Emerging Wireless Networking Technologies

By: Julio Castillo Tito
MS Student
Electrical and Computer Engineering
Outline

- Introduction
- Wireless Networks
  - Benefits
  - How to design
  - Categories
- Case Studies
- Certifications
- Conclusions

Categories of Wireless Networks:

1. Wireless Personal Area Networks (PAN)
2. Wireless Local Area Networks (WLAN)
3. Wireless Metropolitan Area Networks (WMAN)
4. Wireless Sensor Networks (WSN)
5. Wireless Mesh Networks (WMN)
Introduction

- Why Wireless Networks?
  - People moves.
    - Wired Networks vs. Wireless Networks.
  - People today have more portable devices:
    - Laptops, PDAs, smartphones, gadgets.
  - People expect to be connected and use the network everywhere.
Wireless Networks

- A network that uses radio signal frequencies to communicate among computers and other network devices.
- One of the most important technologies today!
# Wireless Networks: Benefits

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobility</td>
<td>People moves, devices too.</td>
</tr>
<tr>
<td>Cost</td>
<td>Cheap to develop.</td>
</tr>
<tr>
<td>Installation</td>
<td>Wireless can install anywhere.</td>
</tr>
<tr>
<td>Ease of use</td>
<td>Plug &amp; Play.</td>
</tr>
<tr>
<td>Transparency</td>
<td>Users work similar like wired LANs.</td>
</tr>
<tr>
<td>Time savings</td>
<td>Temporary networks</td>
</tr>
</tbody>
</table>
Design a Wireless Network: Requirements

- Before choosing a wireless networking technology
  - Try to understand the requirements.
- Find the right devices.

- Coverage
- Data rate
- Cost
- Mobility
- Security
- Power consumption
Design a Wireless Network: Examples

- In the office environment, we need:
  - Basic deployment (<$)
  - Small coverage
  - High data rate
  - Low cost
  - Moderate mobility
  - Security

- In the battle field, we may need:
  - Strong planning and design
  - Large coverage
  - High mobility
  - Reliability
  - Strong security
Categories of Wireless Networks

- Cellular networks
  - GSM, CDMA, WiMAX.
- Wireless Personal Area Networks (PAN)
  - Bluetooth, Wibree, Zigbee.
- Wireless Local Area Networks (WLAN)
  - Standards IEEE 802.11
- Wireless Metropolitan Area Networks (WMAN)
  - Standards IEEE 802.16 (WiMAX)
- Wireless Sensor Networks (WSN)
  - Based on the wireless networks
- Wireless Mesh Networks (WMN)
  - Built with the existing network technologies: WPAN, WLAN, WMAN.
## Cellular Networks

<table>
<thead>
<tr>
<th>Gen.</th>
<th>Technology</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>1G</td>
<td>• AMPS</td>
<td>• Analog Voice Communication only.</td>
</tr>
<tr>
<td>2G</td>
<td>• GSM</td>
<td>• Digital voice and data</td>
</tr>
<tr>
<td></td>
<td>• IS-95 CDMA</td>
<td>• Simple email and text messages</td>
</tr>
<tr>
<td>3G</td>
<td>• WCDMA (European)</td>
<td>• Data transfer rates up to 2.4Mbps</td>
</tr>
<tr>
<td></td>
<td>• CDMA2000 (USA)</td>
<td>• Supports better Internet connections</td>
</tr>
<tr>
<td></td>
<td>• TD-SCDMA (China)</td>
<td>• Video.</td>
</tr>
<tr>
<td>4G</td>
<td>• WiMAX (USA)</td>
<td>• Based on Internet technology</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Very high speed (&gt;100Mbps)</td>
</tr>
</tbody>
</table>
Wireless Personal Area Networks (WPAN)

- Bluetooth, Wibree and Zigbee.

