Course Goals

• Provide students a understanding of the structure, system aspects and protocols of wireless networks.

• The focus in on the generations of cellular networks, WirelessMANs, WirelessLANs, and Wireless PANs.
Text and Grading

- **Text:** Mobile Communications 2nd edition, Jochen Schiller, Addison Wesley
  also recommend
- **Overview of wireless network architectures**
  - Will post many links to papers to fill in on newer developments
- **Grading**
  - Homework + Labs (2 or 3 labs) 25%
  - Midterm 25%
  - Final Exam 30%
  - Term Project 20%
  - Group or individual project that involves a wireless network technology
    - Past Projects include
      - Evaluation of battlefield WLAN implementation
      - WiMAX QoS planning techniques
      - Comparative evaluation of smart antenna techniques
      - Ad hoc extensions of cellular networks for disaster/fault recovery
      - Paper on Regulatory issues for software/cognitive radios
      - Paper on Health issues of wireless technology

Course Outline

- **Introduction (Ch 1)**
  - Overview or wireless networks, applications and issues
- **Wireless communication fundamentals (Ch 2 -3)**
  - Frequencies, Propagation, Modulation and Antennas, (Ch 2, + Notes)
  - Mitigation Techniques and Multiple Access (Slides + Ch 3)
- **Wireless Wide Area Networks**
  - Cellular Networks: (Slides + Ch 4)
    - Voice oriented cellular (frequency reuse, traffic engineering, etc.
    - GSM, cdmaone
    - Data oriented cellular
      - 2.5 G (GPRS) and 3G UMTS, cdma2000
  - Satellite Networks (Ch 5)
  - Location Technology
Course Outline

- Wireless Local Area Networks (Ch 7)
  - IEEE 802.11 standard and MAC layer
  - Variations in a,b,g,n
- Wireless Personal Area Networks (Ch 7)
  - IEEE 802.15, Bluetooth
  - Zigbee and sensors
- Wireless Metro Area Networks (slides + notes)
  - IEEE 802.16 (WiMAX)
- Application Development and higher layer protocols (Ch 8, 10)

Wireless Communication Systems

- Wireless Communication System:
  - Any electrical communication system that uses a naturally occurring communication channel, such as air, water, earth.
- Examples:
  - Cell phone, Sonar, ground penetrating radar
  - Broadcast: (one way)
    - Radio, TV, pagers, satellite TV, etc.
  - Two Way:
    - walkie talkie, cell phones, satellite phones, wireless local area networks, etc.
- Fundamentally different from wired networks
Mobile vs. Wireless

- **Wireless Communication System:**
  - Any electrical communication system that uses a naturally occurring communication channel, such as air, water, earth.

- **Mobile and Wireless are not interchangeable**
  
  **Wireless vs. Mobile**
  
<table>
<thead>
<tr>
<th>Wireless</th>
<th>Mobile</th>
</tr>
</thead>
<tbody>
<tr>
<td>✗</td>
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- **Mobile wireless communication systems focus**
  - Communicate over the air via radio-waves
  - Support some form of user mobility

- Examine how they are different from wired networks

Wireless Issues

- **Wireless link implications**
  - *communications channel* is the air
    - poor quality: fading, shadowing, weather, etc.
    - data rate and coverage vary
  - regulated by governments
    - frequency allocated, licensing, etc.
  - limited bandwidth
    - low bit rate, frequency planning and reuse, interference
  - power issues
    - Power levels regulated (safety issue), conserve mobile terminal battery life
  - security issues
    - wireless channel is a broadcast medium!
Mobility Issues

• Mobility Types
  – User mobility: user can access network while mobile
    • must handoff calls/connections in progress as user moves
    • track users as they move so they can receive info/calls
  – Service mobility: user’s services follow them
    • Need to have authentication and services follow user

• Degree of Mobility
  – Geographic range
    • ranges from a house/apartment to worldwide
  – Speed
    • ranges from stationary to bullet train
    • cordless phone vs. cell phone

• Mobility → portable device

Device Issues

• Mobile Device Issues
  – Portability
    • Device and accessories size and weight
  – Usability
    • User characteristics (size, dexterity, knowledge, etc.)
    • Environment characteristics (Temperature, degree of mobility, etc)
    • Device Characteristics
      – startup time
      – data integrity and security
      – cpu speed and memory size
      – power supply
      – user interface (keypad, stylus, voice, etc.)
  – Functionality (standalone, network dependent)
  – Connectability (always, partial, never)

