Voice Over Wi-Fi

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• A brief history of VoWi-Fi
• Voice RF Design
• QoS
• VoIP signaling and encoding
• Let’s make some calls
A Brief History

The Early Years

- The first VoIP company establishes in 1995
- The first Wi-Fi standard 802.11 is published in 1997
- 802.11b and 802.11a are published in 1999
A Brief History

- 2002 - 802.11b Wi-Fi handsets become available
- 2003 - IEEE ratifies 802.11g
- 2005 - IEEE ratifies 802.11e
- 2006 - 802.11g Wi-Fi handsets become available
- 2007 - 802.11a Wi-Fi handsets become available
- 2008 - IEEE ratifies 802.11r
- 2009 - IEEE ratifies 802.11n
- 2010 - 802.11n Wi-Fi handsets become available
- 2013 - IEEE ratifies 802.11ac
VoWi-Fi WLAN Design

Different challenges for different spectrum

<table>
<thead>
<tr>
<th>Challenges</th>
<th>2.4 GHz</th>
<th>5 GHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coverage</td>
<td>Easy</td>
<td>Not So easy</td>
</tr>
<tr>
<td>Interference</td>
<td>Not so easy</td>
<td>Easy</td>
</tr>
<tr>
<td>Roaming</td>
<td>Easy</td>
<td>Not so easy</td>
</tr>
<tr>
<td>Device Support</td>
<td>Easy</td>
<td>Easy</td>
</tr>
</tbody>
</table>
Voice RF Design

#1 Coverage
- How much? Typically -67dBm
  - SNR & Retries
- Biggest challenges
  - Stairwells
  - Elevators
  - Metal Mesh
  - Heavy Metals
Voice RF Design

#1 Coverage
- Stairwells are off limits to AP installation
- Elevators are challenging too
  - AP in the elevator car
  - Antennas at the top and bottom
  - Elevator regulation
  - Cars travel 5-10 ft/s
Voice RF Design

#1 Coverage

- Metal mesh can attenuate and scatter the signal
- Lead lined walls in hospitals will require more AP’s
- Manufacturing facilities have a lot of metal beams, large metal molds and presses that reflect signals and create RF shadows
Voice RF Design

#1 Coverage

- Surveying for Voice
  - Again -67dBm target but...
  - Reference the client receive sensitivity
- Take measurements with the handset in survey mode
- Look for retries and observe the RSSI
Voice RF Design

#2 Interference
- Create a static channel plan to avoid CCI
- Which channels? 2.4 or 5 GHz
  - UNII-1 36-48
  - UNII-2 52-64
  - UNII-2 ext 100-136
  - UNII-3 149-161
  - ISM 165
  - ISM 1-11
Voice RF Design

#2 Interference
Typical static channel plan for 2.4 and 5 GHz to avoid CCI and ACI

2.4 GHz Channel Plan
1
11
6

5 GHz 8 Channel Plan
Using only UNII-1 & 3
149
44
161
149
36
153
48
36

36
157
40
Voice RF Design

- Three types of signal
  - want
  - don’t want
  - don’t care
- Goldilocks approach
  - -45dBm = 54Mbps
  - -65dBm = 54Mbps
  - No benefit from more power

Don’t Want

Want

Don’t Care

-67dBm

-85dBm

-100dBm
These AP’s go to eleven!
Voice RF Design

#3 Roaming

- 2.4 GHz vs 5 GHz
- Number of channels
- Security Suite
- Active vs Passive Scanning
Voice RF Design

#3 Roaming 2.4 vs 5 GHz

- 2.4 GHz has 3 non-overlapping channels
- 5 GHz has 24 non-overlapping channels
- Clients must scan channels in order to roam
- Fewer channels are better for roaming
Voice RF Design

#3 Roaming 2.4 vs 5 GHz

- Passive scanning requires a client to listen to beacons from nearby AP’s
- Active Scanning is quicker but requires transmitting a probe request on every channel in use
- Either can take a lot of time
Voice RF Design

#3 Roaming 2.4 vs 5 GHz

- 2.4 GHz roam times should be better than 5 GHz
- 5 GHz roam times should be under 50ms nonetheless
- WPA2-PSK will be quicker than WPA2-Enterprise
- 802.11k can improve scanning intelligence
#3 Roaming with WPA-Enterprise

- WPA-Enterprise EAP requires additional frame exchanges for username and password
- 802.11r reduces those frame exchanges by combining frames
- 802.11r&k are not implemented in dedicated voice handsets to date
Voice RF Design

#4 Device Support

- What component of a WLAN is the biggest challenge?
- The client devices have the biggest constraints
  - Power use
  - Size
  - Durability
Voice RF Design