**Features:**
- Low Power
- Coverage (radius < 10 meters)

**Bluetooth™**
- Operates in the 2.4 GHz spectrum.
- Standards:
  - IEEE 802.15.1: Bluetooth v1.1
  - IEEE 802.15.3: High data rate (11~55Mbps)
  - IEEE 802.15.5: Enable Mesh networking

**Wibree**
- Bluetooth low energy technology
  - Bluetooth ULP (Ultra Low Power)
Zigbee - IEEE 802.15.4

- Zigbee Alliance
  - Group of developers, vendors and manufacturers.
- IEEE 802.15.4 standard
- Uses 2.4 GHz spectrum
- Features:
  - Low cost, power and bandwidth.
  - Powered by long-life batteries
  - Simpler, cheaper than Bluetooth
Zigbee: Topology

- Coordinator (ZC): Only one, Most Capability, functionality.
- Router (ZR): Passes data among end-devices.
- End Device (ZED): switches, detectors.
Zigbee: Applications

ZigBee
Wireless Control that Simply Works
# WPAN: Comparison

<table>
<thead>
<tr>
<th></th>
<th>Bluetooth</th>
<th>Wibree</th>
<th>ZigBee</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Band</strong></td>
<td>2.4GHz</td>
<td>2.4GHz</td>
<td>2.4GHz, 868MHz, 915MHz</td>
</tr>
<tr>
<td><strong>Antenna/HW</strong></td>
<td></td>
<td>Shared</td>
<td>Independent</td>
</tr>
<tr>
<td><strong>Power</strong></td>
<td>100 mW</td>
<td>~10 mW</td>
<td>30 mW</td>
</tr>
<tr>
<td><strong>Target Battery Life</strong></td>
<td>Days - months</td>
<td>1-2 years</td>
<td>6 months - 2 years</td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td>10-30 m</td>
<td>10 m</td>
<td>10-75 m</td>
</tr>
<tr>
<td><strong>Data Rate</strong></td>
<td>1-3 Mbps</td>
<td>1 Mbps</td>
<td>25-250 Kbps</td>
</tr>
<tr>
<td><strong>Component Cost</strong></td>
<td>$3</td>
<td>Bluetooth + 20¢</td>
<td>$2</td>
</tr>
<tr>
<td><strong>Network Topologies</strong></td>
<td>Ad hoc, point to point, star</td>
<td>Ad hoc, point to point, star</td>
<td>Mesh, ad hoc, star</td>
</tr>
<tr>
<td><strong>Security</strong></td>
<td>128-bit encryption</td>
<td>128-bit encryption</td>
<td>128-bit encryption</td>
</tr>
<tr>
<td><strong>Time to Wake and Transmit</strong></td>
<td>3s</td>
<td>TBA</td>
<td>15ms</td>
</tr>
</tbody>
</table>
Wireless Local Area Networks (WLANs)

- The most popular Wireless network
- IEEE 802.11 standards.
- Coverage
  - radius < 200~500 meters
- Applications: Medicine, Education, Government, Public Access, etc.

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Release Date</th>
<th>Op. Frequency</th>
<th>Data Rate (Typ)</th>
<th>Data Rate (Max)</th>
<th>Range (Indoor)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legacy</td>
<td>1997</td>
<td>2.4 -2.5 GHz</td>
<td>1 Mbit/s</td>
<td>2 Mbit/s</td>
<td>?</td>
</tr>
<tr>
<td>802.11a</td>
<td>1999</td>
<td>5.15-5.35/5.47-5.725/5.725-5.875 GHz</td>
<td>25 Mbit/s</td>
<td>54 Mbit/s</td>
<td>~50 meters</td>
</tr>
<tr>
<td>802.11b</td>
<td>1999</td>
<td>2.4-2.5 GHz</td>
<td>6.5 Mbit/s</td>
<td>11 Mbit/s</td>
<td>~100 meters</td>
</tr>
<tr>
<td>802.11g</td>
<td>2003</td>
<td>2.4-2.5 GHz</td>
<td>11 Mbit/s</td>
<td>54 Mbit/s</td>
<td>~100 meters</td>
</tr>
<tr>
<td>802.11n</td>
<td>2006 (draft)</td>
<td>2.4 GHz or 5 GHz bands</td>
<td>200 Mbit/s</td>
<td>540 Mbit/s</td>
<td>~250 meters</td>
</tr>
</tbody>
</table>
WLAN: More Standards (1)

