High Density Wi-Fi Design, Deployment, and Optimization

Matt Swartz
Cisco Wireless,
Distinguished Engineer, CCIE #13232

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

BRKEWN-2087

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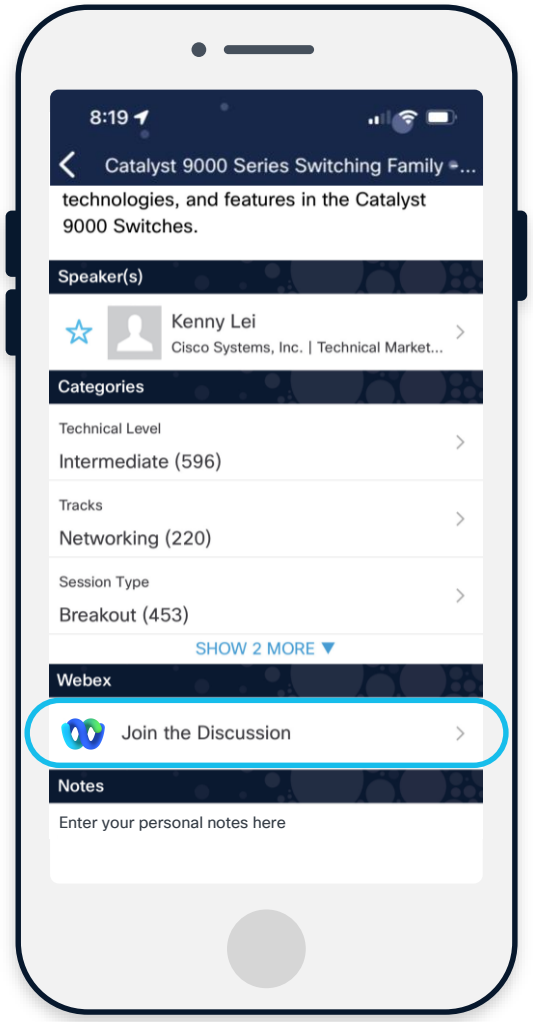


Agenda

01 HD RF Design Fundamentals

02 AP/Antenna Selection

03 All About CW9179F

04 AP/Antenna Placement

05 6GHz HD Considerations

06 Maximizing the Spectrum

07 HD Config Fundamentals

08 Common Mistakes

09 Our Favorite Tools

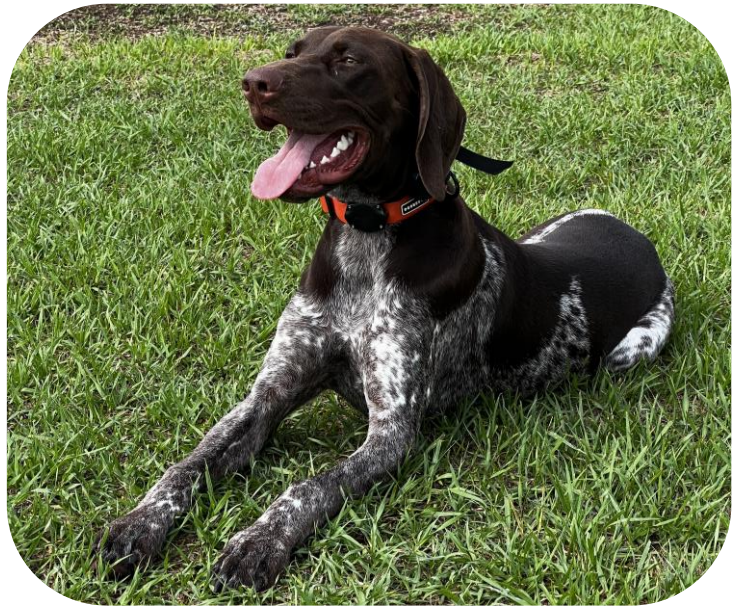
Matt Swartz

Distinguished Engineer, Cisco Wireless

CCIE #13232 (R/S, Wireless)

First HD WiFi Project: New York Yankees, 2008

Husband, dad, mountain biker, likes food ☺



Josh Suhr

Principal Architect, Cisco Customer Experience (CX)

CCIE #39980 (Wireless)

First HD WiFi Project: Sporting Kansas City, 2011

Long-time husband & recent dad; BBQ lover

Key Trends in High Density Wi-Fi

High Density is everywhere!

CW9179F: Software-defined antenna + Integrated AP

6 GHz / WiFi 6E & WiFi 7

Auto authentication & OpenRoaming

Designing RF for High Density

The Fundamentals

Designing for the 3 Key RF Relationships

Designing for the 3 Key RF Relationships

1 **AP to Client**: How does the client device “hear” the AP?

Designing for the 3 Key RF Relationships

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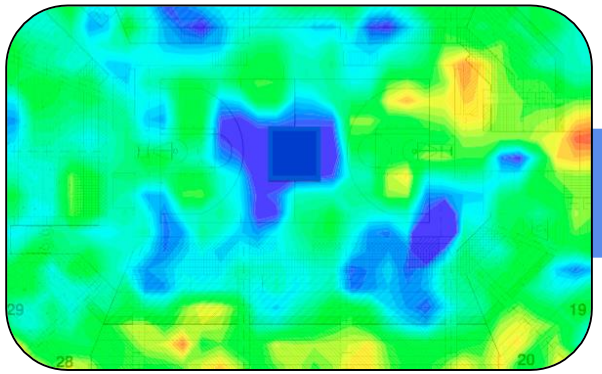
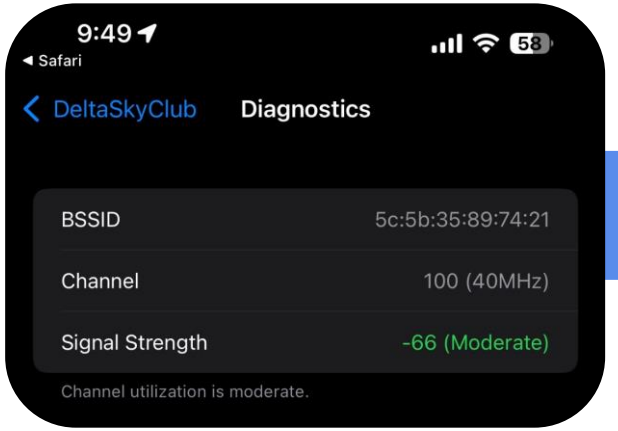


Site Survey

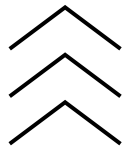
Verify with:



Real Clients

Designing for the 3 Key RF Relationships

2 **Client to AP**: How does the AP “hear” the client device?



Designing for the 3 Key RF Relationships

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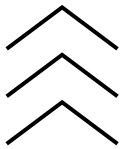


Verify with:

WLC UI or CLI

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

Cloud Dashboard

CLIENTS

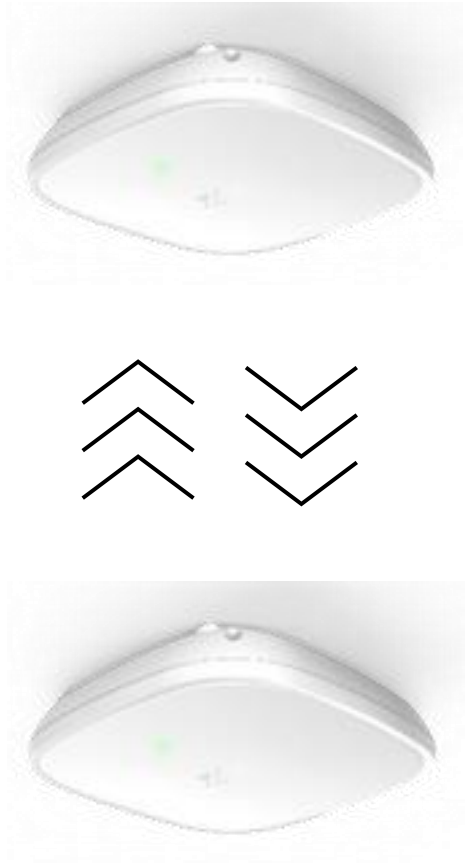
Joshua-Ds-iPhone

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,	iPhone 13 Pro, iOS16.4.1

Designing for the 3 Key RF Relationships

3 **AP to AP**: How do AP's "hear" each other? (especially co-channel)



Designing for the 3 Key RF Relationships

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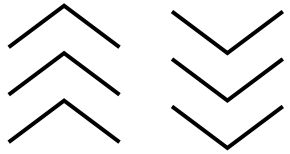
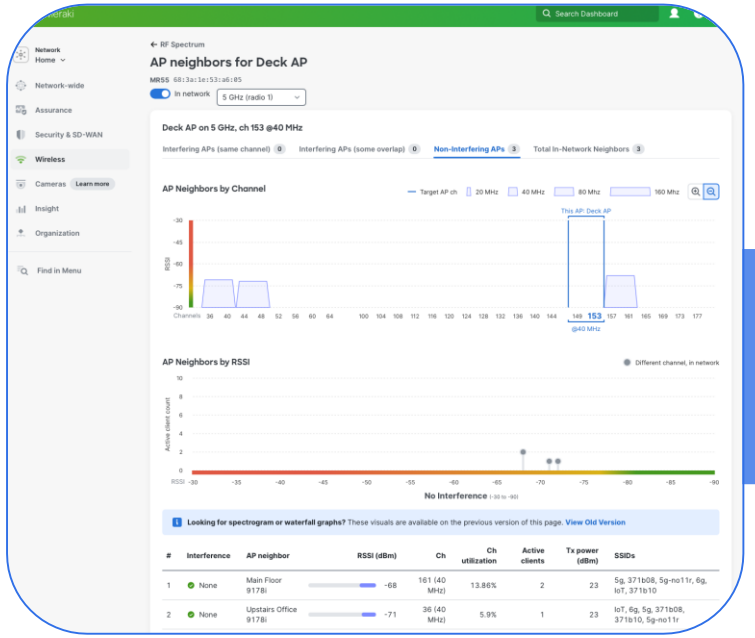


Verify with:

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

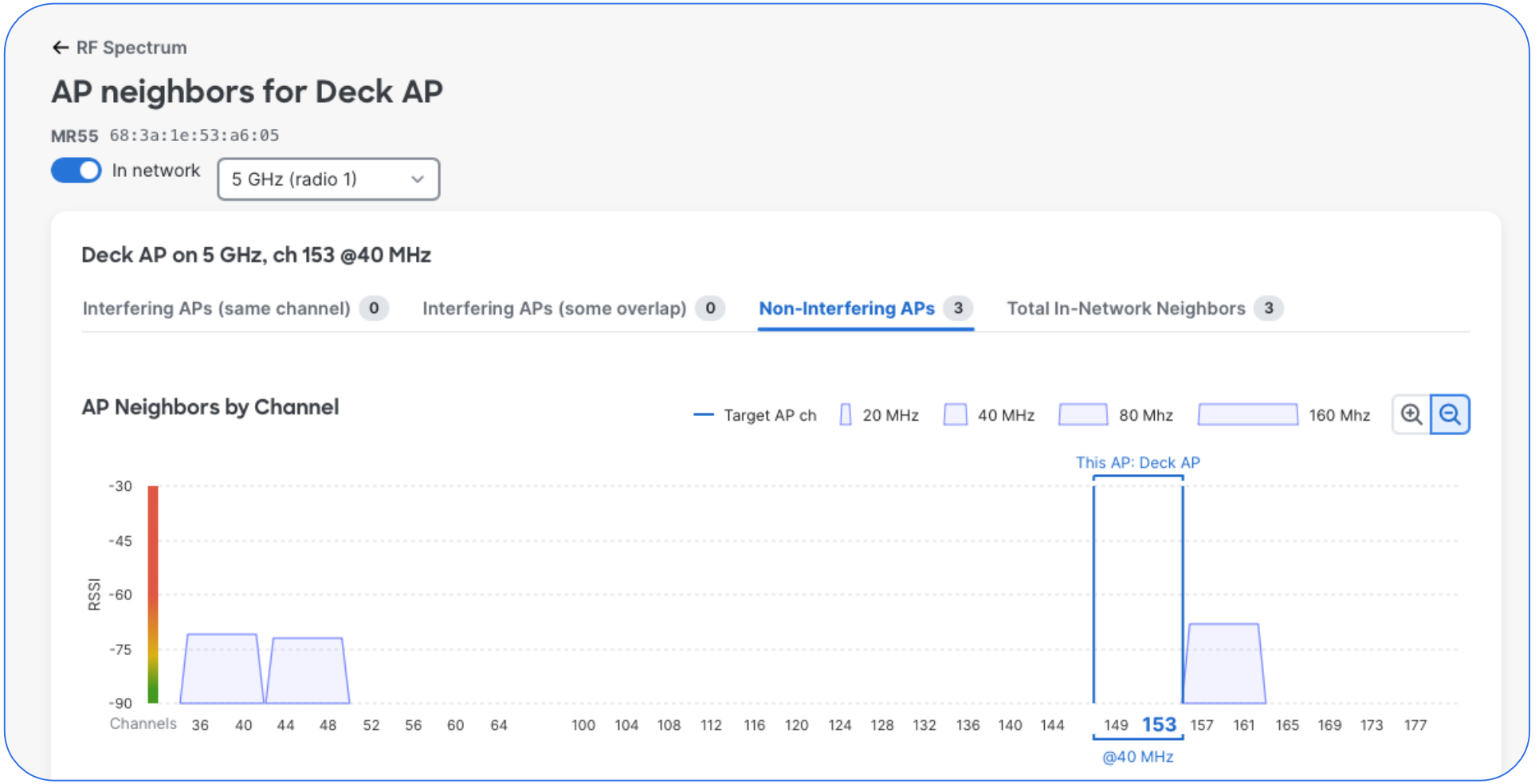
WCAE



Cloud Dashboard

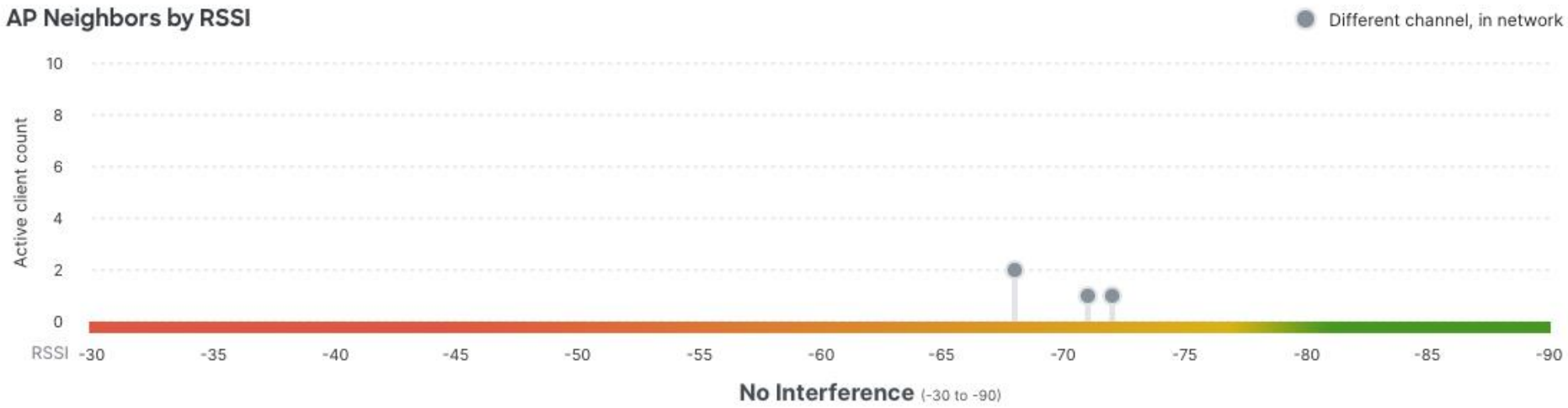
Designing for the 3 Key RF Relationships

A Closer Look: AP→AP Relationships



Designing for the 3 Key RF Relationships

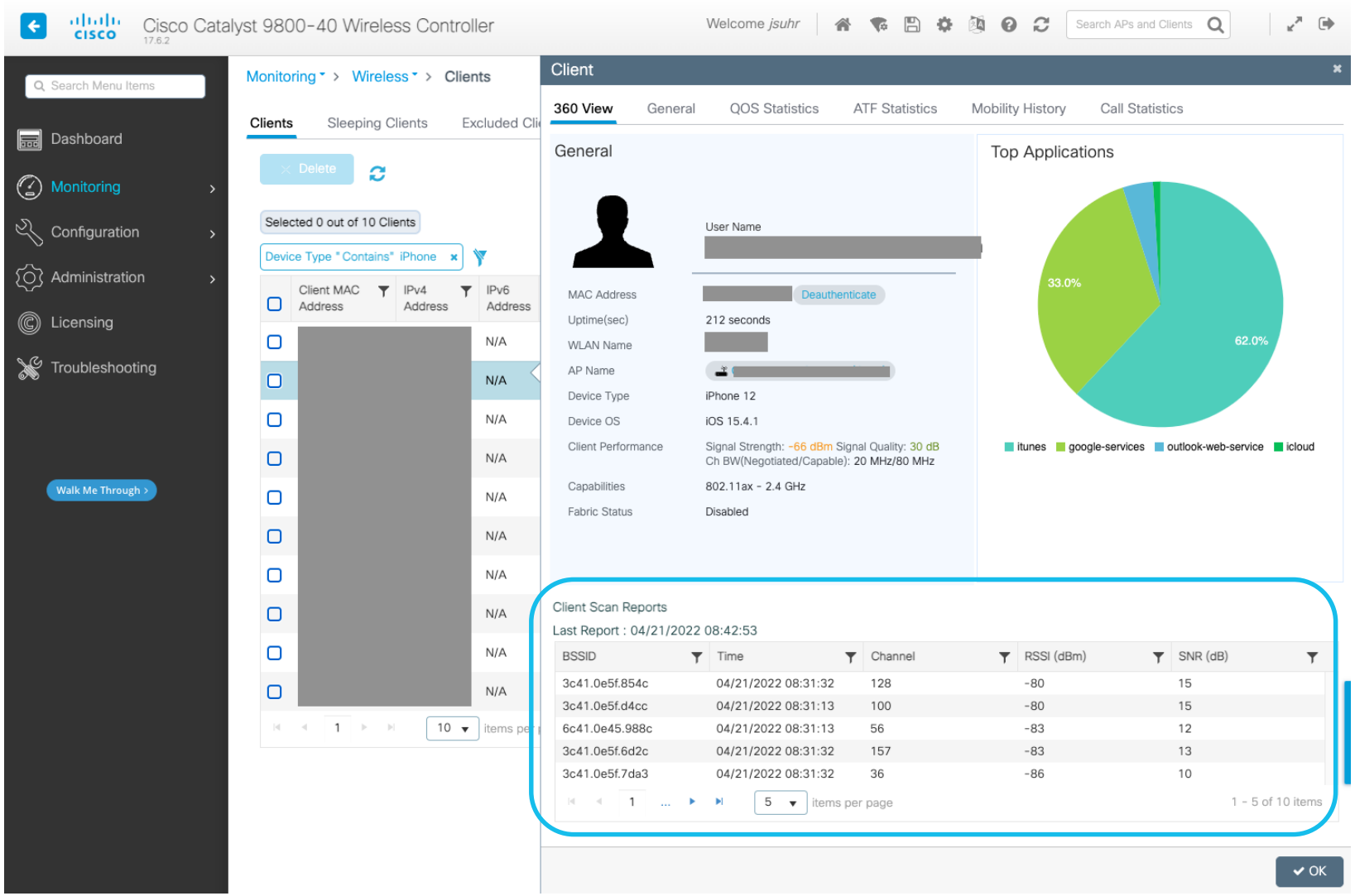
A Closer Look: AP→AP Relationships



Looking for spectrogram or waterfall graphs? These visuals are available on the previous version of this page. **View Old Version**

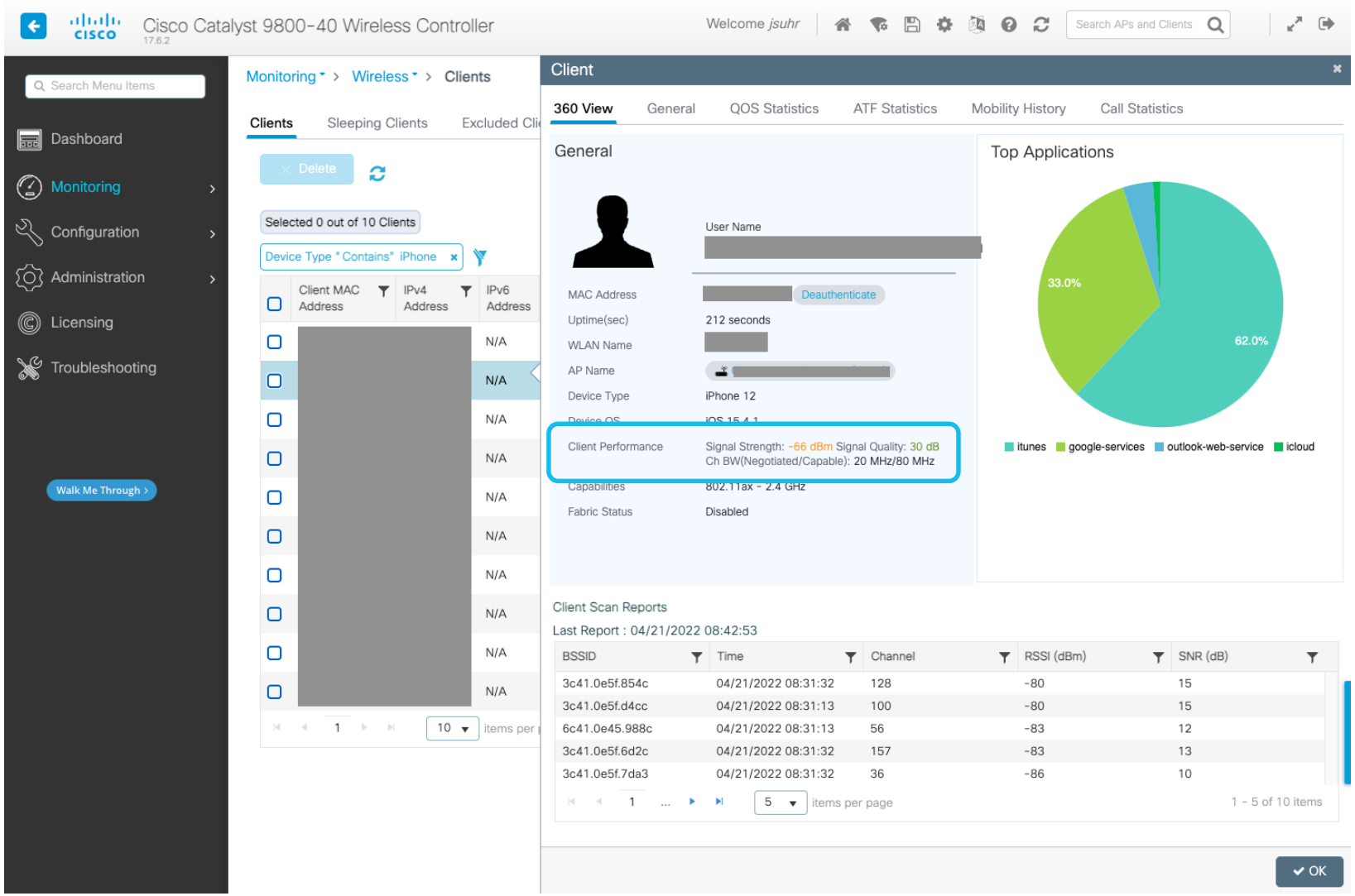
#	Interference	AP neighbor	RSSI (dBm)	Ch	Ch utilization	Active clients	Tx power (dBm)	SSIDs
1	None	Main Floor 9178i	-68	161 (40 MHz)	13.86%	2	23	5g, 371b08, 5g-no11r, 6g, IoT, 371b10
2	None	Upstairs Office 9178i	-71	36 (40 MHz)	5.9%	1	23	IoT, 6g, 5g, 371b08, 371b10, 5g-no11r

How Clients Hear AP's – C9800 UI



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

How AP's Hear Clients – C9800 UI



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

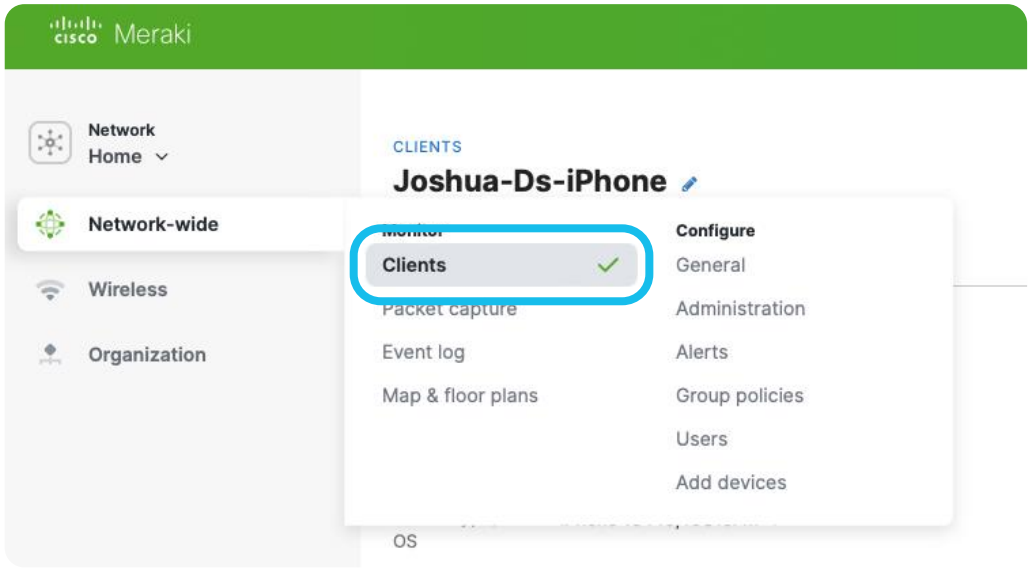
For a detail on a single client, at AP CLI:

