

cisco *Live!*

Let's go



The bridge to possible

High Density Wi-Fi Design, Deployment, and Optimization

Matt Swartz - Cisco Customer Experience, Distinguished Engineer,
CCIE #13232

Josh Suhr - Cisco Customer Experience, Principal Architect,
CCIE #39980



Agenda

CISCO Live!

- Designing RF for High Client Densities
- HD Wi-Fi Configuration Tips
- HD Wi-Fi Engineering Toolkit



Josh Suhr

Principal Architect, Cisco CX
CCIE #39980 (Wireless)

First HD WiFi Project: Sporting Kansas City, 2011
Husband, recent dad, soccer fan, beer & pizza connoisseur

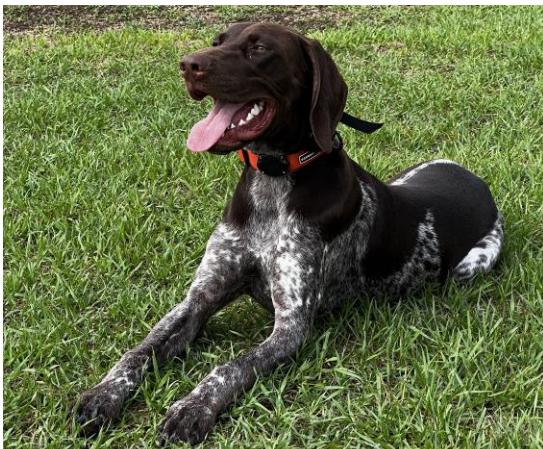




Matt Swartz

Distinguished Engineer, Cisco CX
CCIE #13232 (R/S, Wireless)

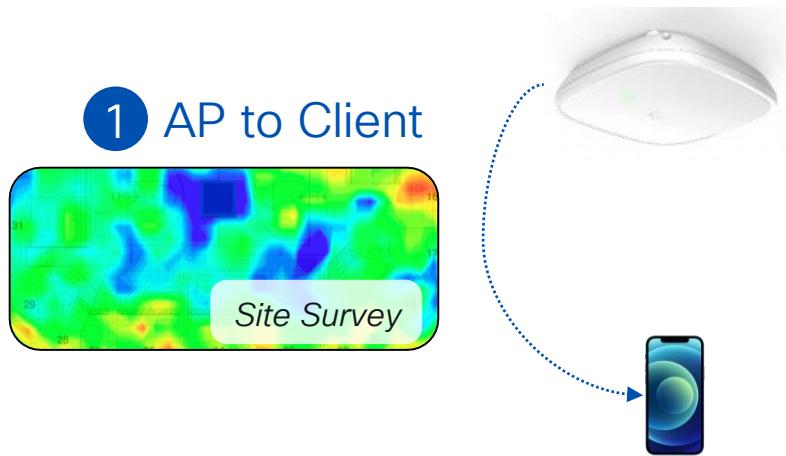
First HD WiFi Project: New York Yankees, 2008
Husband, dad, mountain biker, beer connoisseur



Key Trends in High Density Wi-Fi

- Wi-Fi 6 - new hardware and HD improvements
- Software-defined antenna (C9104)
- 6GHz / Wi-Fi 6E - more spectrum!!!
- More devices per user
- Auto authentication & OpenRoaming

Designing for the 3 Key RF Relationships



Designing for the 3 Key RF Relationships



Designing for the 3 Key RF Relationships



*Bonus points: Client <-> Client - harder to influence

How Clients Hear AP's – C9800 UI

The image shows the Cisco Catalyst 9800-40 Wireless Controller UI. The left sidebar has icons for Dashboard, Monitoring (selected), Configuration, Administration, Licensing, and Troubleshooting. A 'Walk Me Through' button is at the bottom. The main area shows 'Monitoring > Wireless > Clients'. Under 'Clients', it says 'Selected 0 out of 10 Clients' for 'Device Type *Contains* iPhone'. A table lists client details: MAC Address (N/A), Uptime (212 seconds), WLAN Name (N/A), AP Name (N/A), Device Type (iPhone 12), Device OS (iOS 15.4.1), Client Performance (Signal Strength: -66 dBm, Signal Quality: 30 dB, Ch BW(Negotiated/Capable): 20 MHz/80 MHz), Capabilities (802.11ax - 2.4 GHz), and Fabric Status (Disabled). To the right is a 'Top Applications' pie chart (62.0% itunes, 33.0% google-services, 5% outlook-web-service, 2% icloud). A red box highlights the 'Client Scan Reports' section at the bottom, which shows a table of BSSIDs, times, channels, RSSI, and SNR for a report from 04/21/2022 08:42:53. The table has 10 items per page, showing 1-5 of 10 items.

BSSID	Time	Channel	RSSI (dBm)	SNR (dB)
3c41.0e5f.854c	04/21/2022 08:31:32	128	-80	15
3c41.0e5f.d4cc	04/21/2022 08:31:13	100	-80	15
6641.0e45.988c	04/21/2022 08:31:13	56	-83	12
3c41.0e5f.6d2c	04/21/2022 08:31:32	157	-83	13
3c41.0e5f.7da3	04/21/2022 08:31:32	36	-86	10

*Client Scan Report
shows how this
client hears all AP's
within range*

How AP's Hear Clients – C9800 UI

The screenshot shows the Cisco Catalyst 9800-40 Wireless Controller interface. The left sidebar includes links for Dashboard, Monitoring (which is currently selected), Configuration, Administration, Licensing, and Troubleshooting. The main content area is titled 'Monitoring > Wireless > Clients' and shows a list of clients. A search bar at the top right allows searching for 'Search APs and Clients'. The client list table has columns for Client MAC Address, IPv4 Address, and IPv6 Address, all showing 'N/A'. A red box highlights the 'Client Performance' row for an iPhone 12 client, which shows Signal Strength: -66 dBm, Signal Quality: 30 dB, Ch BW(Negotiated/Capable): 20 MHz/80 MHz, and Capabilities: 802.11ax - 2.4 GHz. To the right of the client list is a 'Top Applications' pie chart showing 62.0% for itunes and 33.0% for google-services. Below the client list is a 'Client Scan Reports' table with columns for BSSID, Time, Channel, RSSI (dBm), and SNR (dB). The table lists 10 items, with the first few rows being: 3c41.0e5f.854c (04/21/2022 08:31:32, 128, -80, 15), 3c41.0e5f.d4cc (04/21/2022 08:31:13, 100, -80, 15), 6c41.0e45.988c (04/21/2022 08:31:13, 56, -83, 12), 3c41.0e5f.6d2c (04/21/2022 08:31:32, 157, -83, 13), and 3c41.0e5f.7da3 (04/21/2022 08:31:32, 36, -86, 10). A '1 - 5 of 10 items' message is at the bottom of the table. A 'OK' button is at the bottom right of the main content area.

Client Performance readings show how the currently associated AP hears this client

How AP's Hear Clients: Catalyst AP

For a table of [all clients on an AP, at AP CLI:](#)

Telnet/SSH to AP and use “show dot11 clients” [for immediate client RSSI readings of ALL clients associated to the specified radio](#)

```
ap#show dot11 clients
AP Mode - Local
Client MAC      Slot ID WLAN ID AID      WLAN Name RSSI Maxrate NGB
FC:F8:AE:60:98:34      1      3 1 AbrahamLinksys -47 MCS82SS  No
00:24:D7:7E:48:D8      1      3 2 AbrahamLinksys -54   M23   No
78:F8:82:EF:2E:A0      1      3 3 AbrahamLinksys -37 MCS82SS  No
84:38:35:42:E1:F0      1      3 4 AbrahamLinksys -71 MCS82SS  No
```

How AP's Hear Clients: Catalyst AP

For a detail on a single client, at AP CLI:

Telnet/SSH to AP and use “show controller d <0|1> client <mac-addr>” for immediate client RSSI readings of a single client

```
10#sho controller d 1 client FC:F8:AE:60:98:34
```

```
<clip>
```

```
Additional info for client FC:F8:AE:60:98:34
```

```
RSSI: -47
```

```
<clip>
```

```
Statistics for client FC:F8:AE:60:98:34
```

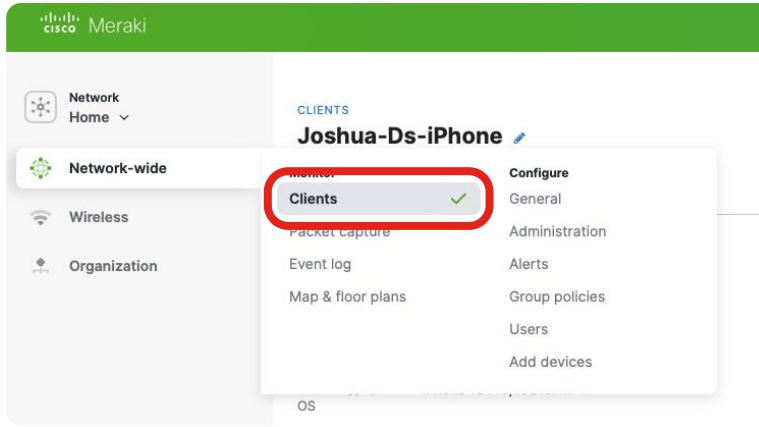
```
mac <clip> stats_ago expiration
```

```
FC:F8:AE:60:98:34 <clip> 0.700000 0
```



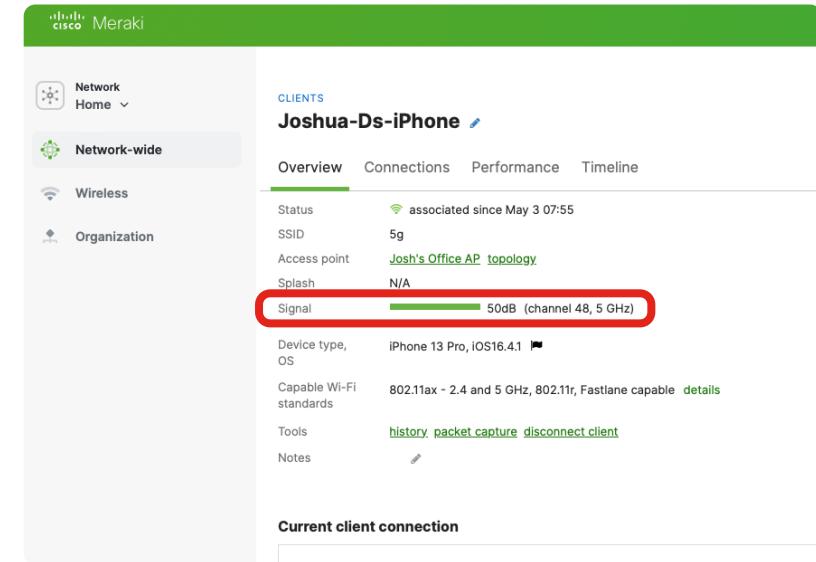
How long ago were these stats updated (in sec)?

How AP's Hear Clients: Meraki AP



The screenshot shows the Meraki UI for managing clients. The top navigation bar has 'Network Home' and 'Clients' selected. The main content area is titled 'CLIENTS' and shows a list for 'Joshua-Ds-iPhone'. A red box highlights the 'Clients' tab in the top navigation bar of the list view.

Actions	Configure	General	Administration
Packet capture			
Event log			
Map & floor plans			
	Alerts		
	Group policies		
	Users		
	Add devices		



The screenshot shows the Meraki UI for managing clients in detail. The top navigation bar has 'Network Home' and 'Clients' selected. The main content area is titled 'CLIENTS' and shows a list for 'Joshua-Ds-iPhone'. A red box highlights the 'Signal' section in the client details view.

Overview	Connections	Performance	Timeline
Status: associated since May 3 07:55			
SSID: 5g			
Access point: Josh's Office AP topology			
Splash: N/A			
Signal: 50dB (channel 48, 5 GHz)			
Device type, OS: iPhone 13 Pro, iOS16.4.1			
Capable Wi-Fi standards: 802.11ax - 2.4 and 5 GHz, 802.11r, Fastlane capable	details		
Tools: history packet capture disconnect client			
Notes:			

It All Starts with Layer 1: RF Design

Antenna Selection:

Decide which antenna is right for the job.

Consider:

- Density of clients to be served
- Available mounting assets
 - Within 65'/20m of furthest client (or 200'/60m with C-ANT9104)

Antenna Placement:

Where will this antenna provide the best throughput and most reliable service?

Consider:

- Line of sight
- Isolation from ambient RF
- Angle of incidence to client devices

Antenna Selection

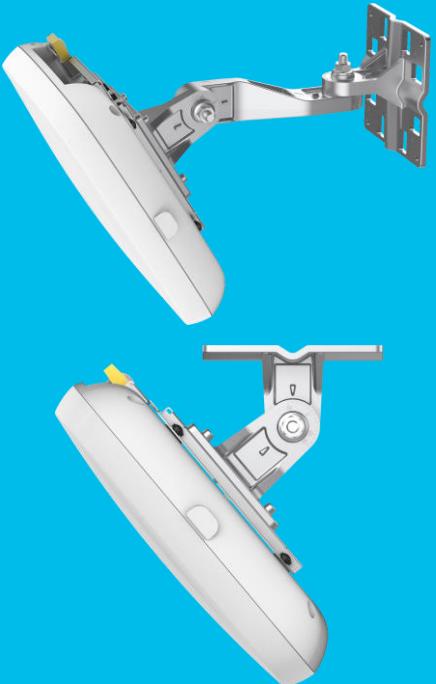
		Beamwidth	Use Case
	<p>Dual-Band “Narrow” 8x8 Patch Antenna AP: 9130AXE Antenna: C-ANT9103</p>	<p>2.4/5GHz 75/70° Az 70/70° Elev</p>	Augmentation and short-distance HD coverage (15'/5m – 30'/10m to clients)
	<p>Dual-Band “Wide” Patch Antenna AP: 3802E/P, 9120AXE/P, 9130AXE Antenna: AIR-ANT2566P4W-R</p>	<p>2.4/5GHz 105/125° Az 70/60° Elev</p>	Augmentation and short-distance HD coverage (< 30' / 10m to clients)
	<p>Dual-Band “Narrow” Patch Antenna AP: 3802E/P, 9120AXE/P, 9130AXE Antenna: AIR-ANT2566D4M-N</p>	<p>2.4/5GHz 65/65° Az 65/65° Elev</p>	Augmentation and short-distance HD coverage (15'/5m – 30'/10m to clients)
	<p>Dual-Band High Density Antenna C-ANT9104 (Antenna + Integrated AP)</p>	<p>70/70° 2.4GHz 80/25° 5GHz (Wide) 25/25° 5GHz (Narrow)</p>	Primary overhead coverage (i.e. seating areas; > 30'/10m, <200'/60m to clients)

9166D1 Wi-Fi 6 Access Point

NEW

Cisco® Catalyst® 9166D1-x

Directional, Tri-Radio with 12 Spatial Streams!



CISCO Live!



Penta-Radio Architecture

1. 2.4 GHz Client Radio: 4x4:4SS
2. 5 GHz Client Radio: 4x4:4SS
3. 6 GHz Client Radio 4x4:4SS (XOR to 5GHz)
4. Dedicated tri-band auxiliary radio
5. 2.4 GHz IoT Radio



Directional antenna architecture

- 2.4+5 GHz: 6 dBi gain (70x70 deg), 6 GHz: 8 dBi (60x60)
- Same X,Y as CW9166I – and only 0.1cm taller!
- Wide support for pan/tilt combinations



Internet of Things Capabilities

- Built-In Environmental Sensors
- Application Hosting Technology
- USB port with 4.5 W power output



5 Multigigabit (mGig) PoE Port

- Optional DC Power

Meraki AP & Antenna Selection: Directional

CW9166D1



MR86



or



Part No.	Type	Beam (Az)	Beam (Elev.)
MA-ANT-25	Patch	75 deg	84 deg
MA-ANT-27	Sector	65 deg	18 deg
AIR-ANT2513P4M-N	Array	31 deg	27 deg
CW9166D1	Integrated Directional	70 deg (5ghz) 60 deg (6ghz)	70 deg (5ghz) 60 deg (6ghz)

Cisco Catalyst C-ANT9104 – Stadium Antenna + Integrated AP

- The C-ANT9104 antenna is designed specifically to solve challenges encountered in stadium/Large Public Venue/High Client Density environments.
- Dual 5 GHz on two individual 5 GHz 4x4 Arrays
- Configurable electronic beam steering as well as Narrow and Wide modes of the antenna
- Catalyst C9800 release 17.6.1 adds configuration support for these new controls



A photograph showing three generations of Cisco stadium antennas. From left to right: 1. AIR-ANT25137NP-R=, a rectangular antenna with a light blue frame and a light blue faceplate. 2. AIR-ANT2513P4M-N=, a rectangular antenna with a light blue frame and a light grey faceplate. 3. C-ANT9104=, a large, rounded rectangular antenna with a light grey faceplate. The Cisco logo is embossed on the faceplate of the C-ANT9104. A yellow sticker on the C-ANT9104 faceplate reads "Prestige Unit Demo Only" and "Not for sale or lease to the general public".

AIR-ANT25137NP-R=

AIR-ANT2513P4M-N=

C-ANT9104=

Three generations of High-Density WiFi Stadium Antennas

C-ANT9104: Key Things to Know

Antenna Design Improvements

Cover Clients from Longer Distances (up to 200' / 60m line-of-sight)

Integrated Unit, Outdoor-Rated

AP + Antenna all-in-one, no enclosures required, outdoor-rated

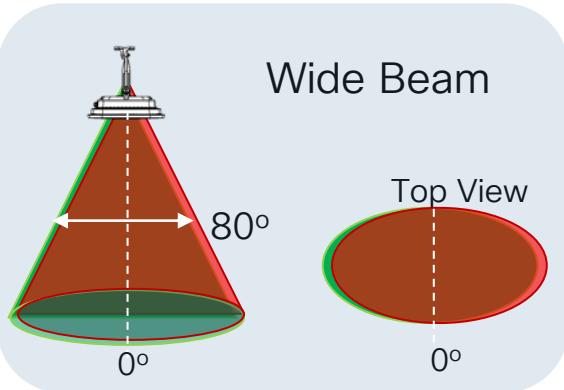
Deployment Flexibility

Beam Switching & Beam Steering; switch between narrow/wide, meet needs of multiple different coverage types

Important Notes

Band-Locked Slots & Tx Power Implications
Tight RF patterns, minimal sidelobes, RF Isolation = no RRM

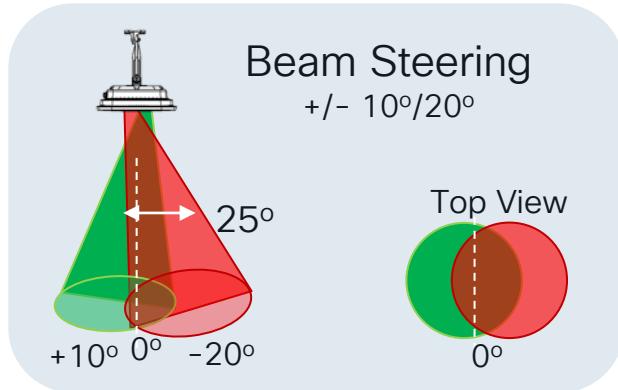
C-ANT9104: Software-Configurable Beams



Wide sector beamwidth
Dual 4x4 5GHz (80°x25°)
2.4 GHz (75°x85°)
8 dBi gain



Narrow sector beamwidth
Dual 4x4, 5 GHz (25°x25°)
10 dBi gain



Software defined beam steering
Each 5GHz 4x4 can steer
+/- 10°, 20° off center

5GHz Software Defined Beamwidth and Direction

C-ANT9104: Deployment Checklist

Physical Install:

- All-In-One – no enclosures needed
- Portrait vs landscape
- Physical orientation of higher-power slot

Channel & power planning

Determine initial beam configuration (surveys / prediction)

- Define Radio Profiles & RF Tags
- Less (or no) RX-SOP optimization needed
- Validate & optimize

C-ANT9104 Power Table Summary

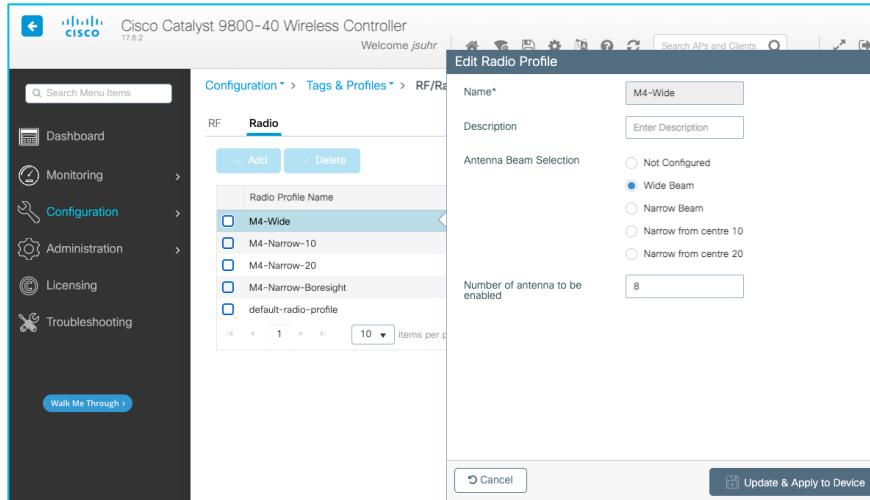
[Slot 1]

UNII-2e / 12 channels: 17dBm
UNII-3 / 5 channels: 23dBm

[Slot 2]

UNII-1 / 4 channels: 21dBm
UNII-2 / 4 channels : 17dBm

C-ANT9104: Configuration (GUI)



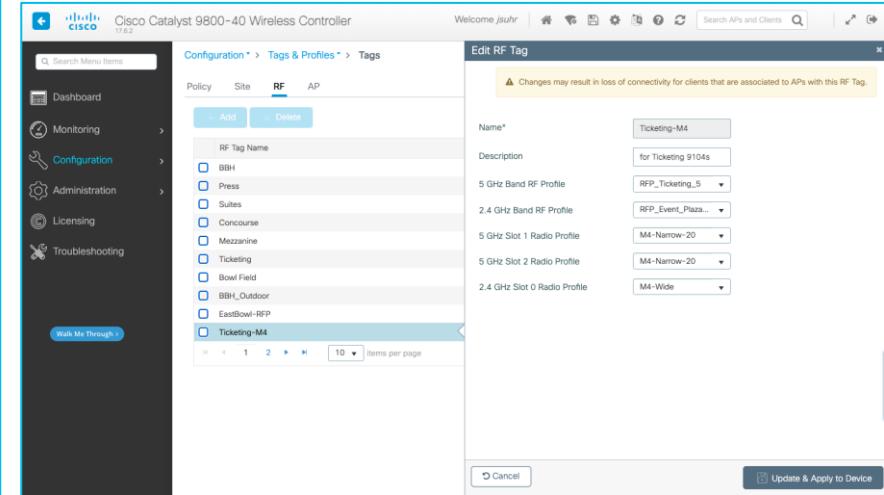
The screenshot shows the Cisco Catalyst 9800-40 Wireless Controller's configuration interface. On the left, the navigation menu includes Dashboard, Monitoring, Configuration (selected), Administration, Licensing, and Troubleshooting. The main content area is titled 'Edit Radio Profile' and shows the following fields:

- Name: M4-Wide
- Description: Enter Description
- Antenna Beam Selection: Wide Beam (selected)
- Number of antenna to be enabled: 8

On the left sidebar, under 'RF' profiles, 'M4-Wide' is selected. The bottom right of the main window has 'Cancel' and 'Update & Apply to Device' buttons.

