

The background features a vibrant, abstract design. On the left, there are horizontal, wavy bands of color in shades of red, orange, yellow, and green. On the right, a bright white light source emits a series of colorful rays in shades of blue, cyan, and yellow, creating a sunburst effect. The overall composition is dynamic and energetic.

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

- 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

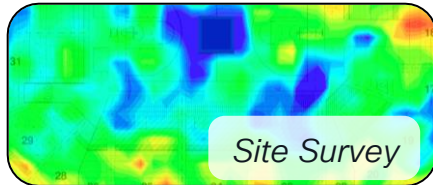


Designing for the 3 Key RF Relationships

Name	Slot	Channel	Power Level	Power dBm	Neigh. Name	Neigh. Slot	Neigh. Channel	Neigh. Power	Compensated Power
AP12	1	112	6	4	AP1	1	52	-42	-57
AP12	1	112	6	4	AP2	1	144	-51	-66
AP12	1	112	6	4	AP3	1	120	-53	-65
AP12	1	112	6	4	AP4	1	100	-53	-65
AP12	1	112	6	4	AP5	1	124	-57	-66
AP12	1	112	6	4	AP6	1	60	-61	-73
AP12	1	112	6	4	AP7	1	136	-62	-74
AP12	1	112	6	4	AP8	1	44	-69	-69
AP12	1	112	6	4	AP9	1	104	-79	-85
AP12	1	112	6	4	AP10	1	60	-80	-89
AP12	1	112	6	4	AP11	1	153	-81	-84

WCAE

1 AP to Client



3 AP to AP

2 Client to AP

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
Fabric Status	Disabled

WLC UI / CLI



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

How Clients Hear AP's – C9800 UI

The screenshot displays the Cisco Catalyst 9800-40 Wireless Controller interface. The left sidebar contains navigation options: Dashboard, Monitoring, Configuration, Administration, Licensing, and Troubleshooting. The main content area is titled 'Monitoring > Wireless > Clients'. A 'Client' window is open, showing details for a client with ID 360. The 'General' tab is selected, displaying fields for User Name, MAC Address, Uptime, WLAN Name, AP Name, Device Type (iPhone 12), Device OS (iOS 15.4.1), Client Performance, Capabilities, and Fabric Status. A 'Top Applications' pie chart shows iTunes at 62.0% and Google Services at 33.0%. Below the client details, the 'Client Scan Reports' section is highlighted with a red box. It shows the last report from 04/21/2022 08:42:53 and a table of scan results.

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
6c41.0e45.988c	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 displays the Cisco Catalyst 9800-40 Wireless Controller interface. The left sidebar contains navigation options: Dashboard, Monitoring (selected), Configuration, Administration, Licensing, and Troubleshooting. The main content area is titled 'Monitoring > Wireless > Clients'. A 'Clients' tab is active, showing a list of clients with columns for Client MAC Address, IPv4 Address, and IPv6 Address. A red box highlights the 'Client Performance' section for a selected client, showing Signal Strength: -66 dBm, Signal Quality: 30 dB, and Ch BW(Negotiated/Capable): 20 MHz/80 MHz. To the right, a 'Top Applications' pie chart shows iTunes at 62.0% and Google Services at 33.0%. Below the chart, a 'Client Scan Reports' table lists scan results for various BSSIDs, including Time, Channel, RSSI (dBm), and SNR (dB).

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
6c41.0e45.988c	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 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	WGB
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
```

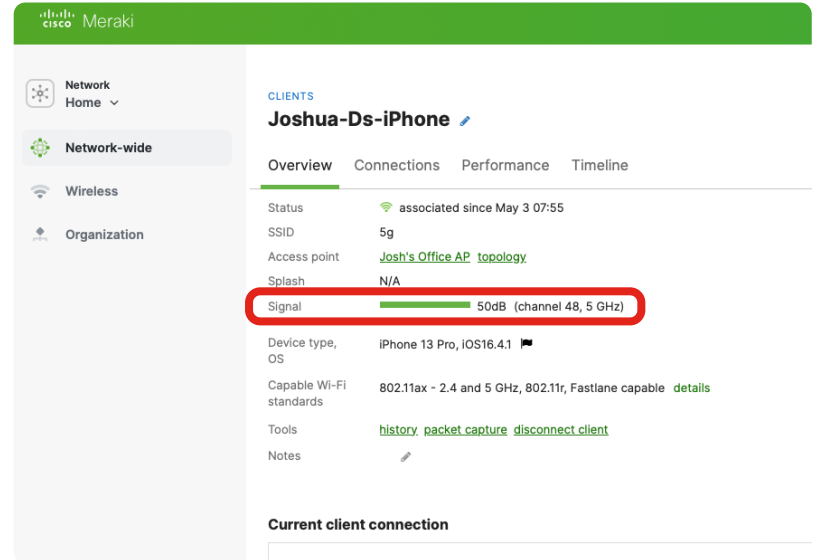
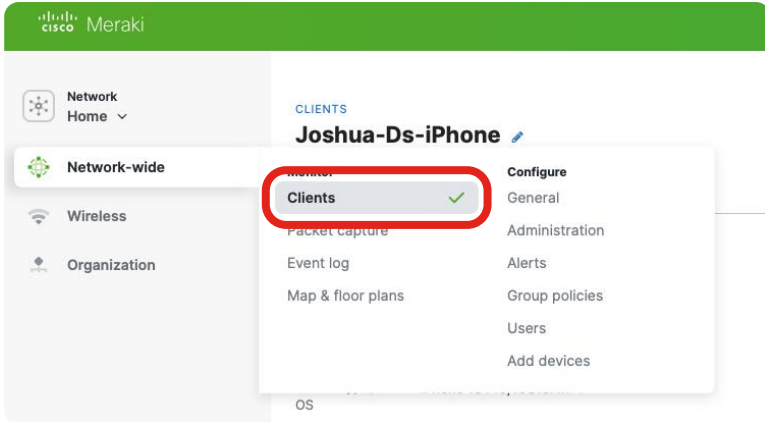
```
mac          <clip> stats_ago expiration
```

```
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



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

9166D1 Wi-Fi 6 Access Point



Cisco® Catalyst® 9166D1-x

Directional, Tri-Radio with 12 Spatial Streams!



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



or

MR86



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





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

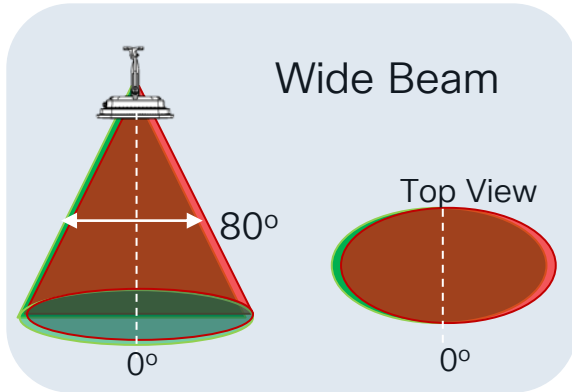
Deployment Flexibility

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

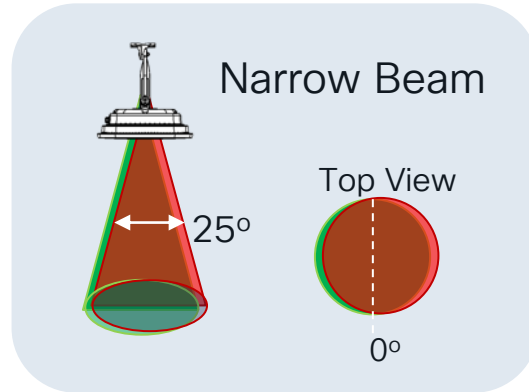
Important Notes

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

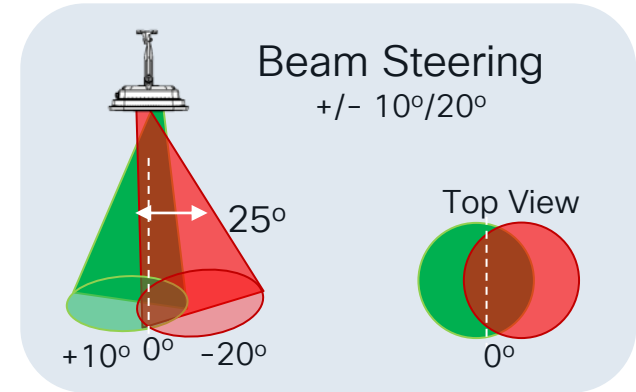
C-ANT9104: Software-Configurable Beams



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

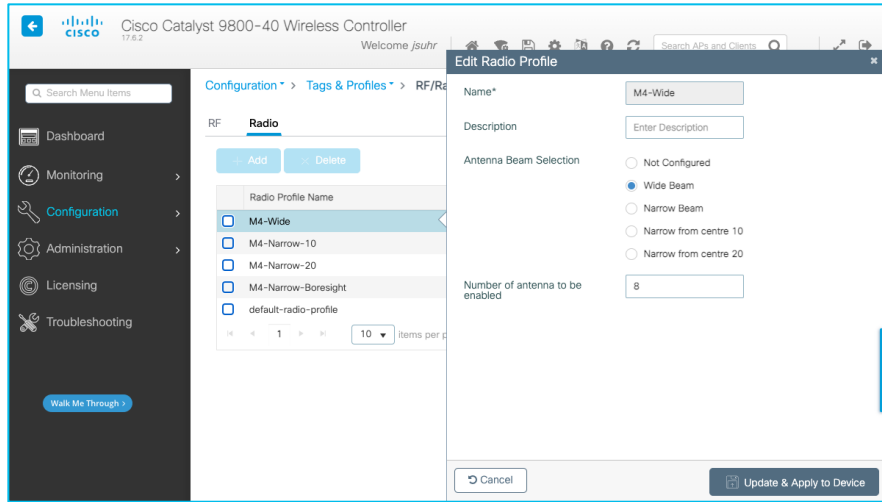
UNII-3 / 5 channels: 23dBm

[Slot 2]

UNII-1 / 4 channels: 21dBm

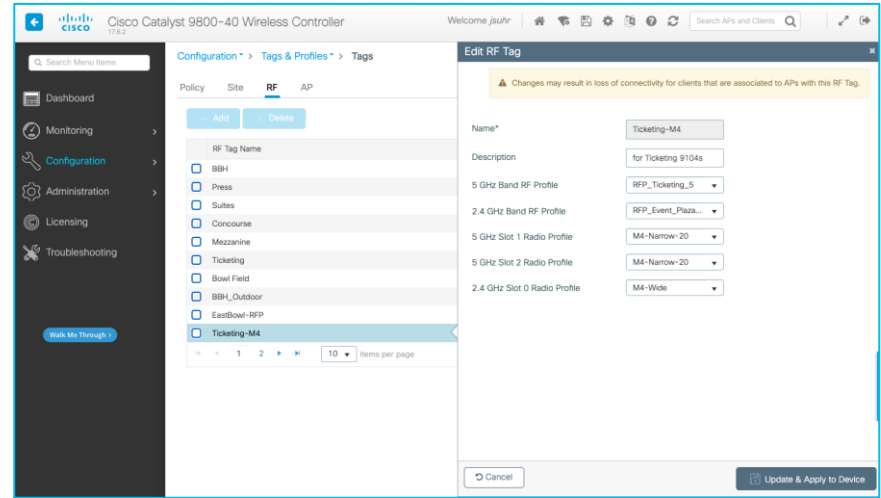
UNII-2 / 4 channels : 17dBm

C-ANT9104: Configuration (GUI)



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

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



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
```

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
```

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
```

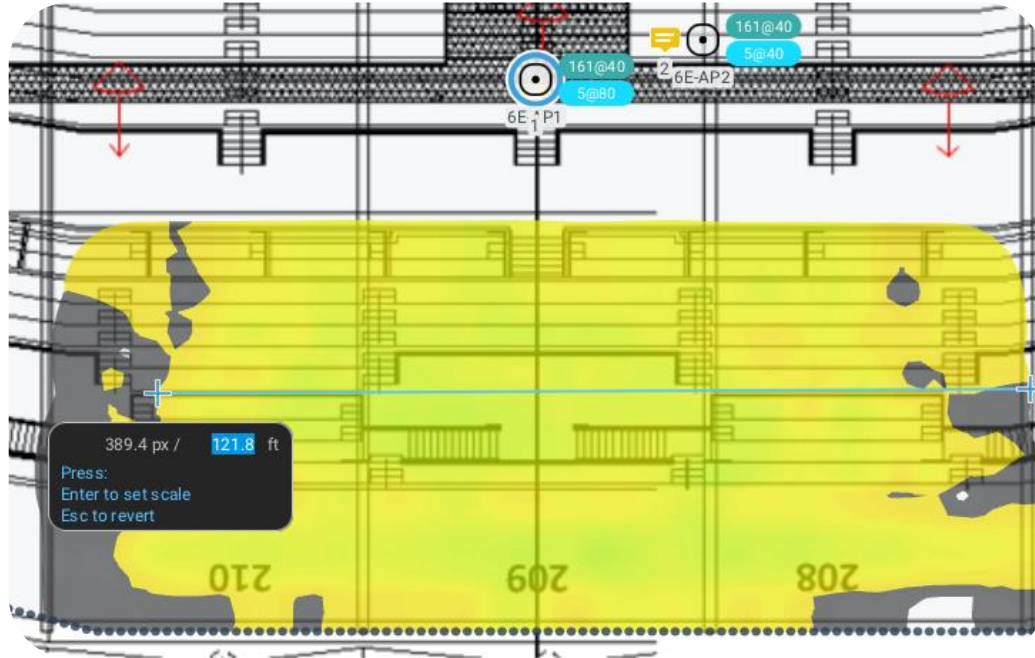
4 Apply tags to AP(s):

```
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

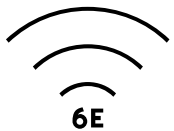
```
ap f4bd.9ed1.4700
policy-tag policy-tag-1
rf-tag MP1-rf-tag
site-tag site-tag-1
```

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



1542



1562



9124



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



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



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 Series* (Wi-Fi 6)

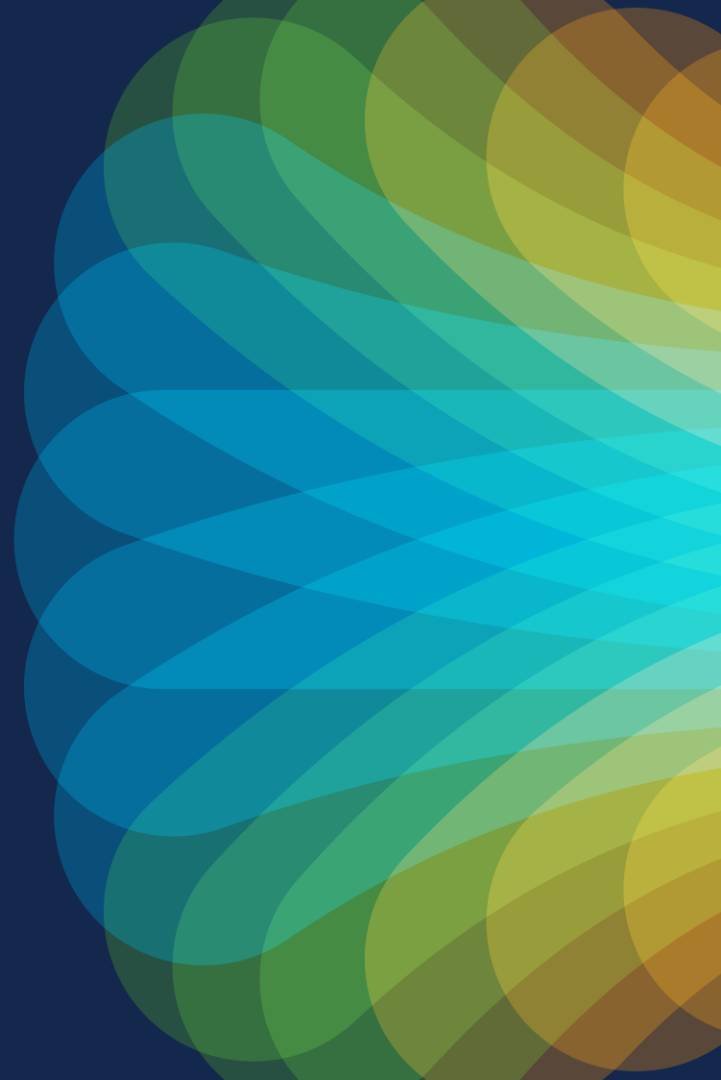
- 802.11AX, MU-MIMO, OFDMA
- 4x4 + 4x4:4
- Cisco RF ASIC for next-gen Cisco CleanAir
- IoT ready
- 1x 2.5G mGig
- SFP
- PoE-In 802.3af/at/bt
- DC power input (24 to 56 VDC)
- 1 Gbe PoE-Out
- 30 dBm Transmit Power (Same as 1572 and higher than 1562)
- Centralized, FlexConnect, Flex+Bridge**, Mesh**, and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

* C9124AXE-x unavailable until Summer calendar year 2021.

