Wireless LAN 101

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Agenda

• Wireless LAN Standards
• WLAN Technology and Design
• IEEE 802.11n
• CAPWAP and Centralized Wireless
• Wireless Mesh and AWPP (dot11s)

*Many of the slide source material from Cisco
WIRELESS LAN STANDARDS
The Virtuous Standards Cycle

- Standardization
- Market Growth
- Innovation
## Types of Standards Bodies

<table>
<thead>
<tr>
<th>Organization</th>
<th>Primary Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institute of Electrical and Electronics Engineers (IEEE) <a href="http://www.ieee.org">www.ieee.org</a></td>
<td>Development of Hardware Standards</td>
</tr>
<tr>
<td>Internet Engineering Task Force (IETF) <a href="http://www.ietf.org">www.ietf.org</a></td>
<td>Development of Software Standards</td>
</tr>
<tr>
<td>Wi-Fi Alliance <a href="http://www.wi-fi.org">www.wi-fi.org</a></td>
<td>‘Marketing’ of Technical Standards</td>
</tr>
</tbody>
</table>
### ‘Marketing’ Names for 802.11 Standards

<table>
<thead>
<tr>
<th>Wi-Fi Alliance Interoperability Name</th>
<th>IEEE 802.11 Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wi-Fi Certified™</td>
<td>802.11 / a / b / g</td>
</tr>
<tr>
<td>Wi-Fi Protected Access™ (WPA v1 &amp; v2)</td>
<td>802.11i</td>
</tr>
<tr>
<td>Wi-Fi MultiMedia™ (WMM)</td>
<td>802.11e</td>
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</tbody>
</table>
Standards Terminology

When is a Standard not a Standard?
• Does it have a completion date in the past?
• Does it use the word ‘Ratified’?

Look out for words like:
• Pre-standard
• Draft ‘x’
• Expected to be compliant
• De Facto Standard
## 802.11 Ratified Standards

<table>
<thead>
<tr>
<th>Task Group</th>
<th>Description</th>
<th>Ratified</th>
</tr>
</thead>
<tbody>
<tr>
<td>802.11</td>
<td>Base MAC and PHY Specifications</td>
<td>1999</td>
</tr>
<tr>
<td>802.11a</td>
<td>5GHz OFDM PHY (Radio)</td>
<td>1999</td>
</tr>
<tr>
<td>802.11b</td>
<td>2.4GHz DSSS PHY (Radio)</td>
<td>1999</td>
</tr>
<tr>
<td>802.11d</td>
<td>Additional Regulatory Domains (World Mode)</td>
<td>2001</td>
</tr>
<tr>
<td>802.11g</td>
<td>Data Rate Extension for 2.4GHz</td>
<td>2003</td>
</tr>
<tr>
<td>802.11h</td>
<td>Spectrum Management for 5GHz in Europe</td>
<td>2003</td>
</tr>
<tr>
<td>802.11i</td>
<td>Data Plane Security Extensions</td>
<td>2004</td>
</tr>
<tr>
<td>802.11j</td>
<td>4.9-5.0GHz Operation in Japan</td>
<td>2004</td>
</tr>
<tr>
<td>802.11e</td>
<td>QoS Extensions</td>
<td>2005</td>
</tr>
<tr>
<td>802.11k</td>
<td>Radio Resource Management</td>
<td>2008</td>
</tr>
<tr>
<td>802.11r</td>
<td>Fast Roaming</td>
<td>2008</td>
</tr>
<tr>
<td>802.11n</td>
<td>High Throughput</td>
<td>2009</td>
</tr>
<tr>
<td>802.11s</td>
<td>Mesh Networking</td>
<td>2011</td>
</tr>
</tbody>
</table>
Current State of 5GHz Bridging Spectrum

**US (FCC)**
- **Conducted Power**
  - Tx Output Power: 20 dBm
- **Spectral Mask Designators (20 MHz)**
  - UNII-1: 17 dBm
  - UNII-2: 24 dBm

