

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.

cisco *Live!*

Let's go

#CiscoLiveAPJC



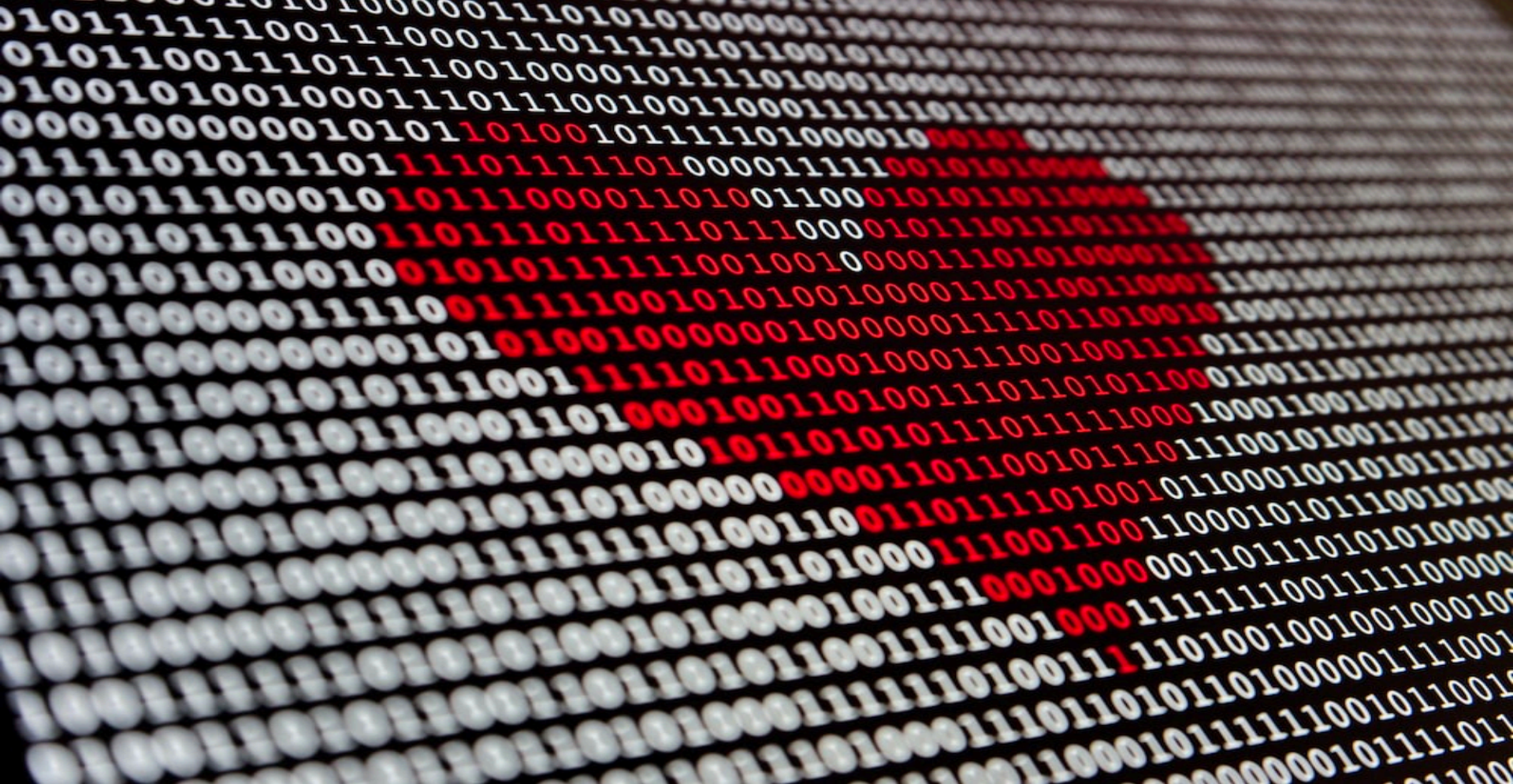
The bridge to possible

High Density Wi-Fi, Design, Deployment and Optimisation

Ric Beeching, Solutions Engineer
@ricbeeching
BRKEWN-2087

CISCO *Live!*

#CiscoLiveAPJC





Ric Beeching

Solutions Engineer



Cisco Webex App

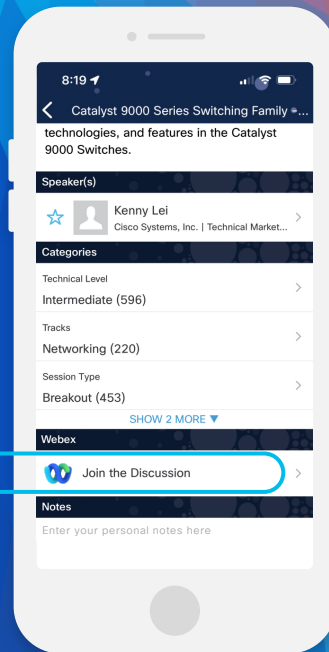
Questions?

Use Cisco Webex App to chat with the speaker after the session

How

- 1 Find this session in the Cisco Live Mobile App
- 2 Click “Join the Discussion”
- 3 Install the Webex App or go directly to the Webex space
- 4 Enter messages/questions in the Webex space

Webex spaces will be moderated by the speaker until December 22, 2023.



<https://ciscolive.ciscoevents.com/ciscolivebot/#BRKEWN-2087>

Agenda

- RF Concepts Review
- Design
- Deploy
- Optimise
- Tools

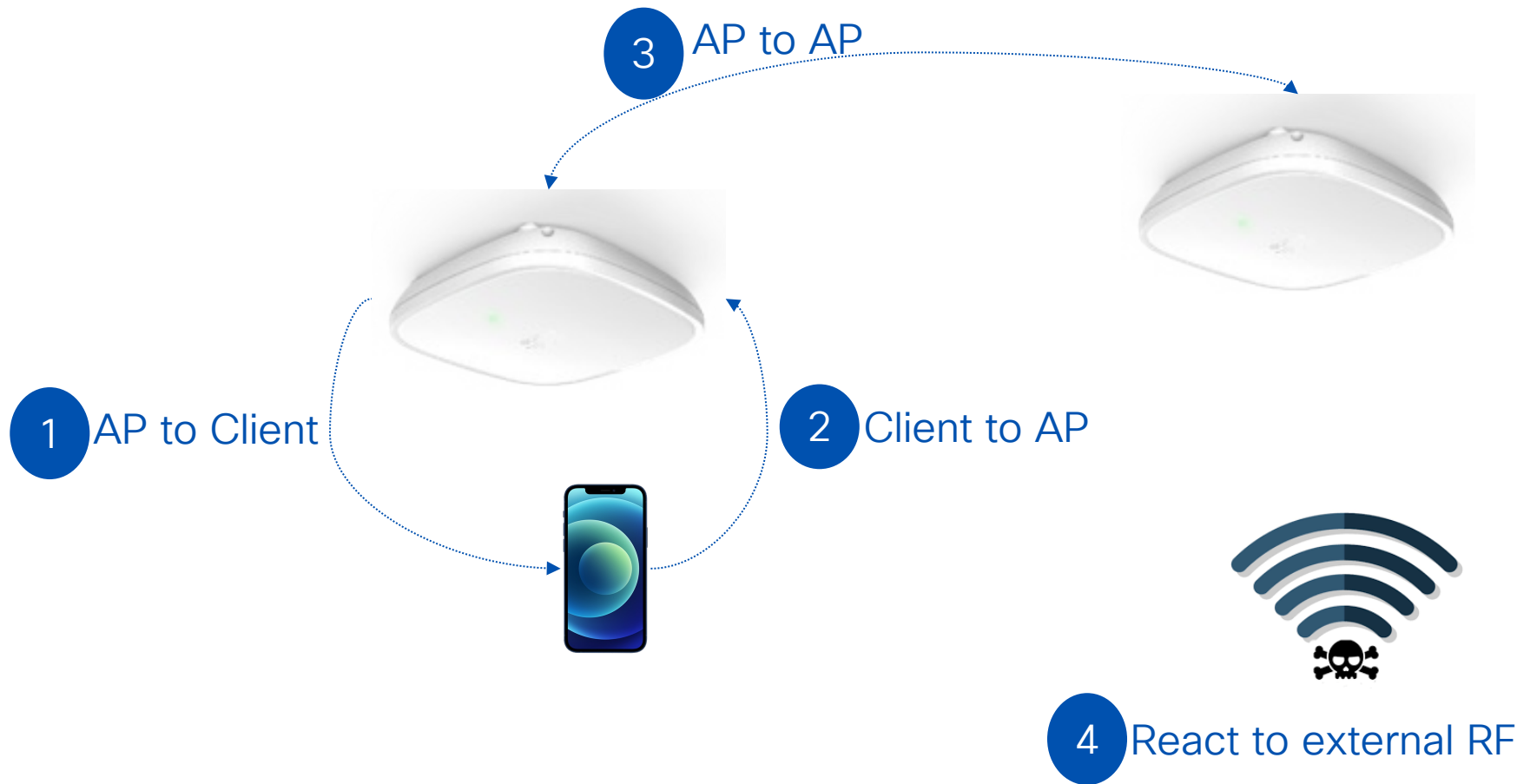


1 AP to Client



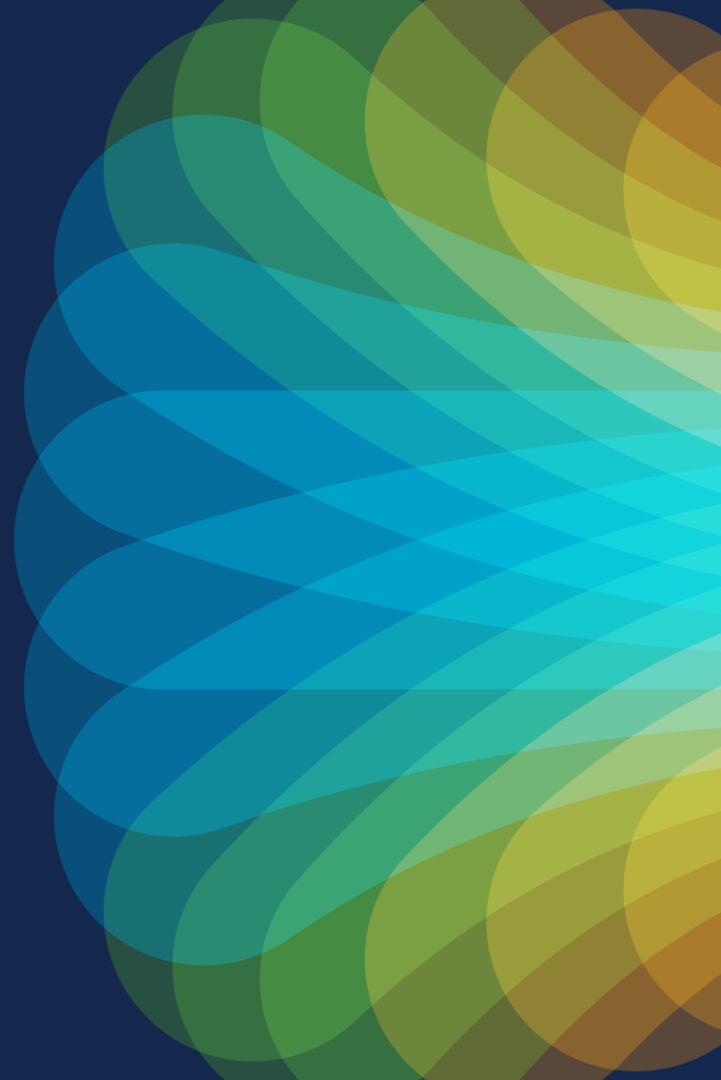








RF Concepts Review

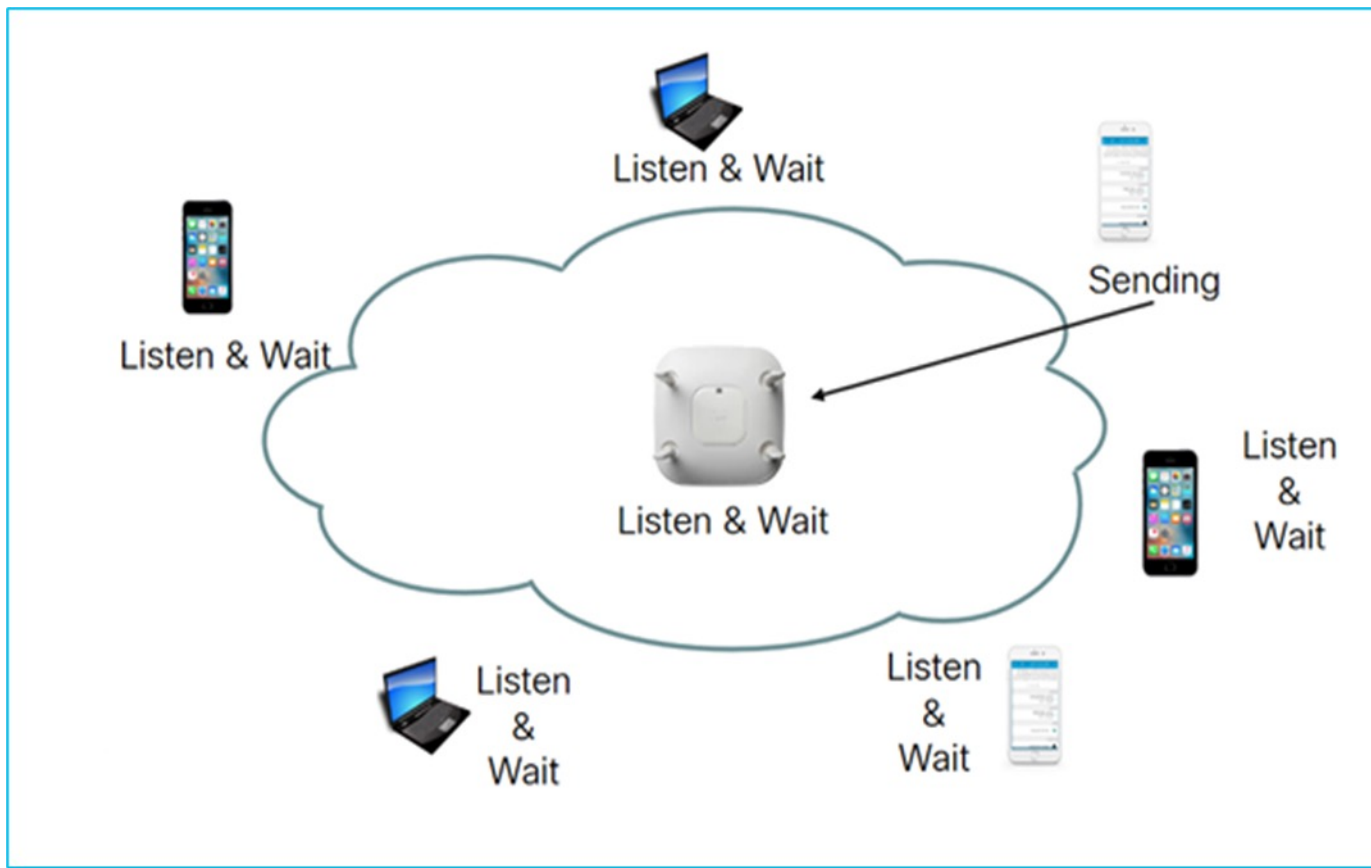


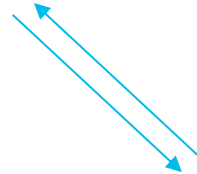


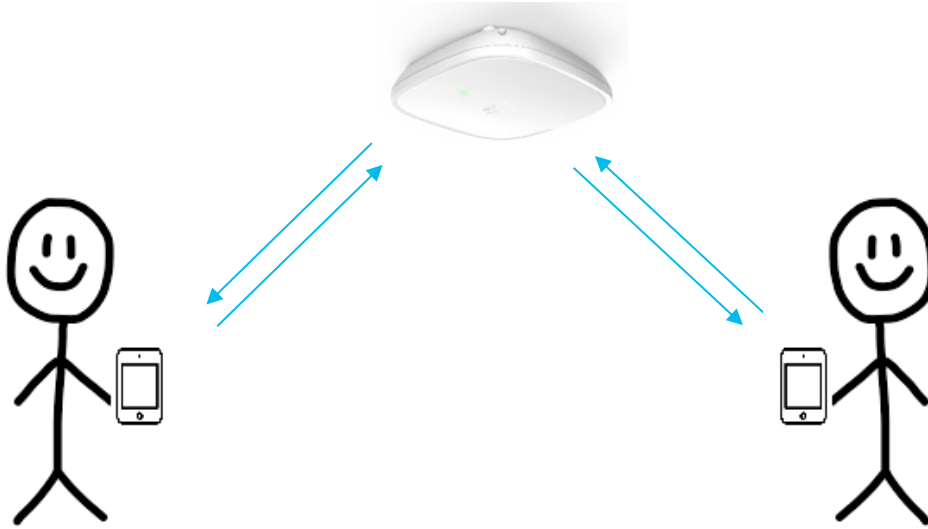


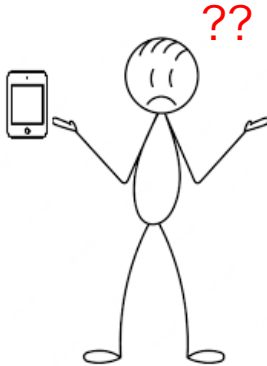
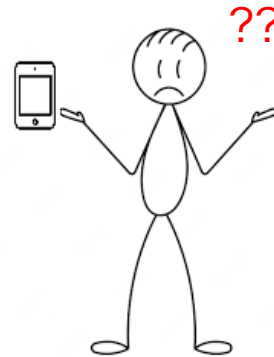
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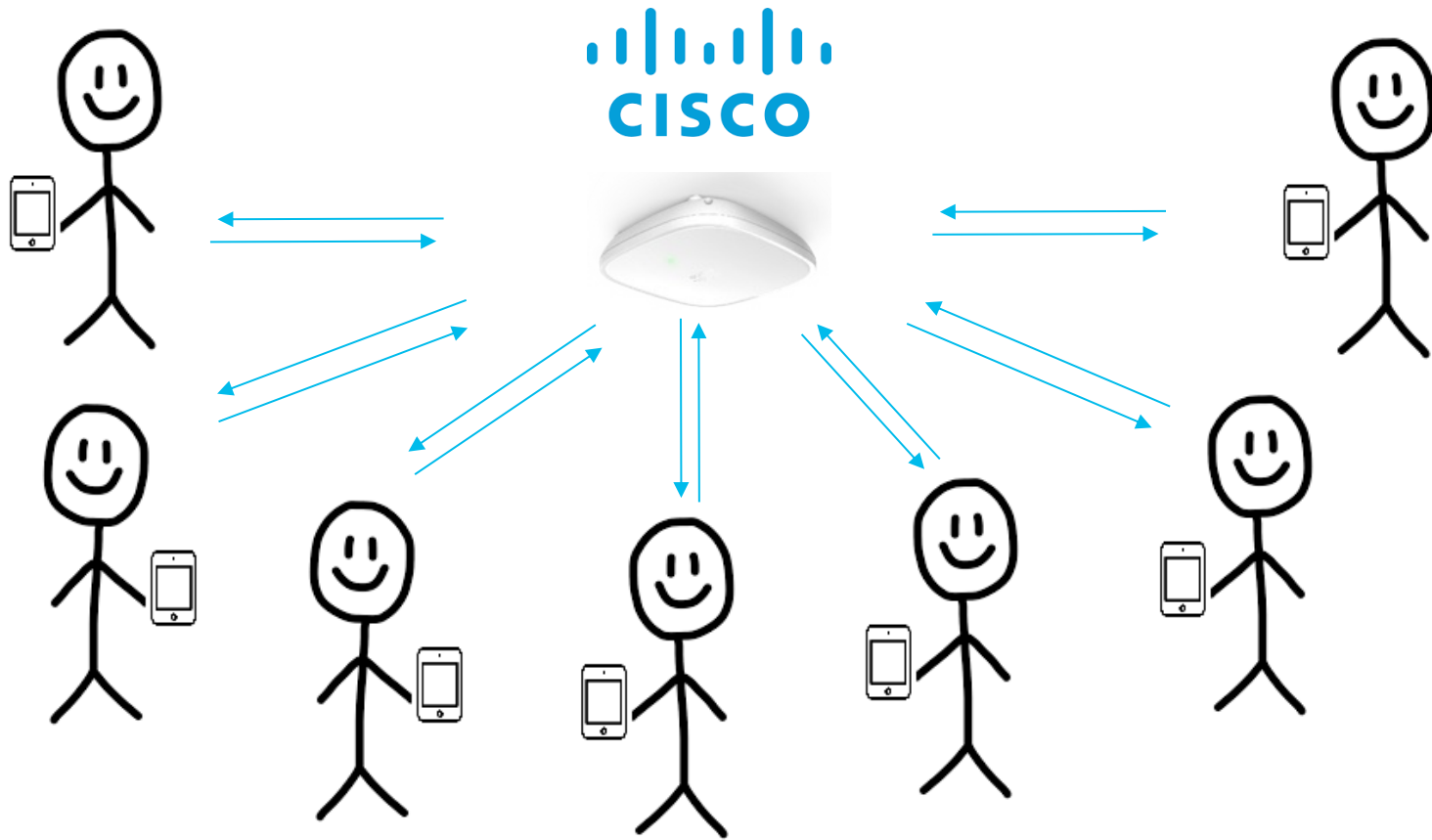


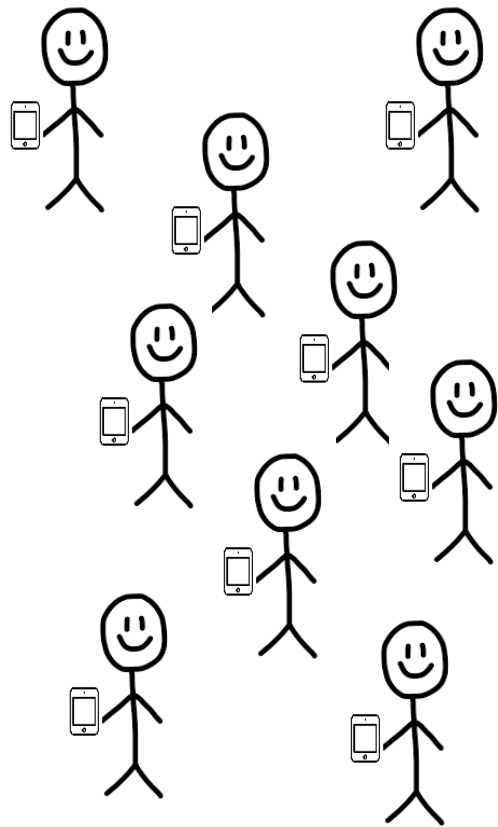




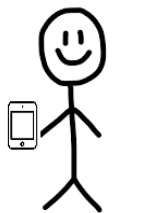
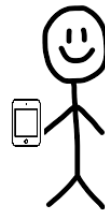








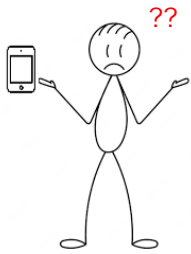
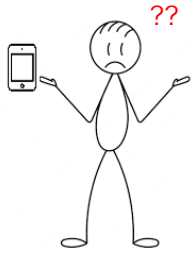
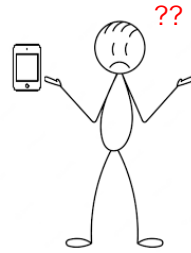
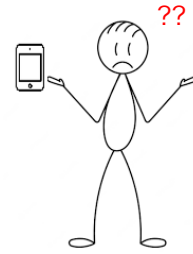
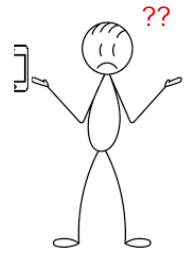
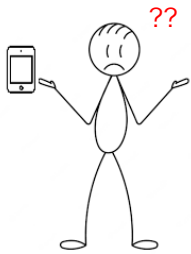
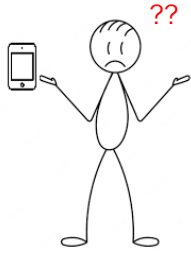
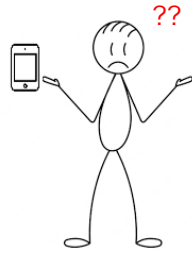
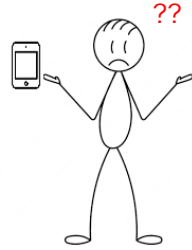
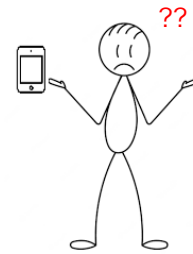
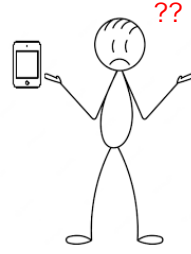
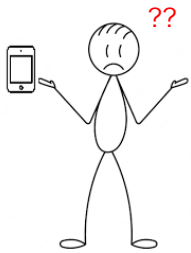
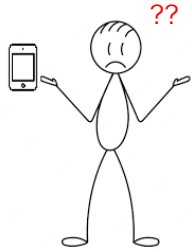
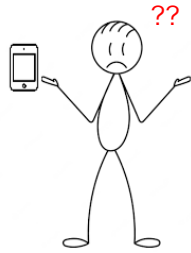
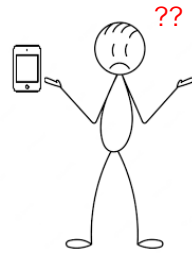
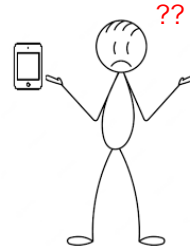
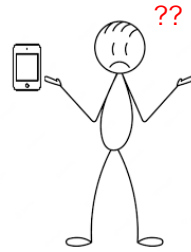

CISCO

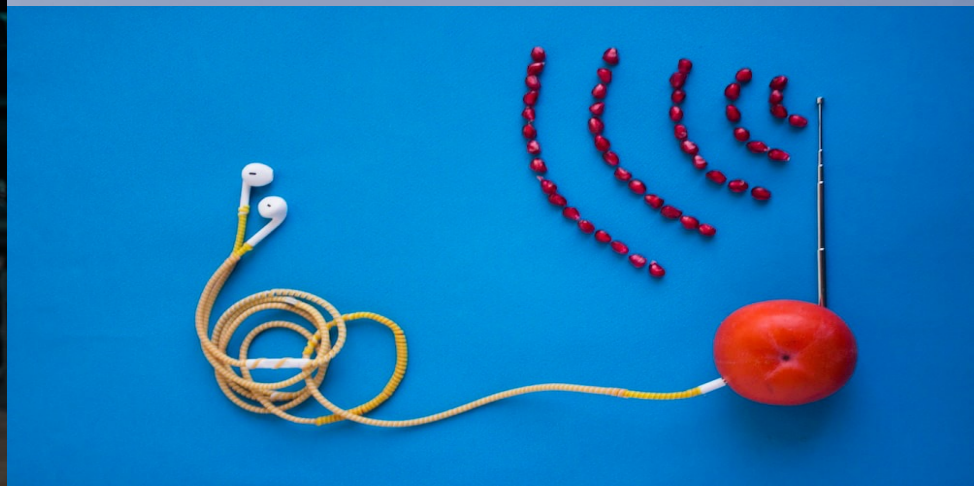


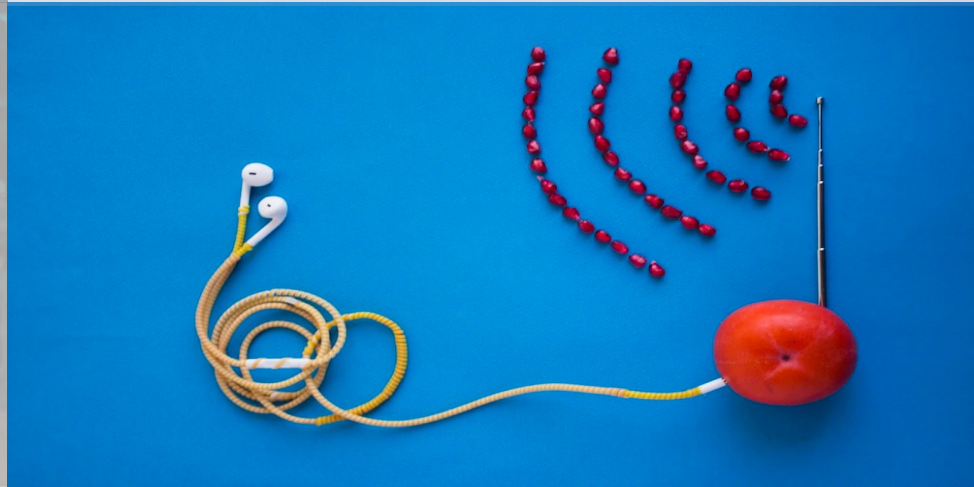
CISCO *Live!*





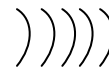






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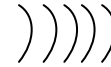
10101011 →



2 Modulation

1 Digital Data

10101011 →



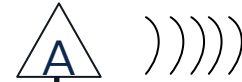
2 Modulation

1 Digital Data

10101011 →



3 Energy Output



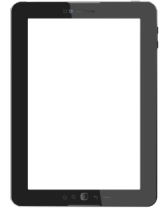
2 Modulation

1 Digital Data

10101011 →



3 Energy Output



4 Digital Data

Cafe.pcap

File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help

Apply a display filter ... <Ctrl-/> Expression...

