Lecture 1 - EE 359: Wireless Communications - Fall 2005

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.
   - 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 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.
   - 2G systems have extended their technology to support both voice and some data capabilities.
   - 3G integrates voice and data, but has had a disappointing rollout.

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.
   - Current generation based on 802.11b standard doing well.
   - Emerging 802.11a standard has better performance, but slightly higher cost and existing 802.11b base may hinder its acceptance. New 802.11g standard in 802.11b band has higher rates. Many wireless LAN cards now include all three standards.

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, is targeting data rates of 70 Mbps. Spectral has not yet been allocated, is expected to be in the 10-66 GHz range.

10. **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.
    - Most two-way systems struggling or bankrupt.
    - Expensive alternative to terrestrial systems.

11. **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.

12. **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.
    - Interesting applications starting to emerge.

13. **Ad Hoc Networks:**

    - Flexible self-configuring multihop wireless network
    - Capacity of such networks unknown
    - Protocol designs generally ad hoc.

14. **Sensor Networks:**

    - Energy is the driving constraint
    - Data flows to a centralized location
    - Local nodes have information correlated in space and time

- Should exploit cooperative transmission, reception, compression, and signal processing.

15. **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.

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).
- 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 radios, interference management, etc.).

17. **Standards:**

- Communication systems that interact with each other require standardization.
- Companies try to get their technology adopted as a standard.
- Alternatively, try for a "de-facto" standard by winning the marketplace.
- Standards determined by the TIA/CTIA in U.S.
- IEEE standards often adopted.
- Worldwide standards determined by the Telecommunications Standards division of the ITU (ITU-T).
- In Europe ETSI is the IEEE equivalent for standards development.
- The standards process is fraught with inefficiencies and conflicts of interest.

18. **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.