• In general have a limited power supply, user interface and speed compared to stationary device
Mobile Devices

Pager
- receive only
- tiny displays
- simple text messages
- two way pagers

PDA/Smartphone
- graphical displays
- character recognition
- WWW
- simple versions of standard applications

Laptop and Tablet PC
- fully functional
- standard applications

Mobile phones
- voice, data
- simple text displays
- simplified WWW

Palmtop
- tiny keyboard
- simple versions of standard applications

Sensors, embedded controllers

Performance and Cost

Wireless Networks

- **Wireless Wide Area Networks (WWANs)**
  - **Cellular Networks**:  
    - GSM, cdmaone (IS-95), UMTS, cdma2000 EVDO
  - **Satellite Networks**:
    - Iridium, Inmarsat, GPS, etc.

- **Wireless Metro Area Networks (WMANs)**
  - IEEE 802.16 WiMAX

- **Wireless Local Area Networks (WLANs)**
  - IEEE 802.11, a, b, g, etc. (infrastructure, ad hoc)

- **Wireless Personal Area Networks (WPANs)**
  - IEEE 802.15 (Bluetooth), IrDa, Zigbee, sensor, etc.
Wireless Networks

<table>
<thead>
<tr>
<th>Network</th>
<th>Geographic Coverage</th>
<th>Typical Throughput</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>WMANs</td>
<td>Metro, suburb, campus 1-15 km</td>
<td>100 Mbps – 10Gbps</td>
<td>IEEE 802.16</td>
</tr>
<tr>
<td>WLANs</td>
<td>In building, campus wide, subdivision wide, Range ~ 100 M per AP</td>
<td>1-106 Mbps</td>
<td>IEEE 80211a, b, g, etc.</td>
</tr>
<tr>
<td>WPANs</td>
<td>5-10 M around device</td>
<td>.1 – 1Mbps</td>
<td>IEEE 802.15 IrDa, BlueTooth, Zigbee</td>
</tr>
</tbody>
</table>

Mobile phone systems

- Support communication to mobile users via wireless radio channel
- Fastest growing technical device EVER!
  - Nokia sold over 120 million phones last year!
  - More cell phones than wired phones
  - More internet capable cell phones than PCs
- Variety of systems and standards:
  - Analog 1G : NMT, AMPS, TACS
  - Digital 2G: GSM, IS-95b (cdmaone),
  - 3G: UMTS, cdma 2000
- Scope of services and coverage areas growing
  - SMS, MMS, laptop data, etc.
  - Focus now on wireless data and location aware services
Cellular Network Architecture

• **Cell**: Area covered by 1 radio tower unit (base station)

• **Cellular Systems**:
  - provide wireless coverage to a geographic area with a set of slightly overlapping cells. Use a set of low power radio stations to provide coverage, each cell has different set of frequencies or codes, support handoff of mobile from one cell to another, track mobile for incoming call

  Cell coverage, size and actually shape depends on local geography, power level, cell site height, antenna type, etc.

  Hexagonal idealized cell shape

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Cellular Network Architecture

• **Cellular Network Components**:
  - Mobile Station (Terminal) – handset
  - Base Station (cell site)
  - Base Station Controller (BSC)
  - Mobile Switching Center (MSC)
  - Gateway MSC (interface to wired phone)
  - Home Location Register (HLR)
  - Visitor Location Register (VLR)
  - Authentication register (AUC)
  - HLR/VLR/AUC databases to track, bill and authentic users
2G Cellular Network Architecture

Cell Phone Market

- Stratification of market
  - Teenage
  - Safety/children
  - Business – low end
  - Business – high end
  - Families
  - Luxury

- Improvements in
  - display technology
  - memory
  - cpu speed

- Smaller devices greater functionality ➔ merger with other portable devices or accessories
2.5/3G/WLAN Mobile Devices

- More Internet-friendly interface
  - Wide, color screens
- More flexible to support new applications
  - Voice
  - Video telephony capabilities
  - Web browsing
  - Web Games
  - Electronic postcards
  - Location-based services
  - Streaming applications
- Various I/O modes/interfaces
  - Keypad,
  - Voice recognition,
  - Character recognition,
  - Pen based, etc.