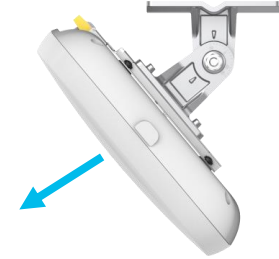
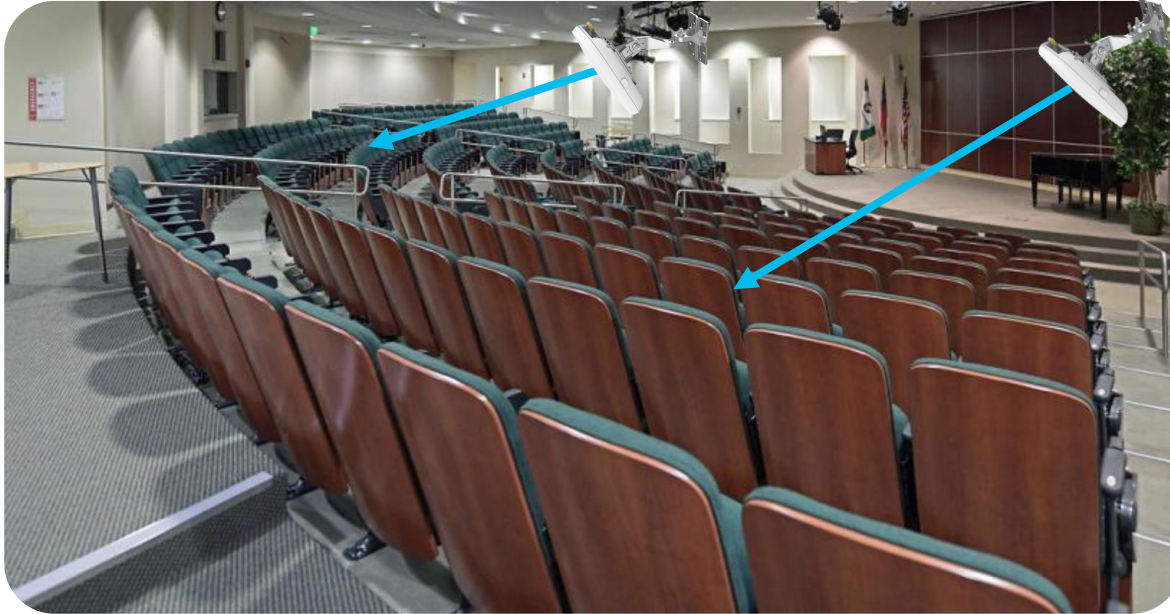
Catalyst 9124AXI-x and 9124AXD-x initially available in US and Canada only. Worldwide availability set for Summer calendar year 2021.

** 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

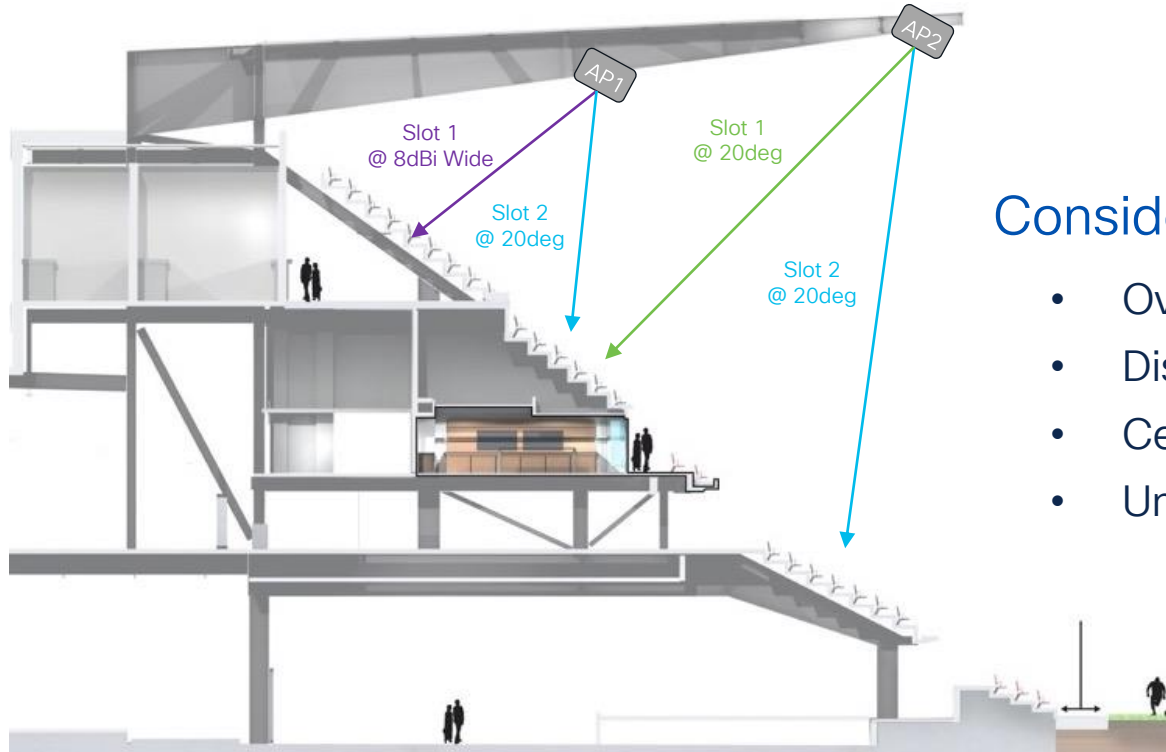
Conference Halls, Airports

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



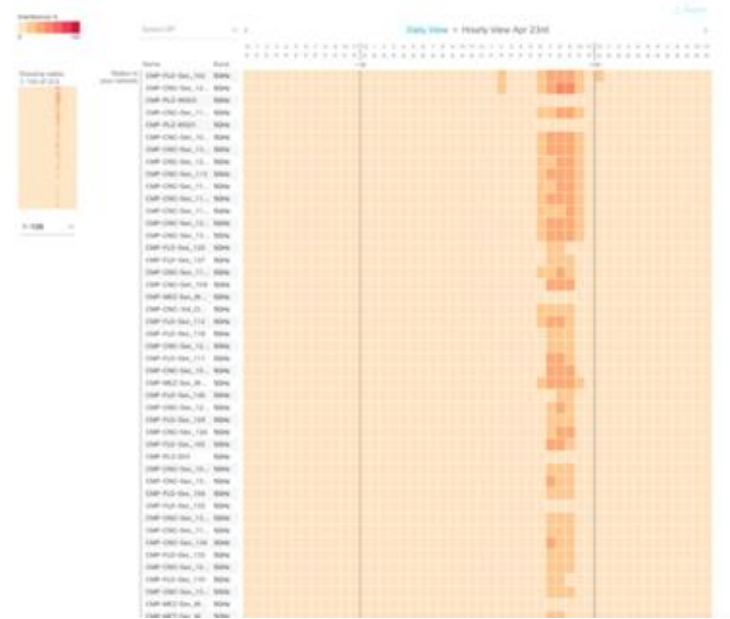
Consider:

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

Performance Comparison

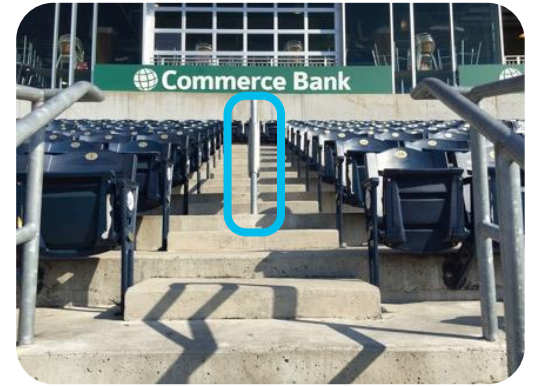
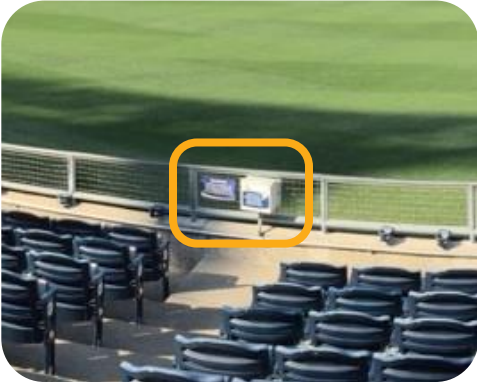


Under seat/Omni

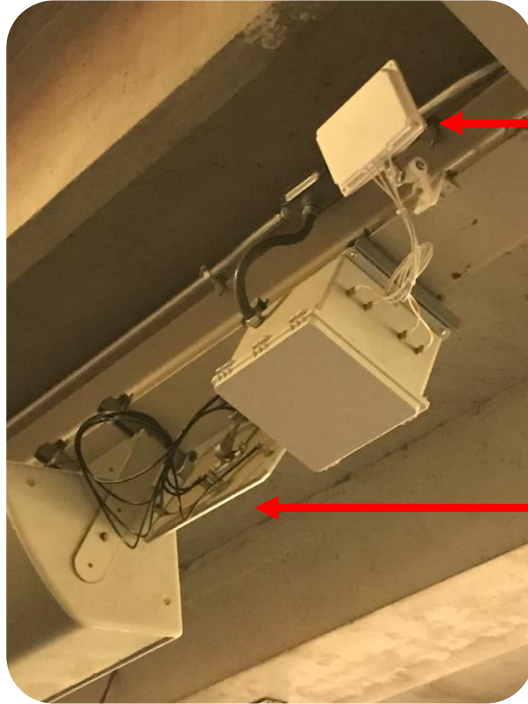


Overhead/Directional

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

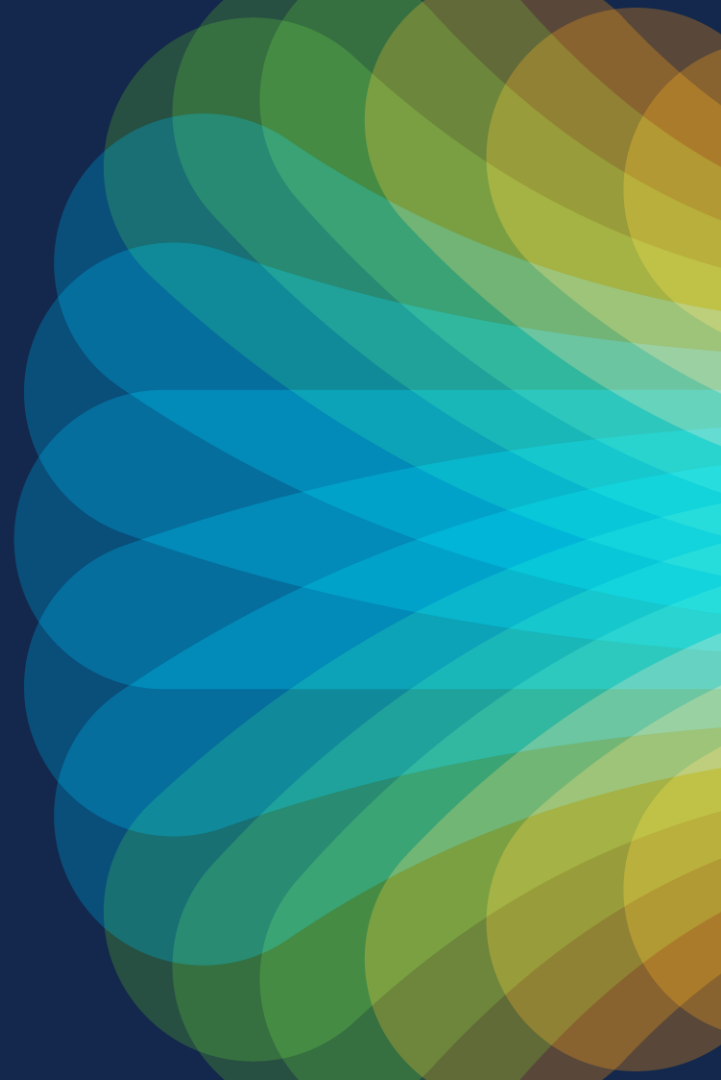


Avoid long-distance shots with poor angle of incidence / line of sight to each client



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

2.4 GHz

3

20 MHz



60 MHz of spectrum and
3x 20-MHz channels

1

40 MHz



60 MHz of spectrum and
3x 20-MHz channels

5 GHz

25

20 MHz



12

40 MHz



6

80 MHz



2

160 MHz



500 MHz of spectrum and
25x 20-MHz channels

6 GHz

59

20 MHz



29

40 MHz



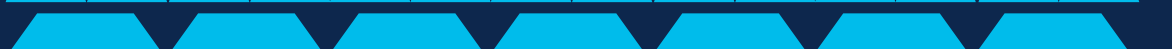
14

80 MHz



7

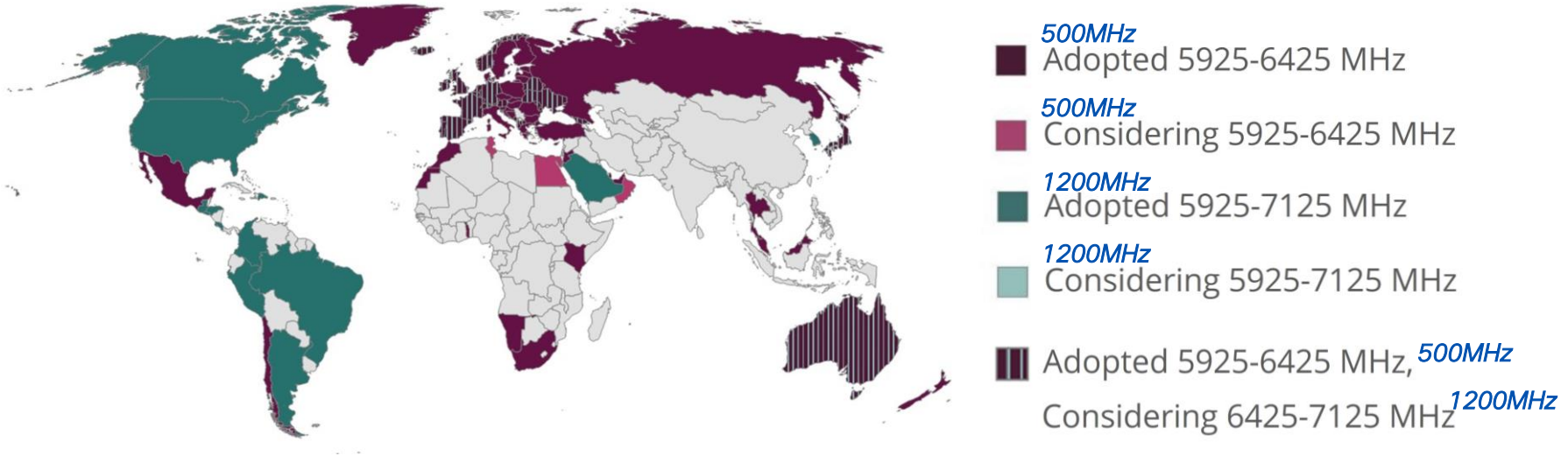
160 MHz



1200 MHz of
spectrum and
59x 20-MHz
channels in US

500 MHz of
spectrum in EU

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 Gurmurthy, Technical Marketing Engineering Technical Leader, Cisco Systems, Inc.