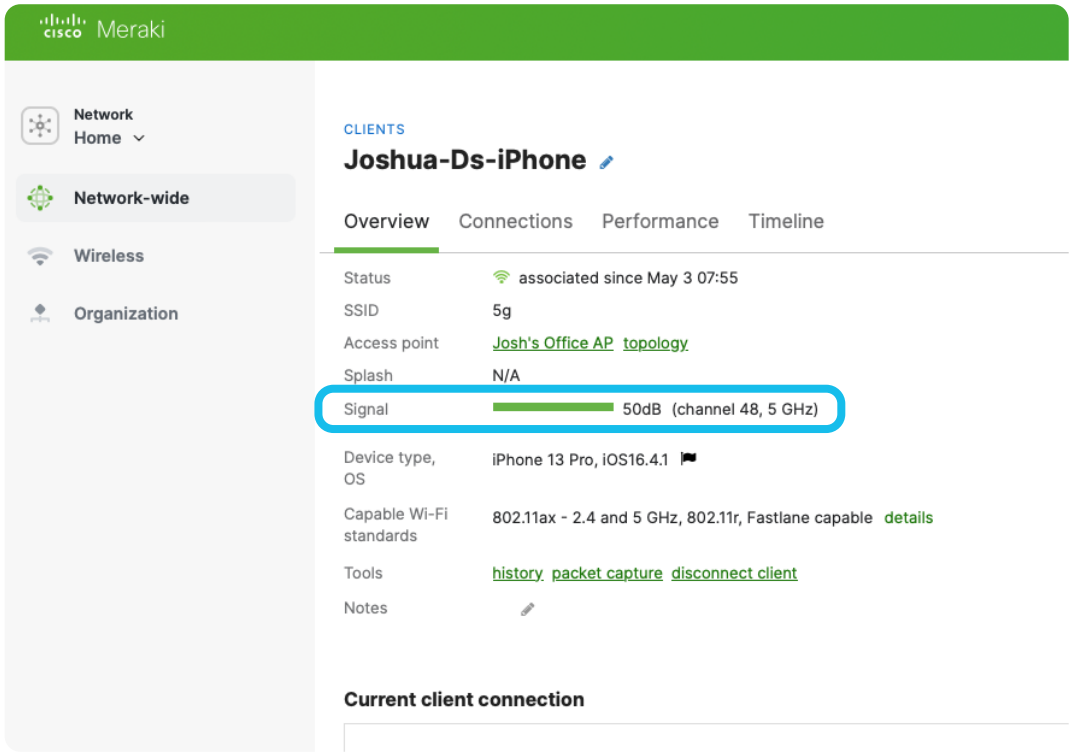
Telnet/SSH to AP and use "show controller d <0|1> client <mac-addr>" for immediate client RSSI readings of a single client

```
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: Cloud-Managed AP





Hidden Slide – For Your Reference

AP + Antenna Selection

RF Design: AP & Antenna Selection

AP & 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 CW9179F)

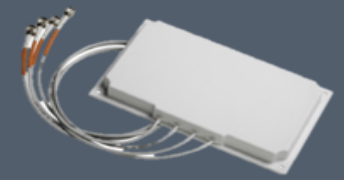
Antenna Placement:

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

Directional AP/Antenna Selection

	AP/Antenna	Beamwidth	Approx. Distance
	**Integrated AP + Directional Antenna** CW9166D1 (WiFi 6E) / Indoor *Cloud- or On-Prem-managed*	2.4: 70° 5GHz: 70° 5GHz XOR : 60° 6GHz: 60°	15’/5m – 30’/10m from AP to clients
	**Integrated AP + Directional Antenna** CW9176D1 (WiFi 7) / Indoor *Cloud- or On-Prem-managed*	2.4: 80° 5GHz: 70° 6GHz: 70°	15’/5m – 30’/10m from AP to clients
	**Dual-Band “Wide” Patch Antenna** **AP: 9120AXE/P, 9130AXE** **Antenna: AIR-ANT2566P4W-R**	2.4GHz: 105/70 ° 5GHz: 125/60°	< 30’ / 10m from AP to clients
	**Integrated AP + Antenna: High Gain** CW9179F / Indoor or Outdoor* *Cloud- or On-Prem-managed*	2.4GHz: 70° 5/6GHz: 70x35 (Wide) 5/6GHz: 35x35 (Narrow)	Primary overhead coverage (i.e. seating areas / conference halls; **<u>> 30’/10m, <200’/60m to clients</u>**

**Outdoor CW9179F installation requires separate Environment Pack*

All About the CW9179F (!)

CISCO WIRELESS

Launching at Cisco Live!!

Industry's first Wi-Fi 7 access point for large venues

Wi-Fi that reaches everywhere

Wi-Fi 7 speed and performance for everyone in the audience and more

Designed for every venue

Indoor/Outdoor, concourse-ready and multi-use all-in-one, integrated access point

Configurable and flexible installation

Comprehensive coverage to get the best value from your install

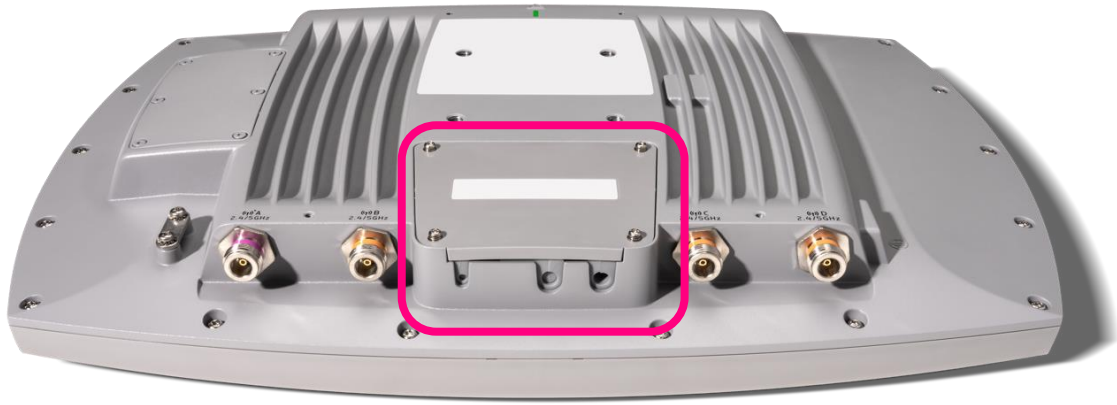
On-Prem or Cloud-Managed

One PID, flexible management options

CW9179F

CW9179F – Indoor & Outdoor Usage

Indoor Deployment / LPI Mode	Outdoor Deployment / SP Mode (with Environment Pack)



***Environment Pack**: Weatherizes & Signals to AP that it is Standard Power only*

CW9179F – Back-Facing Infill (2.4GHz / 5GHz-Low)

5GHz (H) + 6GHz

2.4GHz / 5GHz (L)

*New antenna example
CW-ANT-T-D3-N

CW9179F: Key Things to Know

WiFi 7, “Swiss Army Knife” / Stadium / LPV Indoor/Outdoor AP

Antenna Design Improvements	Cover Clients from Long Distances (up to 200’ / 60m line-of-sight)
Integrated Unit, Outdoor-Rated	AP + Antenna all-in-one, no enclosures required, outdoor-rated
Deployment Flexibility	Choose between narrow/wide beams, meet the needs of multiple different coverage types
Indoor or Outdoor	Use the Environment Pack to convert from indoor to outdoor deployment capability

CW9179F: Deployment Checklist

Physical Installation	Indoor (default) vs. Outdoor (requires Environment Pack) GPS/GNSS signal accessibility (external antenna available) Front-and-back mode – antenna selection Portrait & Landscape installation orientations
Channel & Power Planning	Tx power balance between 5GHz slots
Beam Configuration	Plan & configure beam modes per survey data

CW9179F: Balancing 5GHz Power

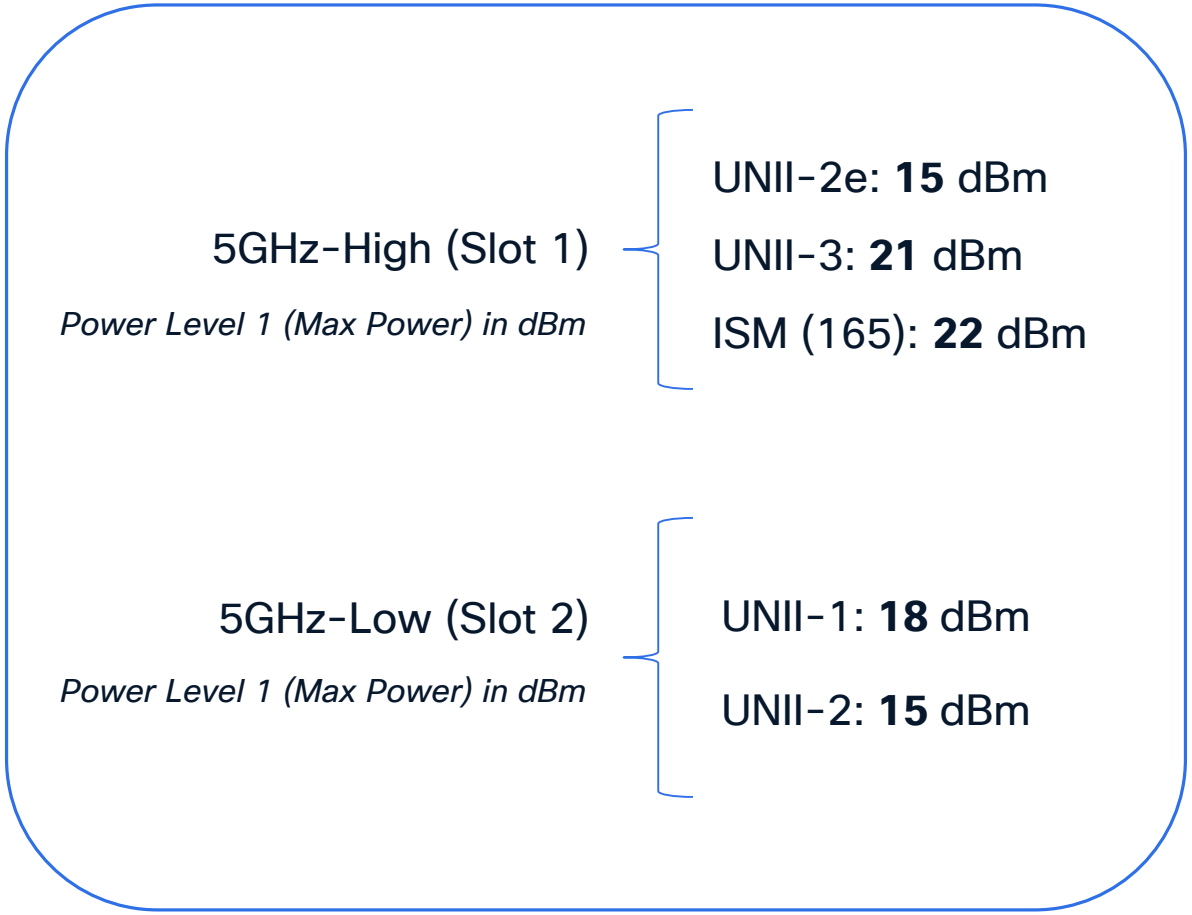
Key Considerations

- 5GHz slots are band-locked and will vary in Tx power
- Not quite as big of a concern in Wide mode with -15 / +15 degrees of separation for the 5GHz cells
- In Boresight (Narrow) mode – this means overlapping 5GHz cells that may have different Tx Power values (in dBm)
- The “hotter” slot will take more clients

What to do

A) Use this to your advantage where possible (e.g., portrait mode / use Slot 1-UNII3 for longer throw areas)

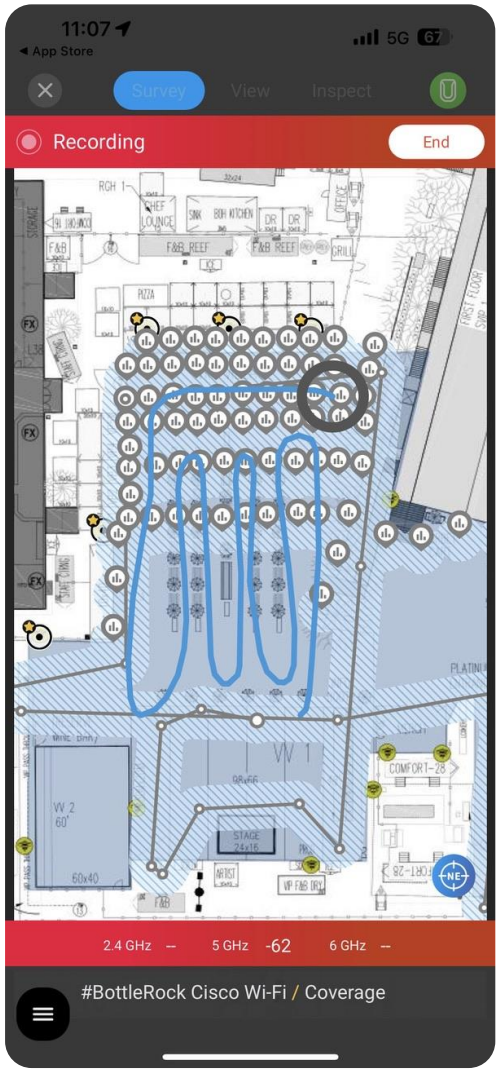
B) Use min/max TPC or set static Tx power, paying attention to dBm values, to ensure the two slots are as close to each other as possible



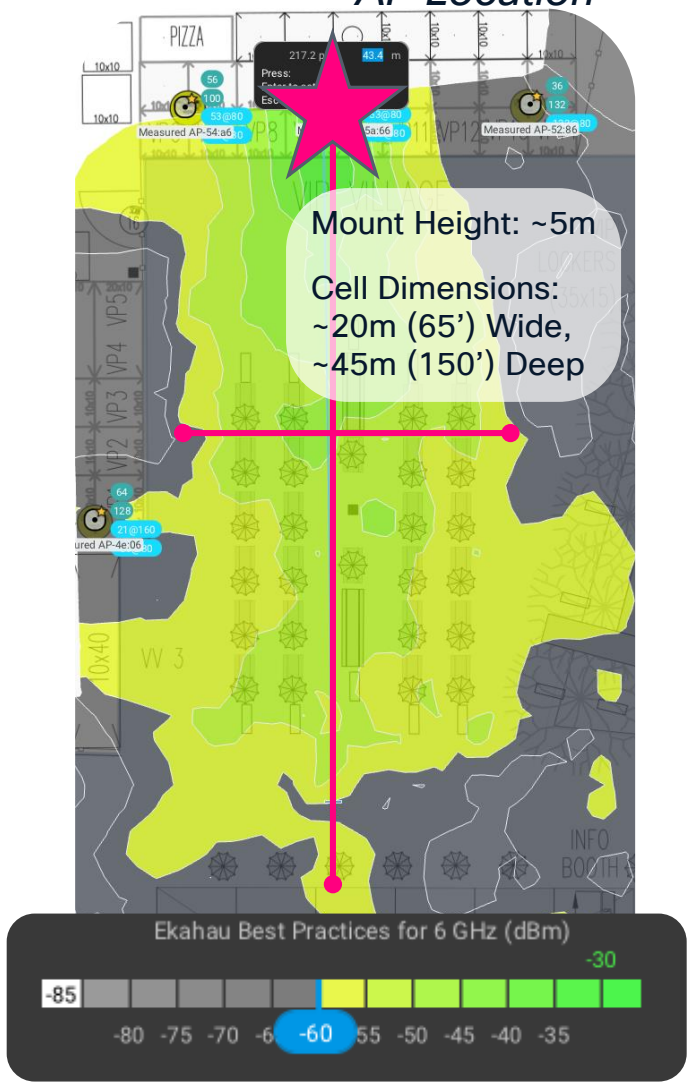
Hidden Slide – For Your Reference

CW9179F – Real World Data

6GHz – Boresight Beam Mode



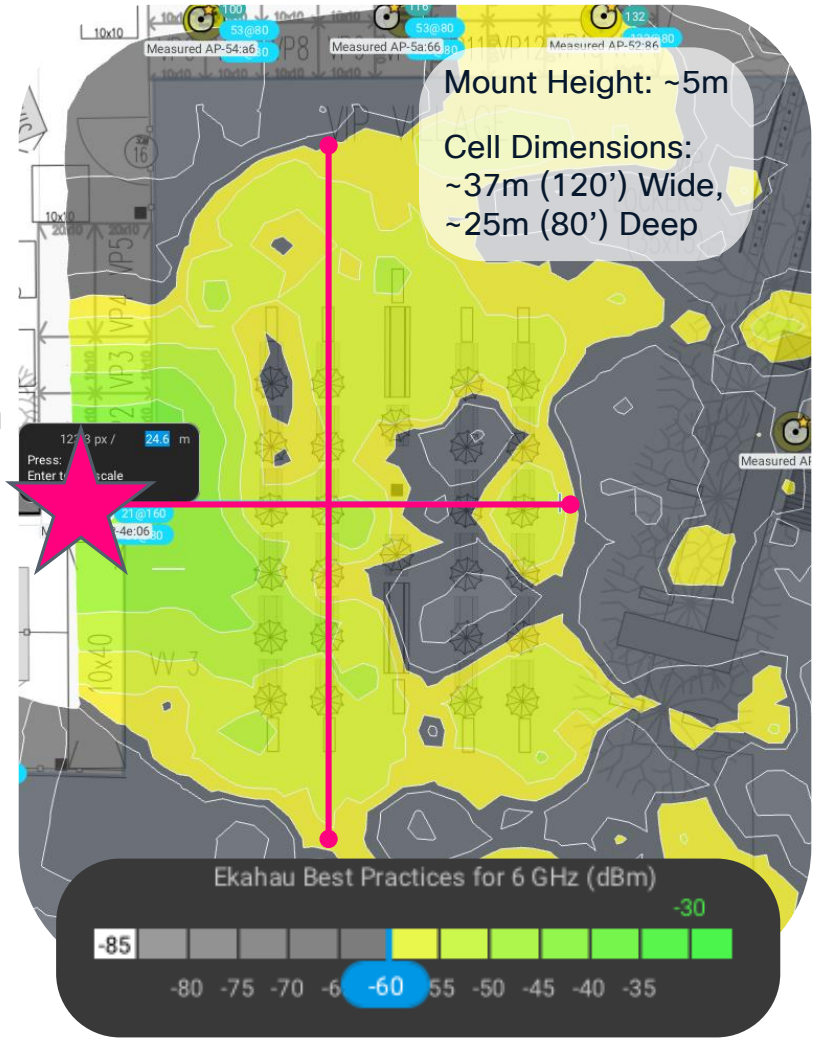
AP Location



CW9179F – Real World Data

6GHz - Wide Beam Mode

AP Location

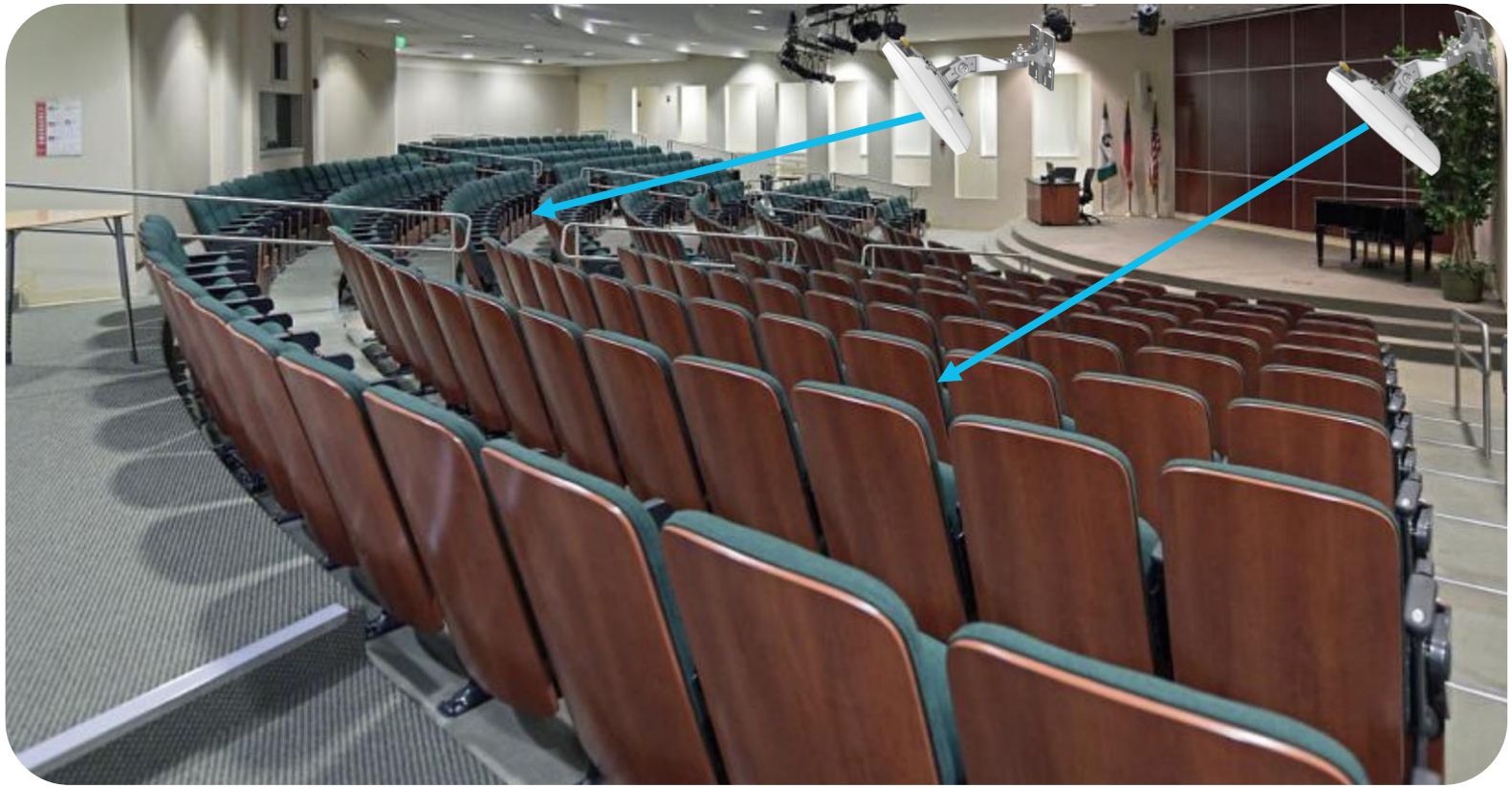


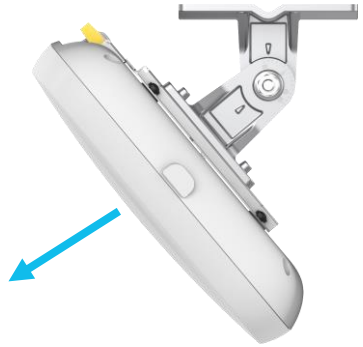

JaM CABERNET
BOTTLEROCK


MOUNTAIN WATER
STILL DRINKING WATER
Liquid Death
SPECTRUM
Spectrum Live
Spectrum History
Speed
Video
Downstream
Map
VPN

