YOU HAVE HOW MANY DEVICES?

WI-FI NETWORK DESIGN

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

WI-FI DESIGN ELEMENTS

CUSTOMER/ORGANIZATION REQUIREMENTS

A MODERN DENSE 5 GHZ NETWORK REQUIRES MORE EQUIPMENT THAN AN OLDER 2.4 GHZ NETWORK

BUDGET

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.

CLIENT DEVICES

- 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

Application	Required Throughput
Web Browsing	500 Kbps - 1 Mbps
SD Video Streaming	1 - 1.5 Mbps
AppleTV Streaming	2.5 - 8 Mbps

From the Aerohive High Density Design Guide

DENSITY

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

WI-FI DESIGN ELEMENTS

UNDERSTANDING YOUR SITE

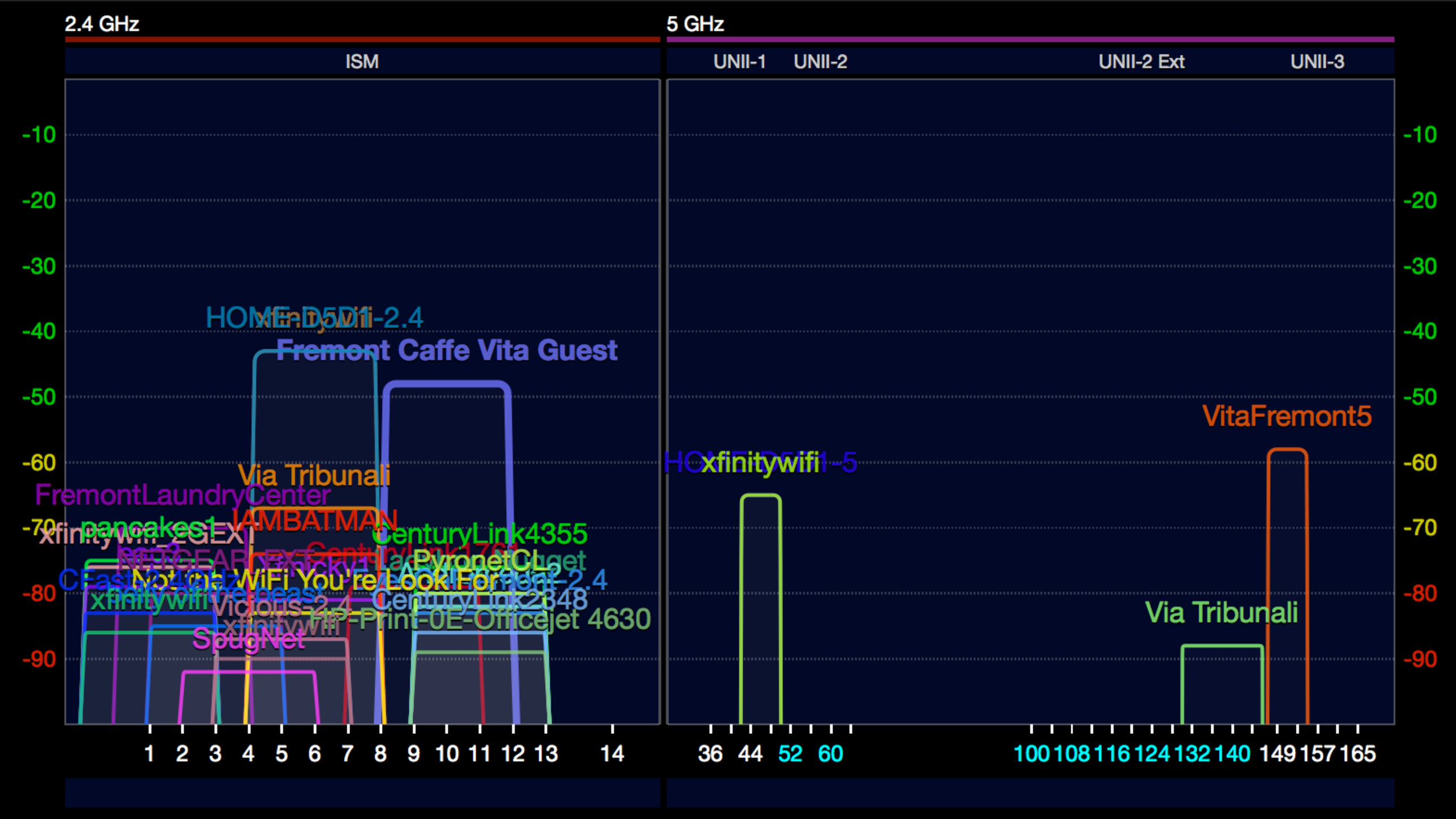
FACILITY SIZE

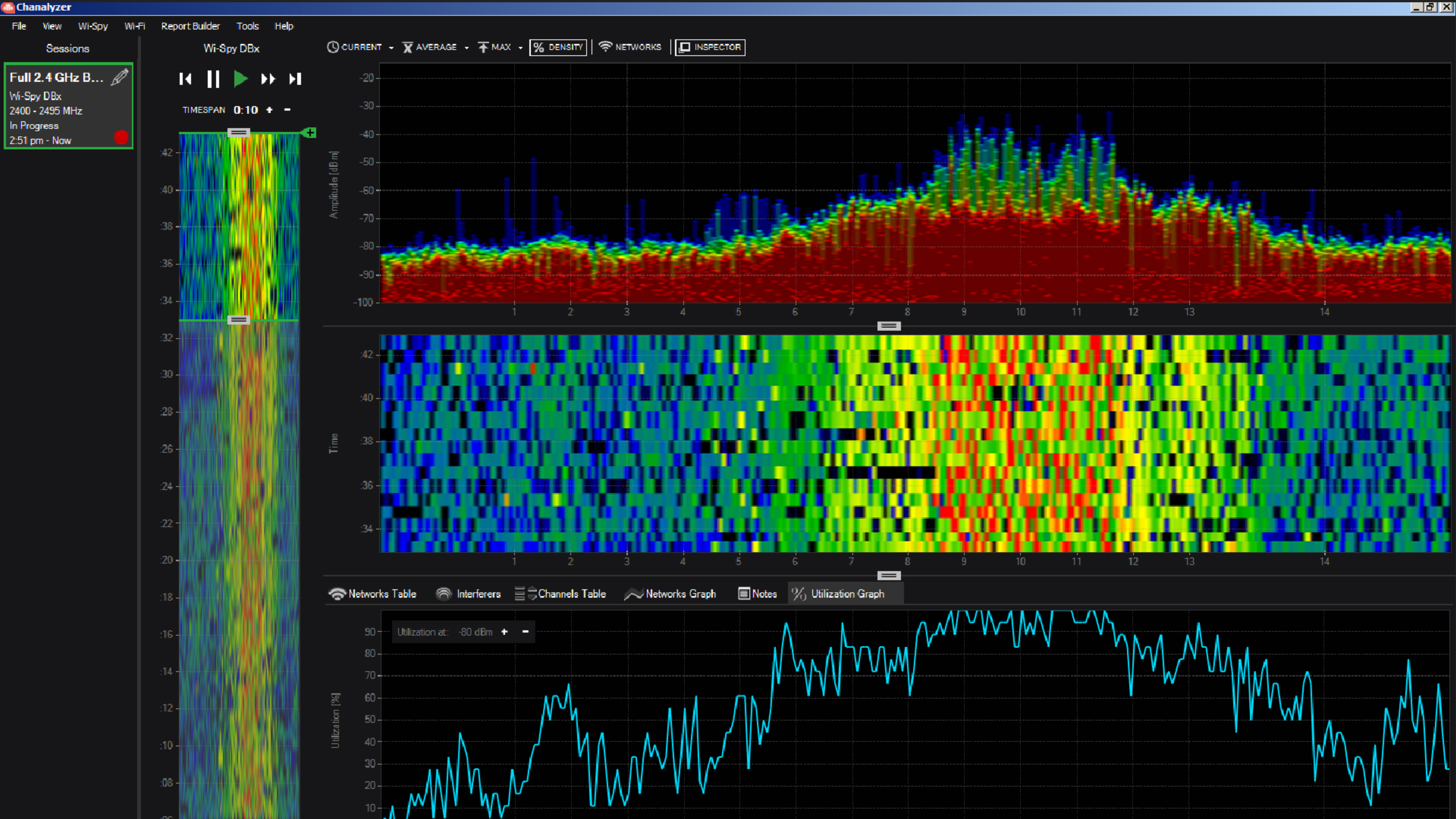
- Facility size can provide a starting point for estimating the equipment required
- Ceiling heights affect coverage and signal intensity at clients
- Multiple floor facilities require special care to avoid channel overlap issues