No.	Time	Source	Destination	Protocol	Length	Info
13	0.107129	CiscoInc_00:0c:00	HonHaiPr_00:0a:00	LLC	1570	I, N(R)=0, N(S)=0; DSAP NU...
14	0.107131		CiscoInc_00:0b:00 (...)	802.11	46	Acknowledgement, Flags=...
15	0.107873	CiscoInc_00:0c:00	HonHaiPr_00:0a:00	LLC	136	I, N(R)=0, N(S)=0; DSAP NU...
16	0.107874		CiscoInc_00:0b:00 (...)	802.11	46	Acknowledgement, Flags=...
17	0.107877		HonHaiPr_00:0a:00 (...)	802.11	46	Acknowledgement, Flags=...
18	0.110252	CiscoInc_00:0d:00	Broadcast	802.11	286	Beacon frame, SN=1809, FN=...
19	0.110254	Apple_00:09:00	Broadcast	LLC	114	I, N(R)=0, N(S)=0; DSAP NU...
20	0.112889		HonHaiPr_00:0a:00 (...)	802.11	46	Acknowledgement, Flags=...
21	0.131663	CiscoInc_00:03:00	Apple_00:0e:00	802.11	261	Probe Response, SN=3648, F...
22	0.131885	CiscoInc_00:03:00	Apple_00:0e:00	802.11	261	Probe Response, SN=3648, F...
23	0.134527	CiscoInc_00:0f:00	Broadcast	802.11	273	Beacon frame, SN=2006, FN=...
24	0.136262	CiscoInc_00:0c:00	HonHaiPr_00:0a:00	LLC	169	I, N(R)=0, N(S)=0; DSAP NU...
25	0.136264		CiscoInc_00:0b:00 (...)	802.11	46	Acknowledgement, Flags=...
26	0.140906	CiscoInc_00:10:00	Broadcast	802.11	289	Beacon frame, SN=1811, FN=...
27	0.141005	IntelCor_00:11:00	Broadcast	LLC	114	I, N(R)=0, N(S)=0; DSAP NU...
28	0.142378	Azurewav_00:12:00	CiscoInc_00:13:00	LLC	128	I, N(R)=0, N(S)=0; DSAP NU...
29	0.142751	Azurewav_00:12:00	CiscoInc_00:13:00	LLC	128	I, N(R)=0, N(S)=0; DSAP NU...
30	0.142752		Azurewav_00:12:00 (...)	802.11	46	Acknowledgement, Flags=...
31	0.142875	Azurewav_00:12:00	CiscoInc_00:13:00	LLC	128	I, N(R)=0, N(S)=0; DSAP NU...

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0010 00 00 00 00 01 00 24 00 6c 09 c0 00 00 00 c9 ae  ....$. 1.....
0020 d4 00 00 00 00 25 d3 00 12 00 95 81 44 f0      ....%.. ....D.

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Cafe

Packets: 68611 · Displayed: 68611 (100.0%) · Load time: 0:1.511 | Profile: Default

Source: Metageek

Cafe.pcap

File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help

Apply a display filter ... <Ctrl-/> Expression...

No.	Time	Source	Destination	Protocol	Length	Info
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14	0.107131		CiscoInc_00:0b:00 (...)	802.11	46	Acknowledgement, Flags=...
15	0.107873	CiscoInc_00:0c:00	HonHaiPr_00:0a:00	LLC	136	I, N(R)=0, N(S)=0; DSAP NU...
16	0.107874		CiscoInc_00:0b:00 (...)	802.11	46	Acknowledgement, Flags=...
17	0.107877		HonHaiPr_00:0a:00 (...)	802.11	46	Acknowledgement, Flags=...
18	0.110252	CiscoInc_00:0d:00	Broadcast	802.11	286	Beacon frame, SN=1809, FN=...
19	0.110254	Apple_00:09:00	Broadcast	LLC	114	I, N(R)=0, N(S)=0; DSAP NU...
20	0.112889		HonHaiPr_00:0a:00 (...)	802.11	46	Acknowledgement, Flags=...
21	0.131663	CiscoInc_00:03:00	Apple_00:0e:00	802.11	261	Probe Response, SN=3648, F...
22	0.131885	CiscoInc_00:03:00	Apple_00:0e:00	802.11	261	Probe Response, SN=3648, F...
23	0.134527	CiscoInc_00:0f:00	Broadcast	802.11	273	Beacon frame, SN=2006, FN=...
24	0.136262	CiscoInc_00:0c:00	HonHaiPr_00:0a:00	LLC	169	I, N(R)=0, N(S)=0; DSAP NU...
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26	0.140906	CiscoInc_00:10:00	Broadcast	802.11	289	Beacon frame, SN=1811, FN=...
27	0.141005	IntelCor_00:11:00	Broadcast	LLC	114	I, N(R)=0, N(S)=0; DSAP NU...
28	0.142378	Azurewav_00:12:00	CiscoInc_00:13:00	LLC	128	I, N(R)=0, N(S)=0; DSAP NU...
29	0.142751	Azurewav_00:12:00	CiscoInc_00:13:00	LLC	128	I, N(R)=0, N(S)=0; DSAP NU...
30	0.142752		Azurewav_00:12:00 (...)	802.11	46	Acknowledgement, Flags=...
31	0.142875	Azurewav_00:12:00	CiscoInc_00:13:00	LLC	128	I, N(R)=0, N(S)=0; DSAP NU...

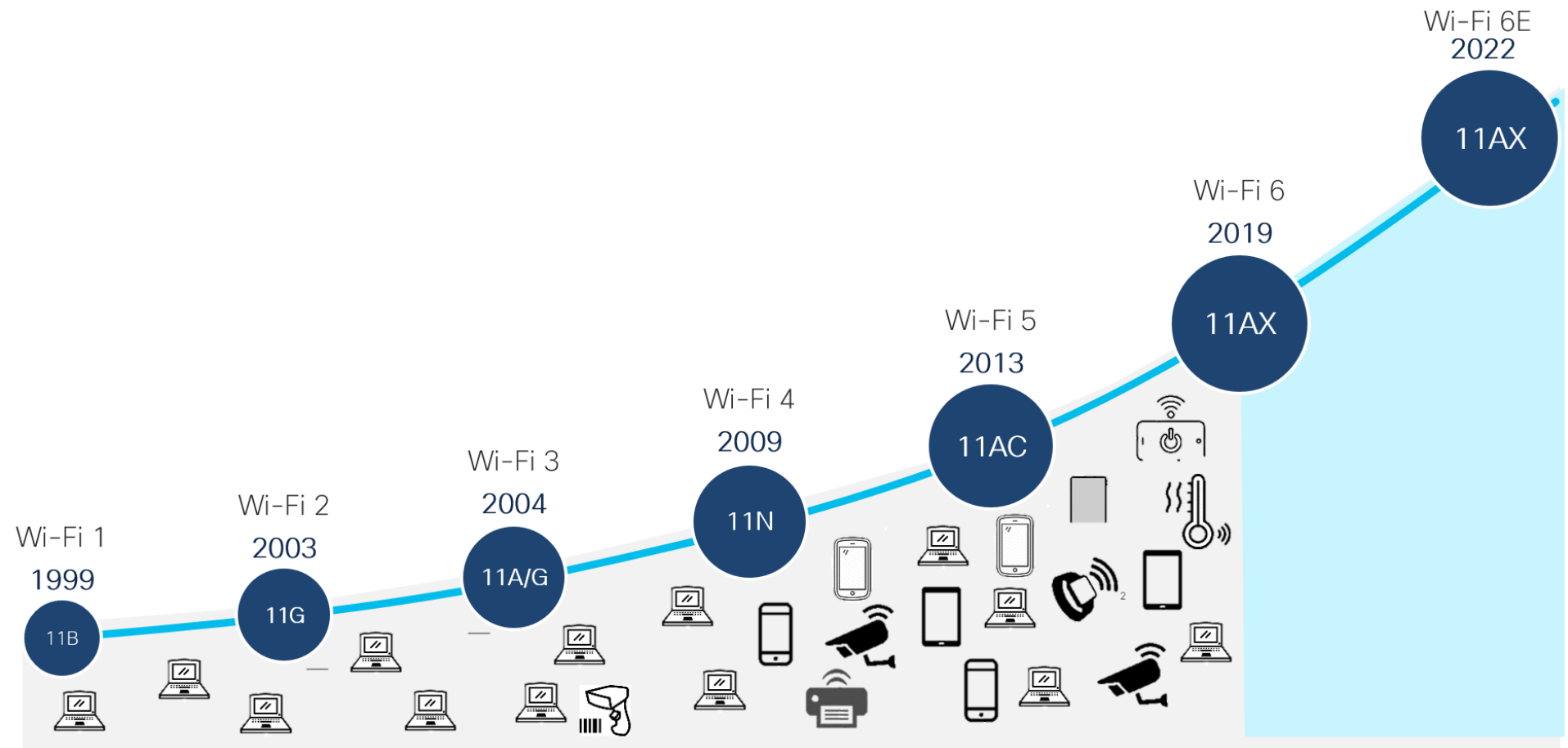
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0020 d4 00 00 00 00 25 d3 00 12 00 95 81 44 f0 .....%. ....D.

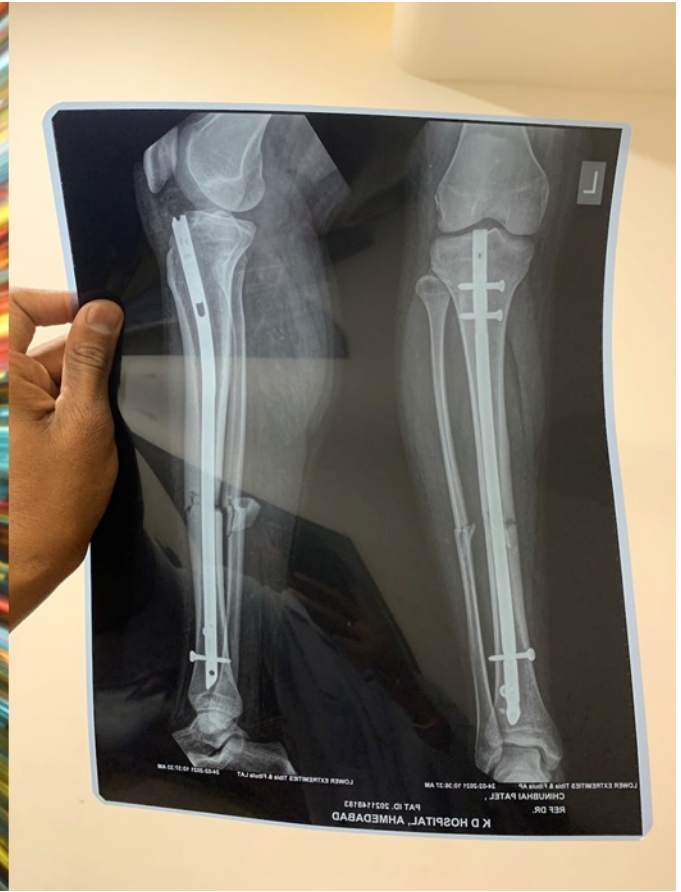
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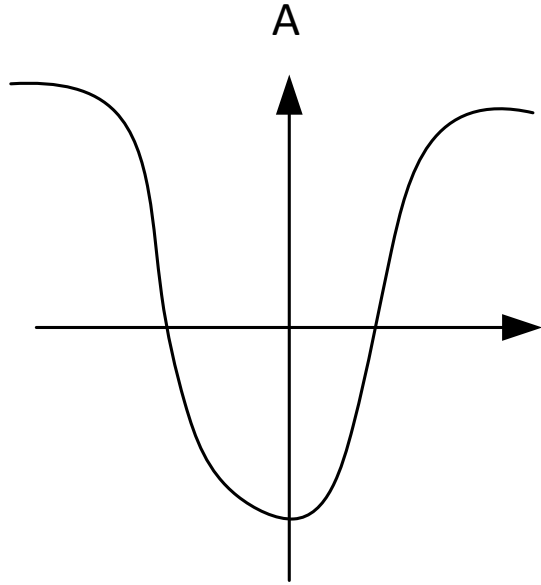
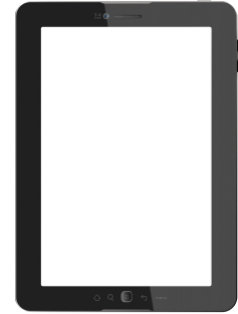
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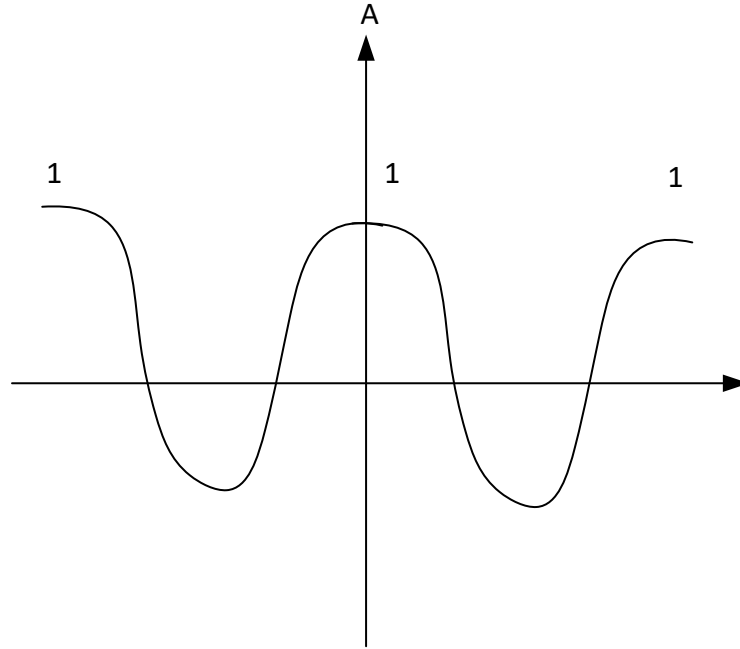
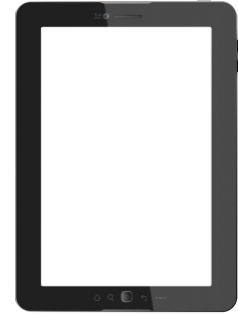
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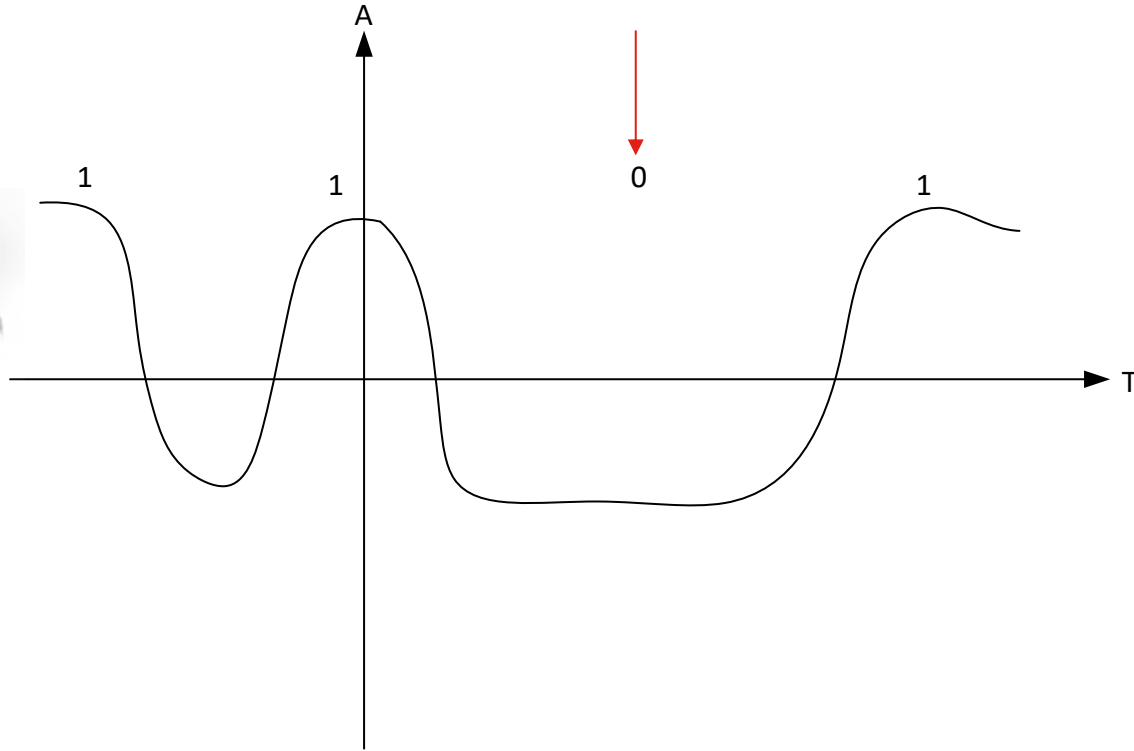
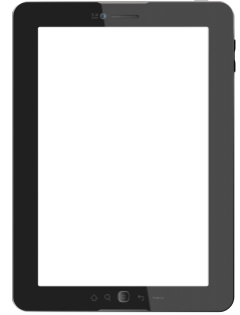




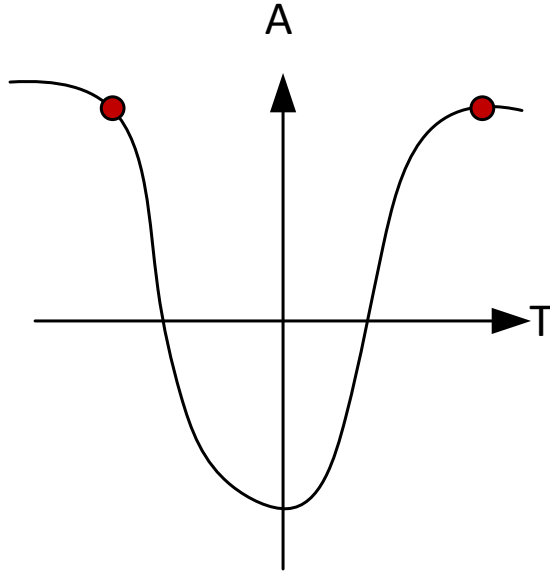
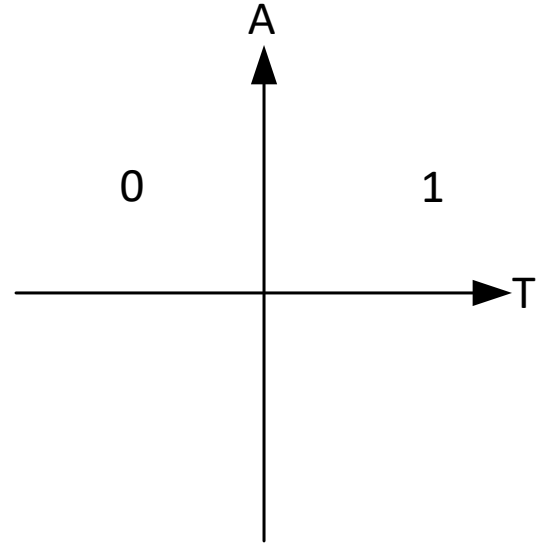






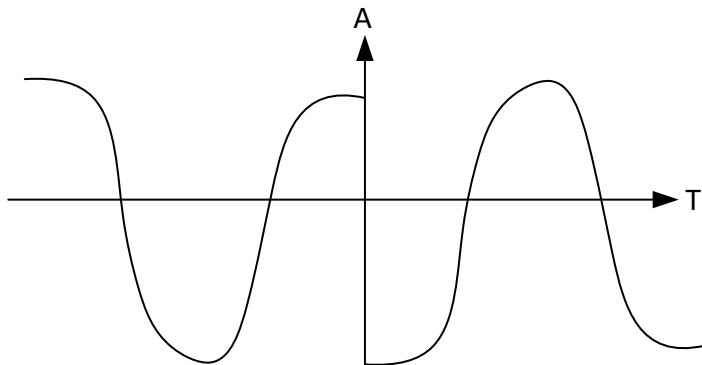
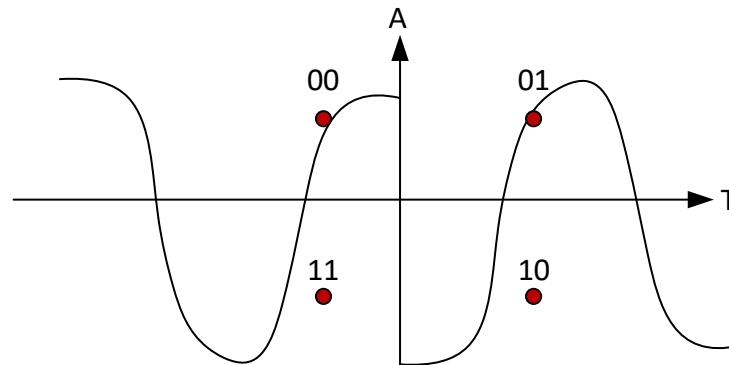


Modulation - BPSK

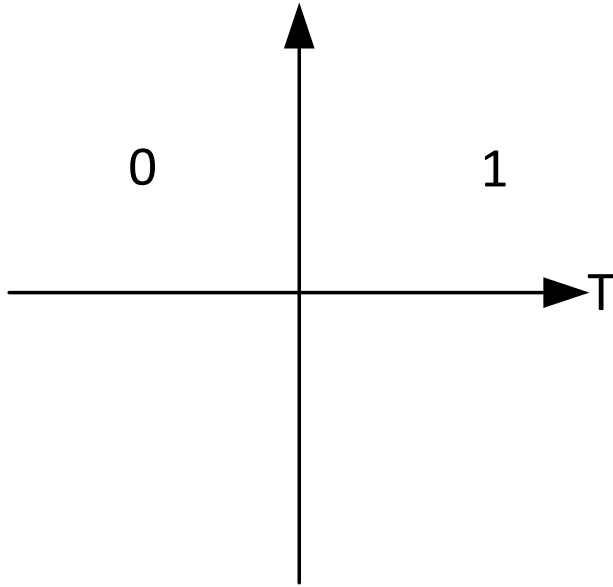
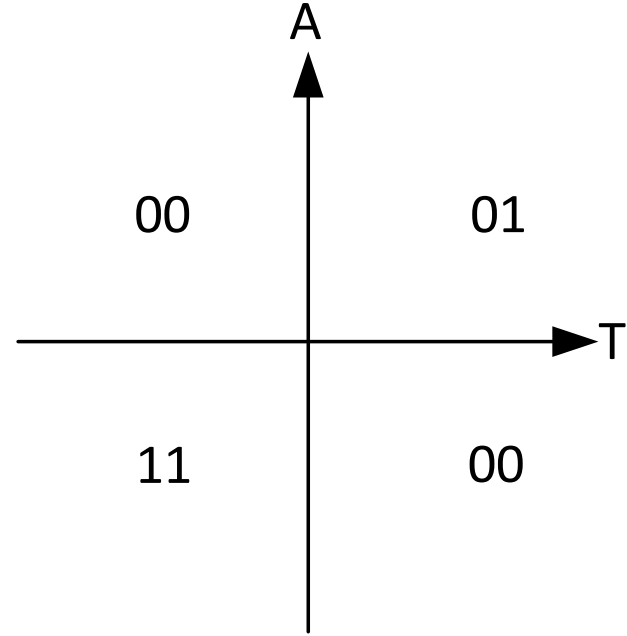




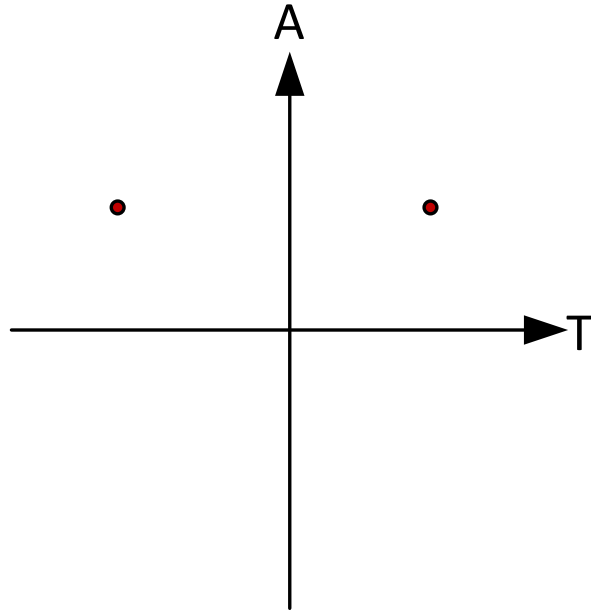
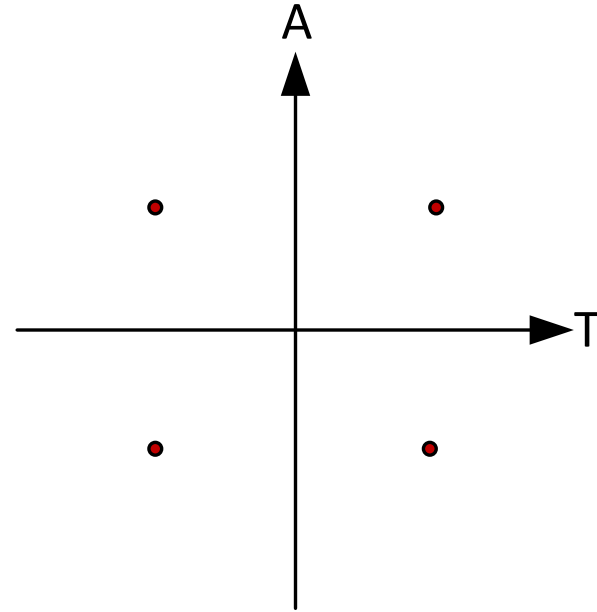
Modulation - QPSK



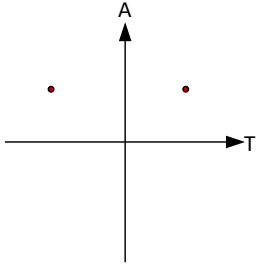
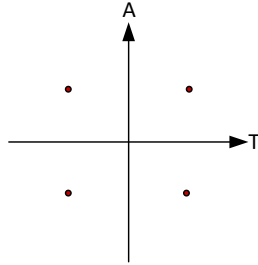
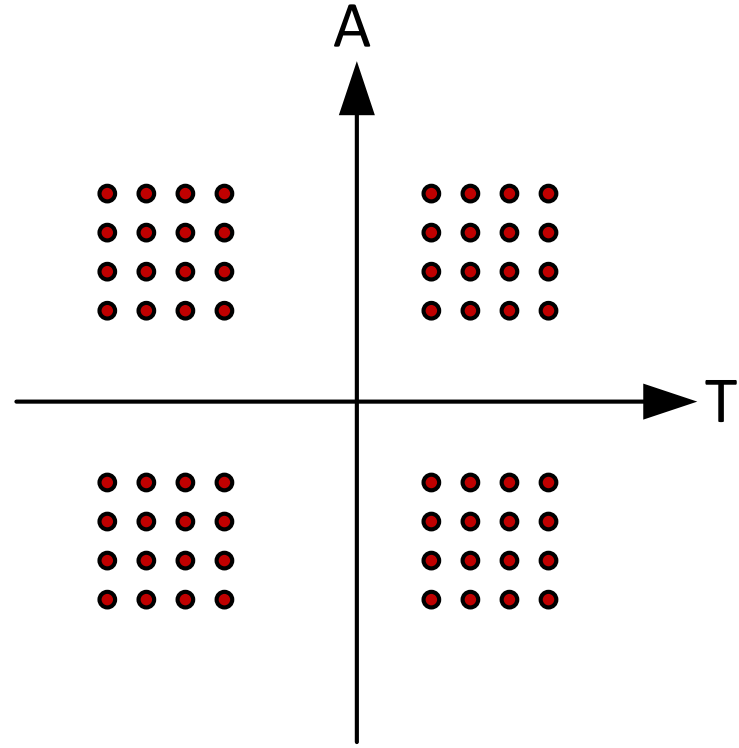
Modulation – BPSK vs QPSK



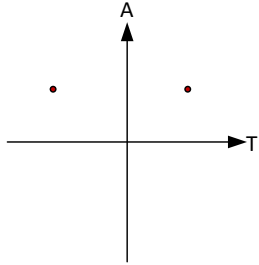
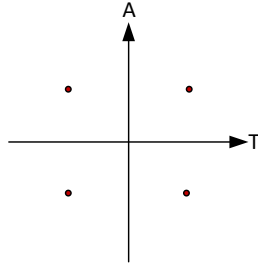
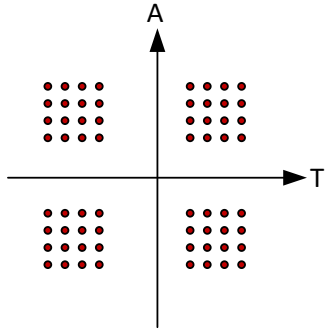
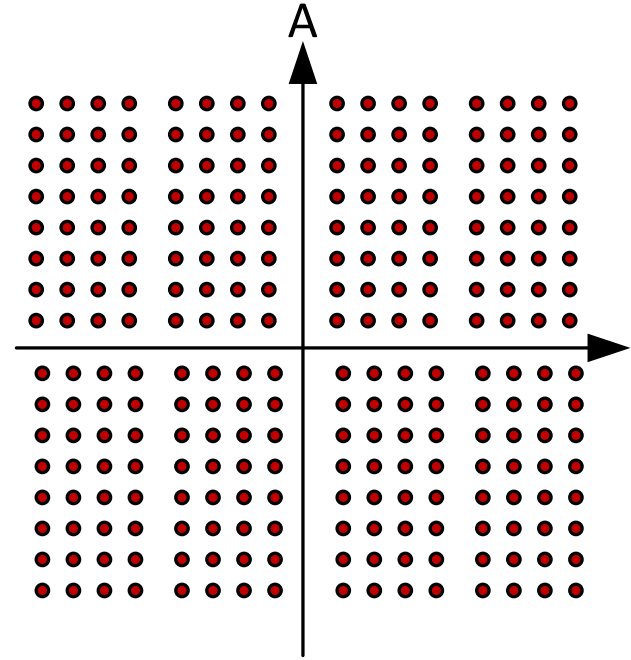
Modulation – BPSK vs QPSK