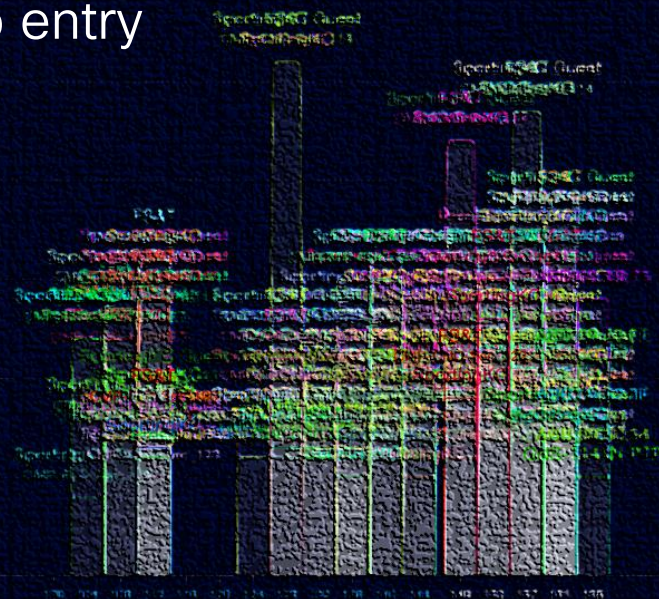
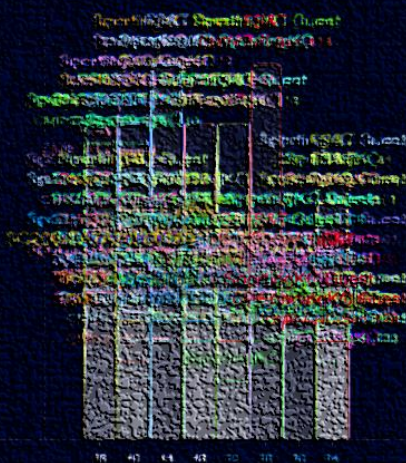
This session deep dives into the newly introduced Wi-Fi 6E standard in 6GHz band. It begins with an overview of the 6GHz band and the worldwide regulations and then dives into the specifics of Wi-Fi 6E protocol including device classes and AP discovery. The session covers aspects of the protocol optimization 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

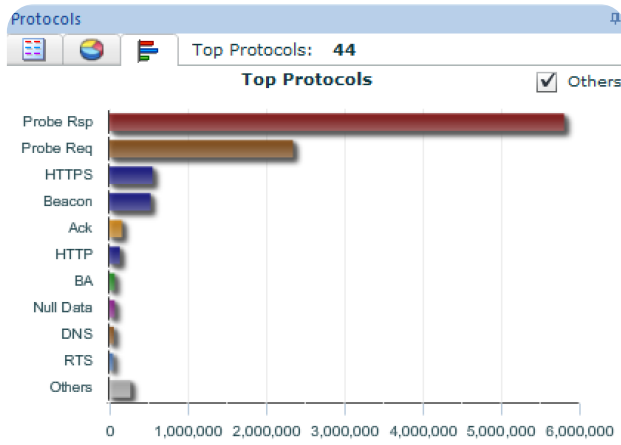
Maximize your Spectrum

- 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

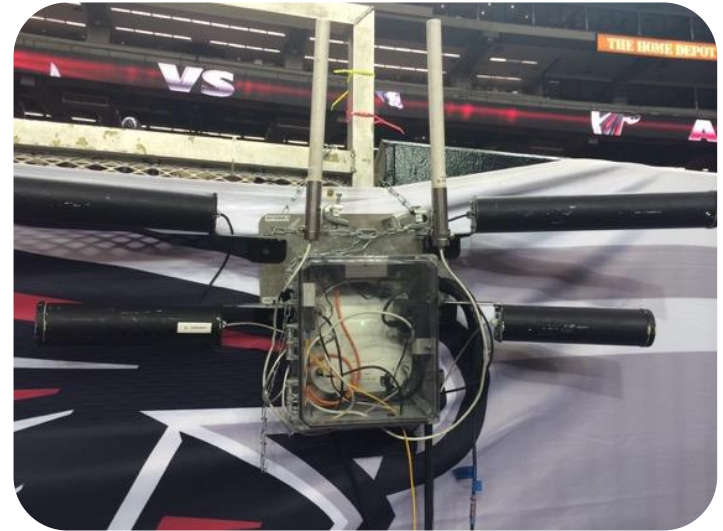
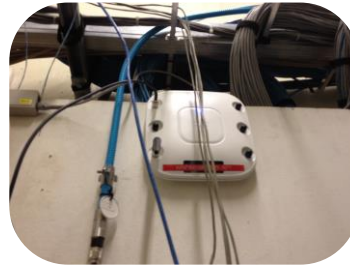


- Always aim for 1 SSID
 - Especially in high density areas
- **More SSID's = Worse Performance**
- Why?
 - Each SSID requires a separate beacon
 - Each SSID will beacon at the minimum mandatory data rate
 - Radios will respond to null probe requests for each broadcast SSID
 - **Exponential** amounts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

Maximizing the Spectrum

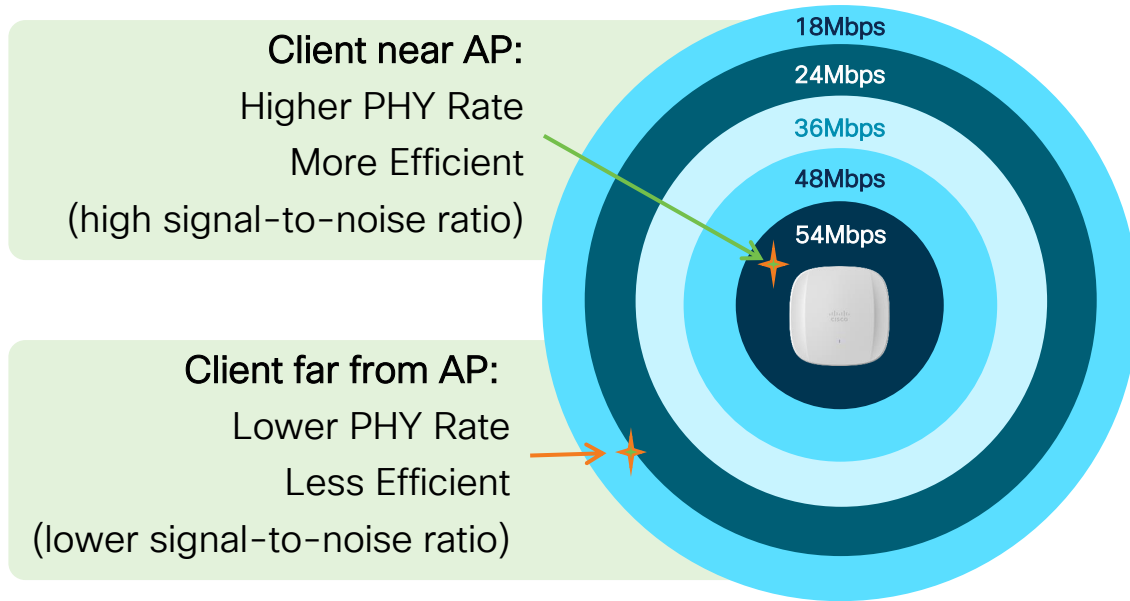
Integrate Existing WLANs

- 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

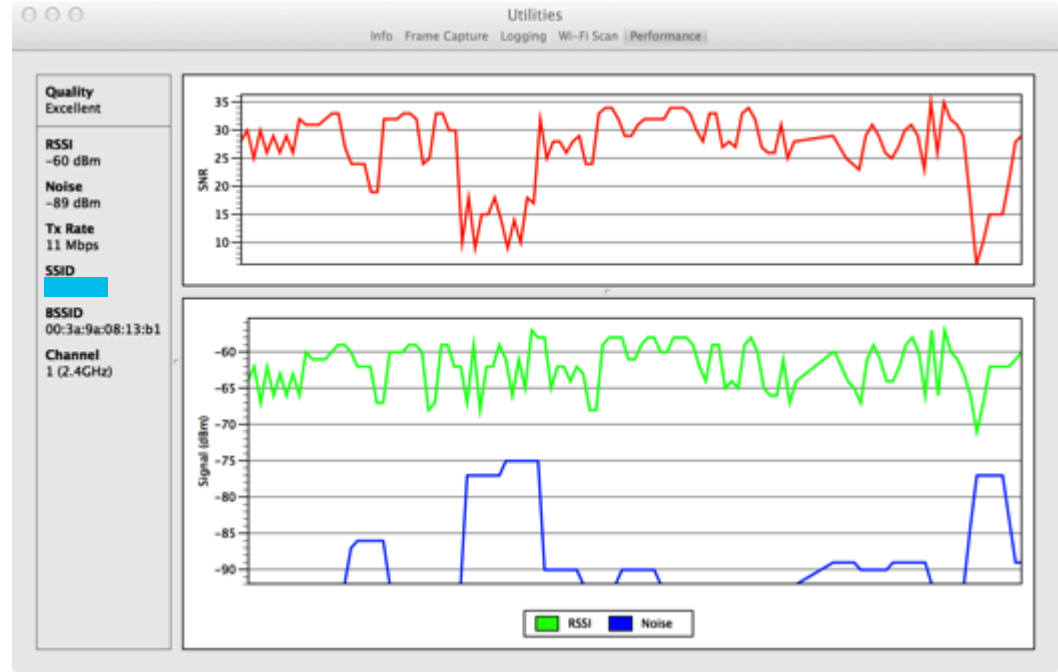


- Tune your **Minimum Mandatory** and **Supported** data rates to optimize airtime
- Higher rates require higher SNR – don't be too aggressive
- Leave 1 or 2 rates below your Minimum Mandatory rate as “supported” to provide a “soft landing” and allow some SNR flexibility
- Generally, no need to adjust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

Maximizing the Spectrum

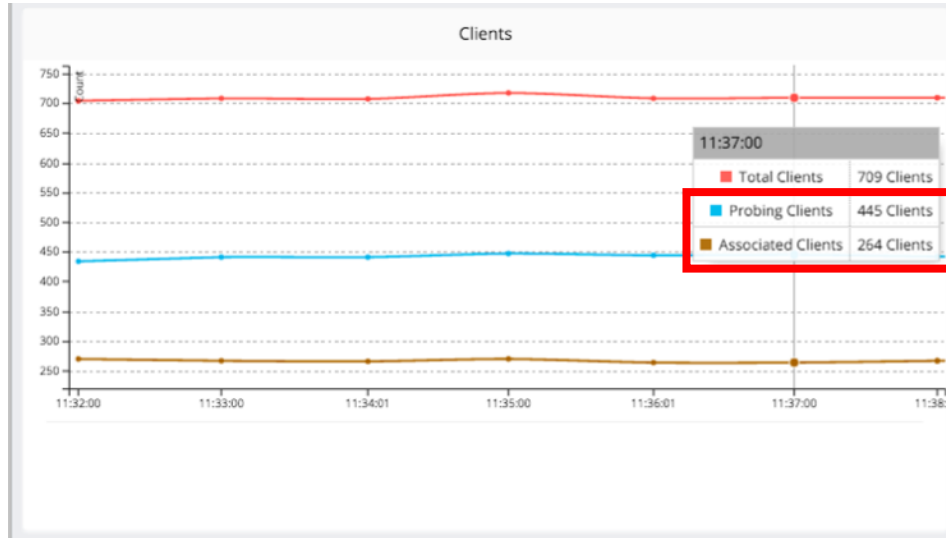
RSSI vs. SNR

- 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

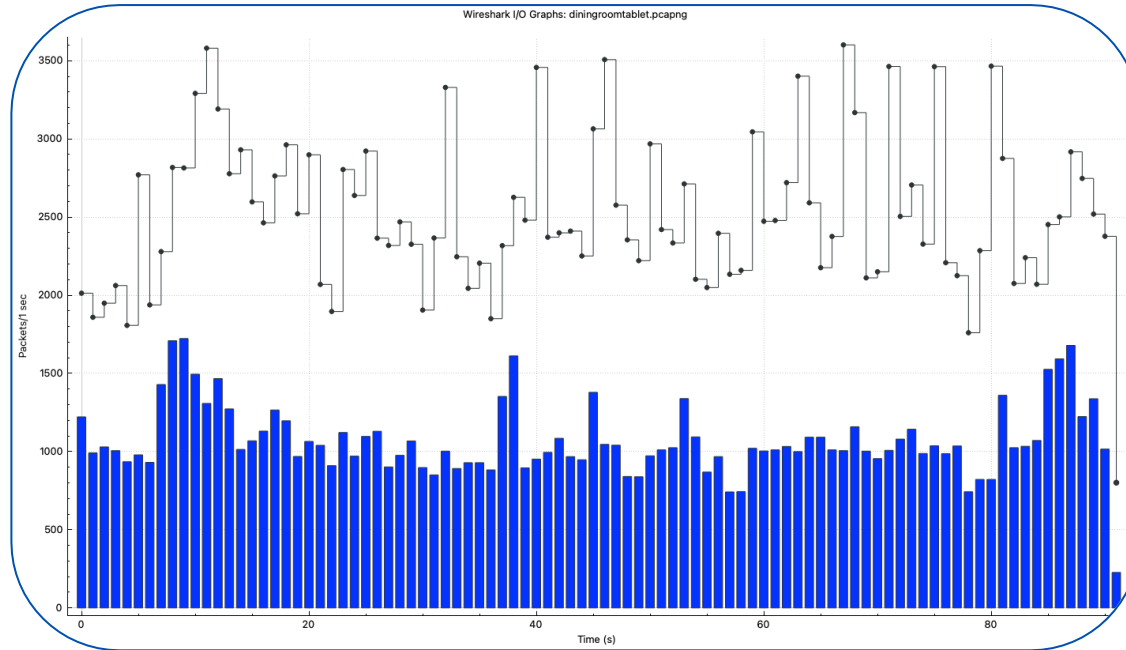
Ease-of-Use & Client Induced Interference



- 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


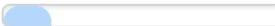

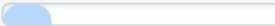


Eliminating unnecessary traffic over the air



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

Maximizing the Spectrum

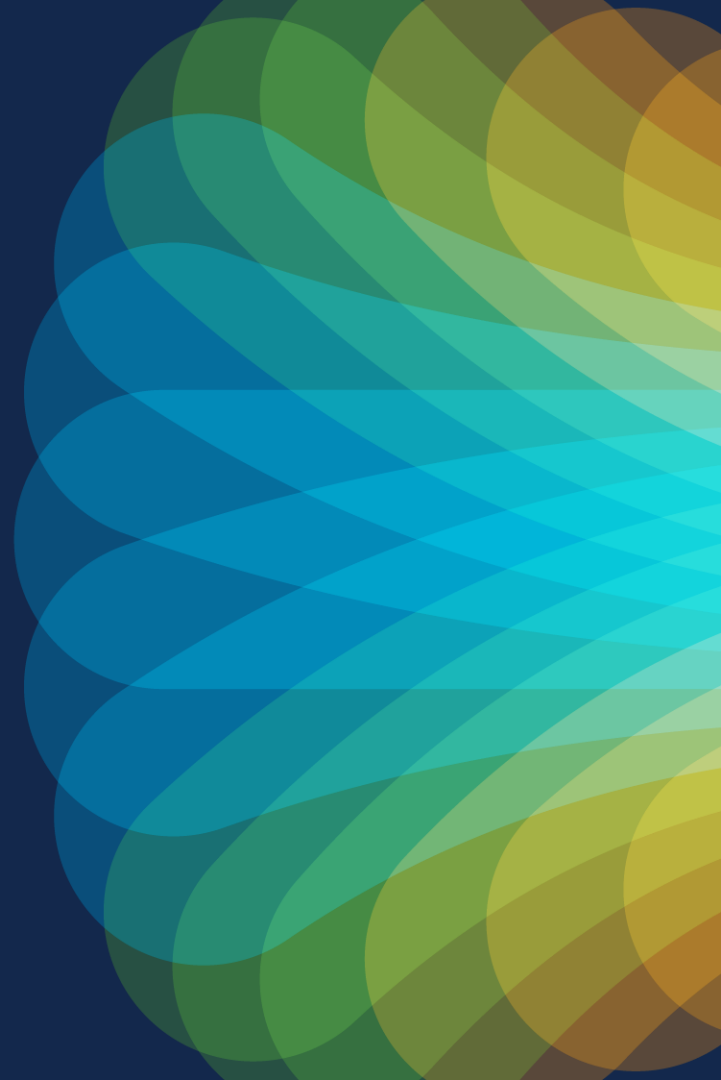
Eliminating unnecessary traffic over the air