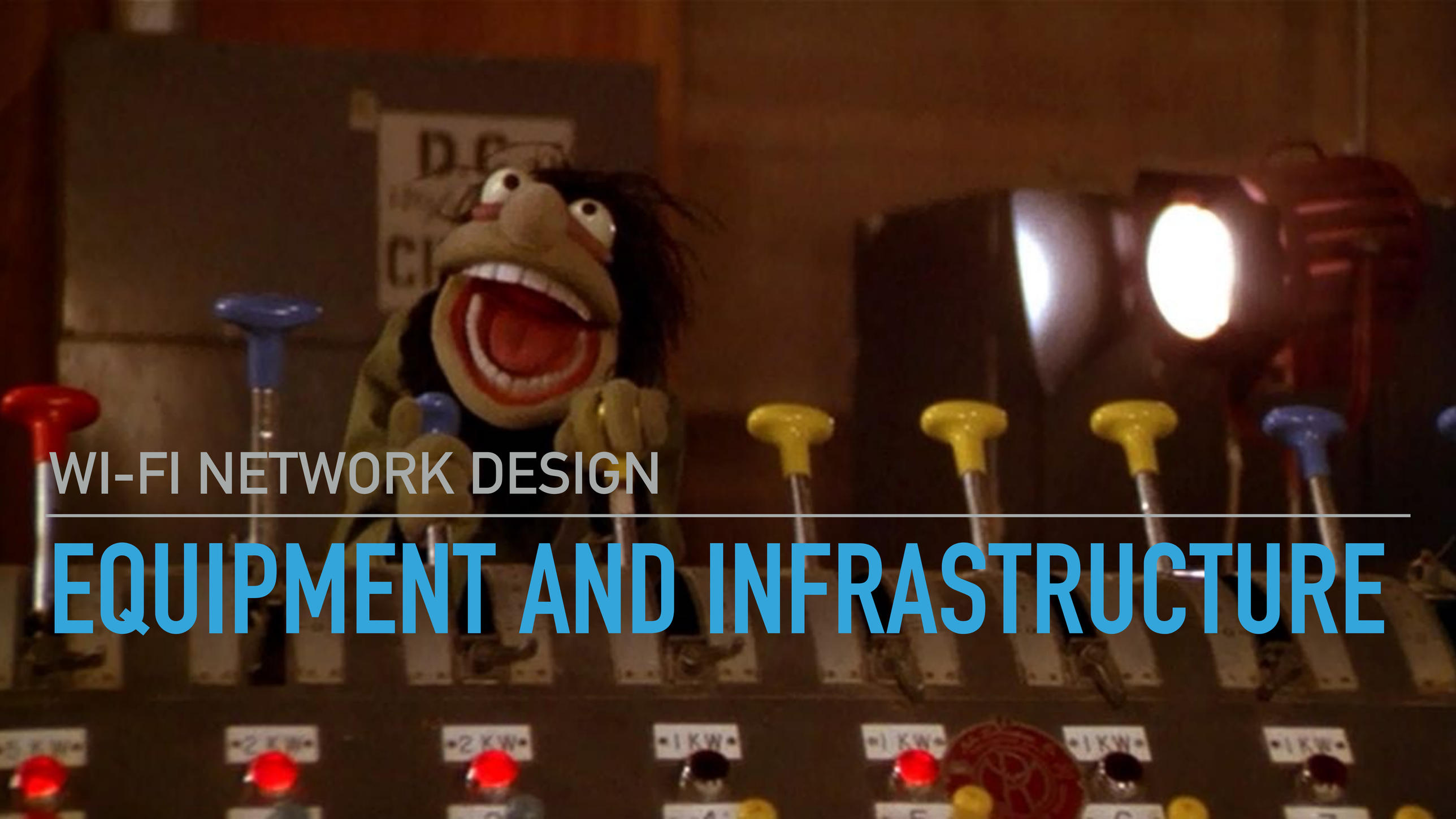
CONSTRUCTION AND OBSTACLES

- 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

USAGE AND KEY SPACES


2.4 GHz
5 GHz
ISM
UNII-1
UNII-2
UNII-2 Ext
UNII-3
-10
-20
-30
-40
-50
-60
-70
-80
-90
HOME-D5D1-2.4
Fremont Caffe Vita Guest
Via Tribunali
FremontLaundryCenter
pancakes1
IAMBATMAN
CenturyLink4355
PyronetCL
WiFi You're Looking For
CenturyLink2348
Victorious-2.4
SpugNet
HOME-D5D1-5
xfinitywifi
VitaFremont5
Via Tribunali
1 2 3 4 5 6 7 8 9 10 11 12 13 14
36 44 52 60
100 108 116 124 132 140 149 157 165


Chanalyzer
File
View
Wi-Spy
Wi-Fi
Report Builder
Tools
Help
Sessions
Full 2.4 GHz B...
Wi-Spy DBx
2400 - 2495 MHz
In Progress
2:51 pm - Now
Wi-Spy DBx
TIMESPAN 0:10
CURRENT
AVERAGE
MAX
DENSITY
NETWORKS
INSPECTOR
Amplitude [dBm]
Time
Networks Table
Interferers
Channels Table
Networks Graph
Notes
Utilization Graph
Utilization at: -80 dBm
Utilization [%]



WI-FI NETWORK DESIGN

EQUIPMENT AND INFRASTRUCTURE

EQUIPMENT AND INFRASTRUCTURE

CABLING

NETWORK CABLING

- Sufficient cabling to appropriate locations
- Cabling according to specifications

POWER

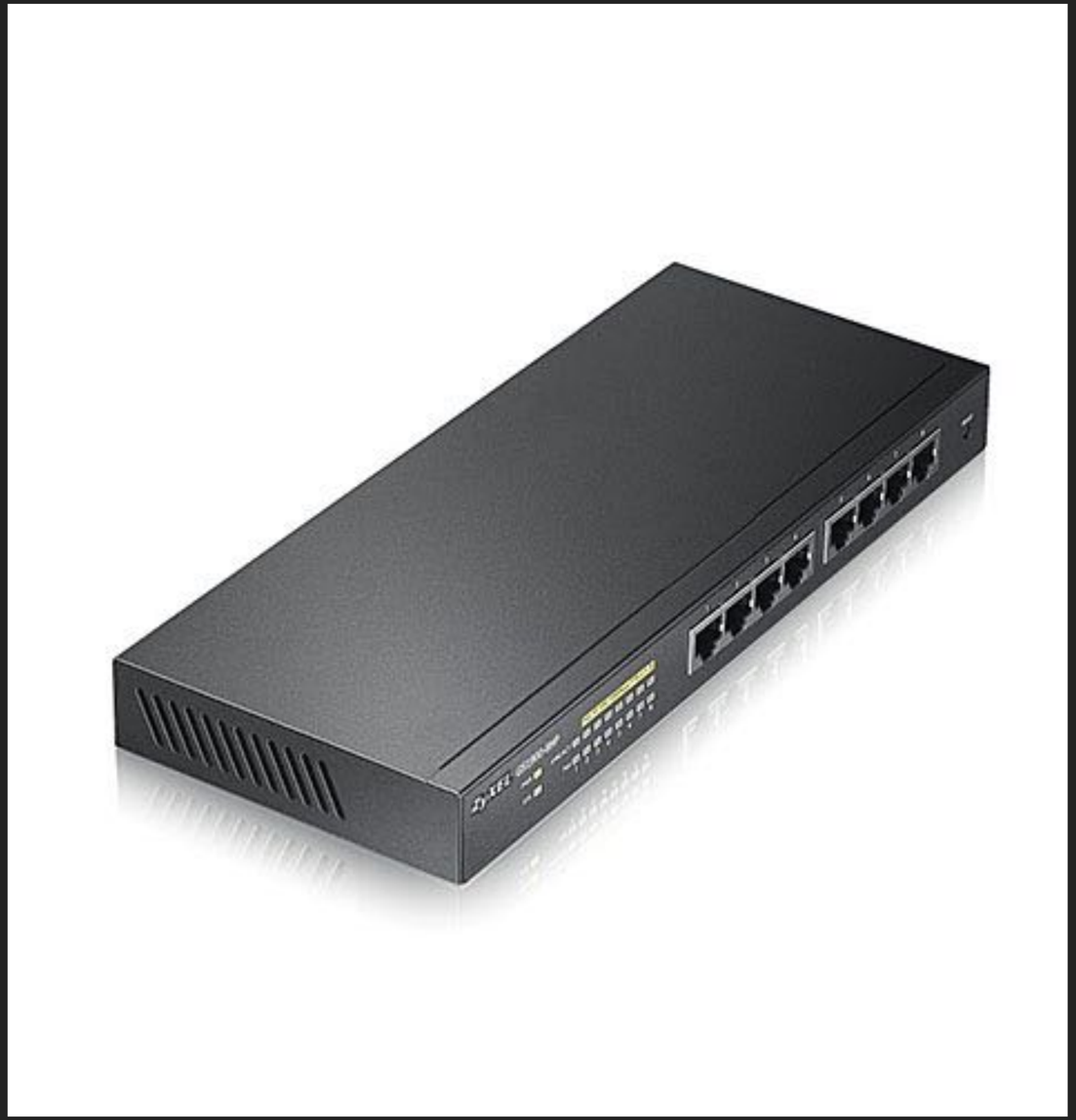
- Access points require power
- Access points often go in hard to reach places
- Enter Power over Ethernet (PoE)

