Wireless Networks

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Wireless Lectures Outline

- Overview of Wireless Systems
  - Terminology, types of systems, issues, etc.

- Wireless LANs
  - IEEE802.11, Hiperlan1/2

- Personal Area Networks
  - Bluetooth

- Cellular Telecommunication Systems
  - GSM, CDMA (e.g., IS-95)

- Ad Hoc Networks
Wireless Communication Systems

Target Information Systems:
“Anytime, Anywhere, Anyform”

Applications: Ubiquitous Computing/Information Access

Market in continuous growth:
- 35-60% annual growth of PCS
- Number of subscribers:
  - 2001: over 700M wireless subscribers
  - 2003: 1.160 billion wireless subscribers
  - 2006: over 2 billion wireless subscribers (source

Large diversity of standards and products!!!
Confusing terminology
ad hoc

IMT200, WLAN, DAB, GSM, TETRA, ...

Personal Travel Assistant, DAB, PDA, laptop, GSM, cdmaOne, WCDMA, WLAN, Bluetooth, 1x EV-DO, ZigBee...
Evolution of Number of Subscribers

Cellular subscribers (analogue, CDMA, GSM, etc.)

March 2003: Total (1.160B), GSM (825M),
US: Total: 140M, CDMA: 60M

September 2005: over 2B; GSM family (inc. WCDMA): 1.6B

Source:
- EMC World Cellular Database (www.emc-database.com)
- Wireless Intelligence (www.wirelessintelligence.com)
Wireless Communication

Types of wireless communications?

Radio frequency spectrum

- twisted pair
- coax cable
- optical transmission

<table>
<thead>
<tr>
<th>Frequency Bands</th>
<th>1 Mm</th>
<th>10 km</th>
<th>100 m</th>
<th>1 m</th>
<th>10 mm</th>
<th>100 μm</th>
<th>1 μm</th>
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<tbody>
<tr>
<td></td>
<td>300 Hz</td>
<td>30 kHz</td>
<td>3 MHz</td>
<td>300 MHz</td>
<td>30 GHz</td>
<td>3 THz</td>
<td>300 THz</td>
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- VLF
- LF
- MF
- HF
- VHF
- UHF
- SHF
- EHF
- infrared
- visible light
- UV

ISM: Industrial, Scientific and Medical frequency bands

Wireless versus Mobile:
- Can we have wired-mobile node or wireless-fixed node?
Attributes of Wireless & Mobile Communication Systems

Wireless:
- limited bandwidth: frequencies have to be coordinated, useful frequencies are almost all occupied
- broadcast medium: requires efficient access mechanisms
- variable link quality (noise, disconnection, interference)
- high latency, higher jitter (cellular):
  - connection setup time: several hundred milliseconds; Packet/bit interleaving
- heterogeneous air interfaces
- security: easier snooping

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

Portability:
- limited battery capacity
- limited computing and memory
- small dimensions (limited user interfaces)
Classification of Wireless Personal Communication

Mobility scale:
- within a house or building: cordless telephone, WLAN
- within a campus, city: (cellular radio, WLAN, wide area wireless data, radio paging, extended cordless)
- throughout the world: cellular radio, paging, satellite-based wireless

Communication modes:
- two-way voice
- data a multimedia
- messaging

Convergence through all-IP networks and voice-over-IP with multiple physical layer interfaces
Wireless Systems: Past, Present and Future

- Cellular
  - Macro-cellular
  - Micro-cellular
  - Paging
  - Messaging
  - Phone point
  - WPABX
  - Cordless

- Wireless Area Data
  - Macro-cellular
  - Micro-cellular
  - WLANs

- Cordless
  - High-tier PCS
  - Low-tier PCS

- WLANs
  - WLANs

- Satellites
  - Sensor Networks

hotspots

cellular
Wireless "Standards"

- Wireless ATM
- Wireless LAN: IEEE 802.11, Hipelan2
- 3G IMT 2000, WCDMA, CDMA2000, GPRS, EDGE, 1xEVDO
- Cellular: GSM, IS95, IS54, PDC
- Wireless Data: Mobitex, CDPD, pACT, GPS
Cordless Telephones (1970s-)