	<i>Before Optimization</i>	<i>After Optimization</i>
	Slot 1 (5 GHz)	Slot 1 (5 GHz)
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

- 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

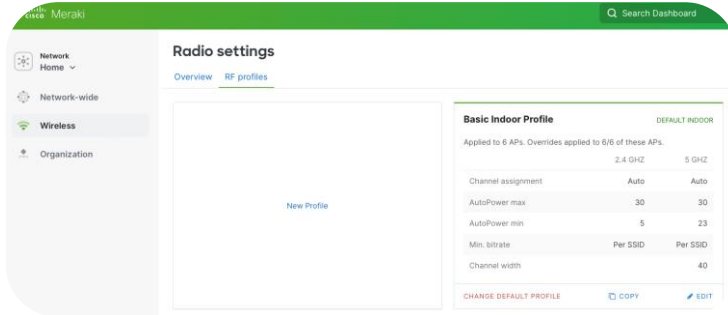
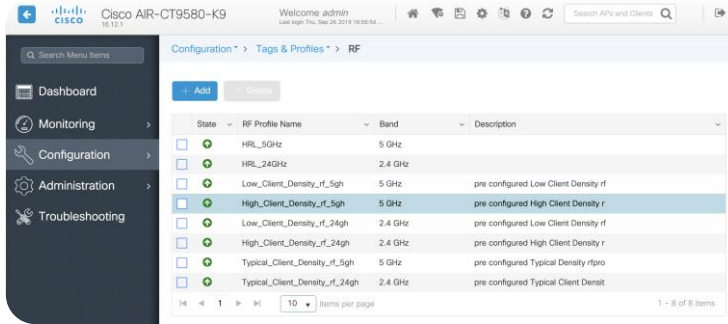
- **Wireless Config Analyzer Express (WCAE)** is an extremely valuable tool when validating and optimizing a Cisco Wi-Fi deployment
- Feed your WLC config output to WCAE and it will help you:
 - Find and troubleshoot problems quickly
 - Identify top areas for RF optimization
 - Check configs against 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	Client Audit	AP Information
Log Summary	Apple iOS	APs Configuration
Upgrade Advisor	Cisco 8821	AP Slot Configuration
Best Practices	Draeger	APs Interface Status
WLAN Summary	Spectralink	APs RF Summary 2.4GHz
Interface Summary	Vocera	APs RF Summary 5GHz
RF Profiles 2.4 GHz		APs RF Summary 6GHz
RF Profiles 5 GHz		APs RF Health Details
RF Profiles 6 GHz		APs NDP Summarization 2.4GHz
Site Tags		APs NDP Summarization 5GHz
Hardware State		APs RF Neighbors 2.4GHz
Resources		APs RF Neighbors 5GHz
Client Types		6GHz Predictive Planning
AAA Server Details		AP Channel Config Export
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		

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

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

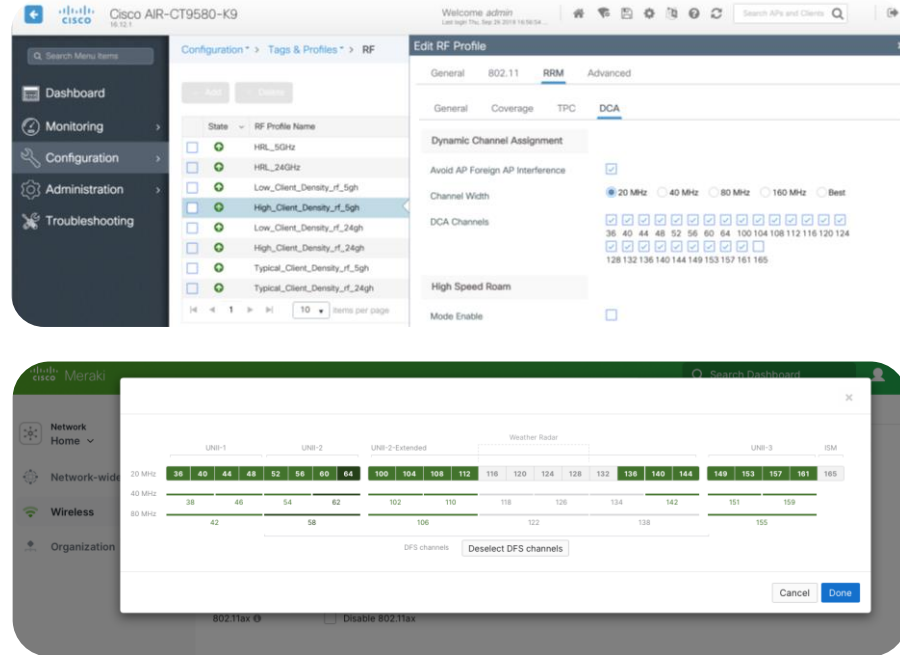
High Density WLAN Features & Configurations



- 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



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 dB	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 Catalyst configuration interface for a Cisco AIR-CT9580-K9. The breadcrumb trail is Configuration > Tags & Profiles > RF. The 'Edit RF Profile' page is displayed with tabs for General, Coverage, TPC, and DCA. The TPC tab is active, showing the 'Transmit Power Control' section with three input fields: Maximum Power Level(dBm)* set to 30, Minimum Power Level(dBm)* set to 7, and Power Threshold V1(dBm)* set to -65. A table below lists RF profile names and their states.

State	RF Profile Name
<input type="checkbox"/>	HRL_5GHz
<input type="checkbox"/>	HRL_24GHz
<input type="checkbox"/>	Low_Client_Density_rf_5gh
<input type="checkbox"/>	High_Client_Density_rf_5gh
<input type="checkbox"/>	Low_Client_Density_rf_24gh
<input type="checkbox"/>	High_Client_Density_rf_24gh

The bottom screenshot shows the Cisco Meraki configuration interface. The breadcrumb trail is General > 2.4 GHz > 5 GHz. The 'Radio transmit power range (dBm)' section is visible, featuring a slider from 2 to 30 dBm. Below the slider, there is a link 'Set RX-SOP...' and a checkbox 'Disable 802.11ax' which is currently unchecked. A note below the checkbox states: 'If this is disabled and 5GHz ax is enabled, we highly recommend to disable per ap band steering so client'.

Identifying Possible Power Imbalance

[WCAE](#) – ‘APs RF Summary’ tab – “TX Power dBm” and “Total Clients” columns

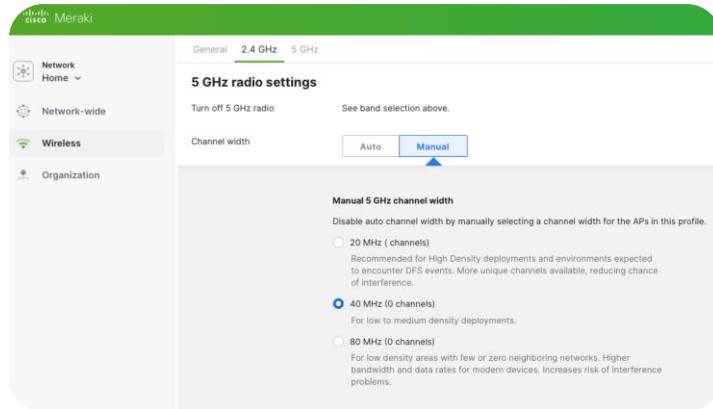
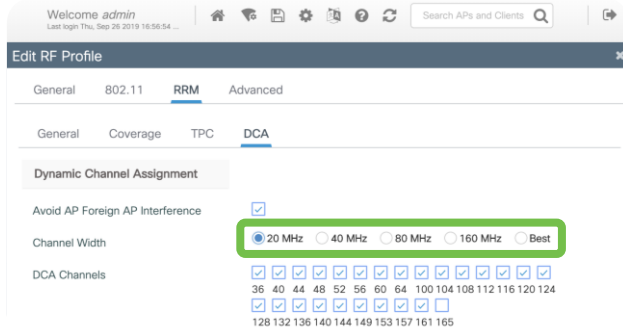
Name	Slot	Band	Channel	TX Power	TX Power dBm	Total Clients
AP1	1	5	100	1	17	21
AP1	2	5	48	1	23	70

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



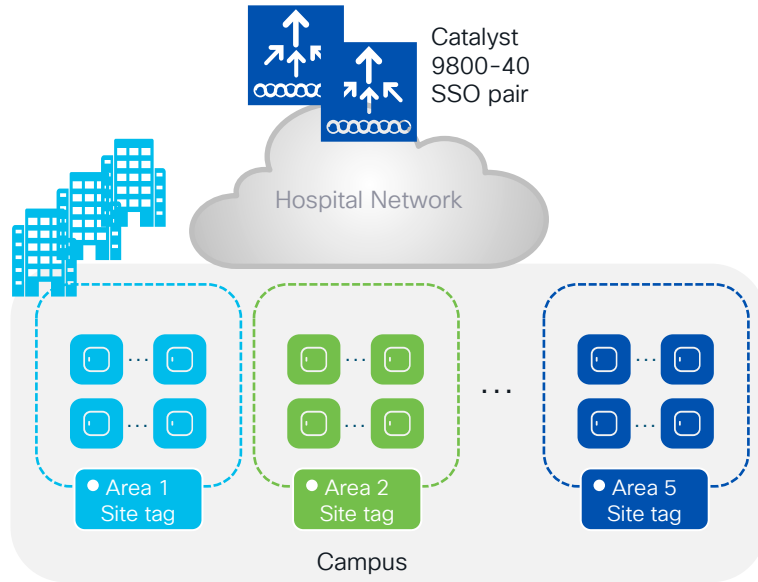
5GHz

- 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!)

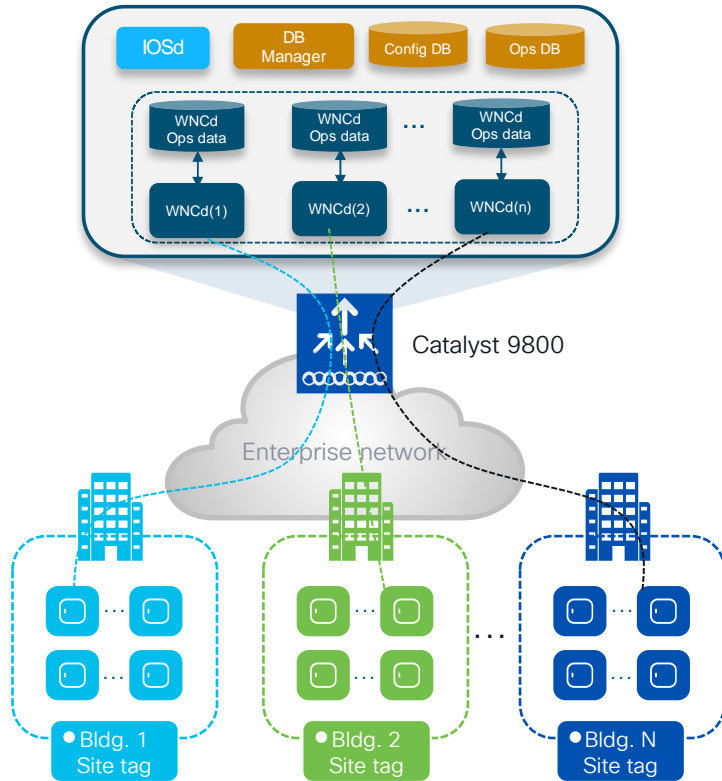
C9800 Site Tag Design in High Density



- 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 WNCd's 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
██████████	SITE TAG	177
██████████	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)

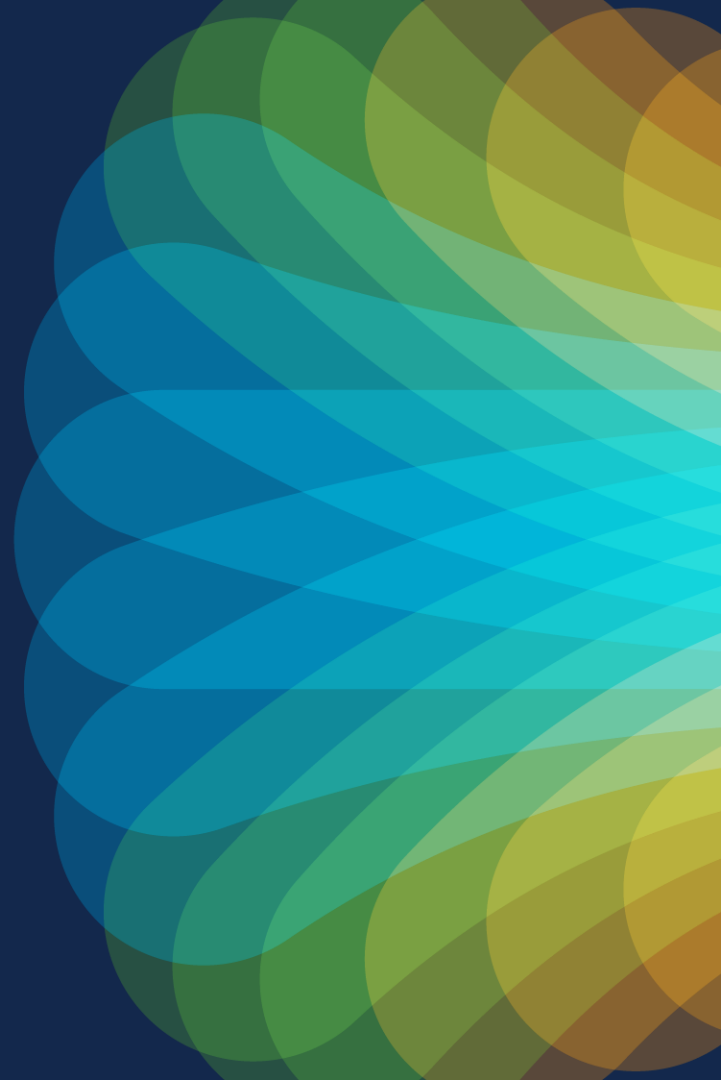
Primary reasons you may need an SVI:

- 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%	7
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%	2
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%	3
Cisco Sys...	-62 dBm	-96 dBm	34 dB	44	79%	
Cisco Sys...	-64 dBm	-96 dBm	32 dB	44	79%	2
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...	-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%	2

Receive Sensitivity Threshold (RX-SOP)

What does it do?