POWER OVER ETHERNET

	802.3af	802.3at
Nickname	PoE	PoE+ (plus)
Wattage/port	15.4W	34.2W
Wattage/ guaranteed	12.95W	25.5W

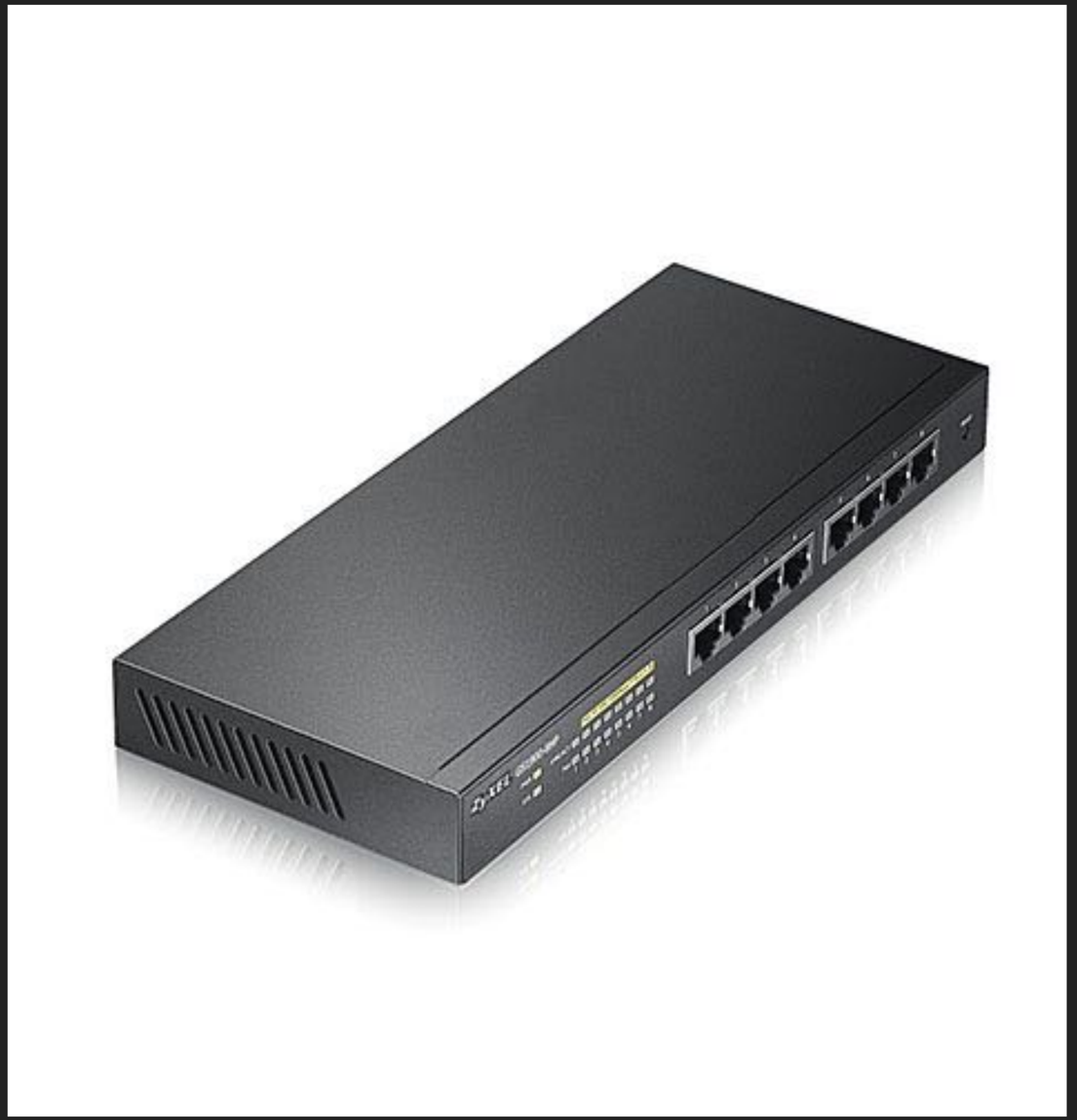
POE BUDGET

- 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

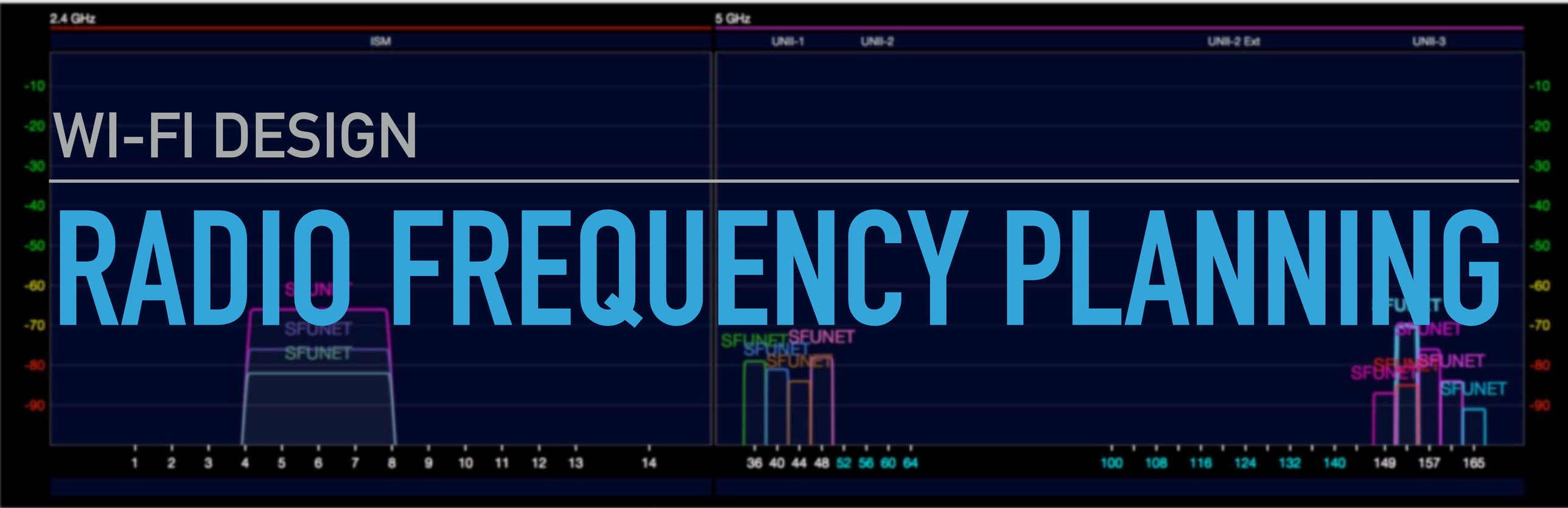
POWER

- 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

SFUNET	20:83:99:...	Enterasys Networks...	5 GHz	149	9 dB	-87	-96	8%	130 Mbps	2	24 Mbps	20 MHz	149	a/n
SFUNET	20:83:99:...	Enterasys Networks...	5 GHz	161	12 dB	-84	-96	6%	217 Mbps	3	6 Mbps	20 MHz	161	a/n
SFUNET	D8:84:66...	Extreme Networks	5 GHz	165	5 dB	-91	-96	4%	217 Mbps	3	6 Mbps	20 MHz	165	a/n
SFUNET	20:83:99:...	Enterasys Networks...	5 GHz	40	15 dB	-81	-96	3%	217 Mbps	3	24 Mbps	20 MHz	40	a/n
SFUNET	20:83:99:...	Enterasys Networks...	5 GHz	36	17 dB	-79	-96	3%	217 Mbps	3	6 Mbps	20 MHz	36	a/n
SFUNET	20:83:99:...	Enterasys Networks...	5 GHz	44	12 dB	-84	-96	3%	130 Mbps	2	24 Mbps	20 MHz	44	a/n
SFUNET	20:83:99:...	Enterasys Networks...	5 GHz	48	18 dB	-78	-96	3%	217 Mbps	3	24 Mbps	20 MHz	48	a/n

