Chapter 2: Introduction to Wireless Networking

Outline
- History
- Wireless Network Architecture
- Benefits of Wireless Networks
- Concerns of Wireless Communication
- Wireless Spectrum

History of Wireless Networks
- Progress of transmission:
  - fire and smoke used by Indians ==> messenger on horseback ==> telephone line ==> networks
- Traditional networks (LAN, MAN, WAN) have provided great convenience:
  - in office, hotel room, or home.
  - But you cannot utilize the service unless you are physically connected to a LAN or a telephone line.
- ALOHANET by Univ. of Hawaii:
  - 7 campuses over 4 islands; star-like structure centered at the Oahu island.

(cont.)
- In 80’s, amateur radio hobbyists built TNC (terminal node controller) to interface “hams” radio equipment and their computers.
Progress of Wireless Comm. (cont.)

- In 1985, FCC authorized the use of ISM bands for Industrial, Scientific, and Medical for commercial development.
  - ISM bands = 902MHz and 5.85 GHz
- ISM is very attractive to vendors because NO obtaining FCC license is required.
- In 80’s, small-size computers started to appear.
  - laptop, palmtop, PDA
  - Wireless LAN products populate

Standardization and Promotion

- wireless LAN:
  - IEEE 802.11 standard was finalized in July 1997.
  - IEEE 802.11a, b, e, g, i, etc.
- wireless WAN:
  - Packet radio networks (e.g., RAM)
- Personal Communication Service (PCS):
  - 1.9 GHz sold $7.7 billion to TV company in 1995 by VP Al Gore.
  - $15 billion in 1996.

Wireless Network Architecture

- General functions of networks:
  - bit pipe of data
  - MAC for sharing of a common medium
  - synchronization and error control
  - routing
- OSI reference model: Fig. 1.2
- wireless LAN/MAN/WAN layers: Fig. 1.3

Wireless Network Interface Card

- Functionality:
  - modulation: translate baseband signal to a suitable analog form
  - amplification: raise signal strength
  - synchronization: carrier sense (Fig. 1.6)
  - error checking:
Antenna Concept

- propagation pattern:
  - radiation power: typically less than a few watts
  - gain: degree of amplification
    - omni-directional = 1
    - directional > 1 (good for longer distance)
    - example: watering your lawn
  - direction: omnidirectional or directional

Communication Channel

- Air
  - Pure nitrogen and oxygen are effective for transmission.
  - rain, fog, snow are obstacles.

- Space

- Water

Benefits of Wireless Networks

- Mobility:
  - Example: talking on a cordless phone vs. cord phone.
- Installation in Difficult-to-Wire Areas:
  - rivers, freeways, old building
  - Hazard materials (such as asbestos particles) when drilling.
  - Right-of-way restrictions in some city to dig ground.
- Reduced Installation Time:
  - It may take months to receive right-of-way approvals.
- Increased Reliability:
  - cable vs. cable-less
  - Long-term savings: never need re-cabling

Wireless Network Concerns

- Interference Issues

- Power Management
  - Electricity in battery is a limited resource.
  - modes control:

- System Interoperability
  - e.g., IEEE 802.11 standard
Security Concerns

- Security Threats:
  - Radio waves can easily penetrate walls.
  - One can passively retrieve your radio signal without being noticed (Fig. 1.10).
  - Electronic sabotage: someone maliciously jam your wireless network

Installation Issues

- Wireless coverage as a contour: Fig. 1.12
- Intra-system interference: e.g., between 802.11 access points
- Inter-system interference: e.g., from external Bluetooth, which is also on 2.4 GHz

Health Risks

- So far, no conclusive answer yet!!
  - Radio is safer than cellular phones!!
  - Wireless network is even safer as it operates at 50–100 milliwatts, compared to 600mw–3w of cellular phones.

- US Detp. of Food and Drug classifies risks into 4 classes:
  - class I: wireless LAN, supermarket scanner
  - class III: wireless MAN (could damage eyes if watching directly)
  - class IV: laser scalpel

Wireless Spectrum (LAN vs. WAN)
Wireless MAP

- Where do we spend our time?
  - office (wireless LAN and wireless PBX)
  - residential, public area (PHS, CT-2)
  - mobile (GSM, GPRS, 3G)

Wireless WAN vs. LAN

- Wireless WAN:
  - transmission speed: 10K-1M
  - real-time voice supported: circuit-switching
  - ubiquitous coverage
  - roaming speed: vehicular

- Wireless LAN:
  - transmission speed: > 1Mbps
  - packet-switching
  - coverage: a few hundred meters
  - roaming speed: pedestrian

Wireless WAN Examples

- cellular: now moving from analog to digital
- paging: one-way alerting
- packet-radio: data service (RAM, Mobitex)
- satellite: low earth-orbit system
  - Motorola’s Iridium system: 66 satellites
  - Qualcomm and Microsoft: > 800 satellites
- cordless: smaller cells (DECT)
- PCS: voice + data

The Radio Spectrum
Radio Spectrum (cont.)