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

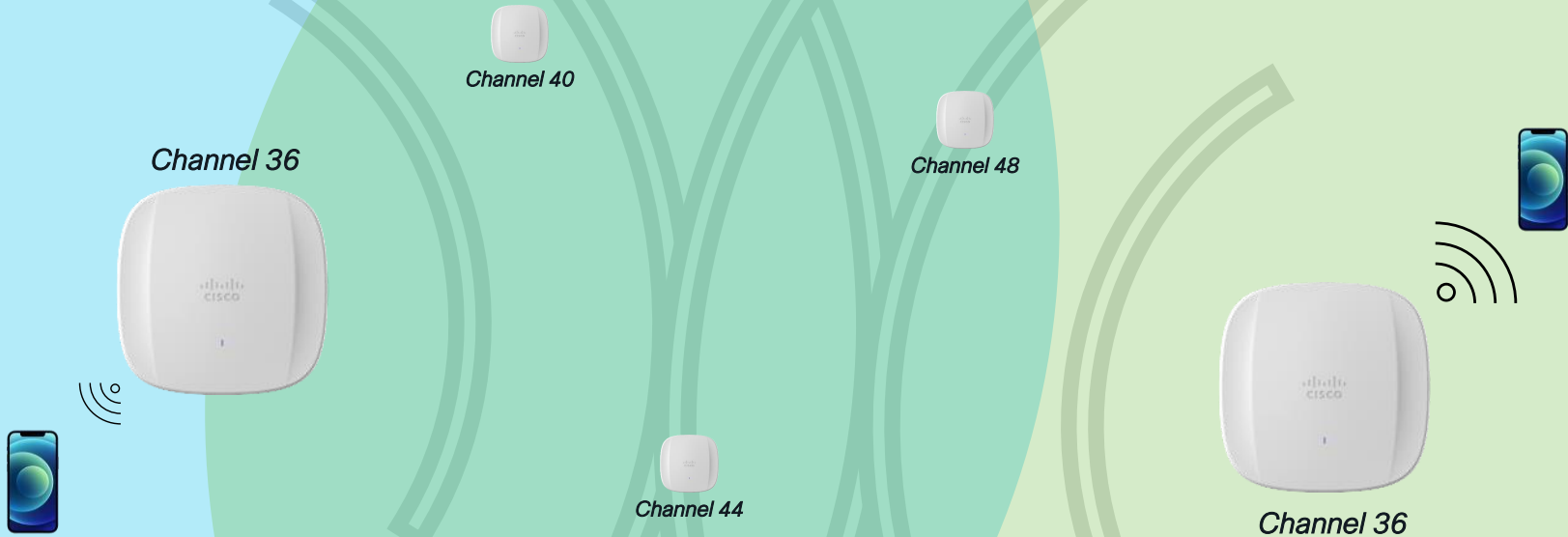
Example: ignore everything coming into the radio at lower than -80dBm, because those devices are unlikely to be in our cell

Why is it helpful?

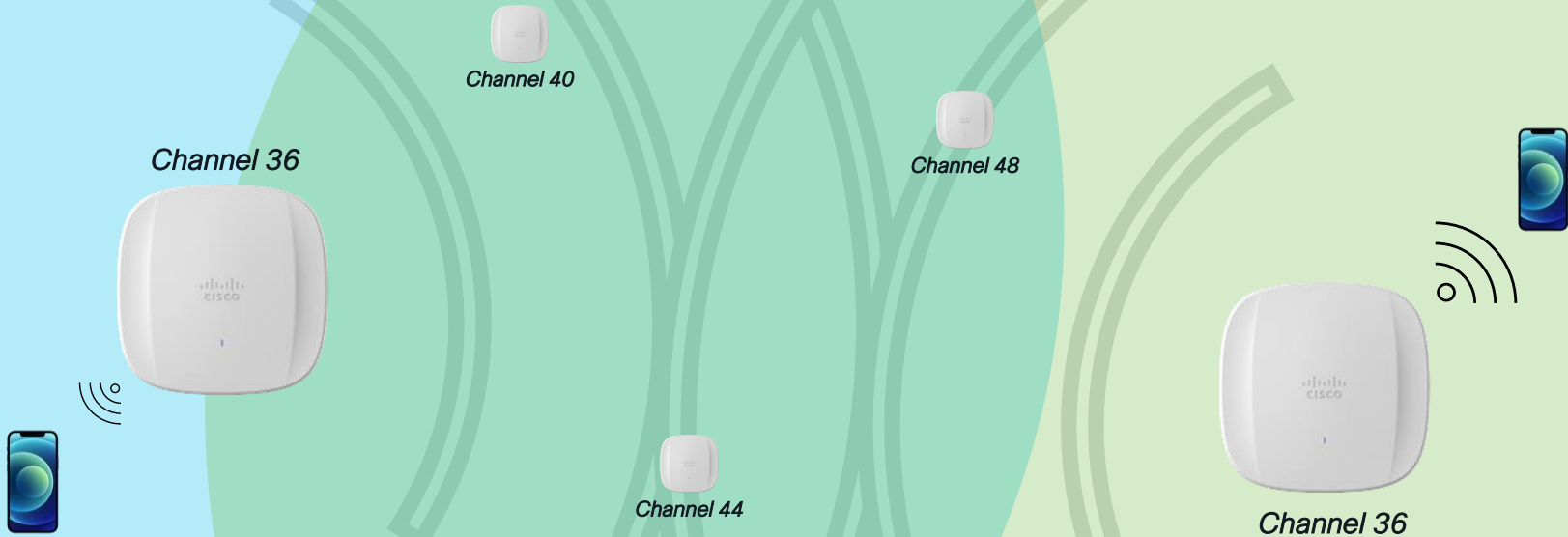
Allows us to transmit more often to clients in our intended cell



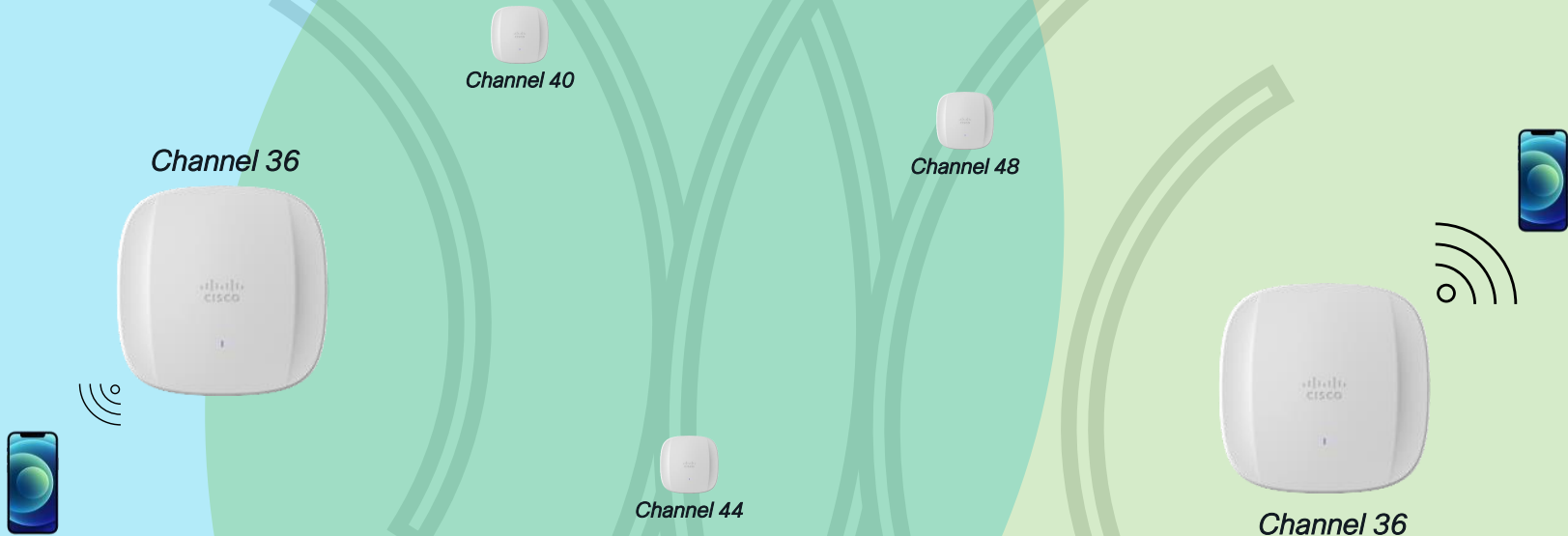
🕒 802.11 is a “polite” protocol



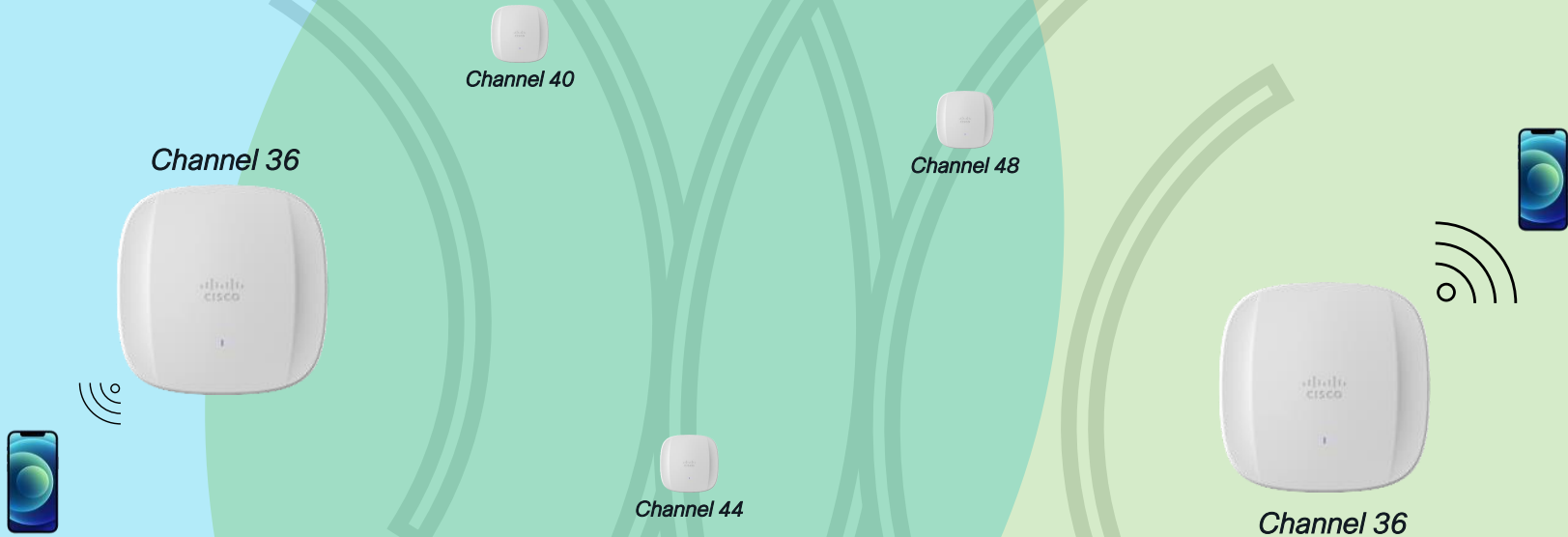
- 802.11 is a “polite” protocol
- I must listen before I start to talk – I will not talk until it’s “quiet” on my channel



- 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



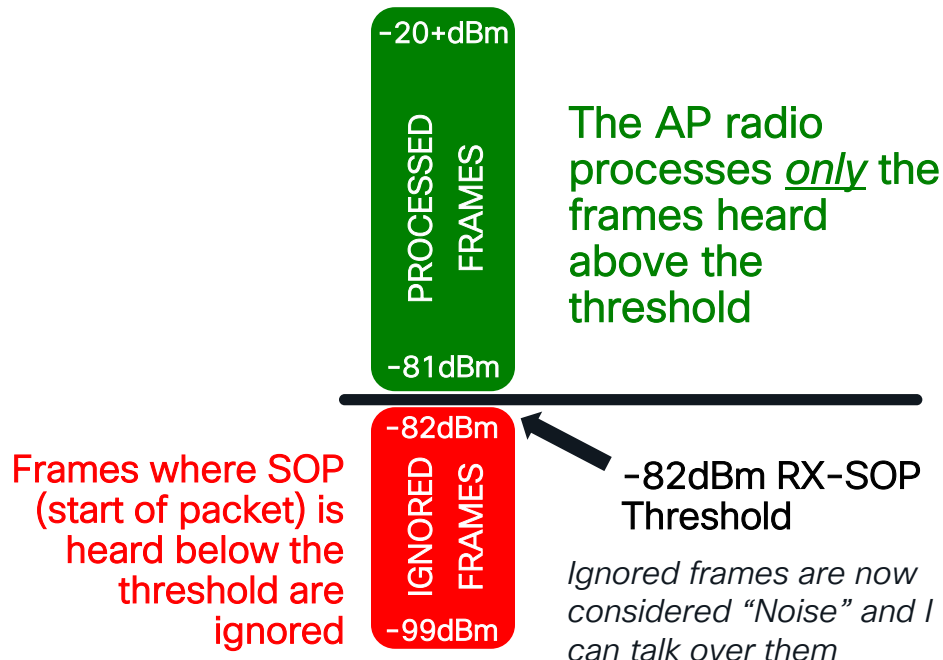
Receive Sensitivity Threshold (RX-SOP)

Without Custom RX-SOP Threshold
(Default / “Auto” Radio Sensitivity)

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



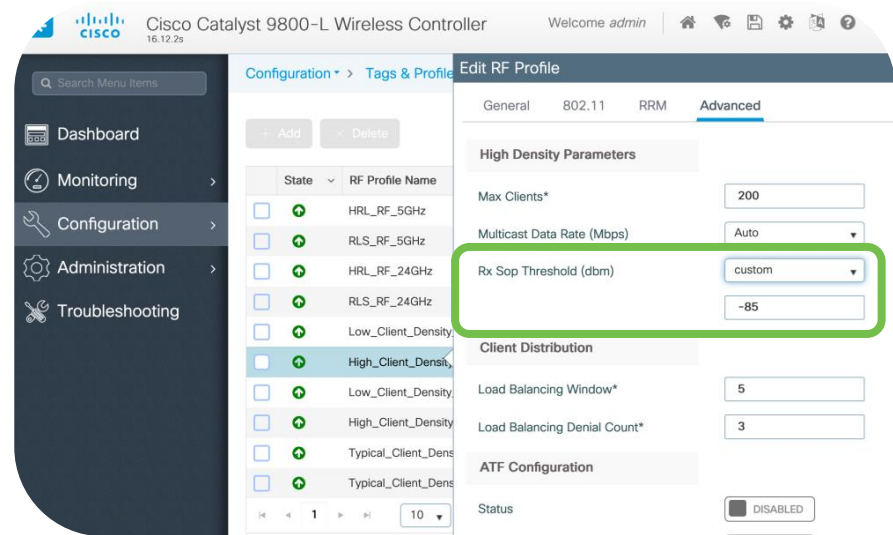
With Custom RX-SOP Threshold



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

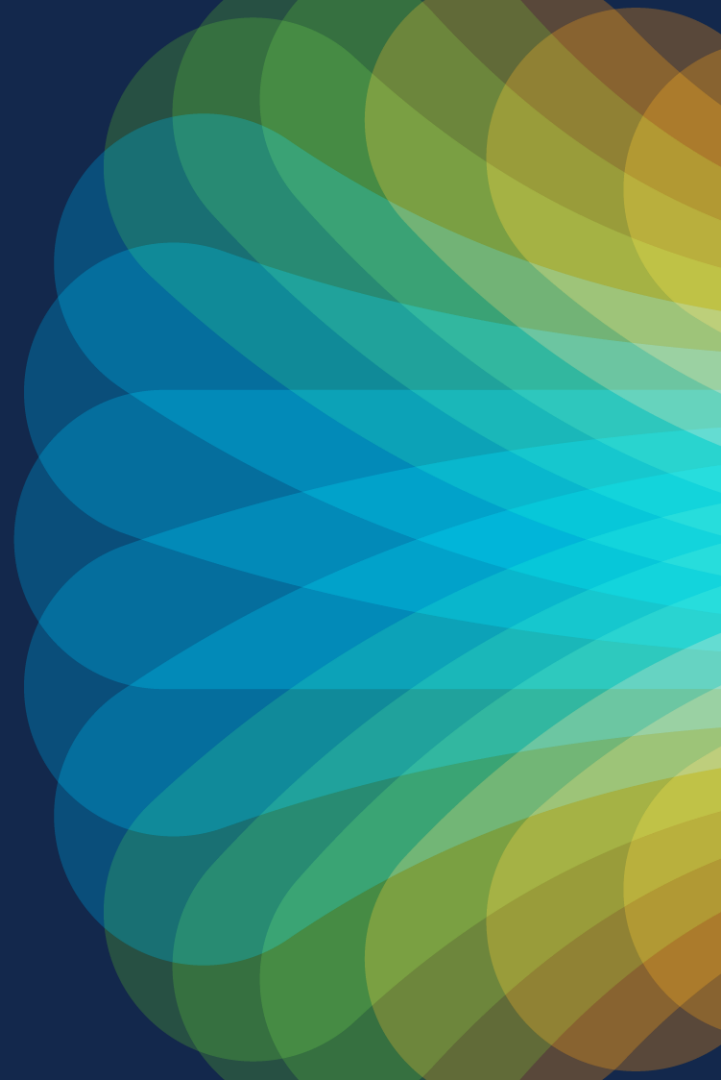
Example: Worst RSSI value is -72; initial RXSOP with 15dB cushion = -87