AP + Antenna Placement

Classrooms & Auditoriums





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

Directional antennas (e.g., CW9176D1) strongly preferred over omnis

Conference Halls, Airports, Open Atriums

High Density Open Areas – Conference Halls, Classrooms

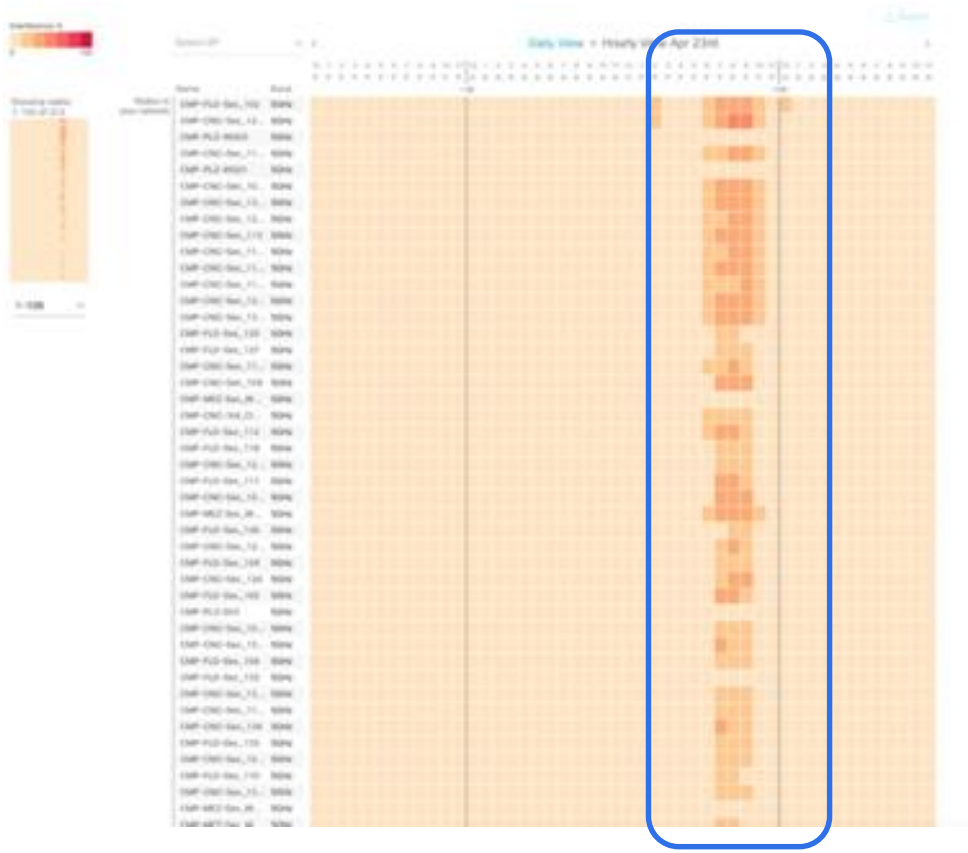
- Omnis not advised for open, high-ceiling areas where high capacity is needed
- Create smaller cells with directional antennas mounted above, aimed directly downward
- Understand RRM implications of this type of design – it may not work as you expect

Performance Comparison: Overhead / Under-Seat

Time of event

Under Seat / Omni

Time of event



Overhead/Directional

Red = High CCI / Poor Performance

Why directional?

A recent airport example, omnis everywhere...

Many radios at max client count

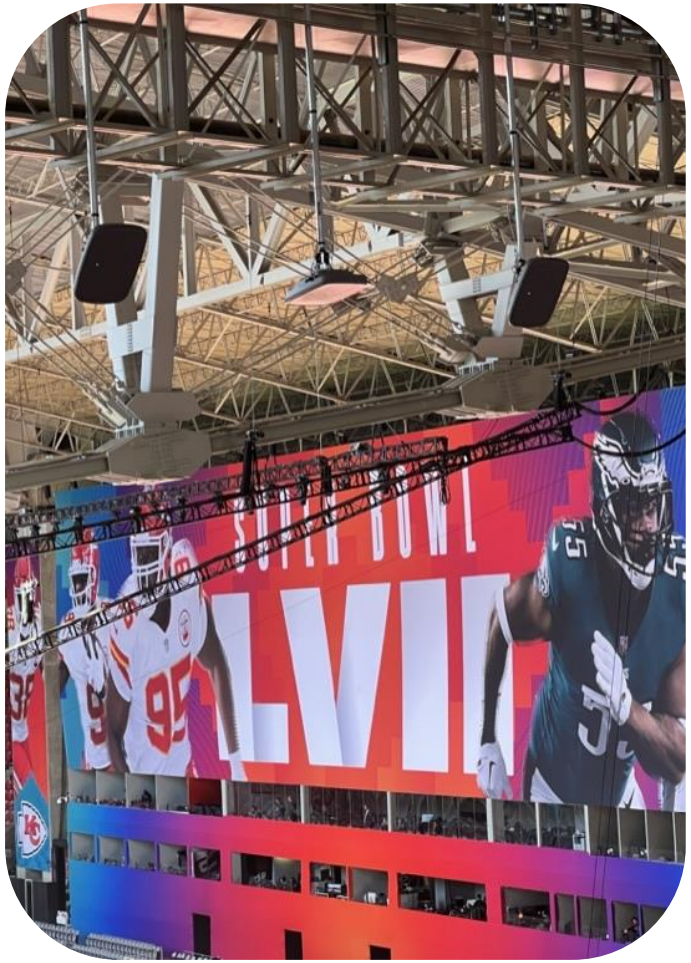
40MHz channel width

Persistently high channel utilization
(even on low-client count APs)

Signal	SNR	Channel	Channel Utilization	Stations	Channel Width
-66 dBm	26 dB	100	86%	101	40 MHz
-53 dBm	40 dB	112	72%	200	40 MHz
-80 dBm	11 dB	100	72%	200	40 MHz
-74 dBm	19 dB	112	60%	200	40 MHz
-68 dBm	25 dB	100	58%	108	40 MHz
-73 dBm	23 dB	56	57%	200	40 MHz
-90 dBm	2 dB	44	55%	200	40 MHz
-81 dBm	13 dB	56	54%	197	40 MHz
-88 dBm	11 dB	56	54%	151	40 MHz
-88 dBm	7 dB	44	53%	87	40 MHz
-88 dBm	3 dB	64	52%	186	40 MHz
-69 dBm	19 dB	56	51%	102	40 MHz
-79 dBm	14 dB	112	51%	120	40 MHz
-75 dBm	11 dB	64	50%	136	40 MHz
-85 dBm	10 dB	64	47%	149	40 MHz
-77 dBm	6 dB	112	46%	185	40 MHz
-79 dBm	14 dB	64	45%	160	40 MHz
-67 dBm	26 dB	44	43%	200	40 MHz
-78 dBm	15 dB	44	41%	152	40 MHz
-58 dBm	***37 dB***	***64***	***40%***	***200***	***40 MHz***
-44 dBm	49 dB	44	38%	189	40 MHz
-80 dBm	13 dB	44	35%	200	40 MHz
-62 dBm	31 dB	36	32%	200	40 MHz

HD AP/Antenna Selection & Placement

Summary



1. Favor directional antennas vs. omni for HD areas
2. Favor overhead placement vs. near-proximity
3. Favor clear line-of-sight from clients to antennas
4. Consider AP-client distance when selecting antennas

6GHz Wi-Fi HD Deployment Considerations

Wi-Fi 6E + Wi-Fi 7: More Spectrum

Radio spectrum is finite! More channels = more “room” for our devices to talk to each other

Wi-Fi 6E + Wi-Fi 7: More Spectrum

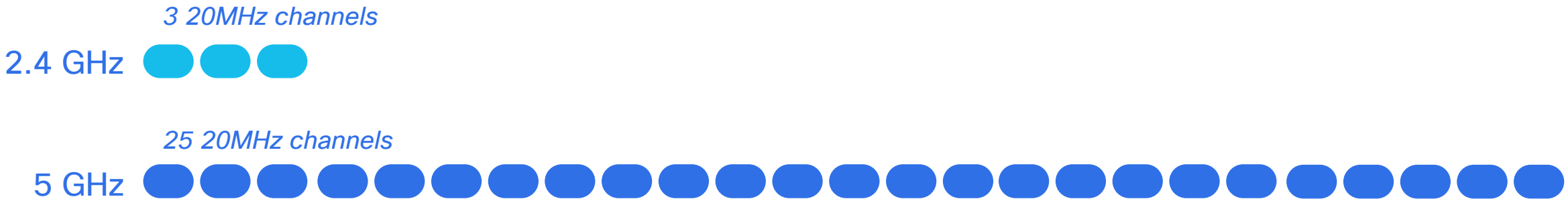
Radio spectrum is finite! More channels = more “room” for our devices to talk to each other

3 20MHz channels

2.4 GHz 

Wi-Fi 6E + Wi-Fi 7: More Spectrum

Radio spectrum is finite! More channels = more “room” for our devices to talk to each other



Wi-Fi 6E + Wi-Fi 7: More Spectrum

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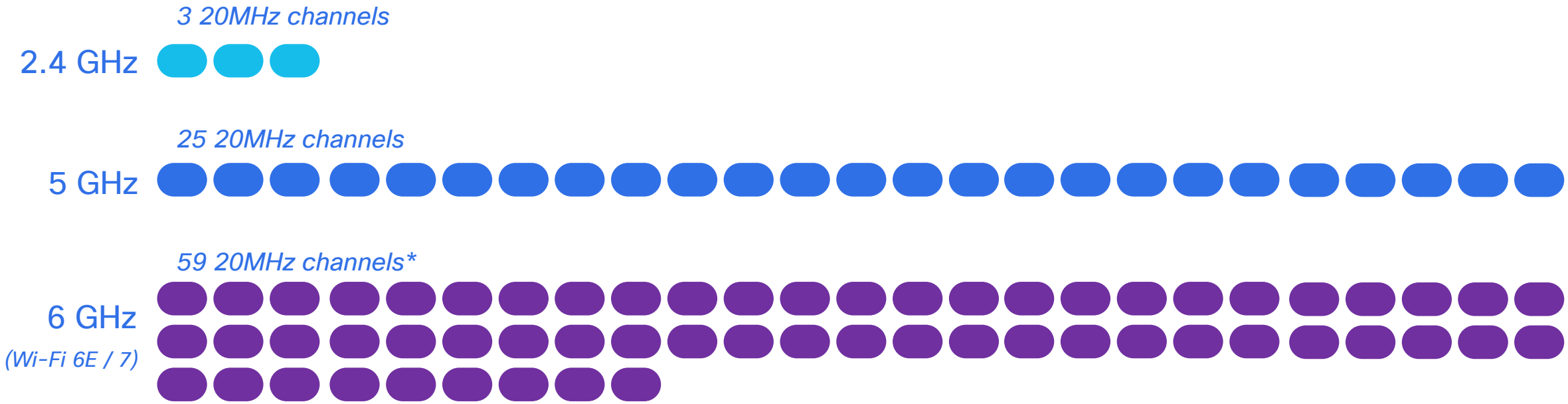
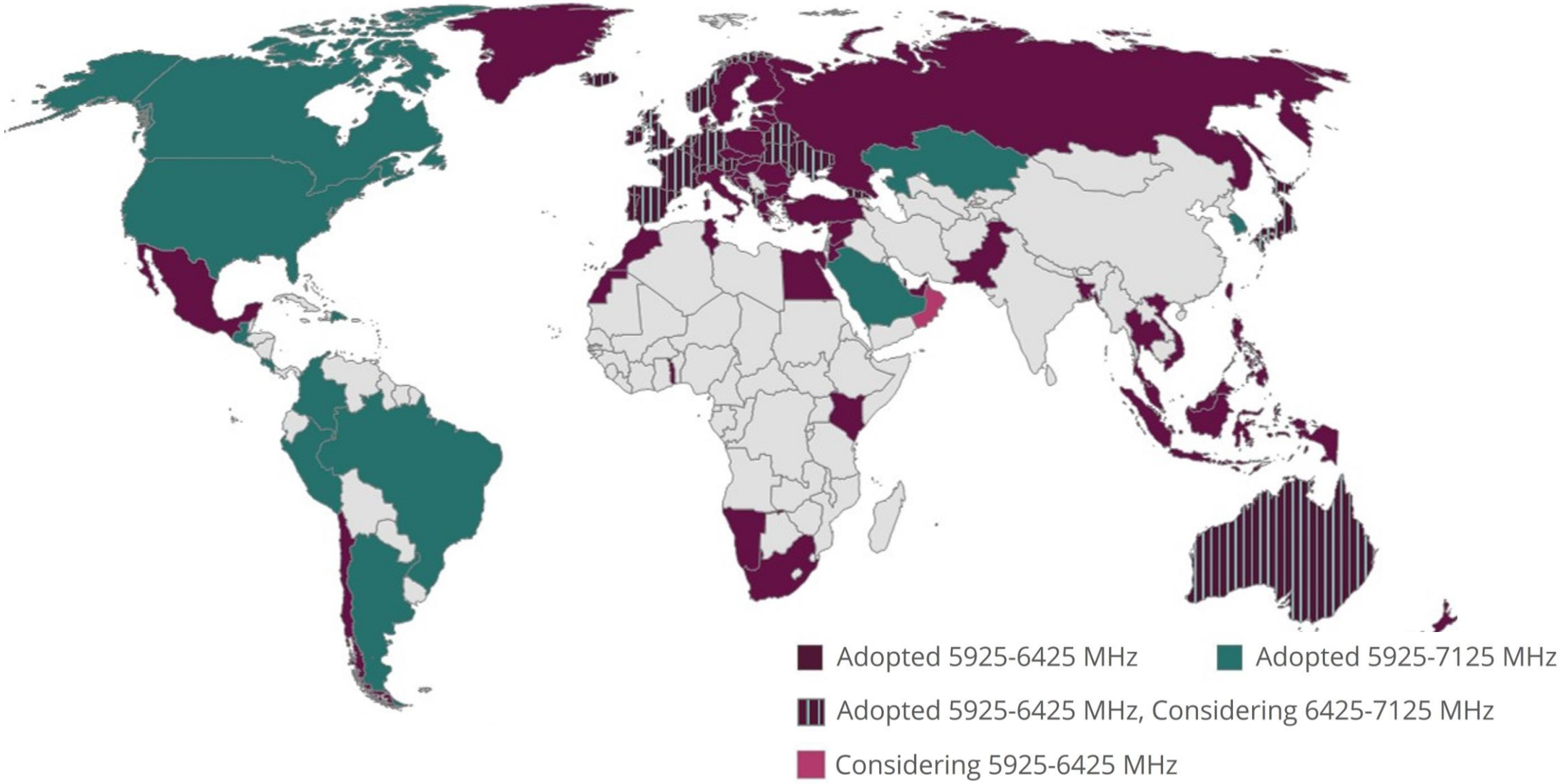


+ many protocol improvements for speed & efficiency

*Region-specific views: https://www.wi-fi.org/regulations-enabling-6-ghz-wi-fi

Global availability of 6 GHz band for Wi-Fi

(https://www.wi-fi.org/countries-enabling-wi-fi-6e)



Planning for 6GHz: Key Considerations

Avoid “**salt and pepper**” designs

Preserve a stable end-user experience

Deploy 6GHz in “whole areas”, not in areas where users may constantly roam between 5GHz- and 6GHz-capable APs

Client adoption drives SSID configuration strategy

Monitor capabilities & experience of key clients

For both 6E and 7, client capabilities will be enabled at different times; unless your need for 6GHz is truly more important than client experience – favor the client experience

Low Power Indoor & Standard Power

LPI = Indoors Only, No Enclosures

When designing – ensure you understand regulatory requirements

Security Planning: WPA3 Deployment Guide

Other Session Recommendations

FULL CONFERENCE | IT LEADERSHIP

Advanced Wi-Fi Tuning: Become an Expert While Getting a Little Help from AI - BRKEWN-3413

Jim Florwick, Principal TME, Cisco - **Distinguished Speaker, Hall of Fame Elite Speaker**

Waitlist Full **Wednesday, Jun 11 | 10:30 AM - 12:00 PM PDT | SDCC - Upper Level, Ballroom 20A**

FULL CONFERENCE | IT LEADERSHIP

Understanding RF in a Wireless First World - BRKEWN-2048

Mark Krischer, Principal Wireless Architect, Cisco - **Distinguished Speaker**

Schedule **Tuesday, Jun 10 | 11:00 AM - 12:30 PM PDT | SDCC - Upper Level, Ballroom 20A**

FULL CONFERENCE | IT LEADERSHIP

Tune your Cisco Wireless networks for Roaming clients and demanding Real-Time applications...with some help from AI! - BRKEWN-2926