Network Details | Signal Strength | Channels | Advanced Details



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

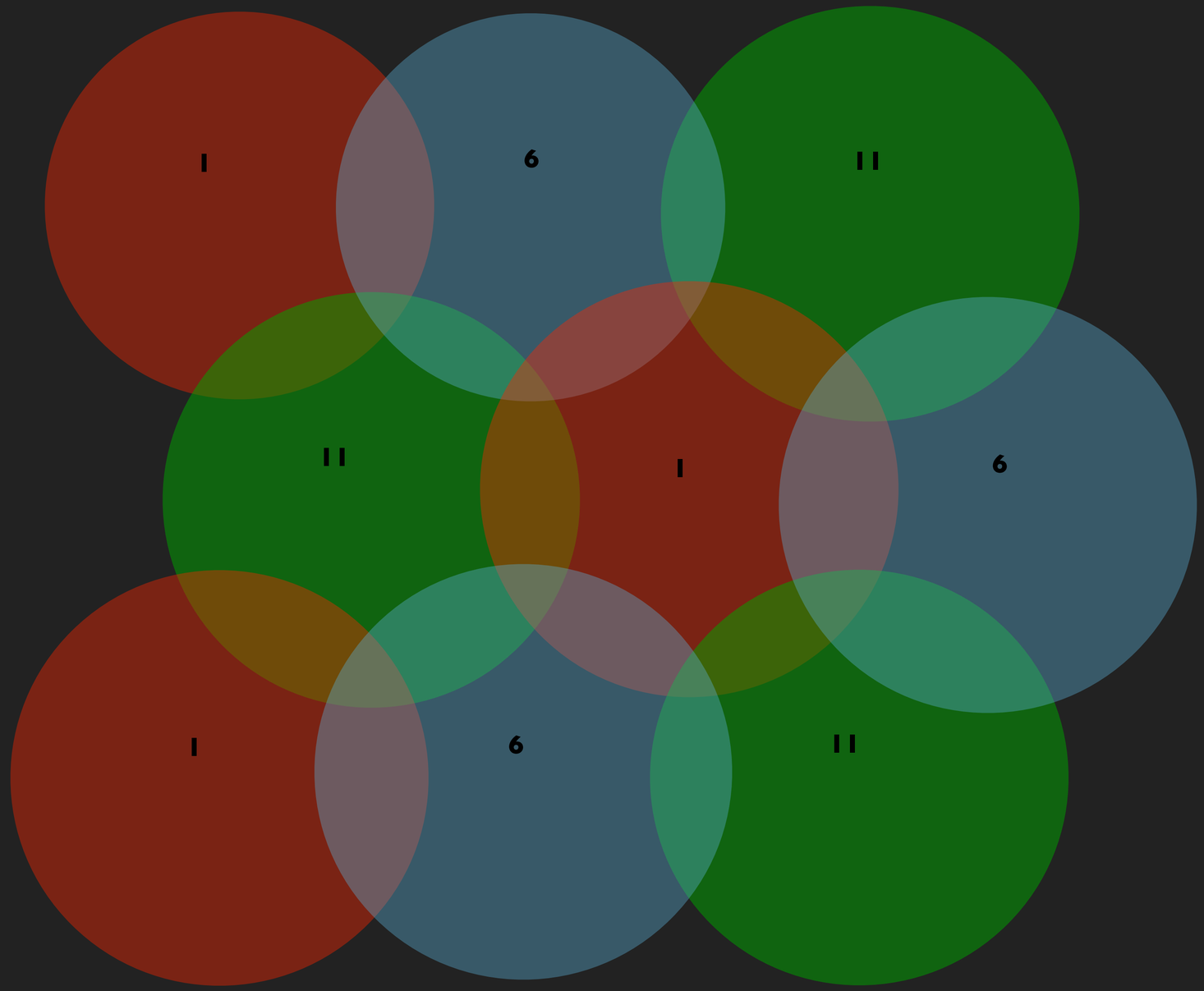
ADJACENT CHEESESTEAK WHO?

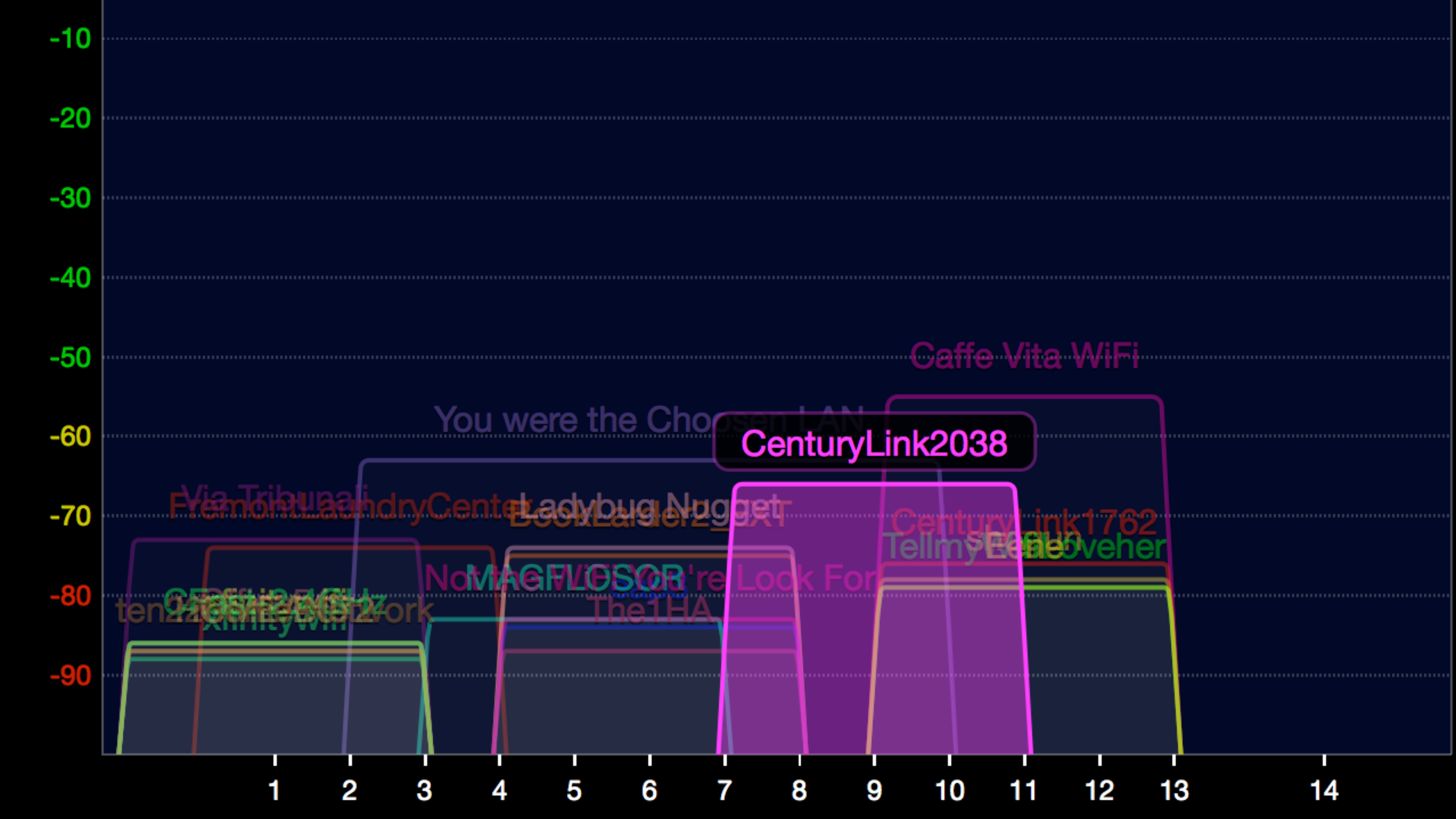
2.4 GHZ

- 3 non-overlapping 20 MHz channels (in North America

  1, 6, 11

- Effective longer range than 5 GHz, but lower overall performance





-10
-20
-30
-40
-50
-60
-70
-80
-90
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Caffe Vita WiFi
You were the Choosen LAN
CenturyLink2038
Via Tribunali
Ladybug Nugget
CenturyLink1762
Tellmy
The1HA