Create **Radio Profiles**, one for each beam configuration you plan to use

*Note: "Number of antenna to be enabled" can be set to 8



The screenshot shows the 'Edit RF Tag' configuration screen. The left sidebar shows 'RF Tags' with 'Ticketing-M4' selected. The main content area shows the following fields:

- Name: Ticketing-M4
- Description: for Ticketing 9104s
- 5 GHz Band RF Profile: RFP_Ticketing_5
- 2.4 GHz Band RF Profile: RFP_Event_Plaza...
- 5 GHz Slot 1 Radio Profile: M4-Narrow-20
- 5 GHz Slot 2 Radio Profile: M4-Narrow-20
- 2.4 GHz Slot 0 Radio Profile: M4-Wide

The bottom right of the main window has 'Cancel' and 'Update & Apply to Device' buttons.

Create new or edit existing **RF Tags** and assign the Radio Profiles to each slot as desired

*Note: 2.4GHz Slot 0 is always "Wide"

C-ANT9104: Configuration (CLI)

1 Define RF Profile(s):

```
ap dot11 5ghz rf-profile MP1-5
high-density rx-sop threshold custom -85
channel chan-width 20
rate RATE_12M supported
rate RATE_18M mandatory
rate RATE_24M supported
rate RATE_6M disable
rate RATE_9M disable
no shutdown
```

3 Build RF tags and assign Radio Profile(s):

```
wireless tag rf MP1-rf-tag
5ghz-rf-policy MP1-5
dot11 24ghz slot0 radio-profile default-radio-profile
dot11 5ghz slot1 radio-profile M4-Narrow-10
dot11 5ghz slot2 radio-profile M4-Narrow-10
```

2 Define Radio Profile(s):

```
wireless profile radio M4-Wide
antenna beam-selection wide
antenna count 8
wireless profile radio M4-Narrow-10
antenna beam-selection narrow tilt 10
antenna count 8
wireless profile radio M4-Narrow-20
antenna beam-selection narrow tilt 20
antenna count 8
wireless profile radio M4-Narrow-Boresight
antenna beam-selection narrow
antenna count 8
```

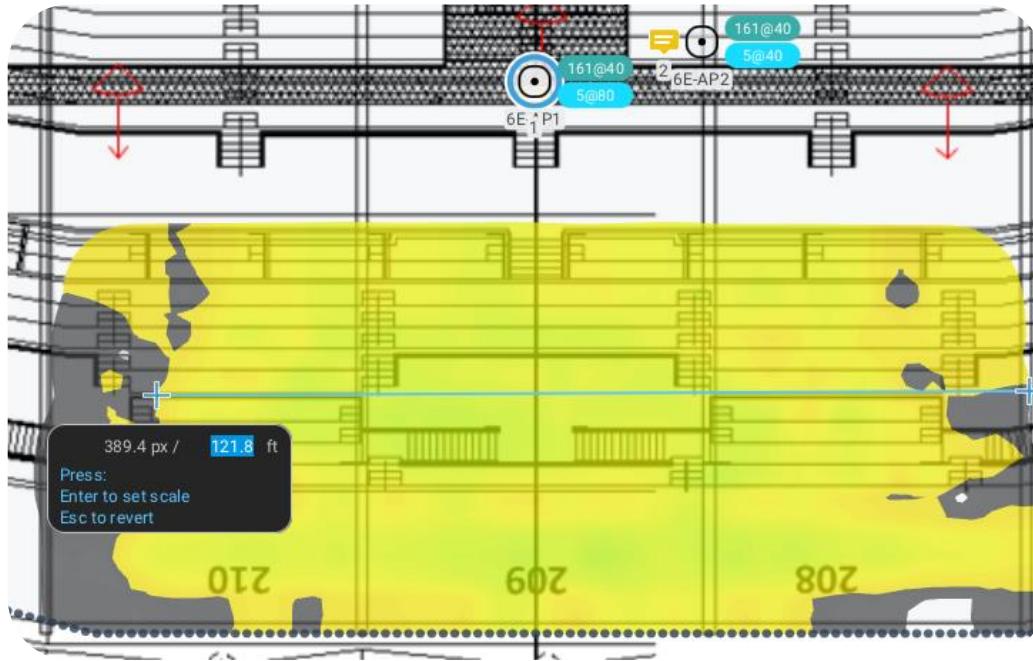
4 Apply tags to AP(s):

```
ap filter name "M4 Portrait Narrow 10"
ap name-regex MP1
tag policy policy-tag-1
tag rf MP1-rf-tag
tag site site-tag-1
ap filter priority 50 filter-name "M4 Portrait Narrow 10"
```

OR

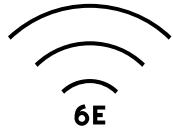
```
ap f4bd.9ed1.4700
policy-tag policy-tag-1
rf-tag MP1-rf-tag
site-tag site-tag-1
```

9166D 6GHz Cell Size @ 55' / 16m Height



- 121' / 37m cell width @ -63dBm
- 5GHz beam is slightly wider than 6GHz beam
- At >30'/10m mount height, consider “overlay” with 9104 for 5GHz

Industry's Best And Broadest Wi-fi 6E And Wi-Fi 6 Portfolio



Assess environmental RF coverage using the Catalyst 9136I's site survey mode



Puts AP in standalone mode and enables it to broadcast 2.4-, 5-, and 6-GHz SSIDs and have clients join via internal DHCP.

Supports WebUI access for easy configuration and viewing of various RF metrics for RF coverage and planning.

Supports configuration of channel number, channel width, Tx power, SSID, and data rates.

Cisco outdoor AP portfolios

1572



1570 Series (Wave 1)

- 802.11ac Wave 1
- 4x4:3 80 MHz; 1.3 Gbps
- External antenna model (EAC)
- Cable modem model (IC/EC)
- SFP
- GPS
- PoE-Out 802.3at (ext. ant. only)
- Flexible antenna ports
- Cisco CleanAir® and ClientLink
- Centralized, Cisco FlexConnect®, and mesh

>

1542



1540 Series (Wave 2)

- 802.11ac Wave 2, MU-MIMO
- 2x2:2, 80 MHz, 867 Mbps
- Ultra low profile
- Internal antenna only
- PoE (802.3af) power
- Centralized, FlexConnect, mesh, and Mobility Express

>

1562



1560 Series (Wave 2)

- 802.11ac Wave 2, MU-MIMO
- 3x3:3, 80 MHz, 1.3 Gbps (I)
- 2x2:2, 80 MHz, 867 Mbps (E/D)
- Internal or external antenna model
- Internal directional antenna model (D)
- SFP
- Flexible antenna ports
- Cisco CleanAir and ClientLink
- Centralized, FlexConnect, mesh, and Mobility Express

>

9124



9124 Series* (Wi-Fi 6)

- 802.11AX, MU-MIMO, OFDMA
- 4x4 + 4x4:4
- Cisco RF ASIC for next-gen Cisco CleanAir
- IoT ready
- 1x 2.5G mGig
- SFP
- PoE-In 802.3af/at/bt
- DC power input (24 to 56 VDC)
- 1 Gbe PoE-Out
- 30 dBm Transmit Power (Same as 1572 and higher than 1562)
- Centralized, FlexConnect, Flex+Bridge**, Mesh**, and EWC**

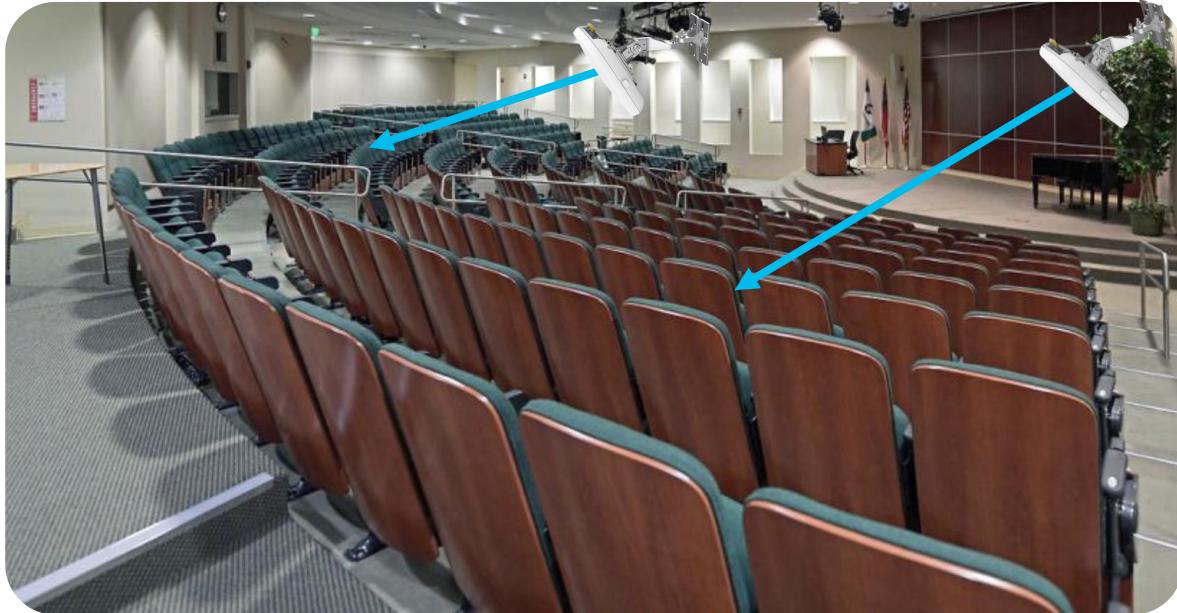
* C9124AXE-x unavailable until Summer calendar year 2021.

Catalyst 9124AXI-x and 9124AXD-x initially available in US and Canada only. Worldwide availability set for Summer calendar year 2021.

** Available second half 2021

Antenna Placement

Classrooms & Auditoriums



Directional antennas:
more coverage cells in
the same physical
area, better control of
the RF environment

Directional antennas strongly preferred over omnis

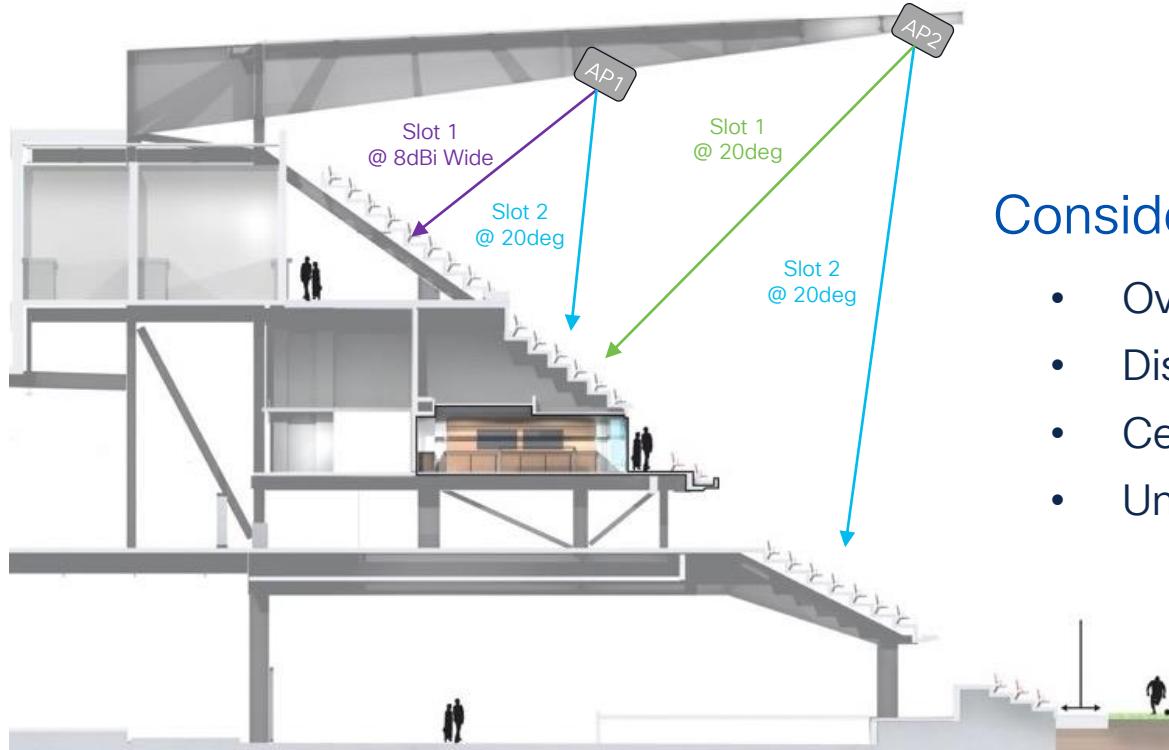
Conference Halls, Airports

High Density Open Areas – Conference Halls, Classrooms



- Omnis not preferred for open areas where high capacity is needed
- Create smaller cells with directional antennas mounted above, aimed directly downward
- Understand RRM implications of this type of design

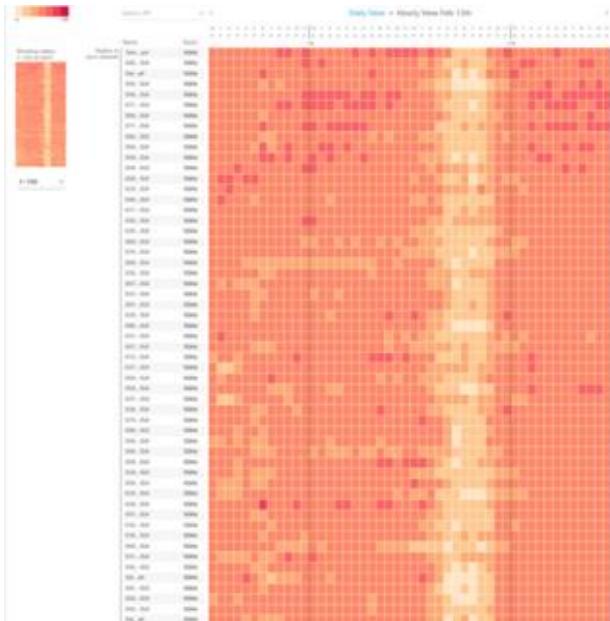
Stadiums & Large Public Venues



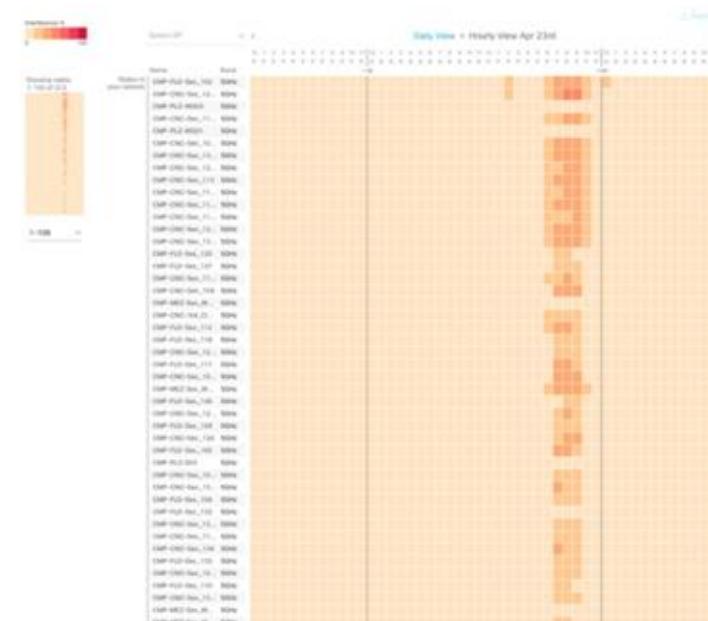
Consider:

- Overhead / Line-of-Sight
- Distance to Clients
- Cell Size & Overlap
- Under seat as backup option

Performance Comparison

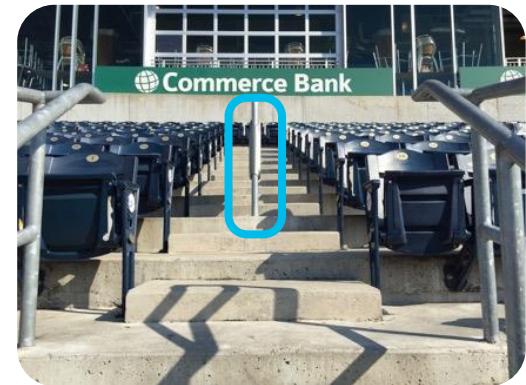
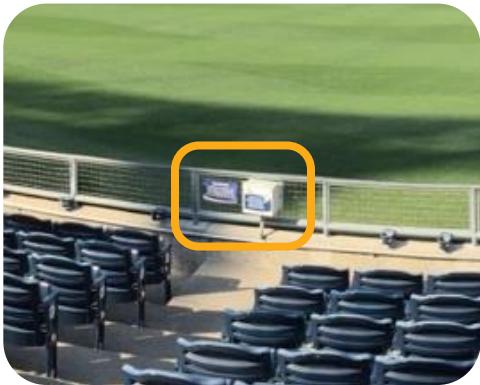