- Evolved from analog to digital:
  - Low transmission power: ≤10mW (limited radio range)
  - Low transmission delay: ≤10ms
  - Dynamic Channel Allocation

- Products
  - Europe-Asia:
    - CT-2 (864-868MHz, bitrate 72Kpbs), DECT (1880-1990MHz, 1.2MBps)
  - USA: several products based on spread-spectrum or very low power transmission systems over the ISM frequency bands (900MHz, 2.4GHz)
  - Japan: PHS (1895-1907MHz, upto 384KBps)

- New services on cordless phones:
  - PhonePoint (CT-2, PHS), WPABX (DECT)
  - Limitations: reduced coverage, inefficient handoffs
  - Combination with cellular phones: GSM-DECT dual mode
Cellular Mobile Radio Systems (Past/Present)

Characteristics:
- Two-way voice service
- High mobility
  - Higher coverage, vehicular speed handoffs
- Messaging
- Mobile transmission power: ~2W
- Low data rate: <10KBps
- Higher RTT: ~200ms (due to interleaving, FEC etc.)

Standards/Products:
- Global Standard for Mobile (GSM):
  - ~825M subscribers (Europe, Asia, USA)
  - Extensions: HSCSD (in practice 28Kbps UL/28Kbps), GPRS (50Kbps)
- Japanese of Personal Digital Cellular (JDC or PDC)
- USA: IS-54/IS-136/DAMPS, GSM/GPRS (TDMA), IS-95/1x/1xEV-DO (CDMA)
Cellular Mobile Radio Systems

Today?

- Third Generation PCS initiated by ITU’s call for proposals (IMT2000)
  - Convergence of wireless PCS into a unique system
  - Efficient coverage
  - High data rates: 144Kbps (high mobility), 384Kbps (low mobility), and up-to 2Mbps for indoor
  - Multi-QoS connections (data-rate, delay, FER)
- Most likely: three standards
  - WCDMA:
    - ETSI proposal (FRAMES European project) [www.3GPP.org]
    - ARIB proposal (Japan)
  - CDMA2000 – 1xRTT – 1xEvDo is an enhancement of Qualcomm’s IS-95 [www.3GPP2.org]
  - EDGE (2.5G): convergence of 2nd generation PCS (TDMA)
    - GSM, D-AMPS, IS-54, IS-136
Wide-Area Wireless Data Systems

Characteristics:
- High mobility (vehicular/pedestrian speed)
- Wide range coverage

Products:
- ARDIS (USA: Motorola), RAM (Ericsson): low data rate <8Kbps
- Metricom (76Kbps):
  - large number of inexpensive base stations,
  - connected through wireless links
  - each base stations has small coverage
- Deployed in San Francisco Bay area, Washington D.C.
- Slow frequency hopping, Pwr <1W over 902-928MHz ISM band
- WiMax IEEE802.16 (the wireless DSL)

Past wide area wireless data systems did not succeed to attract enough users! WiMax future seems brighter.
Wireless Local Area Networks

Characteristics:
- low-mobility
- high data-rate: 1Mbps-54Mbps
- campus/building coverage

Products/standards:
- IEEE802.11, Hiperlan 1/2, Bluetooth, HomeRF,
- Altair Plus, AirLan, Freeport, Intersect, LAWN, WILAN, RadioPort, ArLAN, Radio Link, Range LAN 1-2, Netware, FreeLink

Operate over ISM frequency Band:
- 2.4GHz, 900MHz, 5GHz
Other Wireless Systems

Paging/Messaging:
- Evolution: from 1 bits info, to two-way
- Combined with CT-2 (Phone point), GSM (Short Message Service: SMS)

Blackberry (RIM):
- Initially proprietary basic email services now over GSM

Satellite-Based Mobile Systems:
- Large coverage
- Constellation of satellites (LEO)
- Products: stopped
  - Iridium (Motorola):
  - Globalstar
  - Teledesic (Lockheed Martin, Microsoft, Motorola)
Summary

WLAN/PAN
- Designed for high bit-rate data transmission
- Low-scale mobility, small area coverage
- Use unlicensed ISM frequency bands

PCS
- Originally (2\textsuperscript{nd} generation) designed for voice communication
- Limited bit-rate data transmission
- Large scale mobility and coverage (high-speed, big cells)
- Operate over licensed frequency bands

Wireless Metropolitan Area Networks

Sensor Networks
- Low data rate
- Low power consumption
- Low mobility
- Over ISM
Common Components of Wireless Systems

Antenna:
- A transducer that transforms an electric signal into an electromagnetic signal and reciprocally.