2.4 GHZ RECOMMENDATIONS

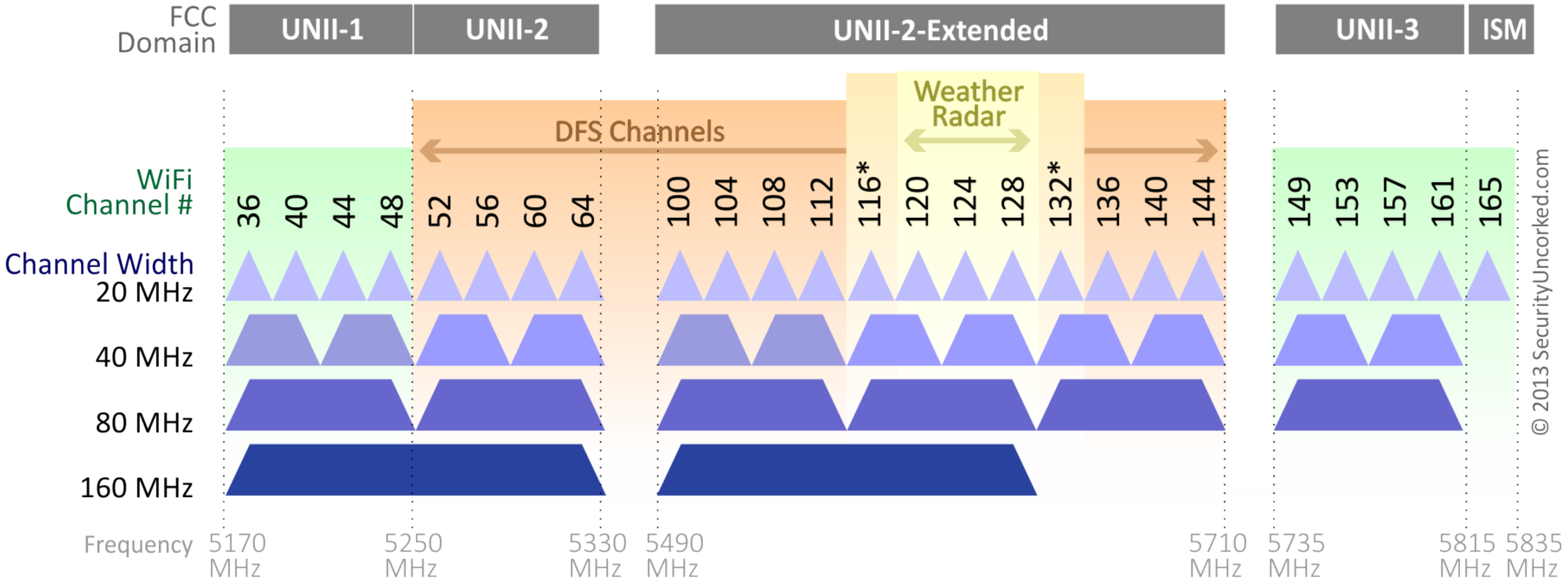
- Consider doing away with 2.4 GHz entirely, per Apple and Cisco (if you can)
- Focus your planning on achieving complete 5 GHz coverage
- If you can’t get away with ditching 2.4 GHz entirely, disable 2.4 GHz radios in some of your APs in order to reduce the likelihood of overlap and resulting CCI.

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)



*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

DYNAMIC FREQUENCY SELECTION

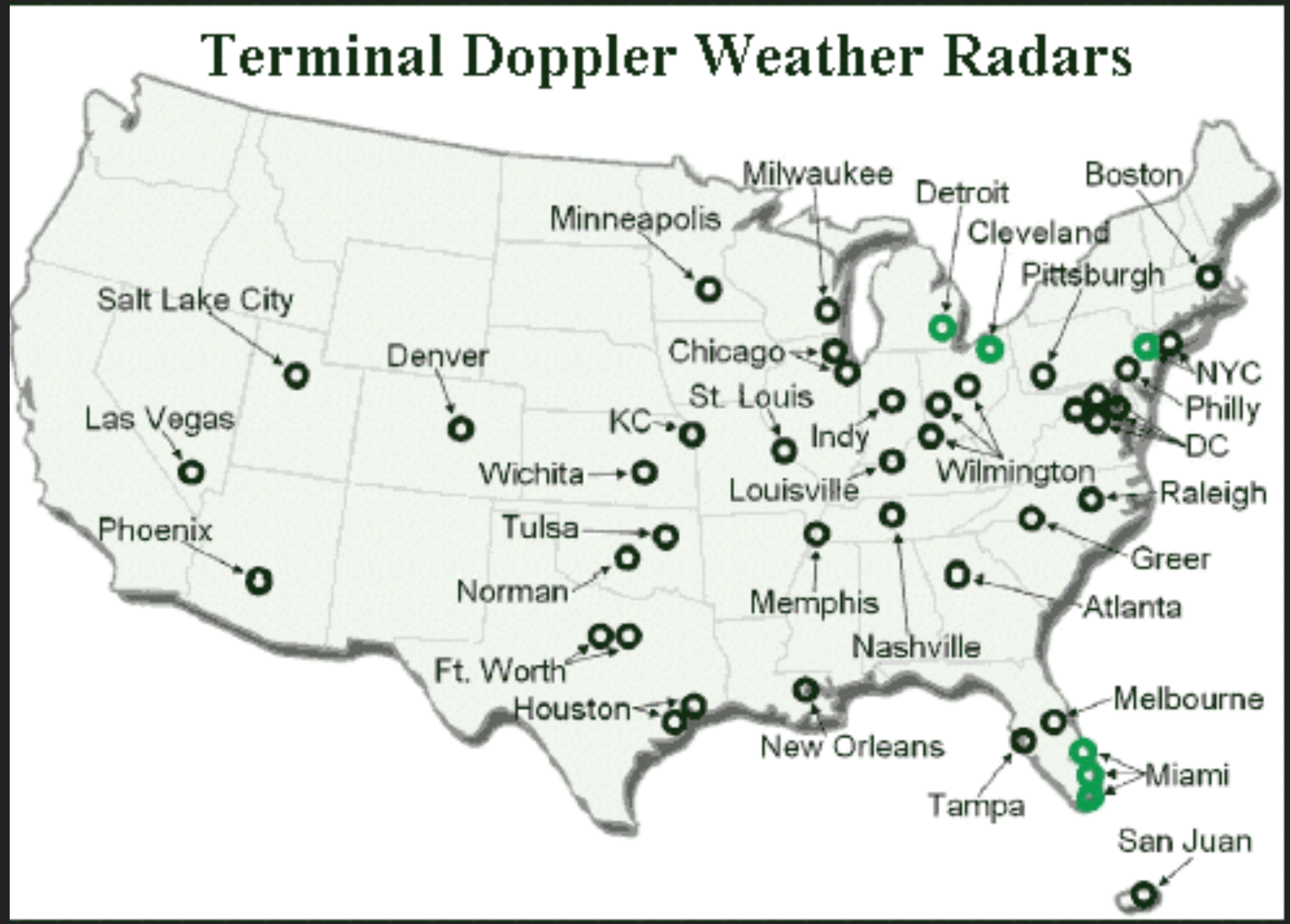
- If an access point using a DFS channel detects radar emissions, the FCC *requires* the AP to dynamically change the channel it is using.

UNII-2: 52, 56, 60 and 64

UNII-2 Extended: 100, 104, 108, 112, 116, 120, 124, 128, 132, 136, 140

5 GHZ AND TDWR

- Beyond the standard DFS channel requirements, regulations prohibit use of 120, 124, and 128 within 35 kilometers of a Terminal Doppler Weather Radar