Jerome Henry, Distinguished Engineer, Cisco - **Distinguished Speaker, Hall of Fame Elite Speaker**

Schedule **Monday, Jun 9 | 11:00 AM - 12:00 PM PDT | SDCC - Upper Level, Room 6B**

FULL CONFERENCE | IT LEADERSHIP

Design and Deploy Cisco Cloud Managed Enterprise Wireless Networks - BRKEWN-2046

Justin Loo, Technical Marketing Engineer, Cisco

Schedule **Tuesday, Jun 10 | 11:00 AM - 12:30 PM PDT | SDCC - Upper Level, Room 28AB**

FULL CONFERENCE | IT LEADERSHIP

Wi-Fi 7 is Here - Are you Ready? - BRKEWN-2025

Anand Gurumurthy, Sr. Technical Leader, Technical Marketing, Cisco

Schedule **Monday, Jun 9 | 10:00 AM - 11:30 AM PDT | SDCC - Upper Level, Ballroom 20D**

EXPLORER | FULL CONFERENCE | IT LEADERSHIP

Scale and Enhance Wireless for the Enterprise - PSOENT-1018

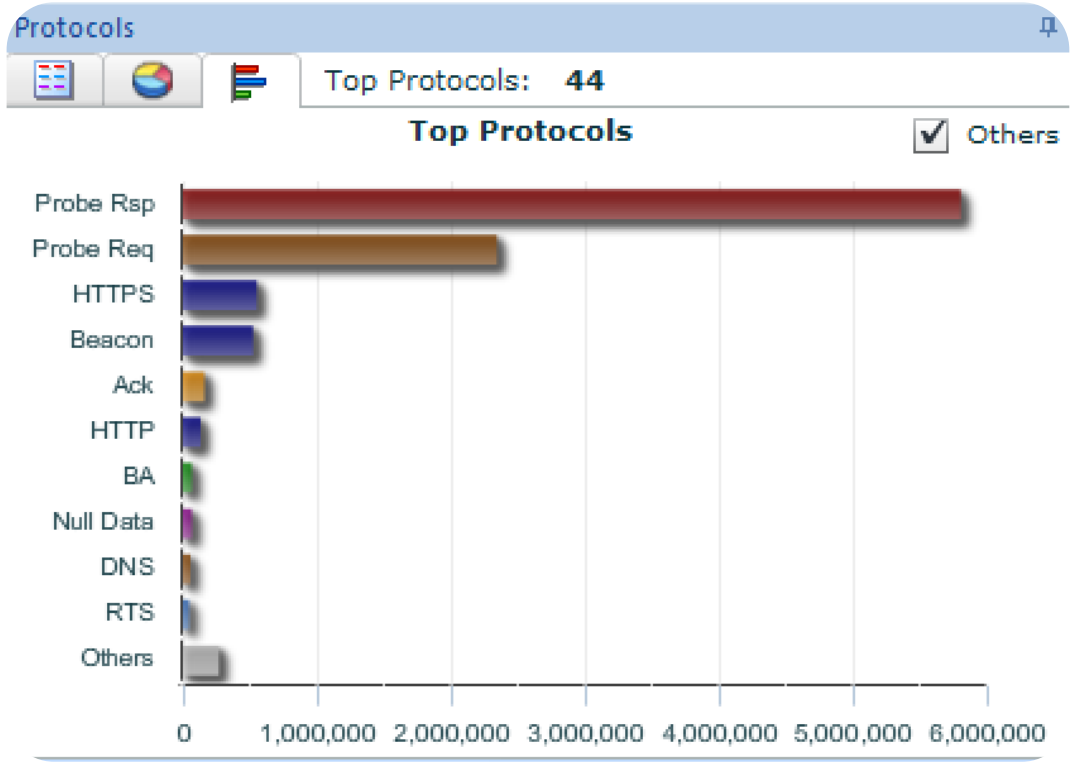
Travis Schlafke, Engineering Product Manager, Cisco
Stefani Johnson, Product Marketing Manager, Cisco

Schedule **Thursday, Jun 12 | 10:30 AM - 11:00 AM PDT | SDCC - Hall F, Cisco Theater 2**

Maximizing the Spectrum

Maximizing the Spectrum

Avoiding Excessive Management Traffic

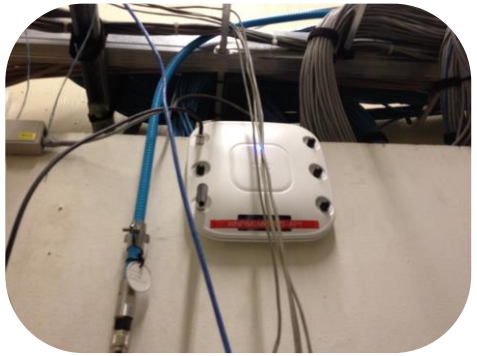


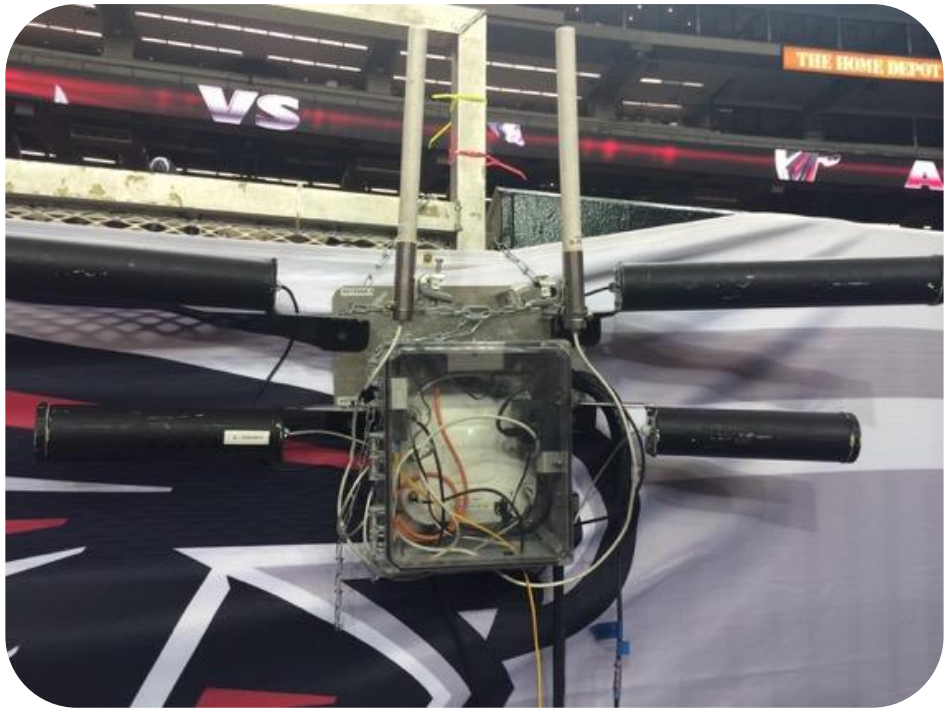
- Always aim for fewer SSIDs
  - Especially in high density areas
- **More SSID's = Worse Performance**
- Why?
  - Each SSID requires a separate beacon
  - Each SSID will beacon at the minimum mandatory data rate
  - Radios will respond to null probe requests for each broadcast SSID
  - **Exponential**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

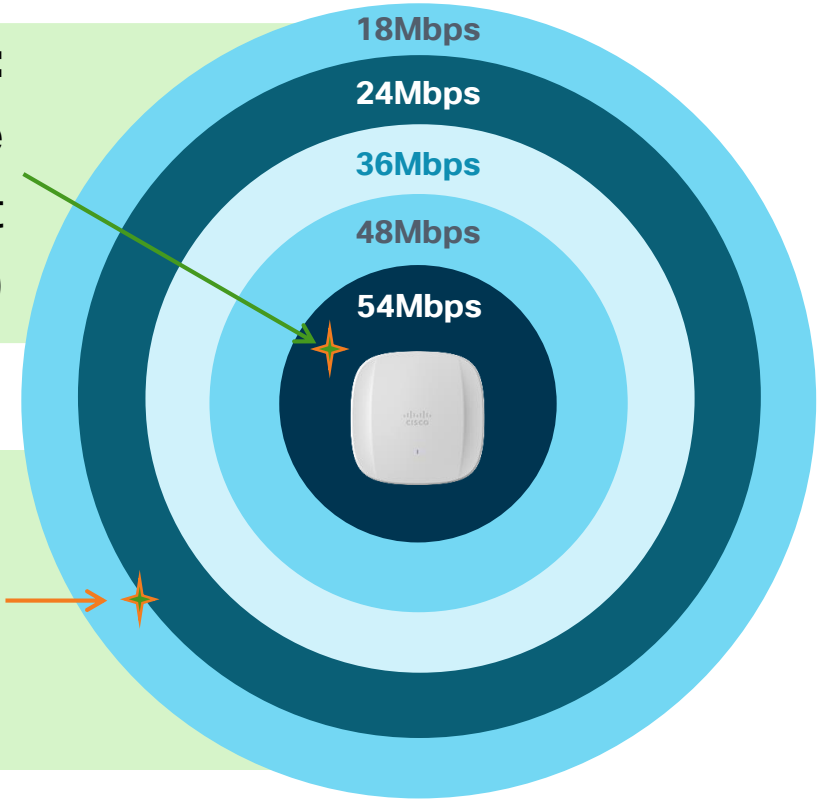




Maximizing the Spectrum

PHY Rate Tuning: Why PHY Rates Matter

Client near AP:
Higher PHY Rate
More Efficient
(high signal-to-noise ratio)



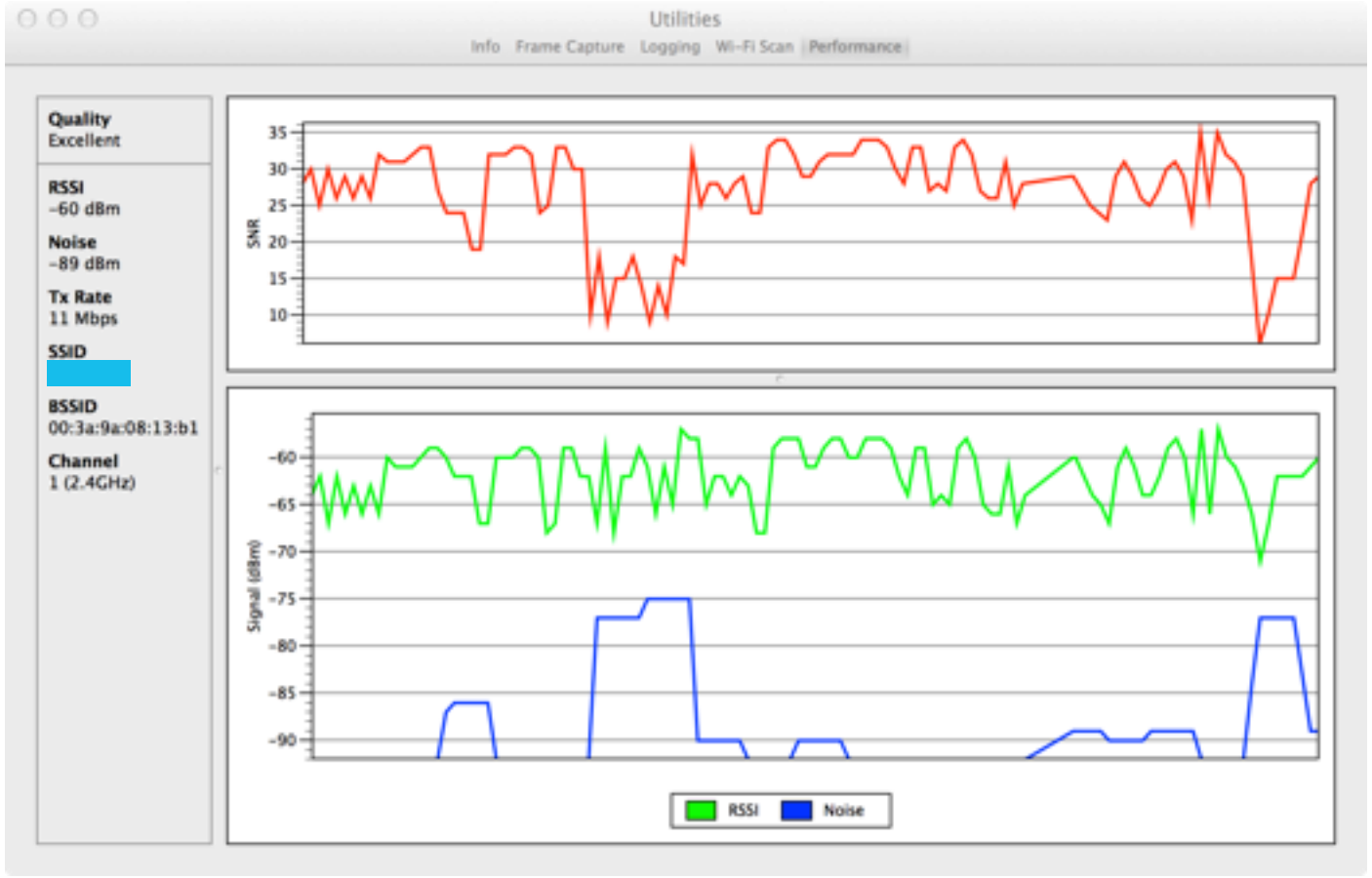
Client far from AP:
Lower PHY Rate
Less Efficient
(lower signal-to-noise ratio)

- 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



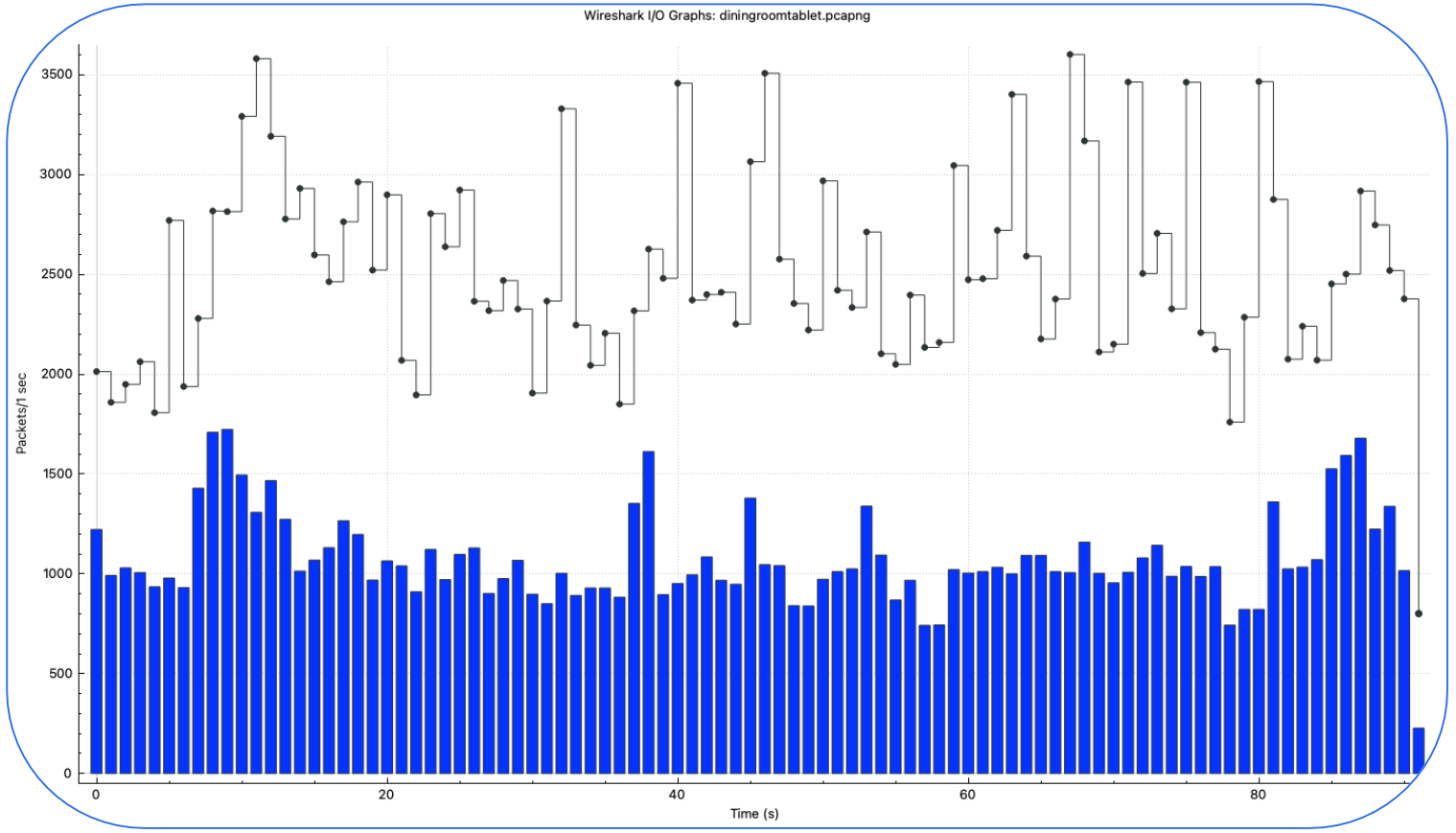
Maximizing the Spectrum

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

	Before Optimization	After Optimization
	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%

- Optimized PHY rates
- Carefully optimized RX-SOP

(stay tuned ☺)

Maximize your Spectrum

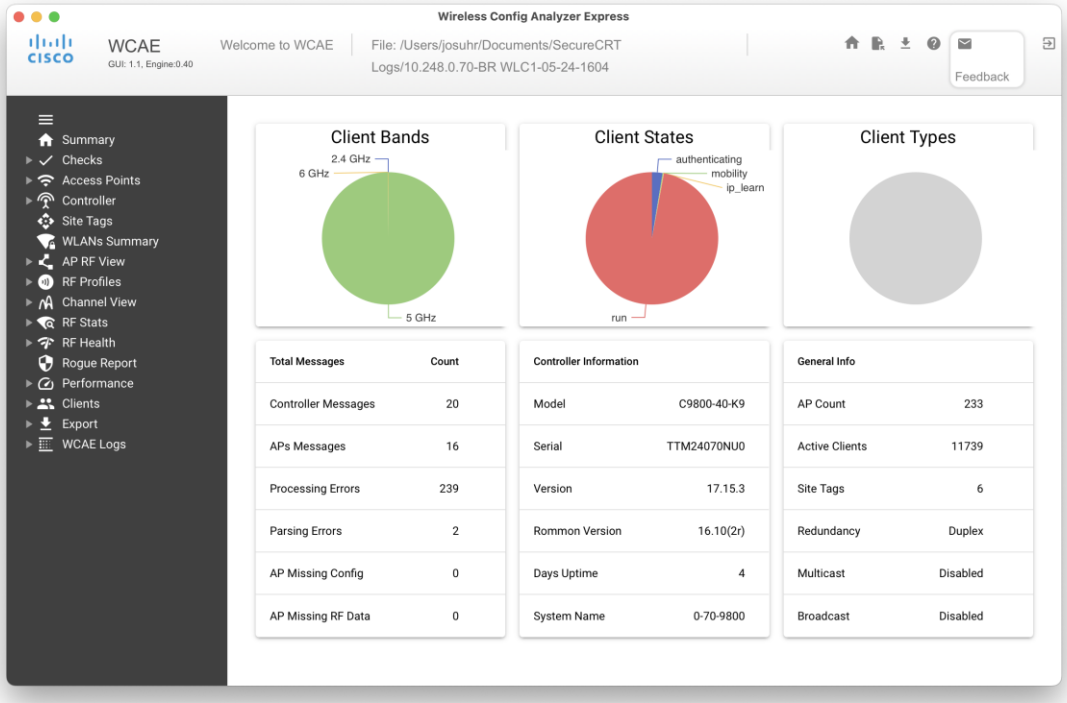
Summary

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

Config Basics:
RF Profiles, TPC, DCA

First – a handy (free!) tool: WCAE

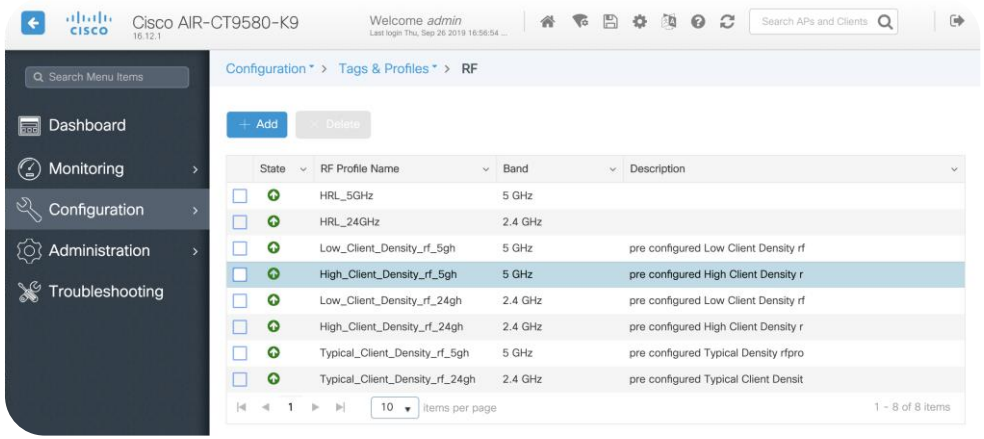
- **Wireless Config Analyzer Express** (**WCAE**) is an extremely valuable tool when validating and optimizing a Cisco Wi-Fi WLC-based deployment
- **Feed your WLC "show tech wireless" output to WCAE and it will help you:**
  - Find and troubleshoot problems quickly
  - Identify top areas for RF optimization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

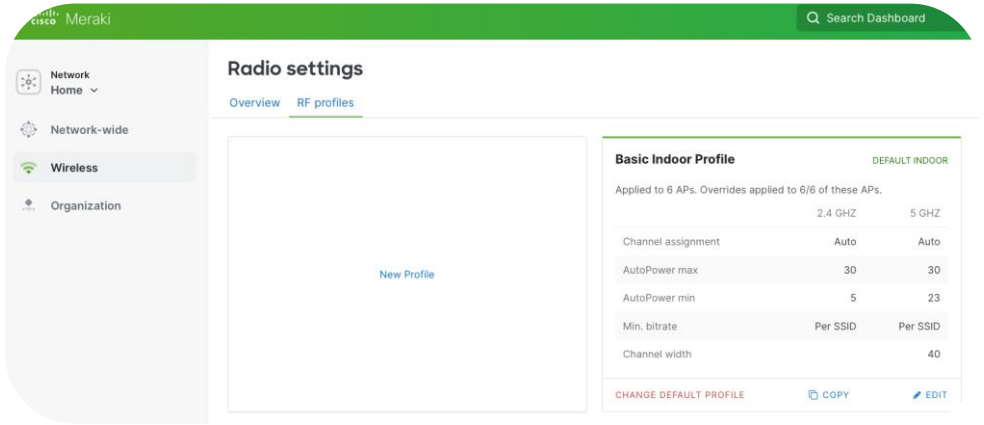


Download: https://developer.cisco.com/docs/wireless-troubleshooting-tools/

More info: Cisco Live Amsterdam 2025 – BRKEWN-3006

High Density WLAN Features & Configurations

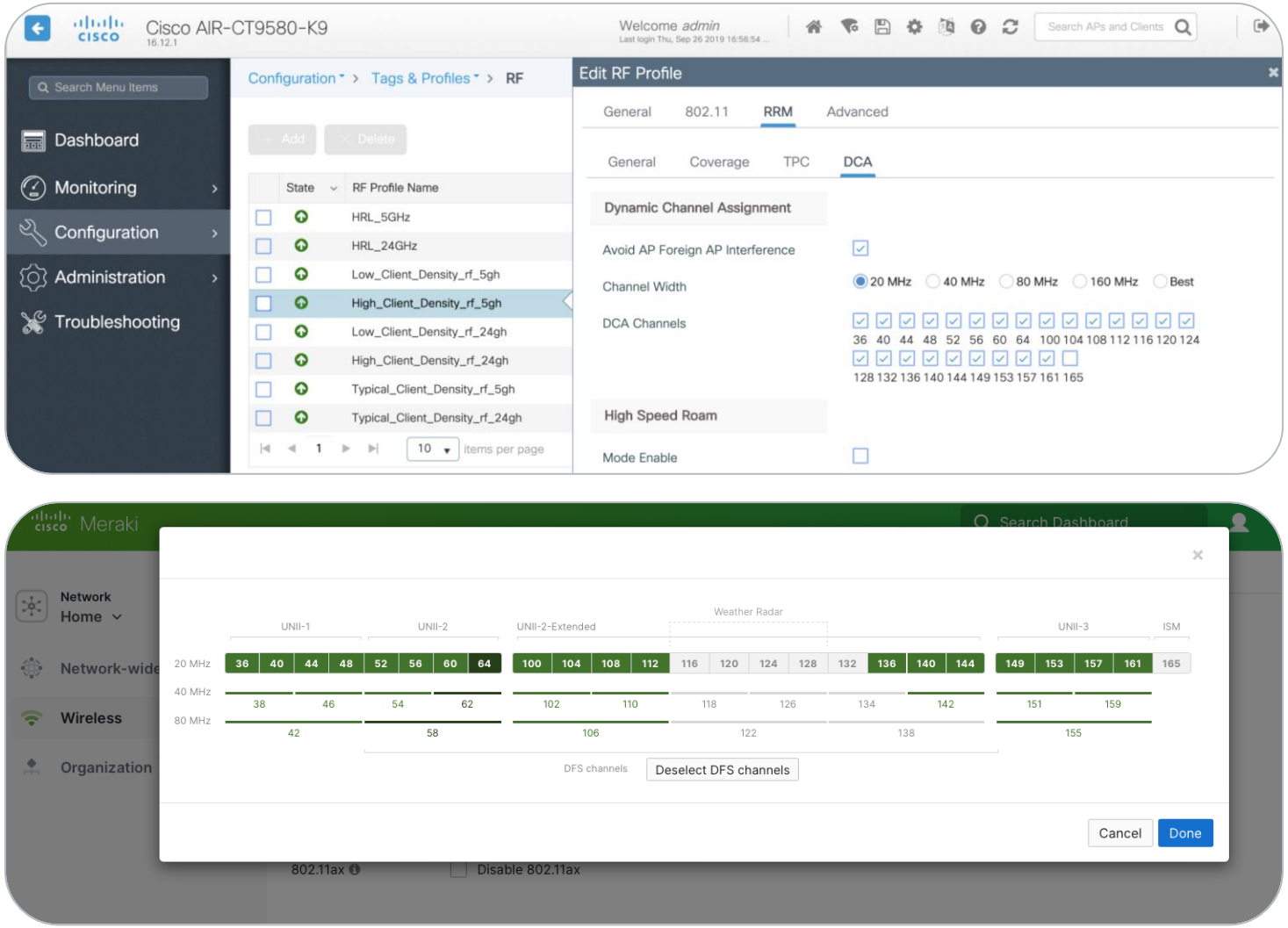




- WiFi deployments **are not "one-size-fits-all"**
- **Use RF Profiles** on both On-Prem and Cloud-Managed deployments for granular RF control
  - **Configure network-wide channel parameters:** remove channels as needed, set channel widths
  - **Configure transmit power min/max:** ensure balance, avoid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

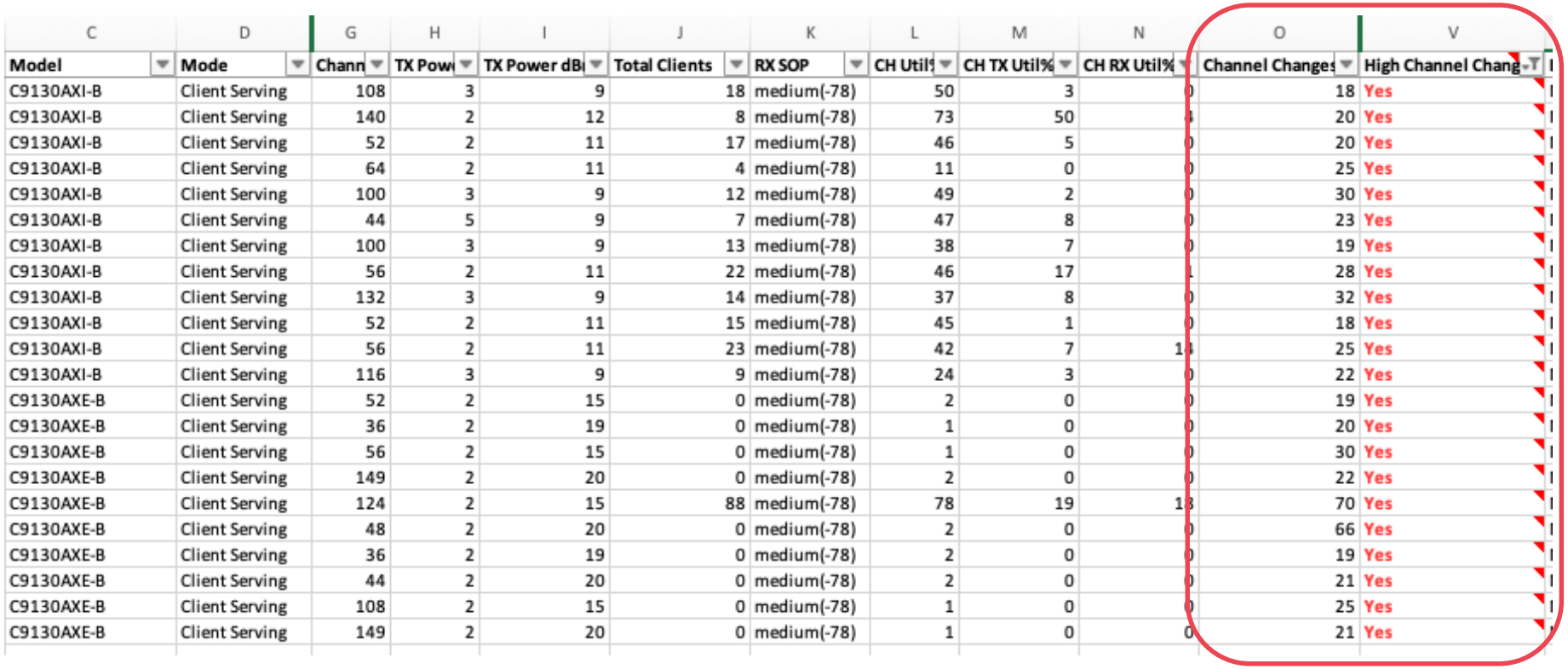
Channel Planning with RF Profiles

- 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

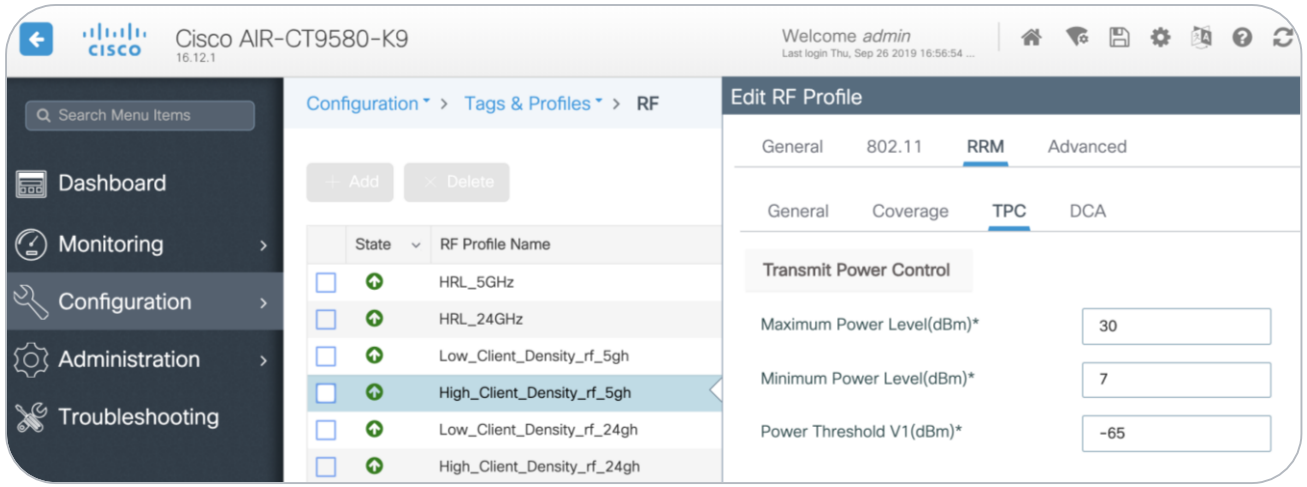


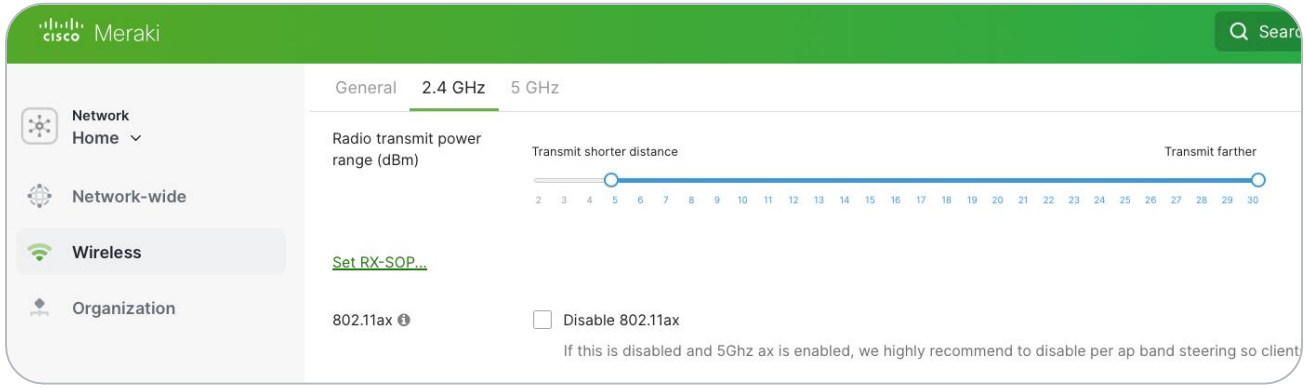
C	D	G	H	I	J	K	L	M	N	O	V
Model	Mode	Chann	TX Pow	TX Power dB	Total Clients	RX SOP	CH Util%	CH TX Util%	CH RX Util%	Channel Changes	High Channel Chang
C9130AXI-B	Client Serving	108	3	9	18	medium(-78)	50	3	0	18	Yes
C9130AXI-B	Client Serving	140	2	12	8	medium(-78)	73	50	4	20	Yes
C9130AXI-B	Client Serving	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	1	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.





Identifying Possible Power Imbalance

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

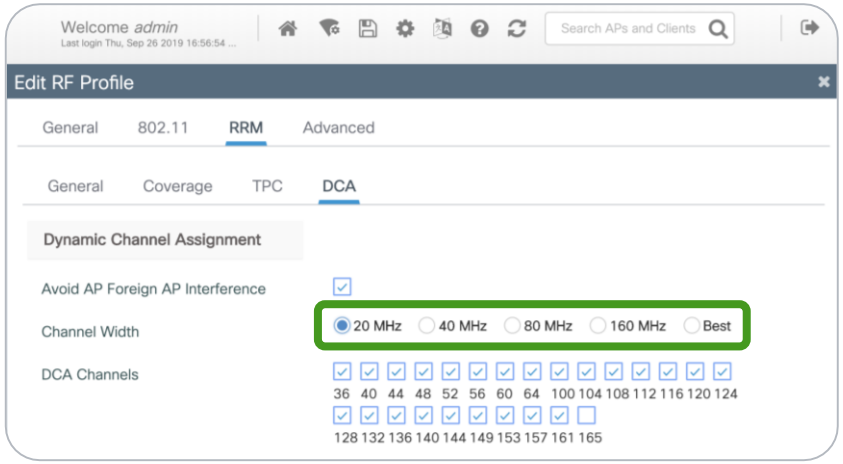
Name	Slot	Band	Channel	TX Power	TX Power dBm	Total Clients
AP1	1	5	100	1	17	21
AP1	2	5	48	1	23	70

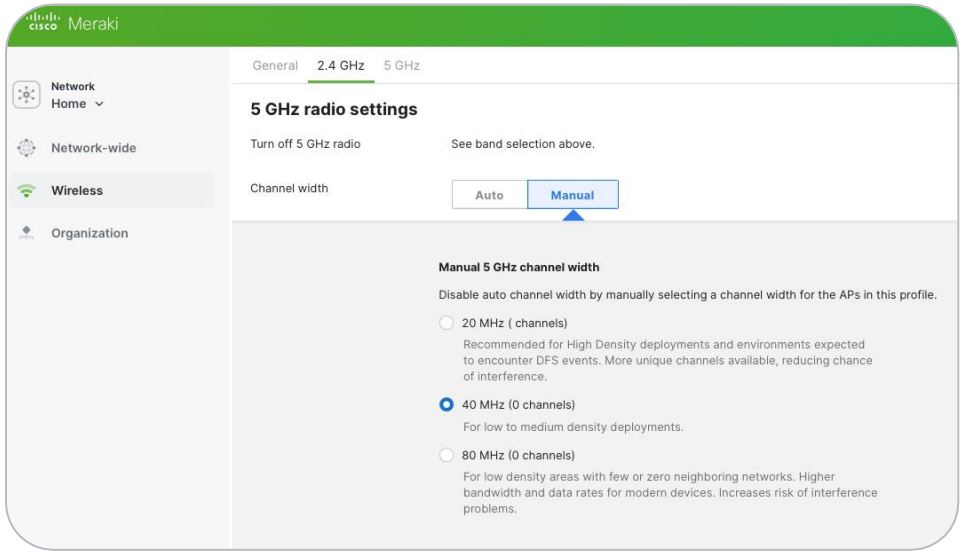
6dB power difference = client imbalance

