YOU HAVE HOW MANY DEVICES?

WI-FI NETWORK DESIGN
**INTRODUCTION**

**WHY ARE WE HERE?**

- Extremely dense client environments mean we can’t wing it any longer
- Effective Wi-Fi design for high capacity is work and knowledge intensive
- It can be tough to know where to begin
WHY ARE WE HERE?

- Extremely dense client environments mean we can’t wing it any longer
- Effective Wi-Fi design for high capacity is work and knowledge intensive
- It can be tough to know where to begin
Elements of Wi-Fi Network Design

- Customer/organization requirements
- Understanding your site
- Infrastructure requirements
- Radio frequency (RF) planning
- Capacity planning
ELEMENTS OF A WI-FI NETWORK DESIGN

- Design techniques and tools
- Network installation
- Testing, validation, and adjustment
CUSTOMER/ORGANIZATION REQUIREMENTS

WI-FI DESIGN ELEMENTS
A modern dense 5 GHz network requires more equipment than an older 2.4 GHz network.
CUSTOMER/ORGANIZATION REQUIREMENTS

CLIENT DEVICES

- Different Wi-Fi clients perform differently.
  - Chipsets
  - Antennas
  - Transmit power
- Document the capabilities of your fleet in order better understand implications for coverage and capacity.
Apple equipment specs usually omit detailed Wi-Fi specifications, but Apple has begun publishing more information in

- OS X Deployment Reference
- iOS Deployment Reference

Also see Mike Albano’s client specs project
## APPLICATION REQUIREMENTS

<table>
<thead>
<tr>
<th>Application</th>
<th>Required Throughput</th>
</tr>
</thead>
<tbody>
<tr>
<td>Web Browsing</td>
<td>500 Kbps - 1 Mbps</td>
</tr>
<tr>
<td>SD Video Streaming</td>
<td>1 - 1.5 Mbps</td>
</tr>
<tr>
<td>AppleTV Streaming</td>
<td>2.5 - 8 Mbps</td>
</tr>
</tbody>
</table>

From the Aerohive High Density Design Guide
CUSTOMER REQUIREMENTS

DENSITY

- How many devices are your users carrying?
- How many devices will be used concurrently in a given area?
UNDERSTANDING YOUR SITE

WI-FI DESIGN ELEMENTS
Facility size can provide a starting point for estimating the equipment required

Ceiling heights affect coverage and signal intensity at clients

Multiple floor facilities require special care to avoid channel overlap issues
CONSTRUCTION AND OBSTACLES

- Look for concrete, rebar, and elevator shafts
- Watch out for heavy metal objects, or liquids
- Attenuation of signal is documented/assumed for common materials, but verify yourself
EQUIPMENT AND INFRASTRUCTURE

WI-FI NETWORK DESIGN
EQUIPMENT AND INFRASTRUCTURE

CABLING
NETWORK CABLEING

- Sufficient cabling to appropriate locations
- Cabling according to specifications
EQUIPMENT AND INFRASTRUCTURE

POWER

- Access points require power
- Access points often go in hard to reach places
- Enter Power over Ethernet (PoE)
## Power Over Ethernet

<table>
<thead>
<tr>
<th></th>
<th>802.3af</th>
<th>802.3at</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nickname</strong></td>
<td>PoE</td>
<td>PoE+ (plus)</td>
</tr>
<tr>
<td><strong>Wattage/port</strong></td>
<td>15.4W</td>
<td>34.2W</td>
</tr>
<tr>
<td><strong>Wattage/guaranteed</strong></td>
<td>12.95W</td>
<td>25.5W</td>
</tr>
</tbody>
</table>
POE BUDGET

- ZyXel GS-1900-8
  - 8 ports
  - 802.3af/802.3at
  - 70W power budget
POE BUDGET

- ZyXel GS-1900-8
  - 8 ports
  - 802.3af/802.3at
  - 70W power budget
- How many APs is that?
  - 2 at 25.4W
  - 5 at 12.95W
**POE BUDGET**

---

**Power**
- Power over Ethernet: 37 - 57 V (802.3at required with functionality-restricted 802.3af mode supported)
- Alternative 12 V DC Input
- Power consumption: 20W max (802.3at)
- Power over Ethernet injector and DC adapter sold separately

---

**POWER**
- 48 volts DC 802.3af power over Ethernet (PoE)
- 12 volts DC for external AC supplied power (adapter sold separately)
- Maximum power consumption: 12.5 watts

---

**POWER DRAW**
- PoE-Powered
  - Idle: 4W
  - Typical: 5.95W
  - Peak: 10.5W
- 12VDC-Powered
  - Idle: 4W
  - Typical: 6.13W
  - Peak: 11.1W
WI-FI DESIGN