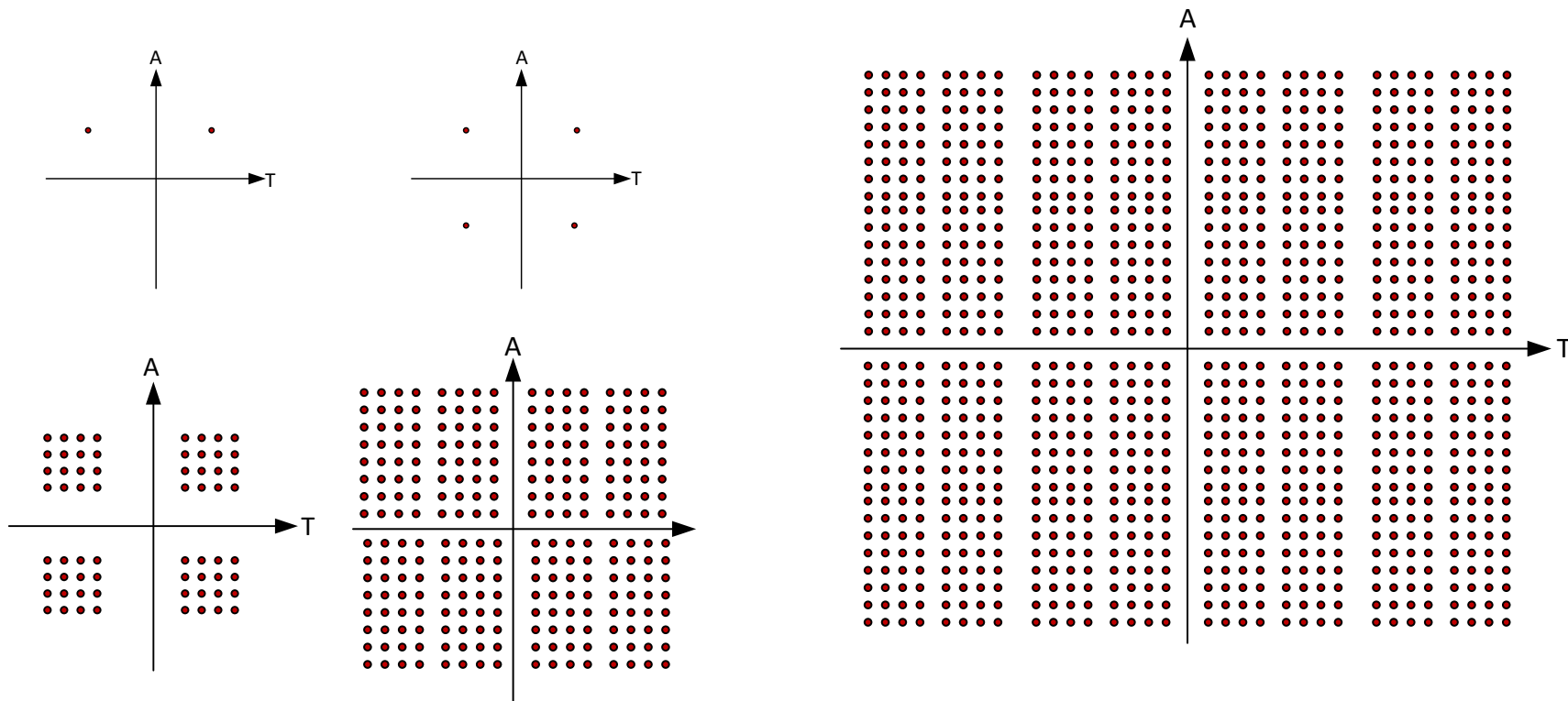
64-QAM - 802.11a/g/n



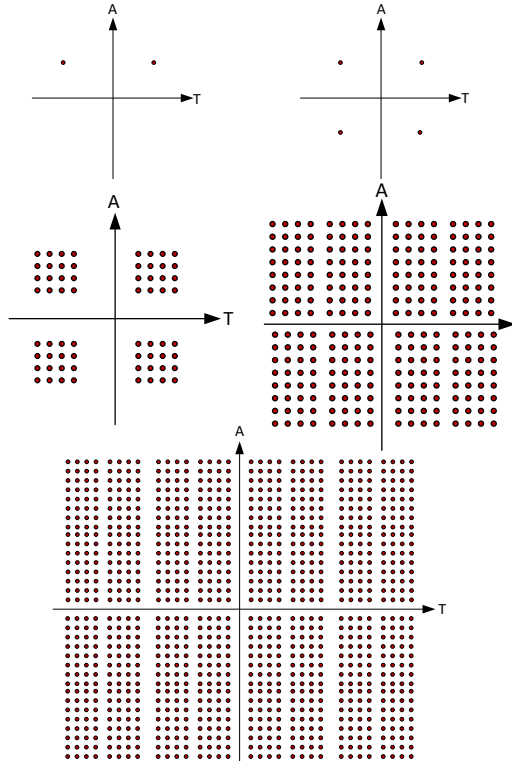
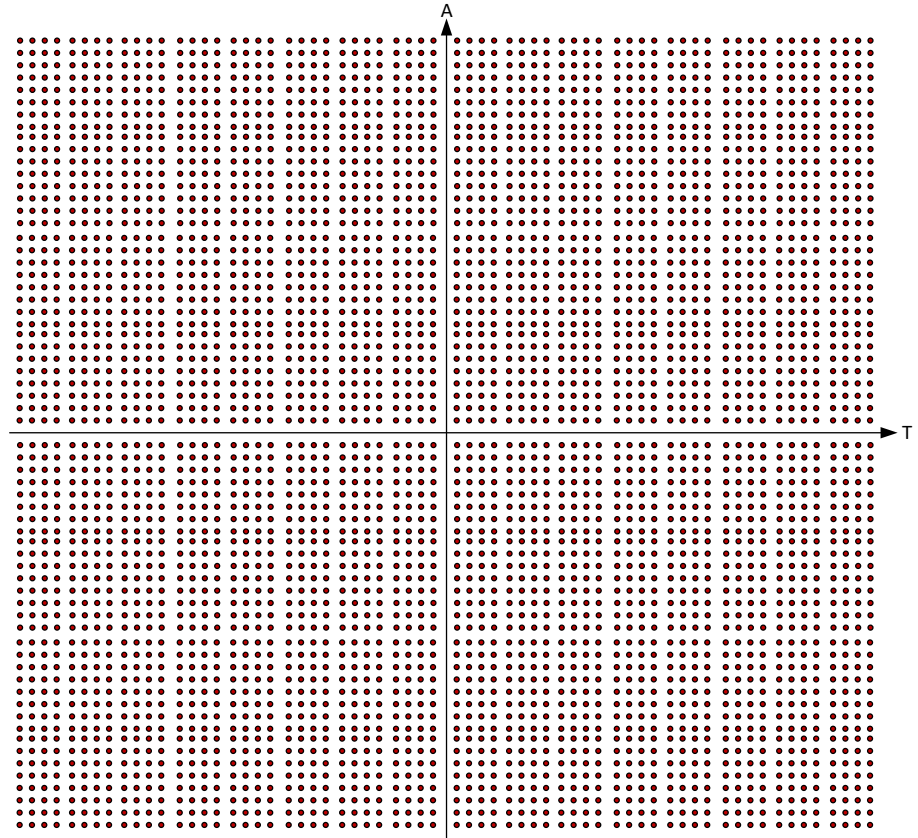
256-QAM / 802.11ac



1024 QAM – 802.11ax



4K QAM – 802.11be!



Modulation and Standards

Modulation Type	Standard	Highest Theoretical Data Rate
QPSK	802.11b (Wi-Fi 1)	11 Mbps
64-QAM	802.11a (Wi-Fi 2)	54 Mbps
64-QAM	802.11g (Wi-Fi 3)	54 Mbps
64-QAM	802.11n (Wi-Fi 4)	600 Mbps
256-QAM	802.11ac (Wi-Fi 5)	6.933 Gbps
1024-QAM	802.11ax (Wi-Fi 6)	9.6 Gbps
	802.11ax (Wi-Fi 6E)*	

*6 GHz only

Modulation and Standards

Modulation Type	Standard	Highest Theoretical Data Rate
QPSK	802.11b (Wi-Fi 1)	11 Mbps
64-QAM	802.11a (Wi-Fi 2)	54 Mbps
64-QAM	802.11g (Wi-Fi 3)	54 Mbps
64-QAM	802.11n (Wi-Fi 4)	600 Mbps
256-QAM	802.11ac (Wi-Fi 5)	6.933 Gbps
1024-QAM	802.11ax (Wi-Fi 6)	9.6 Gbps
	802.11ax (Wi-Fi 6E)*	

6 GHz only

MCS Index Table, Modulation and Coding Scheme Index 11n, 11ac, and 11ax

Full MCS Table (HT/VHT/HE) MCS Table 3SS (HT/VHT/HE) MCS Table HE MCS Table HE (OFDM) MCS Table HE (OFDMA) The Math Behind it Credits

						OFDM (Prior 11ax)								OFDM (802.11ax)												
						20MHz		40MHz		80MHz		160MHz		20MHz			40MHz			80MHz						
MCS Index	HT	VHT	HE	Spatial	Modulation	Coding	0.8µs GI	0.4µs GI	0.8µs GI	0.4µs GI	0.8µs GI	0.4µs GI	0.8µs GI	0.4µs GI	0.8µs GI	1.6µs GI	3.2µs GI	0.8µs GI	1.6µs GI	3.2µs GI	0.8µs GI	1.6µs GI	3.2µs GI	0.8µs GI	1.6µs GI	3.2µs GI
0	0	0	1	BPSK	1/2		6.5	7.2	13.5	15	29.3	32.5	58.5	65	8.6	8.1	7.3	17.2	16.3	14.6	36	34	30.6	72.1	68.1	61.3
1	1	1	1	QPSK	1/2		13	14.4	27	30	58.5	65	117	130	17.2	16.3	14.6	34.4	32.5	29.3	72.1	68.1	61.3	144.1	136.1	122.5
2	2	2	1	QPSK	3/4		19.5	21.7	40.5	45	87.8	97.5	175.5	195	25.8	24.4	21.9	51.6	48.8	43.9	108.1	102.1	91.9	216.2	204.2	183.8
3	3	3	1	16-QAM	1/2		26	28.9	54	60	117	130	234	260	34.4	32.5	29.3	68.8	65	58.5	144.1	136.1	122.5	288.2	272.2	245
4	4	4	1	16-QAM	3/4		39	43.3	81	90	175.5	195	351	390	51.6	48.8	43.9	103.2	97.5	87.8	216.2	204.2	183.8	432.4	408.3	367.5
5	5	5	1	64-QAM	2/3		52	57.8	108	120	234	260	468	520	68.8	65	58.5	137.6	130	117	288.2	272.2	245	576.5	544.4	490
6	6	6	1	64-QAM	3/4		58.5	65	121.5	135	263.3	292.5	526.5	585	77.4	73.1	65.8	154.9	146.3	131.6	324.3	306.3	275.6	648.5	612.5	551.3
7	7	7	1	64-QAM	5/6		65	72.2	135	150	292.5	325	585	650	86	81.3	73.1	172.1	162.5	146.3	360.3	340.3	306.3	720.6	680.6	612.5
	8	8	1	256-QAM	3/4		78	86.7	162	180	351	390	702	780	103.2	97.5	87.8	206.5	195	175.5	432.4	408.3	367.5	864.7	816.7	735
	9	9	1	256-QAM	5/6		N/A	N/A	180	200	390	433.3	780	866.7	114.7	108.3	97.5	229.4	216.7	195	480.4	453.7	408.3	960.8	907.4	816.7
	10	10	1	1024-QAM	3/4										129	121.9	109.7	258.1	243.8	219.4	540.4	510.4	459.4	1080.9	1020.8	918.8
			11	1024-QAM	5/6										143.4	135.4	121.9	286.8	270.8	243.8	600.5	567.1	510.4	1201	1134.3	1020.8
8	0	0	2	BPSK	1/2		13	14.4	27	30	58.5	65	117	130	17.2	16.3	14.6	34.4	32.5	29.3	72.1	68.1	61.3	144.1	136.1	122.5
9	1	1	2	QPSK	1/2		26	28.9	54	60	117	130	234	260	34.4	32.5	29.3	68.8	65	58.5	144.1	136.1	122.5	288.2	272.2	245
10	2	2	2	QPSK	3/4		39	43.3	81	90	175.5	195	351	390	51.6	48.8	43.9	103.2	97.5	87.8	216.2	204.2	183.8	432.4	408.3	367.5
11	3	3	2	16-QAM	1/2		52	57.8	108	120	234	260	468	520	68.8	65	58.5	137.6	130	117	288.2	272.2	245	576.5	544.4	490
12	4	4	2	16-QAM	3/4		78	86.7	162	180	351	390	702	780	103.2	97.5	87.8	206.5	195	175.5	432.4	408.3	367.5	864.7	816.7	735
13	5	5	2	64-QAM	2/3		104	115.6	216	240	468	520	936	1040	137.6	130	117	275.3	260	234	576.5	544.4	490	1080.9	1020.8	918.8
14	6	6	2	64-QAM	3/4		117	130	243	270	526.5	585	1053	1170	154.9	146.3	131.6	309.7	292.5	263.3	648.5	612.5	551.3	1201	1134.3	1020.8
15	7	7	2	64-QAM	5/6		130	144.4	270	300	585	650	1170	1300	172.1	162.5	146.3	344.1	325	292.5	720.6	680.6	612.5	144.1	136.1	122.5
	8	8	2	256-QAM	3/4		156	173.3	324	360	702	780	1404	1560	206.5	195	175.5	412.9	390	351	864.7	816.7	735	1080.9	1020.8	918.8
	9	9	2	256-QAM	5/6		N/A	N/A	360	400	780	866.7	1560	1733.3	229.4	216.7	195	458.8	433.3	390	960.8	907.4	816.7	1201	1134.3	1020.8
	10	10	2	1024-QAM	3/4										258.1	243.8	219.4	516.2	487.5	438.8	1080.9	1020.8	918.8	1201	1134.3	1020.8
			11	1024-QAM	5/6										286.8	270.8	243.8	573.5	541.7	487.5	1201	1134.3	1020.8	1201	1134.3	1020.8
16	0	0	3	BPSK	1/2		19.5	21.7	40.5	45	87.8	97.5	175.5	195	25.8	24.4	21.9	51.6	48.8	43.9	108.1	102.1	91.9	216.2	204.2	183.8
17	1	1	3	QPSK	1/2		39	43.3	81	90	175.5	195	351	390	51.6	48.8	43.9	103.2	97.5	87.8	216.2	204.2	183.8	432.4	408.3	367.5
18	2	2	3	QPSK	3/4		58.5	65	121.5	135	263.3	292.5	526.5	585	77.4	73.1	65.8	154.9	146.3	131.6	324.3	306.3	275.6	648.5	612.5	551.3
19	3	3	3	16-QAM	1/2		78	86.7	162	180	351	390	702	780	103.2	97.5	87.8	206.5	195	175.5	432.4	408.3	367.5	864.7	816.7	735
20	4	4	3	16-QAM	3/4		117	130	243	270	526.5	585	1053	1170	154.9	146.3	131.6	309.7	292.5	263.3	648.5	612.5	551.3	1201	1134.3	1020.8
21	5	5	3	64-QAM	2/3		156	173.3	324	360	702	780	1404	1560	206.5	195	175.5	412.9	390	351	864.7	816.7	735	1080.9	1020.8	918.8
22	6	6	3	64-QAM	3/4		175.5	195	364.5	405	N/A	N/A	1579.5	1755	232.3	219.4	197.4	464.6	438.8	394.9	972.8	918.8	826.9	1080.9	1020.8	918.8
23	7	7	3	64-QAM	5/6		N/A	N/A	405	450	877.5	975	1755	1950	258.1	243.8	219.4	516.2	487.5	438.8	1080.9	1020.8	918.8	1201	1134.3	1020.8

There is 1 interface on the system:

```
Name : Wi-Fi
Description : Intel(R) Wi-Fi 6E AX210 160MHz
GUID : d7e74356-93ca-4efe-91c4-996f35de9847
Physical address : f0:b6:1e:57:92:b6
State : connected
SSID : Simplex
BSSID : 9a:18:98:c6:cc:d3
Network type : Infrastructure
Radio type : 802.11ac
Authentication : WPA2-Personal
Cipher : CCMP
Connection mode : Auto Connect
Channel : 48
Receive rate (Mbps) : 216
Transmit rate (Mbps) : 150
Signal : 78%
Profile : Simplex
```

Wi-Fi Status

General

Connection

IPv4 Connectivity: Internet

IPv6 Connectivity: No network access

Media State: Enabled

SSID: Simplex

Duration: 00:00:18

Speed: 150.0 Mbps

Signal Quality: 

Details... Wireless Properties

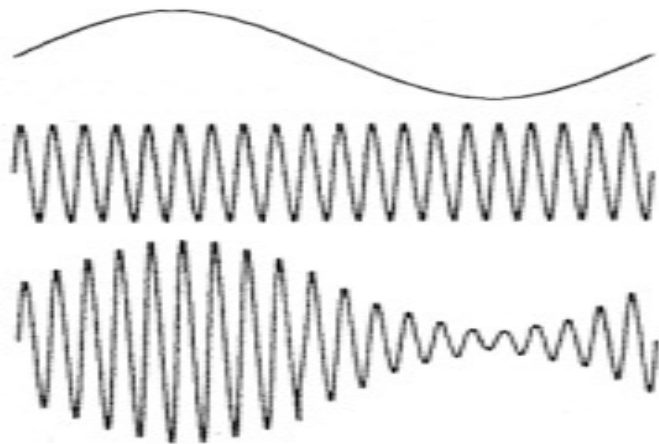
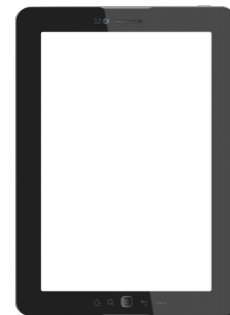
Activity

Sent —  — Received

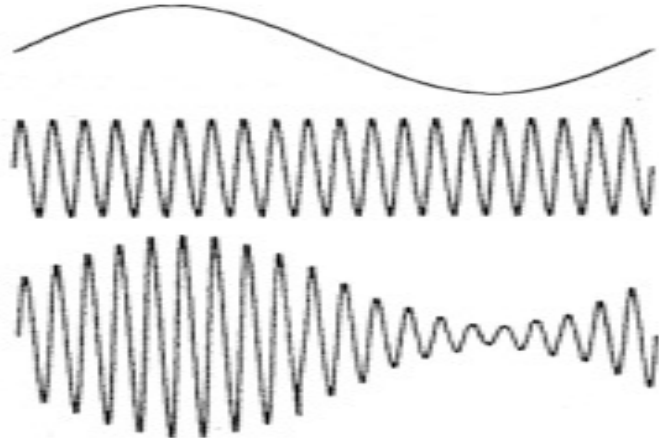
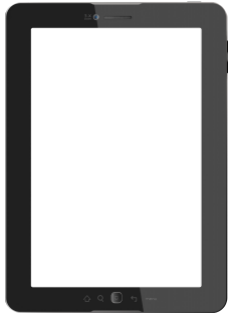
Bytes: 427,328 | 363,375

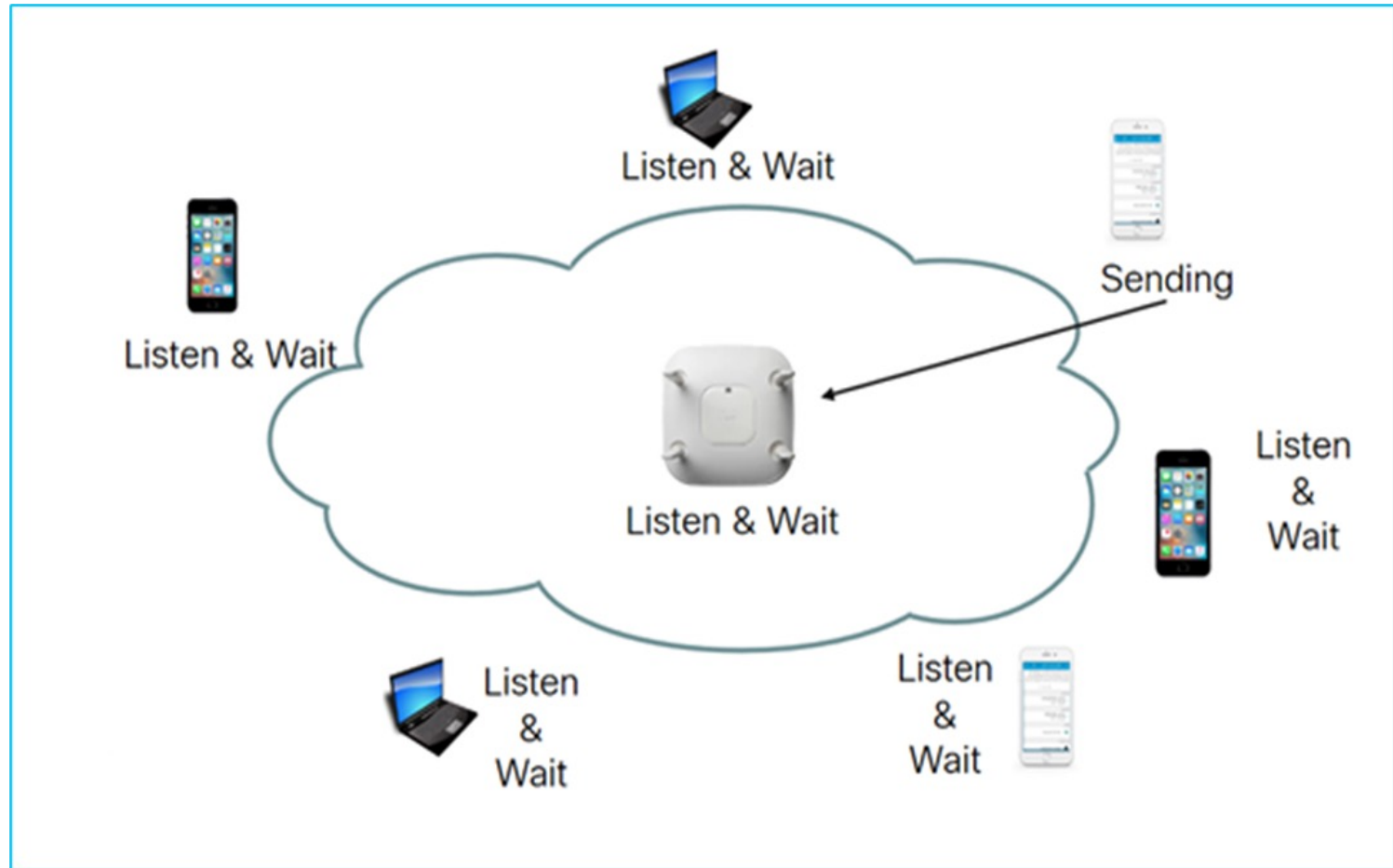
Properties Disable Diagnose

Close

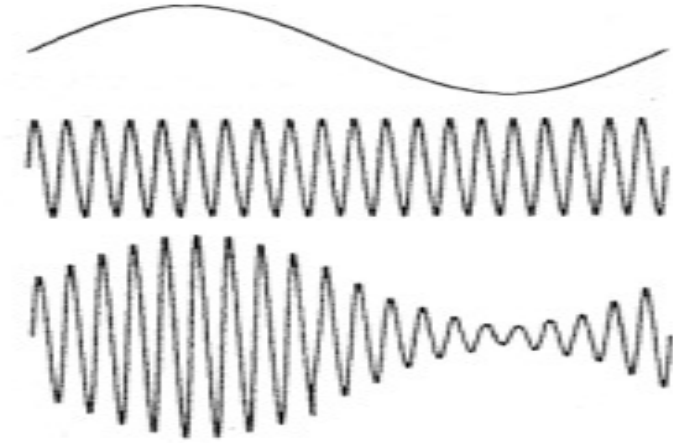


Wired Device – TCP Syn/Ack



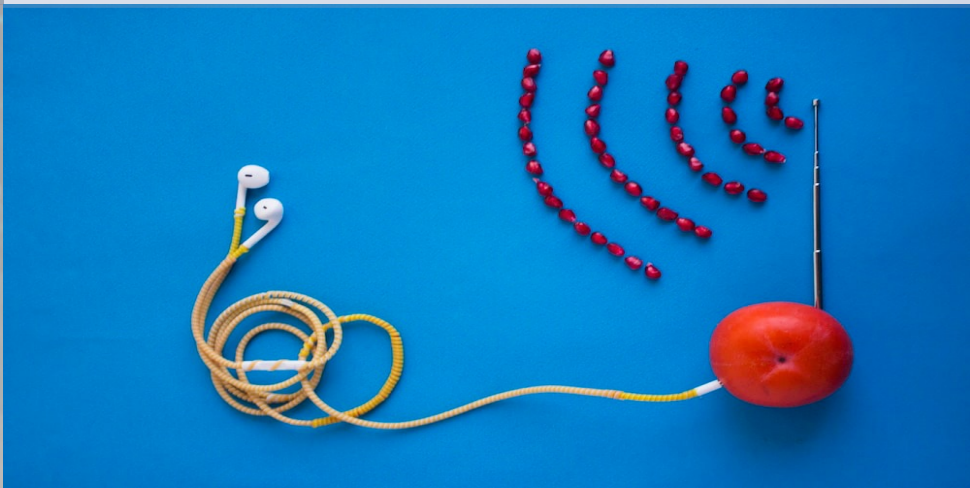


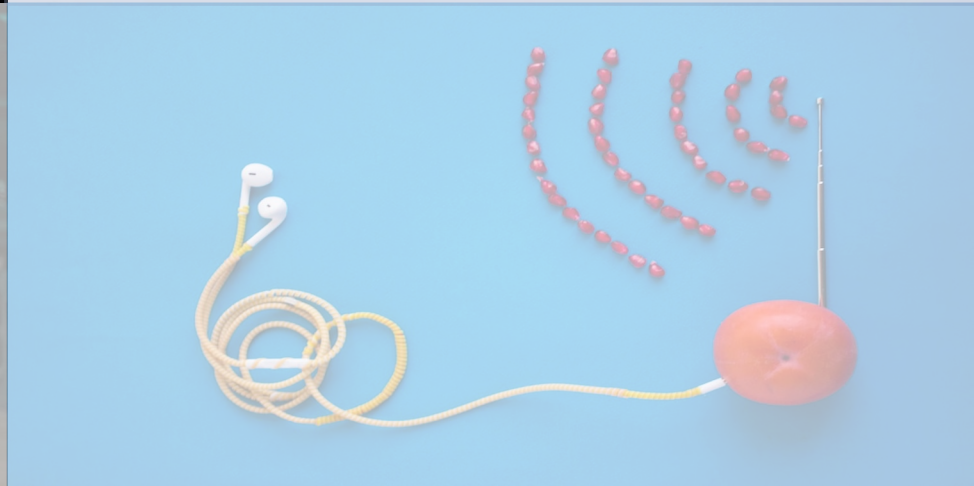
Wired Device – TCP Syn/Ack



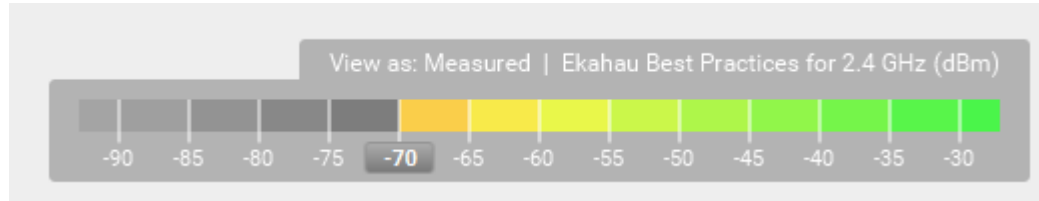
Wi-Fi Frame ACK



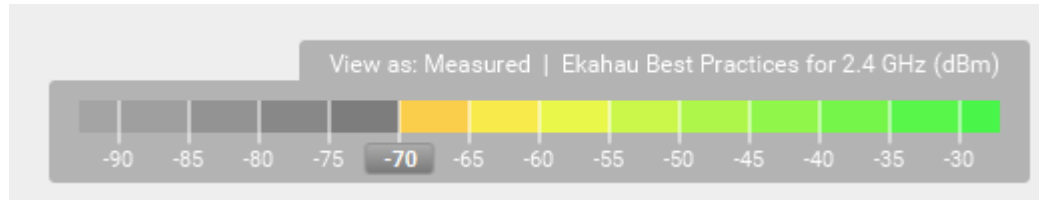
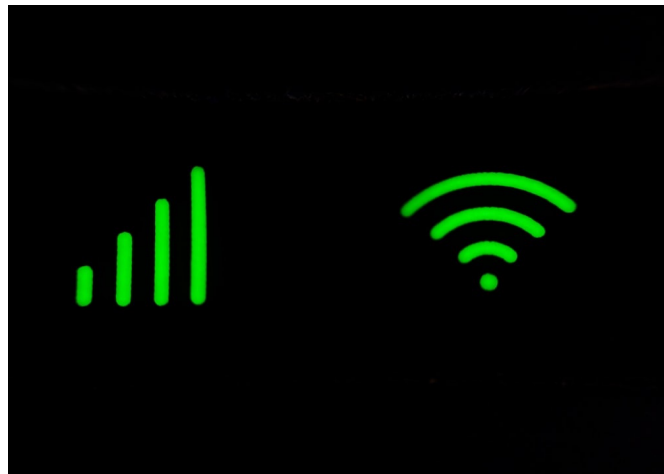