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

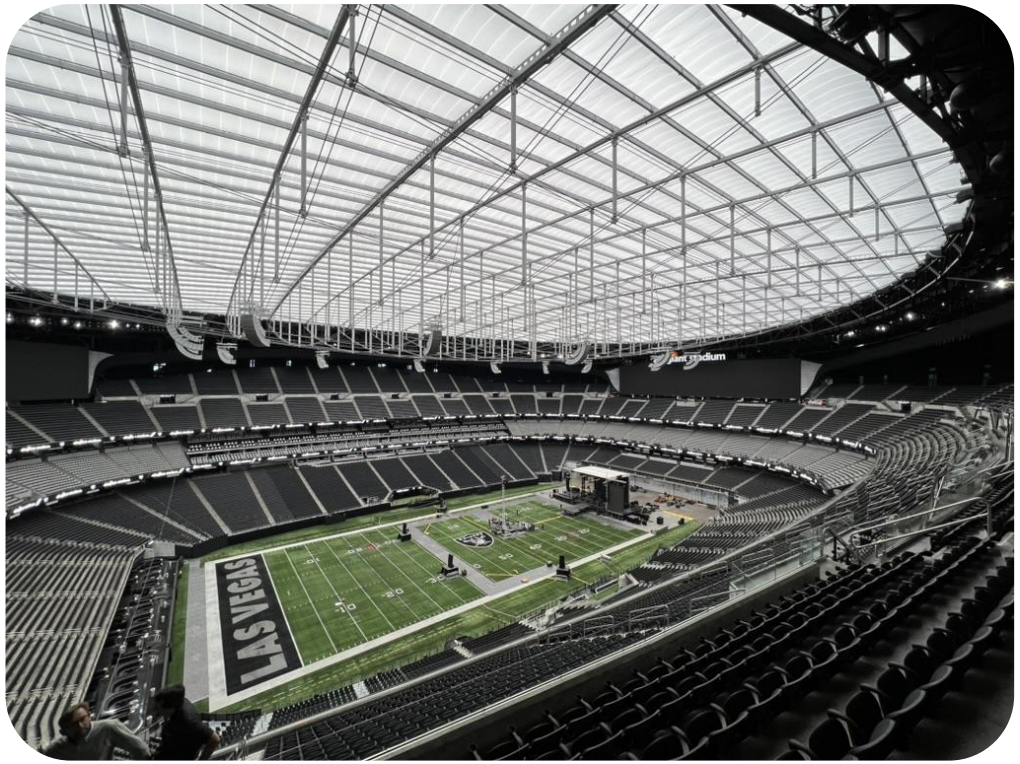
- In general, **20MHz channels** provide the most channel reuse (capacity) for high density environments
- **Wider channels may be used selectively** in more isolated areas – smaller classrooms, lobbies, conference rooms, etc.

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!)

Site Tags & Balancing AP Load on 9800

Key Considerations



In High Density Deployments – **balance your APs across Site Tags.** Do not use the default site tag.

Site Tag does not necessarily equate to a physical “Site”!

Site Tag assigns an AP to a WNCd (9800 logical processor)
(# of available WNCd’s differs per HW platform)

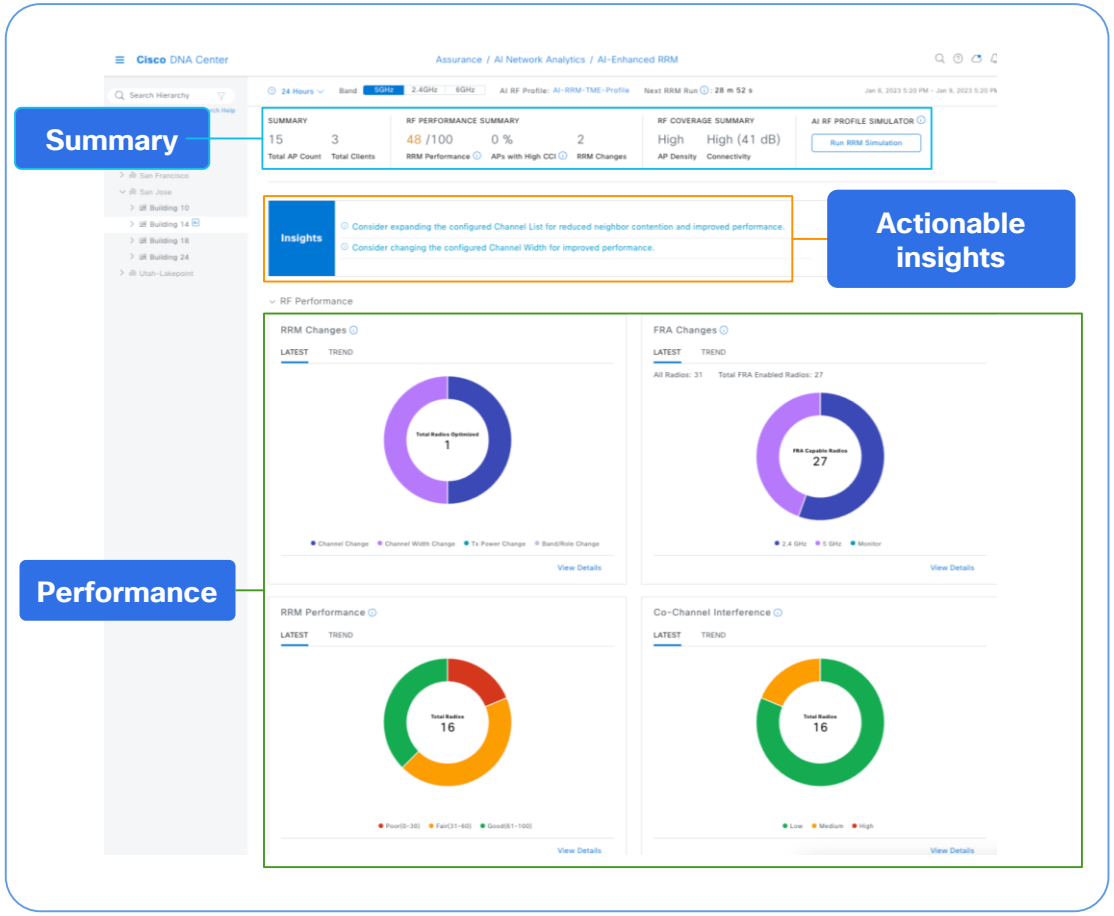
Organize Site Tags into approximate roaming domains

Refer to the C9800 Best Practices guide for the latest guidance

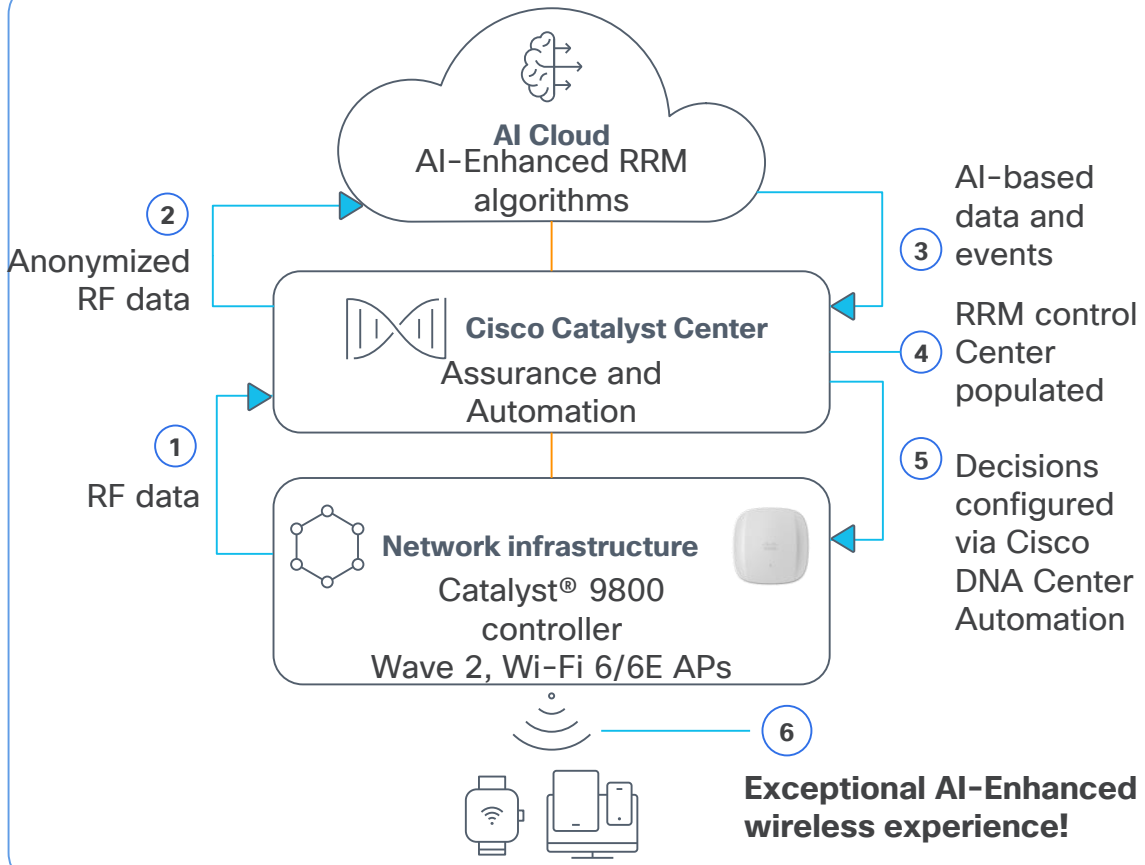
What is AI-Enhanced RRM?

AI-Driven RRM solution

Deep RF visibility & advanced control



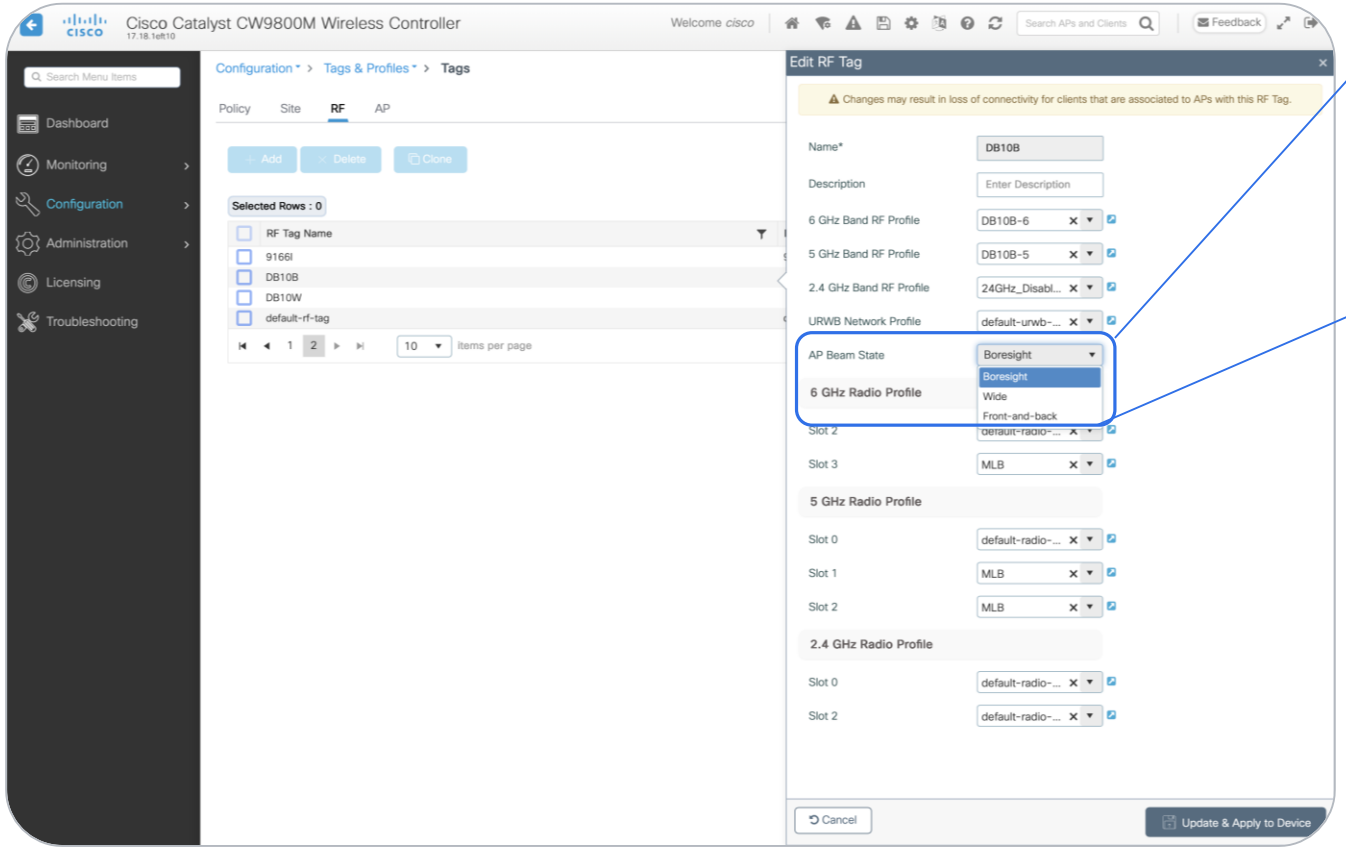
Proactive optimizations for all deployment sizes

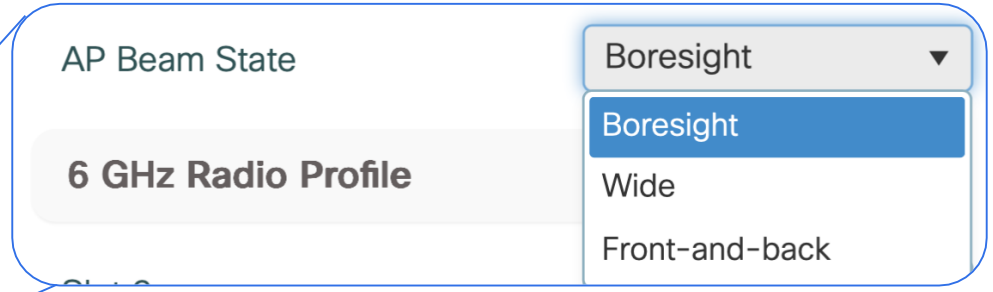


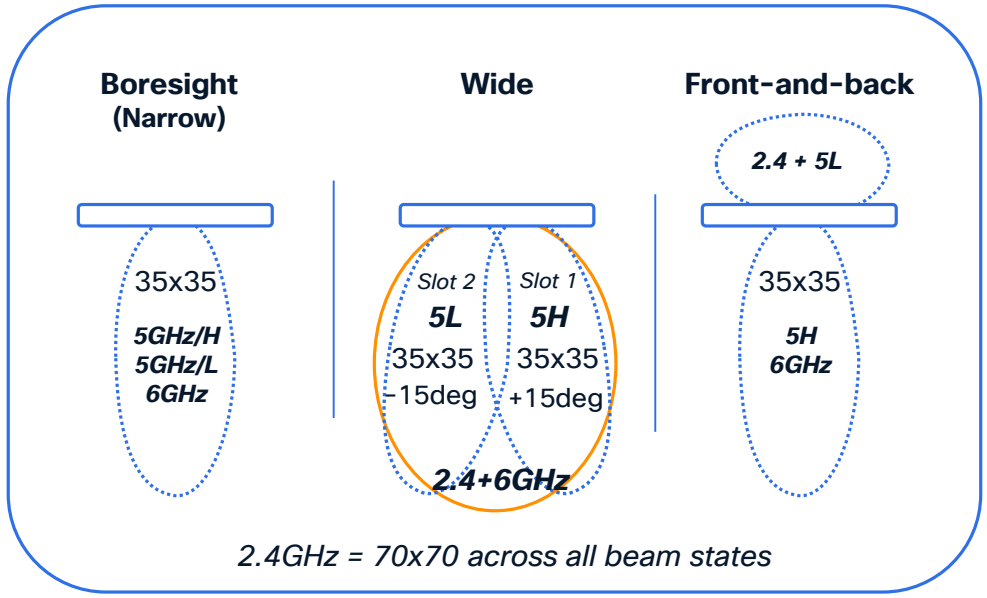
CW9179F: Config Tips

CW9179F: Beam Configuration Options

9800: Configuration > Tags & Profiles > Tags > RF



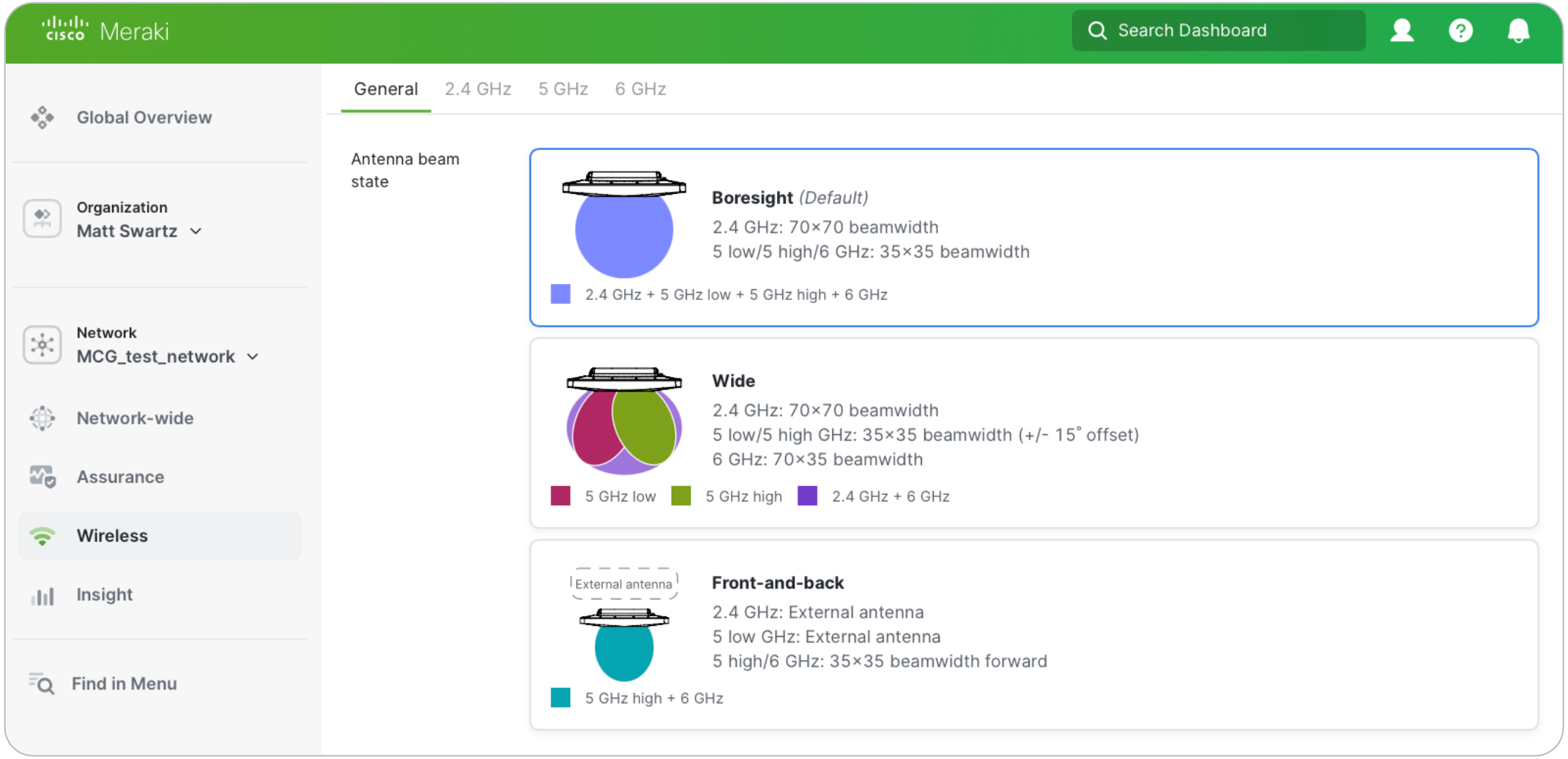




Note: Radio Profiles **are not applicable** to CW9179F

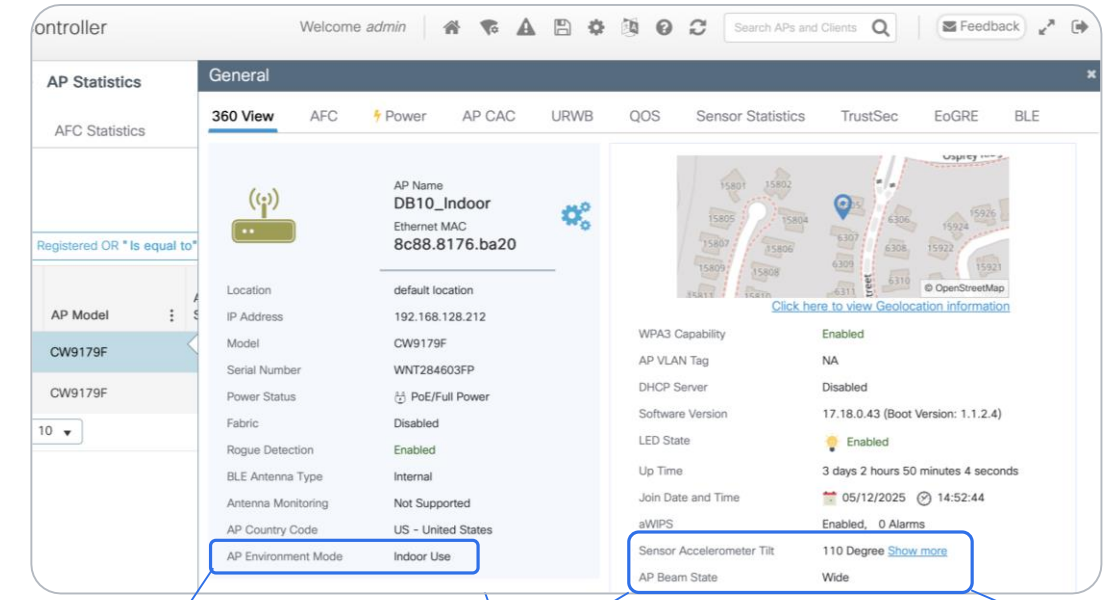
CW9179F: Beam Configuration Options

Dashboard: Wireless > Radio Settings > RF Profiles > Select Existing or Create New

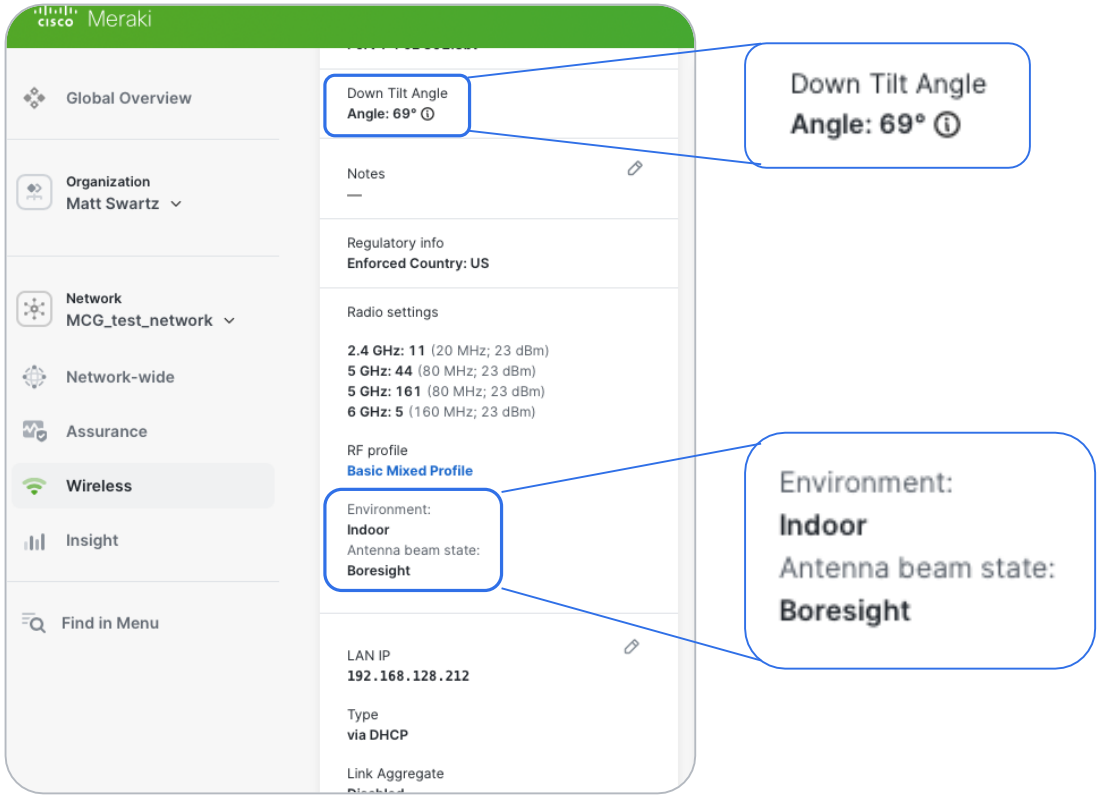


CW9179F: Validating Beam and Tilt

9800: Monitoring > Wireless > AP Statistics

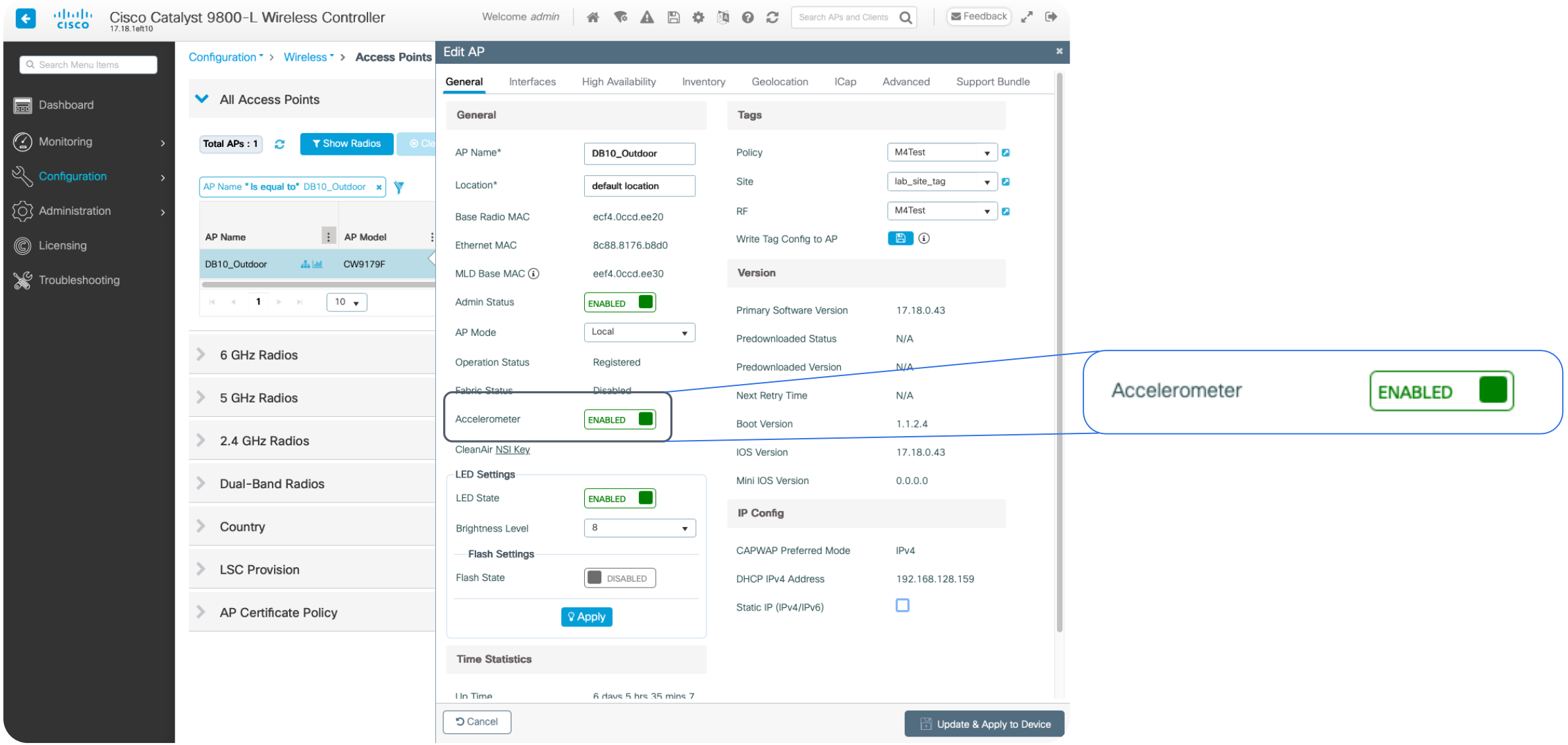


Meraki: Wireless > Monitor > Access Points > Select AP

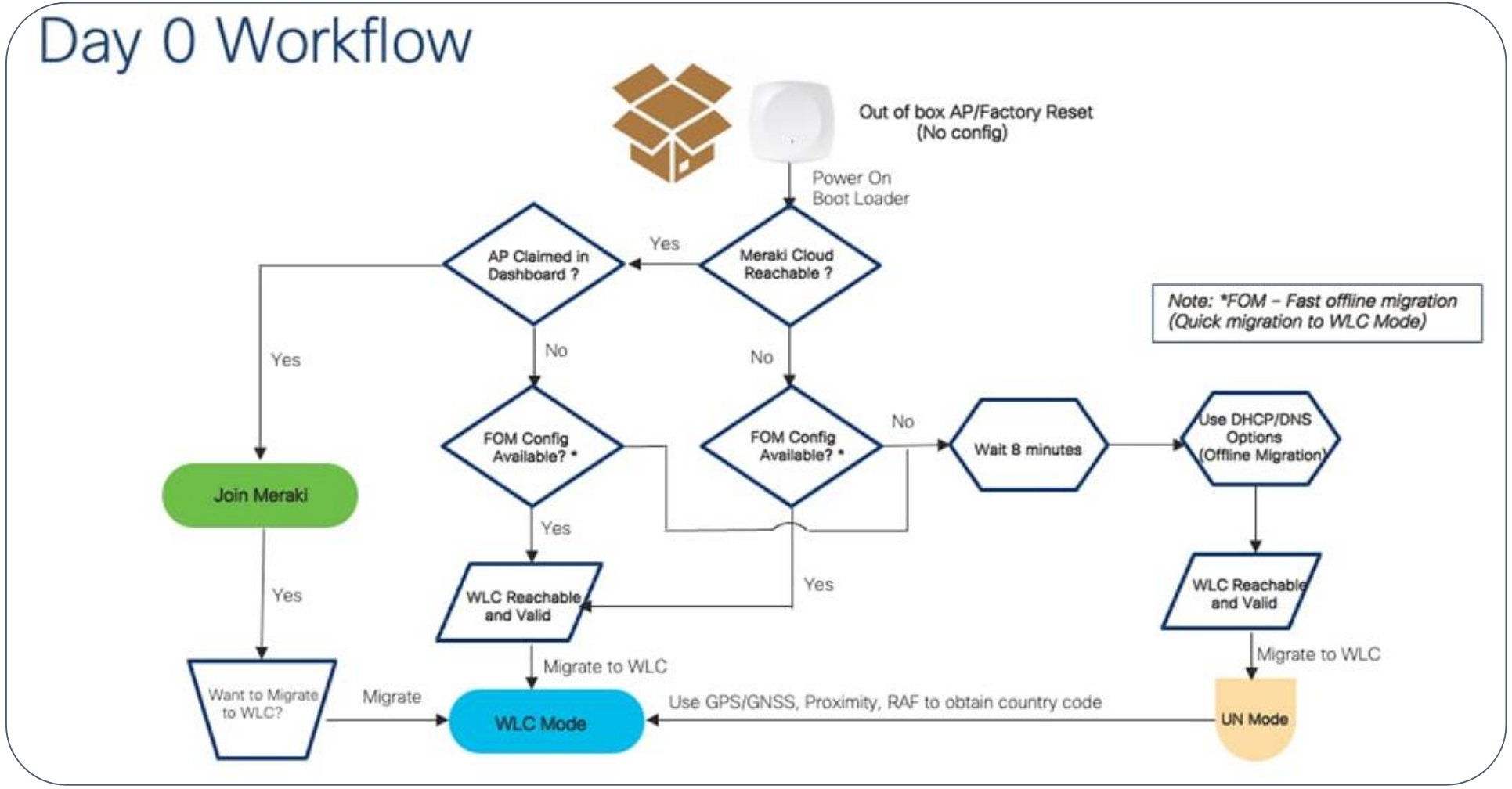


*Accelerometer must be enabled to see tilt measurement

CW9179F: Enabling the Accelerometer



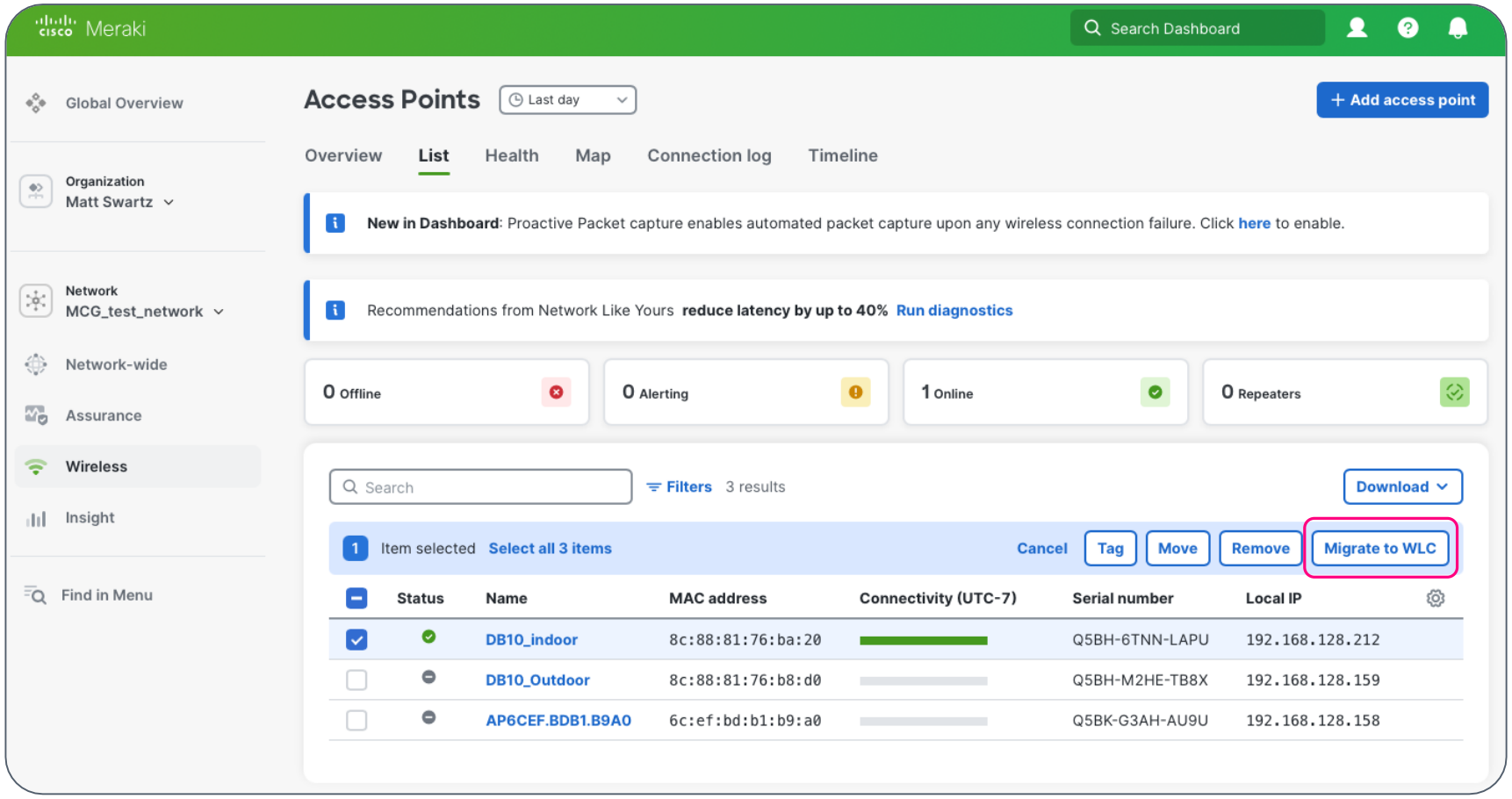
WiFi 7 – Global Use AP Considerations



Cisco Wireless Global Use Access Points Deployment Guide

Migrating Between Management Modes

Cloud > On-Prem



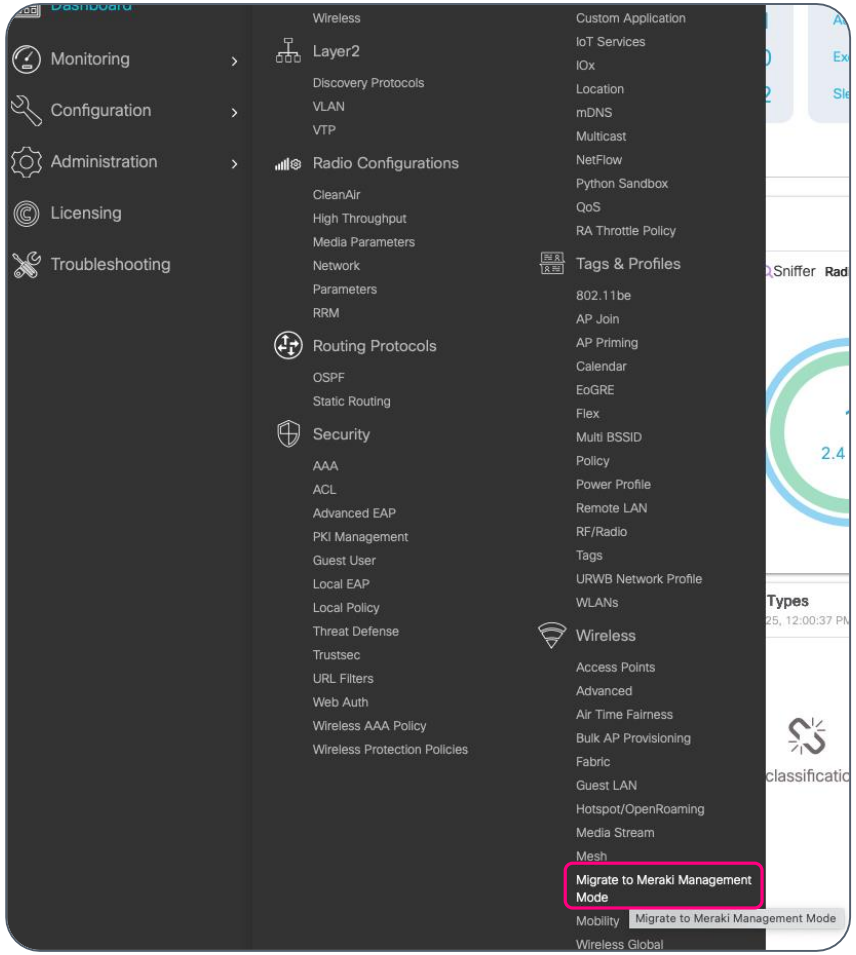
***Note**: You must have a 9800 up and accessible on the network for the converted AP to find a new "home"!*

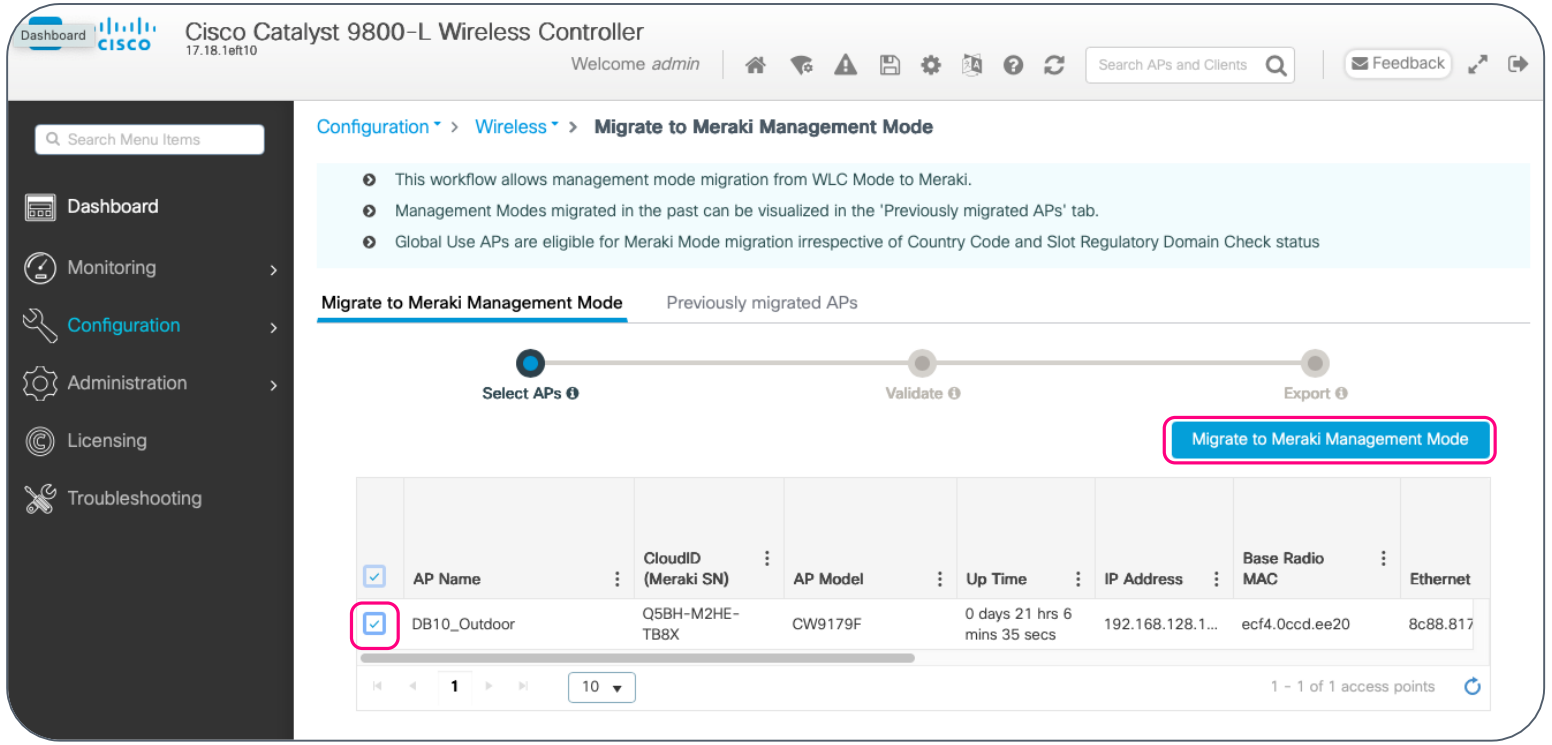
[Global Use APs: Migrating Between Management Modes]

Migrating Between Management Modes

On-Prem > Cloud

Configuration > Wireless > Migrate to Meraki Management Mode

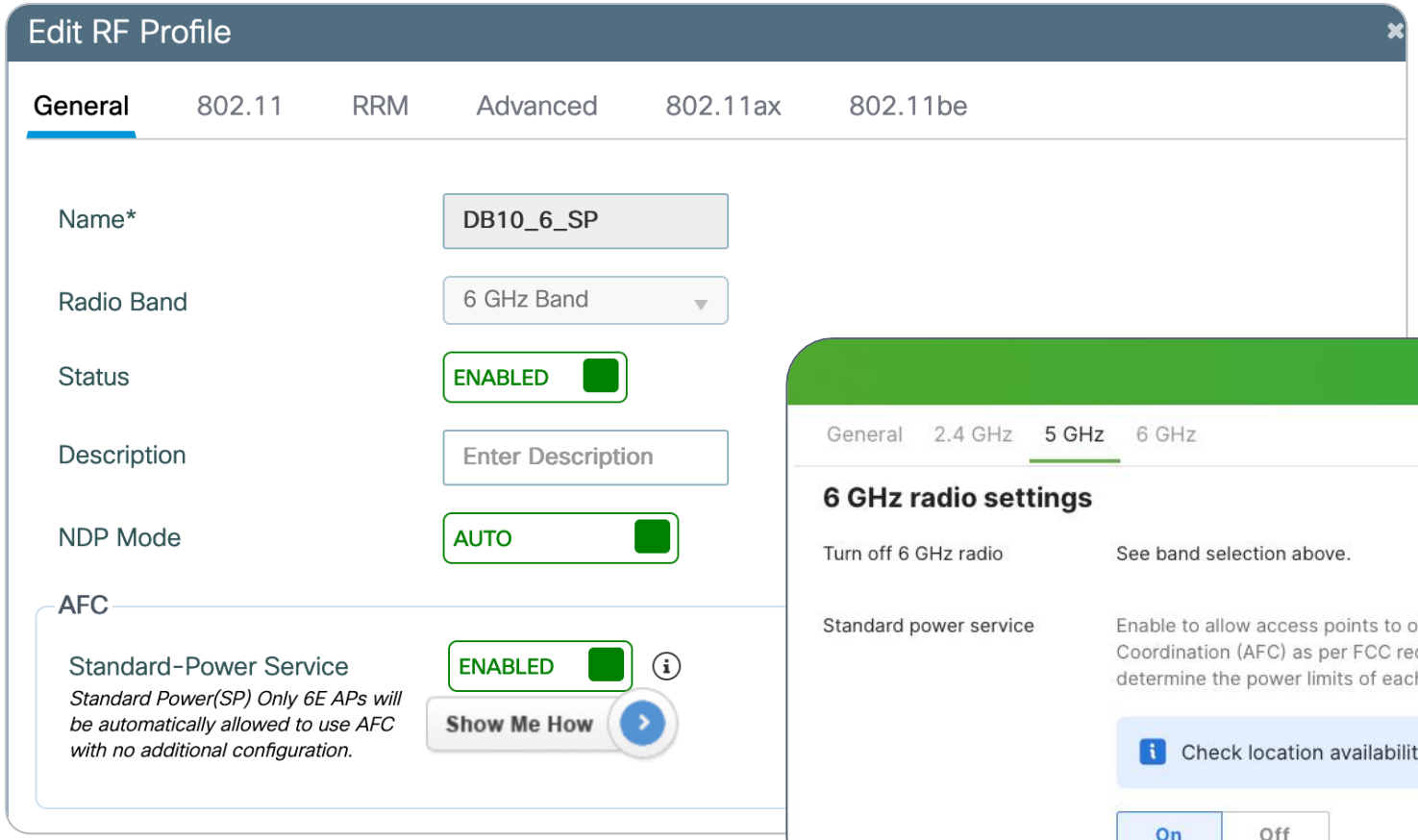




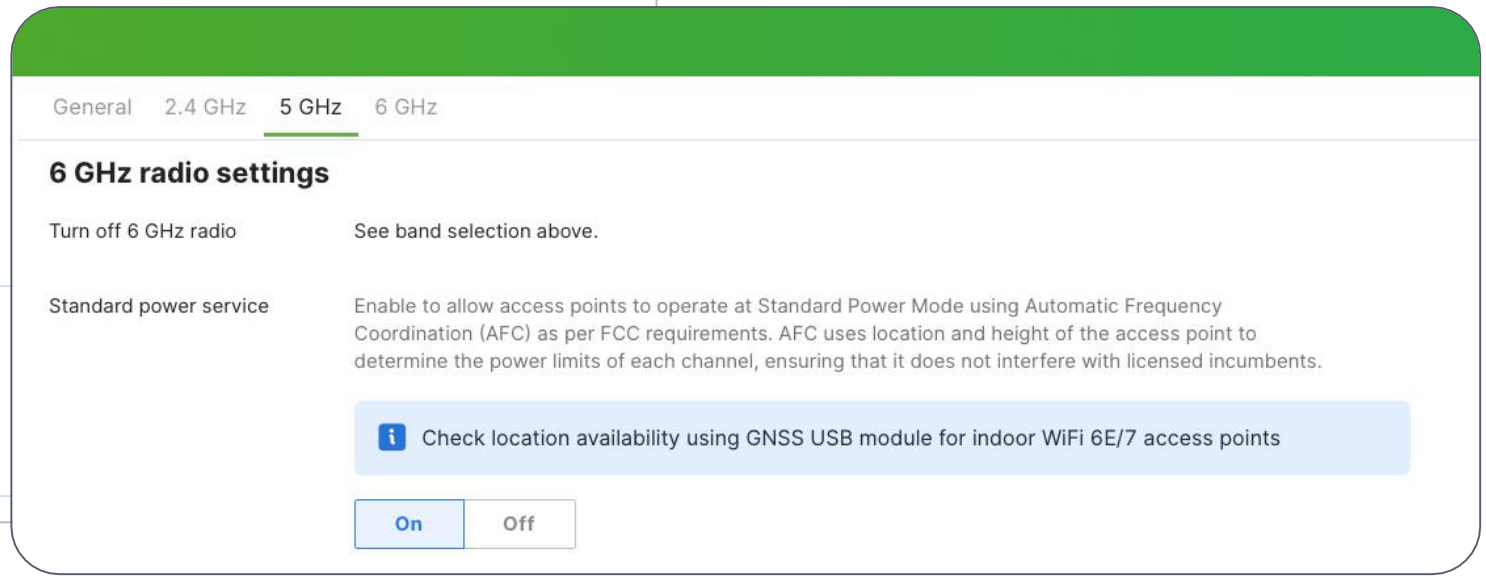
Global Use APs: Migrating Between Management Modes

AFC Configuration

CW9800: Enabling Standard Power / AFC



Cloud Dashboard: Enabling AFC



[Cisco AFC FAQ](#) | [CW9800 AFC Configuration Guide](#) | [Meraki AFC Configuration Guide](#)

CISCO WIRELESS

Launching at Cisco Live!!

Campus Gateway

Enterprise-class cloud functionality

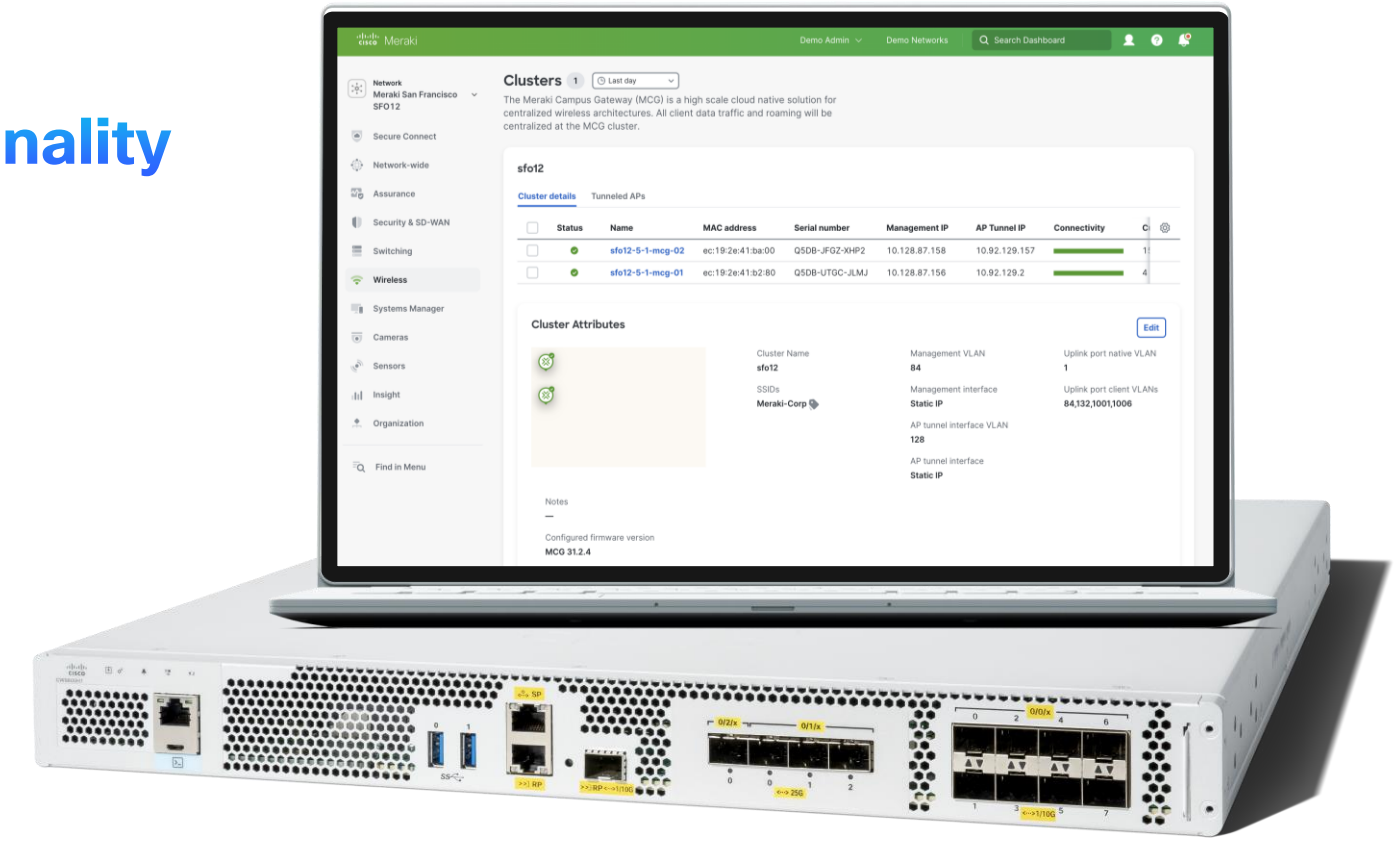
Support critical campus wireless services with cloud management and real-time control plane

Deploy without redesign

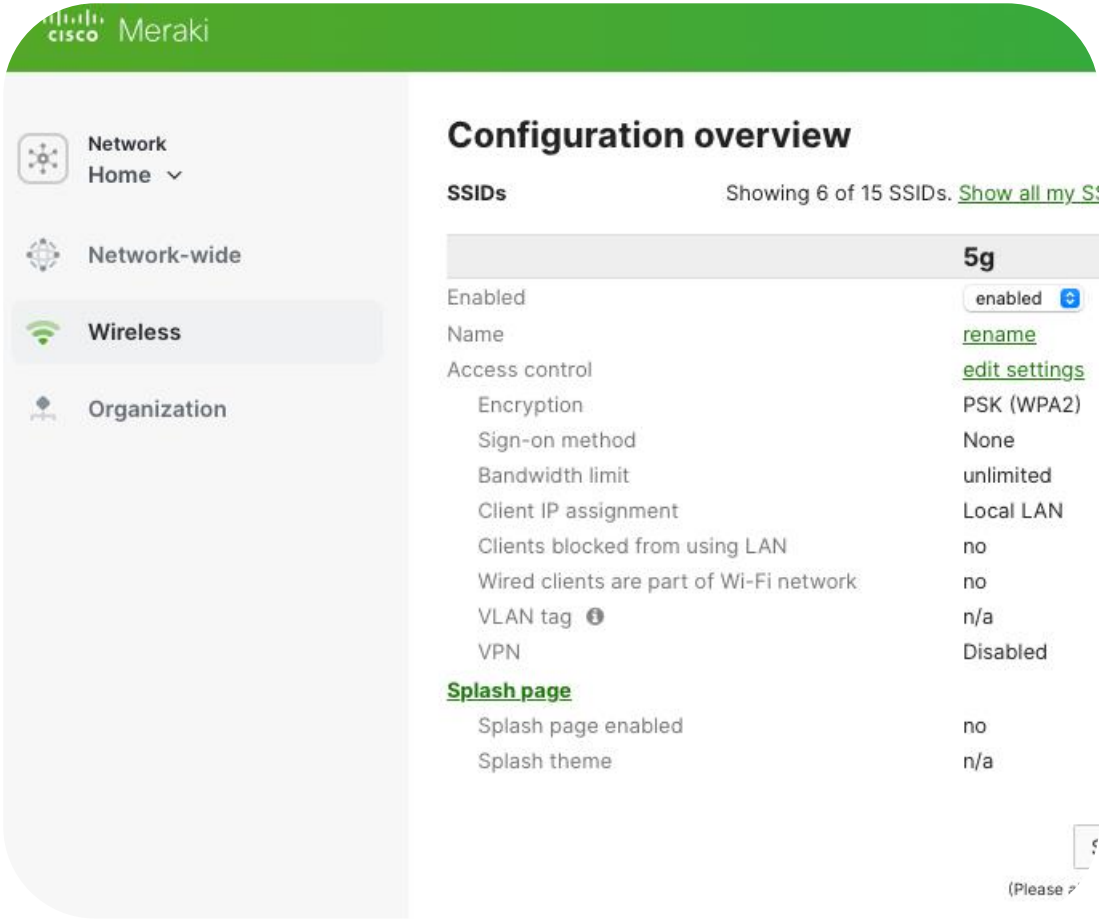
Deploy Campus Gateway with little to no redesign of the on-premises wireless network architecture

Seamless roaming at scale

Scale up to 50,000 client devices and 5,000 access points with a single Campus Gateway



Cloud-Managed High Density

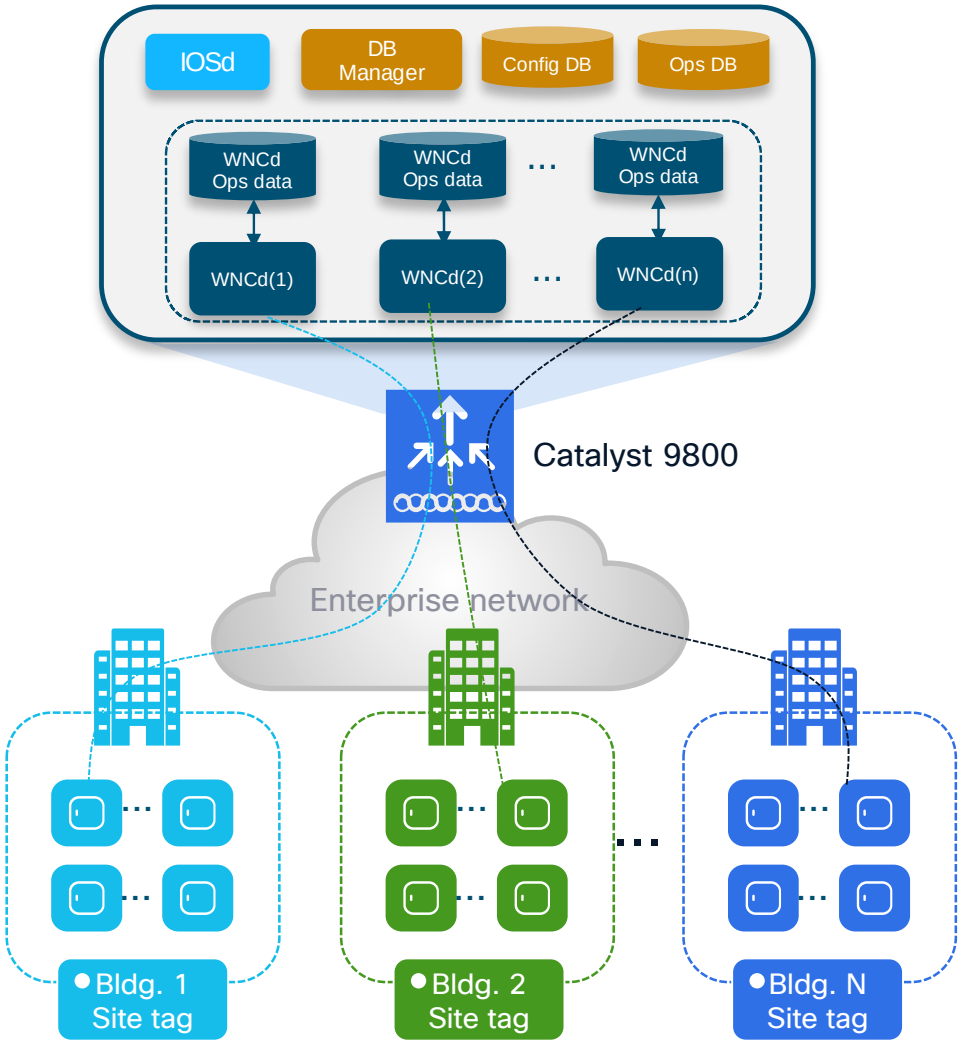


Similarly to “traditional” Catalyst networks:

- 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)

Hidden Slide – For Your Reference

Site Tags – Design considerations



A few more important suggestions:

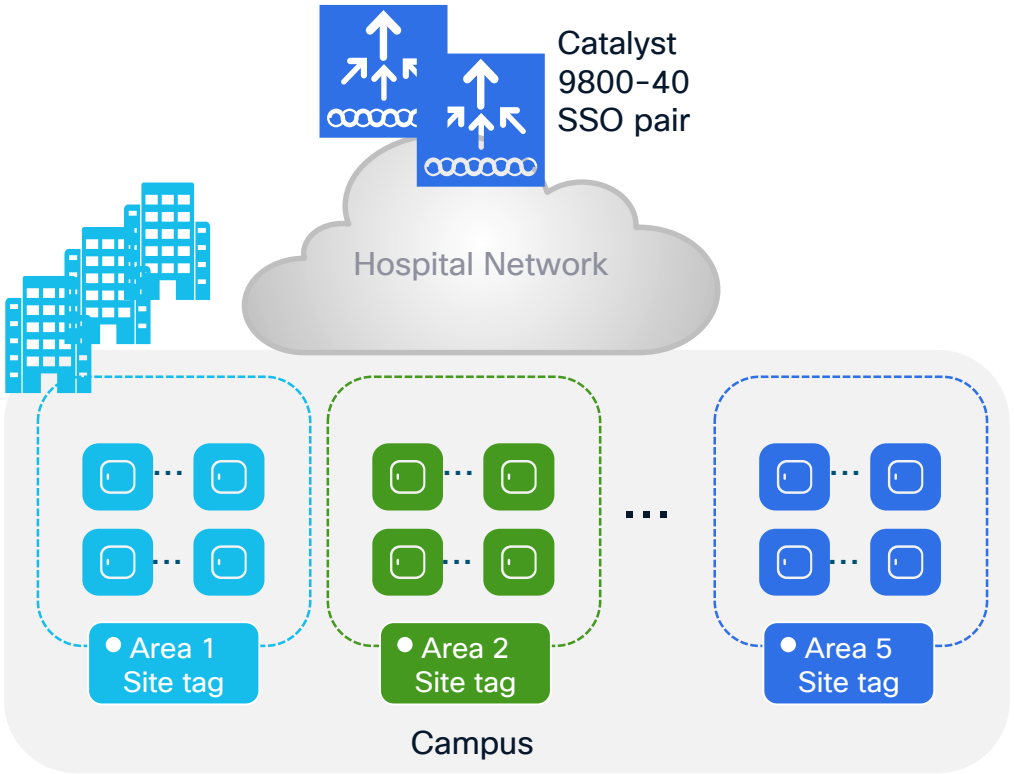
- Distributing APs (and clients) across custom Site Tags (and thus WNCd's) gives better scale and performance
- In large public venues, avoid having more Site Tags than # of WNCd's
- The number of WNCd varies from platform to platform:

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

The following command shows the # of WNCDs processes:

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

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
- 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 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

Hidden Slide – For Your Reference

Helpful Site Tag Monitoring Commands

show wireless stats ap loadbalance summary
- Shows summary of APs assigned to each WNCd