- **IEEE 802.11a** - 54 Mbit/s, 5 GHz standard (1999, shipping products in 2001)
- **IEEE 802.11b** - Enhancements to 802.11 to support 5.5 and 11 Mbit/s (1999)
- **IEEE 802.11c** - Bridge operation procedures; included in the IEEE 802.1D standard (2001)
- **IEEE 802.11d** - International (country-to-country) roaming extensions (2001)
- **IEEE 802.11e** - Enhancements: QoS, including packet bursting (2005)
- **IEEE 802.11g** - 54 Mbit/s, 2.4 GHz standard (backwards compatible with b) (2003)
- **IEEE 802.11h** - Spectrum Managed 802.11a (5 GHz) for European compatibility (2004)
- **IEEE 802.11i** - Enhanced security (2004)
- **IEEE 802.11j** - Extensions for Japan (2004)
- **IEEE 802.11-2007** - A new release of the standard that includes amendments a, b, d, e, g, h, i & j. (July 2007)
- **IEEE 802.11k** - Radio resource measurement enhancements (2008)
- **IEEE 802.11n** - Higher throughput improvements using MIMO (multiple input, multiple output antennas) (November 2009)
- **IEEE 802.11p** - WAVE - Wireless Access for the Vehicular Environment (such as ambulances and passenger cars)
WLAN: More Standards (2)

- IEEE 802.11r - Fast roaming Working "Task Group r" - (2008)
- IEEE 802.11s - Mesh Networking, Extended Service Set (ESS) (working - September 2010)
- IEEE 802.11T - Wireless Performance Prediction (WPP) - test methods and metrics Recommendation cancelled
- IEEE 802.11u - Interworking with non-802 networks (for example, cellular) (working - September 2010)
- IEEE 802.11v - Wireless network management (working - June 2010)
- IEEE 802.11w - Protected Management Frames (working - September 2009)
- IEEE 802.11y - 3650-3700 MHz Operation in the U.S. (2008)
- IEEE 802.11z - Extensions to Direct Link Setup (DLS) (August 2007 - December 2011)
- IEEE 802.11aa - Robust streaming of Audio Video Transport Streams (March 2008 - June 2011)
- IEEE 802.11mb - Maintenance of the standard. Expected to become 802.11-2011. (ongoing)
- IEEE 802.11ac - Very High Throughput <6GHz (September 2008 - December 2012)
- IEEE 802.11ad - Extremely High Throughput 60GHz (December 2008 - December 2012)
WLAN: Topologies

Infrastructure
- BSS
  - Basic Service Set
  - Needs an AP
  - BSSID = SSID
  - Basic Service Set Identifier

Ad-Hoc
- IBSS
  - Independent BSS
  - Peer to peer
  - AP is not necessary

Extended Service Set
- ESS = BSSs + DS
  - Multiple BSS
  - Distribution System
WLAN: Security

WEP
• RC4 Algorithm
• Vulnerable to attacks
• 64 & 128 bit keys

SSID Hiding
• Do not allow SSID broadcast.

MAC Filtering
• Set up into the router.

WPA & WPA2
• Replacement for WEP
• WPA2
  • Based on IEEE 802.11i
  • Use AES & TKIP
Wireless Metropolitan Area Networks (WMAN)

- IEEE 802.16 (WiMAX).
- WiMAX Forum: To promote compatibility and interoperability.

Extends WLANs.
Connects Wi-Fi hotspots to the Internet.
Provides a wireless alternative to cable and DSL.