- We separate frequencies as "extremely low", "very low", "medium", "high", "very high", "ultra high", "microwave region", "infrared region", "visible light region", and "X-ray".
- Audio:
  - 20 Hz to 20 KHz
  - AM radio station: 1 MHz
  - FM and TV: 100 MHz

Paging: 50–500 MHz
- Mobile Radio: < 1 GHz
- Cordless and PCS: about 2GHz
  - Why most wireless networking services are crowded around 1–2 GHz? availability (but is becoming full in recent years)
  - To move to higher frequency:
    - need to use Gallium Arsenide (GaAs): more expensive

Cell Size vs. Throughput
- Cell sizes can vary from tens of meters to thousands of kilometers.
- Data rates may range from 0.1 K to 50 Mbps
- Examples:
  - LAN: high rate (11 M), small range (50 m)
  - Satellite: low rate (10 K), extremely large range (1000 Km)
  - Paging: very low rate (1 Kbps), large cell (10s of Km)

Examples: (cont.)
- Packet Radio Networks:
  - cell size can be 10s of km
  - data rate: 10 to 20 Kbps
- CT-2:
  - cell size: 100 meters
  - data rate: order of 10 Kbps
- PCS:
  - cell size: 100 meters to 10s of km
  - data rate: order of 100 Kbps
Summary

- smaller cell size implies higher data rate, less power consumption, more handovers, and more frequency reuse

Outline

- Cellular
- WLAN
- Bluetooth

Cellular

- One of most prolific voice communication platforms that has been deployed within the last two decades
- Cellular systems have always been able to transport data, and many advancement in different modulation formats allow for the delivery of narrowband data.
- Cellular systems are unable to provide broadband data service
  - The bandwidth limitations
  - Typical data rate: 9 kilobits per second (Kbit/s)
MSC

- MSC (Mobile Switching Center)
  - That in turn connects to the PSTN (Public Switched Telephone Network) or postal, telegraph, and telephone (PTT) systems

Their main usefulness in their capability to maintain the same contact number even if the user moves from one location to another

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Maintaining the telephone number in a wireless and mobile system

Cellular

- Cellular communication is the form of wireless that allows for
  - Frequency reuse
  - Mobility of the subscriber
  - Handoffs
- Typically, the reference of cellular system is AMPS (Advanced Mobile Phone System) or TACS (Total-Access Communications System)
First-Generation Wireless System and Service

Table 1.3 First-Generation Wireless Systems and Services

<table>
<thead>
<tr>
<th>Event and Characteristic</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developments of radio and computer technologies for 800-MHz mobile communication</td>
<td>1976</td>
</tr>
<tr>
<td>WARC (World Administrative Radio Conference) allocates spectrum for cellular radio</td>
<td>1977</td>
</tr>
<tr>
<td>NTT (Nippon Telephone &amp; Telegraph) introduces the first cellular system in Japan</td>
<td>1981</td>
</tr>
<tr>
<td>NMT (Nordisk Mobil Telefon) 000 system introduced by Ericsson Radio System AB and deployed in Scandinavia</td>
<td>1981</td>
</tr>
<tr>
<td>AMPS (Advanced Mobile Phone Service) introduced by AT&amp;T in North America</td>
<td>1984</td>
</tr>
</tbody>
</table>

Cellular

- AMPS operates in the 800-MHz band
  - 821 to 849 MHz for the base station receive
  - 869 to 894 MHz for the base station transmit
  - North America

- TACS
  - 890 to 915 MHz for the base station receive
  - 935 to 960 MHz for the base station transmit

- Many other technologies
  - SMR (Specialized Mobile Radio)
  - IS-136
  - iDEN (Integrated Dispatch Enhanced Network)

- Cellular radio was initially developed by AT&T (Bell Lab.)
  - To provide additional radio capacity for a geographic customer service area.

- MTS (Mobile Telephone System)
  - Initial mobile systems
  - IMTS (Improved Mobile Telephone System)
  - One of the main problem
    - A mobile call could not be transferred (handed off) from one radio station to another without loss of signal
    - This problem was resolved by reusing the allocated frequencies of the system
    - With the handoff problem solved, the market was able to offer higher radio traffic capacity
      - Allows for more users than with the MTS or IMTS
Cellular

- The cellular systems in USA are broken into:
  - MSAs (Metropolitan Statistical Areas)
    - A-band system
  - RSAs (Rural Statistical Areas)
    - B-band system
- The A band is nonwireline system, and B band is the wireline system for the MSA and RSA.