```
[redacted]#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

```
[redacted]#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:

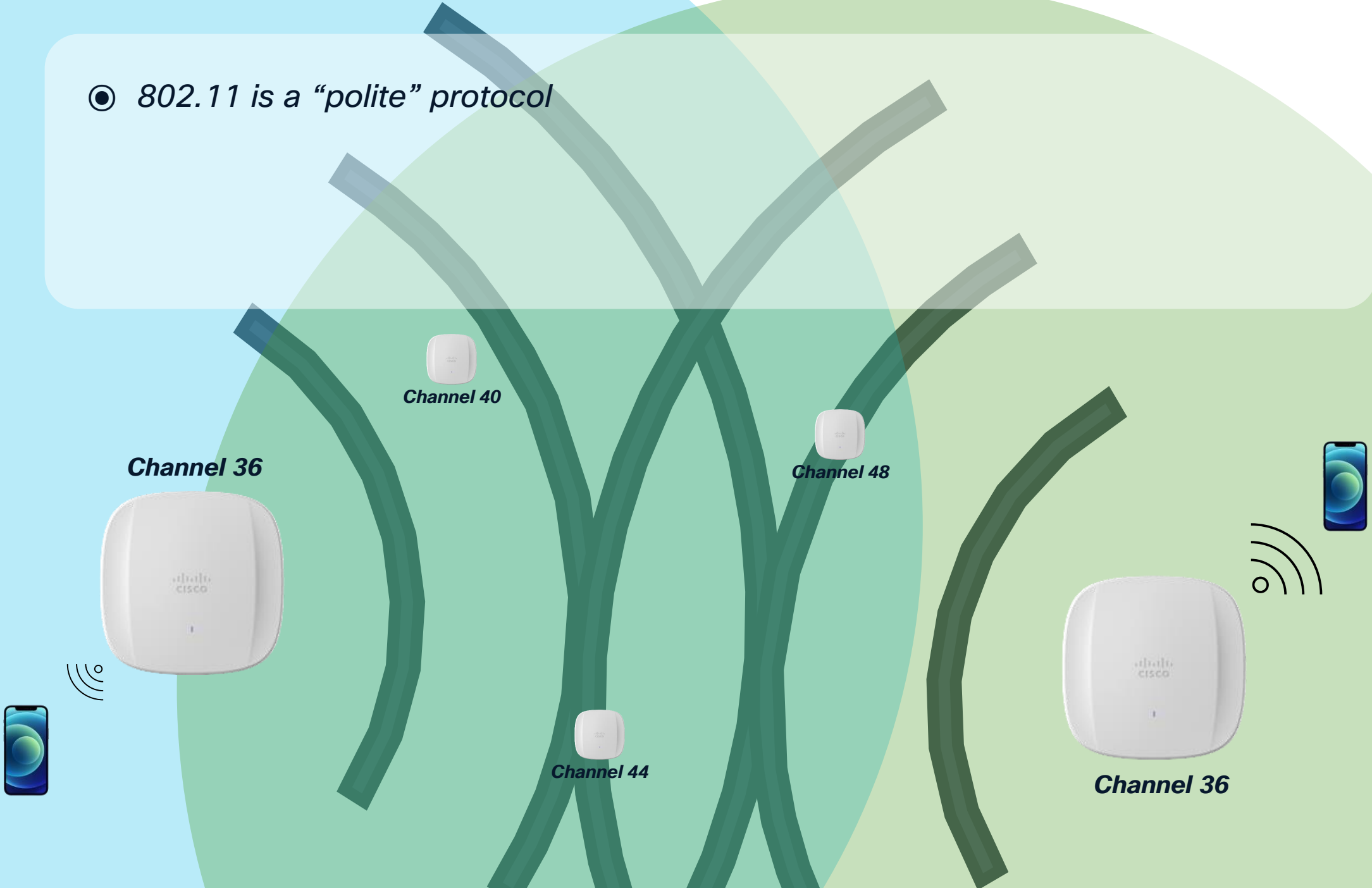
- mDNS
- DHCP Relay (uncommon in High Density)

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

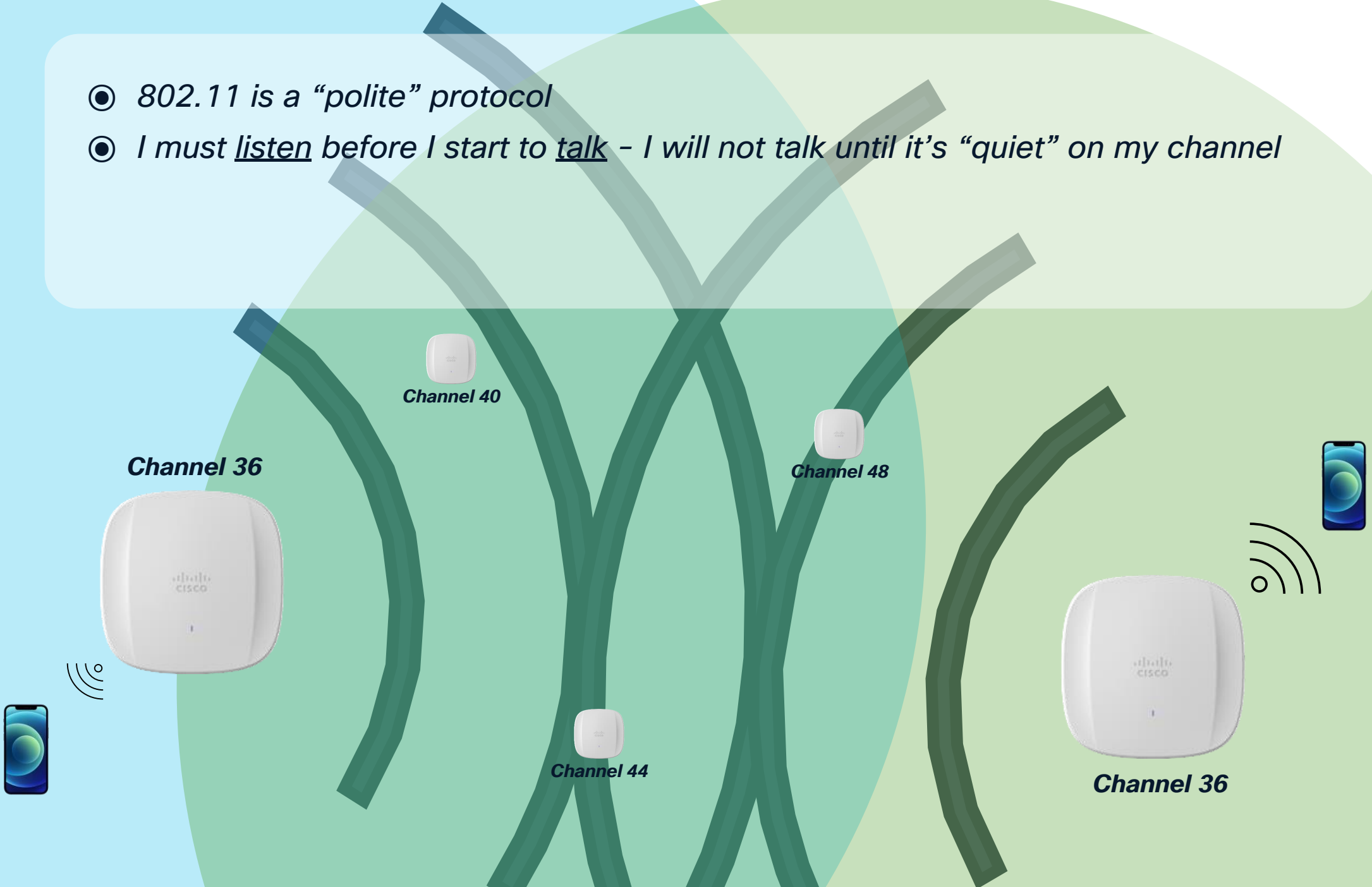
https://www.cisco.com/c/en/us/products/collateral/wireless/catalyst-9800-series-wireless-controllers/guide-c07-743627.html

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

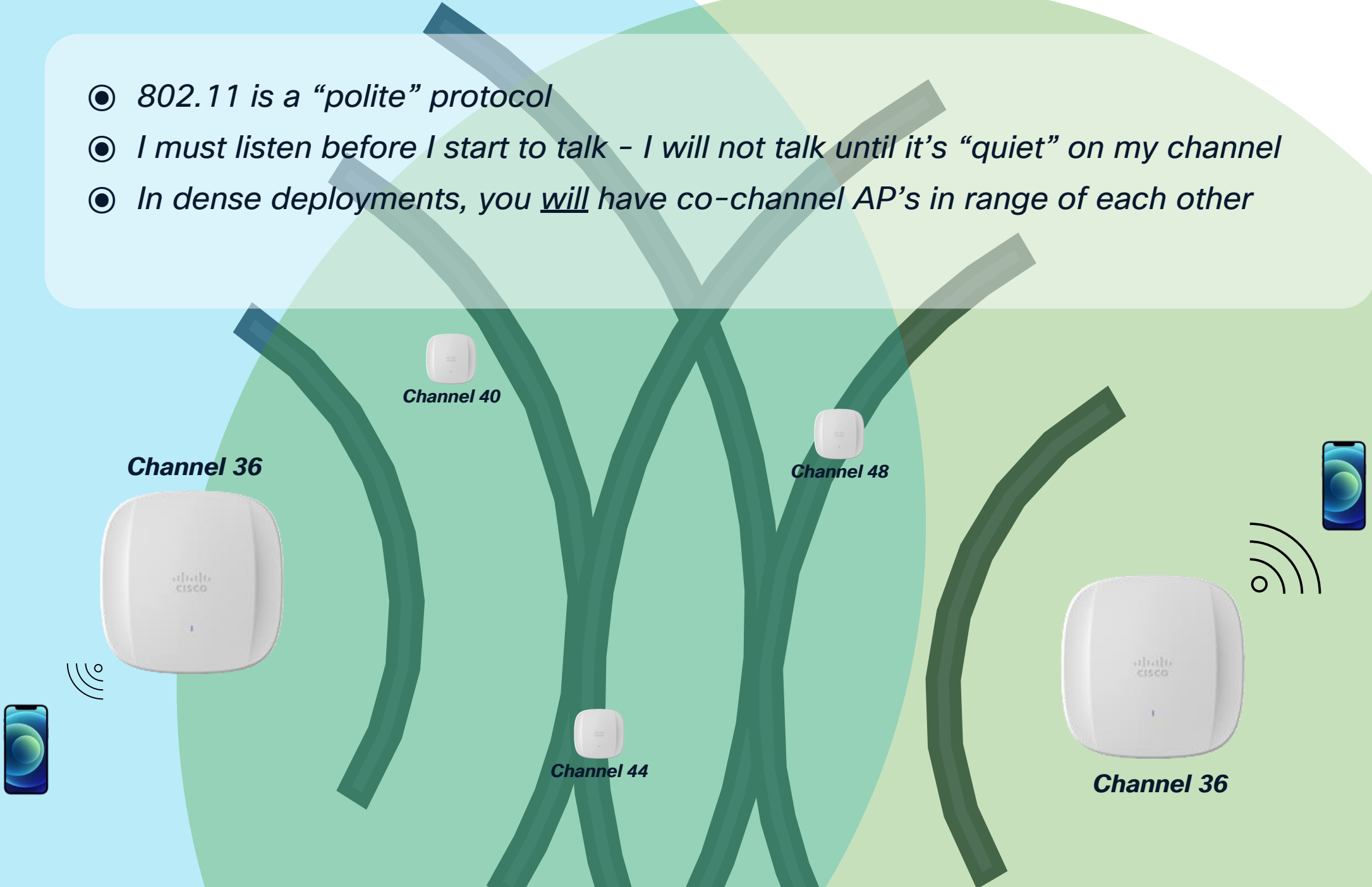
- *802.11 is a “polite” protocol*



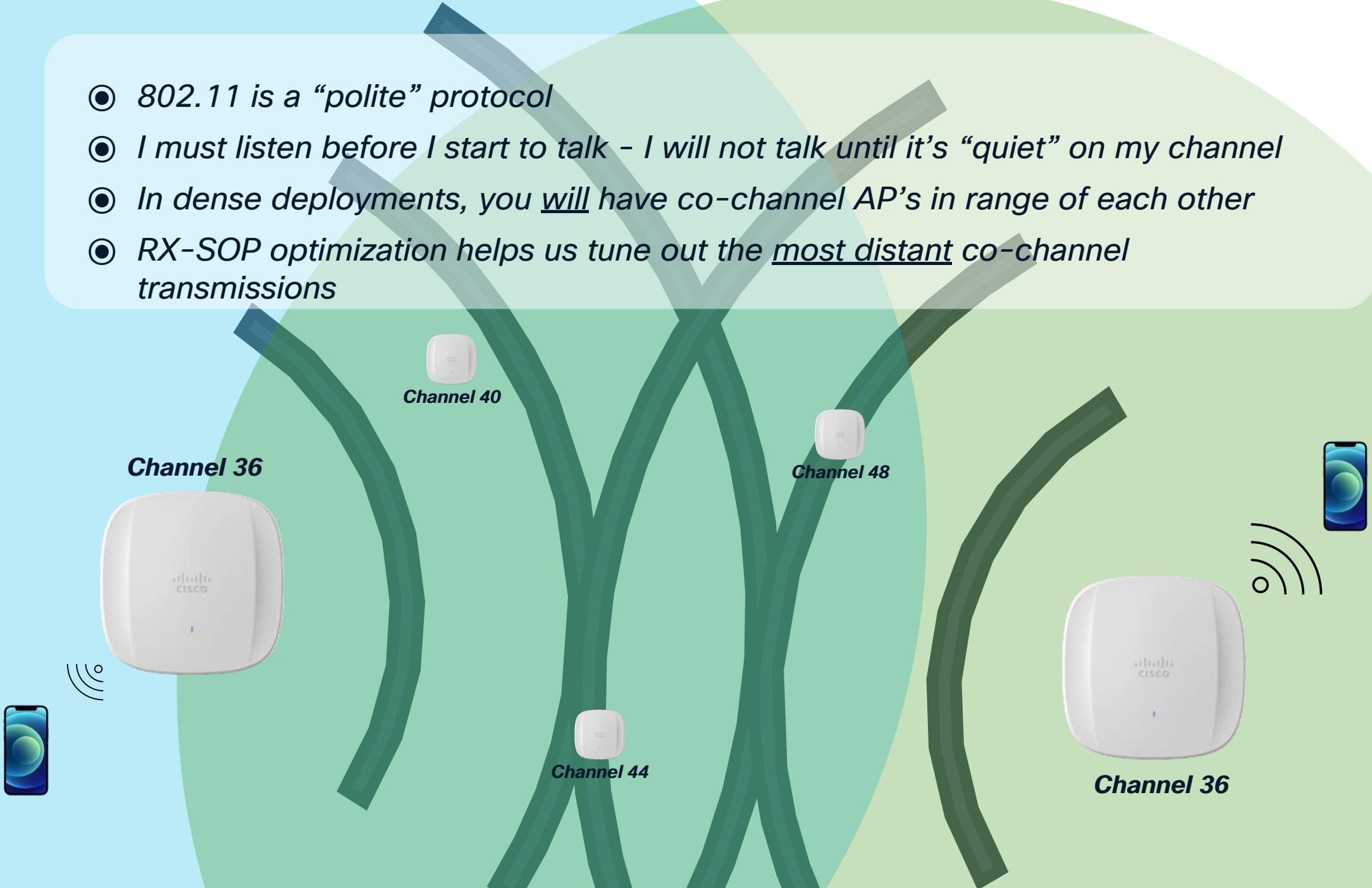
- *802.11 is a “polite” protocol*
- *I must <u>listen</u> before I start to <u>talk</u> – I will not talk until it’s “quiet” on my channel*



- *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 <u>will</u> 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 <u>will</u> have co-channel AP’s in range of each other*
- *RX-SOP optimization helps us tune out the <u>most distant</u> co-channel transmissions*



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?

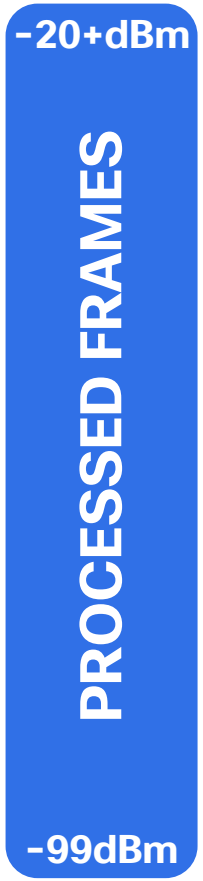
Allows us to transmit more often to clients in our intended cell

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



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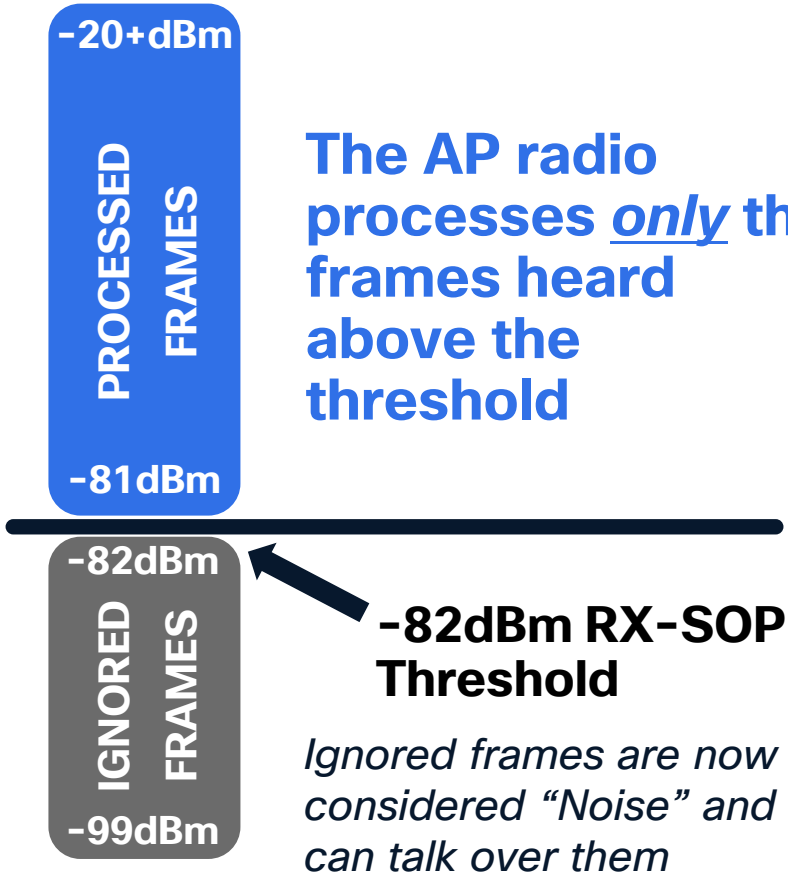
With Custom RX-SOP Threshold



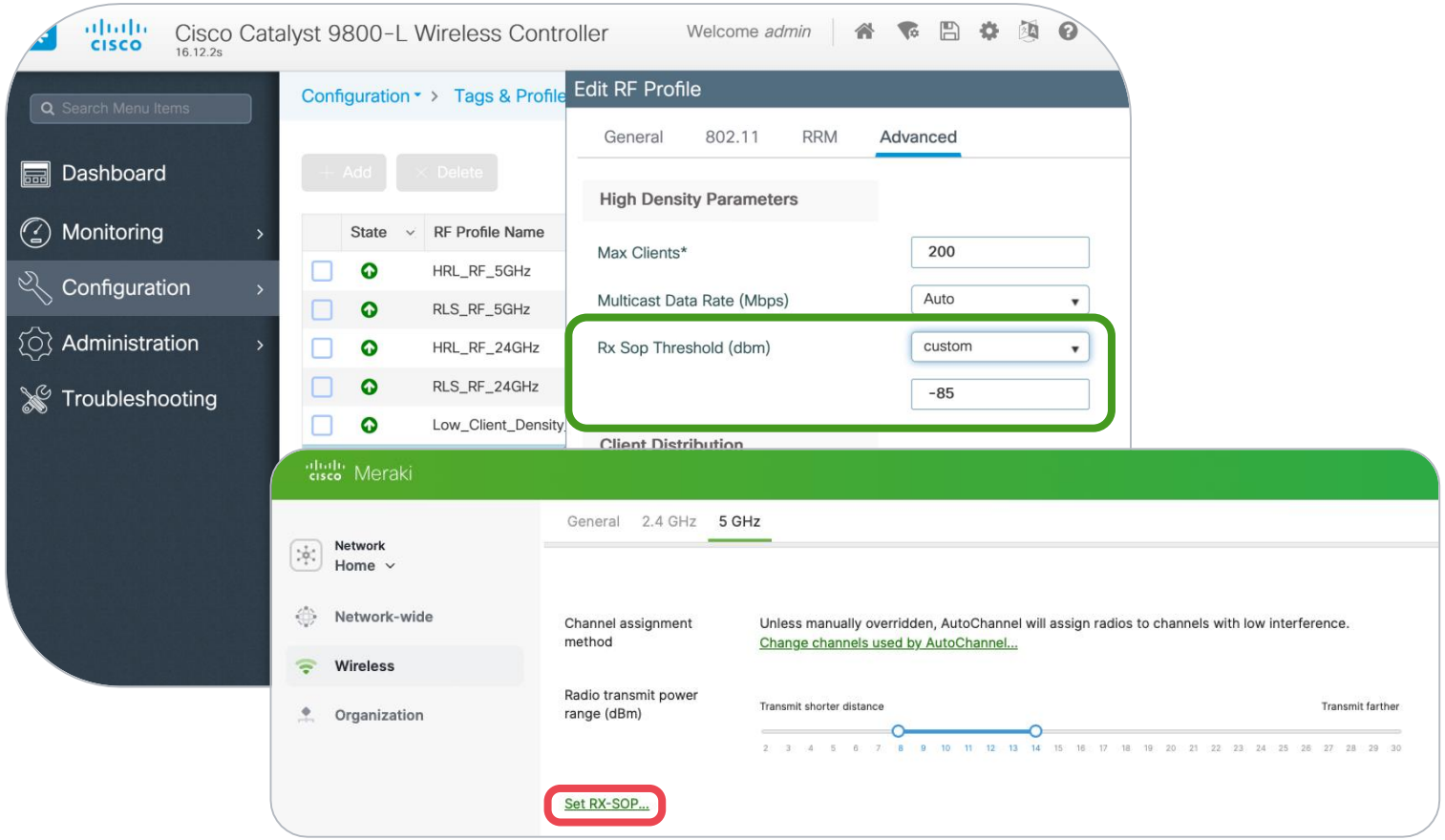
The AP radio processes *only* the frames heard above the threshold

-82dBm RX-SOP Threshold

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

Receive Sensitivity Threshold (RX-SOP)

- **Configure in the RF Profile (On-Prem or Cloud)**



Receive Sensitivity Threshold (RX-SOP)

- **Configure in the RF Profile (On-Prem or Cloud)**
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  - Generally, start in the -80's

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  - High Channel Utilization still affects all clients

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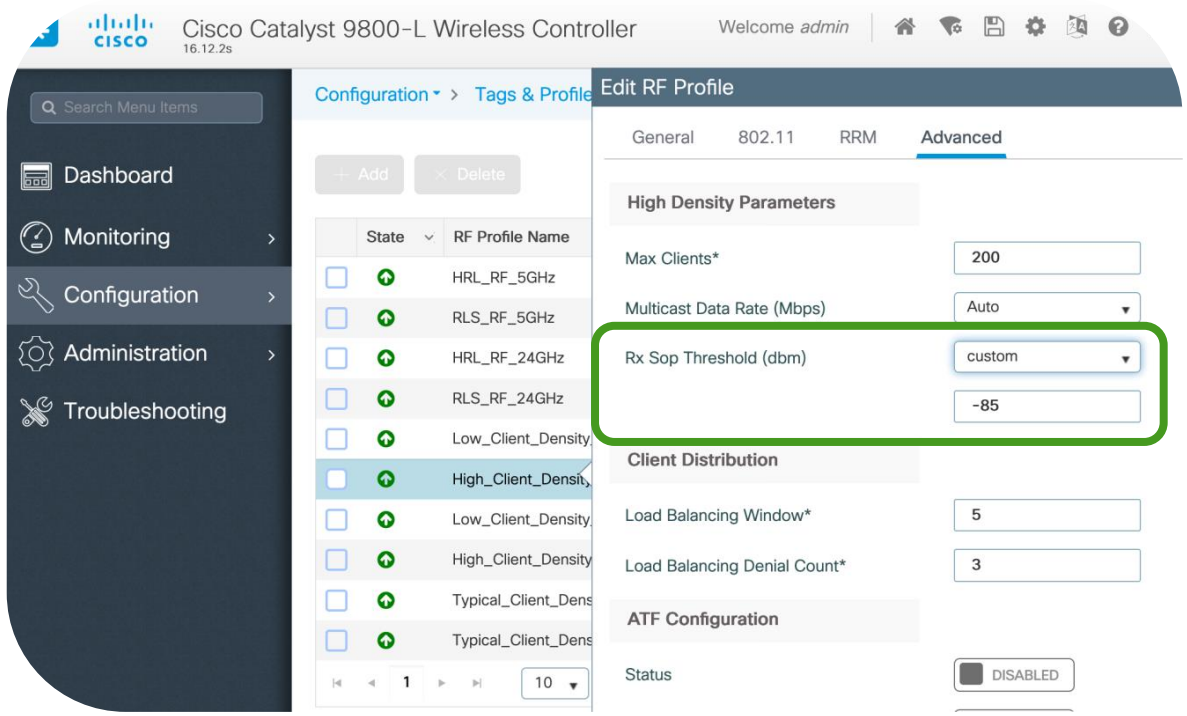
- Remember – adjusting the RX-SOP threshold **doesn't impact the actual RF energy on the channel**, but it does impact APs' sensitivity to it
  - High Channel Utilization still affects all clients
- **WiFi6, WiFi6E, and/or use of C9104/CW9179F may reduce the need for RX-SOP** in some environments; continue to monitor your Channel Utilization and adjust as needed

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

Hidden Slide – For Your Reference

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)?

Hidden Slide – For Your Reference

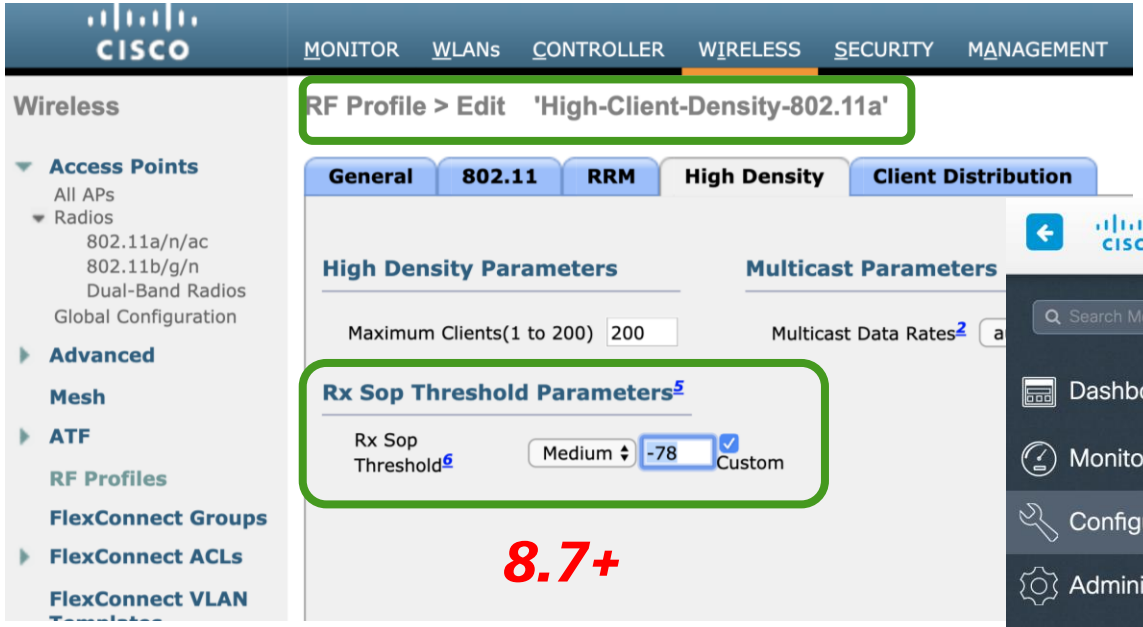
HOW TO: Optimize RX-SOP Thresholds (AireOS)

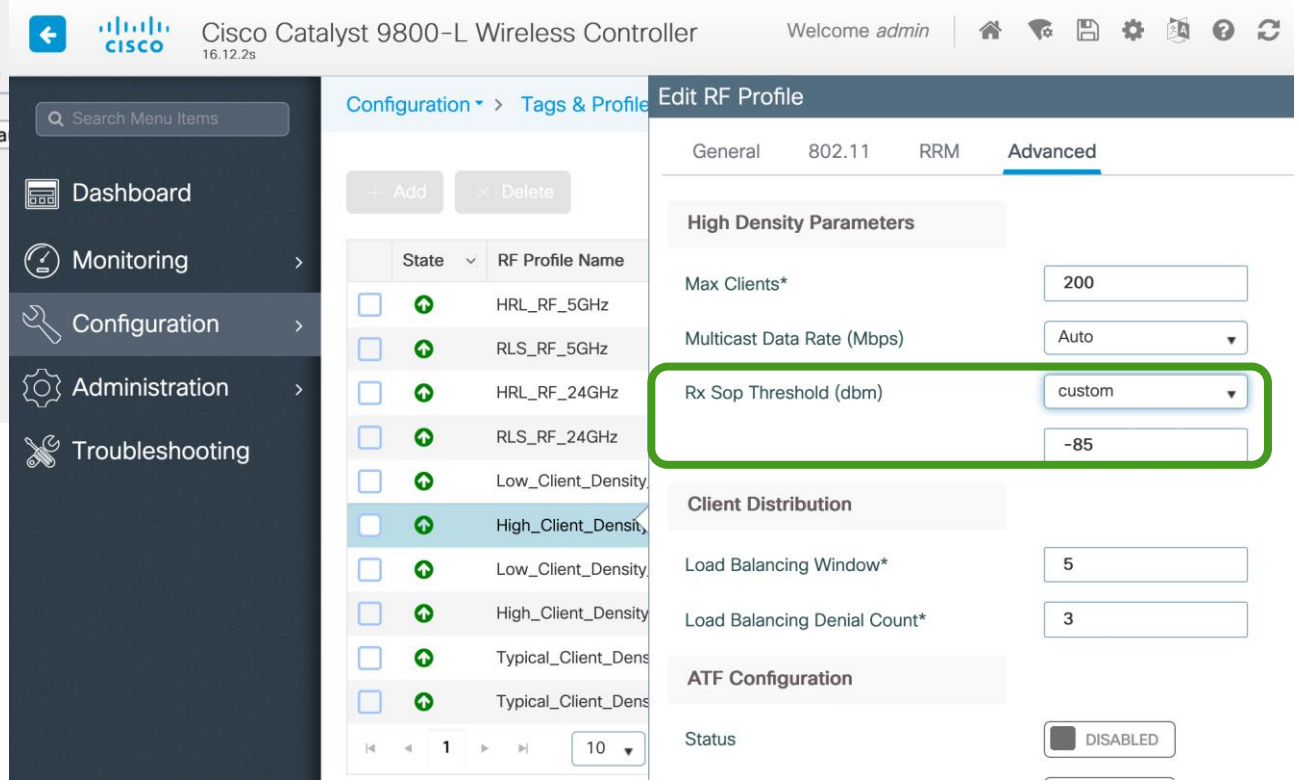
1. Pick the client device(s) you want to test
2. Pick the representative area(s) you want to test
3. Create a new temporary SSID and a new AP Group
4. Add the AP's you want to test to the new AP group
5. Join your client device(s) to the new SSID and monitor how the AP hears your client(s) (from AP CLI – "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

Hidden Slide – For Your Reference

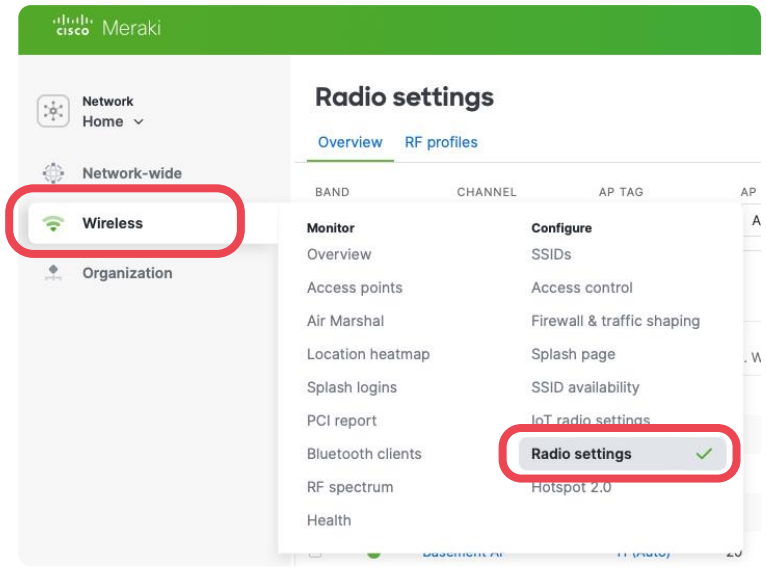
Tuning RX-SOP Thresholds: GUI

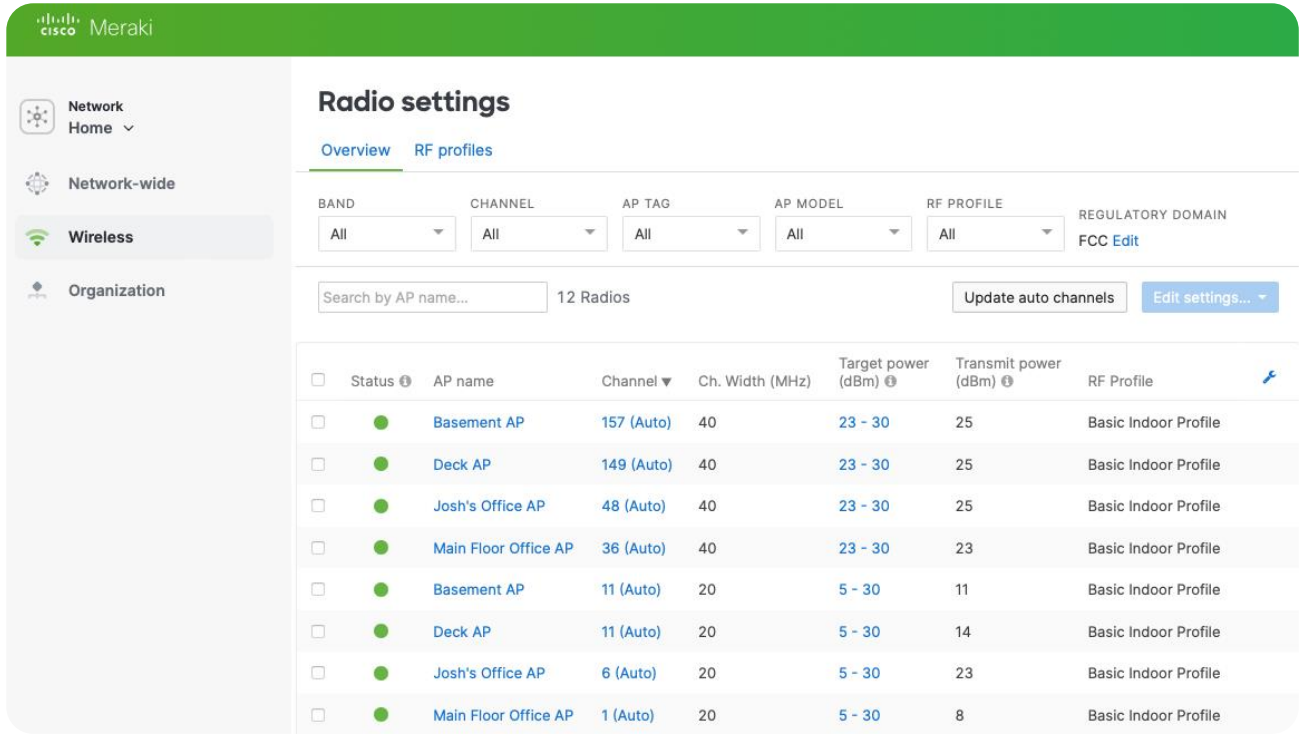




Hidden Slide – For Your Reference

