Mobile Networks

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  - IEEE 802.11

- Approach
Evolution of Computing

- Single user systems
- Batch processing
- Time-sharing
- Networked computing
- Mobile computing
Mobile Computing

- **Goal**
  - Access information anywhere, anytime

- **Derivative**
  - Proactive computing, Nomadic computing, Wireless computing, Ubiquitous computing, Wearable computing, Sensor networks, Mobile social networks,
There are ~4 billion mobile phones. Over 50 countries have mobile phone subscription penetration rates higher than that of the population. (Infoma 2007)

The mobile device will be the primary connection tool to the Internet for most people in the world in 2020. (PEW Internet and American Life Project, Dec. 2008)

“By 2015, US IP traffic could reach an annual total of one zetabyte, or one million million billion bytes.”

Portability Issues

- Battery power restrictions
- Risks to data
  - Physical damage, loss, theft
  - Unauthorized access
  - Encrypt data stored on mobiles
  - Backup critical data to fixed (reliable) hosts
- Small user interface
  - Small displays due to battery power and aspect ratio constraints
  - Cannot open too many windows
  - Difficult to click on miniature icons
- Input - Graffiti, (Dictionary-based) Expectation
  - Gesture or handwriting recognition with Stylus Pen
  - Voice matching or voice recognition
Portability Issues: Power Management

- **Key Ideas**
  - Subsystems may have small duty factor
  - Power down individual components when they are idle

- **Approach**
  - Go to reduced mode after idle for a few time
  - Predictive approach: use history to predict
  - But,
    - Cost of restarting: latency and power

- **Alternatives**
  - Pre-wakeup
  - Dynamic Voltage Scaling
    - Intel SpeedStep
    - Transmeta Crusoe

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*Same area = same work*
*But energy is saved due to low voltage*
### Portability Issues: Power Management

<table>
<thead>
<tr>
<th>802.11 (WaveLAN-II)</th>
<th>Bluetooth (Nokia)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hardware State</strong></td>
<td><strong>Mode of Operation</strong></td>
</tr>
<tr>
<td><strong>Awake</strong></td>
<td>Active</td>
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<td></td>
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<td></td>
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<tr>
<td></td>
<td>Power Save</td>
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<tr>
<td></td>
<td>Doze</td>
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| 2 Mbps, 250 meters | 768 Kbps, 10-100 meters |
Mobility Issues

- Bandwidth restrictions and variability
- Location-aware network operation
  - User may wake up in a new environment
  - Dynamic replication of data
- Querying wireless data & location-based responses
- Bursty network activity during connections & handling disconnections
- Disconnection
  - OS and File System Issues - allow for disconnected operation
  - Database System Issues - when disconnected, based on local data
Mobility Issues: Location Management

- **Purpose**
  - How to track the mobile terminals (MTs)

- **Two aspects of mobility**
  - Handoff (small-scale mobility) : during conversation
  - Roaming (large-scale mobility)
    - Location update (registration) by the mobile phone
    - Paging (search) by the network
Static Update : Reporting Center Selection

- Reporting cells
  - select a subset of all cells
  - a user sends update message only when he enters a reporting cell
  - a search for any user will be restricted to the vicinity of a reporting cell which the user lastly reported
Dynamic Update

- Always Update
  - overhead of many update messages is “high”
  - especially, with small cells or highly mobile users
  - but, overhead for finding users is “zero”

- No Update
  - no overhead for updating
  - but, network-wide search for finding users
  - maximum location uncertainty

- What you want to measure and compare?
  - expected number of update messages by a user (U)
  - expected number of searches necessary to locate a user (S)
Wireless Communication

- Main research challenges due to mobility
  - variable communication conditions
  - energy limitations

- Effects on different layers of OSI hierarchy
  - mobile communication: physical/MAC layer
  - mobile computing: data link/network/transport layer

- Research Issues
  - Mobile Network Layer
  - Mobile Transport Layer
Wireless Proliferation & Challenges

- Sharp increase in deployment
- Variety of standards

Challenges – Limited spectrum, Interoperability, Security, and particularly, “Latency”
IEEE 802.11 Standard
IEEE 802.11 Standard