Under seat/Omni



Overhead/Directional

Creative AP/Antenna Mount Examples



Multiple Coverage Areas with 1 AP



“Wide” Patch Antenna

“Narrow” High-Gain Antenna

Antenna Placement: What Not To Do

Challenging Areas



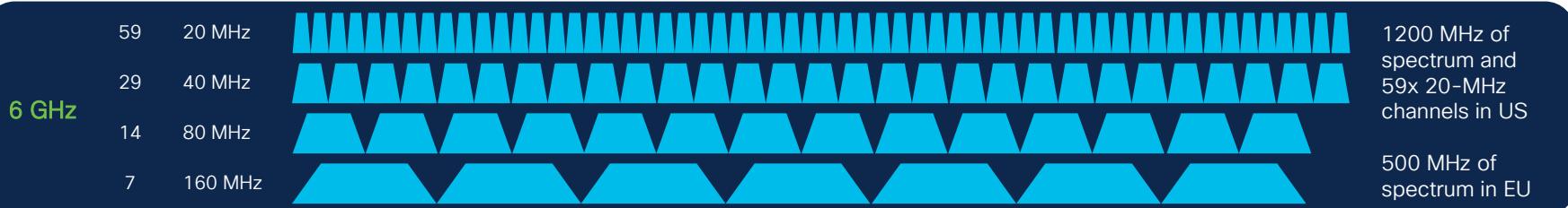
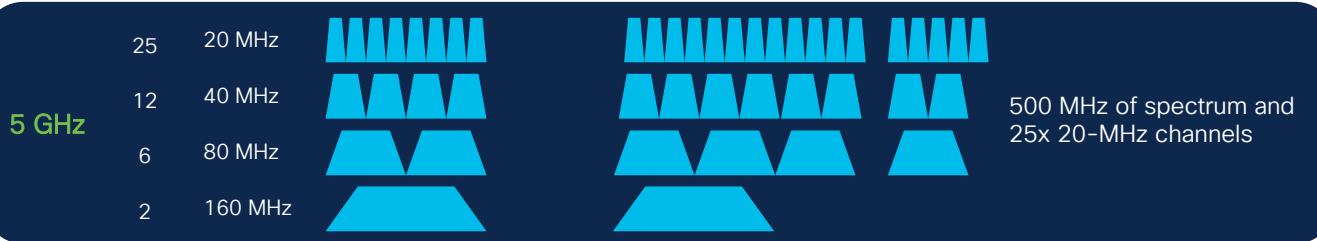
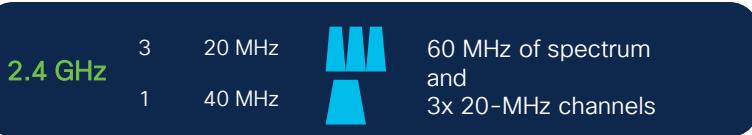
Avoid long-distance shots with poor angle of incidence / line of sight to each client

Avoid obstructions in front of your antennas

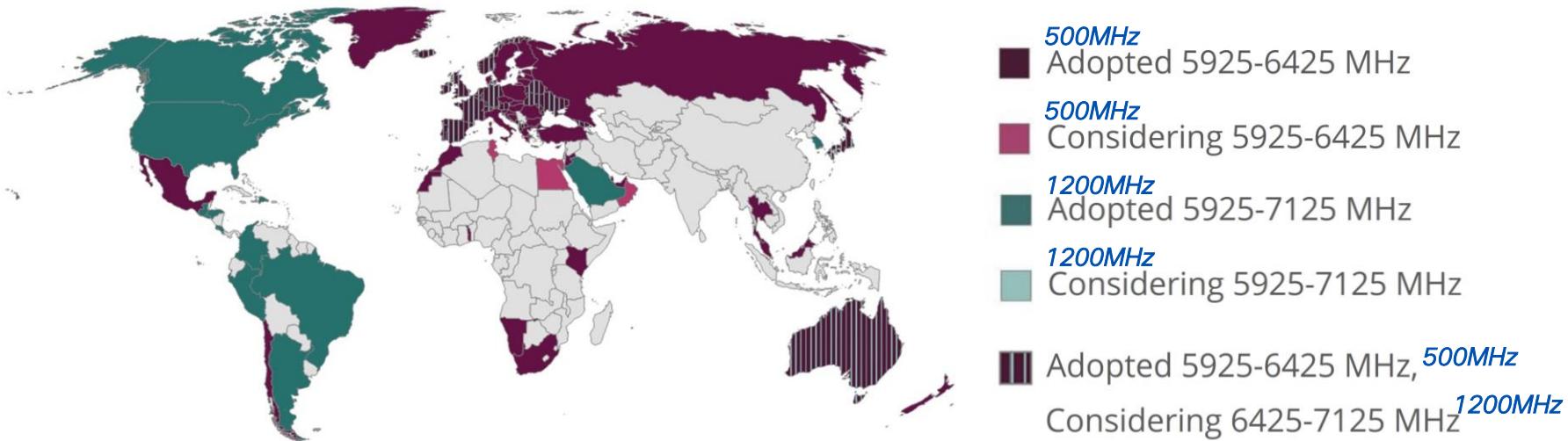
Wi-Fi 6E Deployment Considerations

6 GHz is the biggest Wi-Fi spectrum expansion ever

Band Channels Bandwidth



6GHz Availability – A Global View



<https://www.wi-fi.org/countries-enabling-wi-fi-in-6-ghz-wi-fi-6e>

Deploying and migrating to Wi-Fi 6E

Key Considerations

6GHz SSID Discovery

- Active Scanning is less practical – too many channels
- Reduced Neighbor Report announces 6GHz capable networks for passive detection
- Different device types discover 6GHz networks differently – testing is important

Examples:

- Google Pixel 6: <https://www.jiribrejcha.net/2022/11/google-pixel-6-wi-fi-6e-scanning-and-6-ghz-ssid-discovery/>
- iPad Pro: <https://www.jiribrejcha.net/2022/11/ipad-pro-wi-fi-6e-scanning-and-6-ghz-ssid-discovery/>

Security Requirements

- WPA3 is required for Wi-Fi 6E networks
- OpenRoaming can make the transition easier

6E
Deep
Dive:

Architecting Next Generation Wireless Network with Catalyst Wi-Fi 6E Access Points - BRKEWN-2024

Anand Gurumurthy, Technical Marketing Engineering Technical Leader, Cisco Systems, Inc.

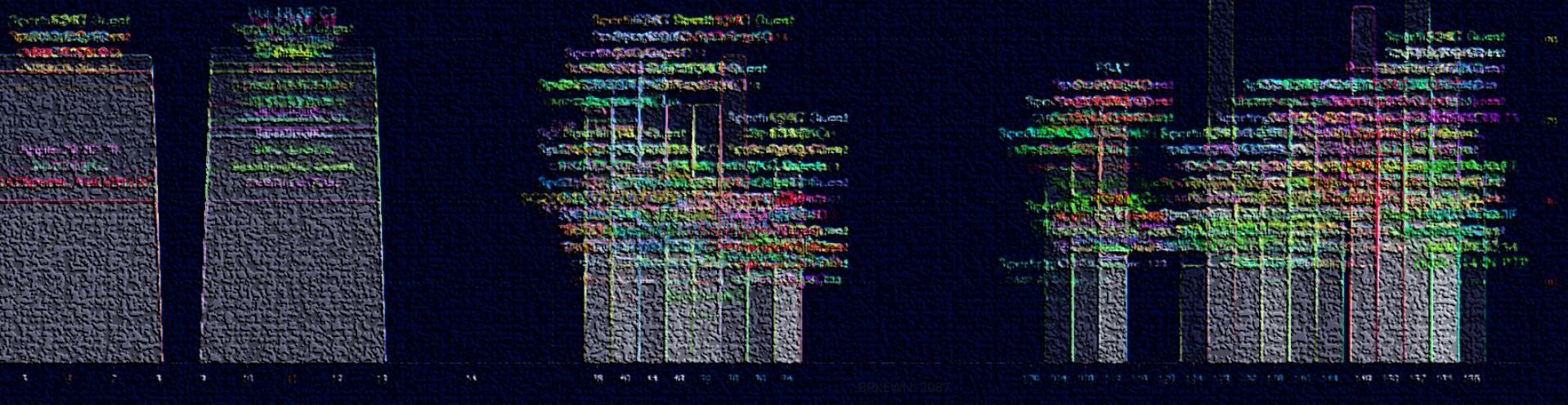
This session deep dives into the newly introduced Wi-Fi6E standard in 6GHz band. It begins with an overview of the 6GHz band and the worldwide regulations and then dives into the specifics of Wi-Fi 6E protocol including device classes and AP discovery. The session covers aspects of the protocol optimization introduced for the clients to discover the WLANs and AP in 6 GHz band. Security in the 6GHz Wi-Fi 6E world is now mandated with WPA3. This session covers the key Wi-Fi 6E security takeaways that the end user needs to be aware of. This session also covers technical deep dive of the new converged Wi-Fi 6E Access Point and walks through the deployment options with Onprem and Cloud, features, capabilities, power requirements and migration.

Wi-Fi 6E Glossary

RNR: Reduced Neighbor Report
FILS: Fast Initial Link Setup
PSC: Primary Scanning Channel

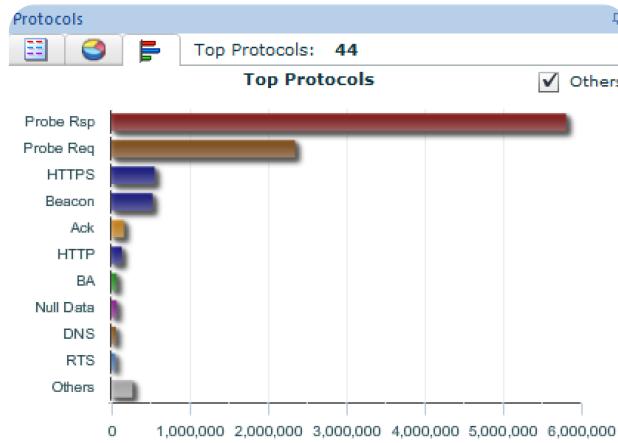
Maximize your Spectrum

- Limit SSIDs (reduce management traffic)
- Integrate existing networks
- Optimize PHY Rates
- Monitor Noise Floor & use power adjustments
- Remove barriers to entry



Maximizing the Spectrum

Avoiding Excessive Management Traffic

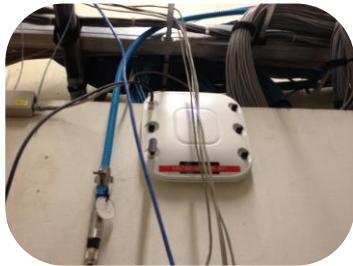


- Always aim for 1 SSID
 - Especially in high density areas
- **More SSID's = Worse Performance**
- Why?
 - Each SSID requires a separate beacon
 - Each SSID will beacon at the minimum mandatory data rate
 - Radios will respond to null probe requests for each broadcast SSID
- **Exponential** amounts of airtime wasted!

Maximizing the Spectrum

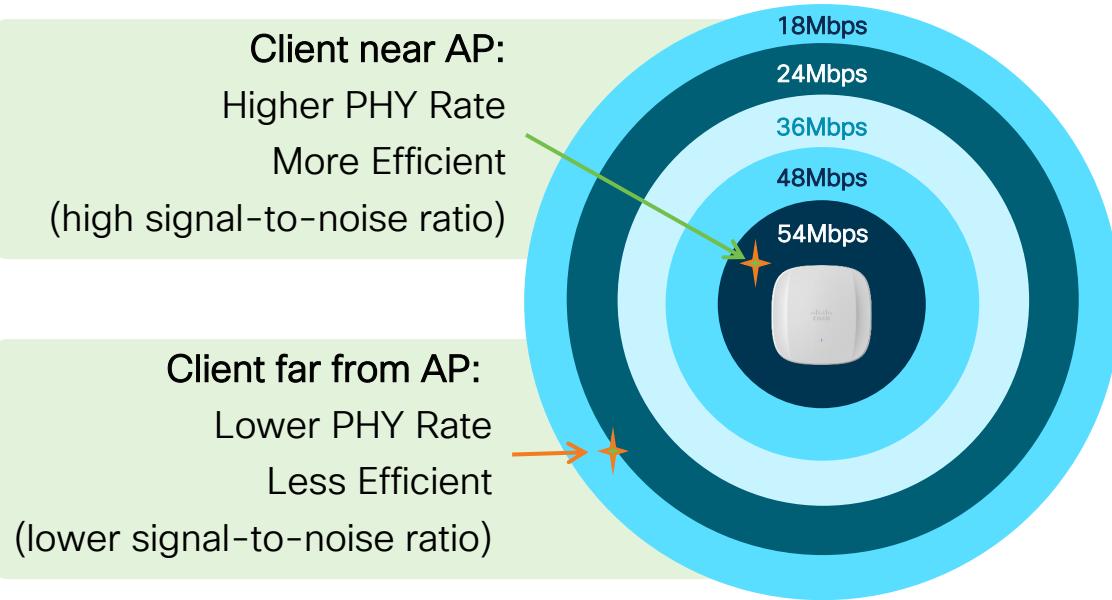
Integrate Existing WLANs

- Common to see various existing WiFi deployments in venues
- Efficient HD WLANs are deployed holistically – one infrastructure
- Benefits?
 - Configuration consistency
 - Airtime efficiency
 - Legacy management traffic that once chewed up 30-40% of airtime typically drops to < 1% of airtime



Maximizing the Spectrum

PHY Rate Tuning: Why PHY Rates Matter

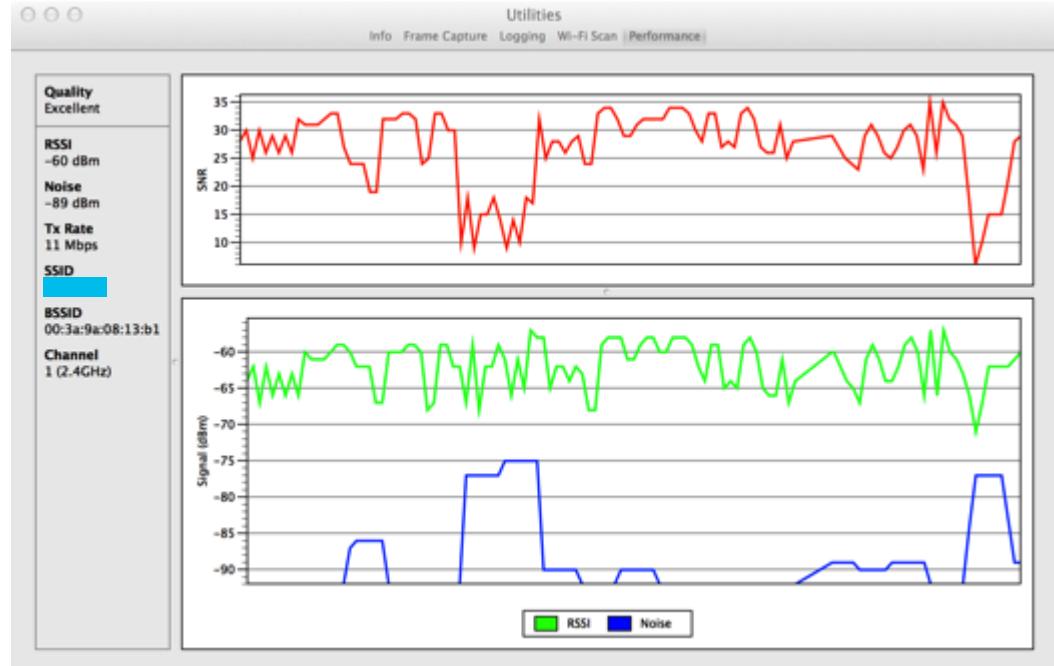


- Tune your **Minimum Mandatory** and **Supported** data rates to optimize airtime
- Higher rates require higher SNR – don't be too aggressive
- Leave 1 or 2 rates below your Minimum Mandatory rate as "supported" to provide a "soft landing" and allow some SNR flexibility
- Generally, no need to adjust MCS rates (client compatibility)
- Common starting points (5ghz): 18mbps Minimum Mandatory, 12mbps Supported, <12 disabled, >18 Supported

Maximizing the Spectrum

RSSI vs. SNR

- Check your noise floor in each band during peak usage
 - Packet captures with a NIC that you trust (MacBook Pro, etc.)
 - Fluke AirCheck
 - Spectrum Expert
 - Metageek Chanalyzer for Clean Air



Maximizing the Spectrum

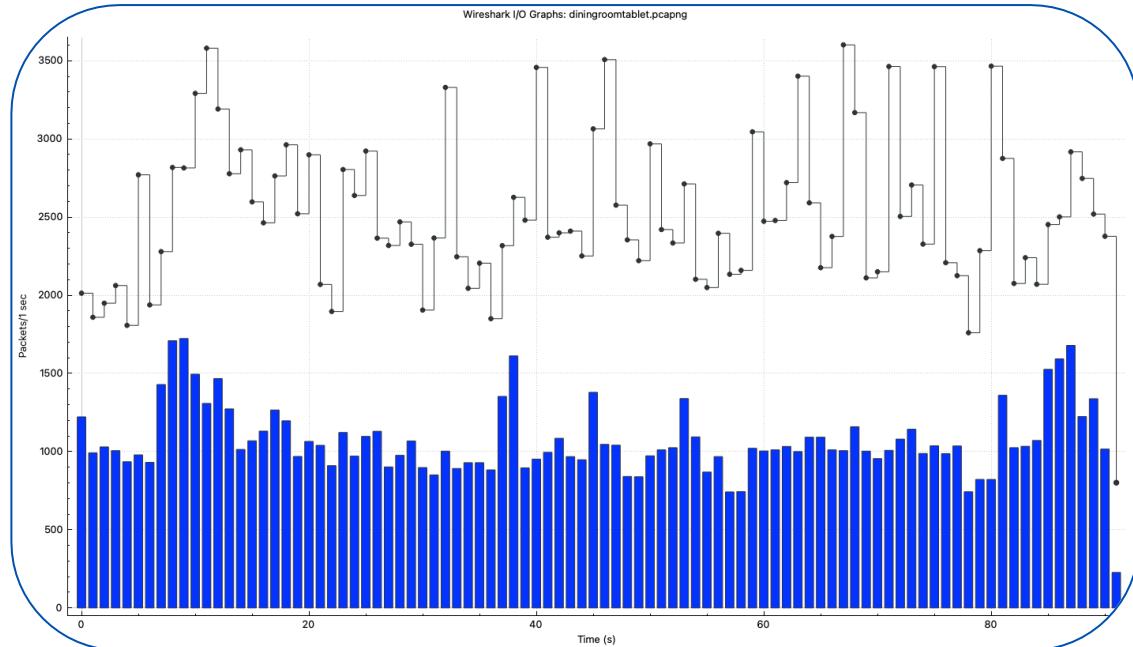
Ease-of-Use & Client Induced Interference



- Ask yourself - how difficult is it to get on your WiFi network?
- Ease-of-use directly impacts airtime efficiency
- Low take rate = lots of probe request noise (1mb, max power, all channels)
 - Results in [Client Induced Interference](#)
- A device on the network is far less damaging than a device off the network!
- Make captive portals easy, implement OpenRoaming, etc.

Maximizing the Spectrum

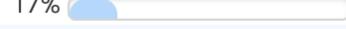
Eliminating unnecessary traffic over the air



Propagation of
mDNS & IPv6
traffic consuming
>40% of airtime
across all channels

Maximizing the Spectrum

Eliminating unnecessary traffic over the air

	<i>Before Optimization</i>	<i>After Optimization</i>
Radio Type	802.11ax - 5 GHz	802.11ax - 5 GHz
Radio Role (Radio Mode)	Automatic (Local)	Automatic (Local)
Admin Status	Enabled	Enabled
Number of Clients	1	1
Current Channel	153	153
Power Level 	*6/8 (8 dBm)	*6/8 (8 dBm)
Channel Utilization	34% 	17% 
Transmit Utilization	29% 	17% 
Receive Utilization	0% 	0% 

Agenda

CISCO Live!