RF Optimization: Radio Settings Overview





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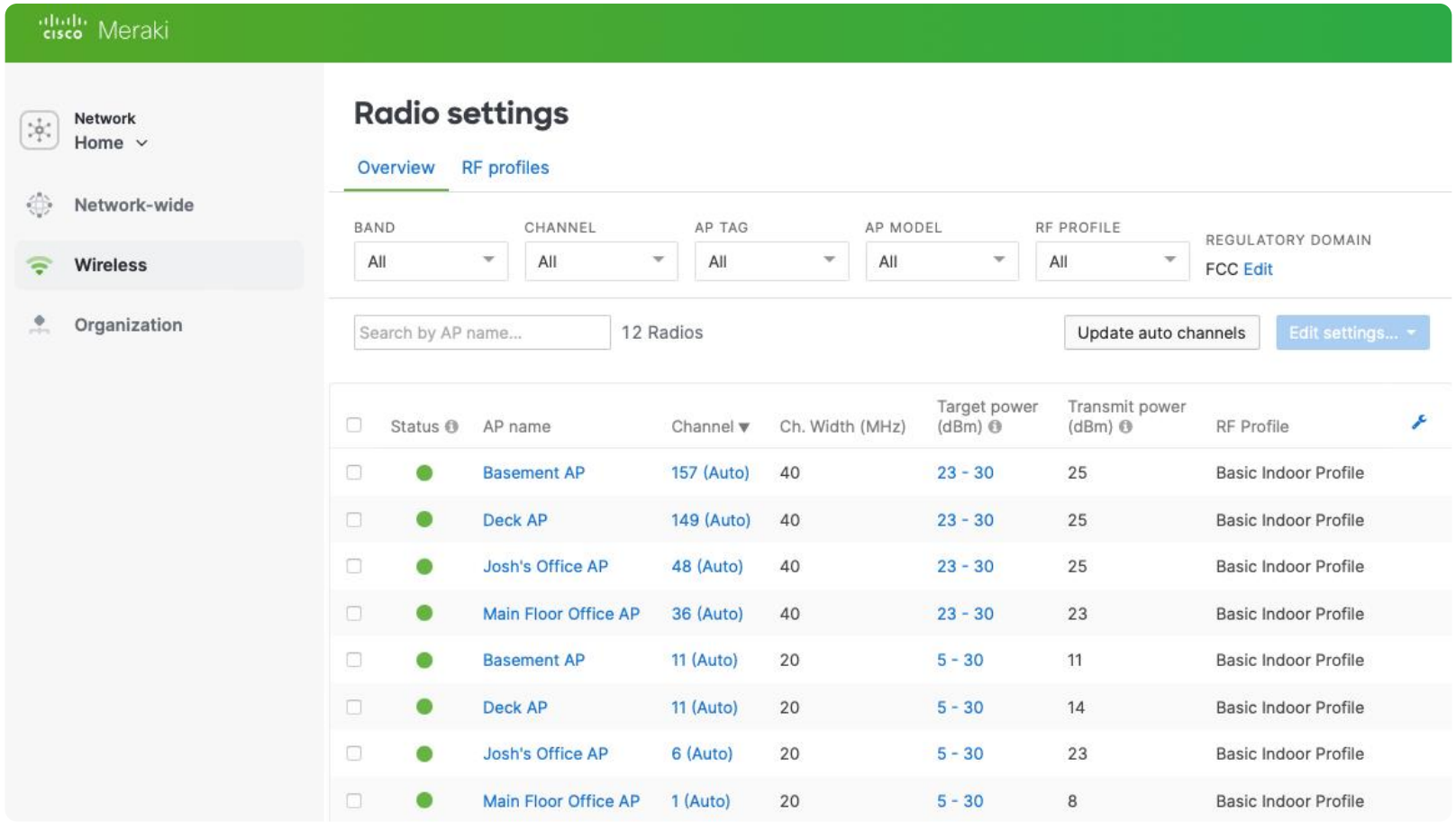
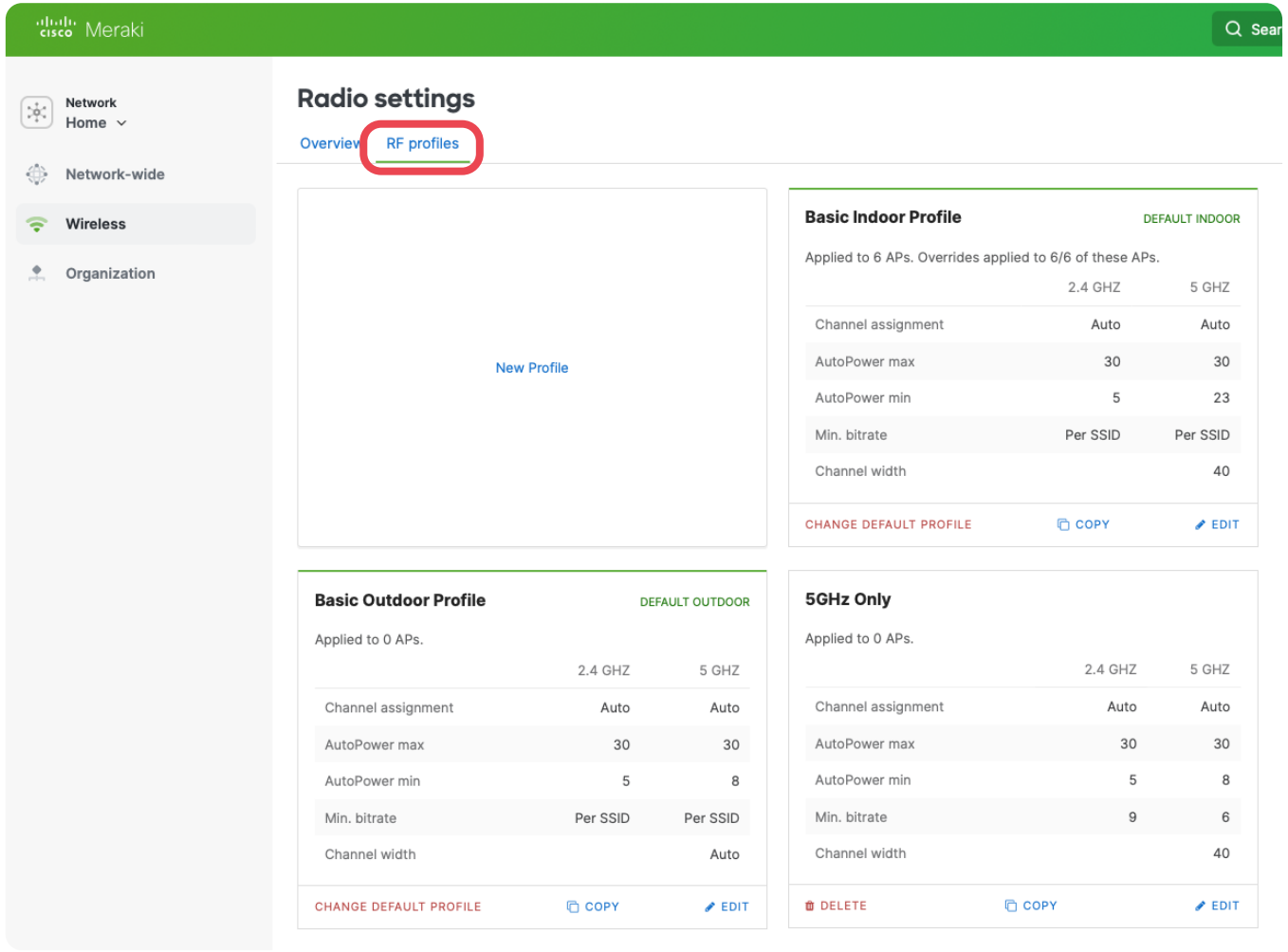
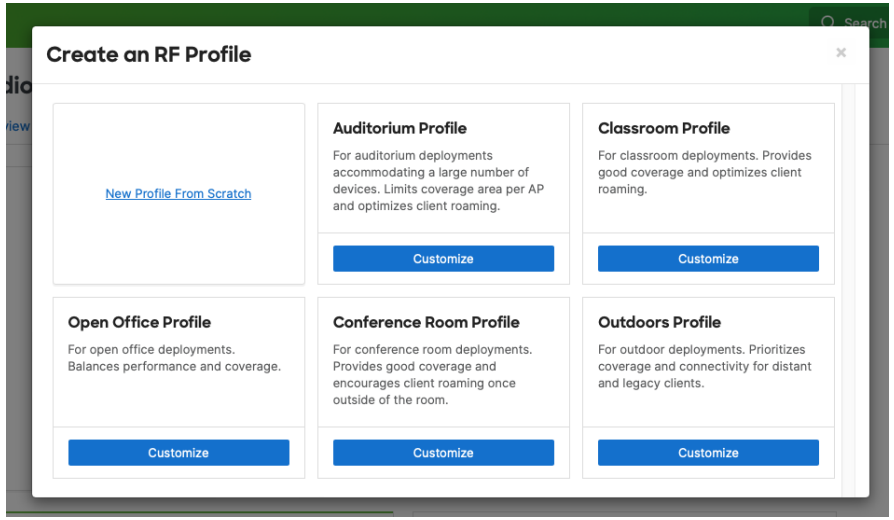


- Sortable / Filterable table for radio settings per AP
- Channel
- Width
- Min/Max Power
- Current Power
- RF Profile

Hidden Slide – For Your Reference

RF Optimization: RF Profiles





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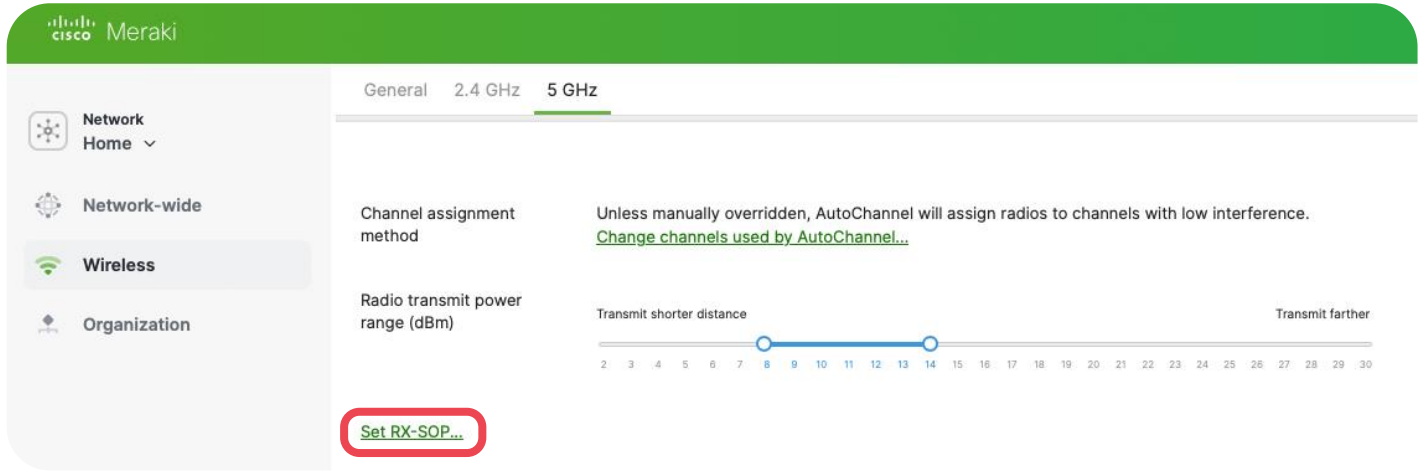
RF Optimization: RX SOP



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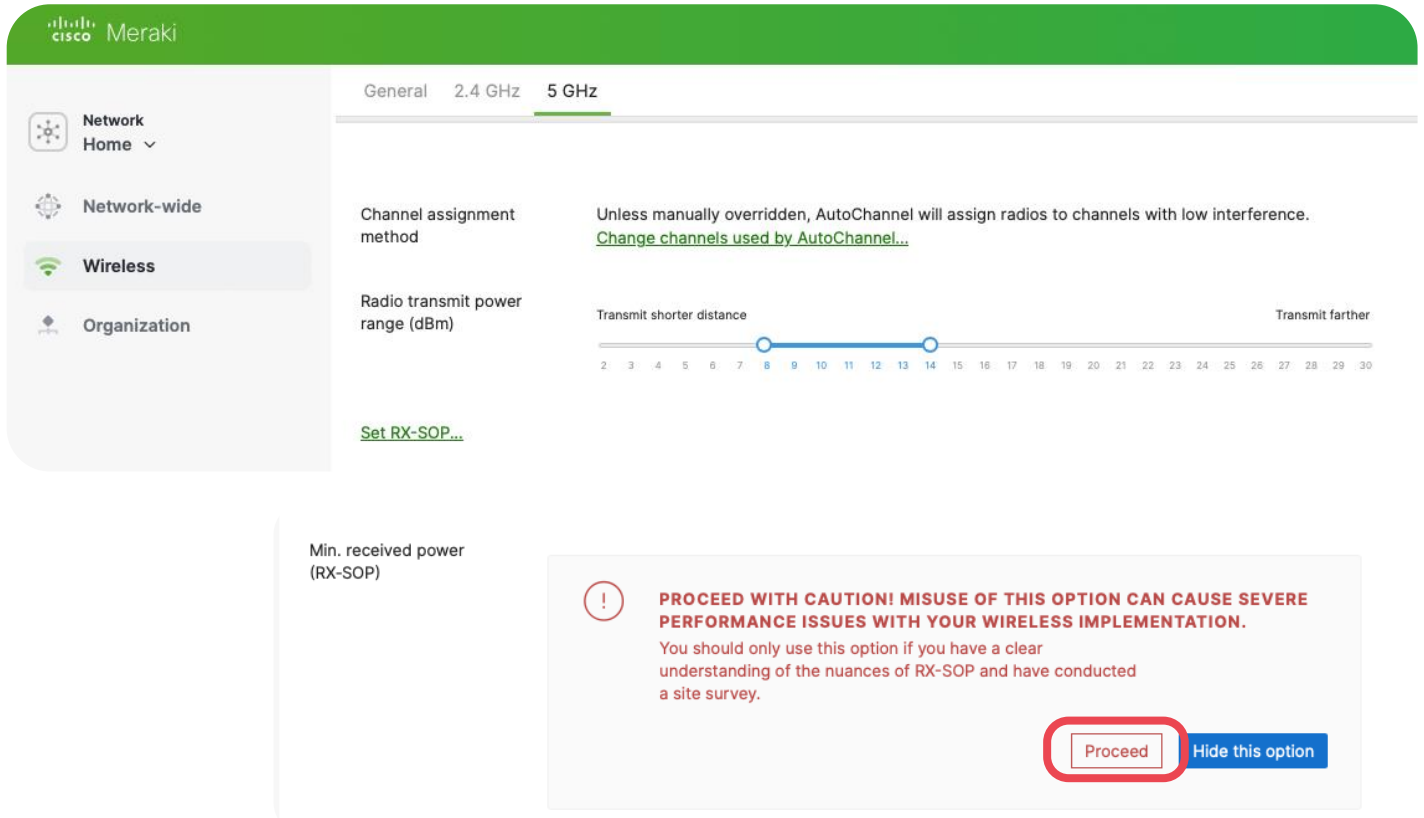

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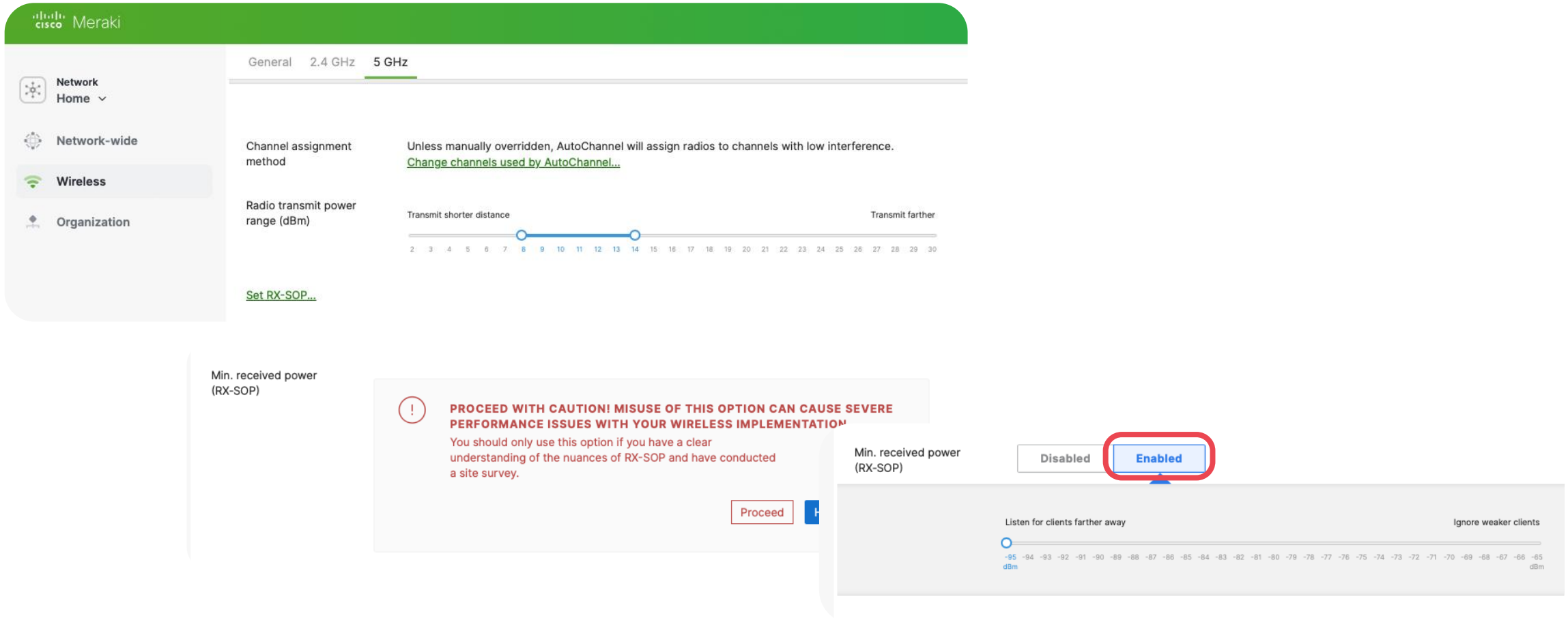

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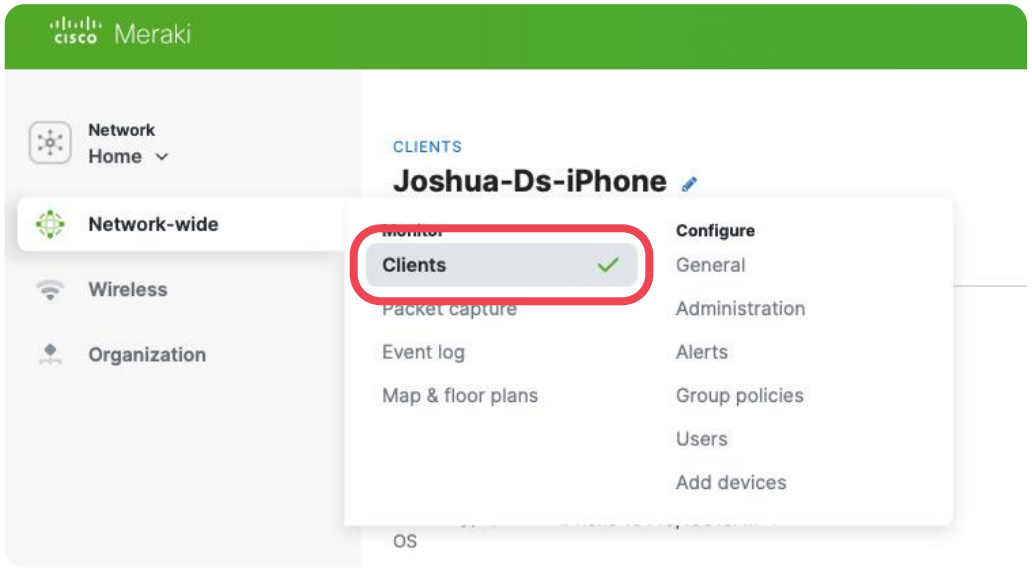
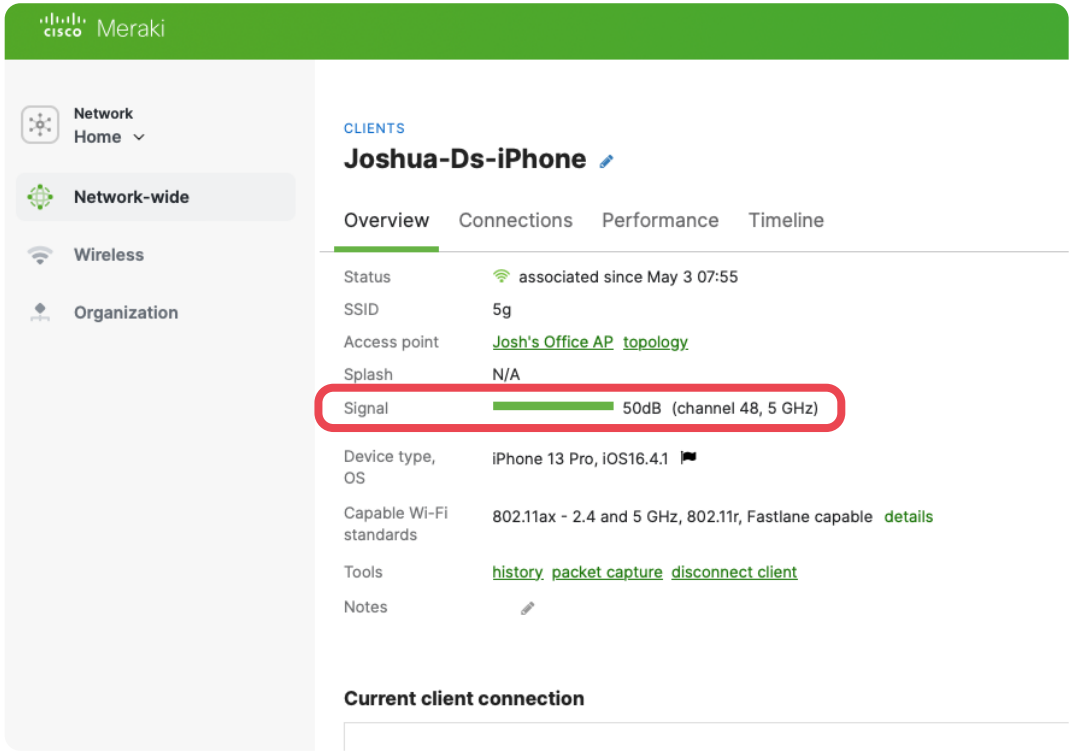
RF Optimization: RX SOP

Hidden Slide – For Your Reference

Monitoring Client RSSI @ AP for RXSOP Testing





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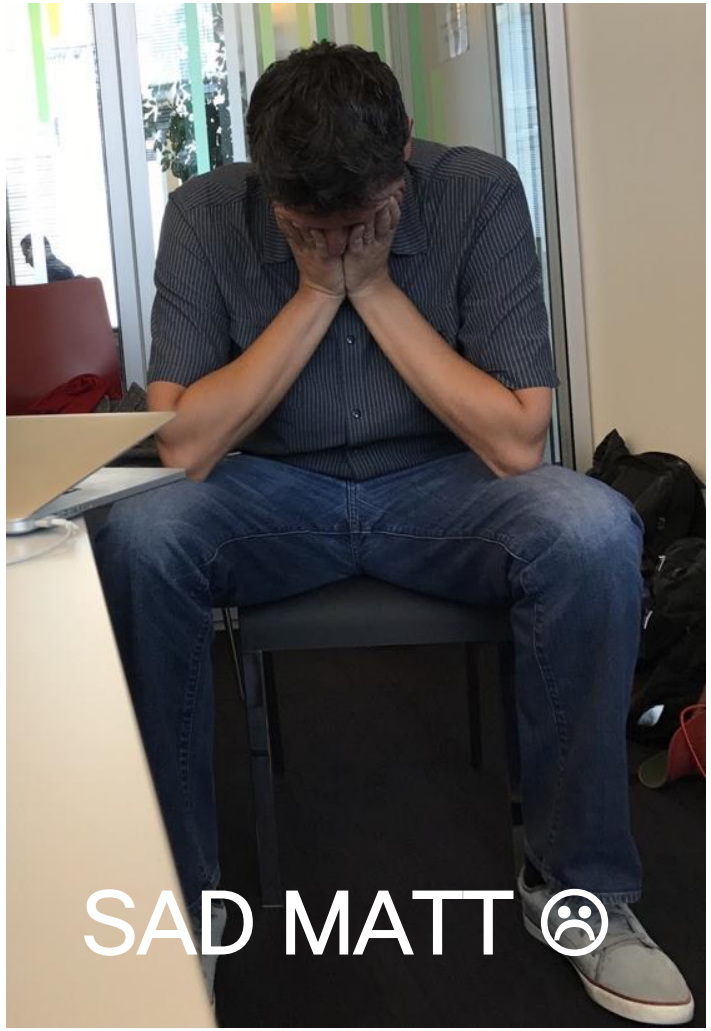
HOW TO: Optimize RX-SOP Thresholds

A key takeaway:

Be **conservative** and make **small adjustments**!

Common High Density Mistakes

Common High Density Optimization Mistakes



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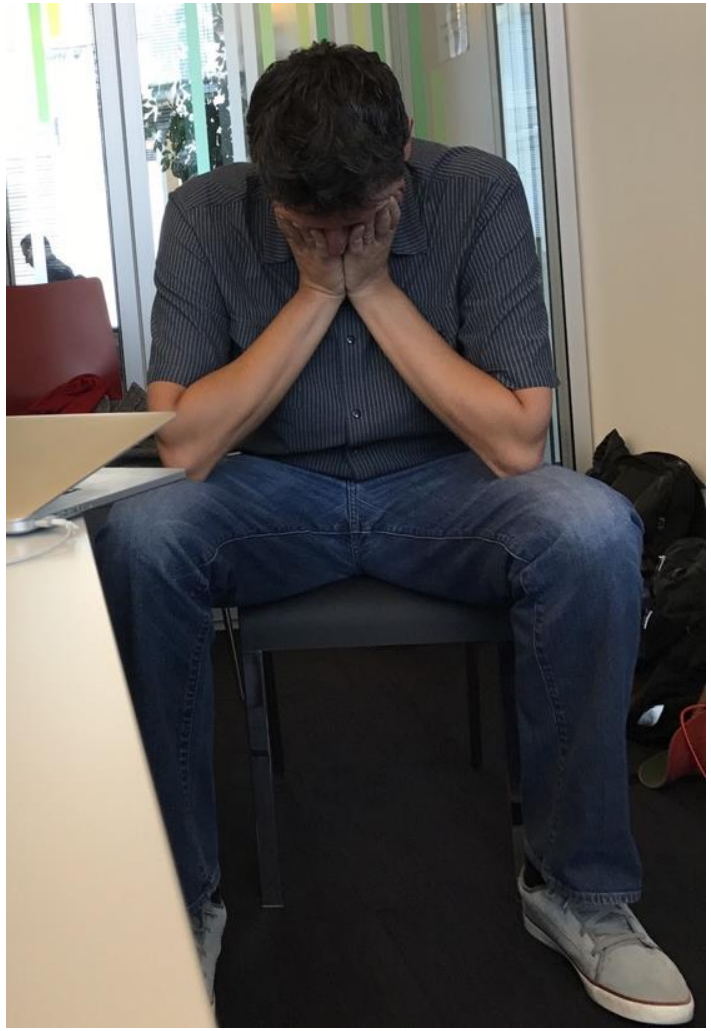


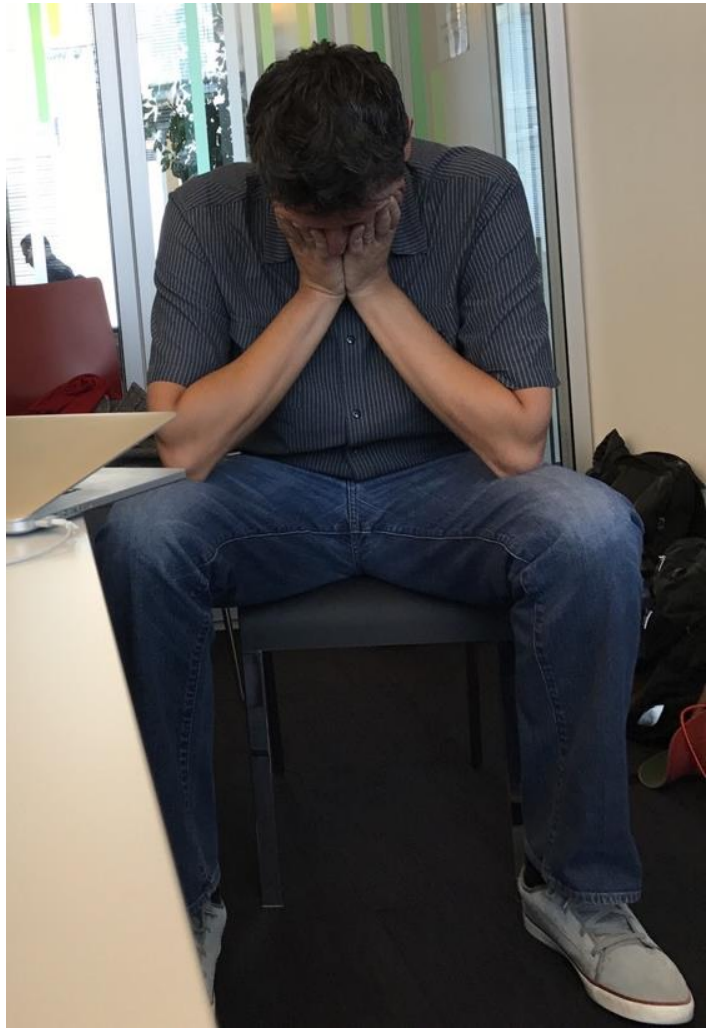
- AP-to-AP transmit power imbalance (causes “Magnet” / overloaded AP’s)

5GHz TX Power: 7dB
2 clients

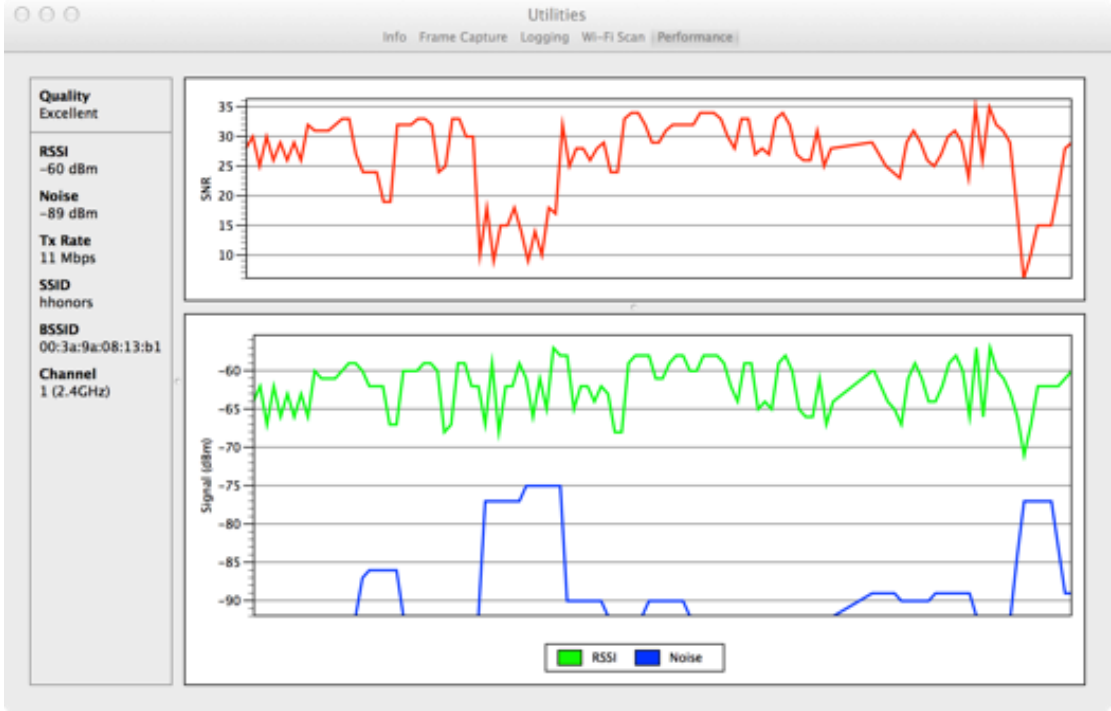
5GHz TX Power: 17dB
50 clients

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)
- Transmit power too low to overcome noise floor



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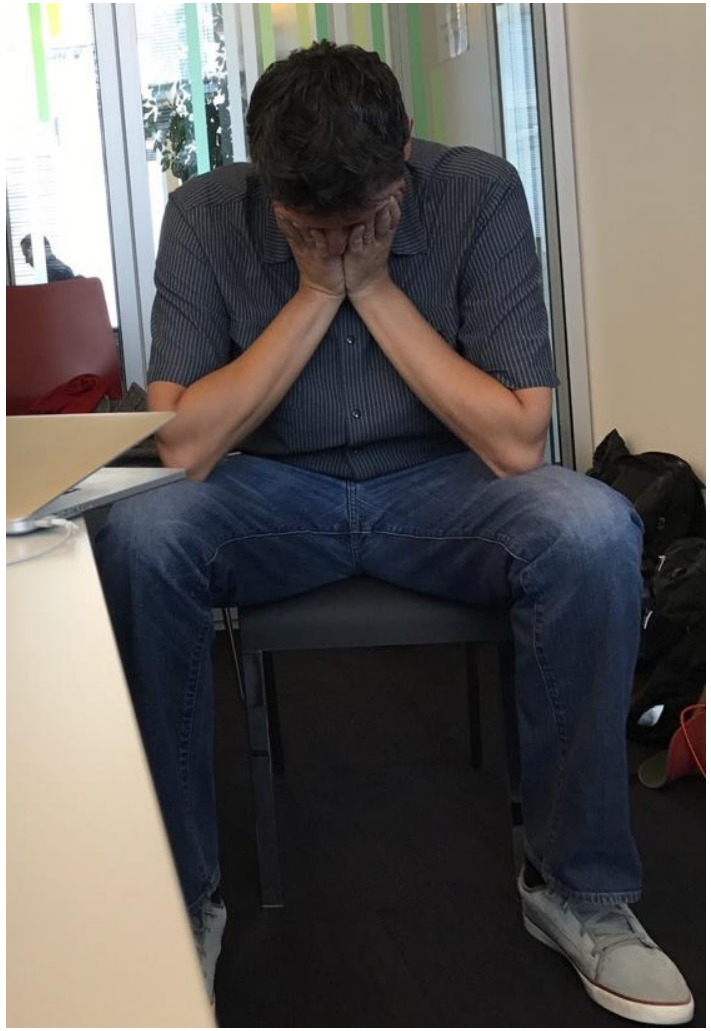

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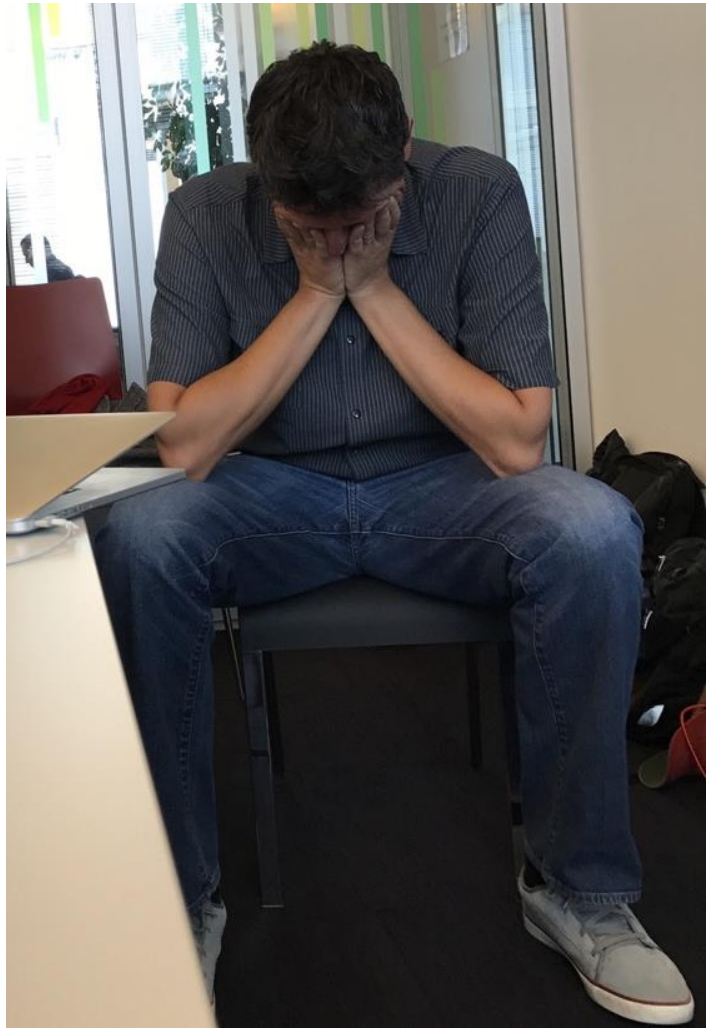

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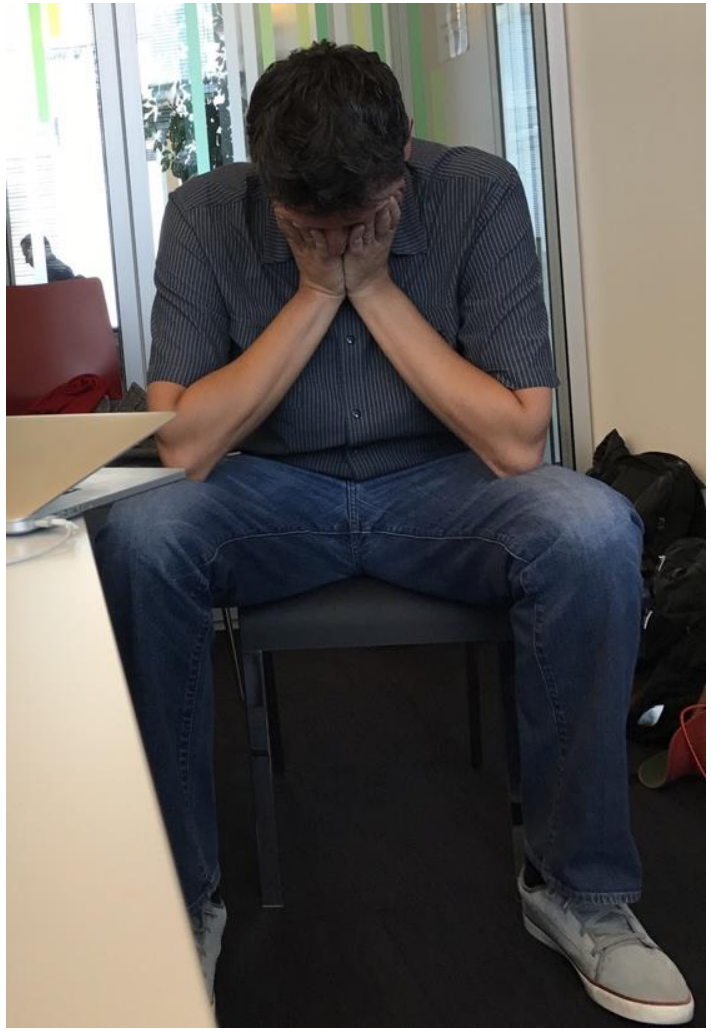

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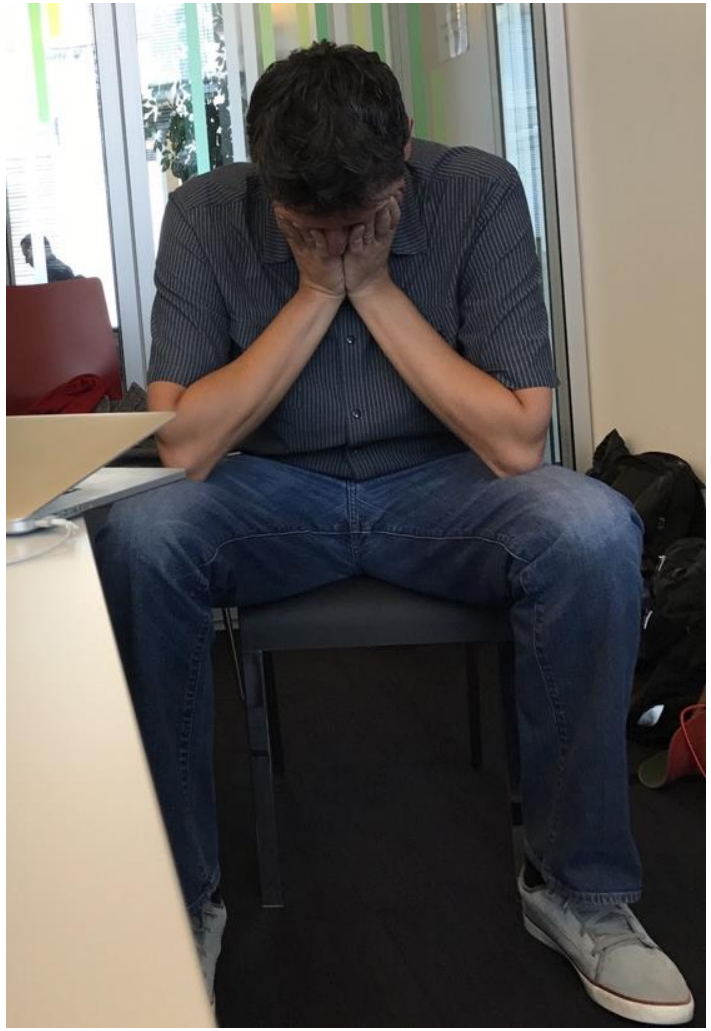

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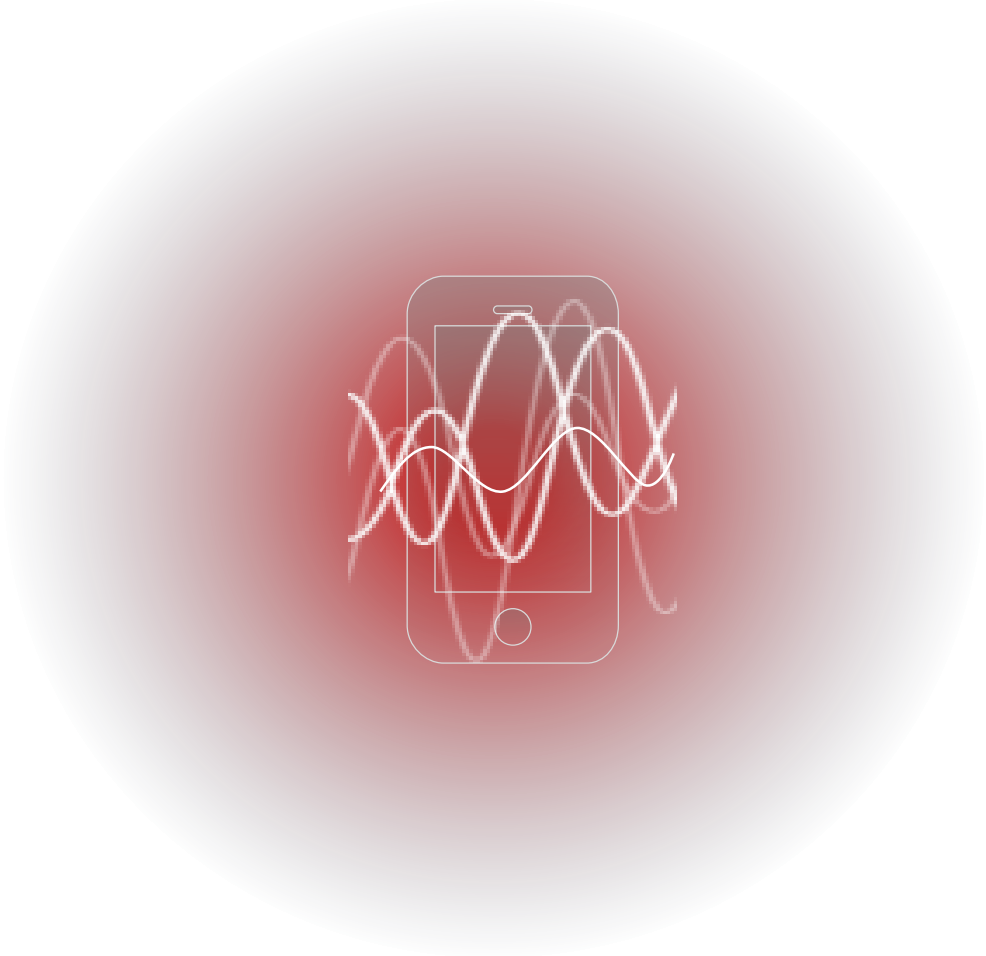
- Unusable channels (especially 5GHz)

Common High Density Optimization Mistakes

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



Hidden Slide – For Your Reference

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

Hidden Slide – For Your Reference

Non-WiFi Interferers

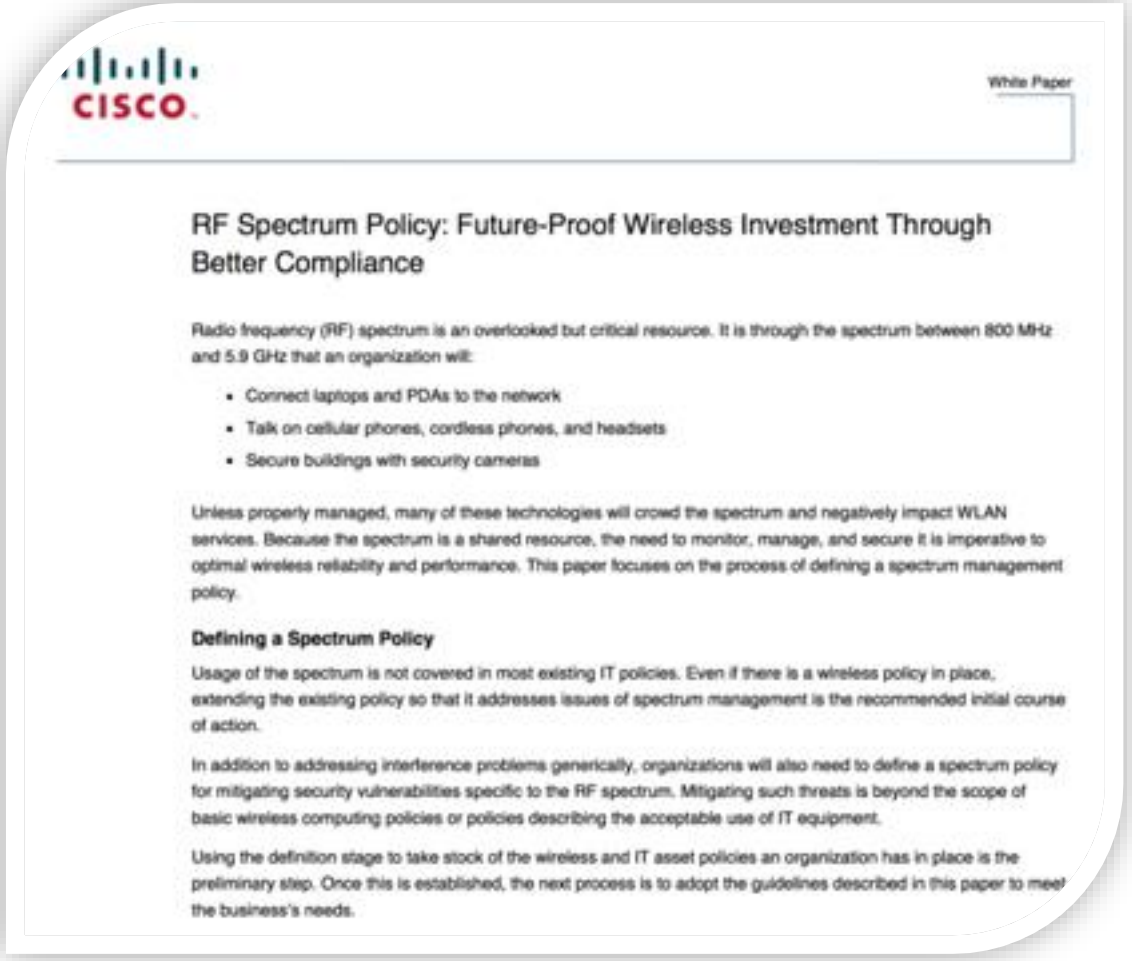
- Video cameras, wireless audio (Coachcomm, Zaxcom), lighting, pyro, and cryo systems, etc.
- Ever look at a Fluke meter and see zero AP's where you'd expect to see dozens? Non-WiFi Interferers often drown out 802.11 altogether.
- Mitigation: remove them altogether or change frequency if possible

Hidden Slide – For Your Reference

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



White Paper

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.

Hidden Slide – For Your Reference

Our Favorite Tools

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
- *(Article)* Analyzing Wireless Packet Captures

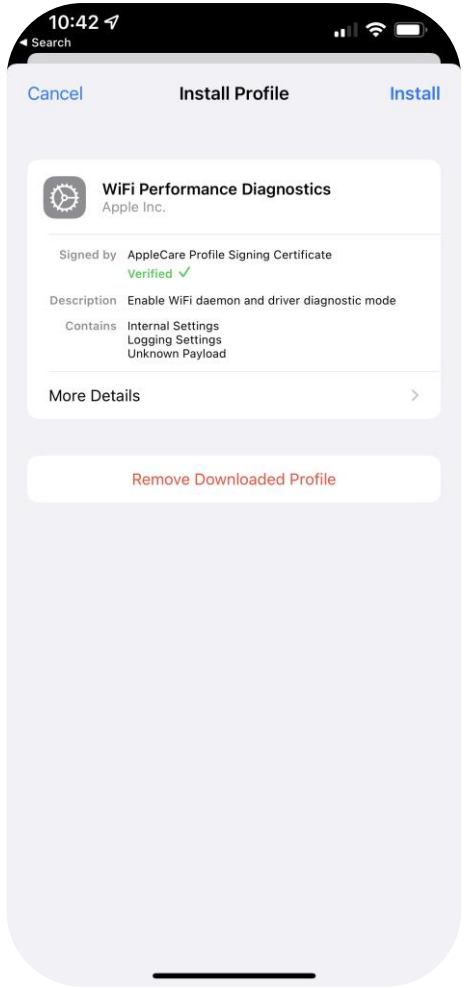
Site Survey Tools

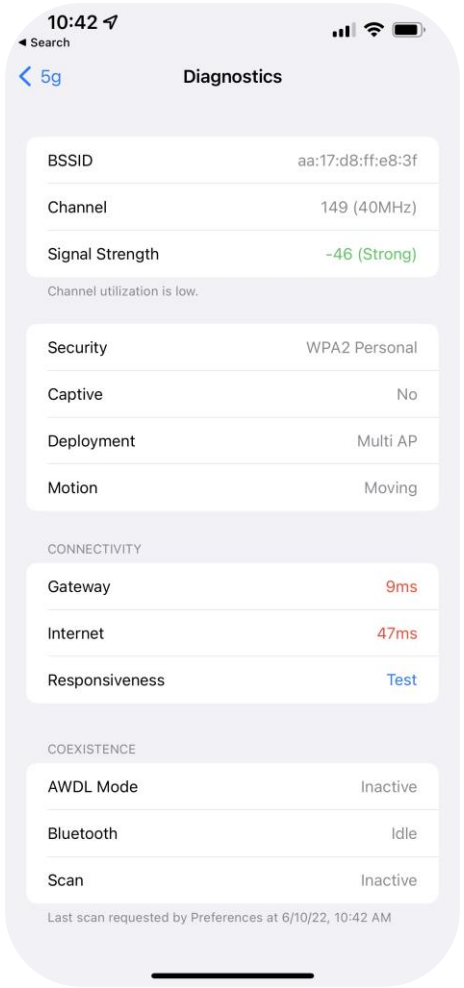
- Hamina
- Ekahau

NetOps, AIOps, DevOps Tools

- Cisco Catalyst Center Assurance