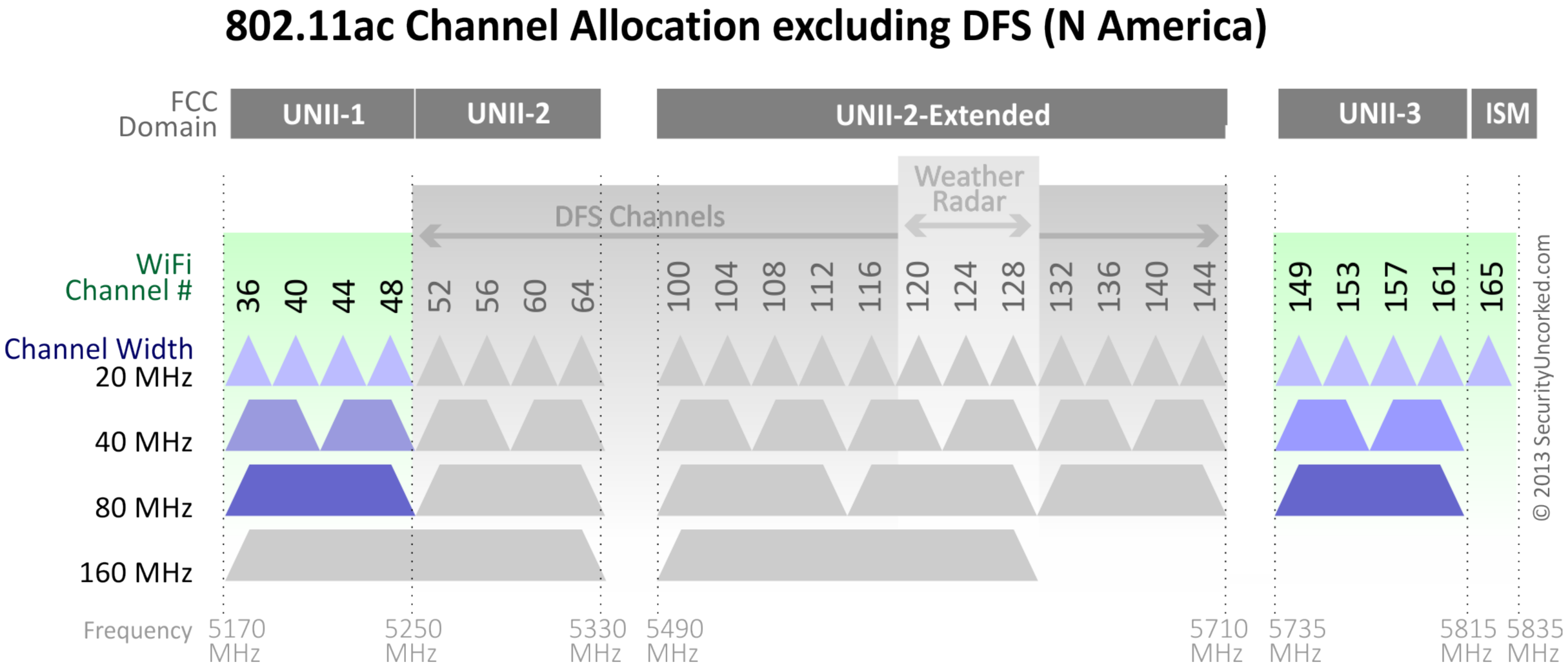
5 GHZ AND TDWR

- The FCC is *serious*
- TDWR Interference and Enforcement records

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



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

WI-FI NETWORK DESIGN

CAPACITY PLANNING

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

DENSITY

- 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

THE WEIRD TURN PRO

AIRTIME

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

$$\frac{Bandwidth\ \ Required}{Real\ \ Throughput} = Airtime\ \ Required$$

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

$$\frac{1 \ \ Mbps}{30 \ \ Mbps} = .033 \ \ or \ \ 3.33\%$$

AIRTIME CALCULATIONS: IPAD2

- 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.

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

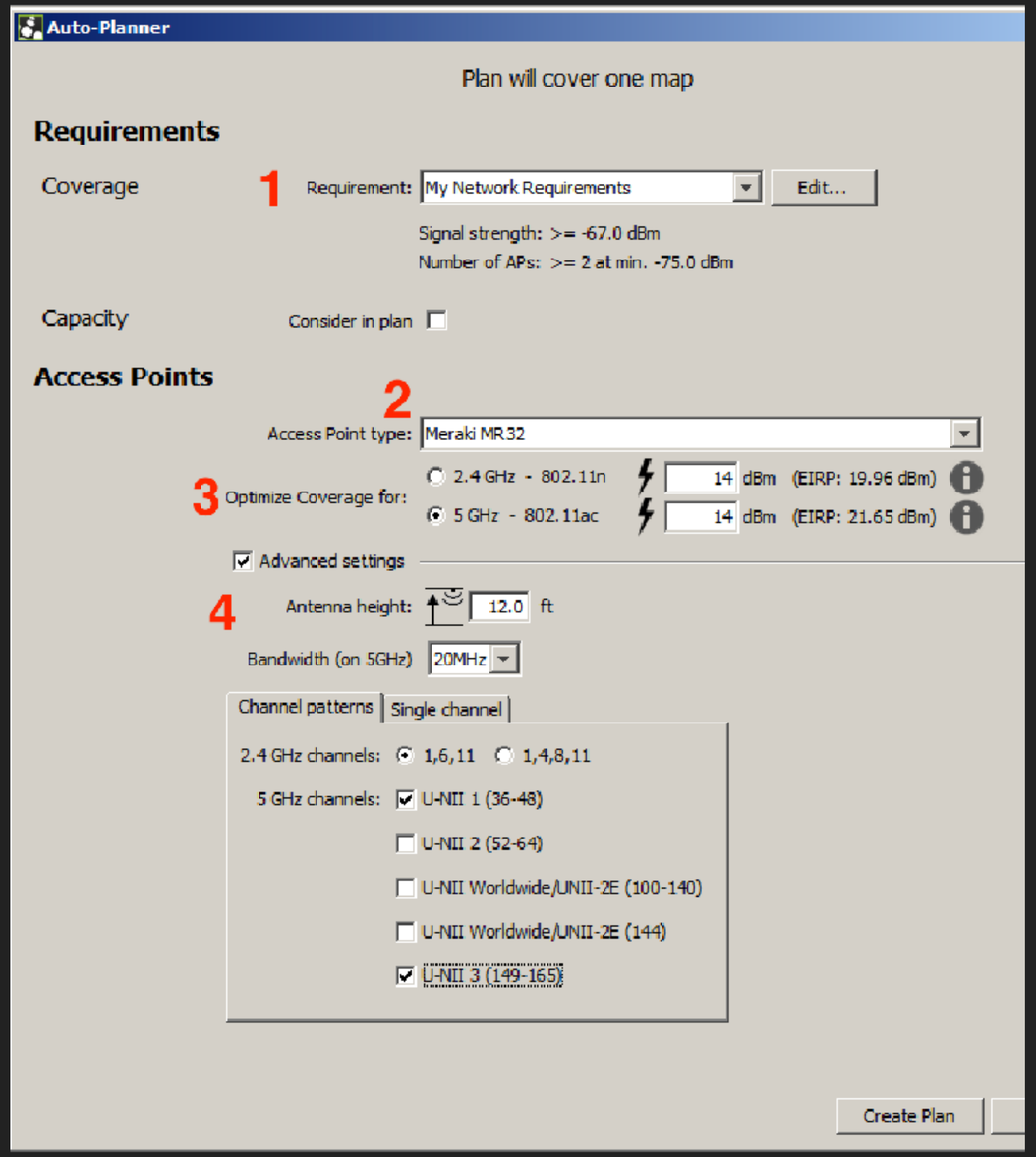
WI-FI NETWORK DESIGN

TOOLS AND TECHNIQUES FOR DESIGN

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

AP ON A STICK



TOOLS AND TECHNIQUES

PREDICTIVE SURVEYS

File Edit View Map Project Measurement Help

S.Str -43dBm | SNR 53dB | Data 450Mbps | #APs 10APs | Ch.O 14APs | No Adapter for Active Survey | Passive: 2.4 5 -41dBm

Access Points | Surveys | Building

Search

Showing:4/4 APs | Quick Select | Actions

OceTDS1863 (4/4 APs)

Show Signal Strength for My Access Points on 2.4 5 | Options

Planning | Survey

OceTDS1863 +

ENLARGED LOCKER/SHOWER RM. PLA

4.9 ft / 3.0dB/m

11 36

1 149 18.0dB/m

6 165

11 48

-90 -67 -45 dBm -80 >= 0

File Edit View Map Project Measurement Help

S.Str -41dBm | SNR 55dB | Data 450Mbps | #APs 11APs | Ch.O 17APs | No Adapter for Active Survey | Passive: 24 5 -40dBm

Access Points | Surveys | Building

Search

Showing:4/4 APs | Quick Select | Actions

OceTDS1863 (4/4 APs)

My Meraki MR32 (1)
n 11 12 ft Edit...
ac 36 12 ft Edit...

My Meraki MR32 (2)
n 1 12 ft Edit.
ac 149 12 ft Edit.

My Meraki MR32 (3)
n 6 12 ft Edit.
ac 165 12 ft Edit.

My Meraki MR32 (4)
n 11 12 ft Edit...
ac 48 12 ft Edit...

Show Signal Strength for My Access Points on 2.4 5 | Options

Planning | Survey

OceTDS1863 +

4.9 ft / 3.0dB/m
7.0dB/m
18.0dB/m
ENLARGED LOCKER/SHOWER RM. PLA
-90 -67 -45 dBm -80 >= 0

File Edit View Map Project Measurement Help

S.Str -43dBm | SNR 53dB | Data 450Mbps | #APs 11APs | Ch.O 18APs | No Adapter for Active Survey | Passive: 24 5 -42dBm

Access Points | Surveys | Building

Search

Showing:4/4 APs | Quick Select | Actions

OceTDS1863 (4/4 APs)

My Meraki MR32 (1)
n 11 12 ft Edit...
ac 36 12 ft Edit...

My Meraki MR32 (2)
n 1 12 ft Edit...
ac 149 12 ft Edit...

My Meraki MR32 (3)
n 6 12 ft Edit...
ac 165 12 ft Edit...

My Meraki MR32 (4)
n 11 12 ft Edit...
ac 48 12 ft Edit...