Handset Market

- Top Ten Phones in US during 1/01-10/30/07
  - Motorola RAZR V3
  - Motorola RAZR V3m
  - LG VX8300
  - Apple iPhone
  - LG Chocolate VX8550/8500
  - Motorola MOTOKRZR K1m
  - Samsung SGH-A707
  - LG VX5300
  - Sanyo Katana II
  - Motorola V323i/V325i
- Still a wide variety of phones and capabilities – high end PDA type phones minority
Base Stations

- Base Station (BS)
  Provides radio channels between mobile units and network
  Pico-cells: (indoor – 0-0.5 Km) support 8-20 channels
  micro-cells: (outdoor – 0-1 Km), macro-cells: (1-30 Km)

Base Stations

- Base Transceiver Station (BTS) - houses radio units
**Base Station Controller**

- **Base Station Controller (BSC)**
  Manages a cluster of BS, channel assignment, handoff, power control, some switching, etc.

**Mobile Switching Center**

- **Mobile Switching Center (MSC) (MTSO)**
  - Provides switching functions, coordinates location tracking, call delivery, handoff, interfaces to HLR, VLR, AUC, etc.
  - Size of central office switch
**HLR/VLR**

- **Home Location Register (HLR)**
  - Specialized database server contains billing info, service profile and general location of a mobile user (one per service provider or one per section of country)
  - Visitor Location Register (VLR) similar to HLR contains location of users and their service profile of all users in a metro type area (one per MSC)

**WWANS - Satellites**

- Over 3500 Satellites in use today - industry overall revenues of $2.3 billion in 2004

  - **Telecommunications**
    - global telephone connections
    - backbone for global networks
    - connections for communication in remote places or underdeveloped areas
    - global mobile communications

- **Other Applications**
  - weather
  - radio and TV broadcast satellites
  - Earth observation (climate change, agricultural, etc.)
  - military: surveillance, imaging, intelligence, early warning
  - Navigation and localization: aeronautic, nautical, etc., (e.g., GPS, NavStar)
Satellite Basics

- Components
  - Earth (ground) Stations – antenna systems on or near earth
  - Uplink – transmission from an earth station to a satellite
  - Downlink – transmission from a satellite to an earth station
  - Typically separated frequencies for uplink and downlink (FDD)
  - Transponder – electronics in the satellite that convert uplink signals to downlink signals
    - transparent transponder: only shift of frequencies (Bent Pipe)
    - regenerative transponder: additionally signal regeneration and formatting

Typical Satellite System

PSTN: Public Switched Telephone Network
Wireless MANs

- Wireless Metropolitan Area Networks (WMANs): provide wireless connectivity across a geographical area the size of a city.

• Wireless Metropolitan Area Network (WMAN)
  - Wireless alternative to DSL/cable modem/Fiber to the Home) services for last mile broadband access.
  - Point to Multipoint (PMP) protocol
  - Scope expanded to include mobility and higher data rates
  - IEEE 802.16 standard
  - Worldwide Interoperability for Wireless Microwave Access (WiMAX)

• Both licensed and unlicensed spectrum deployment
• Advantages: cost, flexibility, mobility
IEEE 802.16 /WiMAX Standard

• Characteristics of 802.16
  – Point to Multipoint (PMP) and Mesh protocol
  – NLOS wireless broadband services including bandwidth on demand
  – QoS support
  – Security
  – Scope expanded to include mobility and higher data rates

• Focus on both licensed and unlicensed spectrum deployment – supports multiple service providers/licenses in same area

• 802.16 Terminology
  – Base Station (BS) is WiMAX cell site/access point
  – Subscriber Station (SS) is customer premise equipment and terminates the wireless link to the user location
  – Mobile Station (MS) is a standalone consumer device equipped with a WiMAX radio

WiMAX Architecture
WiMax Applications

- According to WiMax Forum it supports 5 classes of applications:
  1. Multi-player Interactive Gaming
  2. VOIP and Video Conference
  3. Streaming Media
  4. Web Browsing and Instant Messaging
  5. Media Content Downloads