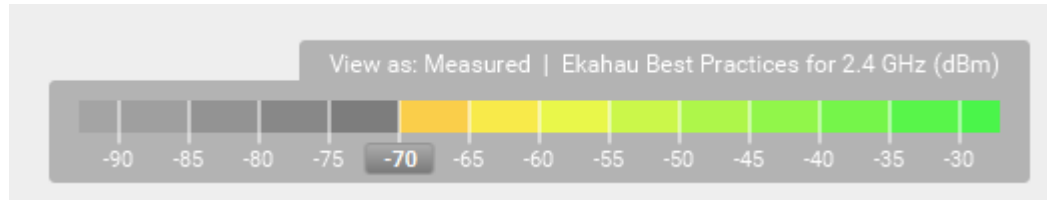
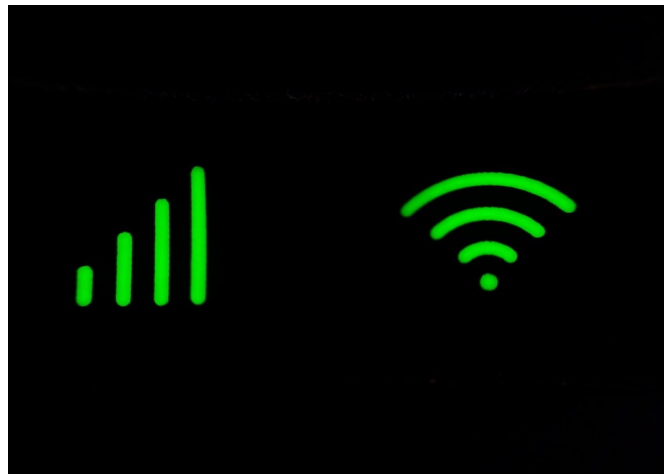
Poor ← —————→ Great



Poor ← ————— → Great

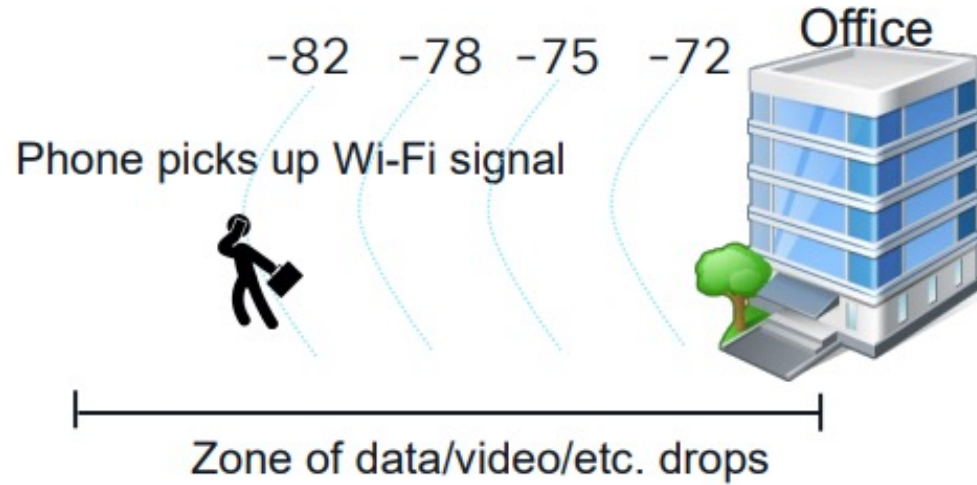


Poor ← ————— → Great



Signal	Rating	Use
-40 dBm	Fantastic	Everything
-67 dBm	Very good	Voice Calling
-70 dBm	Good	General Use
-80 dBm	Terrible	Nothing

Poor ←—————→ Great



Activating Exchanges

11v BSS Transition Support		Scan Defer Time	100
BSS Transition	☒	Assisted Roaming (11k)	
Disassociation Imminent(0 to 3000 TBTT)	200	Prediction Optimization	☐
Optimized Roaming Disassociation Timer(0 to 40 TBTT)	40	Neighbor List	☒
BSS Max Idle Service	☒	Dual Band Neighbor List	☐
BSS Max Idle Protected	☐	DTIM Period (in beacon intervals)	
Directed Multicast Service	☒	5 GHz Band (1-255)	1

How APs Hear Clients

```
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
```

Check Your Clients in WLC/DNAC

AireOS

Not-your-phone

MAC Address
da:30:1a:46:6f:02

Uptime
Associated since 5 Minutes 8 Seconds

SSID
Wiinet

AP Name
Office (Ch 64)

Nearest APs
Hermes(-82 dBm) Master(-81 dBm) Stairs(-64 dBm)

Device Type
iPhone13,3

OS Version
14.2.1

Last disassociated AP
b0:26:80:e4:7b:60

Last disassociation reason
User triggered disassociation

Performance
Signal Strength: -55 dBm Signal Quality: 40 dB Connection Speed: 173 Mbps Channel Width: 20 M

360 View

General

QOS Statistics

ATF Statistics

General



User Name
Jerome

MAC Address 7257.b041.f06a

Uptime(sec) 138 seconds

WLAN Name Corporate

AP Name 4800-B

Device Type iPhone12

Device OS 14.2

Client Performance Signal Strength:-62 dBm

Capabilities 802.11ac

Fabric Status Disabled

IOS-XE

General



User Name
Stephen

MAC Address d286.b8ed.f36c

Uptime(sec) 413 seconds

WLAN Name Corporate

AP Name 4800-B

Device Type Samsung Galaxy Note 20 (Phone)

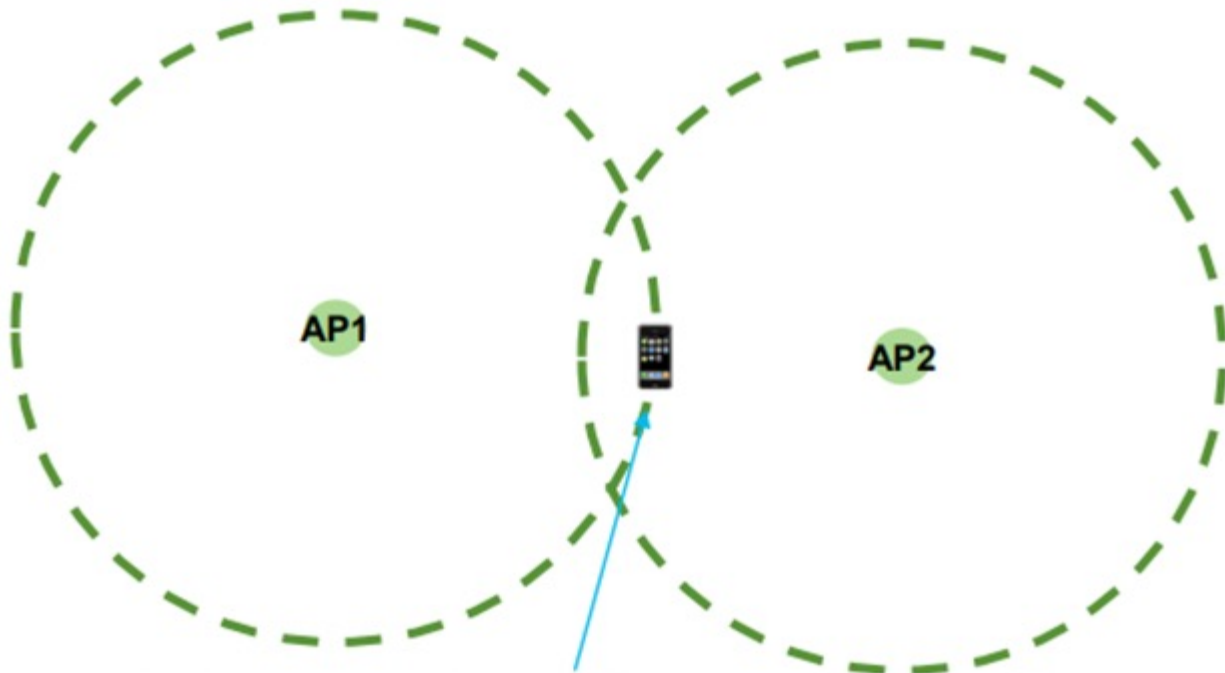
Software Version (Carrier Code) TA1(AUT)

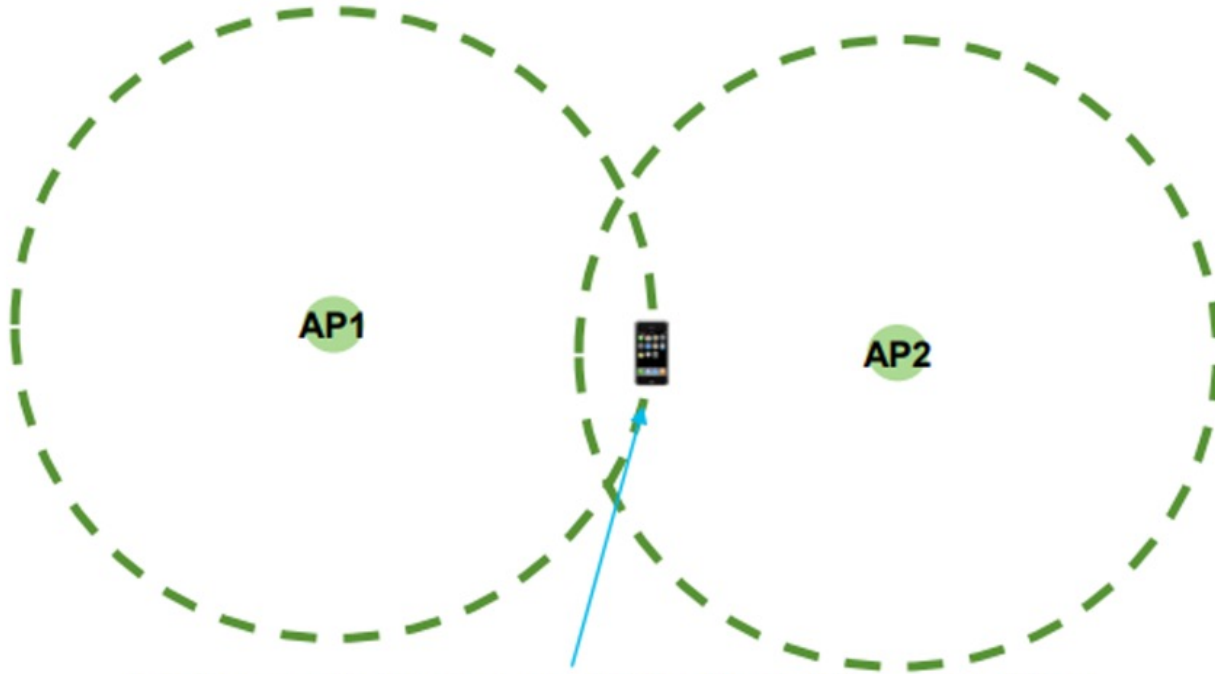
Device OS Android 10

Client Performance Signal Strength:-64 dBm Signal Quality:31 dB

Capabilities 802.11ac

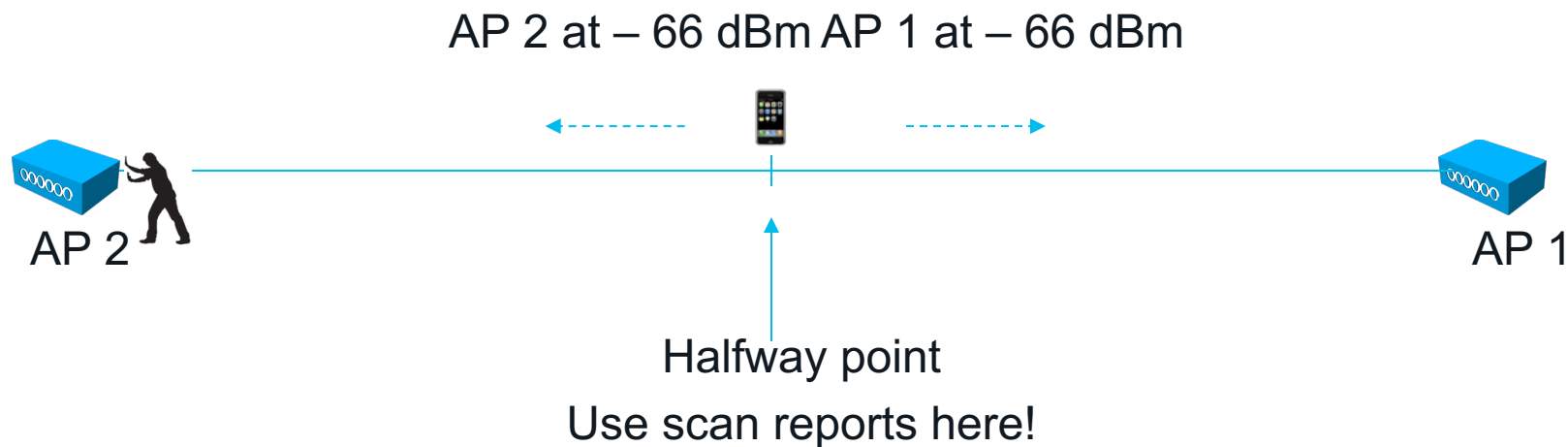
Fabric Status Disabled



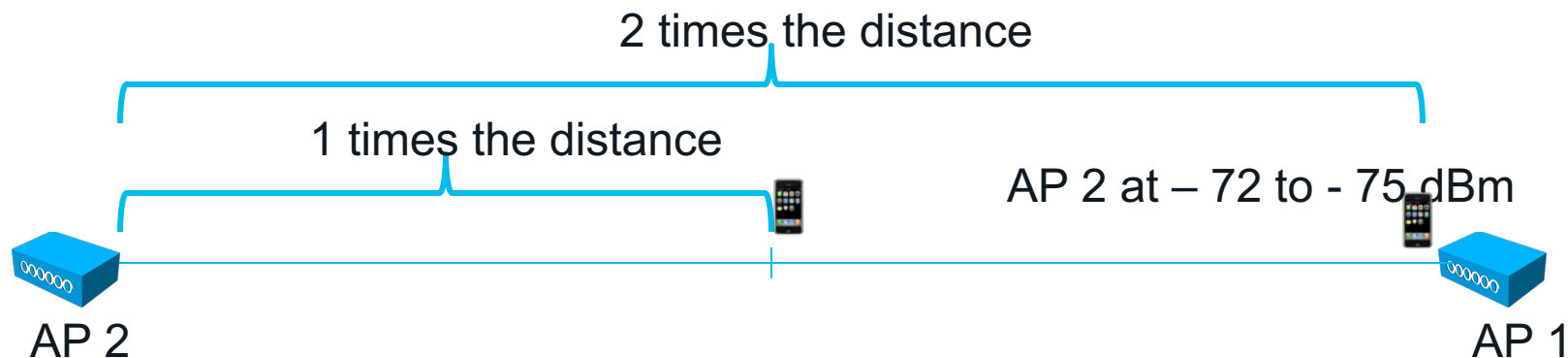


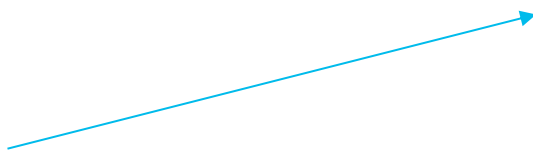
At the point where AP1 signal is -70 dBm,
AP2 signal is -62 dBm
That's a -66 dBm edge

The - 72 dBm Rule



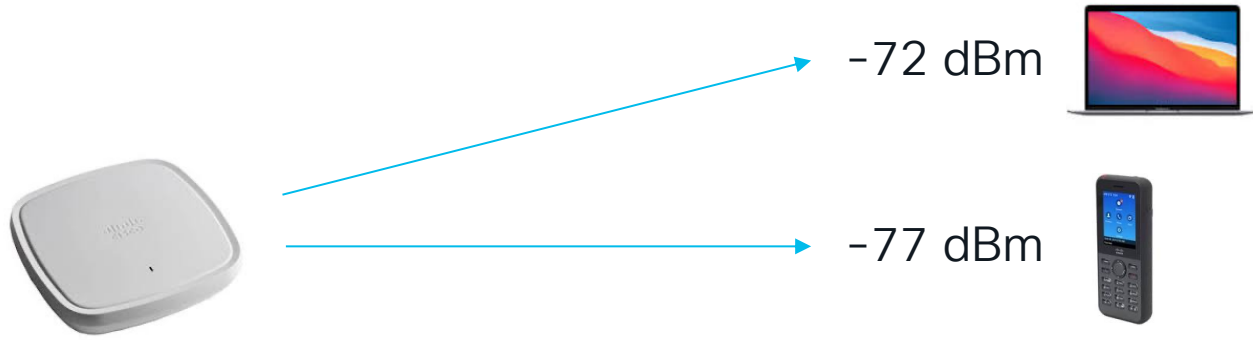
The - 72 dBm Rule

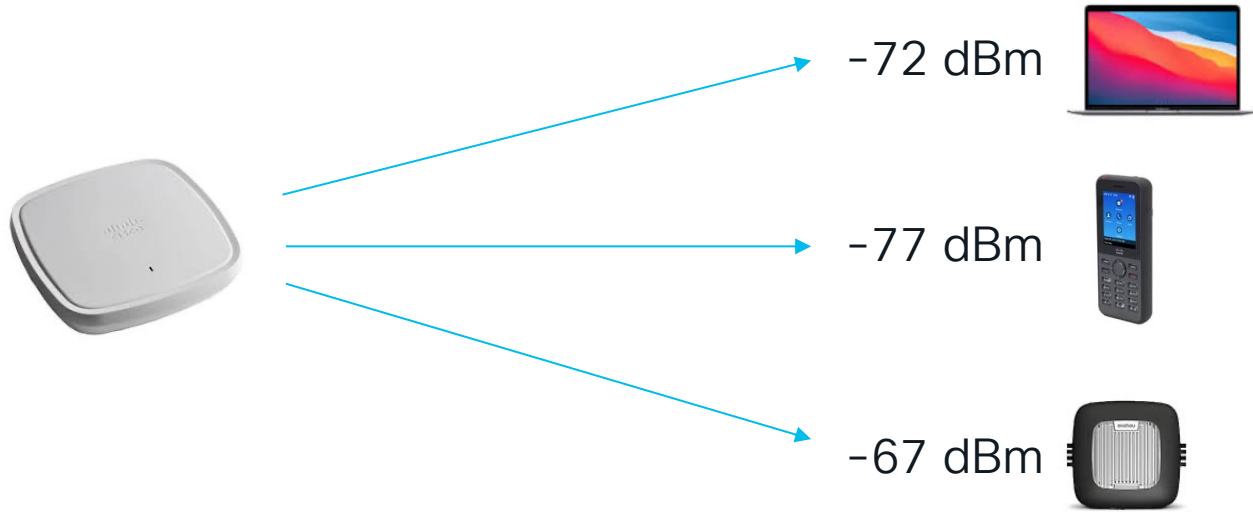


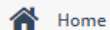


-72 dBm









Home



Device Data



Add Data



Ekahau Offset



Help

Purpose *What is the goal?*

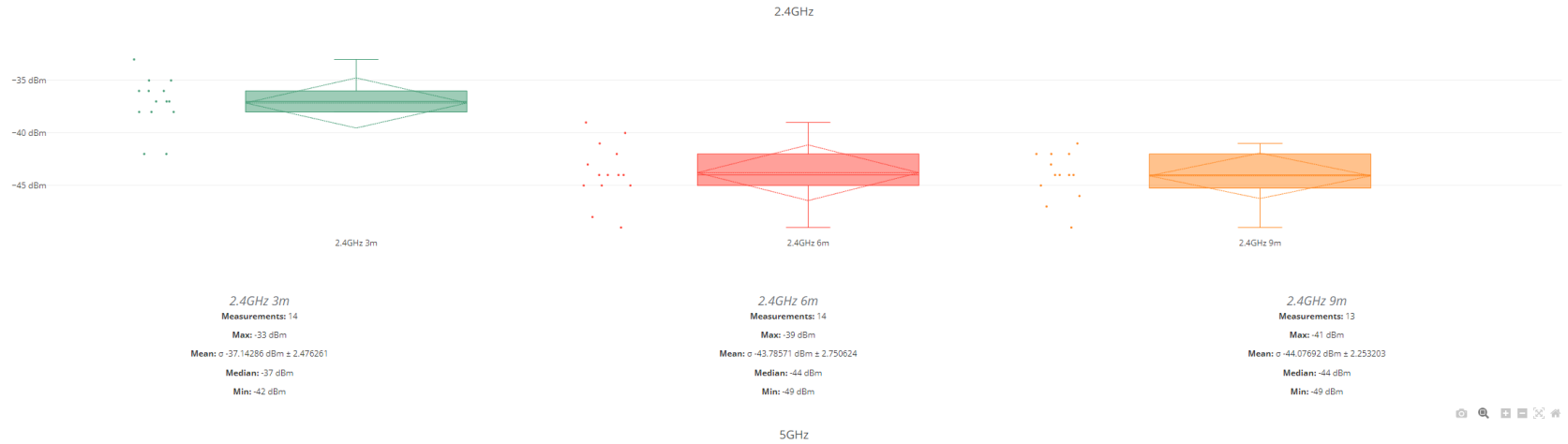
Recently Ekahau released an option to provide a "device offset" when creating devices for WLPC. Immediately a flashback to WLPC occurred where we tried to capture RSSI readings from devices. Which leads us to RSSI|COMPARED, a site where you can see the vast ranges that devices provide. While this data is probably most useful for those that use Ekahau it does provide value to others.

Submit Data *Be social!*

The more data the better! We need YOUR help to constantly add to the device collection.

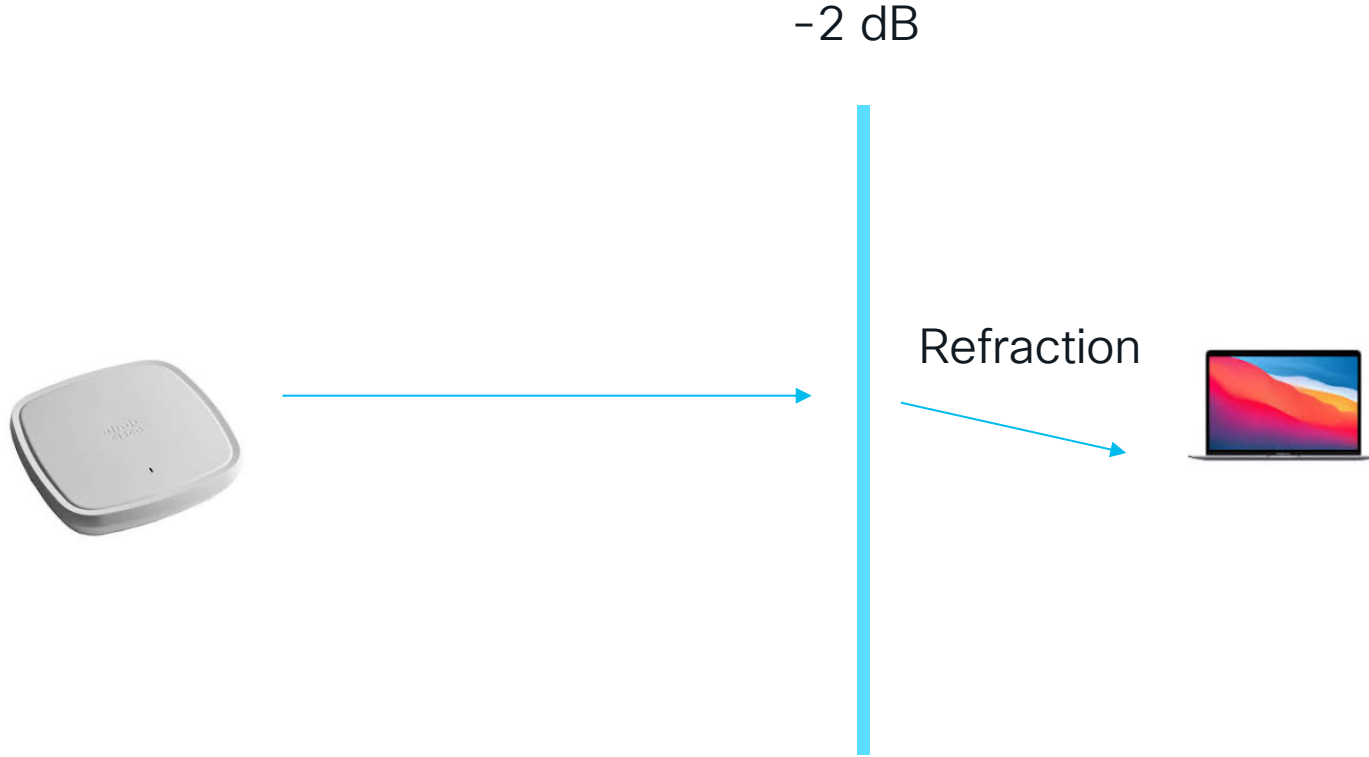
MacBook Pro 13 2017 *Apple*

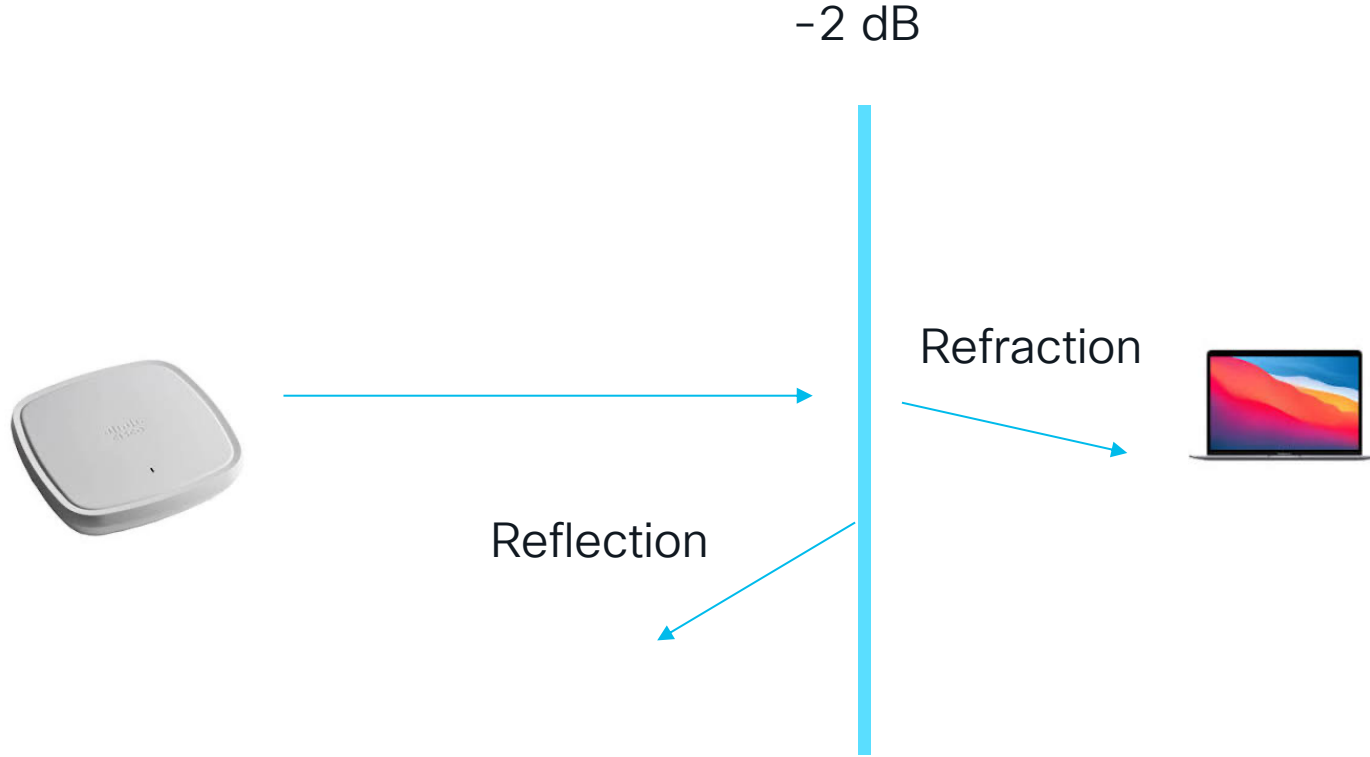
Compare this Device



-3 dB



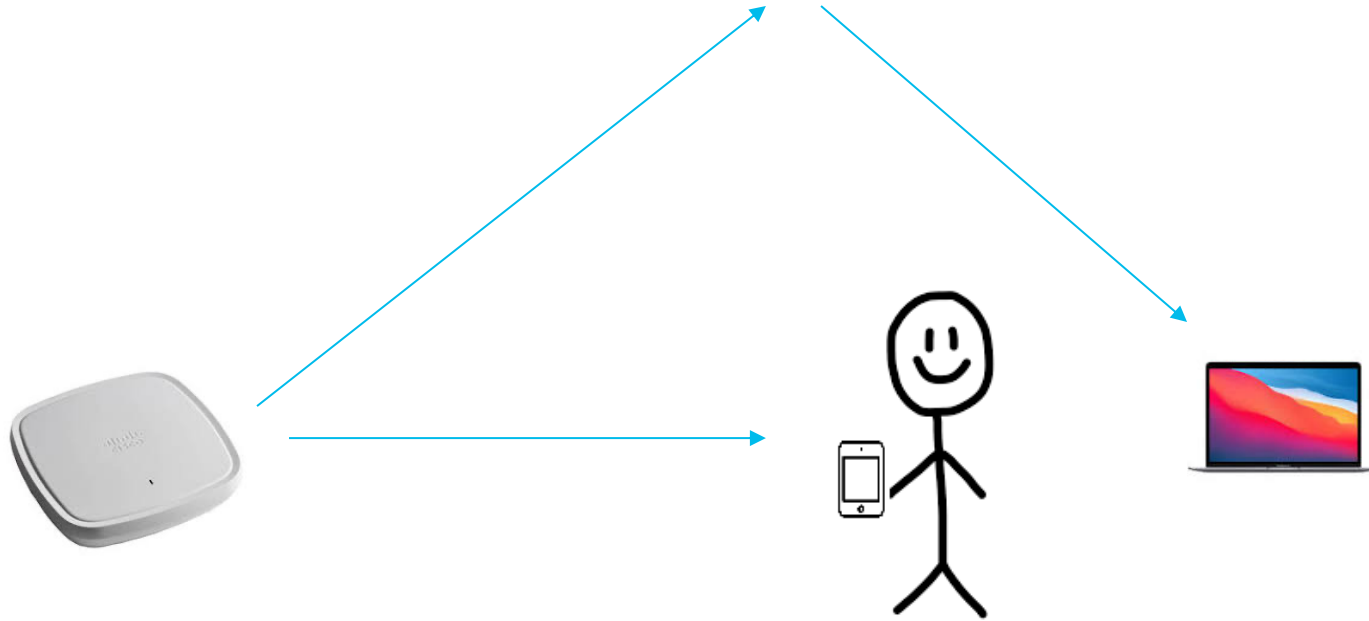






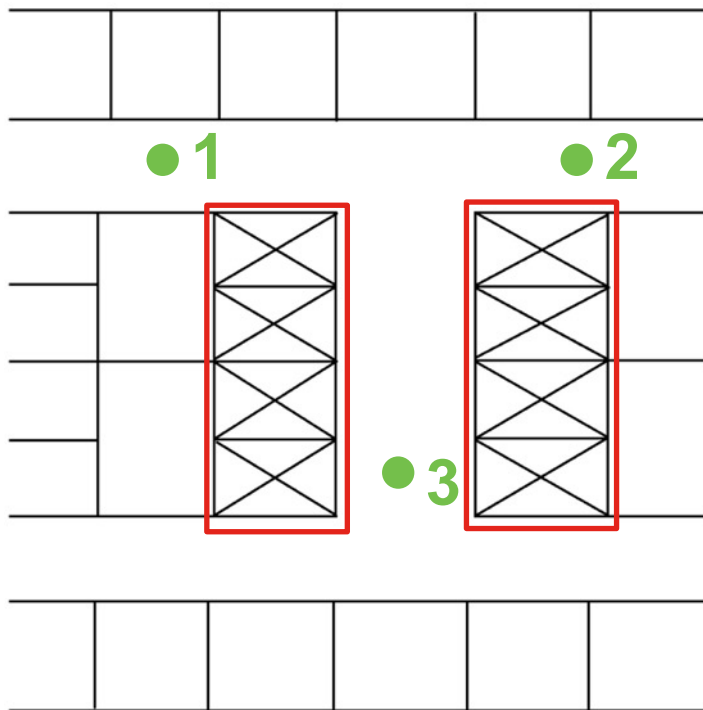
-6 dB?