Show Signal Strength for My Access Points on 2.4 5 | Options

Planning | Survey

OceTDS1863 +

4.9 ft / 3.0dB/m
7.0dB/m
18.0dB/m

Signal Strength:

-70.0dBm - -67.0dBm

Requirement not met.
Requirement for My Network Requirements: -67.0dBm

Name(MAC)	Channel	Signal	Floor
Meraki MR32 (2)	149	-70	OceTDS1863
Meraki MR32 (1)	36	-72	OceTDS1863
Meraki MR32 (4)	48	-79	OceTDS1863
Meraki MR32 (3)	165	-86	OceTDS1863

-90 -80 -67 -45 dBm >= 0

File Edit View Map Project Measurement Help

S.Str -41dBm | SNR 55dB | Data 450Mbps | #APs 11APs | Ch.O 15APs | No Adapter for Active Survey | Passive: 24 5 -39dBm

Access Points | Surveys | Building

Search

Showing:5/5 APs | Quick Select | Actions

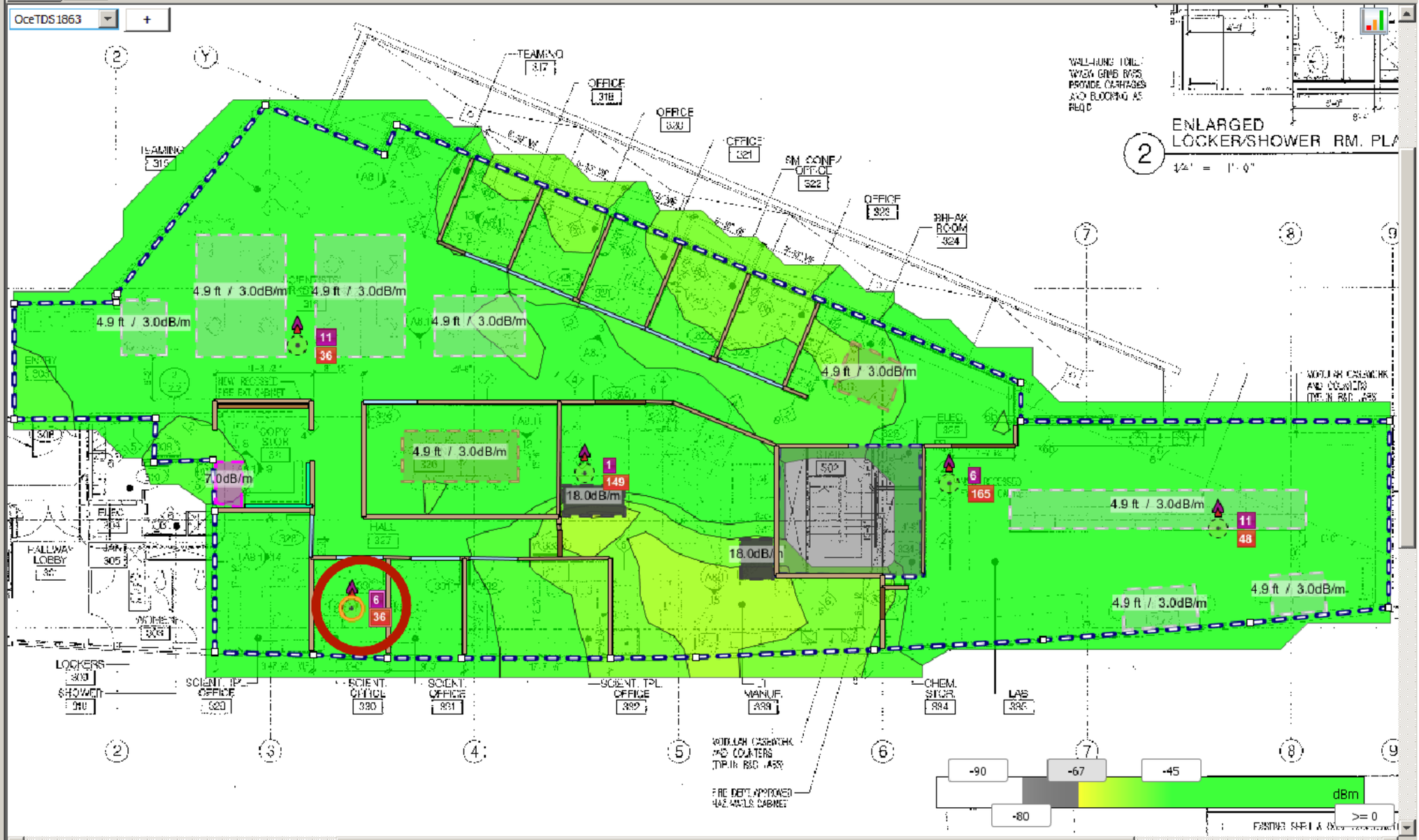
OceTDS1863 (5/5 APs), 2 radios selected

- My Meraki MR32 (1) — OceTDS1863
  - n 11 12 ft Edit...
  - ac 36 12 ft Edit...
- My Meraki MR32 (2) — OceTDS1863
  - n 1 12 ft Edit...
  - ac 149 12 ft Edit...
- My Meraki MR32 (3) — OceTDS1863
  - n 6 12 ft Edit...
  - ac 165 12 ft Edit...
- My Meraki MR32 (4) — OceTDS1863
  - n 11 12 ft Edit...
  - ac 48 12 ft Edit...
- My Meraki MR32 (5) — OceTDS1863
  - n 6 7.9 ft Edit...
  - ac 36 7.9 ft Edit...

Show Signal Strength for My Access Points on 2.4 5 | Options

Planning | Survey

OceTDS1863 +



AP ON A STICK

- Measure real-world performance against your design
- Revise your design if needed

SING A SONG OF SIXPENCE

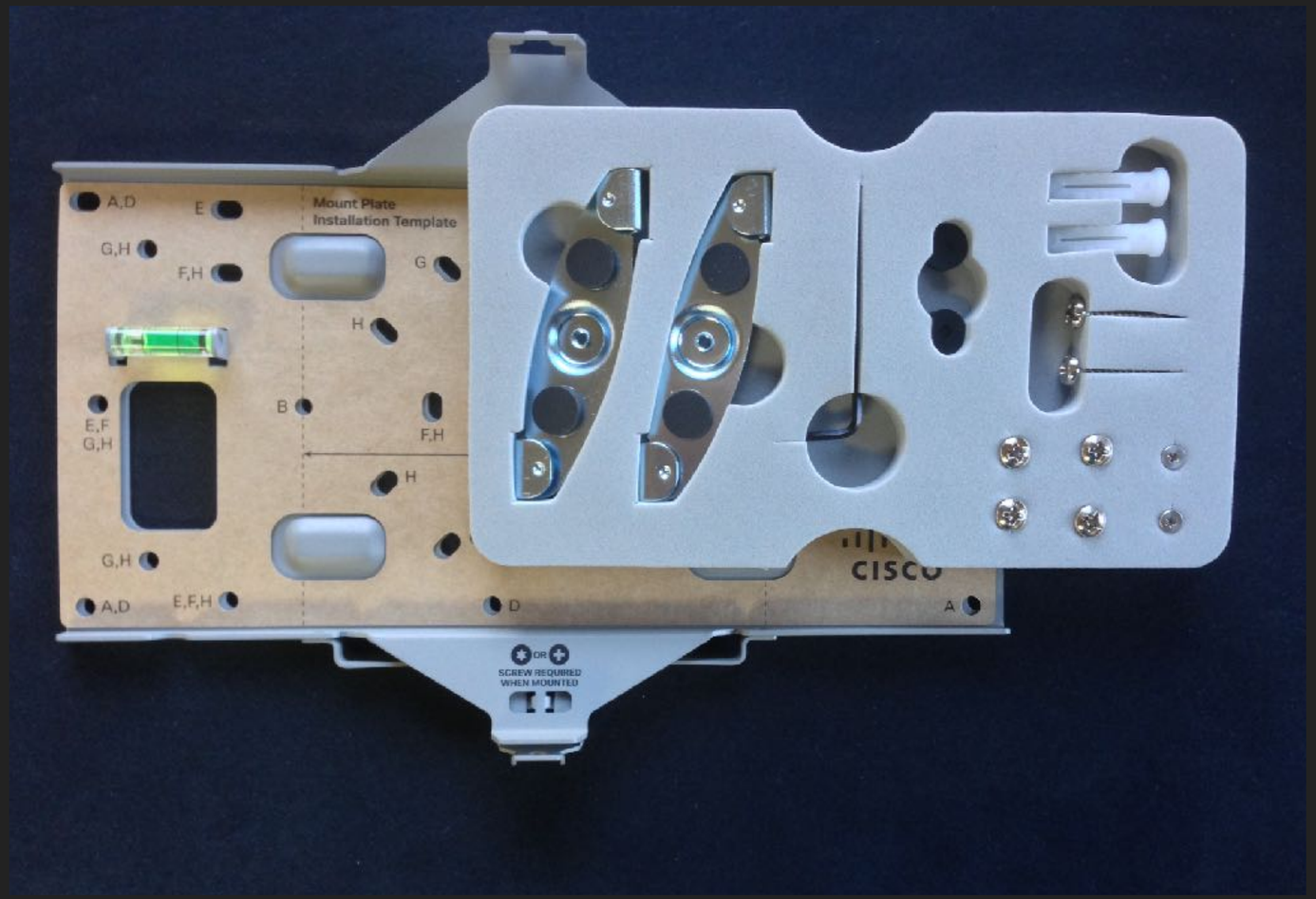
Lin Manuel-Miranda
as Alexander Hamilton