HOW TO: Optimize RX-SOP Thresholds

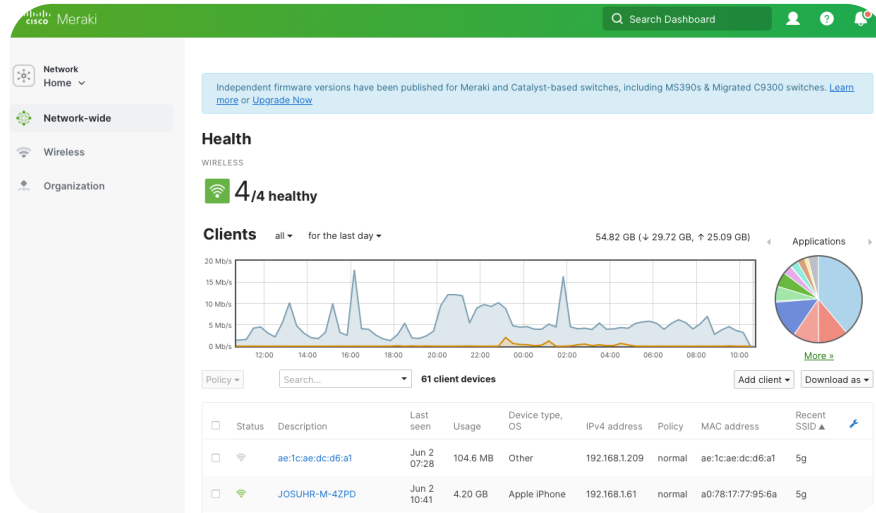
A key takeaway:

Be conservative and make small adjustments!

Cloud-Managed High Density



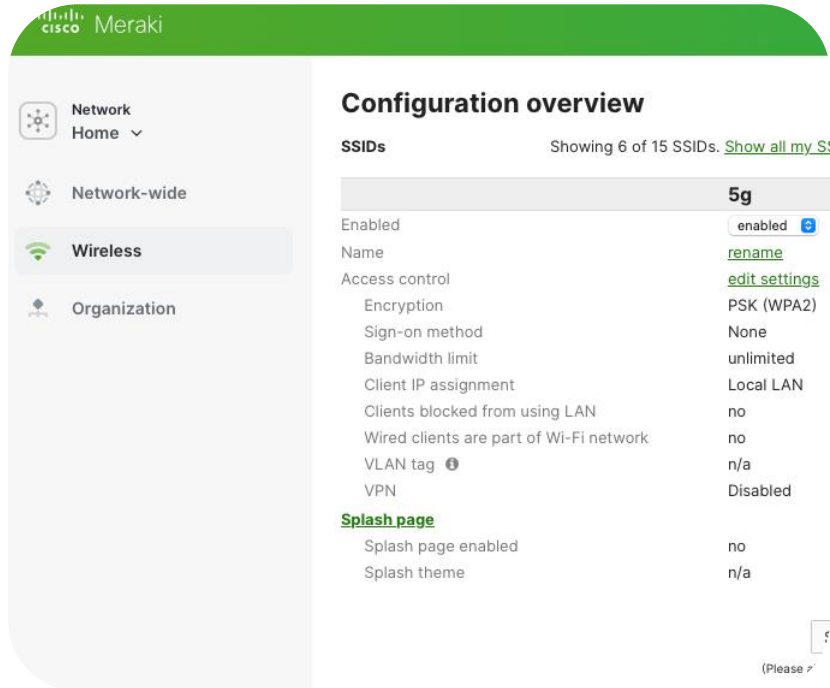
Cloud-Managed High Density



Can be ideal for:
Classrooms
Theaters & Auditoriums
Hotspots

Be aware of:
Switched Network Capacity (L2 / L3)
Roaming Domains & Expected
Roaming Experience

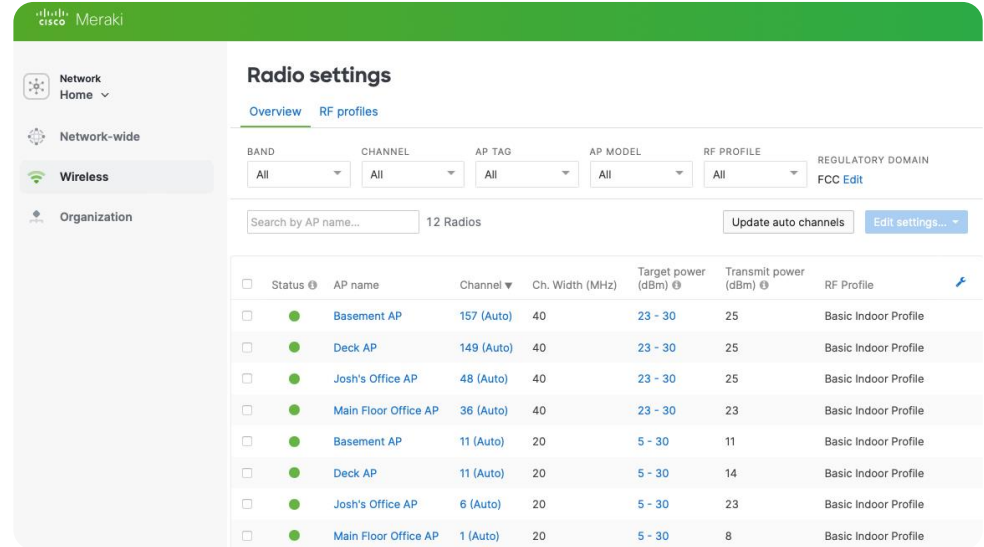
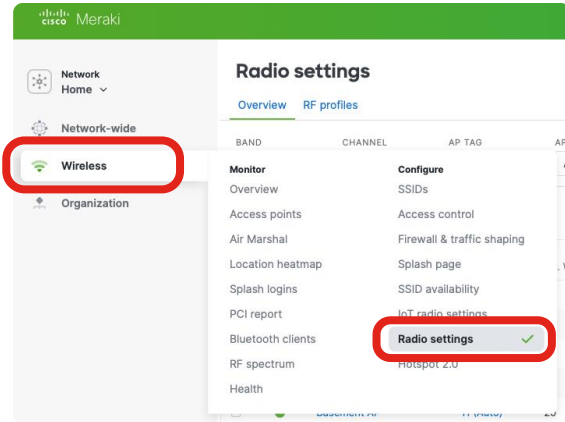
Cloud-Managed High Density



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



RF Optimization: Radio Settings Overview

Radio settings

Overview RF profiles

BAND: All CHANNEL: All AP TAG: All AP MODEL: All RF PROFILE: All REGULATORY DOMAIN: FCC Edit

Search by AP name... 12 Radios Update auto channels Edit settings...

<input type="checkbox"/>	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

Radio settings

Overview **RF profiles**

[New Profile](#)

Basic Indoor Profile DEFAULT INDOOR
Applied to 6 APs. Overrides applied to 6/6 of these APs.

	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
Applied to 0 APs.

	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](#)

5GHz Only
Applied to 0 APs.

	2.4 GHZ	5 GHZ
Channel assignment	Auto	Auto
AutoPower max	30	30
AutoPower min	5	8
Min. bitrate	9	6
Channel width		40

[DELETE](#) [COPY](#) [EDIT](#)

Create an RF Profile

[New Profile From Scratch](#)

Auditorium Profile
For auditorium deployments accommodating a large number of devices. Limits coverage area per AP and optimizes client roaming.

[Customize](#)

Classroom Profile
For classroom deployments. Provides good coverage and optimizes client roaming.

[Customize](#)

Open Office Profile
For open office deployments. Balances performance and coverage.

[Customize](#)

Conference Room Profile
For conference room deployments. Provides good coverage and encourages client roaming once outside of the room.

[Customize](#)

Outdoors Profile
For outdoor deployments. Prioritizes coverage and connectivity for distant and legacy clients.

[Customize](#)

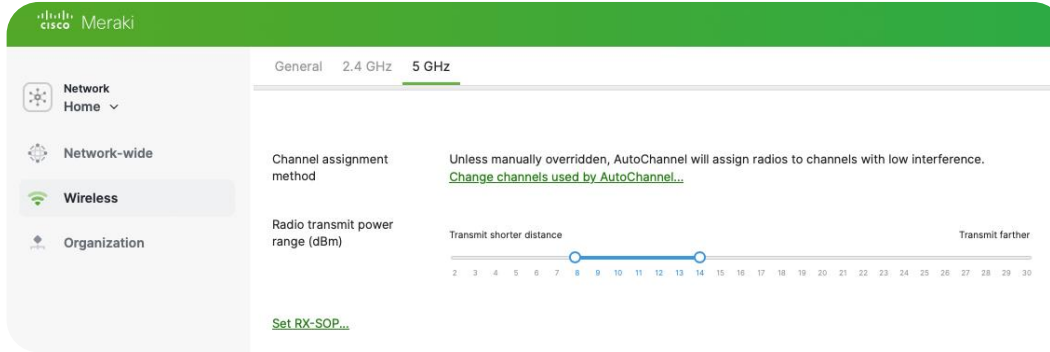
RF Optimization: RX SOP

The screenshot shows the Cisco Meraki dashboard interface. On the left is a navigation sidebar with categories: Network Home, Network-wide, Wireless (highlighted), and Organization. The main content area is titled '5 GHz' and contains two sections: 'Channel assignment method' with a link to 'Change channels used by AutoChannel...' and 'Radio transmit power range (dBm)' with a slider ranging from 2 to 30 dBm. A red circle highlights the 'Set RX-SOP...' button at the bottom left of the main content area.

RF Optimization: RX SOP

The screenshot shows the Cisco Meraki dashboard interface. The top navigation bar is green with the Cisco Meraki logo. The left sidebar contains navigation links: Network Home, Network-wide, Wireless (highlighted), and Organization. The main content area is titled '5 GHz' and includes tabs for General, 2.4 GHz, and 5 GHz. Under the '5 GHz' tab, there are two sections: 'Channel assignment method' and 'Radio transmit power range (dBm)'. The 'Channel assignment method' section states: 'Unless manually overridden, AutoChannel will assign radios to channels with low interference. [Change channels used by AutoChannel...](#)'. The 'Radio transmit power range (dBm)' section features a slider from 2 to 30 dBm, with 'Transmit shorter distance' on the left and 'Transmit farther' on the right. Below the slider is a link: [Set RX-SOP...](#). At the bottom of the page, there is a warning box with a red exclamation mark icon. The text in the warning box reads: '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.' Below the text are two buttons: 'Proceed' (highlighted with a red circle) and 'Hide this option'.

RF Optimization: RX SOP



Meraki

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

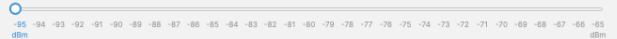
Min. received power
(RX-SOP)

Disabled

Enabled

Listen for clients farther away

Ignore weaker clients



RF Optimization: RX SOP

Min. received
power
(RX SOP)

Disabled

Enabled

Listen for clients farther away

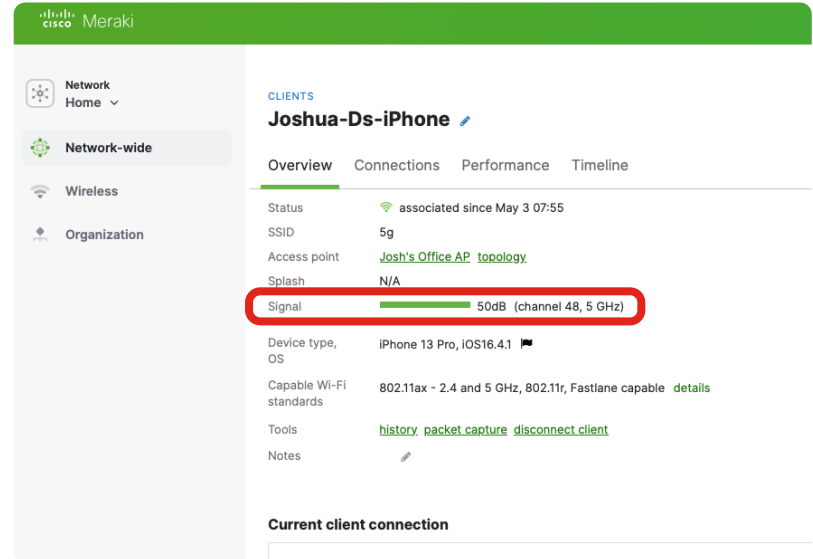
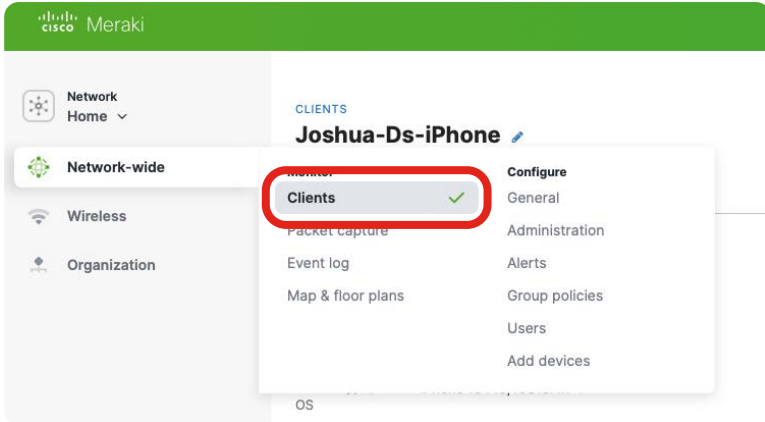
Ignore weaker clients



-95
dBm

-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 -65
dBm

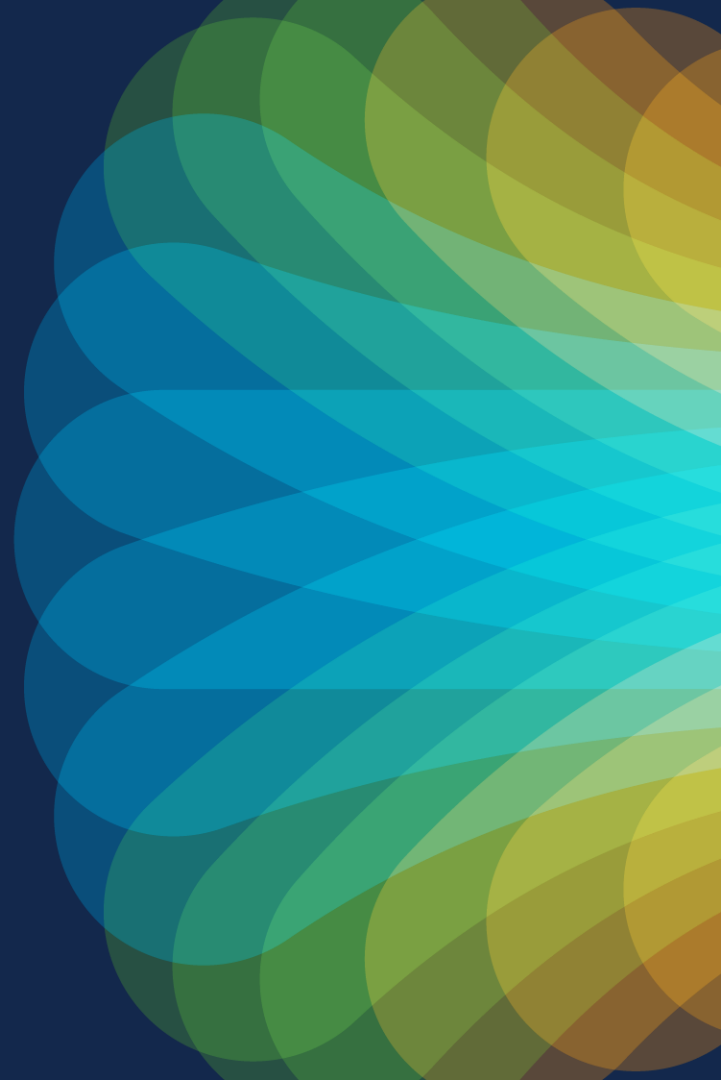
Monitoring Client RSSI @ AP for RXSOP Testing