**Europe (ETSI)**
- **Radiated Power**
  - EIRP (with Antenna): 30 dBm (1W)
- **Dynamic Frequency Selection (DFS)**
- **Target Power Control (TPC)**

**Saudi Arabia (CITC)**
- **Radiated Power**
  - EIRP (with Antenna): 30 dBm (1W)
- **DFS + TPC**

**Designators**
- 2 Channels
  - 4.94
  - 4.99
  - 5.15
  - 5.25
  - 5.35
  - 5.470
  - 5.725
  - 5.825

- 4 Channels
  - 5 Channels
  - 11 Channels

- 4 Channels
  - UNII-3, 30 dBm

TBD: To Be Determined
Radio Waves

- Waves attributes include frequency and wavelength
- Radio devices operate in bands or a designated frequency ranges

5GHz ~ 6 cm
2.4 GHz ~ 12 cm

Frequency = \( f = \frac{V}{\lambda} \) (m/sec)

1 Cycle (\( \lambda \))
1 Second

2 Cycles in 1 Second = 2 Hertz
Multipath

- Ceiling
- TX
- RX
- Floor
- Obstruction

Received Signals
- Time
- Combined Results
- Time
Null Signals

1 Cycle ($\lambda$) 6cm/12cm

Delayed
By $\lambda/2$

Null Signal
Diversity

• In a multipath environment, signals null points are located throughout the area

• Moving the antenna slightly will allow you to move out of a null point and receive the signal correctly

Dual Antennas Typically Means if One Antenna Is in a Null, the Other One Will Not be, therefore Providing Better Performance in Multi-path Environments
Wireless LAN (WLAN)

- A WLAN is a shared RF network
- An Access Point is a shared device and functions like a shared Ethernet hub.
- An AP typically has a wired Ethernet interface
- Uses CSMA/CA protocol
- The same radio frequency is used for sending and receiving (transceiver)
WLAN Speeds & Frequencies

- **802.11b**: 2.4 GHz (ISM) 11 Mbps
- **802.11a**: 5 GHz (UNII-1, -2 & -3) 54 Mbps
- **802.11g**: 2.4 GHz 54 Mbps
- **802.11n**: 2.4/5 GHz 150 Mbps

IEEE 802.11a/b Ratified
IEEE 802.11g Ratified
802.11n

Jan’99 Jan’00 Jan’01 Jan’02 Jan’03 Jan’04 Jan’08 Jan’09
802.11b/g Channels (2.4 GHz ISM-ITU Range)

- Non-overlapping channels should be used when deploying WLAN
- Non-overlapping channels have 22 MHz of separation (at least 5 channels apart)
- There are 3 non-overlapping channels in the 2.4 GHz frequency range (channels 1, 6, 11)
  - Channel 14 can be used as a fourth non-overlapping channel for Japan when using 802.11b access points
IEEE 802.11b/g Channel Allocations

- 5 MHz Channel separation
- 22-MHz-wide stationary channels
- 3 nonoverlapping channels (1, 6, and 11)
- 3 APs can occupy same area - set at different frequencies
802.11b/g Channel Mapping Design

15-20% Overlap
## Increasing Capacity by Design

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Users</th>
<th>Access Points</th>
<th>Per AP Bandwidth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Antenna Power: 30mW</td>
<td>200</td>
<td>3</td>
<td>67</td>
</tr>
<tr>
<td>Reduce Antenna power to 5mW</td>
<td>200</td>
<td>18</td>
<td>11</td>
</tr>
</tbody>
</table>
802.11a Channels – U-NII 1,2 & 3

- 12 non-overlapping channels: 8 indoor, 4 outdoor
- 8 APs can occupy same area - set at different frequencies
- 60-MHz-wide stationary channels
- 20 MHz Channel separation
802.11a Channel Mapping Design