WI-FI NETWORK DESIGN

INSTALLATION

MOUNTING DESIGN

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



INSTALLATION AND MOUNTING

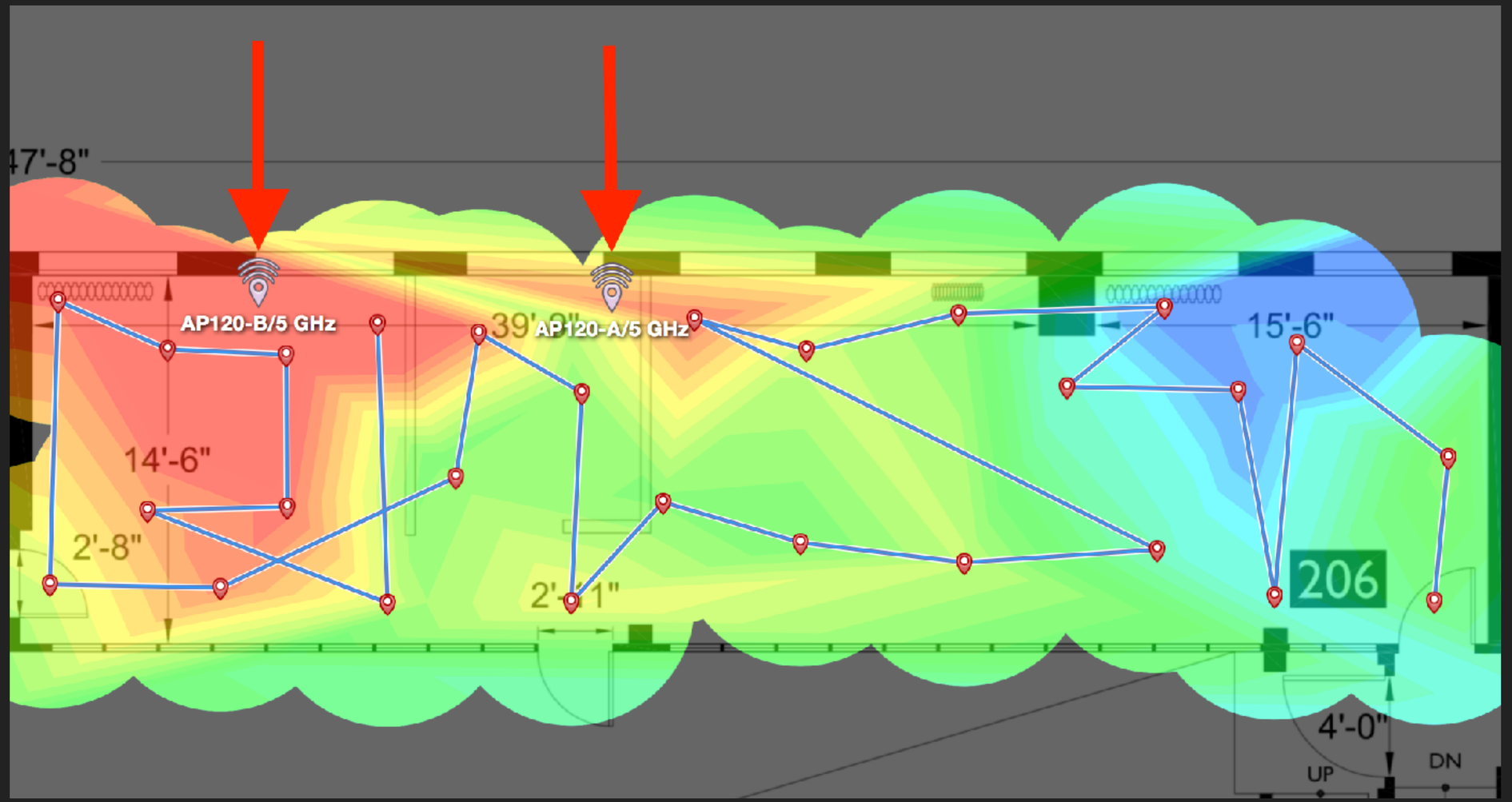
LIKE THIS

NOT LIKE THIS

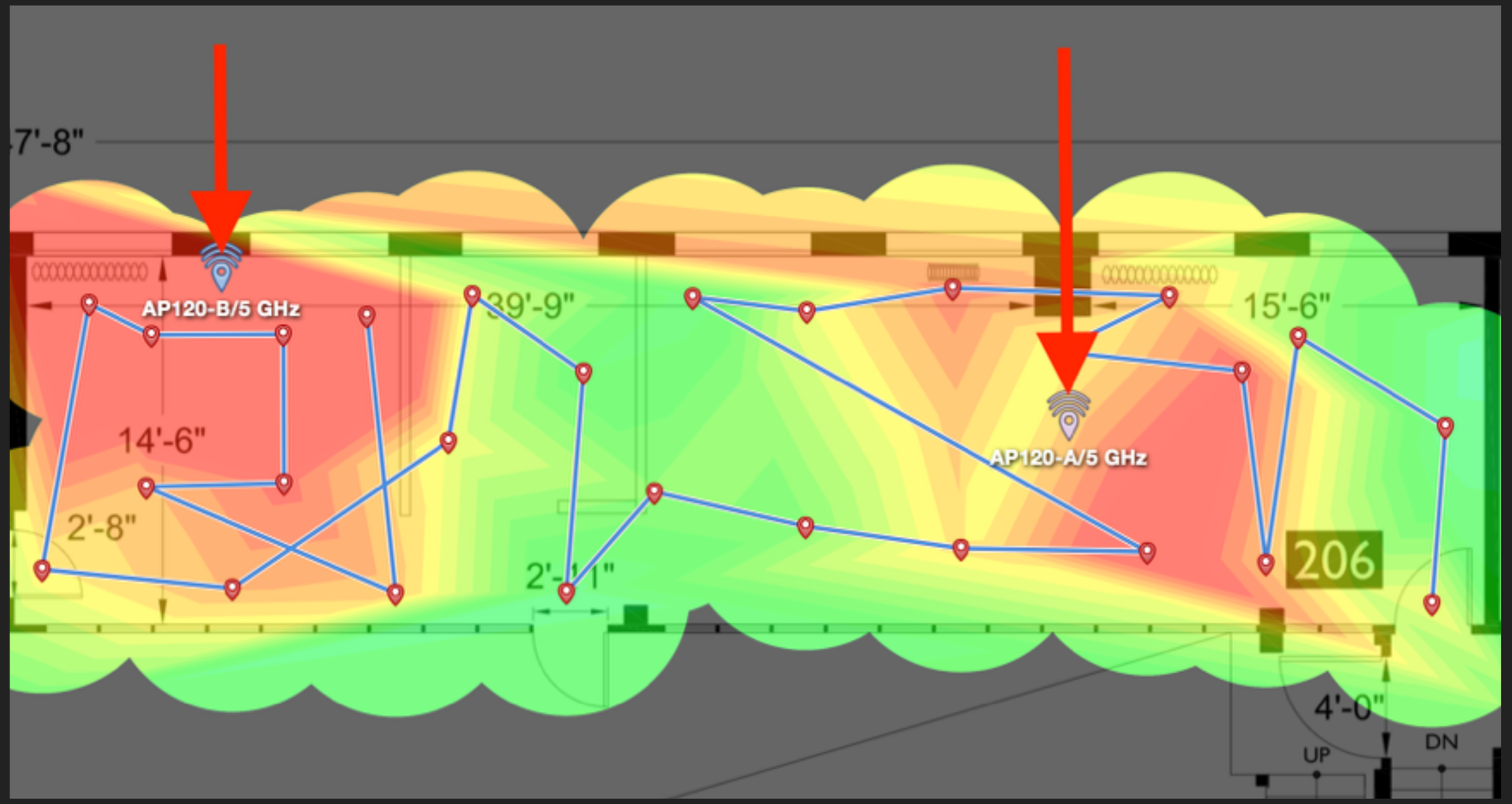
WI-FI NETWORK DESIGN

TESTING AND VALIDATION

PASSIVE SURVEY WITH NETSPOT PRO



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

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

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)

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?