- Designing RF for High Client Densities
- HD Wi-Fi Configuration Tips
- HD Wi-Fi Engineering Toolkit

The Basics: RF Profiles, TPC, DCA

First - a handy (free!) tool: WCAE

- **Wireless Config Analyzer Express (WCAE)** is an extremely valuable tool when validating and optimizing a Cisco Wi-Fi deployment
- Feed your WLC config output to WCAE and it will help you:
 - Find and troubleshoot problems quickly
 - Identify top areas for RF optimization
 - Check configs against best practices
 - RRM overview with the RF Summary

Table of contents

Generated:2023-01-30 11:06
WCAE Version:0.12

Total Message Counts

Errors:	9
Warnings:	30
Informational:	21
Program Execution	
Parsing Errors:	0
Processing Errors:	17

Configuration Checks:

[Controller Checks Results](#)
[APs Checks Results](#)

Controller: ----

[Data Summary](#)
[Log Summary](#)
[Upgrade Advisor](#)
[Best Practices](#)
[WLAN Summary](#)
[Interface Summary](#)
[RF Profiles 2.4 GHz](#)
[RF Profiles 5 GHz](#)
[RF Profiles 6 GHz](#)
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[RF Stats 2.4GHz](#)
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[RF Stats 6GHz](#)
[RF Health 2.4GHz](#)
[RF Health 5GHz](#)
[RF Health 6GHz](#)
[Channel Stats 2.4GHz](#)
[Channel Stats 5GHz](#)
[Channel Stats 6GHz](#)

[Apple iOS](#)
[Cisco 8821](#)
[Drager](#)
[Spectralink](#)
[Vocera](#)

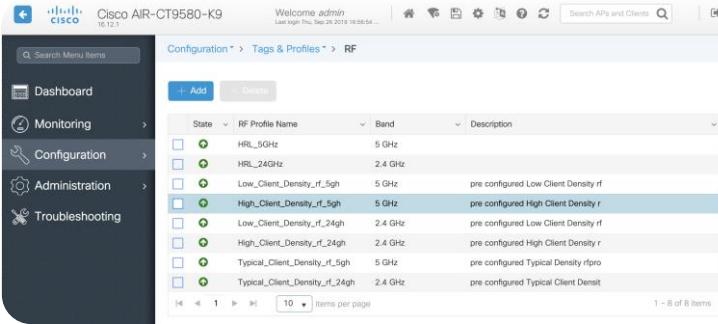
AP Information
[APs Configuration](#)
[APs Slot Configuration](#)
[APs Interface Status](#)
[APs RF Summary 2.4GHz](#)
[APs RF Summary 5GHz](#)
[APs RF Summary 6GHz](#)
[APs RF Health Details](#)
[APs NDI Summarization 2.4GHz](#)
[APs NDI Summarization 5GHz](#)
[APs RF Neighbors 2.4GHz](#)
[APs RF Neighbors 5GHz](#)

[6GHz Predictive Planning](#)
[AP Channel Config Export](#)

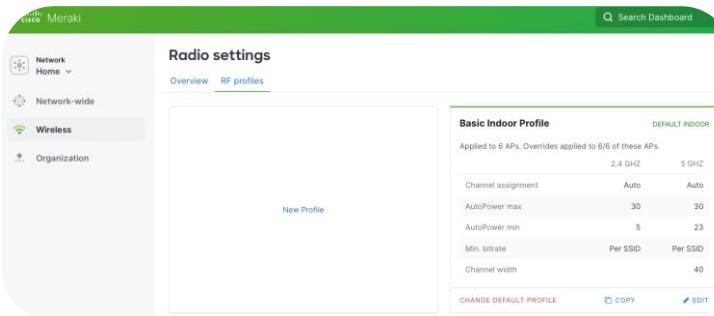
Download: <https://developer.cisco.com/docs/wireless-troubleshooting-tools/>

More info: [Cisco Live US 2022 - BRKEWN-3006](#)

High Density WLAN Features & Configurations



The screenshot shows the Cisco AIR-CT9580-K9 configuration interface. The left sidebar includes 'Dashboard', 'Monitoring', 'Configuration' (selected), 'Administration', and 'Troubleshooting'. The main area is titled 'Configuration > Tags & Profiles > RF'. It displays a table of RF profiles with columns for State, RF Profile Name, Band, and Description. The table lists profiles like 'HRL_5GHz', 'HRL_24GHz', and various 'Low_Client_Density' and 'High_Client_Density' profiles for both 5 GHz and 2.4 GHz bands. A message at the bottom indicates 1 - 8 of 8 items.



The screenshot shows the Meraki Radio settings dashboard. The left sidebar has 'Network Home', 'Network-wide', 'Wireless' (selected), and 'Organization'. The main area is titled 'Radio settings' with tabs for 'Overview' and 'RF profiles'. A 'Basic Indoor Profile' is selected, showing settings for 2.4 GHz and 5 GHz bands, including AutoPower max and min, Min. bitrate, and Channel width. Buttons for 'CHANGE DEFAULT PROFILE', 'COPY', and 'EDIT' are at the bottom.

- WiFi deployments **are not “one-size-fits-all”**
- **Use RF Profiles** on both Catalyst and Meraki deployments for granular RF control
 - **Configure network-wide channel parameters:** remove channels as needed, set channel widths
 - **Configure transmit power min/max:** ensure balance, avoid “client magnets”
 - **Configure RX-SOP thresholds** to selectively reduce radio sensitivity where needed
- On C9800, **plan Site Tags** to balance APs across processes

Channel Planning with RF Profiles

- Plan channels with Dynamic Channel Allocation (Catalyst) or AutoChannel (Meraki) via RF Profile
- If needed – **eliminate unusable channels** for business-critical areas (DFS, etc)
- Reserve channels for use by other systems

The image contains two screenshots of network management interfaces. The top screenshot shows the Cisco AIR-CT9580-K9 configuration interface, specifically the 'Edit RF Profile' screen for the 'RRM' tab. It displays a list of RF profiles including 'HRL_5GHz', 'HRL_24GHz', 'Low_Client_Density_rf_5gh', 'High_Client_Density_rf_5gh', 'Low_Client_Density_rf_24gh', 'High_Client_Density_rf_24gh', 'Typical_Client_Density_rf_5gh', and 'Typical_Client_Density_rf_24gh'. The 'Dynamic Channel Assignment' section includes options for 'Avoid AP Foreign AP Interference' and 'Channel Width' (20, 40, 80, 160 MHz) with specific channel numbers listed. The bottom screenshot shows the Cisco Meraki dashboard with a 'Wireless' configuration dialog. It displays a channel map for UNII-1, UNII-2, UNII-2-Extended, UNII-3, and ISM bands. The map shows channels 36, 40, 44, 48, 52, 56, 60, 64, 100, 104, 108, 112, 116, 120, 124, 128, 132, 136, 140, 144, 149, 153, 157, 161, 165. DFS channels are marked with a red border. A 'Weather Radar' overlay is visible. Buttons for 'Deselect DFS channels', 'Cancel', and 'Done' are at the bottom.

Catalyst Tip: Identifying Potentially Unhealthy Channels

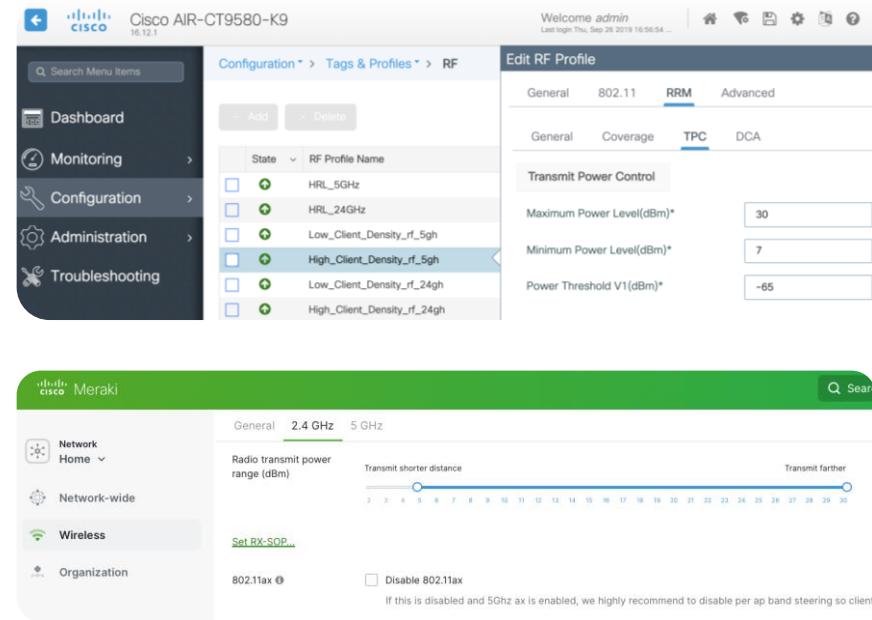
WCAE – ‘APs RF Summary’ tab – “High Channel Changes” column

C	D	G	H	I	J	K	L	M	N	O	V
Model	Mode	Chann	TX Pow	TX Power dBi	Total Clients	RX SOP	CH Util	CH TX Util%	CH RX Util%	Channel Changes	High Channel Chang
C9130AXI-B	Client Serving	108	3	9	18	medium(-78)	50	3	0	18	Yes
C9130AXI-B	Client Serving	140	2	12	8	medium(-78)	73	50	0	20	Yes
C9130AXI-B	Client Serving	52	2	11	17	medium(-78)	46	5	0	20	Yes
C9130AXI-B	Client Serving	64	2	11	4	medium(-78)	11	0	0	25	Yes
C9130AXI-B	Client Serving	100	3	9	12	medium(-78)	49	2	0	30	Yes
C9130AXI-B	Client Serving	44	5	9	7	medium(-78)	47	8	0	23	Yes
C9130AXI-B	Client Serving	100	3	9	13	medium(-78)	38	7	0	19	Yes
C9130AXI-B	Client Serving	56	2	11	22	medium(-78)	46	17	0	28	Yes
C9130AXI-B	Client Serving	132	3	9	14	medium(-78)	37	8	0	32	Yes
C9130AXI-B	Client Serving	52	2	11	15	medium(-78)	45	1	0	18	Yes
C9130AXI-B	Client Serving	56	2	11	23	medium(-78)	42	7	1	25	Yes
C9130AXI-B	Client Serving	116	3	9	9	medium(-78)	24	3	0	22	Yes
C9130AXE-B	Client Serving	52	2	15	0	medium(-78)	2	0	0	19	Yes
C9130AXE-B	Client Serving	36	2	19	0	medium(-78)	1	0	0	20	Yes
C9130AXE-B	Client Serving	56	2	15	0	medium(-78)	1	0	0	30	Yes
C9130AXE-B	Client Serving	149	2	20	0	medium(-78)	2	0	0	22	Yes
C9130AXE-B	Client Serving	124	2	15	88	medium(-78)	78	19	1	70	Yes
C9130AXE-B	Client Serving	48	2	20	0	medium(-78)	2	0	0	66	Yes
C9130AXE-B	Client Serving	36	2	19	0	medium(-78)	2	0	0	19	Yes
C9130AXE-B	Client Serving	44	2	20	0	medium(-78)	2	0	0	21	Yes
C9130AXE-B	Client Serving	108	2	15	0	medium(-78)	1	0	0	25	Yes
C9130AXE-B	Client Serving	149	2	20	0	medium(-78)	1	0	0	21	Yes

“High Channel Change: Yes”
triggered for radios with more than 4 channel changes per day

Balancing Transmit Power with RF Profiles

- TPC (Catalyst) and AutoPower (Meraki)
- Ensures AP-to-AP consistency (no “client magnets”) and 2.4GHz to 5GHz balance (5GHz hotter, 2.4GHz cooler)
- **TPC/AutoPower Min** – lower power limit specified for a given radio. TPC/AutoPower will never adjust power below this level.
- **TPC/AutoPower Max** – upper power limit specified for a given radio. TPC/AutoPower will never adjust power above this level.



The top screenshot shows the Cisco AIR-CT9580-K9 configuration interface. The 'Edit RF Profile' dialog is open on the 'TPC' tab, showing settings for Maximum Power Level (30 dBm), Minimum Power Level (7 dBm), and Power Threshold V1 (-65 dBm). The bottom screenshot shows the Meraki Wireless interface for the 2.4 GHz band, where the 'Radio transmit power range (dBm)' slider is set to 'Transmit shorter distance' at approximately 5 dBm.

Identifying Possible Power Imbalance

WCAE - 'APs RF Summary' tab - "TX Power dBm" and "Total Clients" columns

Name	Slot	Band	Channel	TX Power	TX Power dBm	Total Clients
AP1	1	5	100	1	17	21
AP1	2	5	48	1	23	70

6dB power difference = client imbalance

Refer to AP power tables to determine max TX power per UNII band

Use "show controller" on a sample AP for all details

Selecting Channel Width with RF Profiles

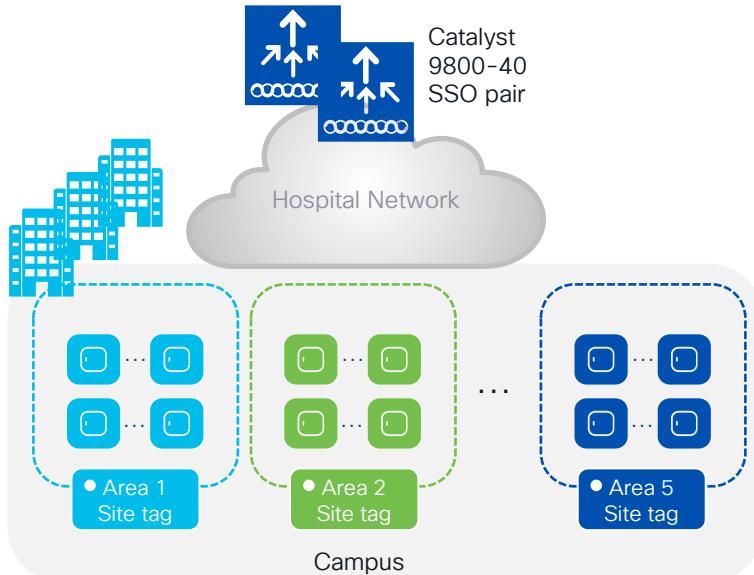
5GHz

- In general, **20MHz channels** provide the most channel reuse (capacity) for high density environments
- **Wider channels may be used selectively** in more isolated areas – smaller classrooms, lobbies, conference rooms, etc.

6GHz

- Heavily dependent on regulatory domain
- Note! Higher channel width results in higher max Tx power for data frames (but not beacons – remember when surveying!)

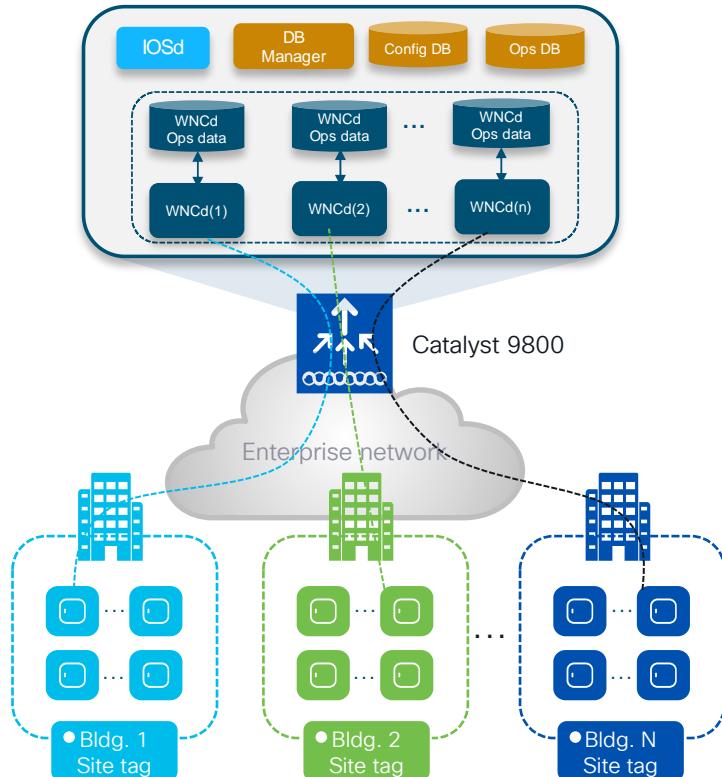
C9800 Site Tag Design in High Density



- **Custom Site Tags** deterministically distribute APs across C9800 processes, aka “WNCd’s”
- Always use Custom Site Tags – not Default – to **ensure load is balanced** in a predictable way
- 500 APs per Site Tag is the rule of thumb, BUT...
- Platform limits on AP count per Site Tag will differ from “ideal limits” in High Density / High Roam frequency environments
- **Recommended AP count per Site Tag will vary** based on the environment
 - Consider roaming patterns and minimize roaming between Site Tags

Refer to the [C9800 Best Practices](#) guide for the latest guidance

Site Tags – Design considerations



Important facts:

- Distributing APs (and clients) across custom Site Tags (and thus WNCd's) gives better scale and performance
- In large public venues, avoid having more Site Tags than # of WNCd's
- The number of WNCd varies from platform to platform:

Platform	# of WNCD instances
EWC (on AP or C9k switch)	1
C9800-L	1
C9800-CL (small)	1
C9800-CL (medium)	3
C9800-40	5
C9800-CL (large)	7
C9800-80	8

Refer to the [C9800 Best Practices](#) guide for the latest guidance

The following command shows the # of WNCDs processes:

```
9800#sh processes platform | inc wncd
```

Site Tag Limitations

Platform	Maximum number of APs per site tag*
C9800-80, C9800-CL (medium and large)	1600
C9800-40	800
Any other C9800 platform	Equal to the maximum number of APs supported

Platform	Recommended number of site tags
C9800-80	8 or a multiple (16, 24, ...)
C9800-CL (large)	7 or a multiple (14, 21, ...)
C9800-40	5 or a multiple (10, 15, ...)
C9800-CL (medium)	3 or a multiple (6, 9, ...)

Always refer to the [C9800 Best Practices](#) guide for the latest guidance

Helpful Site Tag Monitoring Commands

show wireless stats ap loadbalance summary

- Shows summary of APs assigned to each WNCd

```
#show wireless stats ap loadbalance summary
DTLS drop - 380
```

WNCD	APs Discovered	APs Joined	APs Timedout
0	179	179	8715

show wireless loadbalance tag affinity wncd <wncd-number>

- Shows which site tags are assigned to each WNCd

```
#show wireless loadbalance tag affinity wncd 0
```

Tag	Tag type	No of AP's Joined
[REDACTED]	SITE TAG	177
[REDACTED]	SITE TAG	1

Other 9800 Tips: L2/L3

On 9800's - Don't assign an IP Address to SVI's without good reason!
(Can quickly overwhelm upstream L3 hops)

Primary reasons you may need an SVI:

- mDNS
- DHCP Relay (uncommon in High Density)

If you need an SVI - plan Layer 3 scale upstream accordingly!

<https://www.cisco.com/c/en/us/products/collateral/wireless/catalyst-9800-series-wireless-controllers/guide-c07-743627.html>

The (Not So) Secret High Density Weapon: RX-SOP



Receive Sensitivity Threshold (RX-SOP)

What if...

I put AP's wherever I needed them...
I used all the right antennas...
I surveyed and optimized and surveyed
and optimized again...

...but my Channel Utilization is still really high, with almost no “real” traffic?

Vendor	Signal	Noise	SNR	Channel	Channel Utilization	Clients
Cisco Sys...	-85 dBm	-96 dBm	11 dB	48	90%	
Cisco Sys...	-70 dBm	-96 dBm	26 dB	153	89%	
Cisco Sys...	-74 dBm	-96 dBm	22 dB	153	89%	
Cisco Sys...	-74 dBm	-96 dBm	22 dB	153	89%	
Cisco Sys...	-74 dBm	-96 dBm	22 dB	153	89%	
Cisco Sys...	-90 dBm	-96 dBm	6 dB	144	87%	
Cisco Sys...	-78 dBm	-96 dBm	18 dB	157	86%	
Cisco Sys...	-64 dBm	-96 dBm	32 dB	1	84%	
Cisco Sys...	-70 dBm	-96 dBm	26 dB	153	82%	
Cisco Sys...	-76 dBm	-96 dBm	20 dB	153	80%	
Cisco Sys...	-86 dBm	-96 dBm	10 dB	161	80%	
Cisco Sys...	-80 dBm	-96 dBm	16 dB	153	80%	
Cisco Sys...	-64 dBm	-96 dBm	32 dB	44	79%	
Cisco Sys...	-62 dBm	-96 dBm	34 dB	44	79%	
Cisco Sys...	-64 dBm	-96 dBm	32 dB	44	79%	
Cisco Sys...	-80 dBm	-96 dBm	16 dB	153	78%	
Cisco Sys...	-74 dBm	-96 dBm	22 dB	153	77%	
Cisco Sys...	-70 dBm	-96 dBm	26 dB	153	76%	
Cisco Sys...	-80 dBm	-96 dBm	16 dB	153	76%	
Cisco Sys...	-80 dBm	-96 dBm	16 dB	153	76%	
Cisco Sys...	-70 dBm	-96 dBm	26 dB	153	76%	
Cisco Sys...	-80 dBm	-96 dBm	16 dB	153	75%	
Cisco Sys...	-78 dBm	-96 dBm	18 dB	153	75%	
Cisco Sys...	-78 dBm	-96 dBm	18 dB	153	74%	

Receive Sensitivity Threshold (RX-SOP)

What does it do?