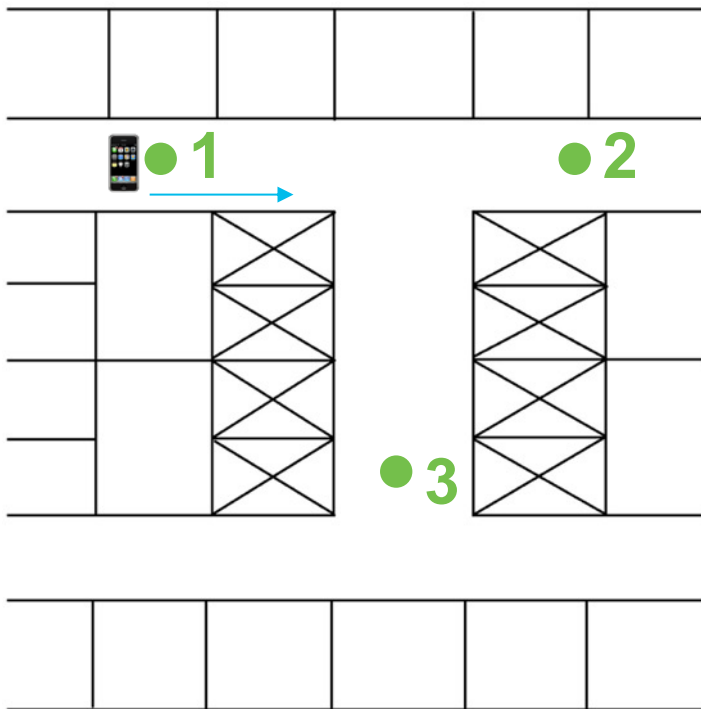


MIMO

Transition Points

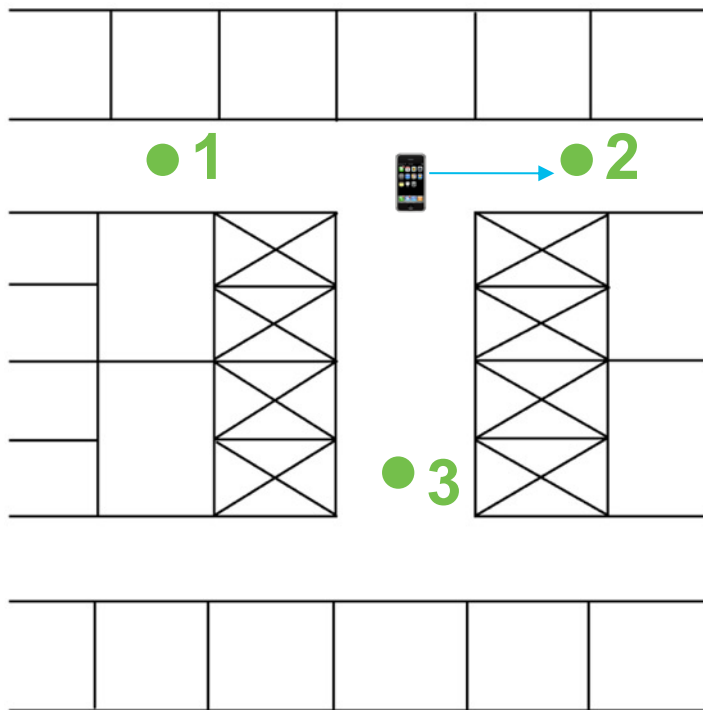


Transition Points



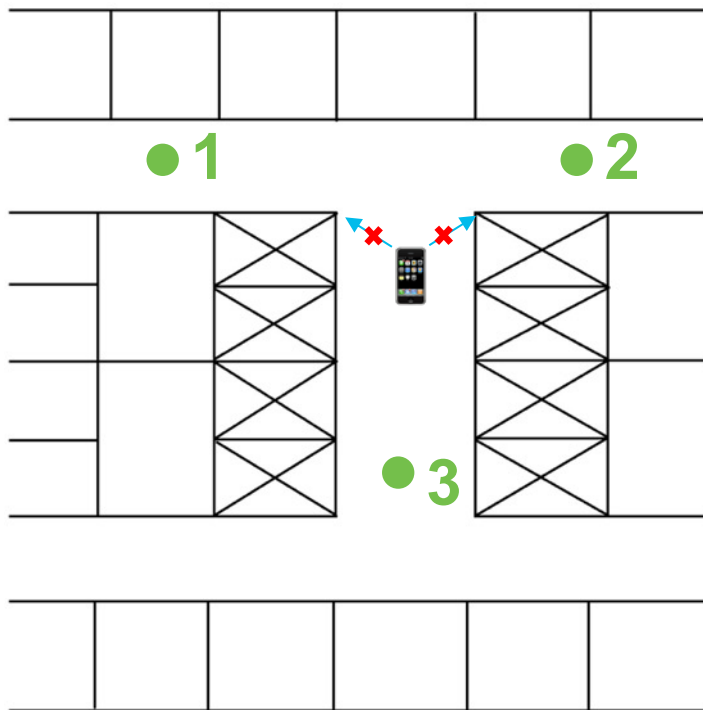
AP List	RSSI
AP1	-66
AP2	-72
AP3	NA

Transition Points



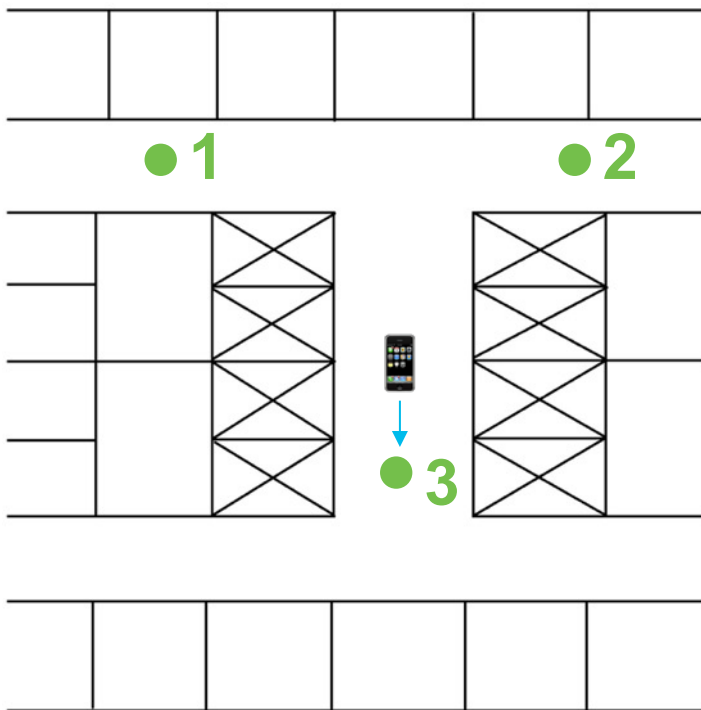
AP List	RSSI
AP1	-66
AP2	-66
AP3	??

Transition Points



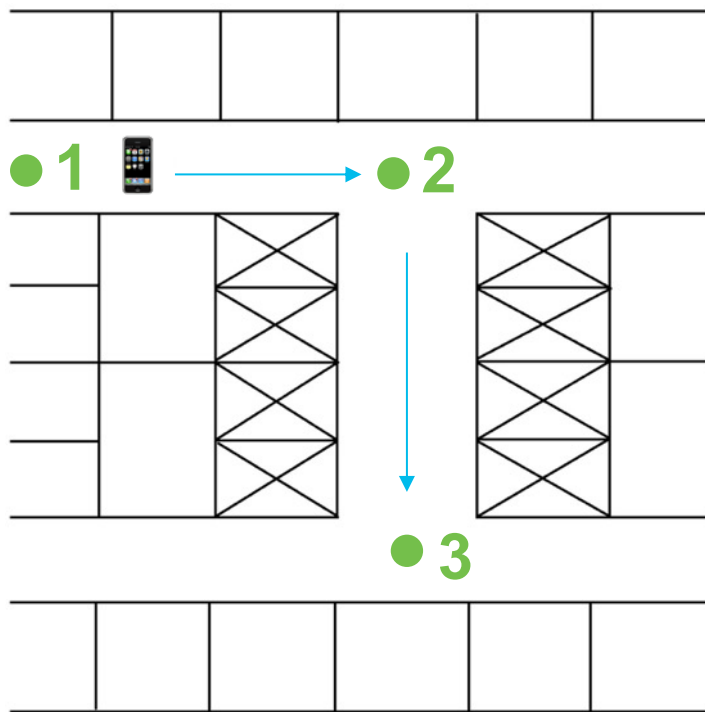
AP List	RSSI
AP1	-80
AP2	-80
AP3	??

Transition Points



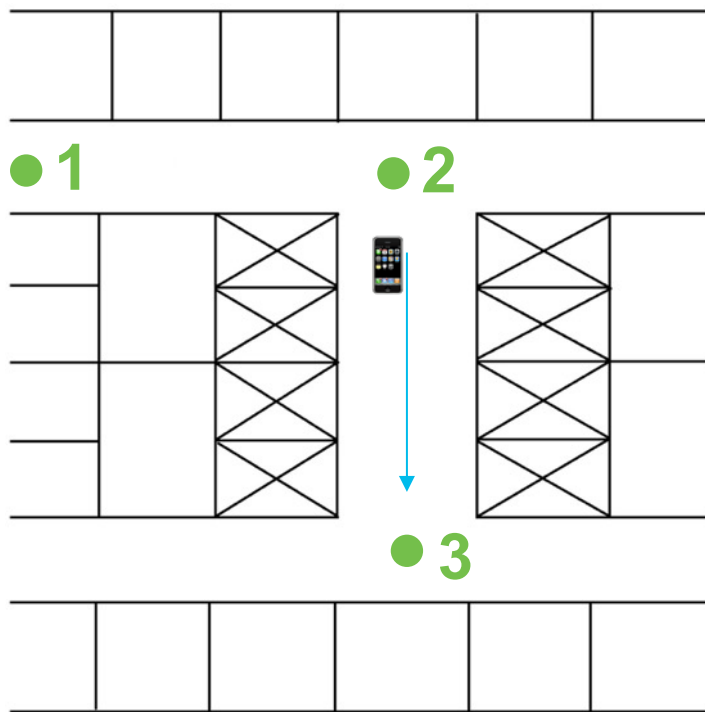
AP List	RSSI
AP1	-85
AP2	-85
AP3	-66

Transition Points



AP List	RSSI
AP1	-66
AP2	-72
AP3	802.11k

Transition Points



AP List	RSSI
AP1	-85
AP2	-66
AP3	-72

Verify on your WLC

Client

360 View

General

QOS Statistics

ATF Statistics

Mobility History

Call Statistics

Recent association history:

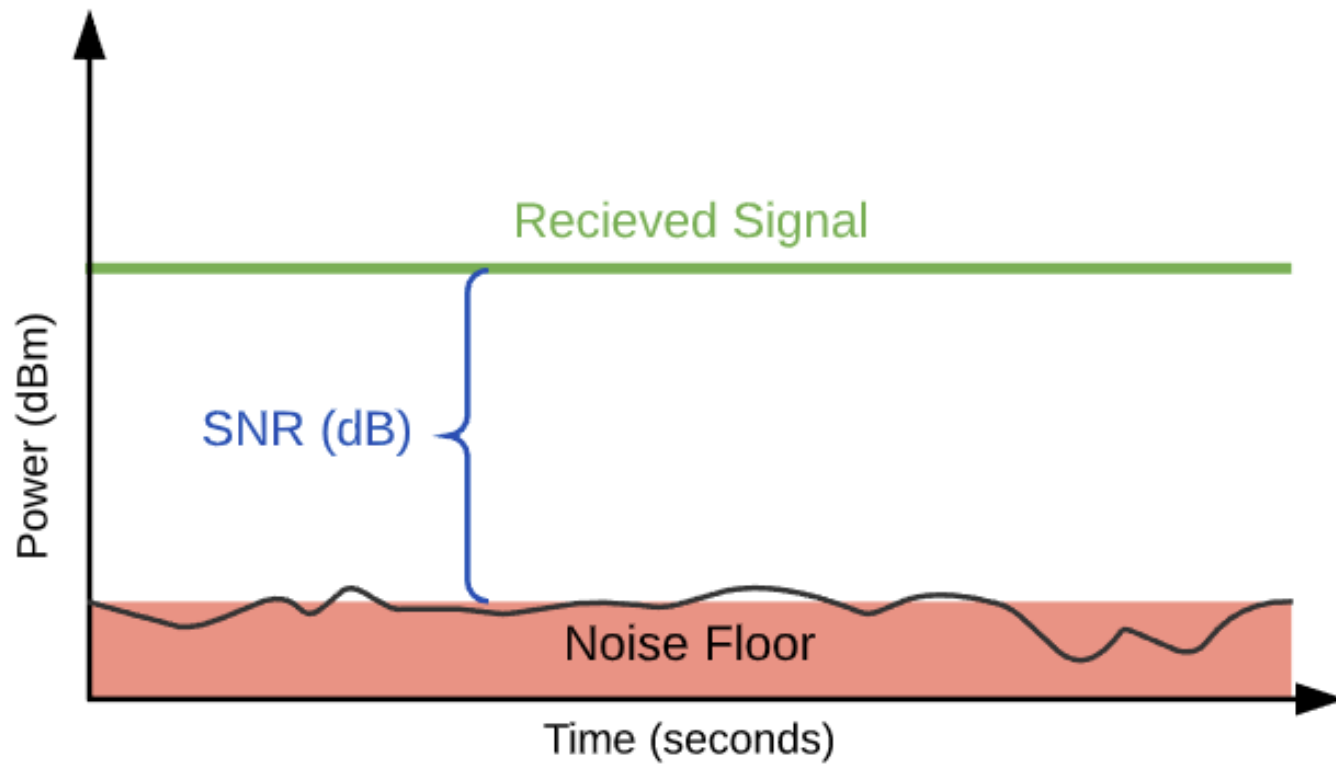
AP Name	BSSID	AP Slot	Assoc Time	Instance	Mobility Role	Run Latency (ms)	Roam Type
4800-B	f4db.e661.148f	1	12/04/2020 17:56:37	0	Local	15	802.11i Slow
4800-B	f4db.e661.1480	0	12/04/2020 17:55:10	0	Local	14	802.11R

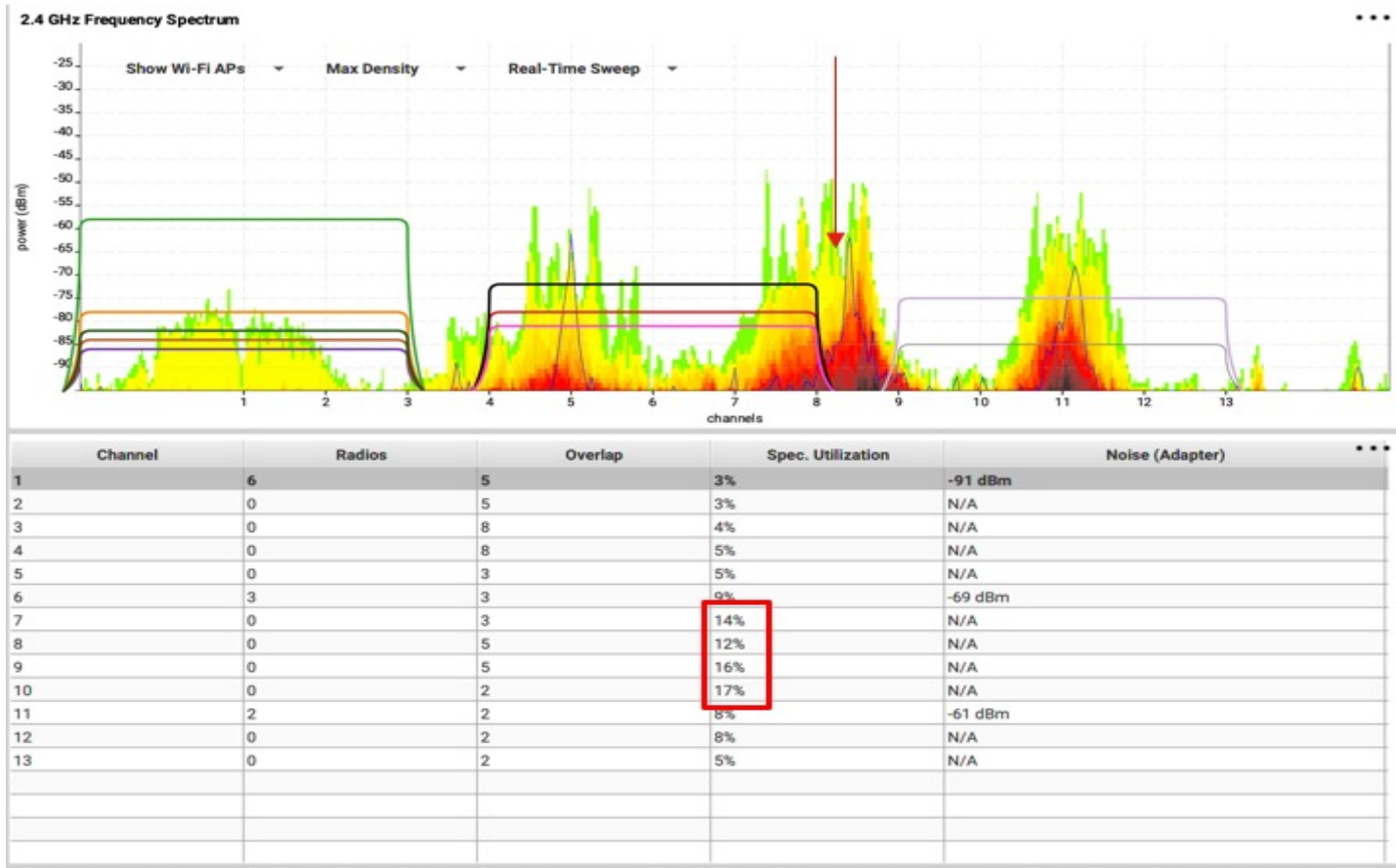


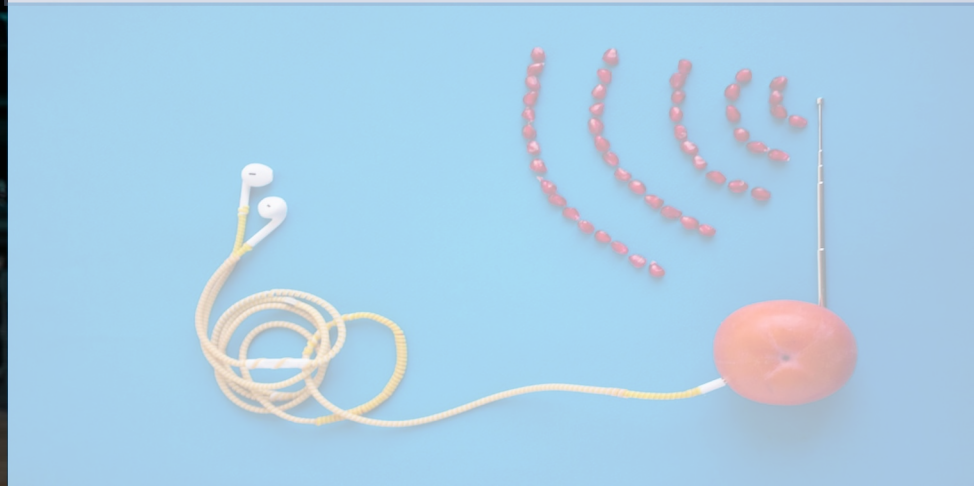
F R E Q U E N C I E S













2.4GHz Unlicensed Spectrum

Wi-Fi

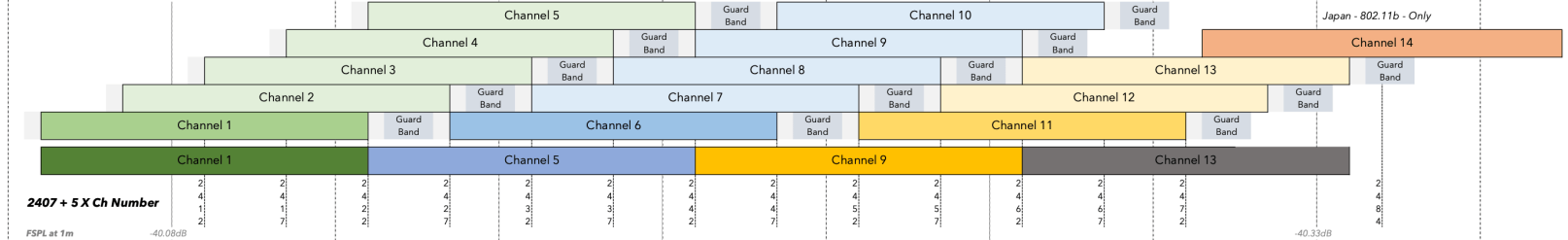
802.11b - 22MHz
802.11g/n/ax - 20MHz

3 20Mhz Channels

4 Ch Plan - Non-US

Center Freq

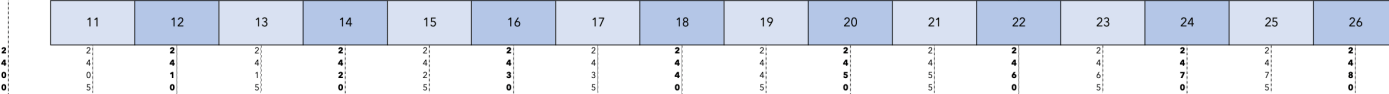
<- Wavelength = 12.4 cm - 4.9"



802.15.4/Zigbee

16 5Mhz Channels

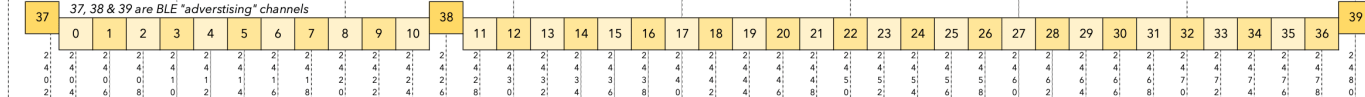
Center Freq



BLE

40 2Mhz Channels

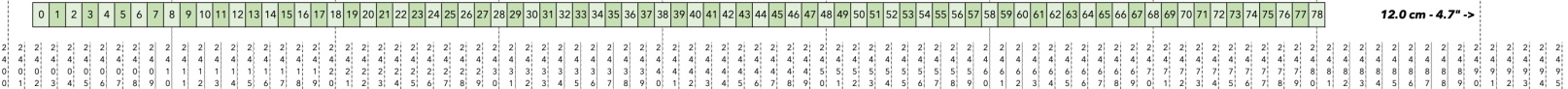
Center Freq



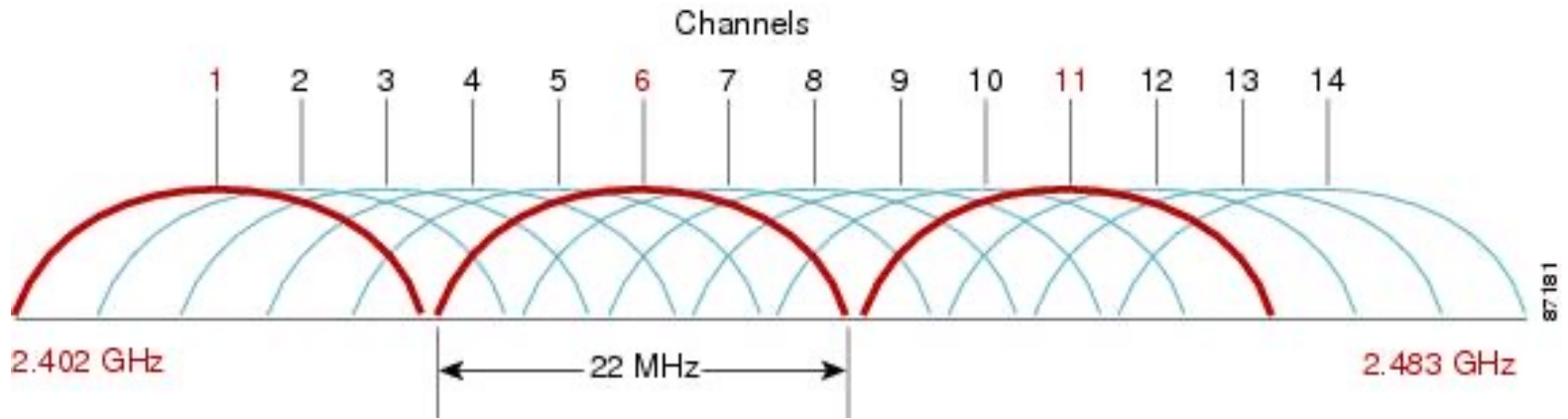
Bluetooth

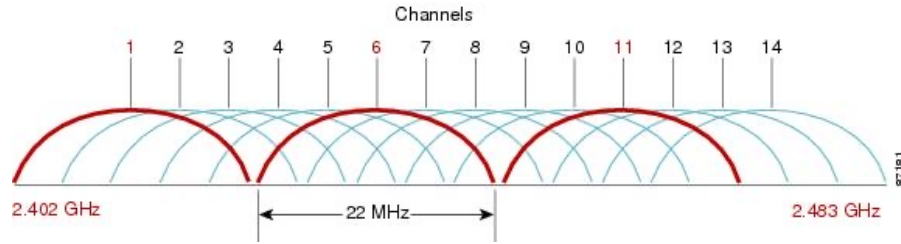
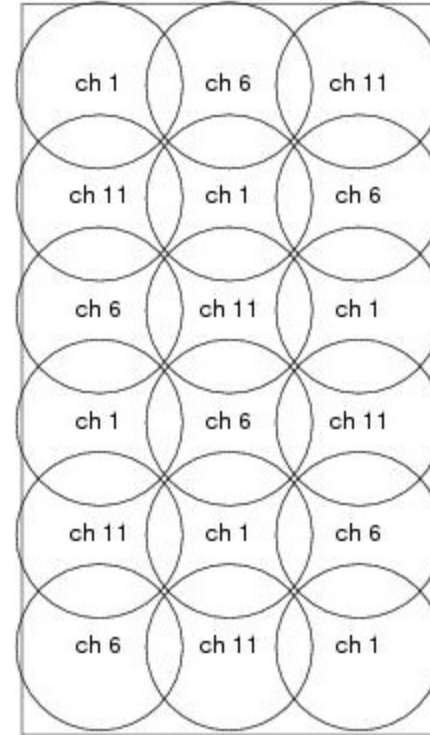
79 1Mhz Channels