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 screenshot displays the Cisco Catalyst 9800-L Wireless Controller GUI. The top navigation bar includes tabs for MONITOR, WLANs, CONTROLLER, WIRELESS, SECURITY, and MANAGEMENT. The left sidebar shows the 'Wireless' section with a tree view containing 'Access Points', 'Radios', 'Advanced', 'Mesh', 'ATF', 'RF Profiles', 'FlexConnect Groups', 'FlexConnect ACLs', and 'FlexConnect VLAN'. The main content area is titled 'RF Profile > Edit 'High-Client-Density-802.11a'' and features tabs for General, 802.11, RRM, High Density, and Client Distribution. The 'High Density' tab is active, showing 'High Density Parameters' and 'Multicast Parameters'. Under 'High Density Parameters', the 'Rx Sop Threshold Parameters' section is highlighted with a green box, showing a dropdown set to 'Medium' and a value of '-78' with a 'Custom' checkbox. A red '8.7+' is overlaid on this section. The 'Multicast Parameters' section shows 'Multicast Data Rates' with a value of '200'. A central sidebar menu lists 'Dashboard', 'Monitoring', 'Configuration', 'Administration', and 'Troubleshooting'. To the right, a 'Configuration > Tags & Profiles' panel shows a table of RF profiles, with 'High_Client_Density' selected. Further right, the 'Edit RF Profile' dialog is open, showing the 'Advanced' tab. The 'High Density Parameters' section in this dialog has a green box around the 'Rx Sop Threshold (dbm)' dropdown, which is set to 'custom' with a value of '-85'. The 'Client Distribution' section shows 'Load Balancing Window*' set to '5' and 'Load Balancing Denial Count*' set to '3'. The 'ATF Configuration' section shows the 'Status' as 'DISABLED'.

Wireless

RF Profile > Edit 'High-Client-Density-802.11a'

General 802.11 RRM High Density Client Distribution

High Density Parameters

Maximum Clients(1 to 200) 200

Multicast Parameters

Multicast Data Rates 200

Rx Sop Threshold Parameters

Rx Sop Threshold Medium -78 Custom

8.7+

Configuration > Tags & Profiles

Edit RF Profile

General 802.11 RRM Advanced

High Density Parameters

Max Clients* 200

Multicast Data Rate (Mbps) Auto

Rx Sop Threshold (dbm) custom -85

Client Distribution

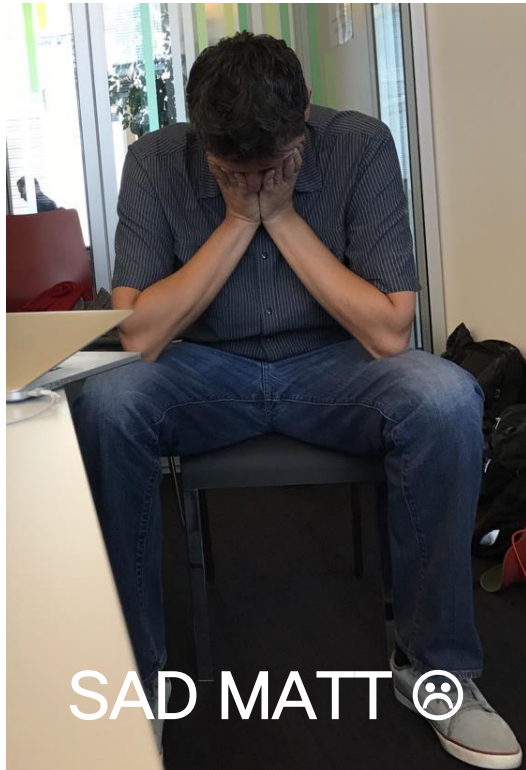
Load Balancing Window* 5

Load Balancing Denial Count* 3

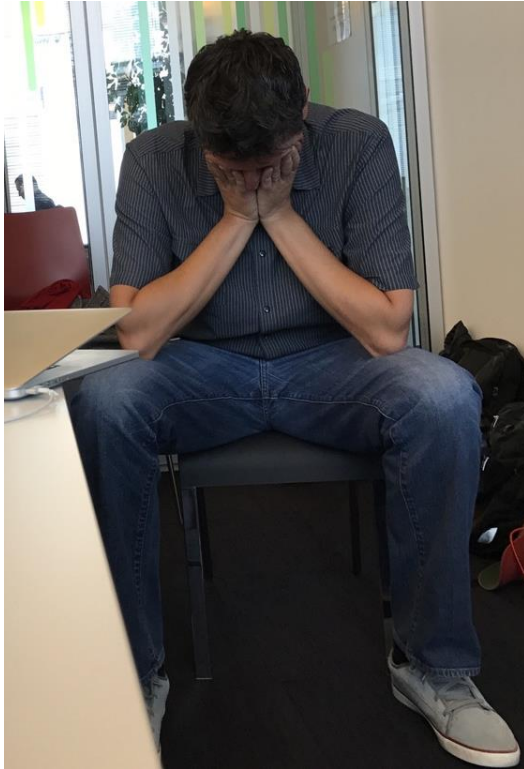
ATF Configuration

Status DISABLED

Common High Density Optimization Mistakes



Common High Density Optimization Mistakes



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



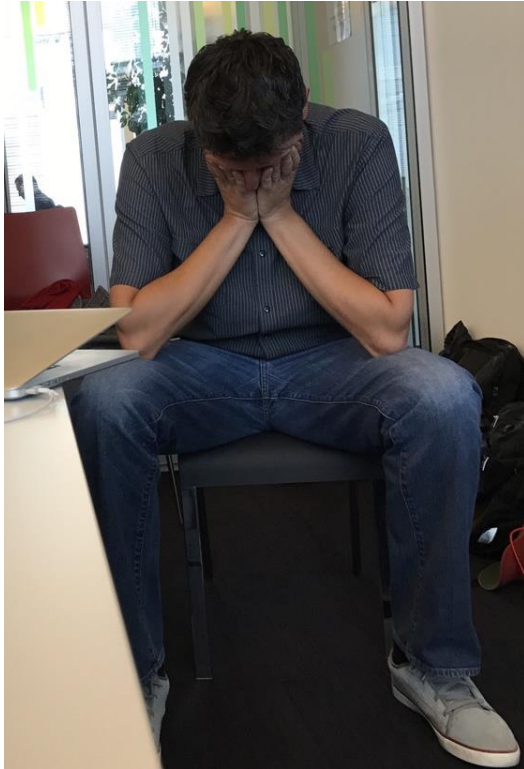
5GHz TX Power: 7dB
2 clients



5GHz TX Power: 17dB
50 clients

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

Common High Density Optimization Mistakes



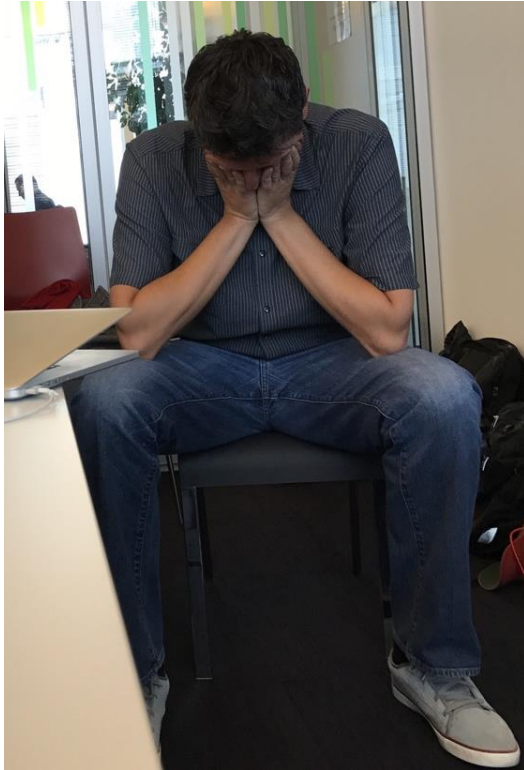
- ❑ AP-to-AP transmit power imbalance (causes “Magnet” / overloaded AP’s)
- ❑ 2.4GHz to 5GHz transmit power imbalance (draws dual-band clients to 2.4GHz)



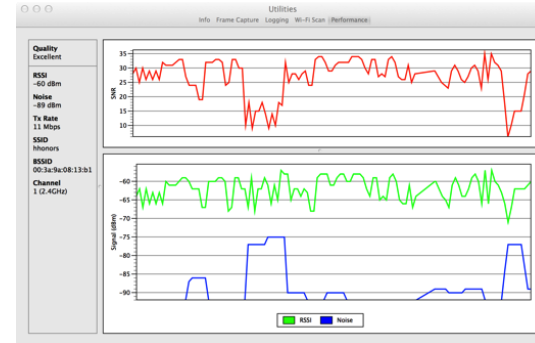
2.4GHz: 13dB
20 dual-band clients

5GHz: 7dB
0 dual-band clients

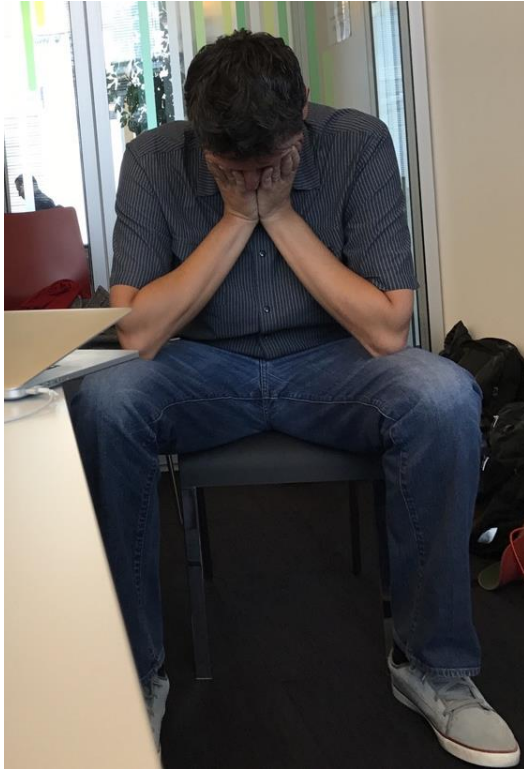
Common High Density Optimization Mistakes



- ❑ 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

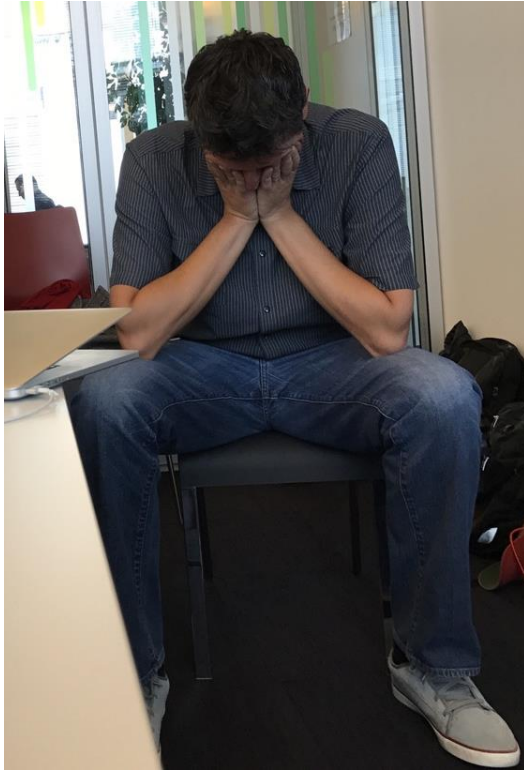


Common High Density Optimization Mistakes



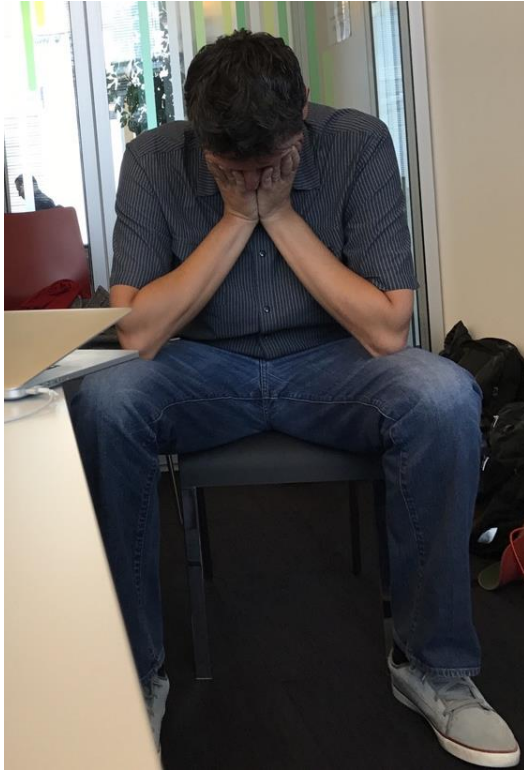
- ❑ AP-to-AP transmit power imbalance (causes “Magnet” / overloaded AP’s)
- ❑ 2.4GHz to 5GHz transmit power imbalance (draws dual-band clients to 2.4GHz)
- ❑ Transmit power too low to overcome noise floor
- ❑ Channel Utilization high without real traffic

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)

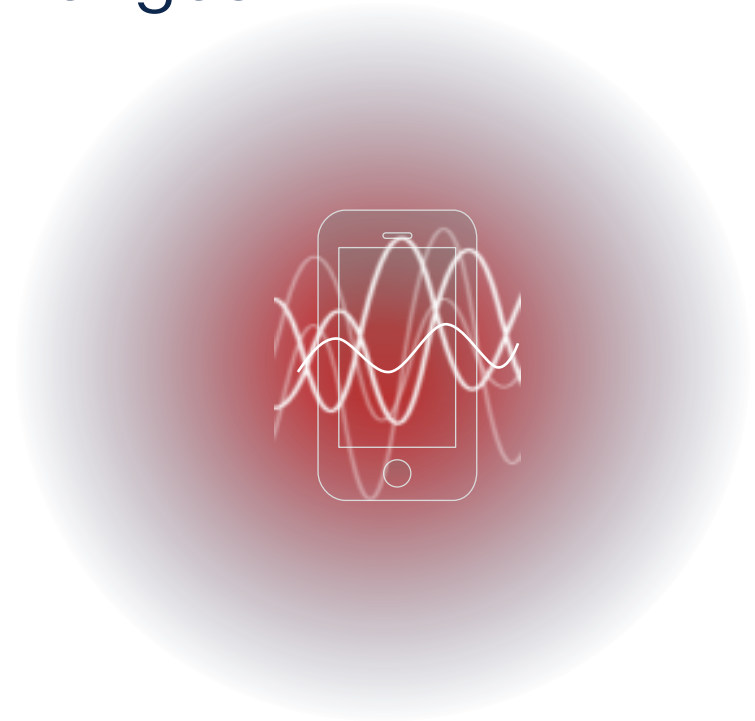
Common High Density Optimization Mistakes