Radio-Frequency Front-End:
- Filters
- Power-Amplifier
- Mixers
- PLLs

Base-Band:
- Demodulation, Forward Error Correction

Multiple-Access Scheme
- FDMA, TDMA, CDMA, etc.
EE view vs. CS view

Electrical Engineer view:
• Ignores issues of routing, reliable transport, various applications requirements
ISO view vs. IETF view

Lack of coordination between higher layers and physical layer

Computer Network Engineer view

FTP  …  Telnet
TCP
UDP
TCP
ARP  …  IP
Data Link Control
Physical Interface

OSI stack

Application
Presentation
Session
Transport
Network
Data Link Control
Physical Interface
WLAN Architectures

**Terminology:**
- Mobile Terminal (MT) or Mobile Station (MS) to denote and mobile node
- Access Point (AP) or Base-Station (BS) to denote the central entity that coordinates and wirelessly connects the mobiles to the wired network

**Types of WLAN:**
- Infrastructure WLAN
- Ad Hoc WLAN:
  - Single: peer-to-peer communication
  - Multi-hop: nodes act both as terminals and routers
Issues in WLAN

Physical Layer
- How to resist to the wireless link limitations? multiple error control coding schemes

Medium Access Layer
- Coordination of nodes
- Dealing with wireless limitations (medium sensing and collisions detections)

Network Layer
- How to maintain the routing tables in the context of highly mobile nodes (multi-hop routing)?

Transport Layer
- TCP is optimized for congestion avoidance how to extend to error control

Application Layer
- How to satisfy the application requirements (delay, throughput)?
- How can the application adapt to the channel?

Resource conservation:
- Power-consumption, bandwidth optimization
- Planning for infrastructure networks (location identification, tele-traffic analysis)
- Self-configuration for multi-hop ad hoc networks
PCS Architectures

BS: Base Station
MSC: Mobile Switching Center
VLR: Visitor Location Register
HLR: Home Location Register
PSTN: Public Switched Telephone Network
POTS: Plain Old Telephone System
Issues in PCS

Planning

- Infrastructure planning:
  - Location of base stations
- Resources planning and management:
  - Frequency, timeslots, codes
  - Fixed (FCA), Dynamic (DCA), Hybrid, etc.

Mobility:

- Handover (or handoff) types:
  - Soft/hard/seamless (data flow), backward/forward (control flow)
  - Mobile controlled (DECT, PACS), network controlled (AMPS, CT-2), mobile assisted (GSM, IS-95)
  - Intra-system handover, inter-system handover
- Admission Control
- Roaming
Summary: Main Wireless Systems

- **Wireless Local Area Networks:**
  - WiFi: IEEE802.11

- **Cellular:**
  - Today: GSM (= DCS1800, PCS1900, GPRS), CDMA (= IS-95), DAMPS (= TDMA, IS-136, IS-54)
  - Being deployed: WCDMA (UMTS = 3GPP, HSDPA), Cdma2000 (=3GPP2: 1xEV-DO)

- **Wireless Metropolitan Area Networks:**
  - WiMax: IEEE802.16

- **Wireless Personal Area Networks**
  - Bluetooth = IEEE802.15.1

- **Sensor Networks:**
  - ZigBee = IEEE802.15.4
Some Trends in Wireless Networks

- **Service architectures:**
  - IEEE802.11b/a/g leading to hotspots
  - Cellular for full coverage, voice, and mobility
  - Hybrid wireless networks: multihop and infrastructure

- **Recent hot physical layer technologies research:**
  - Ultra Wide Band (UWB) derived from radar technology for low interference-low power communication

- **All IP cellular networks:**
  - Flarion, Airvana (CDMA 2000 1xEV-DO), etc.

- **Coexistence of technologies:**
  - Software Defined Radio, single chip multiple radio technologies (Qualcomm)