Ch 36  Ch 149  Ch 56  Ch 48

Ch 52  Ch 44  Ch 161  Ch 60

15-20% Overlap
## 802.11a/b/g Comparison

### Range

<table>
<thead>
<tr>
<th>Data Rates</th>
<th>802.11g</th>
<th>802.11a</th>
</tr>
</thead>
<tbody>
<tr>
<td>54 Mbps</td>
<td>32 m</td>
<td>26 m</td>
</tr>
<tr>
<td>48 Mbps</td>
<td>55 m</td>
<td>46 m</td>
</tr>
<tr>
<td>36 Mbps</td>
<td>79 m</td>
<td>64 m</td>
</tr>
<tr>
<td>24 Mbps</td>
<td>87 m</td>
<td>70 m</td>
</tr>
<tr>
<td>18 Mbps</td>
<td>100 m</td>
<td>79 m</td>
</tr>
<tr>
<td>12 Mbps</td>
<td>108 m</td>
<td>85 m</td>
</tr>
<tr>
<td>11 Mbps</td>
<td>111 m</td>
<td></td>
</tr>
<tr>
<td>9 Mbps</td>
<td>116 m</td>
<td>94 m</td>
</tr>
<tr>
<td>6 Mbps</td>
<td>125 m</td>
<td>100 m</td>
</tr>
<tr>
<td>5.5 Mbps</td>
<td>130 m</td>
<td></td>
</tr>
<tr>
<td>2 Mbps</td>
<td>136 m</td>
<td></td>
</tr>
<tr>
<td>1 Mbps</td>
<td>140 m</td>
<td></td>
</tr>
</tbody>
</table>

Typical indoor ranges measured using an AP1242AG with 2.2-dBi dipole antenna for 2.4 GHz, and 3.5-dBi omnidirectional antenna for 5 GHz.
IEEE 802.11N

High Throughput
802.11n Standard

- Official amendment name: “high throughput”
- IEEE 802.11n standard officially ratified September 2009
- Had a lot of pre-standard activity
- WFA created a certification of 802.11n draft 2.0 products mid-2007
802.11n Throughput Improvements

<table>
<thead>
<tr>
<th>MIMO</th>
<th>Dual Channel</th>
<th>MAC Efficiency</th>
</tr>
</thead>
</table>
| • Maximal Ration Combining  
  • Beam Forming  
  • Spatial Multiplexing | • Two Adjacent 20MHz Channels for a Single a 40MHz Channel | • Packet Aggregation  
  • Block Ack |

- 5x higher throughput
- More reliable and predictable coverage
- Backwards compatibility with 802.11a/b/g clients
MIMO Overview

Maximal Ratio Combining
- Performed by receiver
- Combines multiple received signals
- Increases receive sensitivity
- Works with non-MIMO and MIMO clients

Transmit beam forming
- Performed by transmitter
- Ensures signal received in phase
- Increases receive sensitivity
- Works with non-MIMO and MIMO clients

Spatial Multiplexing
- Transmitter and receiver participate
- Multiple antennas txmt concurrently on same channel
- Increases bandwidth
- Requires MIMO client
40-MHz Channels and Packet Aggregation

**40-MHz Channels:**
802.11n supports both 20- and 40-MHz wide channels
Wider channels mean more BW per AP
(not per physical location)

**Auto Analogy:**
Twice the traffic lanes, twice the cars

**Packet Aggregation:**
Combine multiple data units into one frame
Saves on 802.11n and MAC overhead

**Auto Analogy:**
Car pooling is more efficient than driving by yourself

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**Without Packet Aggregation**

<table>
<thead>
<tr>
<th>802.11n Overhead</th>
<th>Data Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Packet</td>
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**With Packet Aggregation**

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</tbody>
</table>
More consistent, reliable coverage

• Higher mean throughput, more reliable connections for each client
  – Consistent throughput and coverage
  – Better reliability, better user experience
  – Fewer help desk calls
CONTROL AND PROVISIONING OF WIRELESS ACCESS POINTS
CAPWAP

- CAPWAP Protocol
- Business Class Reliability
- Radio Resource Management
Lessons From Cellular Networks...

