

# 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.
- Traffic 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 (20 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 cellular 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 coexistence 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 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.