Reduces “receive” sensitivity of the AP to a pre-determined power level

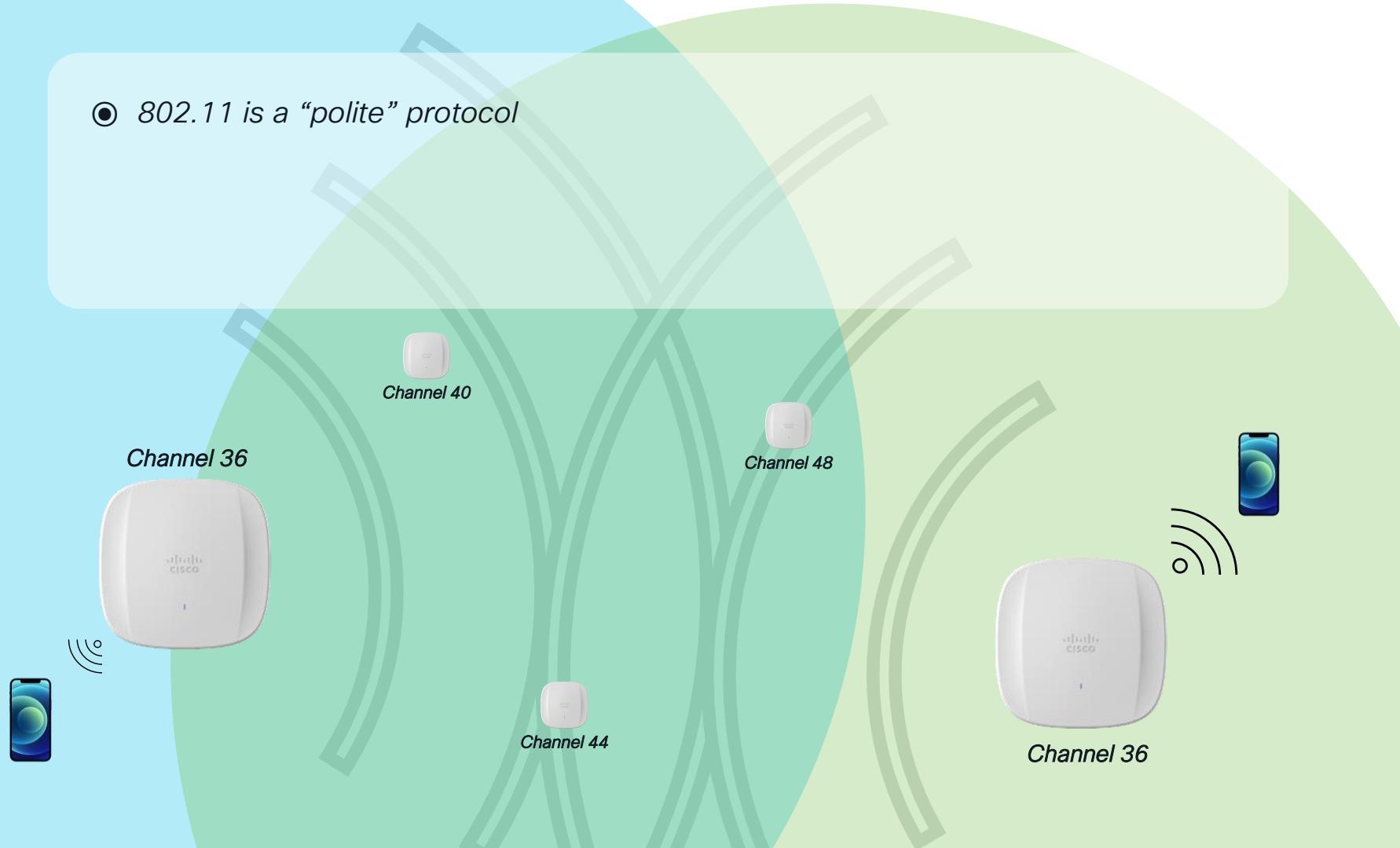
Example: ignore everything coming into the radio at lower than -80dBm, because those devices are unlikely to be in our cell

Why is it helpful?

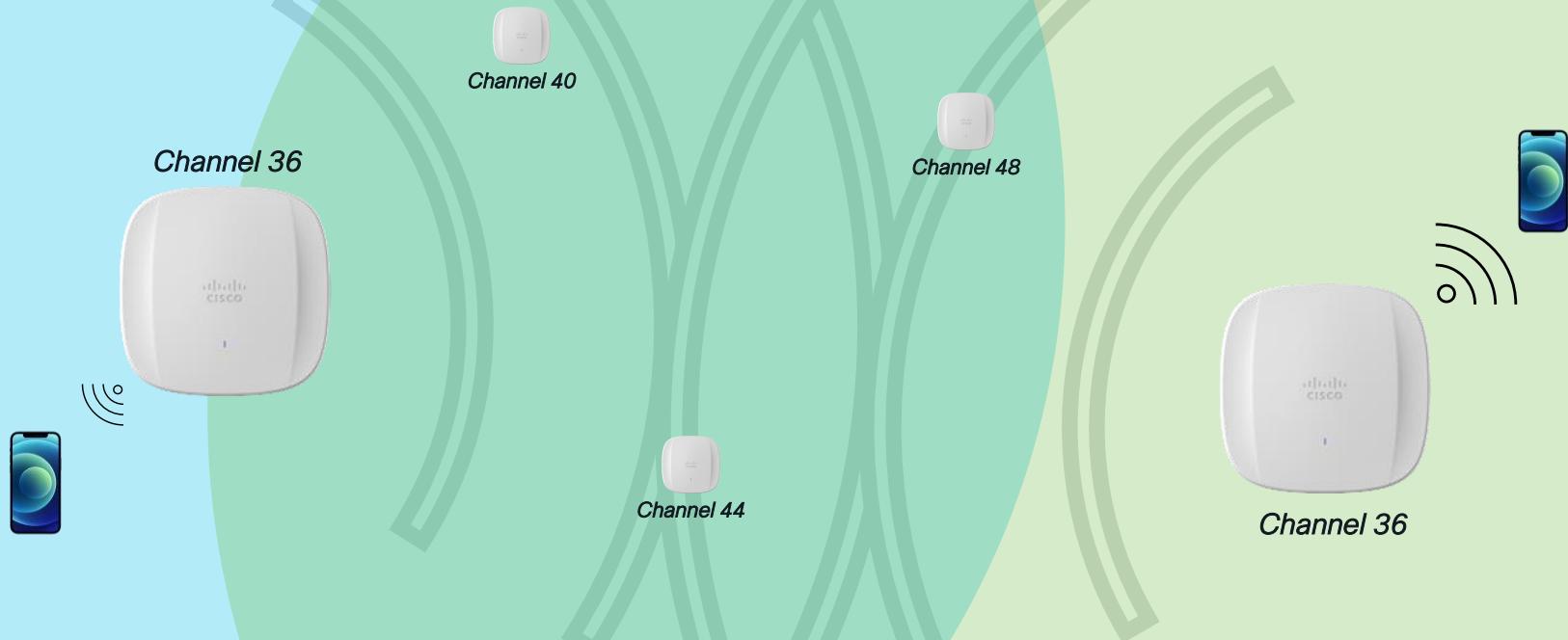
Allows us to transmit more often to clients in our intended cell



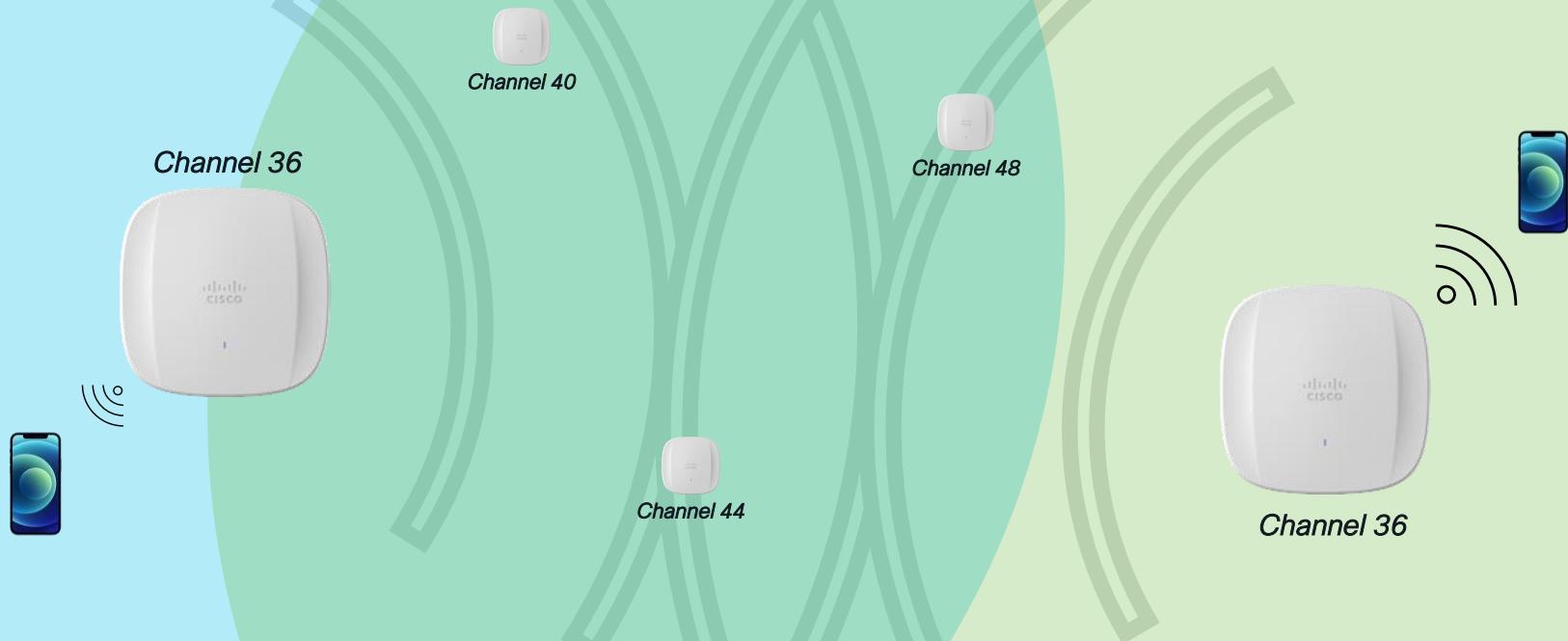
- ⦿ 802.11 is a “polite” protocol



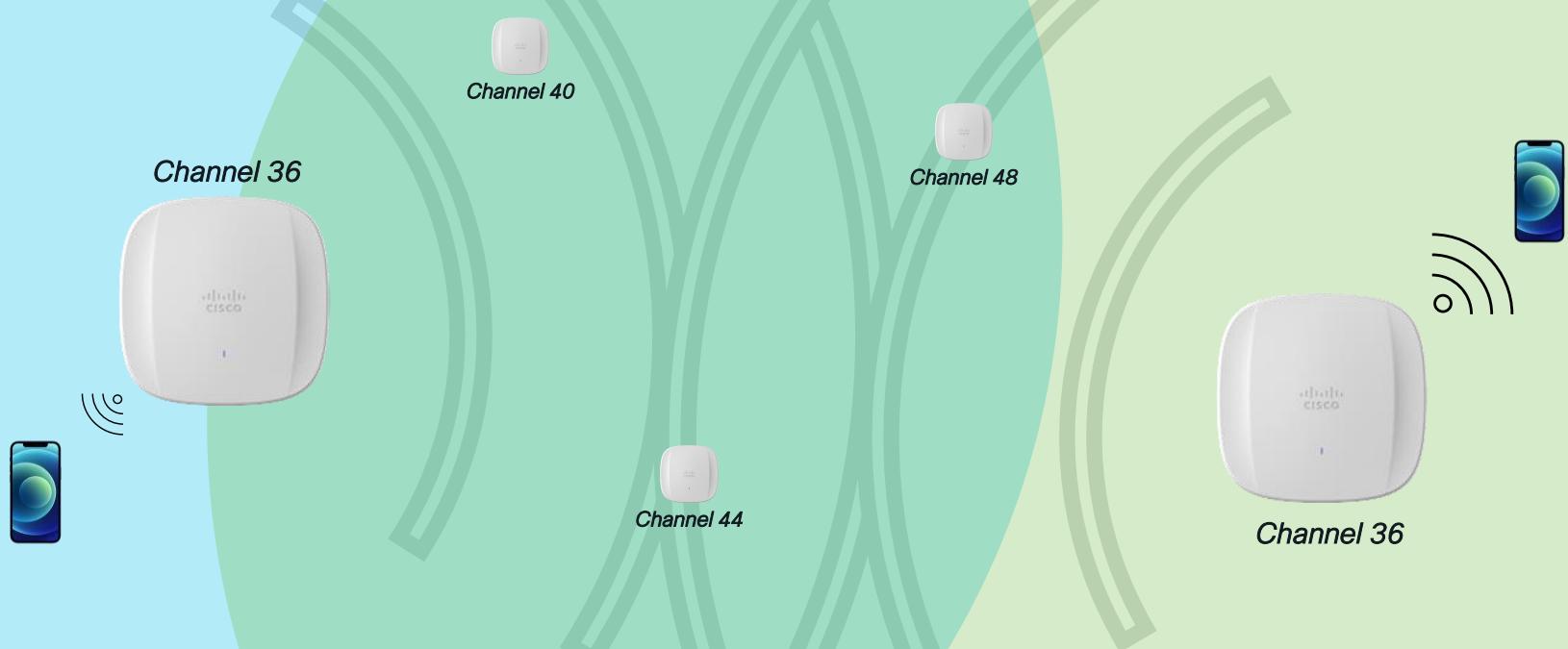
- ⦿ 802.11 is a “polite” protocol
- ⦿ I must listen before I start to talk – I will not talk until it’s “quiet” on my channel



- 802.11 is a “polite” protocol
- I must listen before I start to talk – I will not talk until it’s “quiet” on my channel
- In dense deployments, you will have co-channel AP’s in range of each other



- 802.11 is a “polite” protocol
- I must listen before I start to talk – I will not talk until it’s “quiet” on my channel
- In dense deployments, you will have co-channel AP’s in range of each other
- RX-SOP optimization helps us tune out the most distant co-channel transmissions



Receive Sensitivity Threshold (RX-SOP)

- Be careful and make small adjustments
 - Generally, start in the -80's



Receive Sensitivity Threshold (RX-SOP)



- Be careful and make small adjustments
 - Generally, start in the -80's
- Remember – adjusting the RX-SOP threshold **doesn't impact the actual RF energy on the channel**, but it does impact APs' sensitivity to it
 - High Channel Utilization still affects all clients

Receive Sensitivity Threshold (RX-SOP)



- Be careful and make small adjustments
 - Generally, start in the -80's
- Remember – adjusting the RX-SOP threshold **doesn't impact the actual RF energy on the channel**, but it does impact APs' sensitivity to it
 - High Channel Utilization still affects all clients
- **WiFi6, WiFi6E, and/or use of C9104 may reduce the need for RX-SOP** in some environments; continue to monitor your Channel Utilization and adjust as needed

Receive Sensitivity Threshold (RX-SOP)

Without Custom RX-SOP Threshold

(Default / “Auto” Radio Sensitivity)

Radio processes
everything that it
can hear – any
frame with
enough SNR



Receive Sensitivity Threshold (RX-SOP)

Without Custom RX-SOP Threshold

(Default / "Auto" Radio Sensitivity)

Radio processes everything that it can hear – any frame with enough SNR



With Custom RX-SOP Threshold



The AP radio processes only the frames heard above the threshold



Frames where SOP (start of packet) is heard below the threshold are ignored

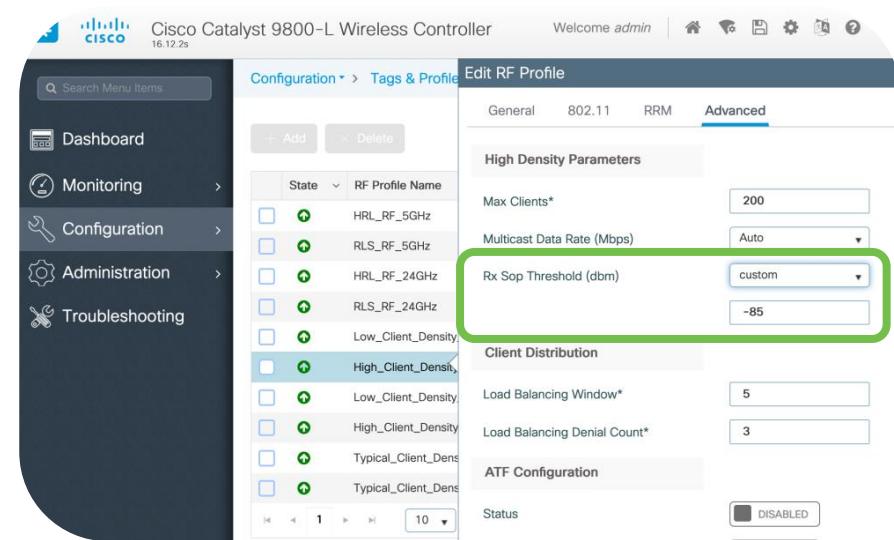
-82dBm RX-SOP Threshold

Ignored frames are now considered "Noise" and I can talk over them

HOW TO: Optimize RX-SOP Thresholds

- 1 Choose client devices and representative areas to test
- 2 Create a temporary SSID on one AP in the test area so your client doesn't roam
(see *hidden slides* for tips on AireOS / 9800)
- 3 Monitor the AP's view of test clients throughout the cell
(from WLC UI, WLC CLI, or AP CLI)
- 4 Pad the worst reading by another 15dB or more = initial RX-SOP threshold

Example: Worst AP-observed RSSI value is -72; initial RXSOP threshold with 15dB cushion = -87 (or higher)



HOW TO: Optimize RX-SOP Thresholds (9800)

1. Pick the client device(s) you want to test
2. Pick the representative area(s) you want to test
3. Create a [new temporary WLAN and Policy Tag](#)
4. Assign the Policy Tag to the test AP
5. Join your client device(s) to the new SSID and monitor how the AP hears your client(s) (from AP CLI – “show controller d 1 client <mac-addr>”)
6. Test for “worst case scenario” – bodies between device and AP, furthest corner of the cell, etc. Continually check RSSI from AP side.
7. Take your “worst” RSSI value, add a 10-15dB cushion, and use that as your [initial RXSOP threshold](#) for that cell type (set in RF Tag)

Example: Worst RSSI value is -72; initial RXSOP with 15dB cushion = -87

Review: How AP's Hear Clients

For a detail on a single client, at AP CLI:

Telnet/SSH to AP and use “show controller d <0|1> client <mac-addr>” for immediate client RSSI readings of a single client

```
10#sho controller d 1 client FC:F8:AE:60:98:34
```

```
<clip>
```

```
Additional info for client FC:F8:AE:60:98:34
```

```
RSSI: -47
```

```
<clip>
```

```
Statistics for client FC:F8:AE:60:98:34
```

```
mac          <clip> stats_ago expiration
```

```
FC:F8:AE:60:98:34  <clip> 0.700000      0
```



How long ago were these stats updated (in sec)?

HOW TO: Optimize RX-SOP Thresholds (AireOS)

1. Pick the **client device(s)** you want to test
2. Pick the **representative area(s)** you want to test
3. Create a new temporary SSID and a new AP Group
4. Add the AP's you want to test to the new AP group
5. Join your **client device(s)** to the new SSID and monitor how the AP hears your client(s) (from AP CLI – “show controller d 1 client <mac-addr>”)
6. **Test for “worst case scenario”** – bodies between device and AP, furthest corner of the cell, etc. Continually check RSSI from AP side.
7. Take your “worst” RSSI value, add a 10-15dB cushion, and use that as your **initial RXSOP threshold** for that cell type

Example: Worst RSSI value is -72; initial RXSOP with 15dB cushion = -87

HOW TO: Optimize RX-SOP Thresholds

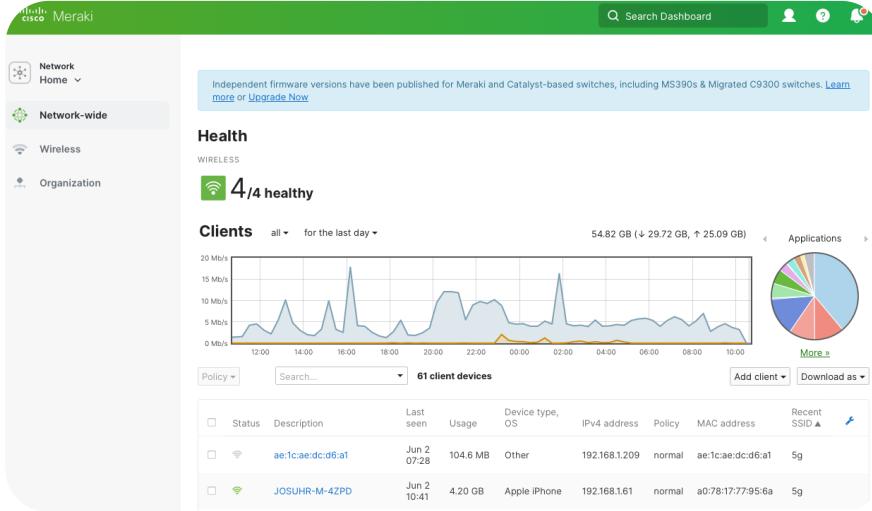
A key takeaway:

Be conservative and make small adjustments!