Advanced mobile phone system (AMPS)

- The cellular standard developed for use in North America
- This type of system operates in the 800-MHz frequency
- Also developed in South America, Asia, and Russia

Nordic mobile telephone (NMT)

- Developed by the Nordic countries of Sweden, Denmark, Finland, and Norway in 1981.
- Operate in the 450- (NMT 450) and 900-MHz (NMT 900) frequency bands.

Second-Generation Wireless System and Service

<table>
<thead>
<tr>
<th>Year</th>
<th>Event and Characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>Groupe Euro-Telecom (CEPT) established for GSM (Global System for Mobile) to define future Pan-European cellular radio standards.</td>
</tr>
<tr>
<td>1983</td>
<td>First Standard (E-140) adopted by TIA.</td>
</tr>
<tr>
<td>1984</td>
<td>Standard E-150 released by TIA.</td>
</tr>
<tr>
<td>1985</td>
<td>PCN licenses issued in North America.</td>
</tr>
<tr>
<td>1990</td>
<td>Phase II GSM is operational.</td>
</tr>
<tr>
<td>1991</td>
<td>North American PCS deploys GSM.</td>
</tr>
<tr>
<td>1992</td>
<td>IS-136 used in North America; IS-95 used in North America, Hong Kong, Israel, Japan, South Korea, and China; etc.</td>
</tr>
<tr>
<td>1993</td>
<td>IS-136 used in China.</td>
</tr>
</tbody>
</table>
Code-division multiple access (CDMA)
- An alternative digital cellular standard in the United States
- Utilizes the IS-95 standard and is implemented as the next generation for cellular systems.
- The CDMA system coexists with the current analog system

Digital AMPS (D-AMPS)
- Also called North American Digital Cellular (NADC)
- The D-AMPS is designed to coexist with current cellular systems
- Relies on both the IS-54 and the IS-136 standards

Global system for mobile communication (GSM)
- The European standard for digital cellular systems operating in the 900-MHz band
- This technology offers international roaming, high speed quality, increased security, and the ability to develop advanced system features
- It was completed by a consortium of 80 pan-European countries working together
  - To provide integrated cellular systems across different borders and cultures

Total-access communications system (TACS)
- Derived from AMPS technology
- The first system was implemented in England
- Later these systems were installed in Europe, China, Hong Kong, Singapore, and the Middle East
- A variation of this standard (JTACS) was implemented in Japan
iDEN utilizes a digital radio format called quadrature amplitude modulation (QAM) and is a derivative of GSM.
Transmission Capacity

Figure 1.6: Transmission capacity as a function of mobility in some radio access systems.

Wireless Technologies and Associated Characteristics

Table 1.6 Wireless Technologies and Associated Characteristics

<table>
<thead>
<tr>
<th>Technology</th>
<th>Service or Devices</th>
<th>Coverage Area</th>
<th>Limitations</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellular</td>
<td>Voice and data</td>
<td>Continuous</td>
<td>Available bandwidth is very low for most data-intensive applications</td>
<td>Cellular phones, personal digital assistants</td>
</tr>
<tr>
<td></td>
<td>through handheld devices</td>
<td>coverage limited to metropolitan regions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wired Access Point</td>
<td>High-speed dedicated wired connections</td>
<td>Wired connections</td>
<td>Internet and Corporate Networks</td>
<td></td>
</tr>
<tr>
<td>Modem</td>
<td>Wired LAN</td>
<td>Point-to-point</td>
<td>Limited range</td>
<td>Novatel's wireless, Motorola's</td>
</tr>
<tr>
<td></td>
<td>(based on satellite)</td>
<td></td>
<td></td>
<td>AMLink, Ericsson's</td>
</tr>
<tr>
<td>Poletop Radio</td>
<td>Applications</td>
<td>Almost anywhere</td>
<td>It is still not available by everyone</td>
<td>GLOBALstar, INVENTOR, ( \text{GLONASS} )</td>
</tr>
<tr>
<td>Ricochet</td>
<td>High-speed, secure mobile access to the desktop (block) from outside the office</td>
<td>Some major cities, airports, and some university areas</td>
<td>Has a transmission limitation, Environmental conditions affect quality of service</td>
<td>MicroCellular Data Network (MC2N)</td>
</tr>
</tbody>
</table>

The Ricochet Network Overview
Easy Installation

Nokia Rooftop Product

Multipoint-to-Multipoint Mesh Network