Center Freq



Source: www.wlanpros.com/spectrum



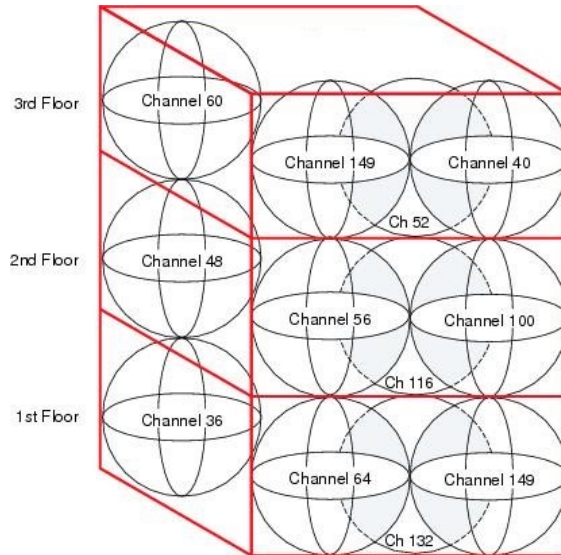


500 MHz



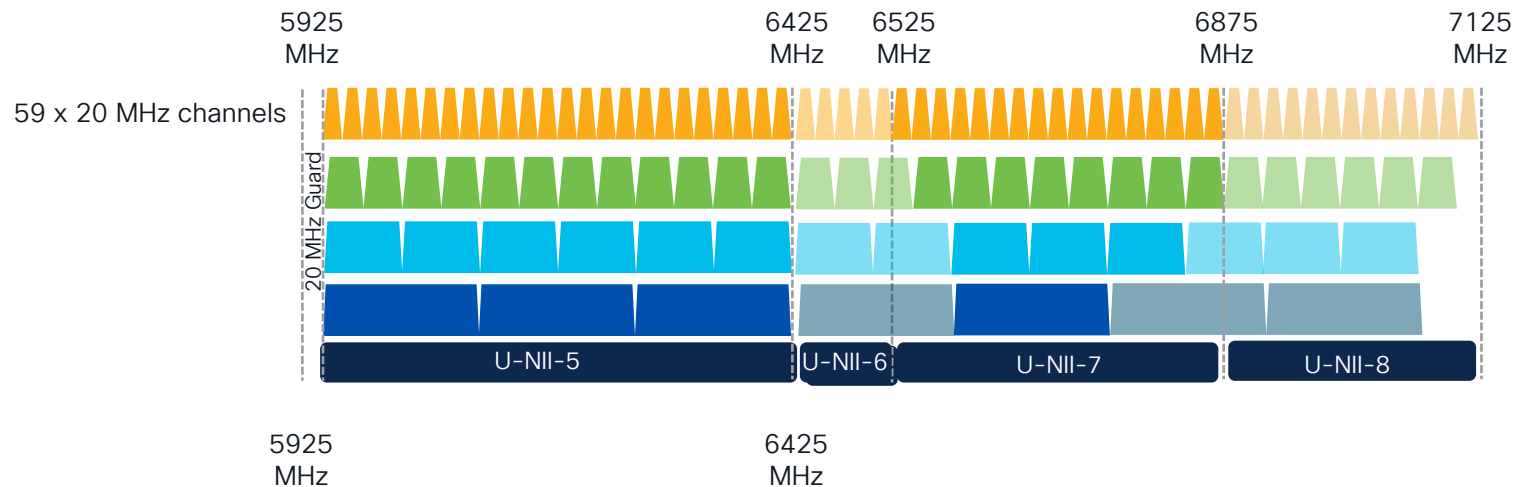
Frequency		5000 + 5 X Ch. Number				DFS Channels				DFS Channels																PROFESSIONAL L																																															
Radio Band		U-NII-1				U-NII-2a				Past Proposal UNII-2b								U-NII-2c (Extended)								U-NII-3				Proposed UNII-4																																											
Center Freq		5.180	5.200	5.220	5.240	5.260	5.280	5.300	5.320	5.340	5.360	5.380	5.400	5.420	5.440	5.460	5.480	5.500	5.520	5.540	5.560	5.580	5.600	5.620	5.640	5.660	5.680	5.700	5.720	5.745	5.765	5.785	5.805	5.825	5.845	5.865	5.885																																				
Qty	25	20 MHz	36	40	44	48	52	56	60	64	68	72	76	80	84	88	92	96	100	104	108	112	116	120	124	128	132	136	140	144	149	153	157	161	165	169	173	177	Qty	25																																	
12	40 MHz	38				54				70				78				86				94				102				110				118				126				134				142				151				159				167				175				12							
6	80 MHz	42				58				74				90												106				122				138				155				171								6																							
2	160 MHz	50								82												114												165 was ISM, now U-NII-3				Proposed								2																											
FCC - US		1,000 mW Tx Power Indoor & Outdoor No DFS needed				250 mw w/6dBi Indoor & Outdoor DFS Required				Not Currently Available for Unlicensed								250 mw w/6dBi Indoor & Outdoor DFS Required				120, 124, 128 US - Allowed				144 Now Allowed				1,000 mW Tx Power Indoor & Outdoor No DFS needed				Not Currently Available For Unlicensed																																							
ISED - Canada		FCC - Except Outdoor License Req. >200 mW				Same as FCC												Same as FCC				TDWR Not Allowed				Same as FCC				Canada PtP allows Higher EIRP																																											
ACMA - Australia		200 mW EIRP Indoor				200 mW EIRP - DFS & TPC 100 mW EIRP - DFS-Only Indoor												1,000 mW - DFS & TPC 500 mW - DFS-Only - No TPC Indoor/Outdoor				TDWR Not Allowed				1,000 mW - DFS & TPC 500 mW - DFS-Only Indoor/Outdoor				4,000 mW Tx Power Indoor & Outdoor No DFS needed																																											
ETSI - EU		100 mW No DFS/TPC Indoor				200 mW EIRP DFS/TPC Indoor												1,000 mW EIRP DFS/TPC Indoor/Outdoor				UK No 144				4,000 mW EIRP DFS/TPC - Outdoor Fixed Wireless Access																																															
		200 mW EIRP DFS/TPC - Indoor																10-min TWDR Scan Time								25mW SRD				25mW - SRD - No DFS																																											
20 MHz		36	40	44	48	52	56	60	64	68	72	76	80	84	88	92	96	100	104	108	112	116	120	124	128	132	136	140	144	149	153	157	161	165	169	173	177																																				
Center Freq		5.180	5.200	5.220	5.240	5.260	5.280	5.300	5.320	5.340	5.360	5.380	5.400	5.420	5.440	5.460	5.480	5.500	5.520	5.540	5.560	5.580	5.600	5.620	5.640	5.660	5.680	5.700	5.720	5.745	5.765	5.785	5.805	5.825	5.845	5.865	5.885																																				
<- Wavelength 5.8cm - 2.3"		<- Wavelength 5.8cm - 2.3"																																				Wavelength 5.1cm - 2.0" ->																																			
Free Space Path Loss 1m		45.74	45.77	45.80	45.84	45.87	45.90	45.94	45.97	46.00	46.03	46.07	46.10	46.13	46.16	46.19	46.23	46.26	46.29	46.32	46.35	46.38	46.41	46.44	46.48	46.51	46.54	46.57	46.60	46.64	46.67	46.70	46.73	46.76	46.79	46.82	46.84																																				

Source: www.wlanpros.com/spectrum



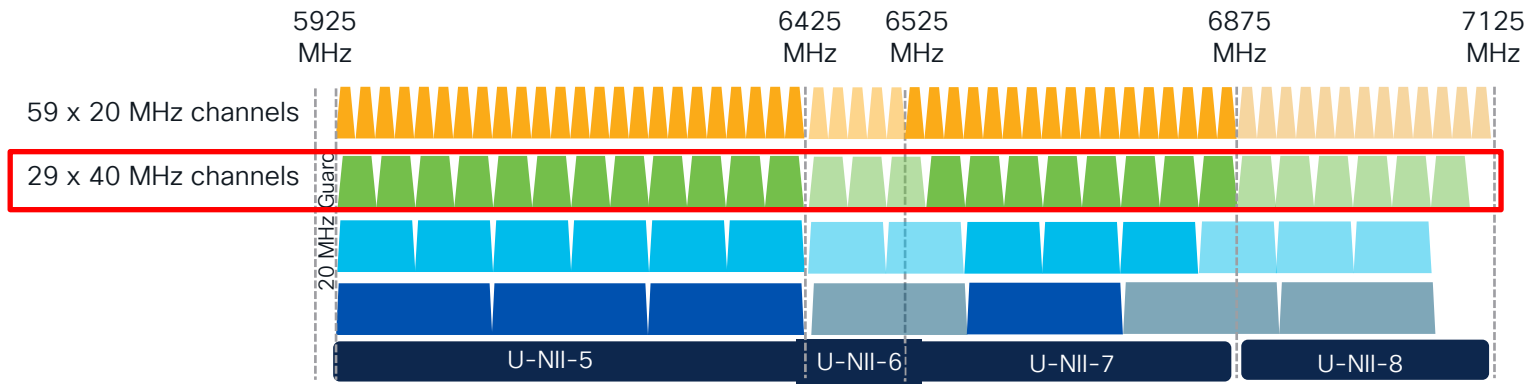


The new 6 GHz band :



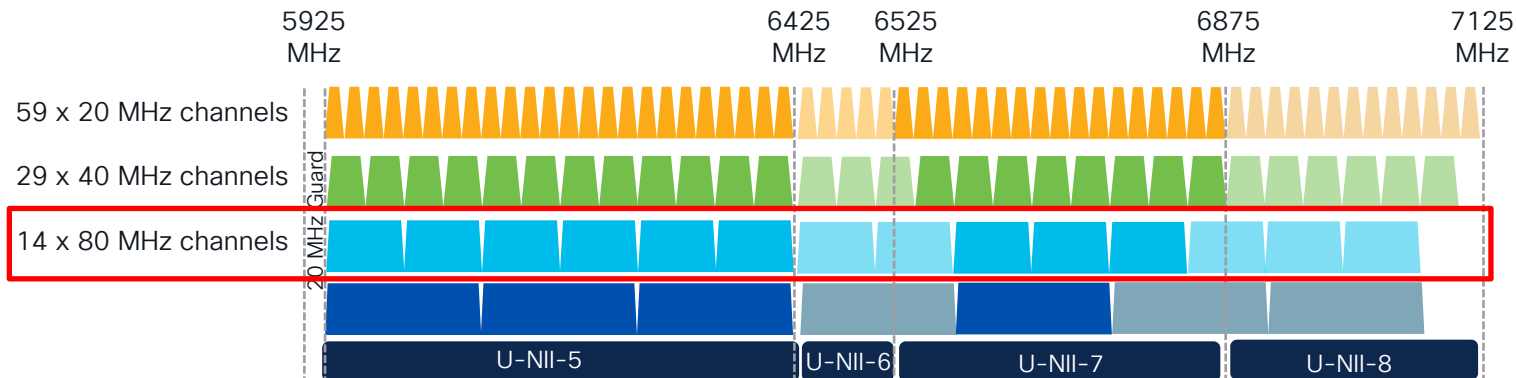
The new 6 GHz band :

United States
1200 MHz (FCC)



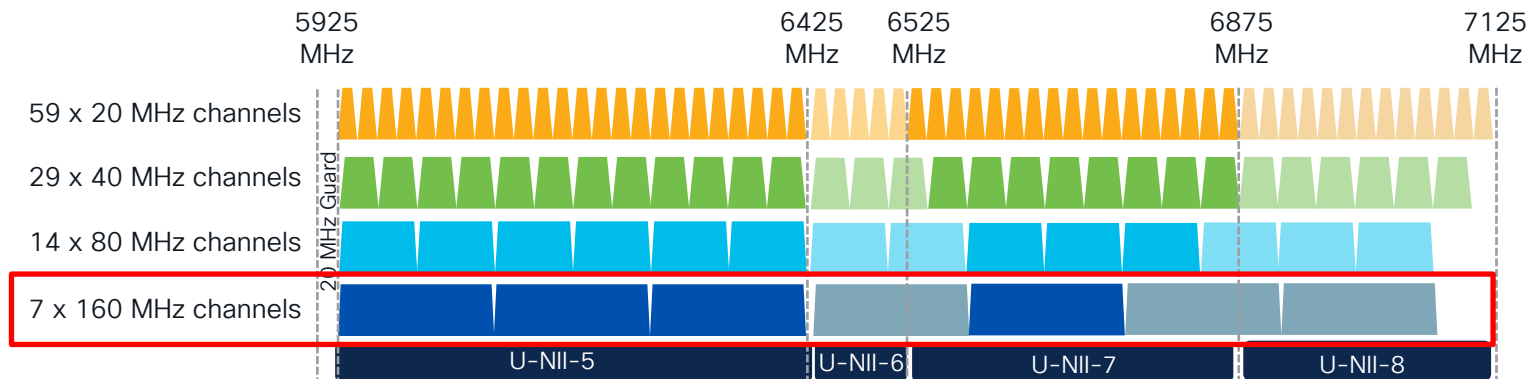
The new 6 GHz band :

United States
1200 MHz (FCC)



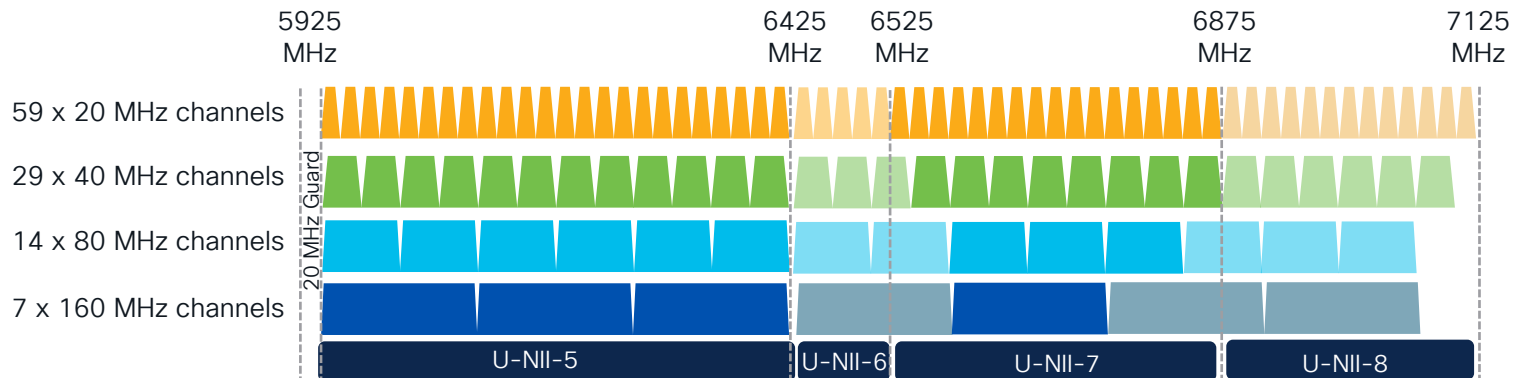
The new 6 GHz band :

United States
1200 MHz (FCC)

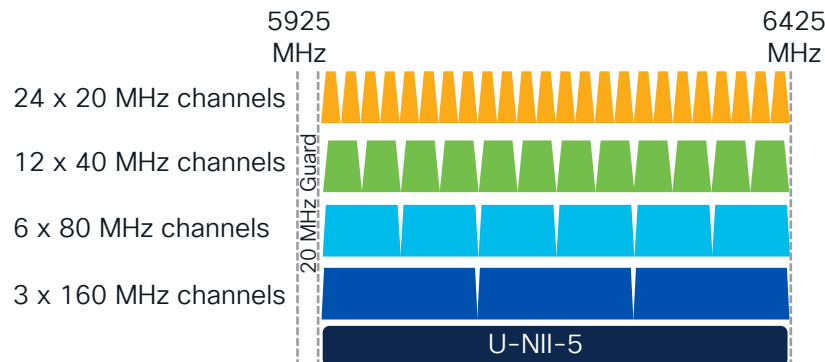


The new 6 GHz band :

United States
1200 MHz (FCC)



AU
500 MHz



6 GHz Channel Allocations

1,200 MHz



FCC - USA

5950 + 5 X Ch. Number

Low Power Indoor

5dBm/MHz - Net EIRP 18dBm

1.2 Gigahertz Proposed

Qty
59
12
6
3

Radio Band
Center Freq

UNII-5																	
5.955	5.975	5.995	6.015	6.035	6.055	6.075	6.095	6.115	6.135	6.155	6.175	6.195	6.215	6.235	6.255	6.275	6.295
1	5	9	13	17	21	25	29	33	37	41	45	49	53	57	61	65	69
3		11		19		27		35		43		51		59		67	
		7			23				39				55				71
																	87

Standard Power AP

36dBm with Automated Frequency Coordination (AFC)

Qty
24
12
6
3

Radio Band
Center Freq

UNII-5																	
5.955	5.975	5.995	6.015	6.035	6.055	6.075	6.095	6.115	6.135	6.155	6.175	6.195	6.215	6.235	6.255	6.275	6.295
1	5	9	13	17	21	25	29	33	37	41	45	49	53	57	61	65	69
3		11		19		27		35		43		51		59		67	
		7			23				39				55				71
																	87

Low Power Indoor

Radio Band
Center Freq

UNII-6										UNII-7										UNII-8																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
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Standard Power AP

Radio Band
Center Freq

UNII-6					UNII-7																	UNII-8											
6.435	6.455	6.475	6.495	6.515	6.535	6.555	6.575	6.595	6.615	6.635	6.655	6.675	6.695	6.715	6.735	6.755	6.775	6.795	6.815	6.835	6.855	6.895	6.915	6.935	6.955	6.975	6.995	7.015	7.035	7.055	7.075	7.095	7.115
					117	121	125	129	133	137	141	145	149	153	157	161	165	169	173	177	181												
						123			131		139		147		155		163		171		179												
									135			151					167																
									143																								

Client Devices

6dB Below AP max Net EIRP of 18dBm - Anticipating 12dBm

Source: www.wlanpros.com/spectrum



Wi-Fi 6E Advantages

Fewer devices

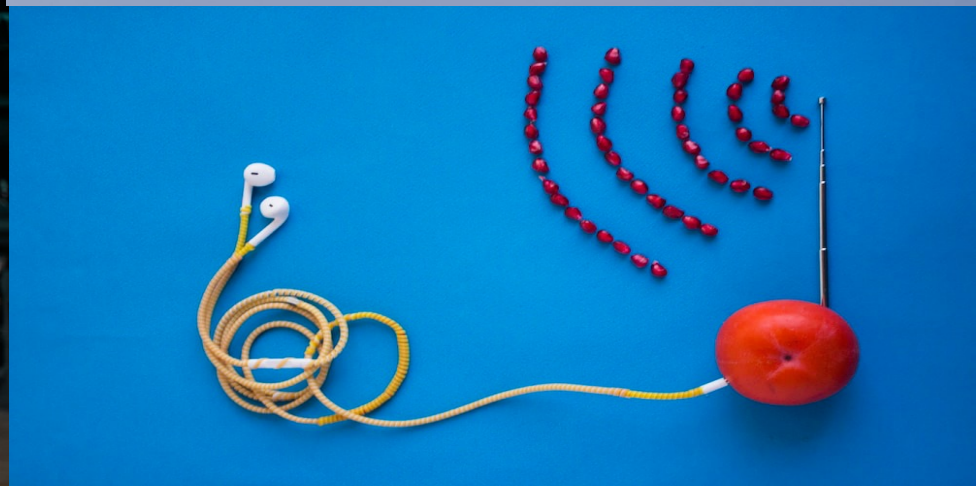
Extended spectrum

Reduced channel congestion

Double the number of channels

No DFS

No legacy devices



Design Themes

Requirements, Requirements, Requirements

Coverage

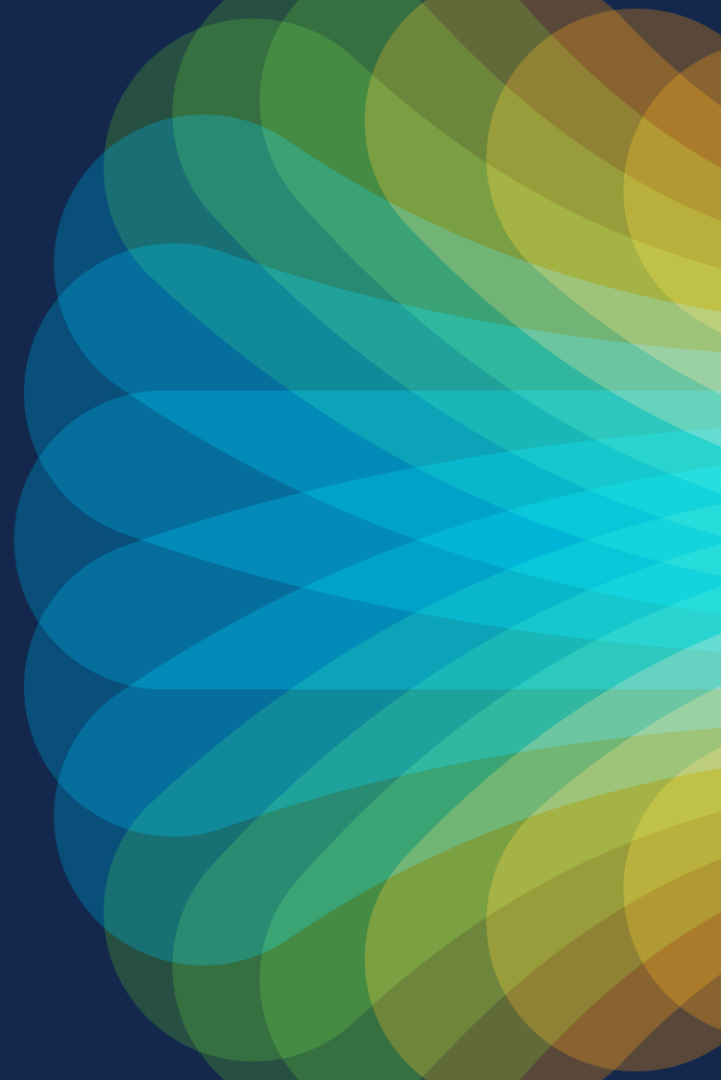
Applications – VC, VoWi-Fi

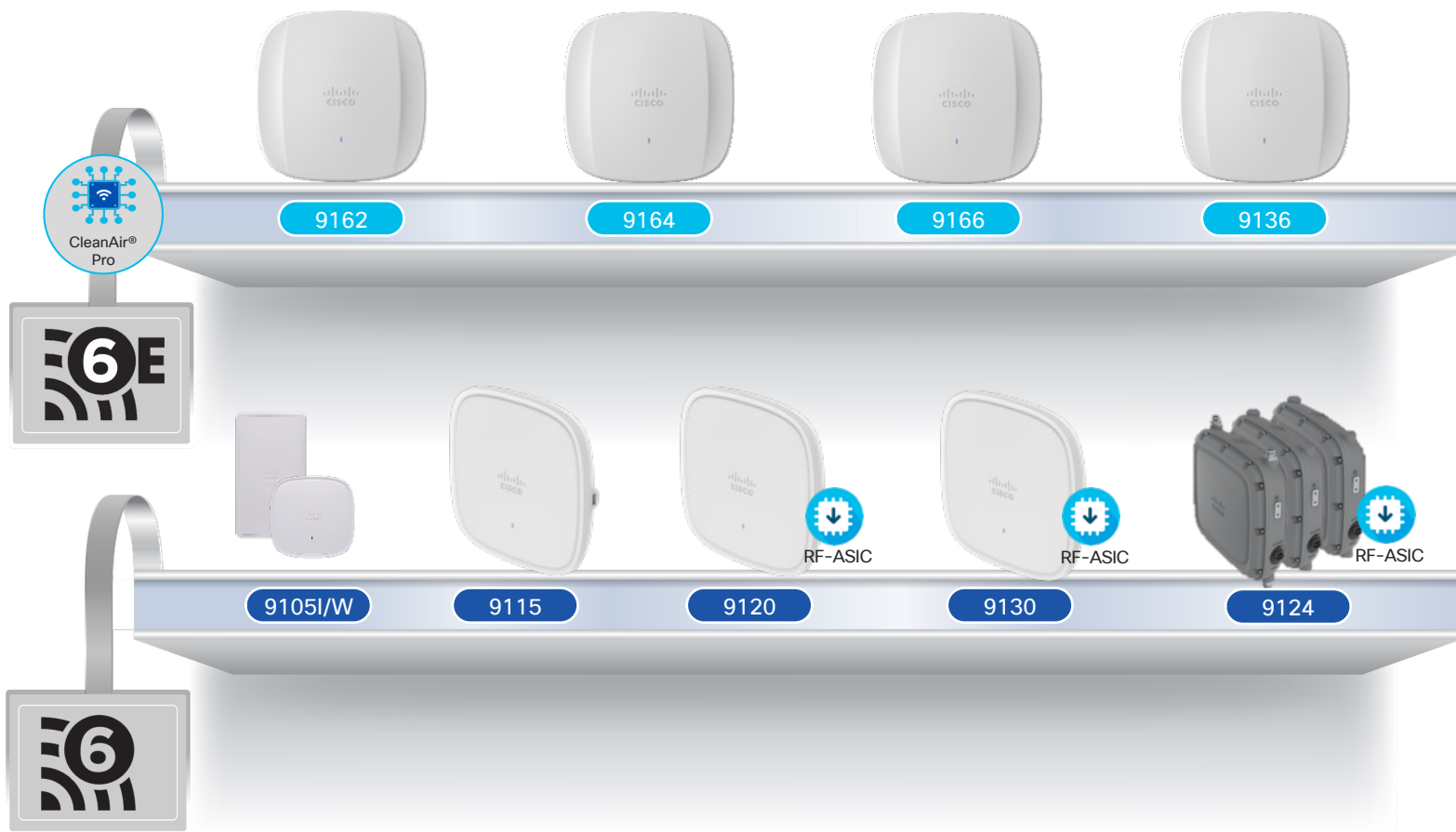
Client capabilities

Site Survey!!