Cloud-Managed High Density



Cloud-Managed High Density



Can be ideal for:

Classrooms

Theaters & Auditoriums

Hotspots

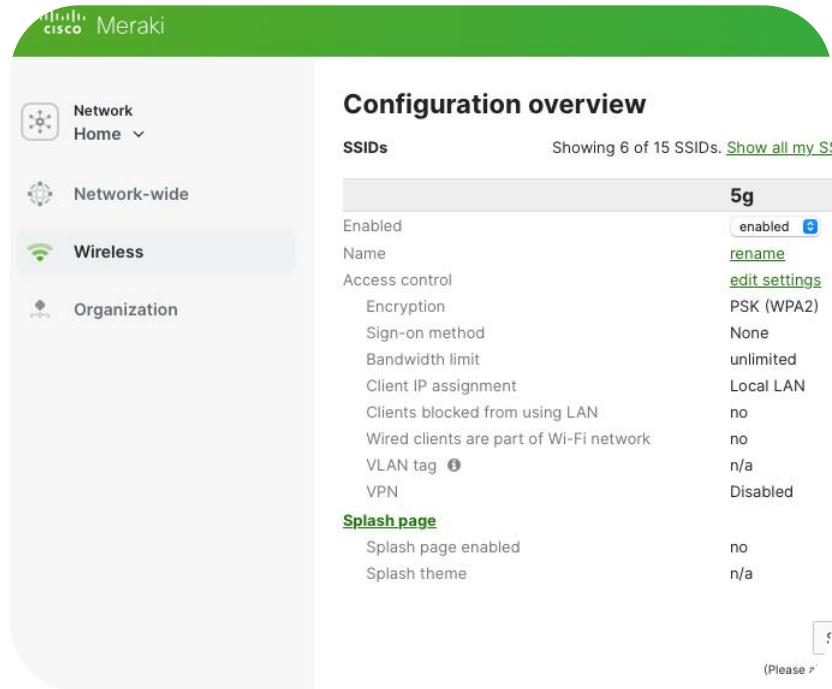
Be aware of:

Switched Network Capacity (L2 / L3)

Roaming Domains & Expected

Roaming Experience

Cloud-Managed High Density



The image shows a screenshot of the Cisco Meraki cloud-managed network interface. The left sidebar has a green header with the Cisco Meraki logo. The main menu includes Network Home, Network-wide, Wireless (which is selected and highlighted in grey), and Organization. The main content area is titled 'Configuration overview' under 'SSIDs'. It shows 6 of 15 SSIDs. The configuration for the '5g' SSID is detailed in a table:

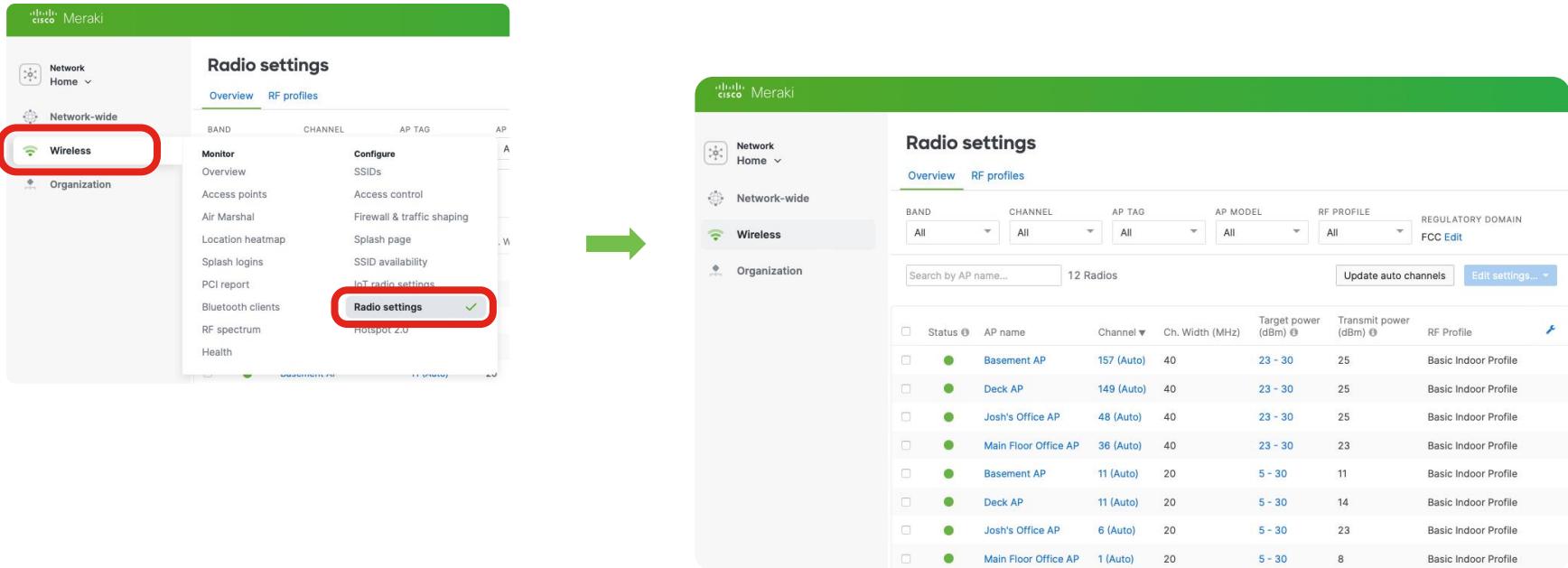
	5g
Enabled	<input checked="" type="checkbox"/> enabled
Name	rename
Access control	edit settings
Encryption	PSK (WPA2)
Sign-on method	None
Bandwidth limit	unlimited
Client IP assignment	Local LAN
Clients blocked from using LAN	no
Wired clients are part of Wi-Fi network	no
VLAN tag <small>?</small>	n/a
VPN	Disabled
Splash page	
Splash page enabled	no
Splash theme	n/a

At the bottom right of the configuration table is a small icon with a question mark and the text '(Please ?)'.

Similarly to “traditional” Catalyst networks:

- Manage AP Tx power appropriately
- Tune PHY rates
- Limit SSID count per AP as much as possible
- Optimize channels
- Leverage RX-SOP (carefully, when needed)

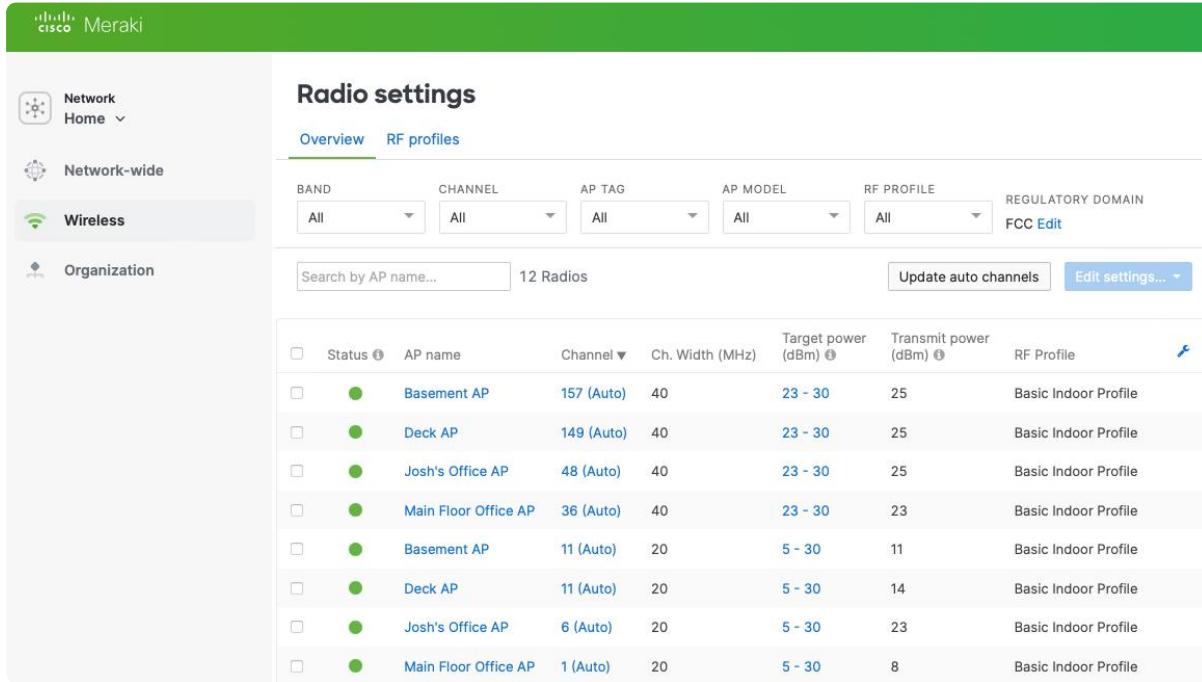
RF Optimization: Radio Settings Overview



The image shows the Cisco Meraki Wireless Radio settings interface. The left panel is a navigation menu with 'Wireless' selected. The right panel is a detailed list of radio settings for 12 radios, including AP name, channel, target power, and RF profile.

AP name	Channel	Target power (dBm)	Transmit power (dBm)	RF Profile
Basement AP	157 (Auto)	40	23 - 30	Basic Indoor Profile
Deck AP	149 (Auto)	40	23 - 30	Basic Indoor Profile
Josh's Office AP	48 (Auto)	40	23 - 30	Basic Indoor Profile
Main Floor Office AP	36 (Auto)	40	23 - 30	Basic Indoor Profile
Basement AP	11 (Auto)	20	5 - 30	Basic Indoor Profile
Deck AP	11 (Auto)	20	5 - 30	Basic Indoor Profile
Josh's Office AP	6 (Auto)	20	5 - 30	Basic Indoor Profile
Main Floor Office AP	1 (Auto)	20	5 - 30	Basic Indoor Profile

RF Optimization: Radio Settings Overview

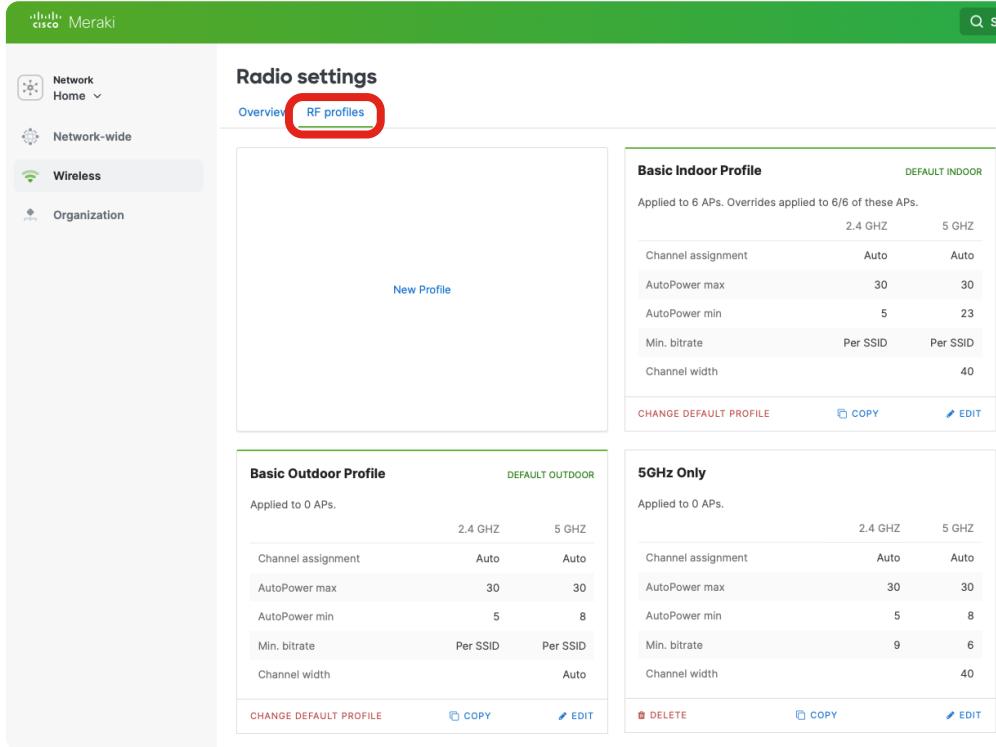


The screenshot shows the Cisco Meraki interface for managing radio settings. The left sidebar includes 'Network Home', 'Network-wide', 'Wireless', and 'Organization' sections. The main 'Radio settings' page has tabs for 'Overview' (selected) and 'RF profiles'. It features filters for 'BAND', 'CHANNEL', 'AP TAG', 'AP MODEL', 'RF PROFILE', and 'REGULATORY DOMAIN'. A search bar and a 'Search by AP name...' input are present. The table displays 12 radios with columns for Status, AP name, Channel, Ch. Width (MHz), Target power (dBm), Transmit power (dBm), and RF Profile. The data is as follows:

Status	AP name	Channel	Ch. Width (MHz)	Target power (dBm)	Transmit power (dBm)	RF Profile
<input type="checkbox"/>	Basement AP	157 (Auto)	40	23 - 30	25	Basic Indoor Profile
<input type="checkbox"/>	Deck AP	149 (Auto)	40	23 - 30	25	Basic Indoor Profile
<input type="checkbox"/>	Josh's Office AP	48 (Auto)	40	23 - 30	25	Basic Indoor Profile
<input type="checkbox"/>	Main Floor Office AP	36 (Auto)	40	23 - 30	23	Basic Indoor Profile
<input type="checkbox"/>	Basement AP	11 (Auto)	20	5 - 30	11	Basic Indoor Profile
<input type="checkbox"/>	Deck AP	11 (Auto)	20	5 - 30	14	Basic Indoor Profile
<input type="checkbox"/>	Josh's Office AP	6 (Auto)	20	5 - 30	23	Basic Indoor Profile
<input type="checkbox"/>	Main Floor Office AP	1 (Auto)	20	5 - 30	8	Basic Indoor Profile

- Sortable / Filterable table for radio settings per AP
- Channel
- Width
- Min/Max Power
- Current Power
- RF Profile

RF Optimization: RF Profiles



The screenshot shows the Cisco Meraki RF Profiles interface. The left sidebar includes icons for Network Home, Network-wide, Wireless, and Organization. The main content area is titled "Radio settings" and has two tabs: "Overview" and "RF profiles", with "RF profiles" highlighted by a red box. Below the tabs, there are two sections: "Basic Indoor Profile" and "Basic Outdoor Profile".

Basic Indoor Profile (DEFAULT INDOOR)

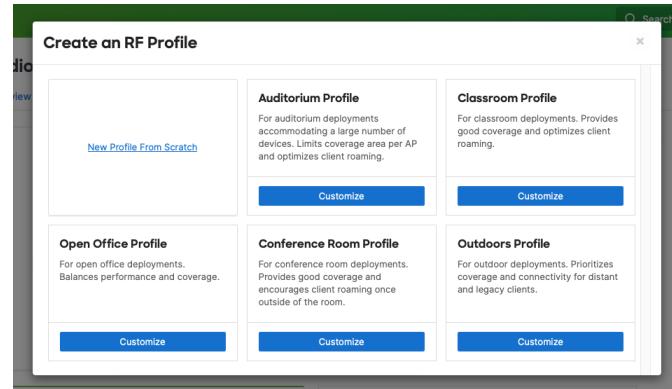
	2.4 GHz	5 GHz
Channel assignment	Auto	Auto
AutoPower max	30	30
AutoPower min	5	23
Min. bitrate	Per SSID	Per SSID
Channel width	40	

[CHANGE DEFAULT PROFILE](#) [COPY](#) [EDIT](#)

Basic Outdoor Profile (DEFAULT OUTDOOR)

	2.4 GHz	5 GHz
Channel assignment	Auto	Auto
AutoPower max	30	30
AutoPower min	5	8
Min. bitrate	Per SSID	Per SSID
Channel width	Auto	

[CHANGE DEFAULT PROFILE](#) [COPY](#) [EDIT](#)

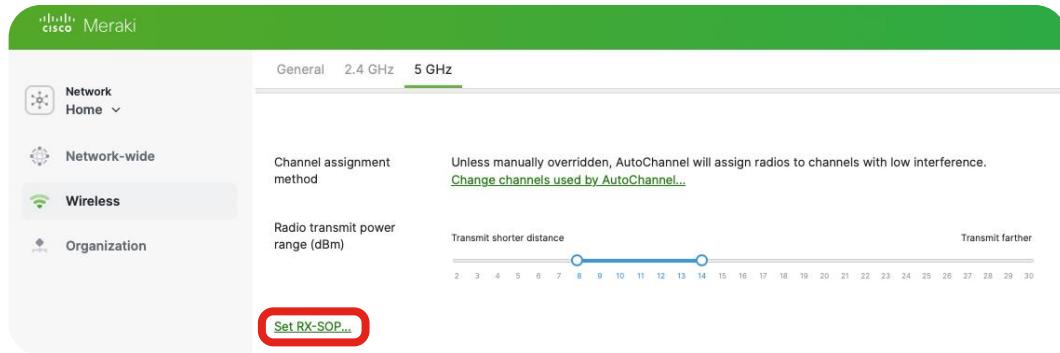


The "Create an RF Profile" dialog box displays six profile options:

- Auditorium Profile**: For auditorium deployments. Describes accommodating a large number of devices and optimizing client roaming.
- Classroom Profile**: For classroom deployments. Provides good coverage and optimizes client roaming.
- Open Office Profile**: For open office deployments. Balances performance and coverage.
- Conference Room Profile**: For conference room deployments. Provides good coverage and encourages client roaming once outside of the room.
- Outdoors Profile**: For outdoor deployments. Prioritizes coverage and connectivity for distant and legacy clients.

[New Profile From Scratch](#) [Customize](#)

RF Optimization: RX SOP



The image shows the Cisco Meraki RF Optimization interface for the 5 GHz band. The top navigation bar includes the Cisco and Meraki logos, and tabs for General, 2.4 GHz, and 5 GHz, with 5 GHz selected. The left sidebar has icons for Network Home, Network-wide, Wireless, and Organization, with Wireless selected. The main content area shows the Channel assignment method as "AutoChannel" and the Radio transmit power range (dBm) as a slider from 2 to 30, currently set between 8 and 14. A red box highlights the "Set RX-SOP..." button at the bottom left.

General 2.4 GHz 5 GHz

Network Home

Network-wide

Wireless

Organization

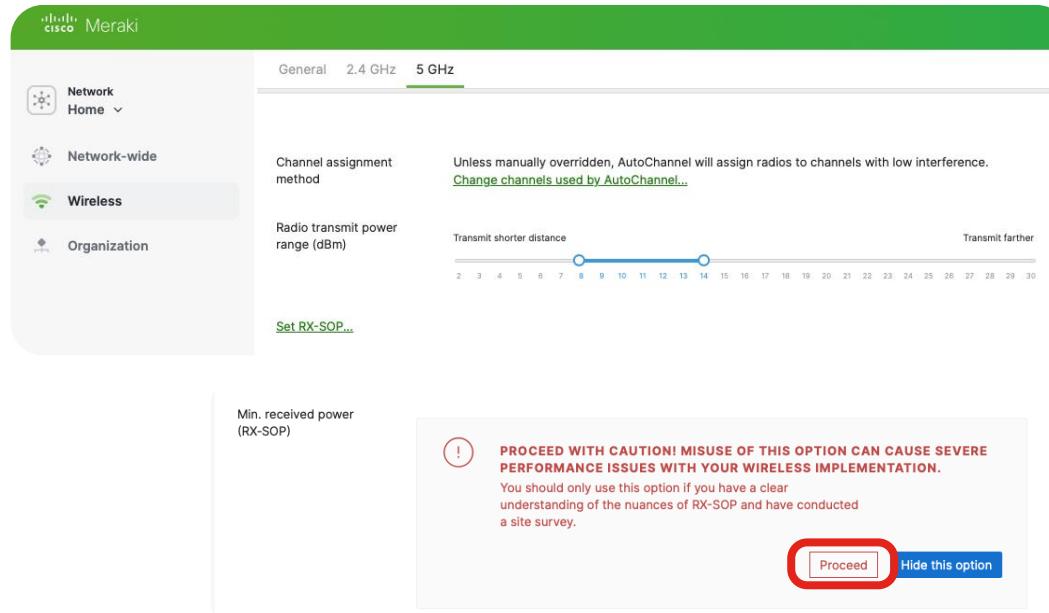
Channel assignment method
Unless manually overridden, AutoChannel will assign radios to channels with low interference.
[Change channels used by AutoChannel...](#)

Radio transmit power range (dBm)

Transmit shorter distance Transmit farther

Set RX-SOP...

