Wireless Networks for Mobile Applications

Prof. Claudio Palazzi
cpalazzi@math.unipd.it
Wireless Frequencies

- VLF = Very Low Frequency
- LF = Low Frequency
- MF = Medium Frequency
- HF = High Frequency
- VHF = Very High Frequency
- UHF = Ultra High Frequency
- SHF = Super High Frequency
- EHF = Extra High Frequency
- UV = Ultraviolet Light

Frequency and wave length:

\[ \lambda = \frac{c}{f} \]

Wave length $\lambda$, speed of light $c \equiv 3 \times 10^8 \text{m/s}$, frequency $f$
Wireless Network Bandwidth

- how can wireless channels have different bandwidth?
  - bits run less or more faster? (NO)
    - Light speed: \(~ <300.000 \text{ Km/s}\) for every bit
  - the channel pipe (spectrum) is bigger (YES/NO)
  - the channel requires less time to accommodate (i.e. to code) one bit on the channel (YES)

![Diagram showing bandwidth comparison between channel A and channel B](image-url)
Wireless Network Technology

- **Narrowband radio system**
  - transmit/receive using a single radio frequency

- **Spread Spectrum technology**
  - bandwidth efficiency vs. reliability and security
  - Frequency Hopping Spread Spectrum
    - narrowband carrier hopping in a pattern sequence
  - Direct Sequence Spread Spectrum
    - bit coding and transmission spreading over the spectrum

- **Infrared technology**
  - line of sight or diffused, short range (in room)
Wireless Network Technology

- Radio transmission coverage

host A (low Tx power)

host B (high Tx power)

“...is there anybody out there?”

both isolated
Wireless Network Technology

- Radio transmission coverage

A receives B

B cannot receive A

unidirectional(*) link

(*) sometimes improperly referred to as “asymmetric link”
Wireless Network Technology

- Radio transmission coverage

A receives B

B receives A

bidirectional(*) link

(*) sometimes improperly referred to as “symmetric link”
Wireless Network Technology

- Radio transmission coverage

bidirectional symmetric link

bidirectional asymmetric link
Wireless Network Technology

- **Narrowband radio system**
  - transmit/receive using a single, licensed, as narrow as possible radio frequency
  - undesired cross-talk between channels requires coordination and license for each site
  - low data-rates
  - e.g. frequency X
  - e.g. frequency Y
Wireless Network Technology

- **Frequency Hopping Spread Spectrum**
  - narrow band carrier changes frequency in a pattern known by both transmitter and receiver (single logical channel)
  - to unintended receiver FHSS appears as impulse noise
Wireless Network Technology

- **Direct Sequence Spread Spectrum**
  - redundant bit pattern (chipping code) spreaded over a large spectrum. Long chips increase probability of recovering the original bit (with no retransmission)
  - to unintended receiver DSSS appears as low power wideband noise
Wireless Network Technology

- **Infrared Technology (IR)**
  - frequencies just below the visible light
  - cannot penetrate opaque objects, and low diffusion
  - line-of-sight limitates mobility
  - short range technology (indoor, PAN, LAN nets)
  - High data-rate potential
## Wireless Network Technology

### Comparison:

<table>
<thead>
<tr>
<th></th>
<th>PROS</th>
<th>CONS</th>
</tr>
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</table>
| Frequency Hopping Spread Spectrum (FHSS) | • Use less power than DSSS  
• Lower cost  
• Increased security due to frequency switching | • Lower throughput than DSSS |
| Direct Sequence Spread Spectrum (DSSS)   | • High performance  
• Low interference  
• Increased security due to chip coding | • Expensive |
| Narrowband Microwave | • Long distance | • Line-of-sight with satellite dish  
• Requires FCC license  
• Not designed for WLAN use |
| Infrared            | • High bandwidth | • Easily obstructed  
• Inexpensive |
Wireless Network Coverage

- **Wireless Wide Area Network (WWAN)**
  - geographic coverage (e.g. satellite, cellular)

- **Wireless Metropolitan Area Net. (WMAN)**
  - Metropolitan coverage (e.g. town, large campus)

- **Wireless Local Area Network (WLAN)**
  - local area coverage (e.g. campus, building, home)

- **Wireless Personal Area Network (WPAN)**
  - reduced local area coverage (e.g. house, office)

- **Wireless Indoor Area Network (indoor)**
  - short range coverage (e.g. room, office)
Wireless Network Positioning

Mobility

- Outdoors
  - Vehicle
  - Walk
  - Fixed
- Indoors
  - Premise
  - Office

1 Mbps 10 Mbps 100 Mbps ??

802.15
802.11 b/g/n/ac...