RADIO FREQUENCY PLANNING
PLANNING GOAL

- Plan channels to minimize co-channel interference (CCI) and avoid adjacent channel interference (ACI)
CO-CHANNEL INTERFERENCE

CO-CHAUCER WHAT?
ADJACENT CHANNEL INTERFERENCE

ADJACENT CHEESESTEAK WHO?
2.4 GHZ

- 3 non-overlapping 20 MHz channels (in North America: 1, 6, 11)
- Effective longer range than 5 GHz, but lower overall performance
2.4 GHZ RECOMMENDATIONS

- Consider doing away with 2.4 GHz entirely, per Apple and Cisco (if you can)
- Focus your planning on achieving complete 5 GHz coverage
- If you can’t get away with ditching 2.4 GHz entirely, disable 2.4 GHz radios in some of your APs in order to reduce the likelihood of overlap and resulting CCI.
5 GHz

- 9 x 20 MHz channels
- 15 x 20 MHz DFS channels that you may be able to use
- Options for wider channels to increase performance
- Channels do not overlap!
5 GHz Channels

802.11ac Channel Allocation (N America)

FCC Domain

UNII-1 | UNII-2 | UNII-2-Extended | UNII-3 | ISM

WiFi Channel #

36 40 44 48 52 56 60 64 100 104 108 112 116* 120 124 128 136 140 144 144 153 157 161 165

Channel Width

20 MHz

40 MHz

80 MHz

160 MHz

Frequency

5170 MHz 5250 MHz 5330 MHz 5490 MHz 5710 MHz 5735 MHz 5815 MHz 5835 MHz

*Channels 116 and 132 are Doppler Radar channels that may be used in some cases.
5 GHz Attenuation

- 5 GHz signals suffer more from attenuation over distance, and weaken more rapidly than 2.4 GHz signals.
- Consequently, a 5 GHz design will require more APs than a 2.4 GHz design.
- 5 GHz will also allow support a greater density of APs.
RADIO FREQUENCY PLANNING

DYNAMIC FREQUENCY SELECTION
If an access point using a DFS channel detects radar emissions, the FCC requires the AP to dynamically change the channel it is using.

UNII-2: 52, 56, 60 and 64

Beyond the standard DFS channel requirements, regulations prohibit use of 120, 124, and 128 within 35 kilometers of a Terminal Doppler Weather Radar.
Therefore, for the combined twelve unlawful operation and interference violations, we will propose the maximum forfeiture authorized by statute, or $16,000 per violation, yielding a $192,000 proposed forfeiture. In addition, for operating the unlicensed wireless broadband transceiver in Miami, we propose the base forfeiture amount of $10,000, which is consistent with our precedent and reflects the fact that the operation of this device did not cause interference to a TDWR system.

Applying the Forfeiture Policy Statement, Section 1.80 of the Rules, and the statutory factors to the instant case, we conclude that **Towerstream is apparently liable for a total forfeiture in the amount of $202,000, consisting of the following elements: $106,000 for seven unlicensed operation violations and $96,000 for six incidents of interfering with TDWR systems.** As discussed above, the forfeitures reflect upward adjustments based on the public safety impact of the interference, Towerstream's prior history of causing interference to radio communications operated by the United States Government, and the seriousness of the violations.
5 GHz CHANNELS MINUS DFS

802.11ac Channel Allocation excluding DFS (N America)

FCC Domain

<table>
<thead>
<tr>
<th>WiFi Channel #</th>
<th>Channel Width</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td>20 MHz</td>
<td>5170 MHz</td>
</tr>
<tr>
<td>40</td>
<td>40 MHz</td>
<td>5250 MHz</td>
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<tr>
<td>44</td>
<td>80 MHz</td>
<td>5330 MHz</td>
</tr>
<tr>
<td>48</td>
<td>160 MHz</td>
<td>5490 MHz</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DFS Channels</th>
<th>Weather Radar</th>
</tr>
</thead>
<tbody>
<tr>
<td>52 - 56</td>
<td>100 - 104</td>
</tr>
<tr>
<td>60 - 64</td>
<td>108 - 112</td>
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<tr>
<td>112 - 116</td>
<td>116 - 120</td>
</tr>
<tr>
<td>120 - 124</td>
<td>124 - 128</td>
</tr>
<tr>
<td>132 - 136</td>
<td>136 - 140</td>
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<td>140 - 144</td>
<td>144 - 144</td>
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<table>
<thead>
<tr>
<th>UNII-1</th>
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<th>UNII-2-Extended</th>
<th>UNII-3</th>
<th>ISM</th>
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<tbody>
<tr>
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<td>5710</td>
<td>5735</td>
<td>5815</td>
<td>5835</td>
<td></td>
</tr>
</tbody>
</table>