Don't leave it at signal

Hardware





Cisco Catalyst 916x Wi-Fi 6E Access Points

Common Platforms will have CW PIDs



CW9162



CW9164



CW9166

Catalyst Access Point w/best of both world Features

Wi-Fi 6

Wi-Fi 6E



C91xx



MRxx



CW91xx

- ✓ Catalyst (Aironet) Brackets
- ✓ DC Power
- ✓ USB Ports
- ✓ LEDs for respective Persona
- ✓ Unified FRA/XOR architecture

Cisco Catalyst Wireless 6E Access Points

Ideal for Small to Medium-sized deployments

Mission Critical, Performance



CW9162I

- 2x2 + 2x2 + 2x2



CW9164I

- 2x2, 4x4, 4x4



CW9166I

- 4x4 + 4x4 + 4x4 (XOR 5/6)



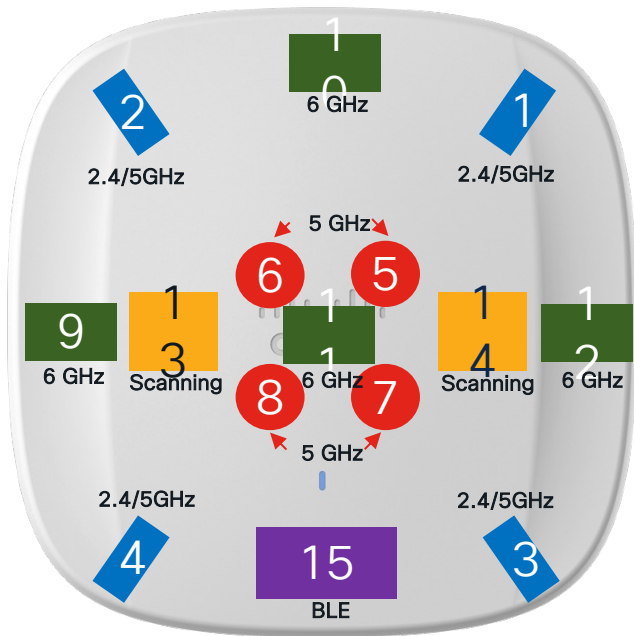
C9136

- 4x4, 8x8, 4x4 (or) 4x4, 4x4+4x4, 4x

Full radio capability (6 GHz @ LPI) on single 30W PoE+

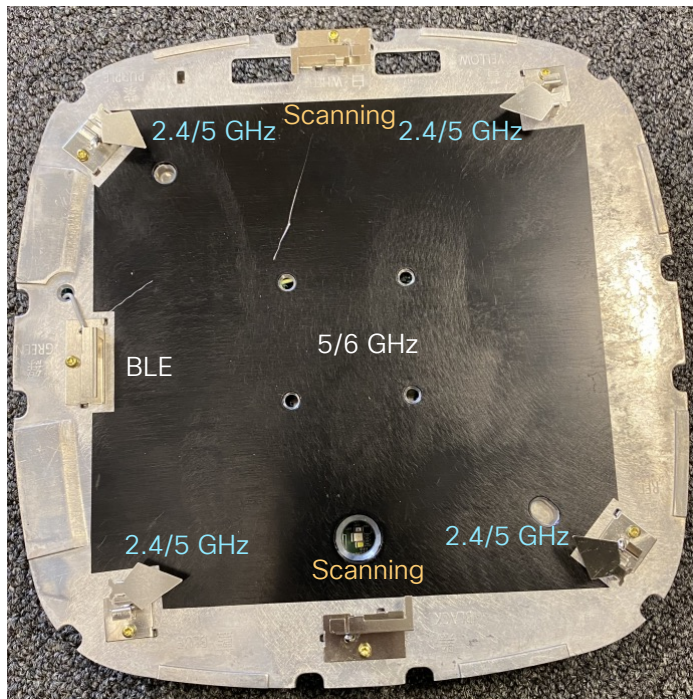
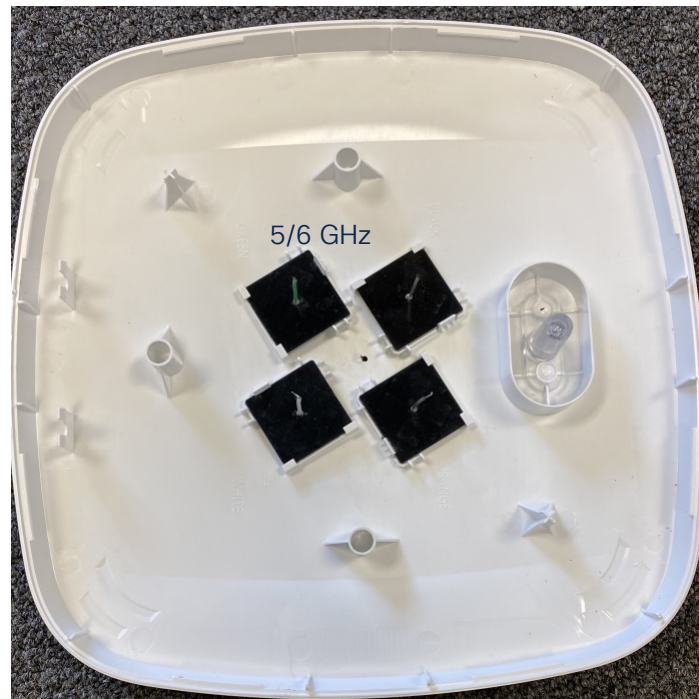
Catalyst 9136I Antenna Array

Only AP in the industry can do 5 GHz @ 8x8 or 2x @4x4 and 6 GHz



Antenna #	Frequency Combination	Antenna Type	Polarization
1 -4	Wi-Fi 2.4/5 GHz	PIFA 3/5 dBi	V-Pol
5-8	Wi-Fi 5 GHz	Alford Loop 5 dBi	H-Pol
9-12	Wi-Fi 6 GHz	PIFA 6 dBi	V-Pol
13-14	Scanning	PIFA 3-6 dBi*	V-Pol
15	BLE	PIFA 5 dBi	V-Pol

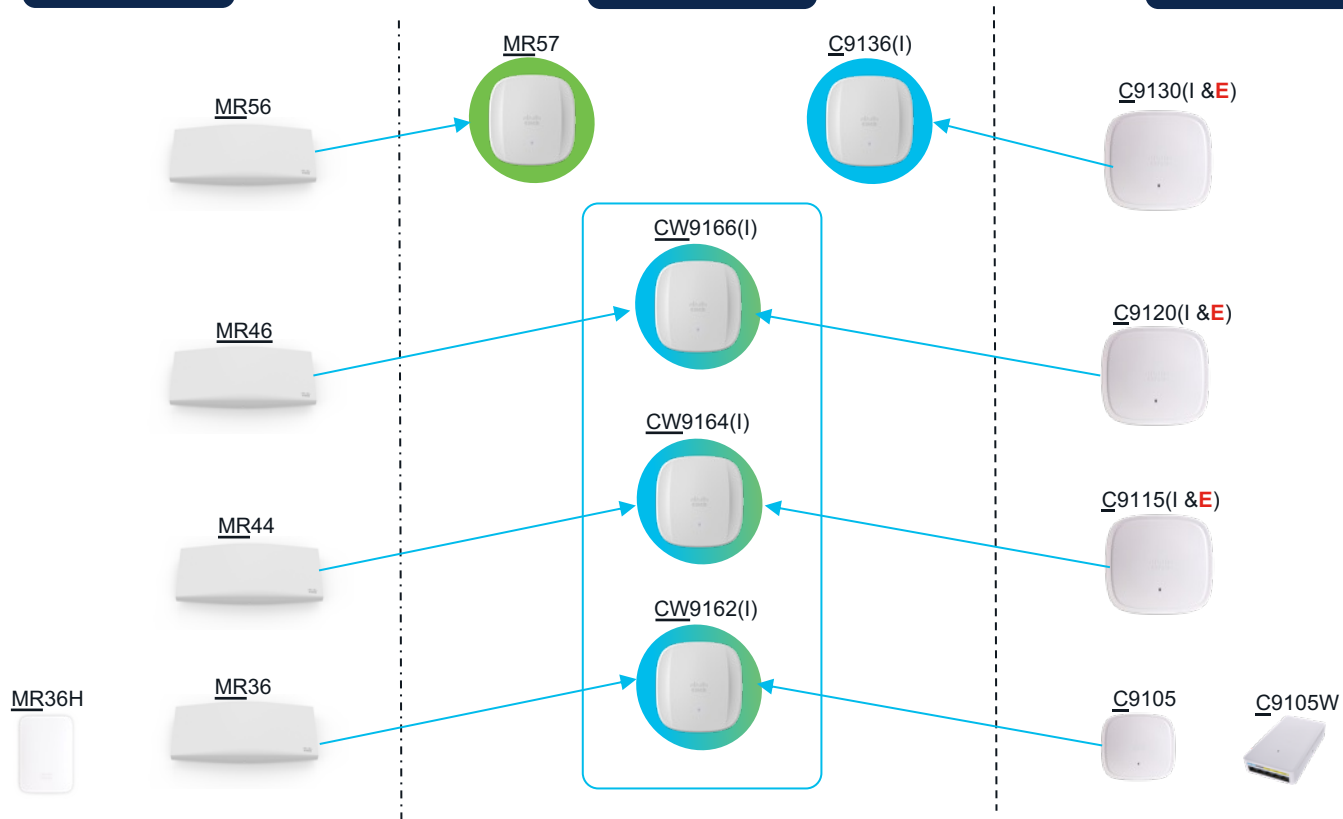
Cisco Catalyst CW9166I Antenna Array



Wi-Fi 6

Wi-Fi 6E

Wi-Fi 6



Cisco outdoor AP portfolios

1572



1542



1562



9124



1570 Series (Wave 1)

- 802.11ac Wave 1



1540 Series (Wave 2)

- 802.11ac Wave 2, MU-MIMO



1560 Series (Wave 2)

- 802.11ac Wave 2, MU-MIMO



9124 Series* (Wi-Fi 6)

- 802.11AX, MU-MIMO, OFDMA

Catalyst 9124AX Outdoor Access Point

C9124AX Internal Omnidirectional & Directional Antenna



Powered by
Cisco RF ASIC

C9124AX External Antenna



Powered by
Cisco RF ASIC

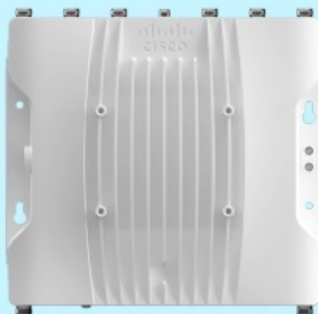
- Dual Radio Mode: 4x4 + 4x4 in both 2.4 and 5 GHz
- Tri-Radio Mode: 2x2 + 2x2 + 2x2 in 2.4 Ghz, 5Ghz(Slot 1) & 5 Ghz(Slot 2)
- 9124 AXI, AXE, AXD models

Introducing Cisco Catalyst IW9167 Series

One hardware, two wireless technologies

NEW

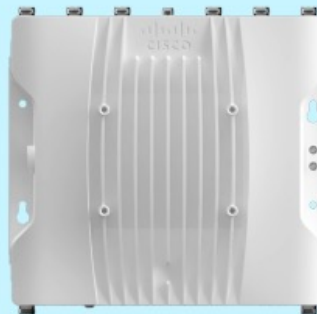
Industrial and outdoor access point (Wi-Fi 6/6E)



Pair with Cisco DNA Center for analytics and efficiency

ENHANCED

Cisco Ultra-Reliable Wireless Backhaul (Cisco URWB)



Deploy and manage with Cisco IoT Operations Dashboard

OR

What's new?

Tri-radio
2.4 GHz, 5GHz, 5/6GHz

4x4
4 spatial streams

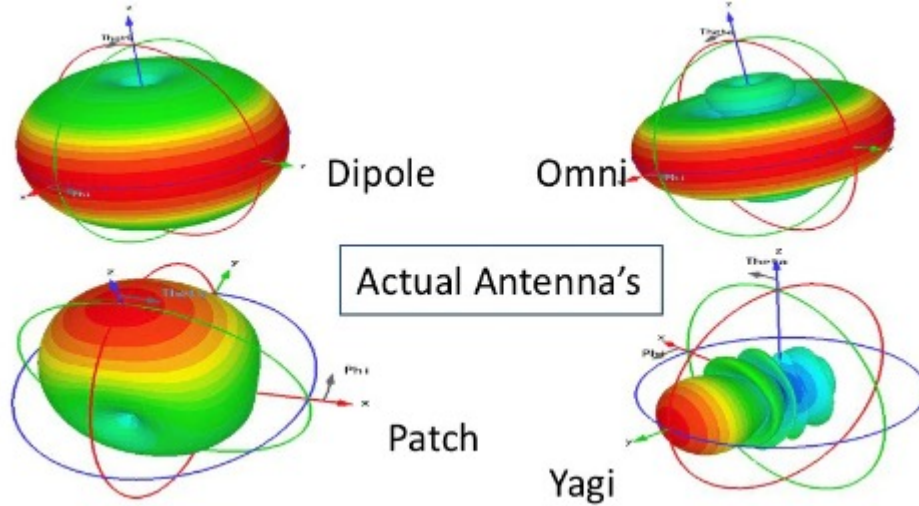
Multigigabit
RJ45, or SFP+, M12 adapters

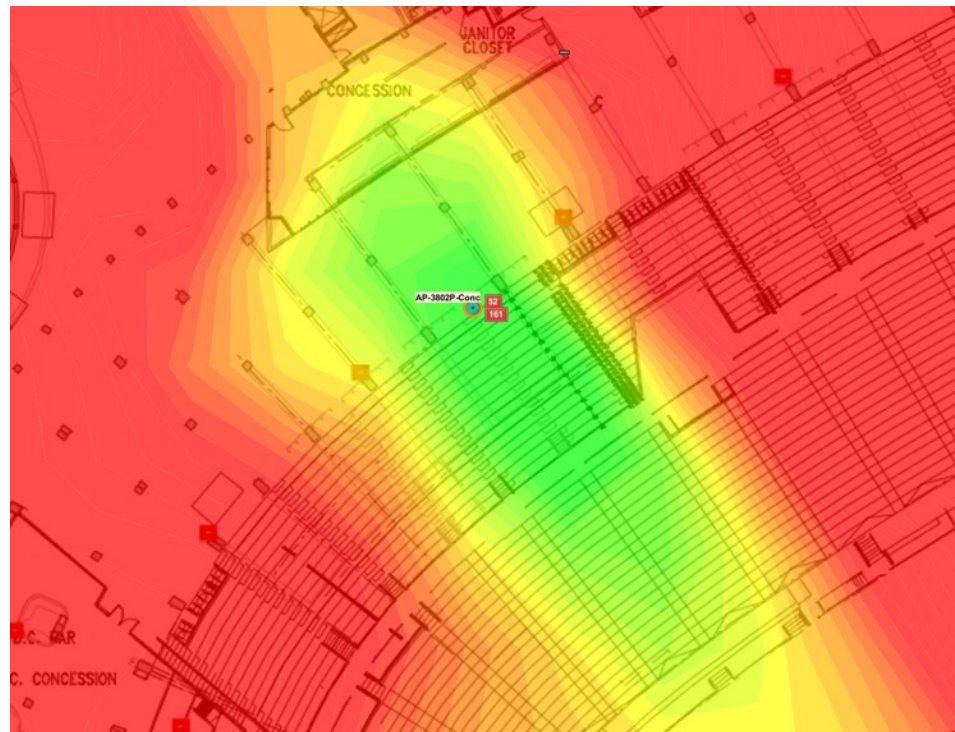
GNSS, BLE,
Scanning Radio

Supporting Cast

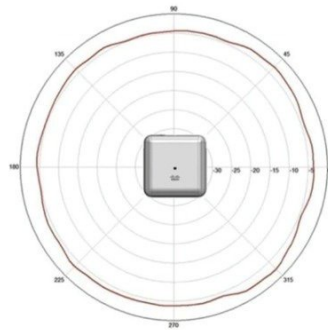
0m <= Bundled cabling length <= 50m	Category 5e	Category 6	Category 6A
2.5GBASE-T			Assured
5GBASE-T Assured			Assured
50m <= Bundled cabling length <= 75m	Category 5e	Category 6	Category 6A
2.5GBASE-T			Assured
5GBASE-T Assured			Assured
75m <= Bundled cabling length <= 100m	Category 5e	Category 6	Category 6A
2.5GBASE-T			Assured
5GBASE-T Assured			Assured
ALSNR Risk	High	Medium	Low

Source: NBASE-T Alliance (Archive)

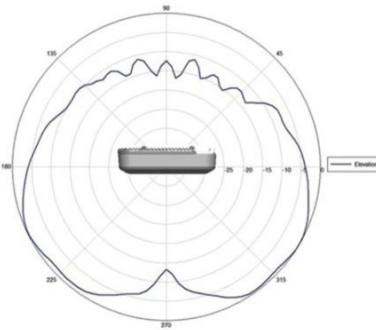




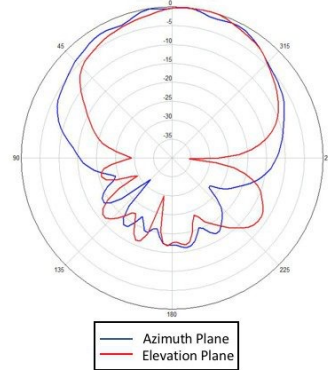
5 GHz Azimuth Macro



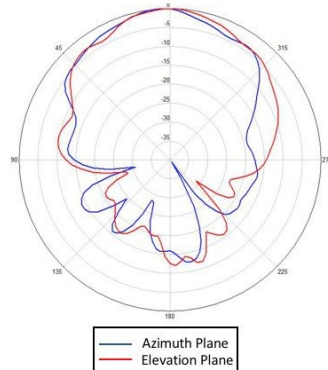
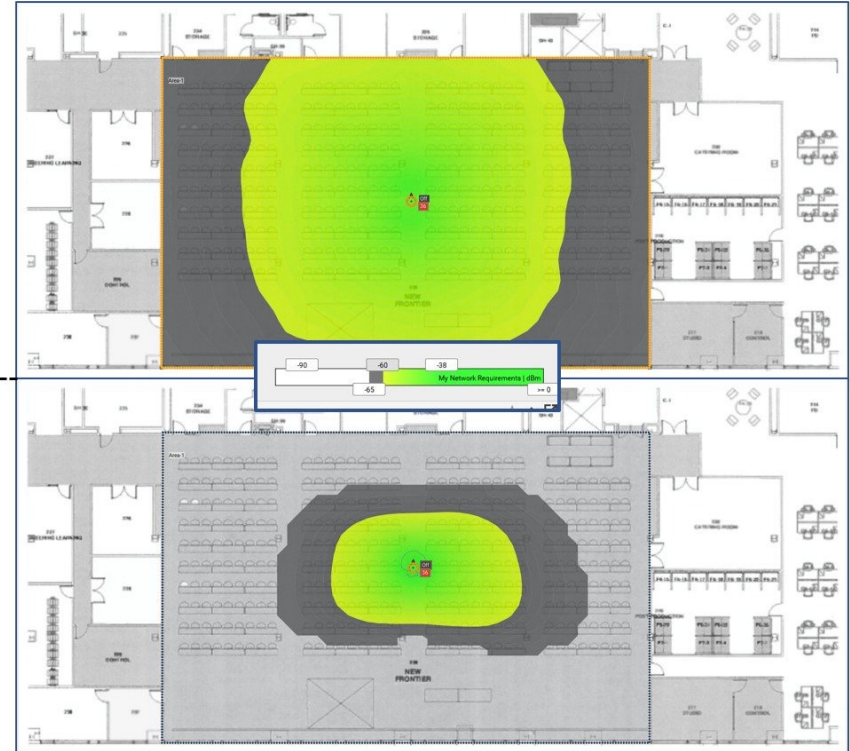
5 GHz Elevation Macro



5 GHz V-Polarized



5 GHz H-Polarized



Antenna Selection

		Beam	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 Stadium 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; > 30'/10m, <200'/60m to clients)

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 <div>New!</div>	Dual-Band Stadium 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; > 30'/10m, <200'/60m to clients)

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Cisco Catalyst C-ANT9104 – Stadium Antenna + Integrated AP





Three generations of High-Density WiFi Stadium Antennas

C-ANT9104 - Software Defined RF Propagation

Configuration > Tags & Profiles > RF/Radio

RF

Radio

Edit Radio Profile

+ Add

× Delete

Radio Profile Name

☐

m4wide

☐

m4narrow

☒

m4narrow10

☐

m4narrow20

☐

default-radio-profile

Name*

m4narrow10

Description

m4narrow10

Antenna Beam Selection

☐

Not Configured

☐

Wide Beam

☐

Narrow Beam

☒

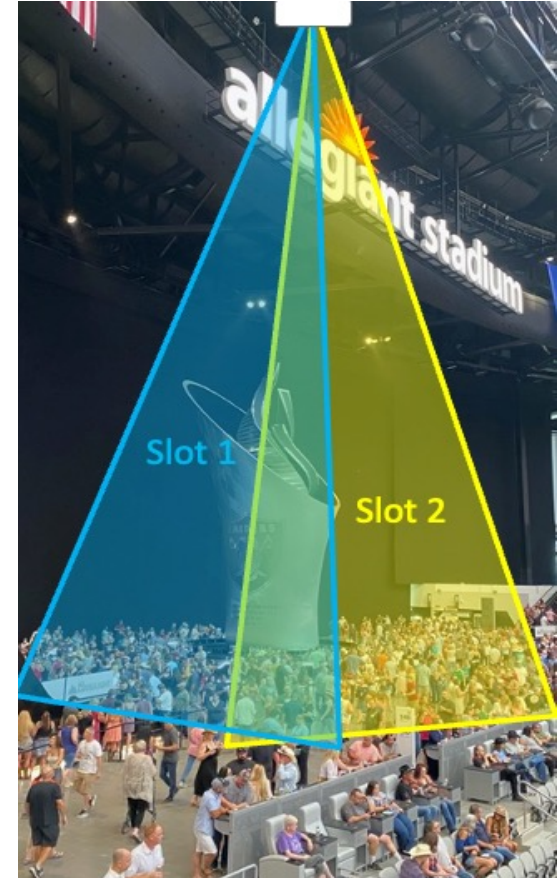
Narrow from centre 10

☐

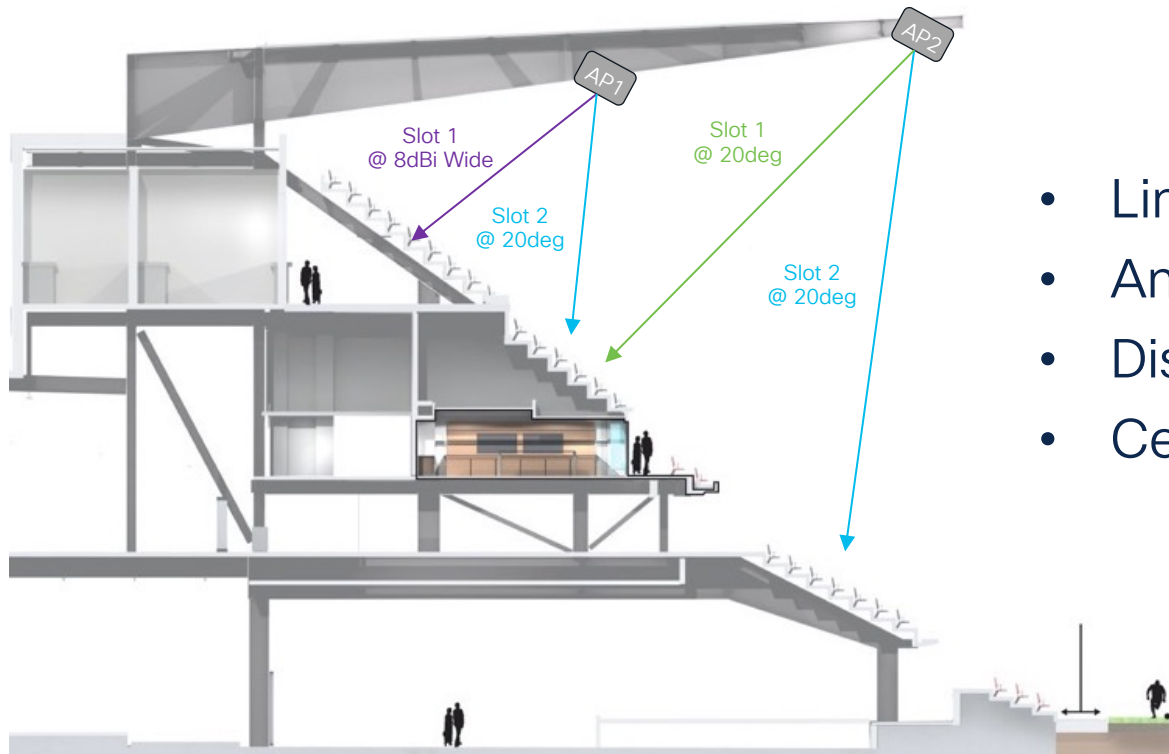
Narrow from centre 20

Number of antenna to be enabled

0



AP Placement Tips



- Line-of-Sight
- Angle of Incidence
- Distance to Clients
- Cell Size & Overlap

Antenna Placement: What Not To Do

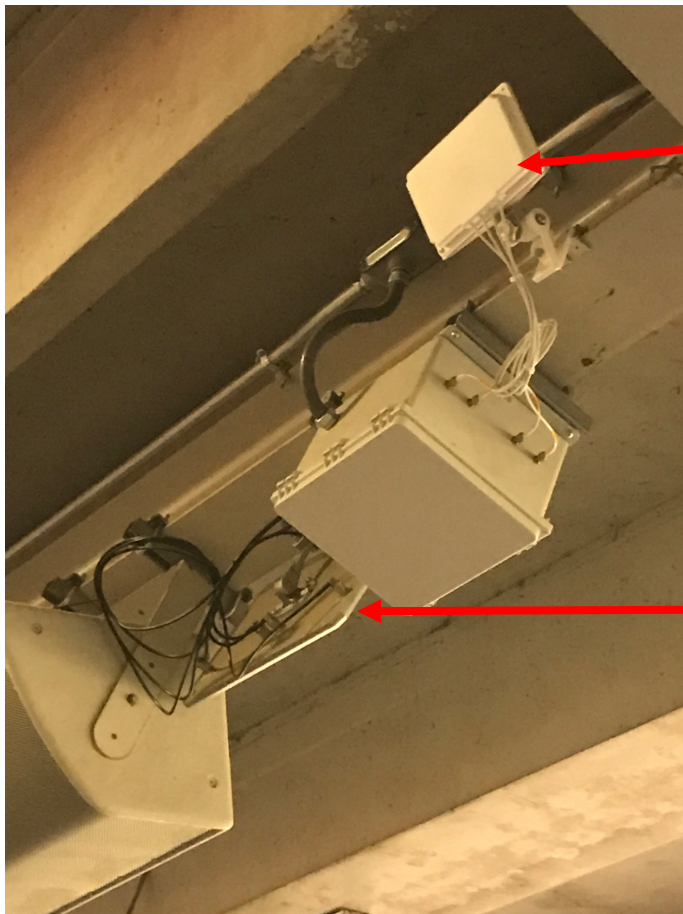
- Seating Area Coverage: Challenging Areas



Avoid long shots like this



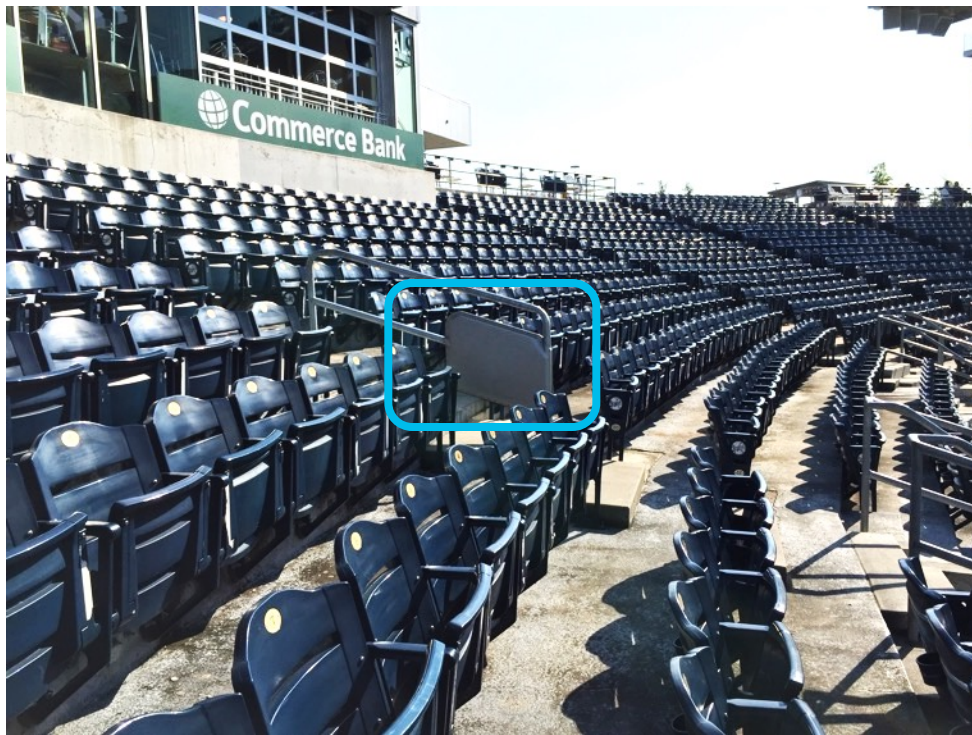
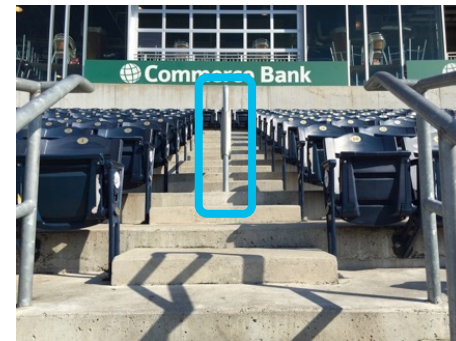
Avoid
obstructions in
front of your
antennas



“Wide” Patch Antenna

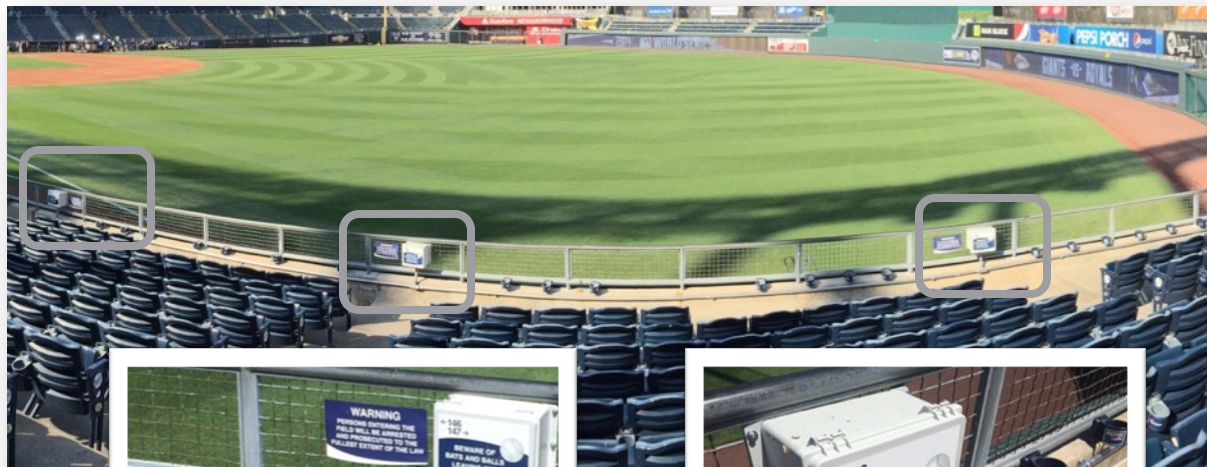
Stadium Antenna

Creative AP/Antenna Mount Examples



Creative AP/Antenna Mount Examples

- Seating Area Coverage: Challenging Areas



- Creative options may be required for low seating rows
 - Handrails
 - Front walls (aimed away from playing surface)
- Ensure compliance with minimum distances to bodies - >20cm
- Stick to directional antennas

Antenna Placement



Flexible Radio Assignment

- A Better Mobile User Experience for High-Density Networks



- **Automatically detects** when a large number of devices are connected to a network
- **Adds capacity** by changing the access points from 2.4/5GHz to Dual 5GHz
- **Monitors the network** for security threats and RF interference that may affect performance
- **Schedule** more capacity through time of day templates
- **For detailed info on FRA (and other advanced RRM topics) – see Jim Florwick’s Cisco Live session BRKEWN-3010:**
<https://www.ciscolive.com/c/dam/r/ciscolive/us/docs/2019/pdf/BRKEWN-3010.pdf>

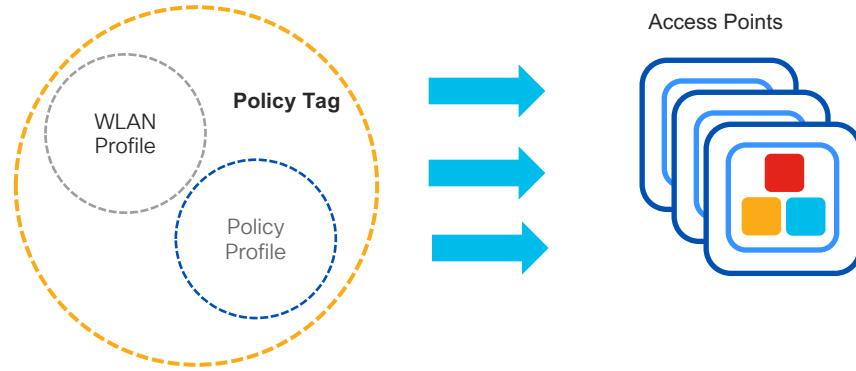
Supported on Cisco Aironet 2800/3800/4800/91XX Series Access Points