#4 Device Support

- What are the target VoWi-Fi clients today?
  - Voice Dedicated Handsets
  - Smartphones
  - Tablets
  - Laptops
  - VoWiFi is being used much more broadly
Voice RF Design

#4 Device Support

- Traditional VoWiFi used dedicated SSID’s on single purpose devices
- QoS was less difficult
- Current VoWiFi uses multipurpose devices on shared SSID’s
- Video uses VoWiFi
Voice RF Design

#4 Device Support
- Lower PHY rate demand
  - 64Mbps for dedicated handsets
  - 130Mbps for smart phones
- No MIMO
- Added cost/complexity with little benefit to the client device
Quality of Service

Making it End to End

- Wi-Fi QoS
  - WMM
  - 802.11e
- Wired QoS
  - 802.1D
  - Diffserv
Quality of Service

Wi-Fi QoS

- IEEE creates standards
- Wi-Fi Alliance certifies them
- IEEE created 802.11e
- The WFA created WMM
Quality of Service

Wireless Arbitration

- DCF
  - Everyone basically has equal access
- EDCA
- Proprietary
Quality of Service

Wireless Arbitration

- Why do we need QoS
  - Wi-Fi is half-duplex
  - DCF does not guarantee the ability to transmit
  - Need a mechanism to improve the odds
Quality of Service

Wireless Arbitration

- DCF
  - Random number selection determines who speaks
- EDCA
  - It’s complicated...
  - but we have 4 different QoS Queues
Quality of Service

**Wireless Queues (AC’s)**
- Voice AC_VO
- Video AC_VI
- Best Effort AC_BE
- Background AC_BK
- 4 AC map to 8 UP’s
- UP numbers are not sequential

<table>
<thead>
<tr>
<th>Priority</th>
<th>UP (Same as 802.1D user priority)</th>
<th>802.1D designation</th>
<th>AC</th>
<th>Designation (informative)</th>
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</thead>
<tbody>
<tr>
<td>Lowest</td>
<td>1</td>
<td>BK</td>
<td>AC_BK</td>
<td>Background</td>
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<tr>
<td></td>
<td>2</td>
<td>—</td>
<td>AC_BK</td>
<td>Background</td>
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<tr>
<td></td>
<td>0</td>
<td>BE</td>
<td>AC_BE</td>
<td>Best Effort</td>
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<td></td>
<td>3</td>
<td>EE</td>
<td>AC_BE</td>
<td>Best Effort</td>
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<td></td>
<td>4</td>
<td>CL</td>
<td>AC_VI</td>
<td>Video</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>VI</td>
<td>AC_VI</td>
<td>Video</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>VO</td>
<td>AC_VO</td>
<td>Voice</td>
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<tr>
<td></td>
<td>7</td>
<td>NC</td>
<td>AC_VO</td>
<td>Voice</td>
</tr>
</tbody>
</table>

2014 CWNP Wi-Fi Conference ~ 15 Years in Wireless
Quality of Service

Wired QoS

- Layer 2 QoS
  - 8 802.1D User Priorities
- Layer 3 QoS
  - 8 IP Precedences
  - 21 defined DSCP markings
  - Differentiated Service Code Points

<table>
<thead>
<tr>
<th>PHB</th>
<th>DSCP</th>
<th>TOS field</th>
<th>CS (PHB)</th>
<th>Drop Prec</th>
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<tr>
<td>Default</td>
<td>0</td>
<td>0000000</td>
<td>000 (0)</td>
<td>000 (0)</td>
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<tr>
<td>AF11</td>
<td>10</td>
<td>0010100</td>
<td>001 (1)</td>
<td>010 (2)</td>
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<tr>
<td>AF12</td>
<td>12</td>
<td>0011000</td>
<td>001 (1)</td>
<td>100 (4)</td>
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<td>AF13</td>
<td>14</td>
<td>0011100</td>
<td>001 (1)</td>
<td>110 (6)</td>
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<tr>
<td>AF21</td>
<td>18</td>
<td>0100100</td>
<td>010 (2)</td>
<td>010 (2)</td>
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<tr>
<td>AF22</td>
<td>20</td>
<td>0101000</td>
<td>010 (2)</td>
<td>100 (4)</td>
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<td>AF23</td>
<td>22</td>
<td>0101100</td>
<td>010 (2)</td>
<td>110 (6)</td>
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<td>AF31</td>
<td>26</td>
<td>0110100</td>
<td>011 (3)</td>
<td>010 (2)</td>
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<tr>
<td>AF32</td>
<td>28</td>
<td>0111000</td>
<td>011 (3)</td>
<td>100 (4)</td>
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<tr>
<td>AF33</td>
<td>30</td>
<td>0111100</td>
<td>011 (3)</td>
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<td>AF41</td>
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<td>100 (4)</td>
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<td>1001100</td>
<td>100 (4)</td>
<td>110 (6)</td>
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<tr>
<td>EF</td>
<td>46</td>
<td>1011100</td>
<td>101 (5)</td>
<td>110 (6)</td>
</tr>
<tr>
<td>CS0</td>
<td>0</td>
<td>0000000</td>
<td>000 (0)</td>
<td>000 (0)</td>
</tr>
<tr>
<td>CS1</td>
<td>8</td>
<td>0010000</td>
<td>001 (1)</td>
<td>000 (0)</td>
</tr>
<tr>
<td>CS2</td>
<td>16</td>
<td>0100000</td>
<td>010 (2)</td>
<td>000 (0)</td>
</tr>
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<td>CS3</td>
<td>24</td>
<td>0110000</td>
<td>011 (3)</td>
<td>000 (0)</td>
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<td>CS4</td>
<td>32</td>
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<td>000 (0)</td>
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<td>CS5</td>
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<td>CS6</td>
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<td>CS7</td>
<td>56</td>
<td>1110000</td>
<td>111 (7)</td>
<td>000 (0)</td>
</tr>
</tbody>
</table>
Quality of Service