Up to 70 Mbps data rate.
Wireless Sensor Networks (WSN)
Wireless Mesh Networks (WMNs)

- Type of Mobile Ad Hoc Network (MANETs).
- Built with the existing network technologies
  - WPAN, WLAN, WMAN.
- Focus:
  - Multihop communications.
- Principal Features:
  - Self-forming
  - Self-healing
  - Self-organizing
WMNs: Architecture

- Consist of mesh routers and mesh clients.
  - Mesh routers have minimal mobility and form the mesh backbone for mesh clients.
WMNs: Applications

- Community networks
- Municipality networks
- Defense
- Emergency networks
- Intelligent transport systems, ..
## Existing Testbeds

### OVERVIEW OF WMNs TESTBED PROJECTS

<table>
<thead>
<tr>
<th>Project</th>
<th>Nodes</th>
<th>802.11</th>
<th>Software</th>
<th>Routing Layer</th>
<th>Protocol</th>
<th>Roaming</th>
<th>Config</th>
<th>MANET</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIT Roofnet</td>
<td>37</td>
<td>b/g</td>
<td>Linux</td>
<td>RL</td>
<td>SrcRR</td>
<td>-</td>
<td>x</td>
<td>-</td>
</tr>
<tr>
<td>Microsoft</td>
<td>21</td>
<td>a/b/g</td>
<td>Windows CE</td>
<td>MAC</td>
<td>MCL</td>
<td>-</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>USCB MeshNet</td>
<td>25</td>
<td>a/b/g</td>
<td>OpenWRT</td>
<td>IP</td>
<td>MCL</td>
<td>-</td>
<td>x</td>
<td>-</td>
</tr>
<tr>
<td>Purdue</td>
<td>32</td>
<td>a/b/g</td>
<td>–</td>
<td>IP</td>
<td>AODV</td>
<td>-</td>
<td>x</td>
<td>-</td>
</tr>
<tr>
<td>Georgia Tech</td>
<td>15</td>
<td>b/g</td>
<td>–</td>
<td>–</td>
<td>AODV,OLSR</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Carleton Univ.</td>
<td>??</td>
<td>a/g</td>
<td>μClinux</td>
<td>IP</td>
<td>–</td>
<td>-</td>
<td>x</td>
<td>-</td>
</tr>
<tr>
<td>Hyacinth</td>
<td>10</td>
<td>a</td>
<td>Windows XP</td>
<td>–</td>
<td>OLSR</td>
<td>x</td>
<td>x</td>
<td>-</td>
</tr>
<tr>
<td>UMIC-Mesh.net</td>
<td>51</td>
<td>a/b/g</td>
<td>Linux</td>
<td>IP</td>
<td>DYMOTO,OLSR</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>
Wireless Mesh Network (WMN) Testbed
WMN: Requirements

- **Hardware**
  - 02 Linksys WRT54GL Routers
  - 02 Laptops
  - Ethernet cord

- **Software**
  - Internet Explorer or Mozilla Firefox
  - dd-wrt.v24 sp1
  - OLSR daemon switch 0.5.6
  - Wireshark-1.2
  - Jperf-2.0
WMN: Topology