RF Optimization: RX SOP



The image shows the Cisco Meraki RF Optimization interface for the 5 GHz band. The left sidebar includes Network Home, Network-wide, Wireless, and Organization sections. The main content area shows the Channel assignment method (AutoChannel) and Radio transmit power range (dBm) from 2 to 30. A callout box for 'Min. received power (RX-SOP)' contains a warning: 'PROCEED WITH CAUTION! MISUSE OF THIS OPTION CAN CAUSE SEVERE PERFORMANCE ISSUES WITH YOUR WIRELESS IMPLEMENTATION.' It also states that the option should only be used with a clear understanding of RX-SOP nuances and a site survey. Buttons for 'Proceed' (highlighted with a red border) and 'Hide this option' are at the bottom.

General 2.4 GHz **5 GHz**

Network Home

Network-wide

Wireless

Organization

Channel assignment method
Unless manually overridden, AutoChannel will assign radios to channels with low interference.
[Change channels used by AutoChannel...](#)

Radio transmit power range (dBm)
Transmit shorter distance Transmit farther

2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

[Set RX-SOP...](#)

Min. received power (RX-SOP)

! PROCEED WITH CAUTION! MISUSE OF THIS OPTION CAN CAUSE SEVERE PERFORMANCE ISSUES WITH YOUR WIRELESS IMPLEMENTATION.
You should only use this option if you have a clear understanding of the nuances of RX-SOP and have conducted a site survey.

Proceed **Hide this option**

RF Optimization: RX SOP

The image shows the Cisco Meraki RF Optimization interface for the 5 GHz band. The left sidebar includes Network Home, Network-wide, Wireless, and Organization tabs. The main area shows the Channel assignment method (AutoChannel) and Radio transmit power range (dBm) from 2 to 30. A 'Set RX-SOP...' button is present. A modal dialog box is displayed, warning about the risks of enabling RX-SOP and providing a 'Proceed' button. The RX-SOP configuration page shows the 'Enabled' state selected (highlighted with a red box), with options to 'Listen for clients farther away' and 'Ignore weaker clients'. A power spectrum graph shows signal strength from -95 to 0 dBm.

Min. received power (RX-SOP)

PROCEED WITH CAUTION! MISUSE OF THIS OPTION CAN CAUSE SEVERE PERFORMANCE ISSUES WITH YOUR WIRELESS IMPLEMENTATION!

You should only use this option if you have a clear understanding of the nuances of RX-SOP and have conducted a site survey.

Proceed

Min. received power (RX-SOP)

Enabled

Listen for clients farther away

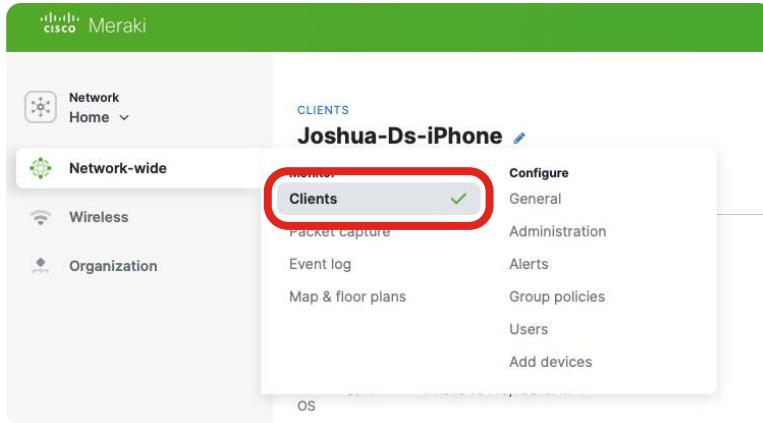
Ignore weaker clients

-95 -94 -93 -92 -91 -90 -89 -88 -87 -86 -85 -84 -83 -82 -81 -80 -79 -78 -77 -76 -75 -74 -73 -72 -71 -70 -69 -68 -67 -66 dBm

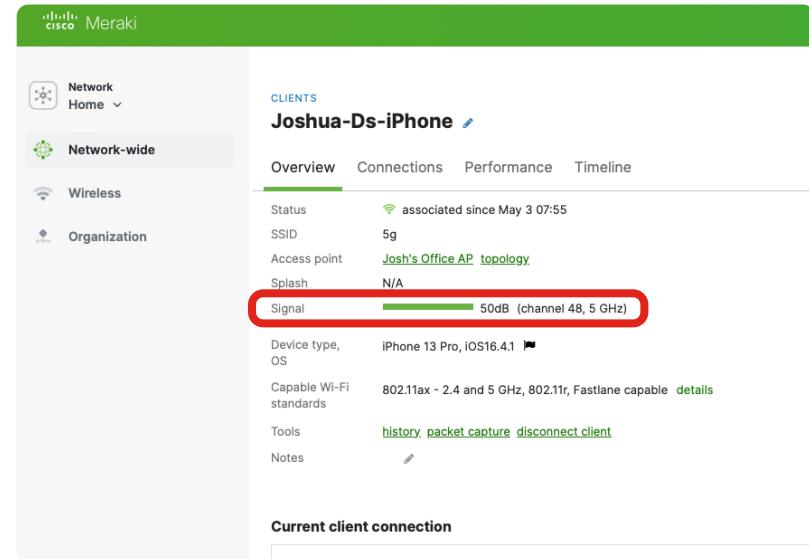
RF Optimization: RX SOP



Monitoring Client RSSI @ AP for RXSOP Testing



The screenshot shows the Cisco Meraki interface for monitoring a client named "Joshua-Ds-iPhone". The left sidebar includes "Network Home", "Network-wide", "Wireless", and "Organization" sections. The main content area is titled "CLIENTS" and shows "Joshua-Ds-iPhone". A red box highlights the "Clients" tab, which is currently selected (indicated by a green checkmark). Other tabs include "Configure", "General", "Administration", "Alerts", "Group policies", "Users", and "Add devices".



The screenshot shows the Cisco Meraki interface for monitoring the same client, "Joshua-Ds-iPhone". The left sidebar is identical. The main content area is titled "CLIENTS" and shows "Joshua-Ds-iPhone". The "Overview" tab is selected, displaying the following details:

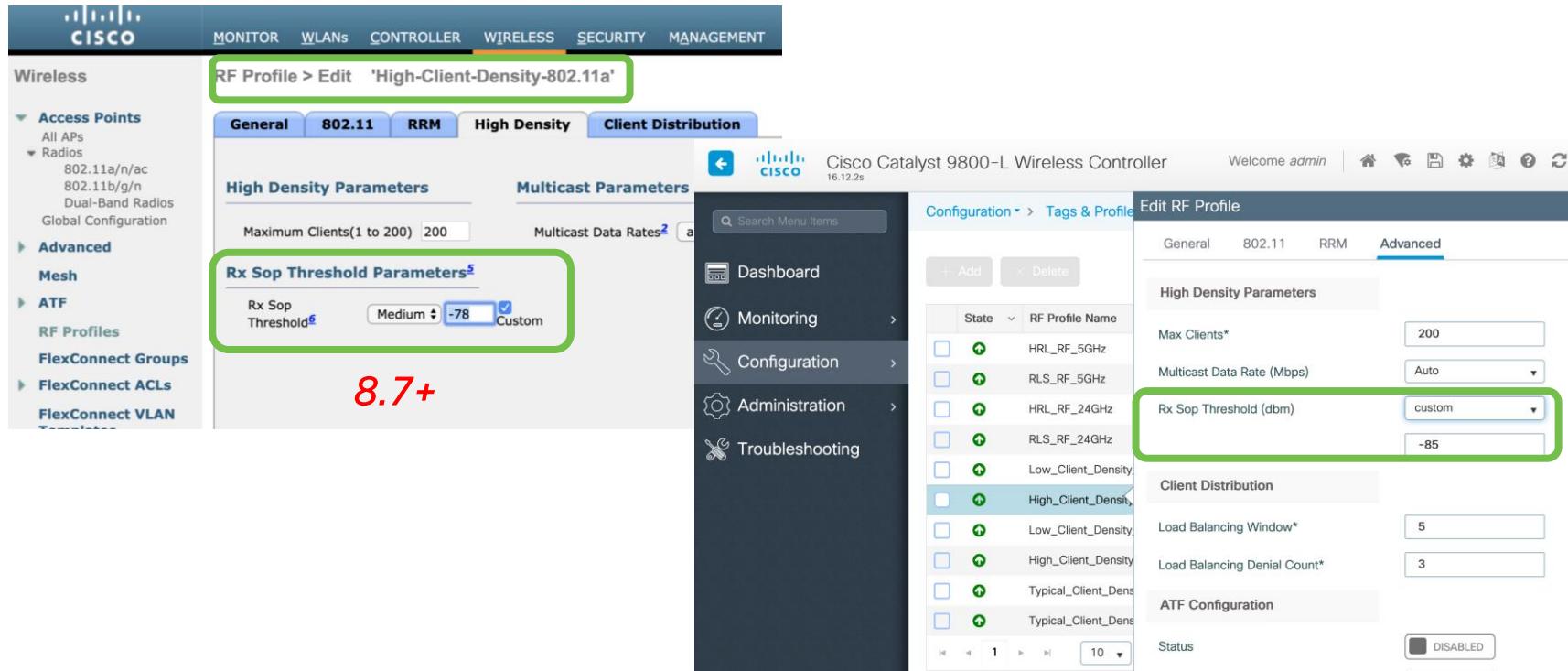
- Status: associated since May 3 07:55
- SSID: 5g
- Access point: [Josh's Office AP topology](#)
- Splash: N/A
- Signal: 50dB (channel 48, 5 GHz) (highlighted with a red box)
- Device type, OS: iPhone 13 Pro, iOS16.4.1
- Capable Wi-Fi standards: 802.11ax - 2.4 and 5 GHz, 802.11r, Fastlane capable
- Tools: [history](#), [packet capture](#), [disconnect client](#)
- Notes: (empty)

Wired Network Considerations

- Roaming domains: Meraki roaming basics
 - Roaming is either concentrator-based or distributed
 - Most viable in large HD networks means ‘hard’ roams across subnets
- Switched network capacity (throughput & L2 / MAC handling)

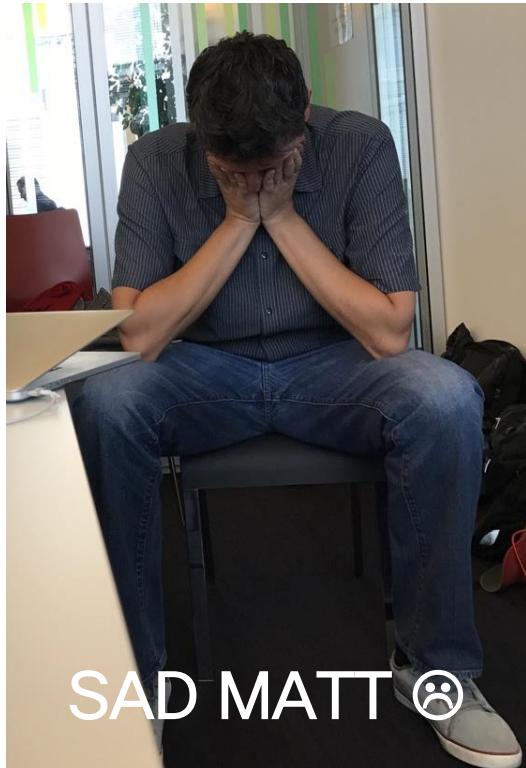
Common High Density Mistakes

Tuning RX-SOP Thresholds: GUI

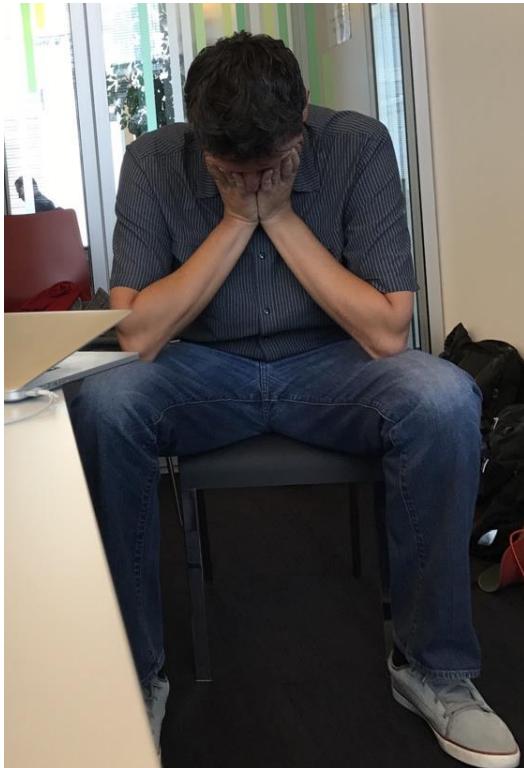


The image displays the Cisco Wireless Controller GUI interface, specifically the 'Edit RF Profile' screen for the 'High-Client-Density-802.11a' profile. The interface is divided into several tabs: General, 802.11, RRM, High Density, and Client Distribution. The 'High Density' tab is currently selected. On the left, a navigation menu includes options like Access Points, Advanced, Mesh, ATF, RF Profiles, FlexConnect Groups, FlexConnect ACLs, and FlexConnect VLAN. The main content area shows 'High Density Parameters' and 'Multicast Parameters'. Under 'High Density Parameters', the 'Rx Sop Threshold Parameters' section is highlighted with a green box and contains a red '8.7+' value. The 'Multicast Parameters' section includes a 'Multicast Data Rates' dropdown set to 'Auto'. On the right, a sidebar shows the 'Cisco Catalyst 9800-L Wireless Controller' version 16.12.2s and a 'Edit RF Profile' configuration panel. This panel contains sections for 'High Density Parameters' (Max Clients: 200, Multicast Data Rate: Auto), 'Client Distribution' (Load Balancing Window: 5, Load Balancing Denial Count: 3), and 'ATF Configuration' (Status: DISABLED). The 'Rx Sop Threshold (dbm)' field is set to 'custom' with a value of '-85'.

Common High Density Optimization Mistakes



Common High Density Optimization Mistakes



- ❑ AP-to-AP transmit power imbalance
(causes “Magnet” / overloaded AP's)

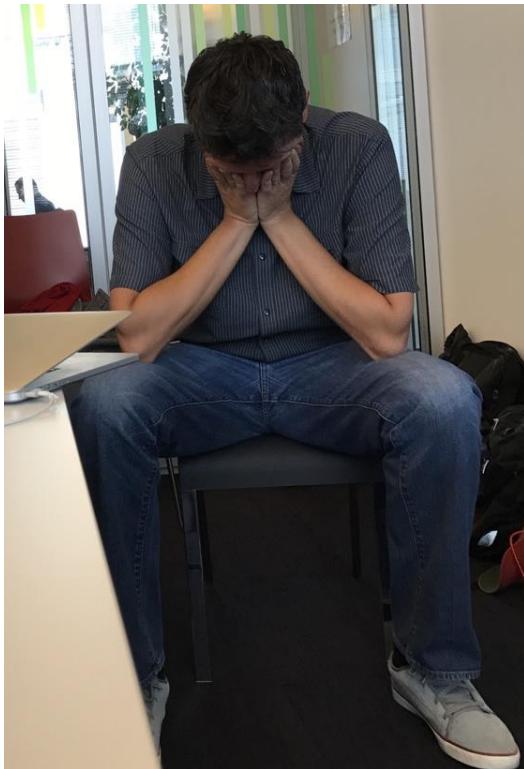


5GHz TX Power: 7dB
2 clients

5GHz TX Power: 17dB
50 clients

Note: This also applies to the dual-5GHz C9104!

Common High Density Optimization Mistakes

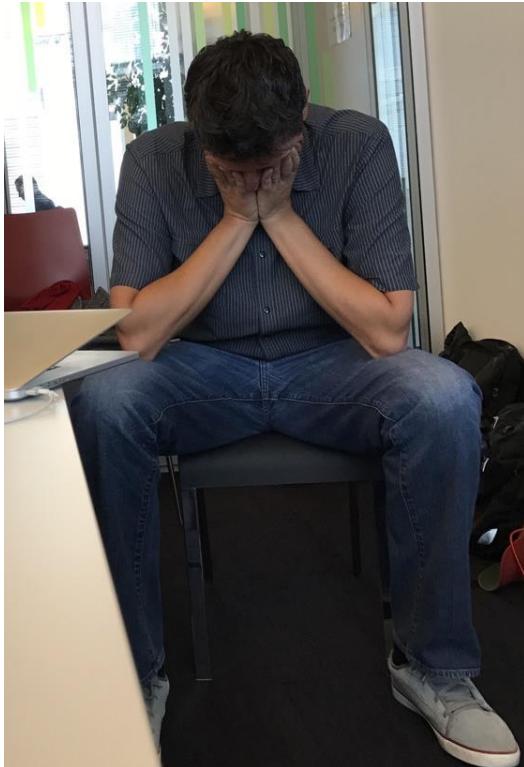


- ❑ AP-to-AP transmit power imbalance (causes “Magnet” / overloaded AP's)
- ❑ 2.4GHz to 5GHz transmit power imbalance (draws dual-band clients to 2.4GHz)

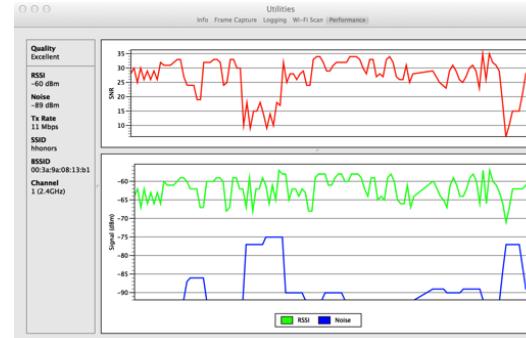


2.4GHz: 13dB	5GHz: 7dB
20 dual-band clients	0 dual-band clients

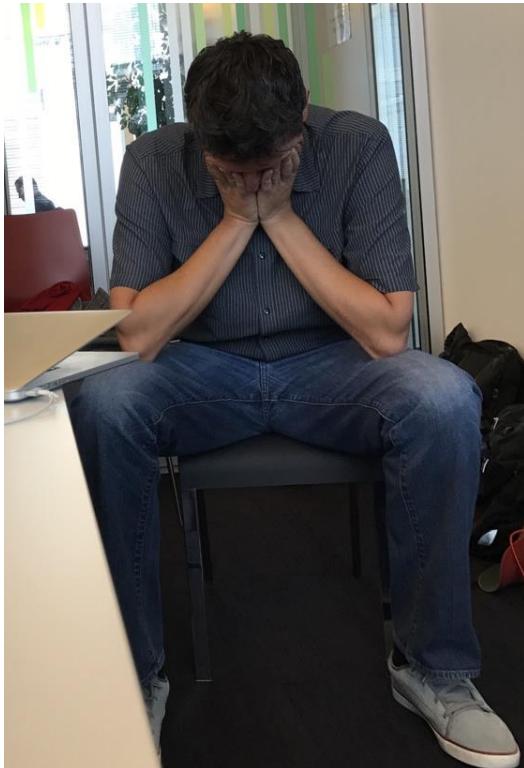
Common High Density Optimization Mistakes



- ❑ AP-to-AP transmit power imbalance (causes “Magnet” / overloaded AP's)
- ❑ 2.4GHz to 5GHz transmit power imbalance (draws dual-band clients to 2.4GHz)
- ❑ Transmit power too low to overcome noise floor