End To End

- Default behavior of many switches is to remove QoS markings before forwarding
- Switch process QoS 3 ways:
  - Strip and forward
  - Honor and forward
  - Process and forward
Signaling and Encoding

IP Voice consists of:

- Call Signaling
- Call Encoding
Signaling and Encoding

Encoding examples:

<table>
<thead>
<tr>
<th>Bit Rate (Kbps)</th>
<th>Sample Size (Bytes)</th>
<th>Sample Rate (kHz)</th>
<th>Sample Interval</th>
<th>MOS</th>
<th>Voice Payload (Bytes)</th>
<th>Voice Payload (ms)</th>
<th>Packets Per Second</th>
</tr>
</thead>
<tbody>
<tr>
<td>G.711</td>
<td>64</td>
<td>8</td>
<td>10 ms</td>
<td>4.1</td>
<td>160</td>
<td>20 ms</td>
<td>50</td>
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<tr>
<td>G.729</td>
<td>8</td>
<td>10</td>
<td>10 ms</td>
<td>3.92</td>
<td>20</td>
<td>20 ms</td>
<td>50</td>
</tr>
<tr>
<td>G.723.1</td>
<td>6.3</td>
<td>24</td>
<td>30 ms</td>
<td>3.9</td>
<td>24</td>
<td>30 ms</td>
<td>33.3</td>
</tr>
<tr>
<td>G.723.1</td>
<td>5.3</td>
<td>20</td>
<td>30 ms</td>
<td>3.8</td>
<td>20</td>
<td>30 ms</td>
<td>33.3</td>
</tr>
<tr>
<td>G.726</td>
<td>32</td>
<td>20</td>
<td>5 ms</td>
<td>3.85</td>
<td>80</td>
<td>20 ms</td>
<td>50</td>
</tr>
<tr>
<td>G.726</td>
<td>24</td>
<td>15</td>
<td>5 ms</td>
<td>3.85</td>
<td>60</td>
<td>20 ms</td>
<td>50</td>
</tr>
<tr>
<td>G.728</td>
<td>16</td>
<td>10</td>
<td>5 ms</td>
<td>3.61</td>
<td>60</td>
<td>30 ms</td>
<td>33.3</td>
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<tr>
<td>G.722</td>
<td>64</td>
<td>80</td>
<td>10 ms</td>
<td>4.13</td>
<td>160</td>
<td>20 ms</td>
<td>50</td>
</tr>
</tbody>
</table>
Signaling and Encoding

**Encoding:**
- Most codecs use 8K samples
- Human ear can hear 20Hz-20KHz
- The human voice range is 300Hz-3400Hz
- Can you guess what range codecs sample?
Signaling and Encoding

Frequency Power Spectrum

Amplitude
0.00 20.0m 40.0m 60.0m 80.0m 100m

Frequency (Hz)
0 2000 4000 6000 8000 10000 12000 14000 16000 18000 20000
Signaling and Encoding

Types of Signaling:
- H.323
- SCCP “Skinny”
- SIP
- SVP

Signaling protocols are created by:
- ITU, IETF, IEEE and others
VoWi-Fi Demonstration

Let’s Make some calls
Sip Server:192.168.2.10
Codec:G.711u
Use Phone #:100 to 120