Install DD-WRT firmware

Set up a WMN with OLSR

Performance Tests
Install DD-WRT firmware: Download files (1)

```
<table>
<thead>
<tr>
<th>File Name</th>
<th>Size</th>
<th>Date</th>
<th>Rev</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>dd-wrt.v24_atheros_wifi.bin</td>
<td>3.6 MB</td>
<td>24-05-08</td>
<td>0</td>
<td>None</td>
</tr>
<tr>
<td>dd-wrt.v24_generic_nokia.bin</td>
<td>3.4 MB</td>
<td>24-05-08</td>
<td>0</td>
<td>None</td>
</tr>
<tr>
<td>dd-wrt.v24_mega_atheros_gen.o.bin</td>
<td>6.1 MB</td>
<td>24-05-08</td>
<td>0</td>
<td>None</td>
</tr>
<tr>
<td>dd-wrt.v24_mega_DIR-330.bin</td>
<td>5.7 MB</td>
<td>24-05-08</td>
<td>0</td>
<td>None</td>
</tr>
<tr>
<td>dd-wrt.v24_mega_generic.bin</td>
<td>5.7 MB</td>
<td>24-05-08</td>
<td>0</td>
<td>None</td>
</tr>
<tr>
<td>dd-wrt.v24_mini_asus.txt</td>
<td>2.8 MB</td>
<td>24-05-08</td>
<td>0</td>
<td>None</td>
</tr>
<tr>
<td>dd-wrt.v24_mini_generic.bin</td>
<td>2.8 MB</td>
<td>24-05-08</td>
<td>0</td>
<td>None</td>
</tr>
<tr>
<td>dd-wrt.v24_mini_we800g.bin</td>
<td>2.8 MB</td>
<td>24-05-08</td>
<td>0</td>
<td>None</td>
</tr>
<tr>
<td>dd-wrt.v24_mini_wr850n.bin</td>
<td>2.8 MB</td>
<td>24-05-08</td>
<td>0</td>
<td>None</td>
</tr>
<tr>
<td>dd-wrt.v24_mini_wr300n.bin</td>
<td>2.8 MB</td>
<td>24-05-08</td>
<td>0</td>
<td>None</td>
</tr>
<tr>
<td>dd-wrt.v24_mini_wr350n.bin</td>
<td>2.8 MB</td>
<td>24-05-08</td>
<td>0</td>
<td>None</td>
</tr>
<tr>
<td>dd-wrt.v24_mini_wr54g.bin</td>
<td>2.8 MB</td>
<td>24-05-08</td>
<td>0</td>
<td>None</td>
</tr>
<tr>
<td>dd-wrt.v24_mini_wr54gs.bin</td>
<td>2.8 MB</td>
<td>24-05-08</td>
<td>0</td>
<td>None</td>
</tr>
<tr>
<td>dd-wrt.v24_mini_wrtsl54gs.bin</td>
<td>2.8 MB</td>
<td>24-05-08</td>
<td>0</td>
<td>None</td>
</tr>
<tr>
<td>dd-wrt.v24_std_generic.bin</td>
<td>3.6 MB</td>
<td>24-05-08</td>
<td>0</td>
<td>None</td>
</tr>
<tr>
<td>dd-wrt.v24_voip_generic.bin</td>
<td>3.6 MB</td>
<td>24-05-08</td>
<td>0</td>
<td>None</td>
</tr>
<tr>
<td>dd-wrt.v24_vpn_generic.bin</td>
<td>3.6 MB</td>
<td>24-05-08</td>
<td>0</td>
<td>None</td>
</tr>
</tbody>
</table>
```
Install DD-WRT firmware: Original (2)
Install DD-WRT firmware: Upgrading mini (3)
Install DD-WRT firmware: Upgrading std (4)
Install DD-WRT firmware: Done (5)
Set up a WMN with OLSR: Mesh Routers (1)

Wireless Physical Interface wlo


- **Wireless Mode**: Adhoc
- **Wireless Network Mode**: Mixed
- **Wireless Network Name (SSID)**: dd-wrt
- **Wireless Channel**: 6 - 2.437 GHz
- **Wireless SSID Broadcast**: Enable

**Set all these marked values**

- **Sensitivity Range (ACK Timing)**: 2000
- **Network Configuration**: Unbridged
- **Multicast forwarding**: Disabled
- **IP Address**: 10.1.1.1
- **Subnet Mask**: 255.255.255.0

**Wireless Network Mode**:
If you wish to exclude Wireless-G clients, choose B-Only mode. If you would like to disable wireless access, choose Disable.

**Note**: when changing wireless mode, some advanced parameters are susceptible to be modified ("Afterburner", "Basic Rate" or "Frame Burst").

**Sensitivity Range**:
Adjusts the ack timing. 0 disables ack timing completely for Broadcom firmwares. On Atheros based firmwares it will turn into auto ack timing mode.
Set up a WMN with OLSR: Mesh Routers (2)

Choose OLSR Router

Operating Mode:
If the router is hosting your Internet connection, select Gateway mode. If another router exists on your network, select Router mode.

Select set number:
This is the unique route number, you may set up to 20 routes.

Route Name:
Enter the name you would like to assign to this route.

Destination LAN NET:
This is the remote host to which you would like to assign the static route.