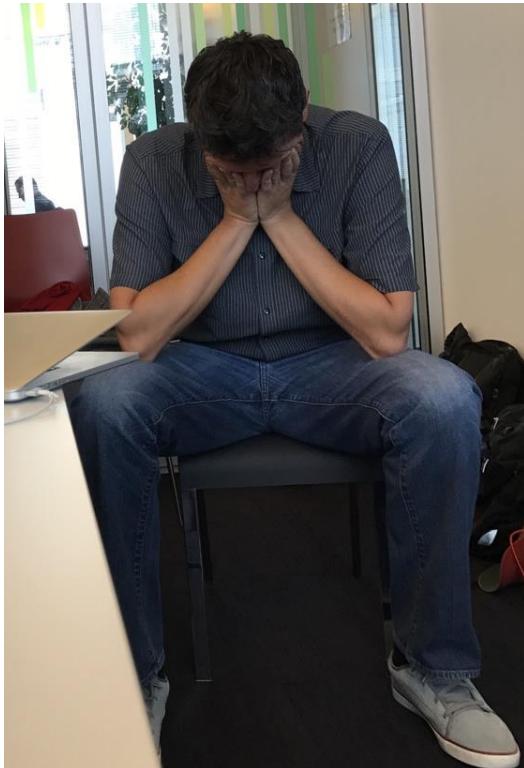


Common High Density Optimization Mistakes



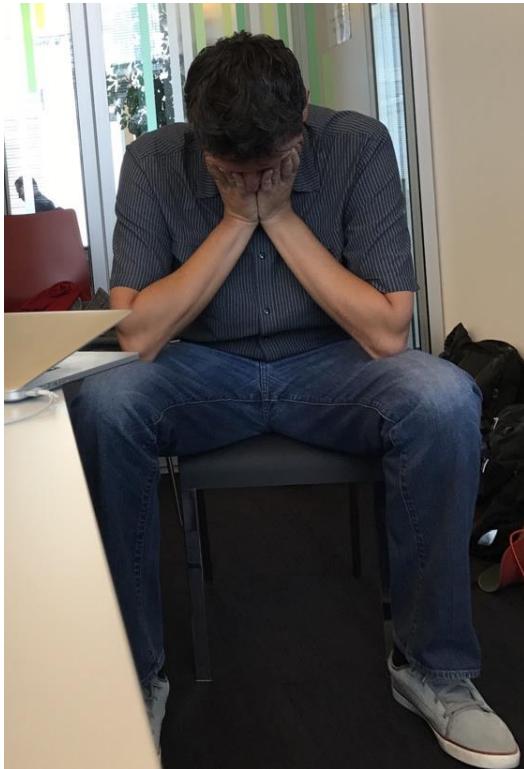
- ❑ AP-to-AP transmit power imbalance
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- ❑ 2.4GHz to 5GHz transmit power imbalance
(draws dual-band clients to 2.4GHz)
- ❑ Transmit power too low to overcome noise floor
- ❑ Channel Utilization high without real traffic

Common High Density Optimization Mistakes



- AP-to-AP transmit power imbalance
(causes “Magnet” / overloaded AP’s)
- 2.4GHz to 5GHz transmit power imbalance
(draws dual-band clients to 2.4GHz)
- Transmit power too low to overcome noise floor
- Channel Utilization high without real traffic
- Minimum mandatory PHY rate improperly tuned
(too high or too low)

Common High Density Optimization Mistakes



- AP-to-AP transmit power imbalance (causes “Magnet” / overloaded AP’s)
- 2.4GHz to 5GHz transmit power imbalance (draws dual-band clients to 2.4GHz)
- Transmit power too low to overcome noise floor
- Channel Utilization high without real traffic
- Minimum mandatory PHY rate improperly tuned (too high or too low)
- Too many SSID’s enabled (not using AP Groups to control where SSID’s are enabled)
- Unusable channels (especially 5GHz)

Common High Density Optimization Mistakes



- ❑ AP-to-AP transmit power imbalance
(causes “Magnet” / overloaded AP’s) **TPC**
- ❑ 2.4GHz to 5GHz transmit power imbalance
(draws dual-band clients to 2.4GHz) **TPC**
- ❑ Transmit power too low to overcome noise floor **TPC**
- ❑ Channel Utilization too high **Env. Cleanup / RXSOP**
- ❑ Minimum mandatory PHY rate improperly tuned
(too high or too low) **PHY Rate tuning**
- ❑ Too many SSID’s enabled (not using AP Groups
to control where SSID’s are enabled) **Policy Tags**
- ❑ Unusable channels (especially 5GHz) **DCA**

Smartphone Roaming Challenges

- As a rule, smartphones pick the loudest AP, then stick to that AP as long as possible
- Many phones won't go looking for a "better" AP unless things are REALLY bad (low RSSI/SNR)
- We attack this problem with workarounds (Optimized Roaming feature) and standards-based features (11k, 11v, adaptive 11r)
- Standards-based methods are best!!



Rogue APs

- DSL/cable modems
 - Are often auto-configured on “least loaded” channel on 2.4ghz
- MiFi's, Eye-Fi's, and hotspot-enabled smartphones
- Low PHY rates, max power
- Often on overlapping channels due to least-congested channel selection
- Causes exponential load on the air due to probe requests/responses and beacons



Looks like it belongs... but it doesn't

Non-WiFi Interferers



- Video cameras, wireless audio (Coachcomm, Zaxcom), lighting, pyro, and cryo systems, etc.
- Ever look at a Fluke meter and see zero AP's where you'd expect to see dozens? Non-WiFi Interferers often drown out 802.11 altogether.
- Mitigation: remove them altogether or change frequency if possible

What can we do?

- Develop and Enforce an RF Policy
- Employ an effective RF policy
- Identify:
 - what's permitted in your environment
 - what is not permitted in your environment
 - whom to contact for further information



The image shows a white paper from Cisco titled "RF Spectrum Policy: Future-Proof Wireless Investment Through Better Compliance". The paper discusses the importance of managing RF spectrum to ensure optimal wireless reliability and performance. It covers the definition of a spectrum policy, the need to extend existing IT policies to address spectrum management, and the mitigation of security vulnerabilities in the RF spectrum. The Cisco logo is visible at the top left, and a "White Paper" label is at the top right.

RF Spectrum Policy: Future-Proof Wireless Investment Through Better Compliance

Radio frequency (RF) spectrum is an overlooked but critical resource. It is through the spectrum between 800 MHz and 5.9 GHz that an organization will:

- Connect laptops and PDAs to the network
- Talk on cellular phones, cordless phones, and headsets
- Secure buildings with security cameras

Unless properly managed, many of these technologies will crowd the spectrum and negatively impact WLAN services. Because the spectrum is a shared resource, the need to monitor, manage, and secure it is imperative to optimal wireless reliability and performance. This paper focuses on the process of defining a spectrum management policy.

Defining a Spectrum Policy

Usage of the spectrum is not covered in most existing IT policies. Even if there is a wireless policy in place, extending the existing policy so that it addresses issues of spectrum management is the recommended initial course of action.

In addition to addressing interference problems generically, organizations will also need to define a spectrum policy for mitigating security vulnerabilities specific to the RF spectrum. Mitigating such threats is beyond the scope of basic wireless computing policies or policies describing the acceptable use of IT equipment.

Using the definition stage to take stock of the wireless and IT asset policies an organization has in place is the preliminary step. Once this is established, the next process is to adopt the guidelines described in this paper to meet the business's needs.

Agenda

CISCO Live!

- Designing RF for High Client Densities
- HD Wi-Fi Configuration Tips
- HD Wi-Fi Engineering Toolkit

Our Favorite Tools

Cisco [Wireless Troubleshooting & Analysis Tools](#) (Free)



Wi-Fi Hawk



WCAE



WLAN Poller

[Intuitibits](#) Tools (Mac)



WiFi Explorer



AirTool



WiFi Signal

Intuitibits Tools (Windows)



[WiFi Explorer Lite](#)

Packet Capture & Analysis Tools



[Metageek Chanalyzer](#)



[Wireshark](#)



Meraki

(Article)

[Analyzing Wireless Packet Captures](#)

Site Survey Tools



[Hamina](#)



[Ekahau Pro](#)

NetOps, AIOps, DevOps Tools



[Cisco DNA Center Assurance](#)

Wireless Troubleshooting Tools

Overview

Wireless Troubleshooting Tools

WLCCA

- Wireless Config Analyzer
- Config Checks and Messages
- Features
- RF Analysis
- RF Health
- Support

WCAE

- Wireless Config Analyzer Express
- How to use - Cloud
- How to use - mini-Desktop
- Changelog
- Support

WLAN Poller

Wireless Troubleshooting Tools

In order to help people in the field, doing Wireless networks troubleshooting and RF analysis, the WNG Escalation, TAC and Development teams have made available several tools to facilitate some of the most common tasks.

- [Wireless Config Analyzer Express - WCAE](#)
 - Cloud Version
 - Mini Desktop Version For access, please request to wcae@cisco.com
- [Wireless Lan Config Analyzer - WLCCA - Download V4.4.14](#)
 - For access, please request to [wlc-conf-app-dev](#)
- [WLAN Poller - Download Windows or Mac OS](#)
 - Bulk data collection script system, focused on capturing debugging data, flash che

Chat with Us!

Download: <https://developer.cisco.com/docs/wireless-troubleshooting-tools/>

Wireless Troubleshooting Tools

- Wireless Config Analyzer Express (WCAE) is an extremely valuable tool when validating and optimizing a Cisco Wi-Fi deployment
- WCAE helps us determine:
 - Configuration consistency across multiple WLC's
 - RF Problem Finder – determine likely “problem” RF areas
 - AP Neighbors – how do AP's hear each other? Too well, not well enough?
 - Additional views of CleanAir data
 - RRM overview with the RF Summary

Table of contents

Generated:2023-01-30 11:06
WCAE Version:0.12

Total Message Counts

Errors:	9
Warnings:	30
Informational:	21
Program Execution	
Parsing Errors:	0
Processing Errors:	17

Configuration Checks:

[Controller Checks Results](#)
[APs Checks Results](#)

Controller: ----

Client Audit

[Data Summary](#)
[Log Summary](#)
[Upgrade Advisor](#)
[Best Practices](#)
[WLAN Summary](#)
[Interface Summary](#)
[RF Profiles 2.4 GHz](#)
[RF Profiles 5 GHz](#)
[RF Profiles 6 GHz](#)
[Site Tags](#)
[Hardware State](#)
[Resources](#)
[Client Types](#)
[AAA Server Details](#)
[WNCD Load Distribution](#)
[Tag/Policy Usage](#)
[RF Stats 2.4GHz](#)
[RF Stats 5GHz](#)
[RF Stats 6GHz](#)
[RF Health 2.4GHz](#)
[RF Health 5GHz](#)
[RF Health 6GHz](#)
[Channel Stats 2.4GHz](#)
[Channel Stats 5GHz](#)
[Channel Stats 6GHz](#)

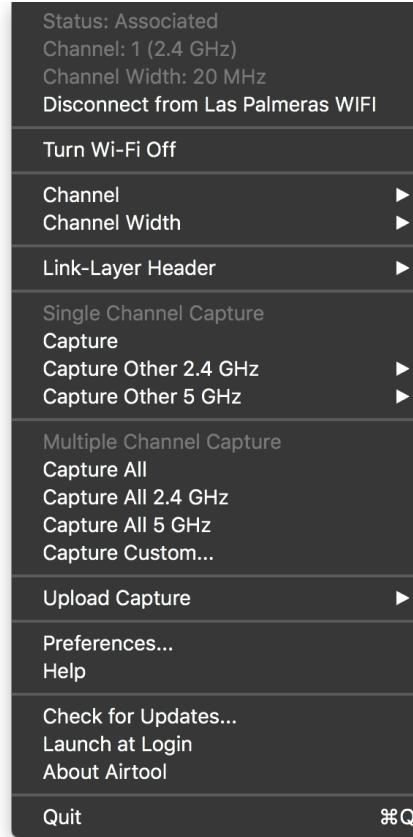
AP Information

[APs Configuration](#)
[APs Slot Configuration](#)
[APs Interface Status](#)
[APs RF Summary 2.4GHz](#)
[APs RF Summary 5GHz](#)
[APs RF Summary 6GHz](#)
[APs RF Health Details](#)
[APs NDI Summarization 2.4GHz](#)
[APs NDI Summarization 5GHz](#)
[APs RF Neighbors 2.4GHz](#)
[APs RF Neighbors 5GHz](#)
[6GHz Predictive Planning](#)
[AP Channel Config Export](#)

Download: <https://developer.cisco.com/docs/wireless-troubleshooting-tools/>

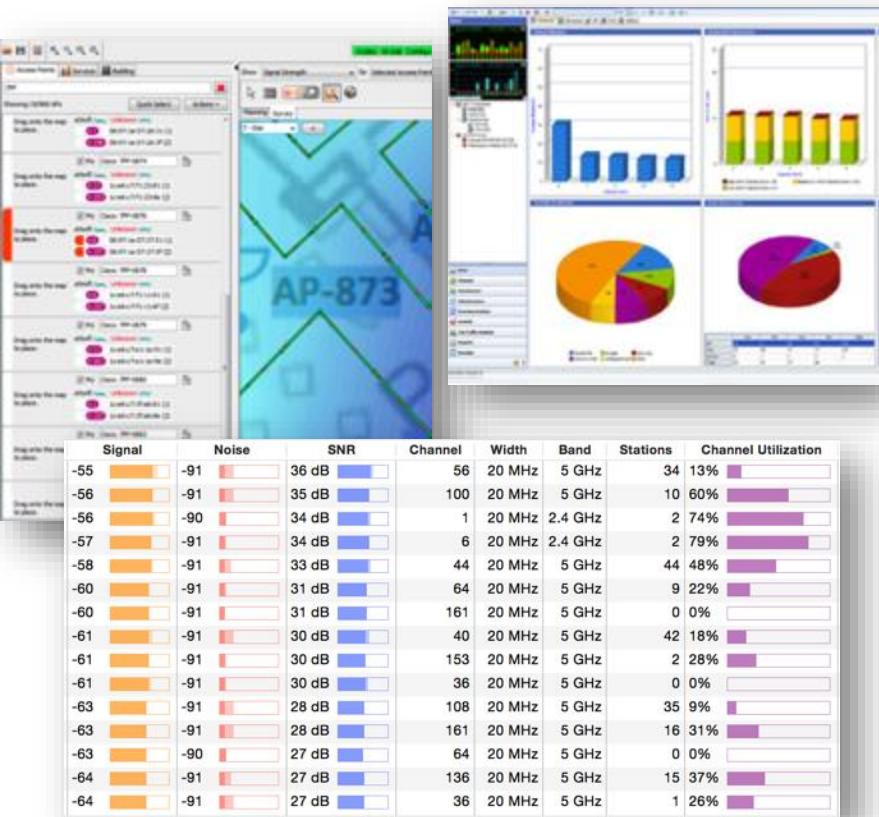
Packet Captures

- OmniPeek/Wireshark
 - For packet captures of the WLAN, including beacons and other management traffic
 - Helpful for troubleshooting of problems at the source
- AirTool
 - Free app for Mac – simplifies packet capture process
 - <https://www.adriangranados.com/aps/airtool>



Site Surveys

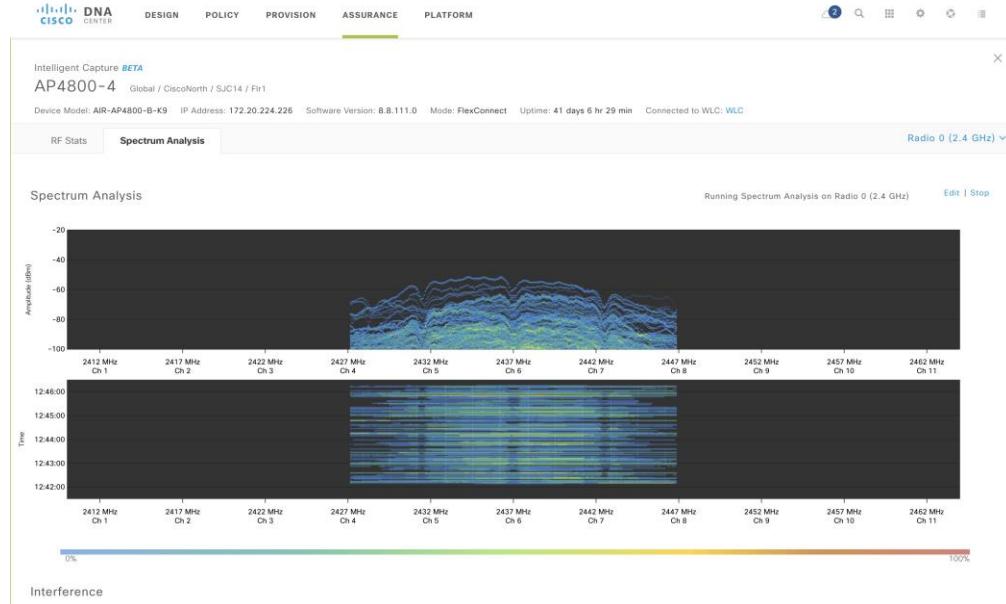
- Ekahau Site Survey Pro
 - Design & Verify
 - Determine differences in coverage that occur as a result of tuning changes



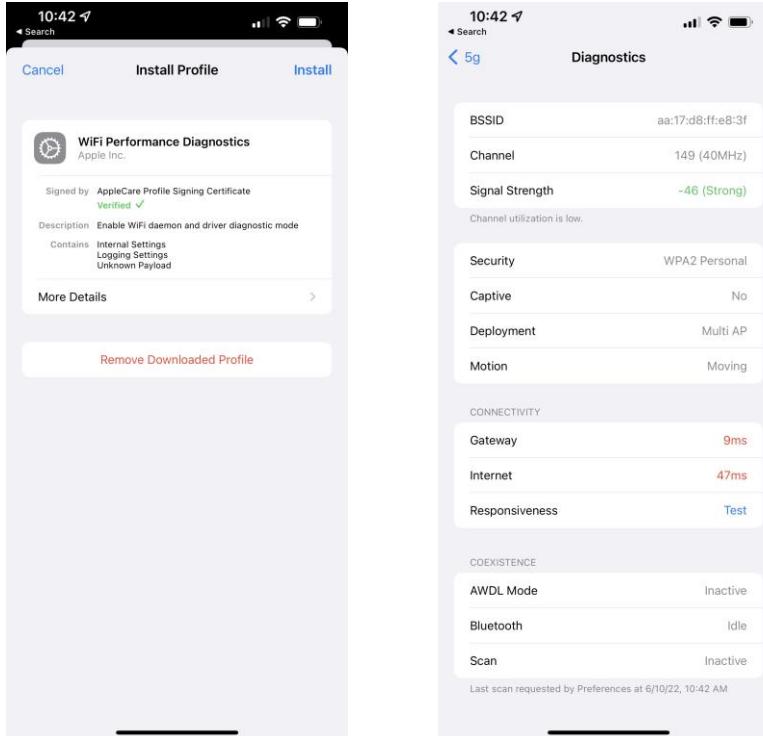
Spectrum Analysis

Cisco DNA Center Intelligent Capture

- Layer 1
- Provides a view of real energy on a channel
- Identify interferers of all types
- Critical part of the “big picture”



iOS Wi-Fi Diagnostics with iOS



Diagnostics Profile for installation on iOS devices extends on-device WiFi diagnostics capabilities

More Info:

<https://tidbits.com/2022/04/22/use-apples-networkquality-tool-to-test-internet-responsiveness/>

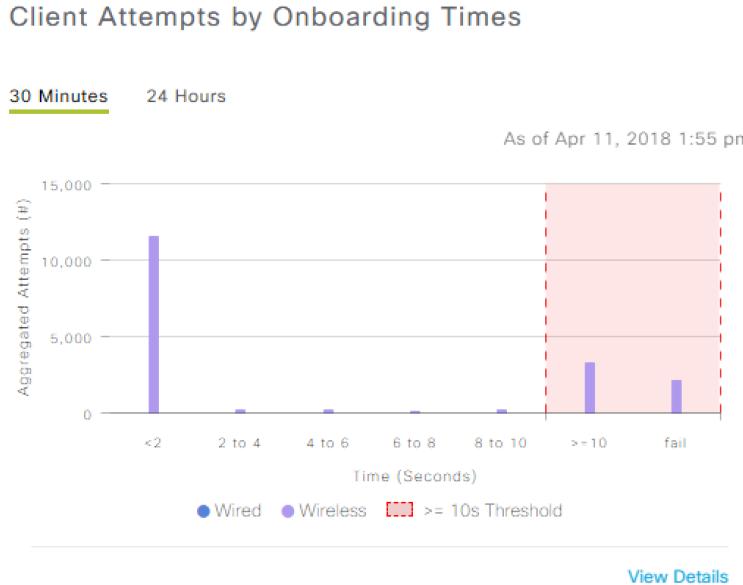
Profile Download:

https://developer.apple.com/services-account/download?path=/iOS/iOS_Logs/MegaWiFiProfile.mobileconfig

Note: Profile auto-expires after 7 days and must be re-installed when needed

Cisco DNA Center Assurance

Broad applicability to High Density deployments



- iOS Analytics
- Detailed client onboarding analysis
- Aironet Active Sensor support
- Intelligent Capture
- Network Time Travel

...and much more!

<https://clnv.s3.amazonaws.com/2018/usa/pdf/BRKEWN-2034.pdf>

Key Takeaways

- Design the RF environment with appropriate antennas and sensible physical placements
- Employ HD-focused WLC feature configurations such as RF Profiles for more flexible and robust designs
- Understand the key outside factors that may impact a live HD WLAN, including enemies of performance
- Get comfortable with Wi-Fi analysis and optimization tools to make informed, data-driven decisions



The bridge to possible

Thank you



cisco *Live!*

Let's go