandwidth of 5-10 MHz.
   - Hopes to be an alternative to cellular, but experiencing slow rollout.

10. **Wimax Systems:**

    - Wide area wireless network standard, with architecture similar to cellular systems.
    - OFDM/MIMO is core link technology
    - Operates in 2.5 and 3.5 GHz bands, with 5-10 MHz bandwidth
    - Fixed Wimax supports 75 Mbps, up to 50 mile cell radius, Mobile Wimax supports 15 Mbps, up to 2 mile cell radius.

11. **Satellite Systems:**

    - Generally cover large areas: countries or continents.
    - Different orbit heights correspond to different properties.
    - Geosynchronous orbits (GEOs) at 39000Km appear stationary from the earth.
    - GEOs have high delay and require a lot of power.

- Low earth orbits (LEOs) at 2000Km have delay that is tolerable for voice.
- LEOs require handoffs between satellites to cover a particular area.
- Satellites optimized for 1-way transmission, especially movie or radio broadcasting (DVB, DVS, Sirius, XM radio, etc.)
- Most two-way systems struggling or bankrupt.
- Global positioning systems (GPS) experiencing high growth; used in cell phones, PDAs, and navigation devices.

12. **Paging Systems:**

- Broad coverage for short messages.
- Message broadcast from all towers/satellites.
- Terminals are small and low power.
- Optimized for 1-way transmission.
- Answer-back is hard.
- Mostly displaced by cellular phones.

13. **Bluetooth**

- Cable replacement RF technology.
- Short range (10 m, can extend to 100 m).
- Operates in crowded 2.4 GHz band (same as 802.11b).
- Supports one 723.2 Kbps asynchronous (data) channel and three 64 Kbps synchronous (voice) channels.
- Many electronics companies integrate Bluetooth into their devices.
- Some networking capability.

14. **UWB**

- Impulse radio - very wideband, uses lots of spectrum.
- Short range, typically 10 ft.
- High data rates, up to 500 Mbps.
- So far has not been successful - may disappear.

15. **Zigbee**

- Low-rate WPAN
- Data rates of 20, 40, and 250 Kbps
- Support for large mesh networking or star clusters

- Support for low latency
- Very low power consumption
- Operates in ISM band

16. **Spectrum Regulation:**

- Spectrum allocation in U.S. controlled by FCC (commercial) or OSM (defense).
- FCC allocates spectral blocks for particular applications.
- Previously the FCC gave away spectral blocks to particular groups or companies.
- Currently the FCC auctions spectral blocks.
- Some spectrum is set aside for universal use following a set of etiquette rules (e.g. HAM, ISM, 2.4 GHz and 5 GHz NII bands). This can lead to coexistance challenges as many devices share the same radio band. Technical solutions include interference cancellation and smart/cognitive radios.
- Worldwide spectral allocation controlled by ITU-R.
- Regulation can stunt innovation, cause economic disasters, and delay rollout.
- There is a current movement to fundamentally change spectrum allocation policy (frequency-agile/cognitive radios, interference management, etc.).

17. **Multiradio Integration**

- Many different radios being integrated into one small device (Wifi, Bluetooth, cellular, GPS, etc.).
- Causes significant interference between devices
- Multiple antennas and multiband antennas needed
- Size and power are significant design challenges for future PDAs/smartphones.

18. **Standards:**

- Communication systems that interact with each other require standardization.
- Companies try to get their technology adopted as a standard or try for a "de-facto" standard by winning the marketplace. This complicates the standards process due to conflicts of interest.
- IEEE develops standards in US, ETSI in Europe.
- Standards determined by the TIA/CTIA in U.S, Telecommunications Standards division of the ITU (ITU-T) worldwide. IEEE standards often adopted worldwide.

19. **Ad Hoc Networks:**

- Flexible self-configuring multihop wireless network

- Capacity of such networks unknown
- Protocol designs generally ad hoc.

20. **Cognitive radios:**
    - Underlay: cognitive radios constrained to cause minimal interference to noncognitive users
    - Interweave: cognitive radios find spectral holes/white spaces to utilize for communication
    - Overlay: Cognitive radios overhear and enhance noncognitive transmissions while "stealing" bandwidth for their own use.

21. **Sensor Networks:**
    - Energy is the driving constraint
    - Data flows to a centralized location, and nodes have information correlated in space and time.
    - Should exploit cooperative transmission, reception, compression, and signal processing.

22. **Distributed Control over Wireless Links:**
    - Packet loss or delay impacts controller performance
    - Network should be tailored to controller requirements, but these are unknown.
    - Radical redesign of communication system often gives best performance.

Main Points:

- The wireless vision encompasses many exciting systems and applications.
- Technical challenges transcend all layers of the wireless system design.
- Cross-layer design emerging as a key theme in wireless.
- Existing and emerging systems provide provide excellent quality for certain applications, but poor interoperability.
- Ad Hoc and sensor networks pose new technical challenges.
- Standards and spectral allocation heavily impact the evolution of wireless technology.