Subnet Mask:
Determines the host and the network portion.

Here Left all options by default
Set up a WMN with OLSR: Mesh Clients (1)
Set up a WMN with OLSR: Mesh Clients (2)

Internet Protocol (TCP/IP) Properties

- Obtain an IP address automatically
- Use the following IP address:
  - IP address: 10.1.1.30
  - Subnet mask: 255.255.255.0
- Default gateway:
- Obtain DNS server address automatically
- Use the following DNS server addresses:
  - Preferred DNS server:
  - Alternate DNS server:

Advanced...

OK

We can modify here for more clients
Set up a WMN with OLSR: Mesh Clients (3)
Set up a WMN with OLSR: Mesh Clients (4)

Here, we can see routers and clients and MPR and MID messages used by OLSR.
Performance Tests: Multihop (1)

```
G:\Documents and Settings\Julio>tracert 10.1.1.3
Tracing route to 10.1.1.3 over a maximum of 30 hops

1  2 ms  1 ms  1 ms  10.1.1.1
2  *     *     Request timed out.
3  *     4 ms  3 ms  10.1.1.3
Trace complete.

G:\Documents and Settings\Julio>tracert 10.1.1.3
Tracing route to 10.1.1.3 over a maximum of 30 hops

1  3 ms  1 ms  1 ms  10.1.1.1
2  3 ms  3 ms  3 ms  10.1.1.3
Trace complete.
```

Achieving 2 Hops
Performance Tests: Wireshark (2)

OLSR running

2 Routers

3 Clients

OLSR uses 698 port
Performance Tests: Jperf (3)
Case Studies at UPRM – ICOM/INEL

- Case 1:
  - Mobile Electrocardiogram (ECG)
    - A capstone project in Fall 2008.

- Case 2:
  - High data-rate wireless sensor network for environmental monitoring
    - WALSAIP project.

- Case 3:
  - Service-oriented wireless mesh network
    - An IAP project in 2008.
# Certifications: Cisco

## General Certifications

<table>
<thead>
<tr>
<th>Certification Paths</th>
<th>Entry-Level</th>
<th>Associate</th>
<th>Professional</th>
<th>Expert</th>
</tr>
</thead>
<tbody>
<tr>
<td>Routing &amp; Switching</td>
<td>CCENT</td>
<td>CCNA</td>
<td>CCNP</td>
<td>CCIE Routing &amp; Switching</td>
</tr>
<tr>
<td>Design</td>
<td>CCENT</td>
<td>CCNA &amp; CCDA</td>
<td>CCDP</td>
<td>CCDE</td>
</tr>
<tr>
<td>Network Security</td>
<td>CCENT</td>
<td>CCNA Security</td>
<td>CCSP</td>
<td>CCIE Security</td>
</tr>
<tr>
<td>Service Provider</td>
<td>CCENT</td>
<td>CCNA</td>
<td>CCIP</td>
<td>CCIE Service Provider</td>
</tr>
<tr>
<td>Storage Networking</td>
<td>CCENT</td>
<td>CCNA</td>
<td>CCNP</td>
<td>CCIE Storage Networking</td>
</tr>
<tr>
<td>Voice</td>
<td>CCENT</td>
<td>CCNA Voice</td>
<td>CCVP</td>
<td>CCIE Voice</td>
</tr>
<tr>
<td>Wireless</td>
<td>CCENT</td>
<td>CCNA Wireless</td>
<td>CCNP Wireless</td>
<td>CCIE Wireless</td>
</tr>
</tbody>
</table>

Certifications: Wireless

http://www.cwnp.com/
Salaries for CWNPs
Conclusions

In this presentation, we have discussed:

- Different Wireless Networks
  - Cellular networks
  - Wireless Personal Area Networks (PAN)
  - Wireless Local Area Networks (WLAN)
  - Wireless Metropolitan Area Networks (WMAN)
  - Wireless Sensor Networks (WSN)
  - Wireless Mesh Networks (WMN)

- WMN Testbed
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Questions

jct.castillo@gmail.com