- CAPWAP is an IETF standard ratified July 2007
- Was originally called LWAPP before standardized (or Light Weight Access Point Protocol)

Access, Control, and Traffic Forwarding must be separated from one another to build scalable, reliable wireless networks

**Access**
Cell sites are made up of base stations that contain numerous pieces of radio equipment (e.g., antennas) for communicating with mobile devices.

**Management/Control**
Base stations are connected to controllers, which are used to handle call setup, handovers, and other functions across an entire cellular network.

**Control and Signaling**

Internet
CAPWAP Architecture

- Security policies
- QoS policies
- RF management
- Mobility management

- Remote RF interface
- MAC layer encryption

Division of Labor
Split MAC

Controller MAC Functions
- 802.11 MAC mgmt: (Re)association requests and action frames
- 802.11 Data: Encapsulate and sent to AP
- 802.11e resource reservation: Control protocol carried to AP in 802.11 mgmt frames—signaling done in the controller
- 802.11i authentication and key exchange

AP MAC Functions
- 802.11: Beacons, probe response, auth (if open)
- 802.11 control: Packet ack and retransmission (latency)
- 802.11e: Frame queuing and pkt prioritization (access to RF)
- 802.11i: Encryption in AP
Understanding WLAN Controllers
The WLAN Controller as a Network Device

- **WLAN Controller**
  - For wireless end-user devices, the controller is a 802.1Q bridge that takes traffic of the air and puts it on a VLAN.
  - From the perspective of the AP, the controller is an CAPWAP Tunnel end-point with an IP address.
  - From the perspective of the network, it’s a Layer-2 device connected via one or more 802.1Q trunk interfaces.
- The AP connects to an access port—no concept of VLANs at the AP.
CAPWAP Adds AP Redundancy for Mission Critical Mobility

- Maximized system availability
  - Controller redundancy
  - Access point failover
- System level management automates failover to guarantee availability

Benefits
- No single point of failure
- Automated network failover decreases support and downtime costs
- Wireless network reliability on par with wired
CAPWAP Radio Resource Management
Real-Time RF Management

- The RF domain is an ever changing environment
  - Users are mobile
  - Interference prone
- The controller has a system level view of the RF domain and adjusts individual access points to optimize coverage and network availability

Benefits
- An optimized RF environment allows for superior application performance and higher network availability
- Complete RF management without specialized RF skills
- No RF recalibration required – decreased support costs
IEEE 802.11S WIRELESS MESH

Adaptive Wireless Path Protocol (AWPP)
AWPP Path Selection Solution Components
Radio Roles

Roof Top Access Point (RAP) mode-
- Wired LWAPP connection to the Controller
- RAP has only backhaul interface, and we do not recommend RAP to have local client access
- More than one RAP for the same Mesh for Redundancy

Pole Top Access Point (MAP) mode-
- No wired connection for Mesh
- Wired connection for Bridging (P2P or P2MP)
- Communicating directly to RAP, or to other MAPs and eventually to RAP
- Support wireless clients
Adaptive Wireless Path Protocol (AWPP)

IEEE 802.11s

- Self-configuring, Self-healing
- Dynamic, Intelligent Path Selection
- AWP establishes and maintains an optimal path to RAP
- Each MAP carries possible successors if topology or link health changes
- Cisco AWP is part of the IEEE 802.11s committee (SEE Mesh)
Routing uses a concept of ‘Ease’ (preferred path is highest ‘Ease’)

- Combination of
  - SNR
  - Hop Value
  - And coefficient, based on various SNR thresholds

- Adjusted Ease = \( \frac{\text{Min Ease at Each hop}}{\text{Hop Count}} \)

- 20% premium to selected parent to prevent flopping (SNR smoothing)
- Loop detection and prevention mechanism
Questions