WPAN

WLAN

WWAN

WMAN

802.16
Wireless Network Structures

- **WWAN and WMAN**
  - Satellite (low orbit, geo-stationary)

3 GEO satellites can cover the whole globe; yet they have around 500 ms of Round Trip Time (RTT)

LEO satellites suffer from *handovers/handoffs* (nodes have to switch from one connection to another one) due to satellite mobility.
Wireless Network Structures

- **WWAN and WMAN**
  - Cellular or multi-Infrastructure WLAN
    - grid of Access Points (AP), managing local Mobiles terminals (MT), and connected to Backbones
Wireless Network Structures

- **WLAN:**
  - Ad-Hoc:
    - peer-to-peer (P2P) “on the fly” communication
    - the network “is” the set of computers
    - no administration, no setup, no cost?
  - Infrastructure:
    - Centralized control unit (Access Point, local server)
    - Roaming between cells
    - resource sharing and backbone connection
Wireless Network Structures

- **WPAN:**
  - cable connection alternative for in-home/office/workspace device connection
  - common technology and protocols required (e.g. HomeRF, Bluetooth)

- **Indoor:**
  - in room/workspace device connection
# Wireless vs Wired

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Wireless PAN/LAN</th>
<th>Wired LAN/PAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Throughput</td>
<td>10-100 Mbps</td>
<td>10-100 Mbps (and more)</td>
</tr>
<tr>
<td>Integrity &amp; Reliability</td>
<td>Subject to interference</td>
<td>Highly reliable</td>
</tr>
<tr>
<td>Simplicity/Ease of Use</td>
<td>• No need to pull cable</td>
<td>• Cable required</td>
</tr>
<tr>
<td></td>
<td>• Set up time is significantly lower</td>
<td>• Set up time is significantly higher</td>
</tr>
<tr>
<td></td>
<td>• Moves, additions &amp; changes much simpler</td>
<td></td>
</tr>
<tr>
<td>Security</td>
<td>• Susceptible to interception</td>
<td>• Not as susceptible to interception</td>
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## Wireless vs Wired

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| **Cost**  | • Initial investment in hardware costs more  
• Installation expenses and maintenance costs can be significantly lower | • Investment cost in hardware lower  
• Installation and maintenance costs can be significantly higher |
| **Scalability** | simple to complex networks | simple to complex networks |
| **Safety** | Very little exposure to radio frequency energy | No exposure to radio frequency energy |
| **Mobility** | Provides access to real-time information anywhere | Does not support mobility |
In a Wireless Environment

- New assumptions for the physical system...
- ...willing to maintain needs for services and applications
  - e.g. audio/video applications, interactive services
- ... dealing with limited resources (e.g. bandwidth, energy)
- ... dealing with device limits (I/O, user interfaces)
  - limited display, no keyboard, no mouse
- ... mobility of users and devices
  - variable number of users in the system
- ... QoS problems, reliability, negotiation
Multiplexing

- **Multiplexing in 4 dimensions**
  - space \( (s_i) \)
  - time \( (t) \)
  - frequency \( (f) \)
  - code \( (c) \)

- **Goal:** multiple use of a shared medium

- **Important:** guard spaces needed!
Frequency Multiplex

- Separation of the whole spectrum into smaller frequency bands
- A channel gets a certain band of the spectrum for the whole time
- Advantages:
  - no dynamic coordination necessary
  - works also for analog signals
- Disadvantages:
  - waste of bandwidth if the traffic is distributed unevenly
  - inflexible
  - guard spaces
Time Multiplex

- A channel gets the whole spectrum for a certain amount of time

Advantages:
- only one carrier in the medium at any time
- throughput high even for many users

Disadvantages:
- precise synchronization necessary
Code Multiplex

- Each channel has a unique code
- All channels use the same spectrum at the same time
- **Advantages:**
  - bandwidth efficient
  - no coordination and synchronization necessary
  - good protection against interference and tapping
- **Disadvantages:**
  - lower user data rates
  - more complex signal regeneration (€)
- Implemented using spread spectrum technology