- Final draft approved in 1997

- The standard defines the physical (PHY) and medium access control (MAC) layers
  - It also performs higher-layer functions such as fragmentation, error recovery, mobility management
### Evolution of 802.11

#### 802.11 network standards

<table>
<thead>
<tr>
<th>802.11 protocol</th>
<th>Release</th>
<th>Freq. (GHz)</th>
<th>Bandwidth (MHz)</th>
<th>Data rate per stream (Mbit/s)</th>
<th>Allowable MIMO streams</th>
<th>Modulation</th>
<th>Approximate indoor range</th>
<th>Approximate outdoor range</th>
</tr>
</thead>
<tbody>
<tr>
<td>—</td>
<td>Jun 1997</td>
<td>2.4</td>
<td>20</td>
<td>1, 2</td>
<td>1</td>
<td>DSSS, FHSS</td>
<td>20 (m) 66 (ft) 100 (m) 330 (ft)</td>
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<tr>
<td>a</td>
<td>Sep 1999</td>
<td>5/3.7[A]</td>
<td>20</td>
<td>6, 9, 12, 18, 24, 36, 48, 54</td>
<td>1</td>
<td>OFDM</td>
<td>35 (m) 115 (ft) 120 (m) 390 (ft)</td>
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<tr>
<td>b</td>
<td>Sep 1999</td>
<td>2.4</td>
<td>20</td>
<td>5.5, 11</td>
<td>1</td>
<td>DSSS</td>
<td>35 (m) 115 (ft) 140 (m) 460 (ft)</td>
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<tr>
<td>g</td>
<td>Jun 2003</td>
<td>2.4</td>
<td>20</td>
<td>6, 9, 12, 18, 24, 36, 48, 54</td>
<td>1</td>
<td>OFDM, DSSS</td>
<td>38 (m) 125 (ft) 140 (m) 460 (ft)</td>
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<tr>
<td>n</td>
<td>Oct 2009</td>
<td>2.4/5</td>
<td>20</td>
<td>7.2, 14.4, 21.7, 28.9, 43.3, 57.8, 65, 72.2 [B]</td>
<td>4</td>
<td>OFDM</td>
<td>70 (m) 230 (ft) 250 (m) 820 [B] (ft)</td>
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<tr>
<td>ac (DRAFT)</td>
<td>Nov. 2011</td>
<td>5</td>
<td>80</td>
<td>433, 867</td>
<td>8</td>
<td>OFDM</td>
<td>70 (m) 230 (ft) 250 (m) 820 [B] (ft)</td>
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<td></td>
<td></td>
<td>160</td>
<td>867, 1.73 Gbit/s, 3.47 Gbit/s, 6.93 Gbit/s</td>
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**400M in 2008:** PC ~50% (+20%), CE ~35% (+40%), Cell ~15% (+50%)

**1B in 2012**

**6B in 2015** (World population?)
802.11 Frequency Bands - ISM

- Industrial, Scientific, and Medical (ISM) bands
- Unlicensed, 22 MHz channel bandwidth

![Diagram showing frequency bands and their categories.](image-url)
802.11 Components

- Station
- BSS - Basic Service Set (Independent BSS or IBSS)
- ESS - Extended Service Set
  - A set of infrastructure BSSs.
  - Connection of APs
  - Tracking of mobility
- DS – Distribution System
  - AP communicates with another

Wired LAN: Distribution System (DS)
Approach

- **How We Know Things**
  - I hear and I forget; I see and I remember; I do and I understand (A. S. Neill)
  - Labs based on ns-2 network simulator and GNU Radio/USRP (Universal Software Radio Peripheral)

- **Subject arrangement**
  - Network layer (MANET, IP, TCP)
  - Link layer (Medium access control)
  - Physical layer (Spread spectrum, Coding, Channel)
set ns [new Simulator]
set n0 [ns node]
set n1 [ns node]

$ns duplex-link $n0 $n1 1.5Mb
10ms DropTail

set tcp [ns create-connection TCP $n0 TCPSink $n1 0]

set ftp [new Application/FTP]
$ftp attach-agent $tcp
$ns at 0.2 "$ftp start"
$ns at 1.2 "exit"
$ns run
USRP & GNU Radio (Software Radio)