iOS Wi-Fi Diagnostics with iOS





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

More Info:

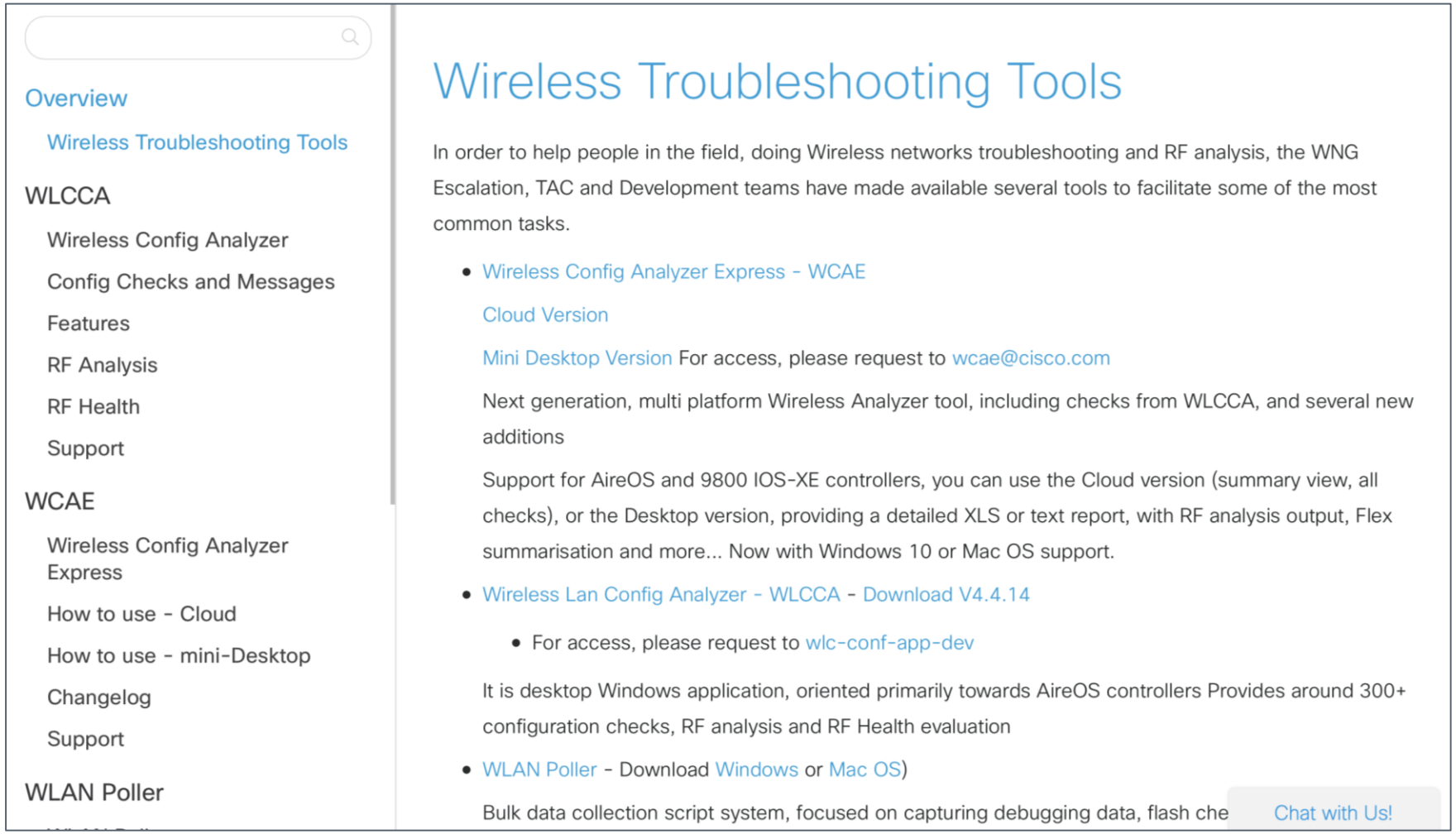
https://tidbits.com/2022/04/22/use-apples-networkquality-tool-to-test-internet-responsiveness/

Profile Download:

1. Use the "easy" button from our friend Jiri
2. Download & install the profile from Apple

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

Wireless Troubleshooting Tools



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

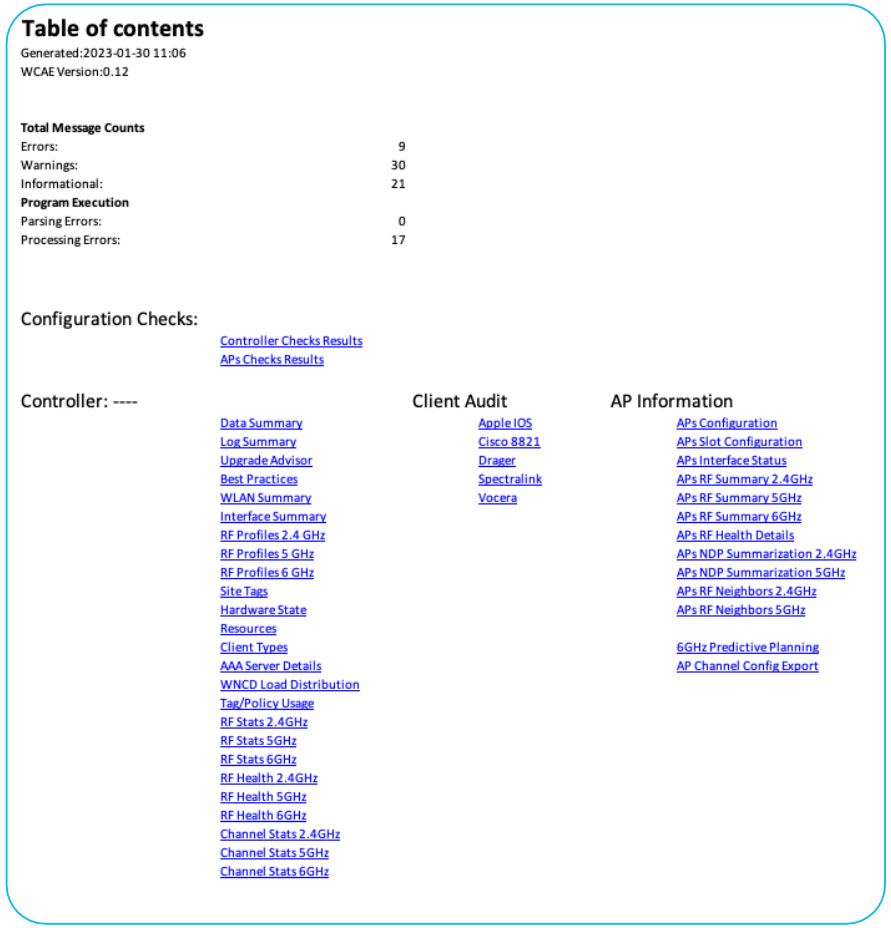


Table of contents

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: ----

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

Client Audit

Apple IOS
Cisco 8821
Drager
Spectralink
Vocera

AP Information

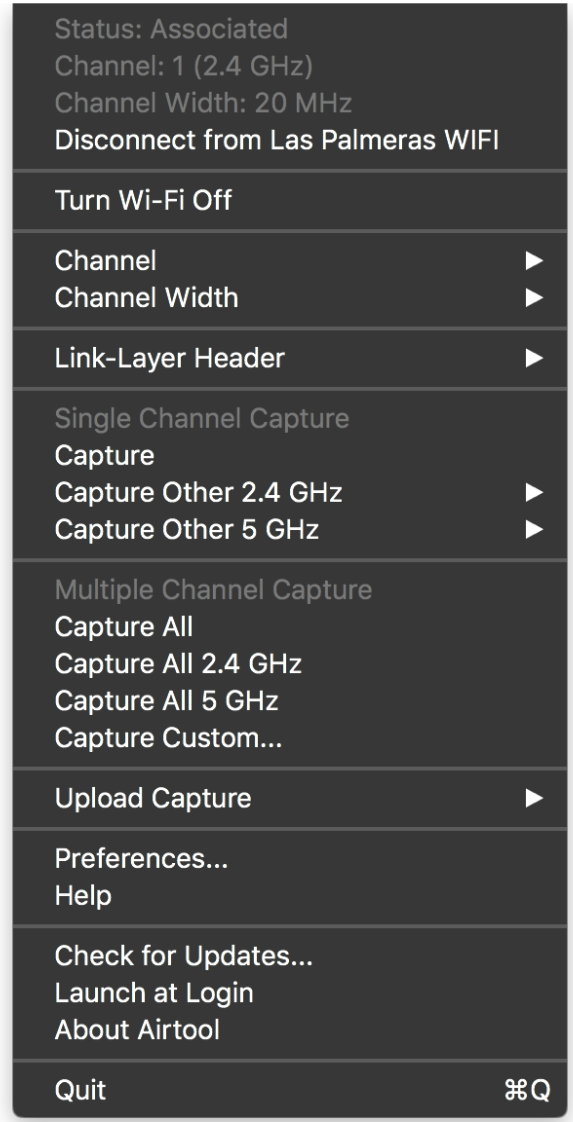
APs Configuration
APs Slot Configuration
APs Interface Status
APs RF Summary 2.4GHz
APs RF Summary 5GHz
APs RF Summary 6GHz
APs RF Health Details
APs NDP Summarization 2.4GHz
APs NDP Summarization 5GHz
APs RF Neighbors 2.4GHz
APs RF Neighbors 5GHz

6GHz Predictive Planning
AP Channel Config Export

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

Packet Captures

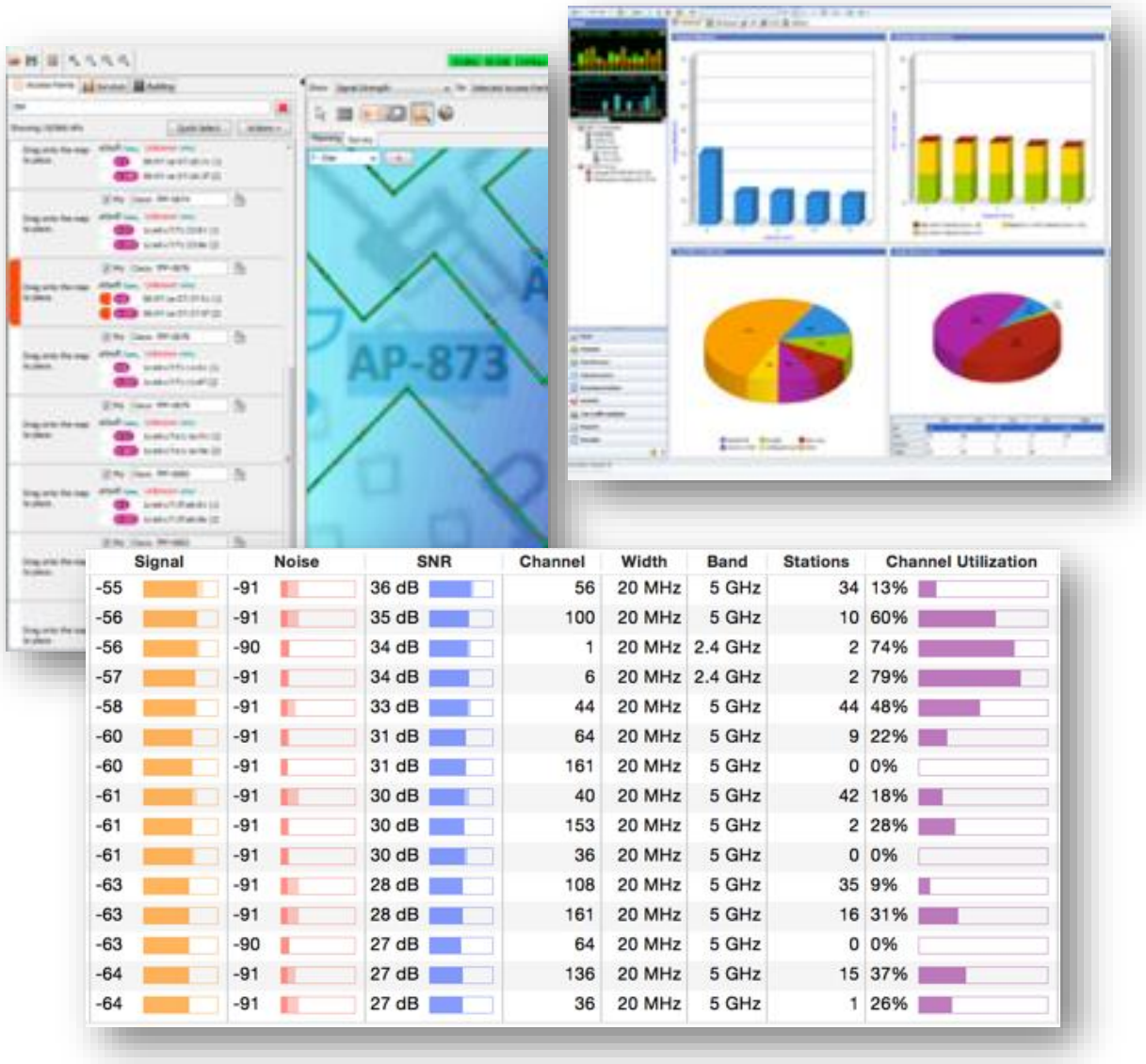
- OmniPeek/Wireshark
  - For packet captures of the WLAN, including beacons and other management traffic
  - Helpful for troubleshooting of problems at the source
- AirTool
  - Free app for Mac – simplifies packet capture process
  - https://www.adriangranados.com/apps/airtool



Hidden Slide – For Your Reference

Site Surveys

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



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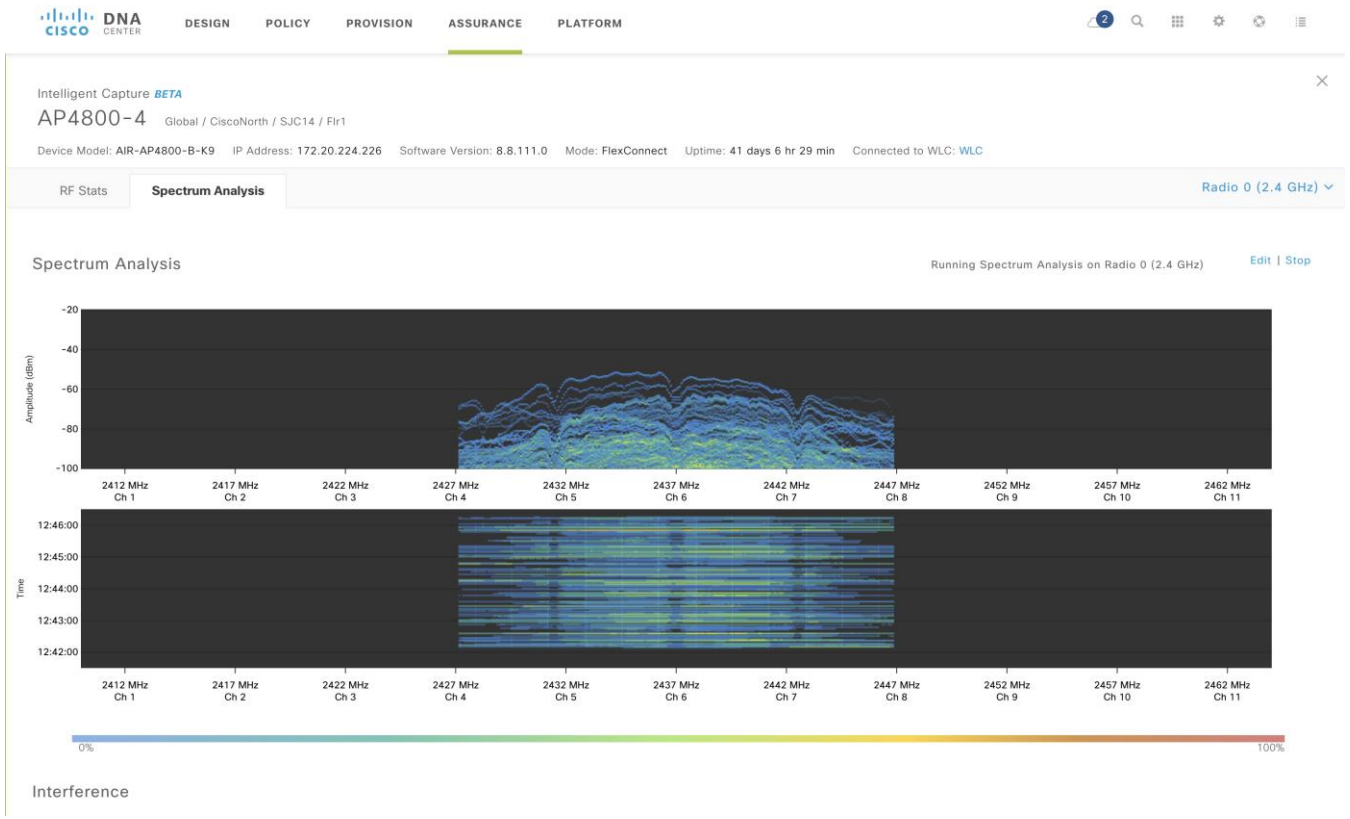
Spectrum Analysis

Cisco Catalyst Center Intelligent Capture / Cloud Dashboard

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



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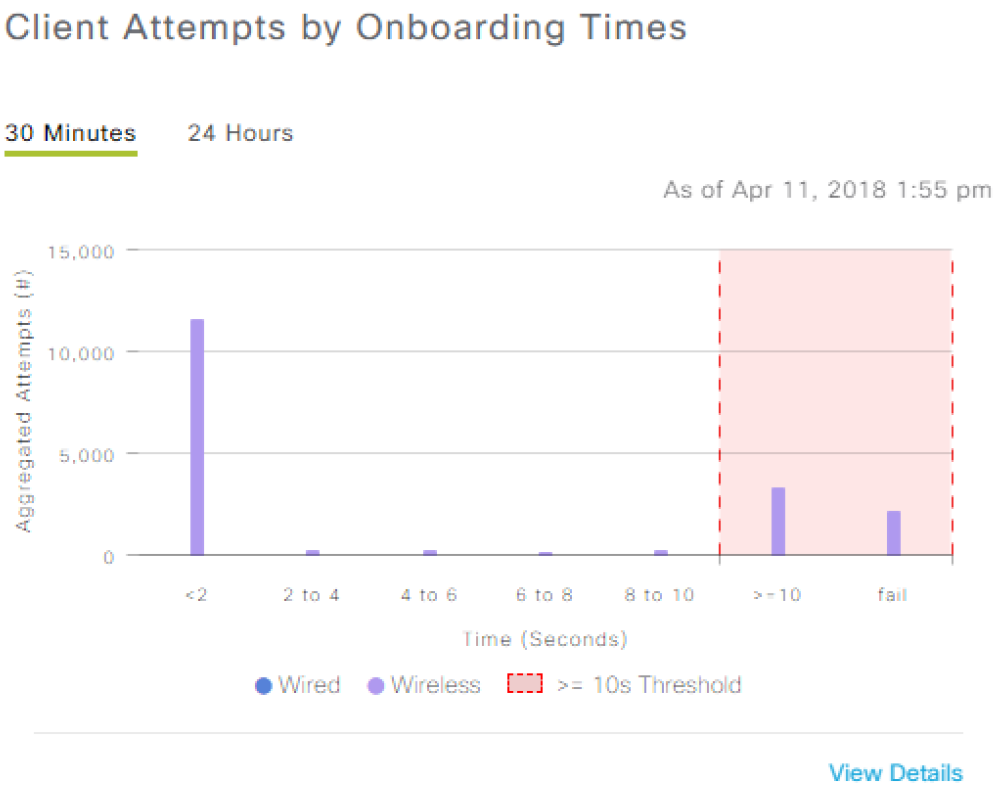
Cisco Catalyst Center Assurance

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

Hidden Slide – For Your Reference

Key Takeaways

- Design the RF environment with appropriate **antennas** and sensible physical **placements**
- Learn and understand your region's specific 6GHz Wi-Fi regulations and begin your planning
- Employ HD-focused **feature configurations** such as RF Profiles for more flexible and robust designs
- Get comfortable with **Wi-Fi analysis and optimization tools** to make informed, data-driven decisions

Complete your session evaluations

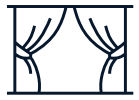
Complete a minimum of 4 session surveys and the Overall Event Survey to be entered in a drawing to win 1 of 5 full conference passes to Cisco Live 2026.

Earn 100 points per survey completed and compete on the Cisco Live Challenge leaderboard.

Level up and earn exclusive prizes!

Complete your surveys in the Cisco Live mobile app.

Continue your education



Visit the Cisco Showcase for related demos

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Attend the interactive education with DevNet, Capture the Flag, and Walk-in Labs

Visit the On-Demand Library for more sessions at www.CiscoLive.com/on-demand

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Thank you

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