Basically the Triple Play

Wireless LANs

- **Wireless Local Area Networks**
  - Support communication to mobile *data* users via wireless channel
  - Types of WLAN
    1. Infrastructure based (most popular)
       - Connect users to a wired infrastructure network
       - Wireless access network like cellular phone system
       - IEEE 802.11, a, b, g, n
    2. Ad-Hoc based networks
       - Provide peer to peer communication – mobiles communicate between each other directly
       - Rapid Deployment (conference room)
       - IEEE 802.11, a, b, g, n, Proprietary
    3. Point – to –Point (cable replacement!)
**WLAN components**

Wireless Fidelity standards for Interoperability
Components: access points, antennas, mobile stations
- 300 manufacturers
- www.wirelessethernet.org

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**IEEE 802.11 Terminology**

- **Access Point (AP)**
  - Provides access to distribution services via the wireless medium
- **Basic Service Area (BSA)**
  - The coverage area of one access point
- **Basic Service Set (BSS)**
  - A set of mobile stations controlled by one access point
- **Distribution system**
  - The fixed (wired) infrastructure used to connect a set of BSS to create an **extended service set (ESS)**
- **Portal(s)**
  - The logical point(s) at which non-802.11 packets enter an ESS
WLAN Topologies

ad-hoc based architecture

Infrastructure based architecture

Point-to-point

Wireless Personal Area Network

- Origins in the BodyLAN project initiated by BBN in the early 1990s
- Networking “personal” devices – sensors, cameras, handheld computers, audio devices, etc. with a range of around 5 feet around a soldier
- Today: Networking digital cameras to cell phones to PDAs to laptops to printers to etc.,
- Most popular application – hands free headset to cellphone
- IEEE 802.15 standard (Bluetooth)
  - Use band available globally for unlicensed users
  - Low powered – medium data rate ~100s kbps
  - Subgroups doing higher data rates and sensors (Zigbee)
### Applications of WPANs

- **Cable Replacement**
  - [Image of cable replacement](image1)

- **Ad hoc connectivity**
  - [Image of ad hoc connectivity](image2)

- **PSTN or the Internet**
  - [Image of PSTN or the Internet](image3)

### Wireless Networks

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Example Network Architecture

Evolving Applications

- Focus on data based services and value added applications
  - Mobile Internet Access
  - Mobile Intranet/Extranet Access
  - Personalized Infotainment
    - Video, audio, games, etc.
  - Multimedia Message Service (MMS)
  - Location Based Services (LBS)
  - Rich Voice

- Theme
  - Multi-mode (multi-media) service
  - Community and identity
Enablers

- Wireless network development
  - Increased bandwidth/data rate
  - Falling costs
  - Always on capability
  - WLAN – hotspots
- Mobile Devices
  - Fast development
  - More connectivity, computing power and autonomy, but lower size, weight and cost
  - More functionality – camera, mms, radio, gps, compass
- Software Infrastructure
  - wap, xml, VXML, J2ME, .NET CF, Device emulators, etc.
  - Smart Clients
    - mobile databases, synchronization technology
- Standardization
  - Software, protocols and hardware (e.g., Bluetooth). etc..

Example: Expert on Call

Less experienced technician at field site #1.

Something doesn’t seem right. Am I testing the right circuit? This is the one I’m working on.

No, that’s not the correct one. Scan to the left, I’ll tell you to stop when you get to the right spot.

Expert technician at field site #2.

Streaming Media, Real-time voice, Best Effort Data Convergence
Feasible with 3G technology
Example Application

Marie buys a new phone. She is showing it to her friend Susie. Marie leaves to work, surprised that her phone helped her not to be late.

The device has learnt where Marie likes to visit and what she does.

"I am going to teach my phone my habits." "Look, it remembers!"

"Would you like to give names to positions?" "Your phone is beeping!"

"Usually silent mode at location 3." "You have your leave next 33 minutes marked at your calendar and your average travel time is 32 minutes."

"Always meeting mode at location 4." "Look, it remembers!"

"Diverting calls to answering machine at position 2." "Mobile phone ID:14563 present usually at position 1."

"Travel time between 1 and 4 average 32 min."

Summary

• Overview of Wireless Networks
  – WWANs (cellular, satellite)
  – WMANs (802.16 - wiMAX)
  – WLANs (802.11)
  – WPANs (802.15)

• Mobile Applications