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RADIO FREQUENCY PLANNING

IN SUMMARY

- Design for 5 GHz
- Use 20 MHz or (maybe) 40 MHz channels
- Plan on more access points than a corresponding 2.4 GHz design
- Take advantage of DFS if you can
CAPACITY PLANNING

WI-FI NETWORK DESIGN
WAYS TO THINK ABOUT CAPACITY

- Number of APs a wireless controller can support
- Number of clients that can use an access point
- Amount of traffic an access point can move
Switch environments provide performance advantages

- Every connection is at full port speed.
- There is a finite limit to the number of devices that can connect to a switch.
VENDOR CLAIMS ARE VARIABLE AND BEST CASE

- Ruckus says 500 per radio, or 100 when you turn on encryption
- Aerohive says 100 per radio
- Cisco Meraki classifies 40+ clients as “high-density”
BECAUSE WI-FI DEPENDS ON A SHARED MEDIUM, THINK OF AN AP MORE LIKE A HUB, BUT ONE WITHOUT PHYSICAL CONNECTION LIMITS.

DENSITY
AIRTIME

- Calculated percentage of the available transmission time a client device will utilize to move data
- Percentage is derived from
  1. Application bandwidth requirement
  2. Real client performance
AIRTIME CALCULATIONS

\[
\frac{\text{Bandwidth Required}}{\text{Real Throughput}} = \text{Airtime Required}
\]
CAPACITY PLANNING

AIRTIME CALCULATIONS: IPAD2

- SD Video: 1 Mbps
- 65 Mbps max TX = 30 Mbps real world*

*Maybe, ideally

Numbers taken from the Aerohive High Density Design Guide
AIRTIME CALCULATIONS: IPAD2

\[ \frac{1 \text{ Mbps}}{30 \text{ Mbps}} = .033 \text{ or } 3.33\% \]
In theory, then, 30 iPad 2 would use 100% of the available Airtime on an AP.

This is true independent of the capabilities of the access point.

It’s also purely theoretical, and unlikely to work in practice.
CAPACITY PLANNING

AIRTIME CALCULATIONS: IPAD2

- Network collisions and congestion
- Distance from the access point
- Interference
AIRTIME

- Compare this to the faster iPad Mini 2 at 144 Mbps TX (65 Mbps expected)
- Older and less capable devices will adversely affect network capacity
- Upgrades to newer devices to mitigate
DEEP DIVE AND AUTOMATION OF CAPACITY PLANNING

- Revolution WiFi Capacity Planner
- Spreadsheet tool and guide developed by Andrew Von Nagy
- Plug in your expected specs, and estimate your equipment requirements
TOOLS AND TECHNIQUES

AP ON A STICK
TOOLS AND TECHNIQUES
PREDICTIVE SURVEYS
Tools and Techniques

AP On A Stick

- Measure real-world performance against your design
- Revise your design if needed
SING A SONG OF SIXPENCE

Lin Manuel-Miranda as Alexander Hamilton
WI-FI NETWORK DESIGN

INSTALLATION
INSTALLATION

MOUNTING DESIGN

- Mount access points according to vendor design
- Remember the inverse square law
- Don’t waste APs
INSTALLATION AND MOUNTING

LIKE THIS
NOT LIKE THIS
WI-FI NETWORK DESIGN

TESTING AND VALIDATION
PASSIVE SURVEY WITH NETSPOT PRO
VALIDATION AND TESTING

ADJUSTING THE INSTALL WITH NETSPOT PRO
RESOURCES
THE EXACT QUOTATION? ALAS, THAT WOULD BE FOUND IN A BOOK BORROWED BY A FRIEND WHO NEVER RETURNED IT, MARKED BY A SLIP OF PAPER THAT FELL OUT LONG AGO.

Nigel Strangeways, Babblings of a Bibliophile
RESOURCES

TEXTS AND DOCUMENTS

- CNWA Study Guide
- Enterprise Best Practices for Apple Devices on Cisco Wireless LAN
- Aerohive High Density Design Guide
- Cisco Meraki High Density Design Guide
RESOURCES

APPLE KBASE ARTICLES AND ONLINE HELP DOCUMENTS

- About OS X wireless roaming for enterprise customers (Mac OS X)
- Wireless roaming reference for enterprise customers (iOS 8 and later)
- Mac OS Deployment Reference (online guide)
- iOS Deployment Reference (online guide)
RESOURCES

BLOGS AND COMMUNITY TOOLS

- Mike Albano’s Client List
- Revolution Wi-Fi
- Revolution Wi-Fi Capacity Planner
WI-FI NETWORK DESIGN

IS THERE EVEN TIME FOR QUESTIONS?