- ❑ 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

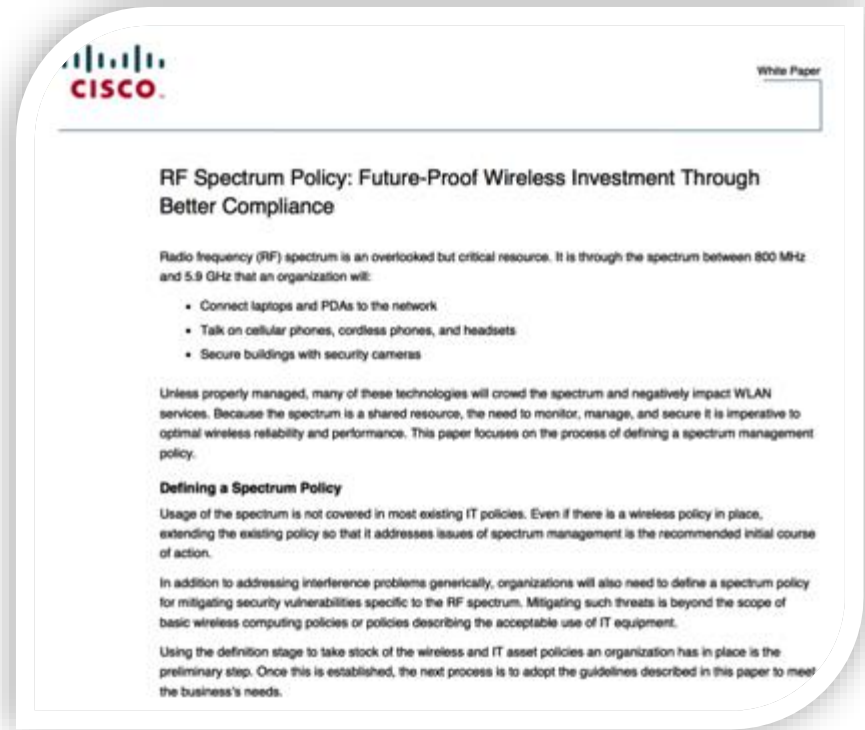
Non-WiFi Interferers



- 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



Agenda

- 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
Next generation, multi platform Wireless Analyzer tool, including checks from WLCCA, and several new additions
Support for AireOS and 9800 IOS-XE controllers, you can use the Cloud version (summary view, all checks), or the Desktop version, providing a detailed XLS or text report, with RF analysis output, Flex summarisation and more... Now with Windows 10 or Mac OS support.
- [Wireless Lan Config Analyzer - WLCCA - Download V4.4.14](#)
 - For access, please request to [wlc-conf-app-dev](#)
It is desktop Windows application, oriented primarily towards AireOS controllers Provides around 300+ configuration checks, RF analysis and RF Health evaluation
- [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:

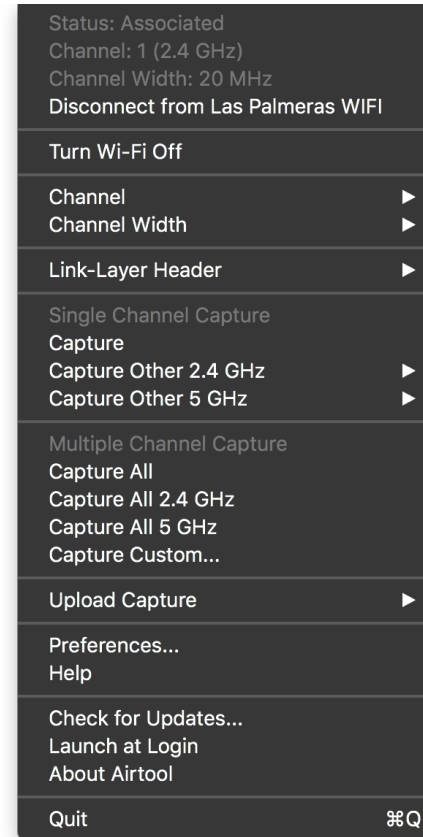
Controller Checks Results		
APs Checks Results		

Controller: ----	Client Audit	AP Information
Data Summary	Apple iOS	APs Configuration
Log Summary	Cisco 8821	AP Slot Configuration
Upgrade Advisor	Draeger	APs Interface Status
Best Practices	Spectralink	APs RF Summary 2.4GHz
WLAN Summary	Vocera	APs RF Summary 5GHz
Interface Summary		APs RF Summary 6GHz
RF Profiles 2.4 GHz		APs RF Health Details
RF Profiles 5 GHz		APs NDP Summarization 2.4GHz
RF Profiles 6 GHz		APs NDP Summarization 5GHz
Site Tags		APs RF Neighbors 2.4GHz
Hardware State		APs RF Neighbors 5GHz
Resources		
Client Types		6GHz Predictive Planning
AAA Server Details		AP Channel Config Export
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		

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

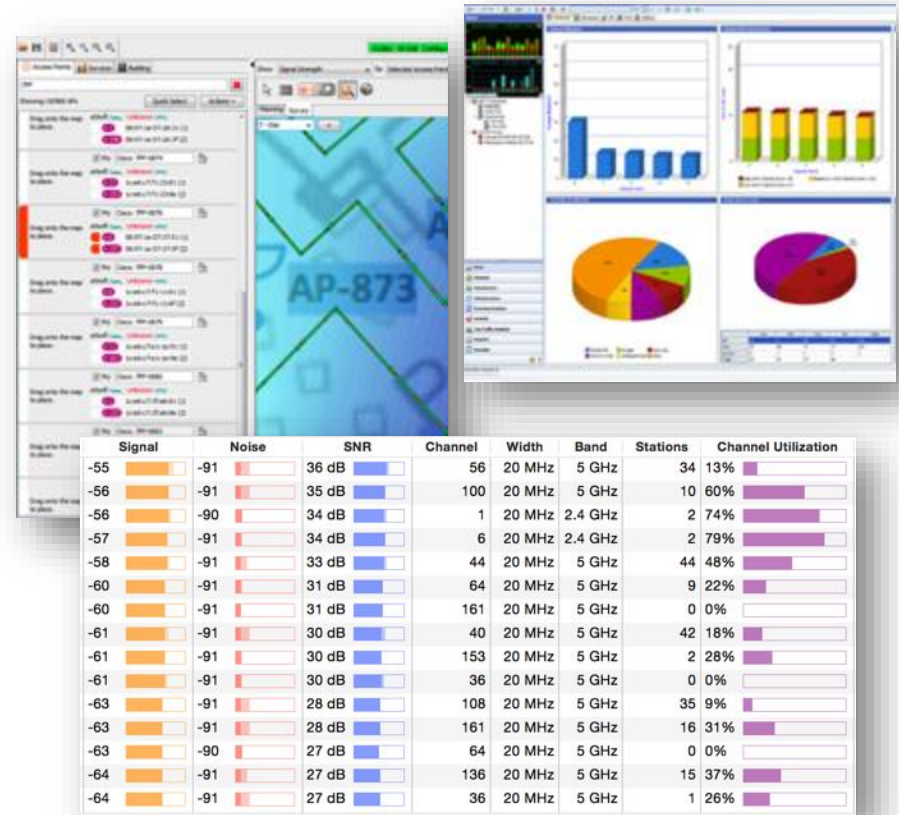
Packet Captures

- 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/apps/airtool>



Site Surveys

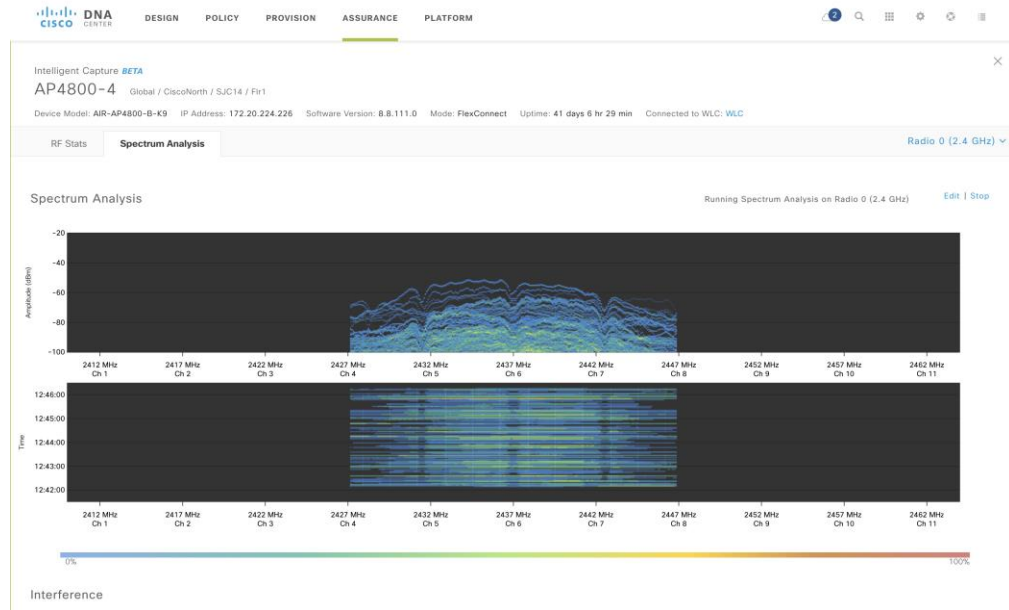
- Ekahau Site Survey Pro
 - Design & Verify
 - Determine differences in coverage that occur as a result of tuning changes



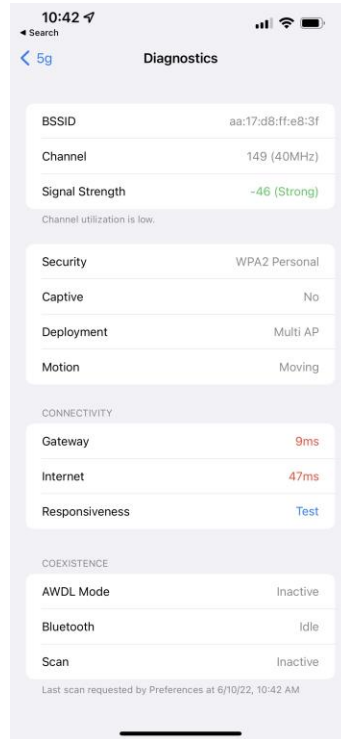
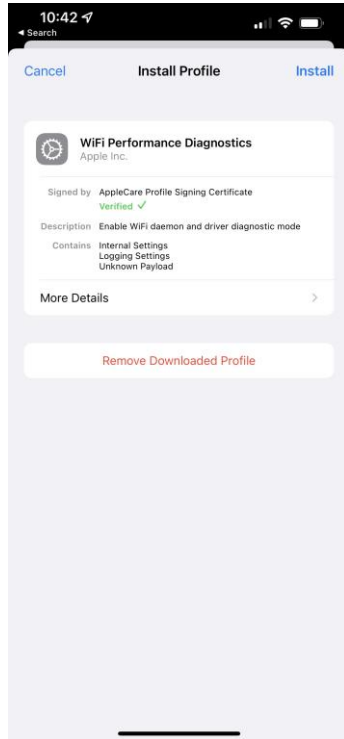
Spectrum Analysis

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:

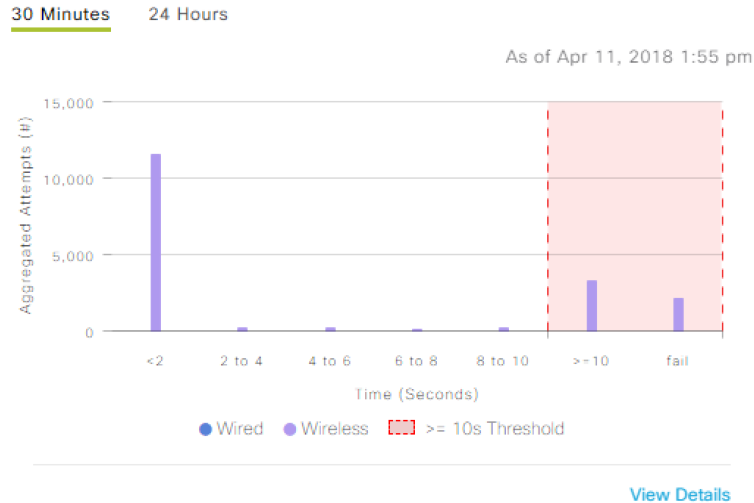
https://developer.apple.com/services-account/download?path=/iOS/iOS_Logs/MegaWifiProfile.mobileconfig

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

Cisco DNA Center Assurance

Broad applicability to High Density deployments

Client Attempts by Onboarding Times



- 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

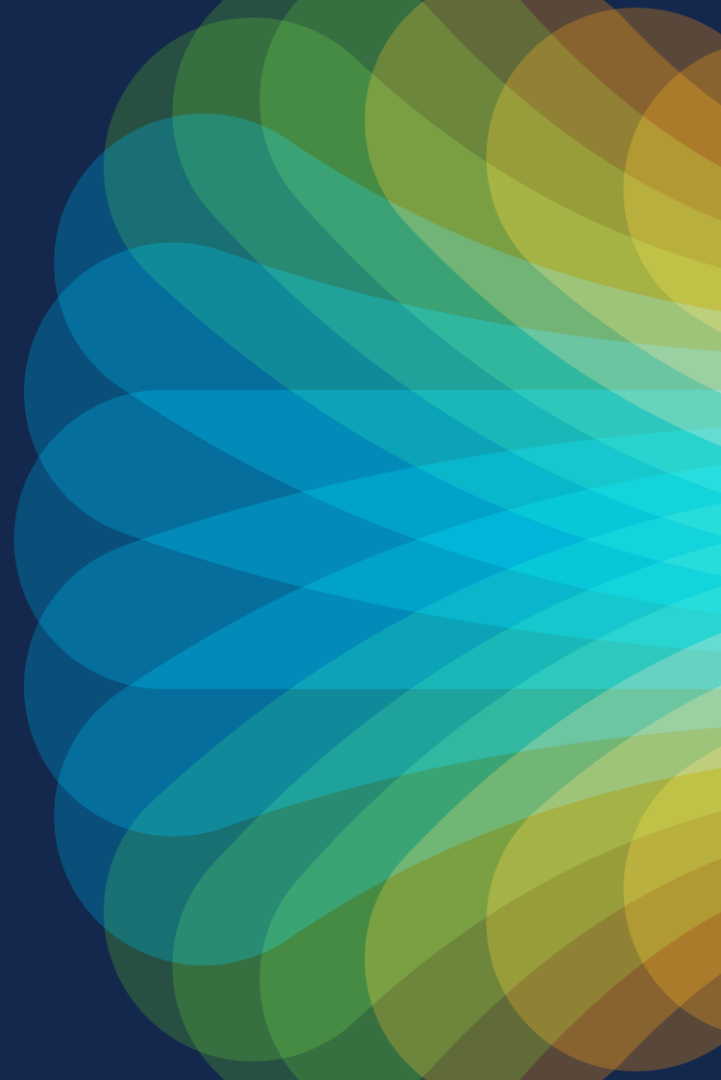
- Design the RF environment with appropriate antennas and sensible physical placements
- Employ HD-focused WLC feature configurations such as RF Profiles for more flexible and robust designs
- Understand the key outside factors that may impact a live HD WLAN, including enemies of performance
- Get comfortable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



The bridge to possible

Thank you

CISCO *Live!*



The background of the slide is a vibrant, abstract graphic. It features a large, stylized cloud shape on the left side, composed of overlapping, semi-transparent layers of orange, red, and yellow. To the right of the cloud, a bright, multi-colored sunburst or starburst pattern radiates from a central point, with rays extending towards the right edge of the frame. The colors in the sunburst transition through a spectrum from blue and purple on the left to yellow and orange on the right. The overall effect is energetic and colorful.

cisco *Live!*

Let's go