RF Profiles, TPC, DCA

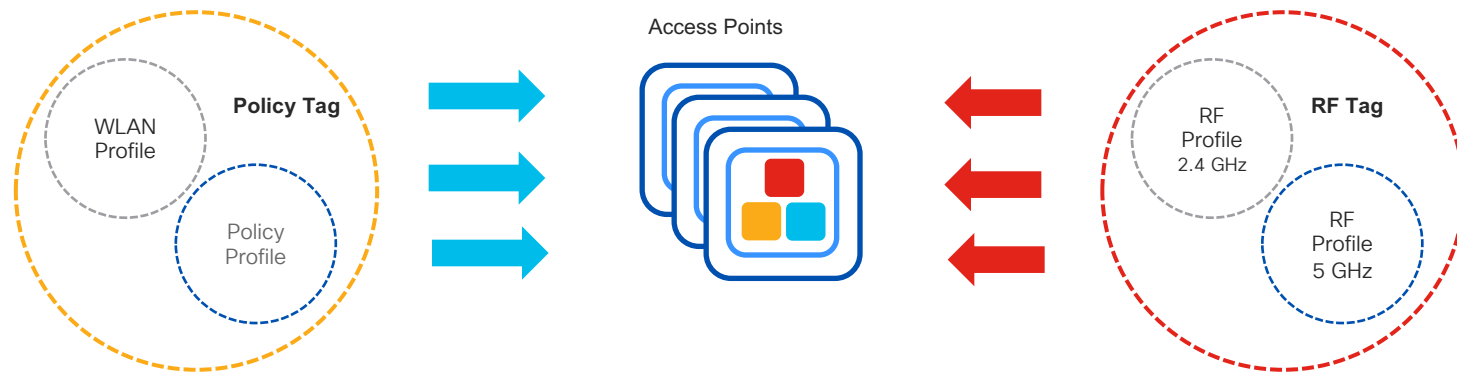
High Density WLAN Features & Configurations



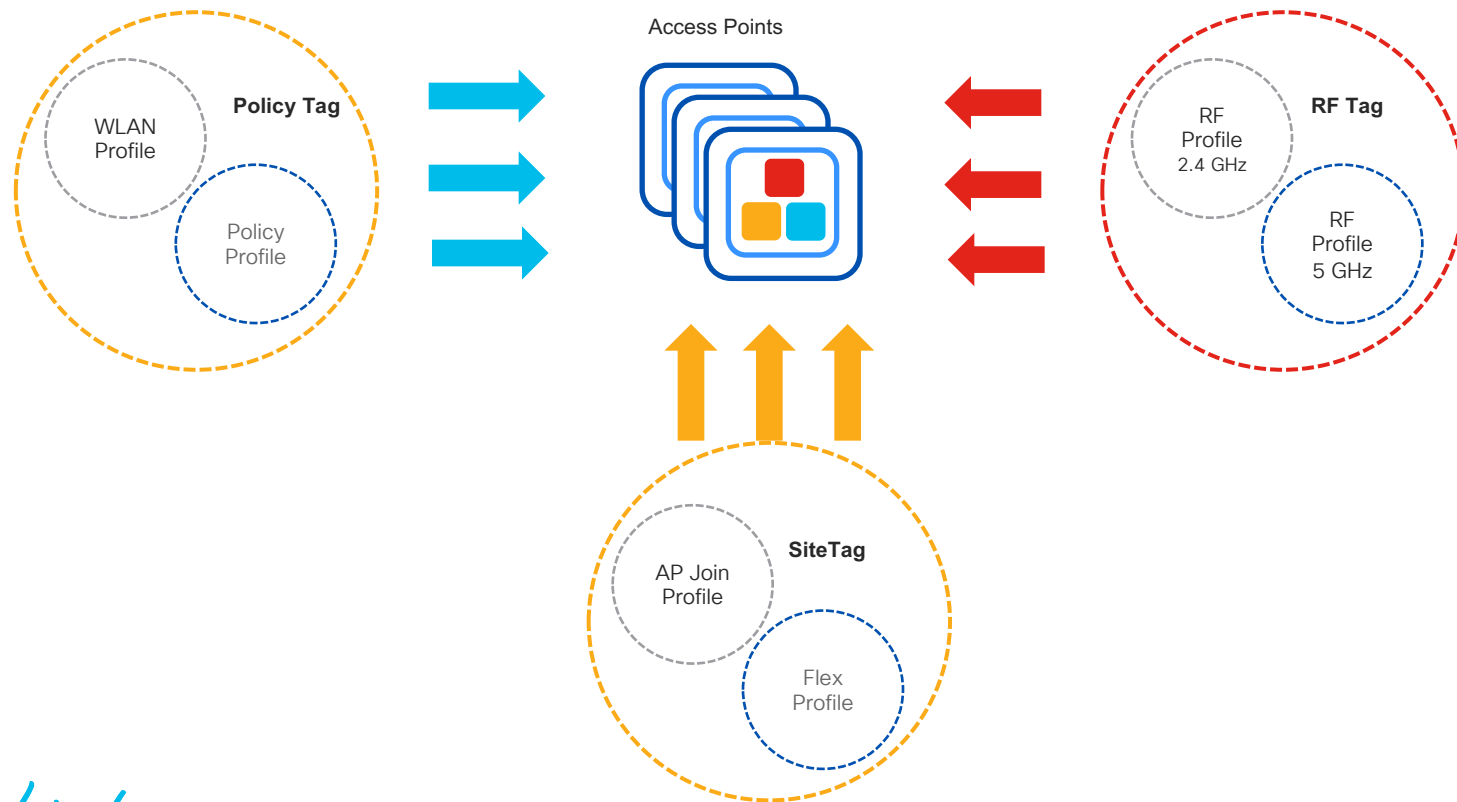
Cisco Catalyst 9800 Config Model



Cisco Catalyst 9800 Config Model



Cisco Catalyst 9800 Config Model



RF Profiles for High Density Optimisation

The screenshot displays the Cisco AIR-CT9580-K9 web interface. The top navigation bar includes the Cisco logo, device name, and user information. The left sidebar contains menu items: Dashboard, Monitoring, Configuration (selected), Administration, and Troubleshooting. The main content area shows the 'Configuration > Tags & Profiles > RF' path. Below this, there are '+ Add' and 'Delete' buttons. A table lists RF profiles with columns for State, RF Profile Name, Band, and Description. The 'High_Client_Density_rf_5gh' profile is highlighted. The table footer shows pagination: 1 - 8 of 8 items.

State	RF Profile Name	Band	Description
☐	HRL_5GHz	5 GHz	
☐	HRL_24GHz	2.4 GHz	
☐	Low_Client_Density_rf_5gh	5 GHz	pre configured Low Client Density rf
☐	High_Client_Density_rf_5gh	5 GHz	pre configured High Client Density r
☐	Low_Client_Density_rf_24gh	2.4 GHz	pre configured Low Client Density rf
☐	High_Client_Density_rf_24gh	2.4 GHz	pre configured High Client Density r
☐	Typical_Client_Density_rf_5gh	5 GHz	pre configured Typical Density rfpro
☐	Typical_Client_Density_rf_24gh	2.4 GHz	pre configured Typical Client Densit

Balancing Transmit Power with RF Profiles

The screenshot displays the Cisco configuration interface for a Cisco AIR-CT9580-K9 device. The top navigation bar includes the Cisco logo, the device name and IP (16.12.1), and a welcome message for the 'admin' user. The left sidebar contains navigation links for Dashboard, Monitoring, Configuration, Administration, and Troubleshooting. The main content area is titled 'Configuration > Tags & Profiles > RF' and shows a table of RF profiles. The 'High_Client_Density_rf_5gh' profile is selected. The right panel, titled 'Edit RF Profile', shows the 'RRM' tab with sub-tabs for General, Coverage, TPC, and DCA. The 'TPC' sub-tab is active, showing 'Transmit Power Control' settings: Maximum Power Level (dBm)* set to 30, Minimum Power Level (dBm)* set to 7, and Power Threshold V1 (dBm)* set to -65.

Configuration > Tags & Profiles > RF

	State	RF Profile Name
☐	↑	HRL_5GHz
☐	↑	HRL_24GHz
☐	↑	Low_Client_Density_rf_5gh
☐	↑	High_Client_Density_rf_5gh
☐	↑	Low_Client_Density_rf_24gh
☐	↑	High_Client_Density_rf_24gh
☐	↑	Typical_Client_Density_rf_5gh
☐	↑	Typical_Client_Density_rf_24gh

10 items per page

Edit RF Profile

General 802.11 **RRM** Advanced

General Coverage **TPC** DCA

Transmit Power Control

Maximum Power Level(dBm)*

Minimum Power Level(dBm)*

Power Threshold V1(dBm)*

Selecting Channel Width with RF Profiles

Welcome *admin*
Last login Thu, Sep 26 2019 16:56:54 ...

Search APs and Clients

Edit RF Profile

General 802.11 **RRM** Advanced

General Coverage TPC **DCA**

Dynamic Channel Assignment

Avoid AP Foreign AP Interference ☒

Channel Width ☒ 20 MHz ☐ 40 MHz ☐ 80 MHz ☐ 160 MHz ☐ Best

DCA Channels

☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒
36	40	44	48	52	56	60	64	100	104	108	112	116	120	124	
☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☐					
128	132	136	140	144	149	153	157	161	165						

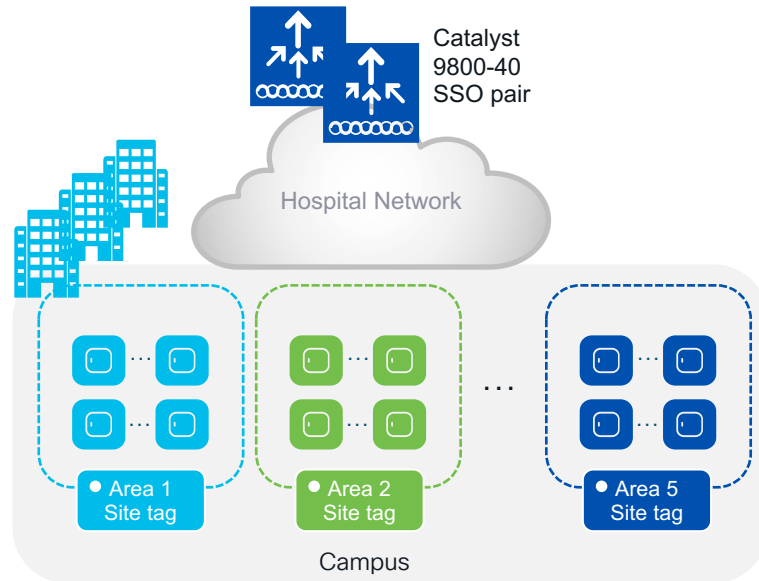
High Speed Roam

Mode Enable ☐

Neighbor Timeout*

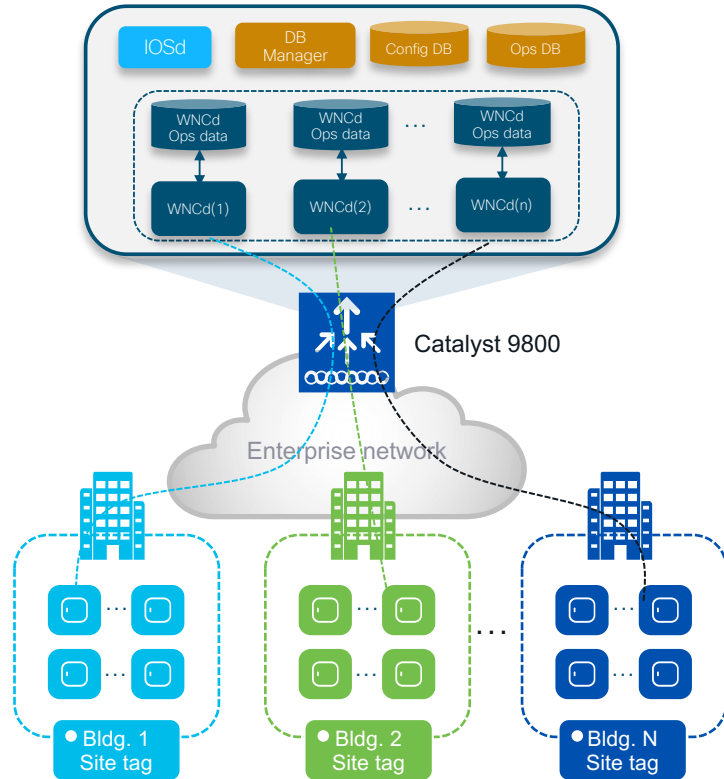
Client Network Preference

C9800 Site Tag Design in High Density



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

Site Tags – Design considerations



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 WNCd's processes:
`9800#sh processes platform | inc wncd`

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

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

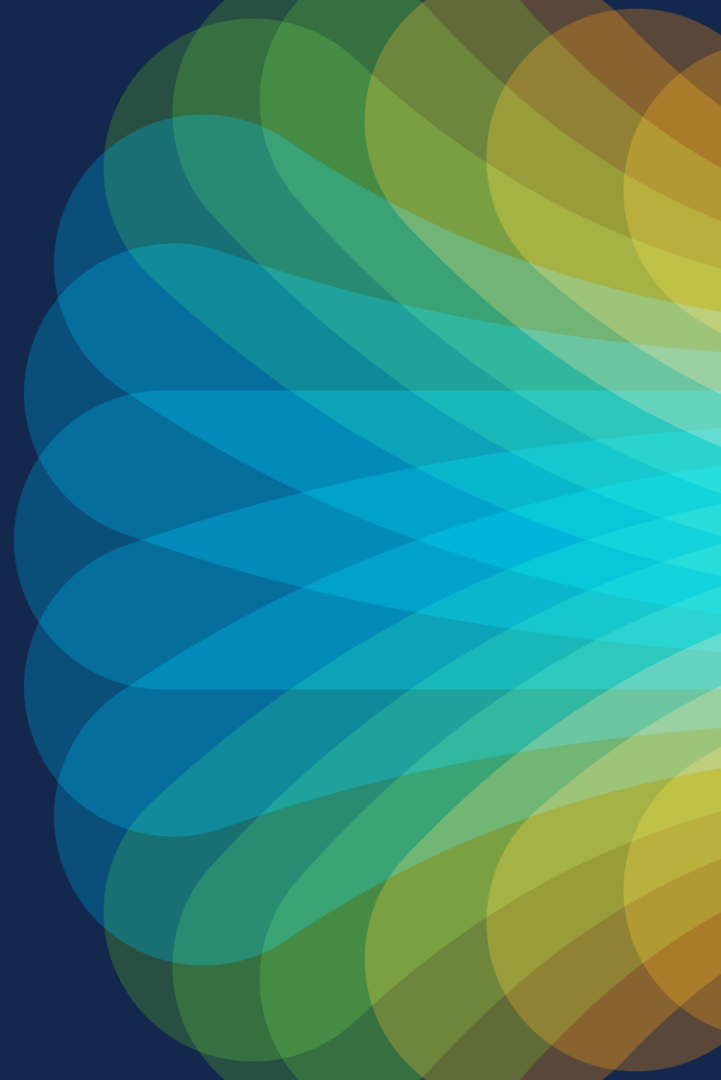
show wireless loadbalance tag affinity wncd <wncd-number>

- 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

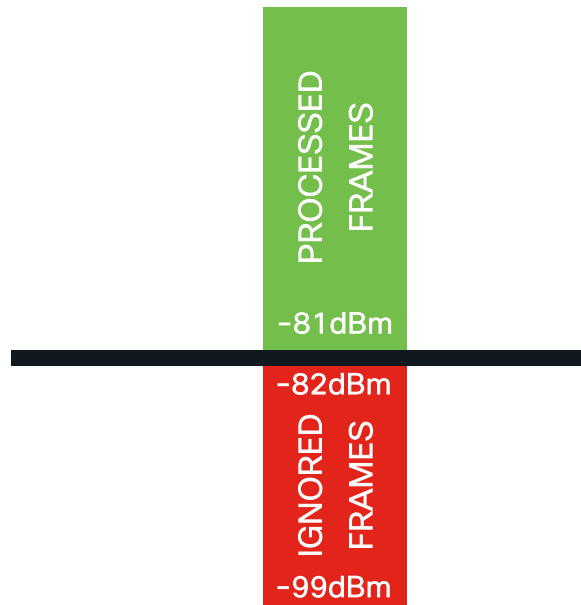
The (Not So) Secret High Density Weapon: RX-SOP



Receive Sensitivity Threshold (RX-SOP)



Receive Sensitivity Threshold (RX-SOP)



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', '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''. Below this, there are 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. It shows 'Maximum Clients(1 to 200)' set to 200 and 'Rx Sop Threshold' set to 'Medium' with a value of '-78' and a 'Custom' checkbox checked. A red '8.7+' is overlaid on the 'Rx Sop Threshold' section. To the right, a 'Configuration > Tags & Profile' panel shows a table of RF profiles. The 'High_Client_Density' profile is selected. Further right, the 'Edit RF Profile' panel is shown with tabs for 'General', '802.11', 'RRM', and 'Advanced'. The 'Advanced' tab is active, showing 'High Density Parameters' and 'Client Distribution'. The 'Rx Sop Threshold (dbm)' is set to 'custom' with a value of '-85', which is also highlighted with a green box. The 'Client Distribution' section shows 'Load Balancing Window*' set to 5 and 'Load Balancing Denial Count*' set to 3. The 'ATF Configuration' section shows '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

Rx Sop Threshold Parameters

Rx Sop Threshold Medium -78 Custom

8.7+

Configuration > Tags & Profile

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

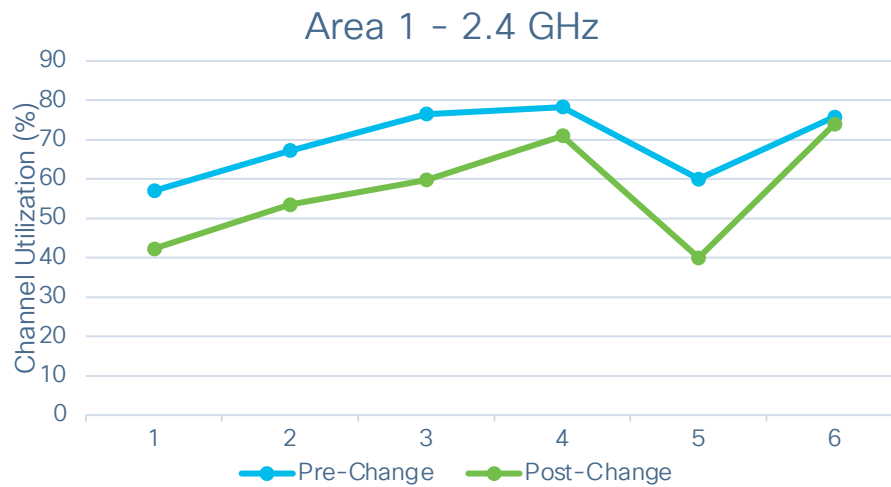
ATF Configuration

Status DISABLED

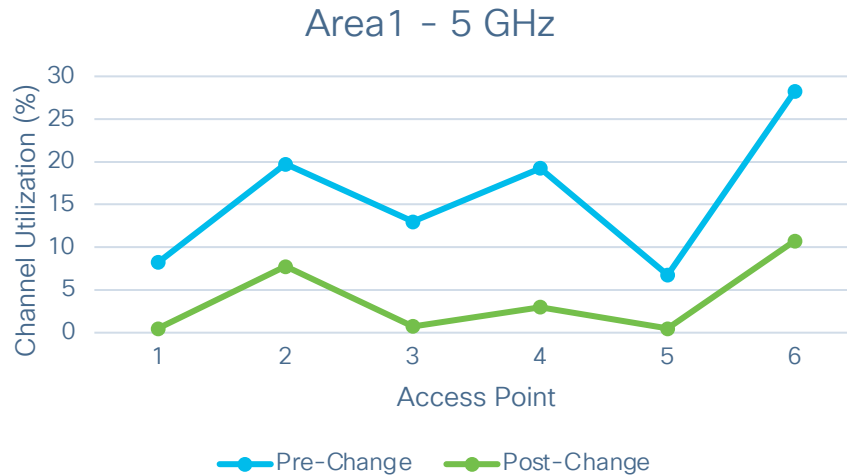
RX-SOP Case Study

RX-SOP Test Summary

- Large open multi-level area
- “Quick Win”
- Channel Utilisation improvement focus
- Test a small area across both bands

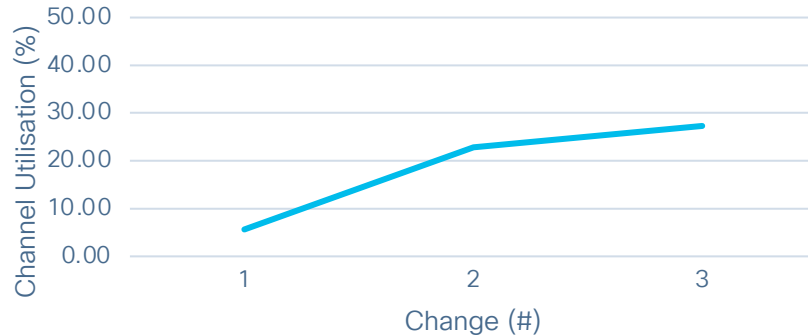


- 2.4 GHz (-85 dBm)
- Up to 13.59% Improvement
- Positive Impact to surrounding APs (5%)

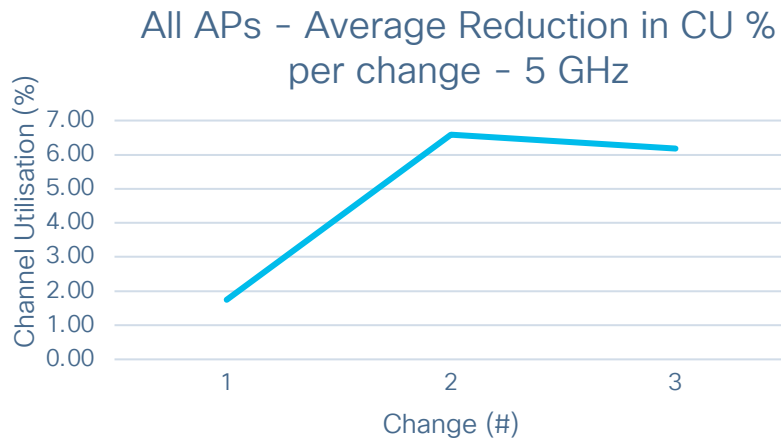


- 5 GHz (-80 dBm)
- Peak of 12.34% Improvement
- Positive Impact to surrounding APs (1.75%)

All APs - Average Reduction in CU %
per change - 2.4 GHz

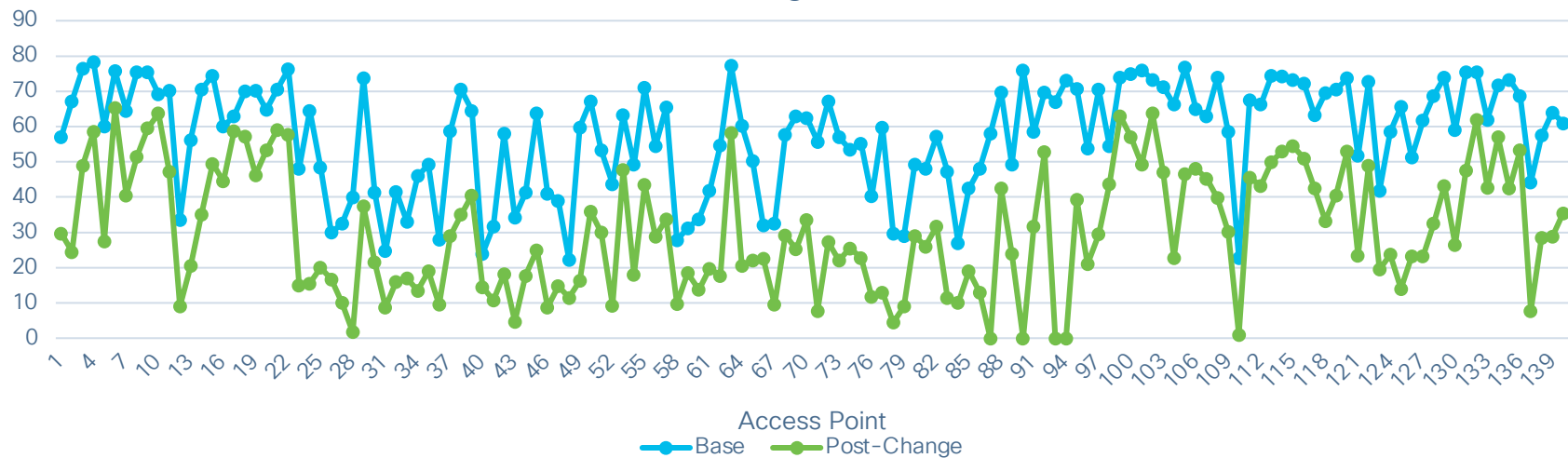


- 2.4 GHz (-79 dBm)
- Almost 30% Improvement on average
- Diminishing returns

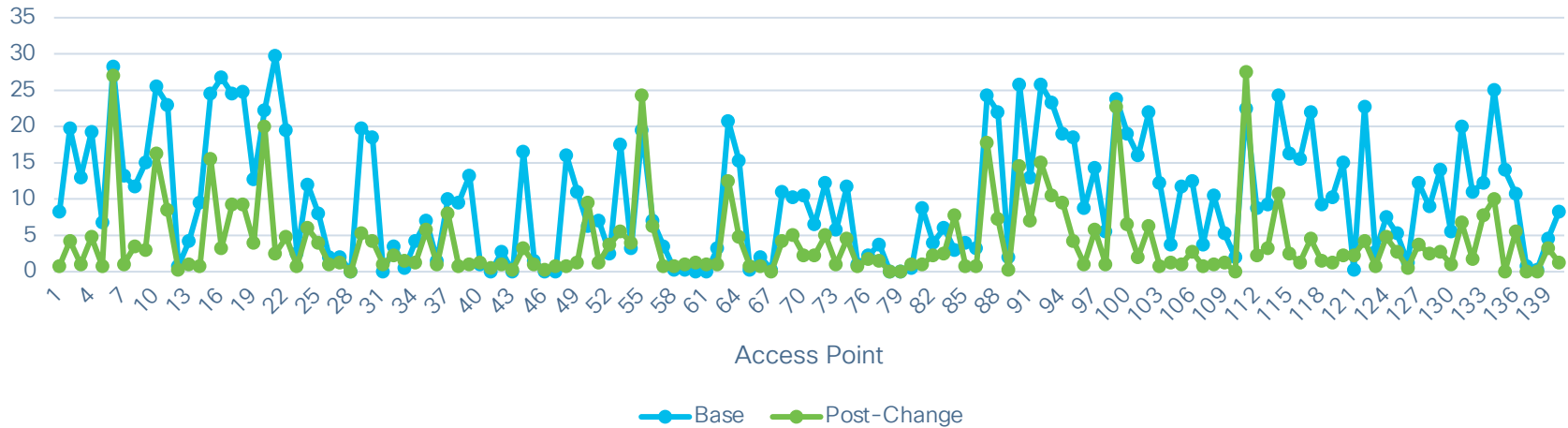


- 5 GHz (-76 dBm)
- Almost 7% improvement on average
- Too aggressive!

Base vs Change 3 - 2.4 GHz



Base vs Change 3 - 5 GHz

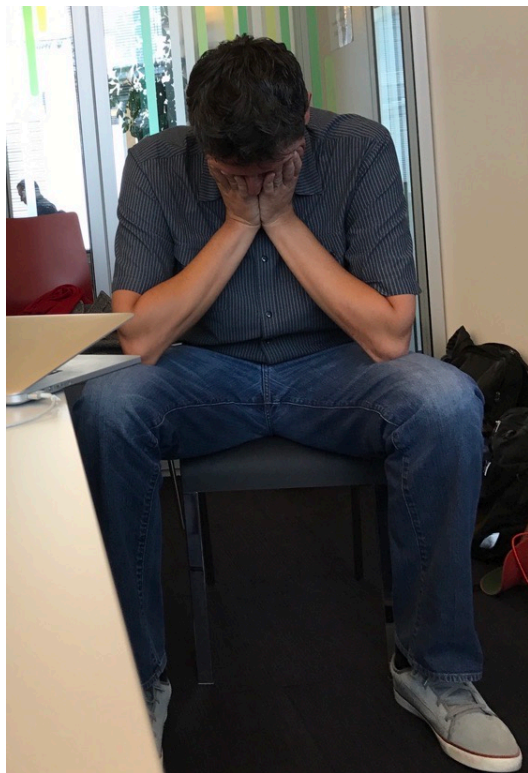


Lessons

- RX-SOP is from the AP perspective only
- Clients have no filters
- Too aggressive a value leads to a negative result

HD Case Study

Common High Density Optimisation Mistakes



- ❑ AP-to-AP transmit power imbalance (causes “Magnet” / overloaded AP’s)
- ❑ 2.4 GHz to 5 GHz transmit power imbalance (draws dual-band clients to 2.4 GHz)
- ❑ Transmit power too low to overcome noise floor
- ❑ Channel Utilization too high - high latency
- ❑ Minimum mandatory PHY rate improperly tuned (too high or too low)
- ❑ Too many SSIDs enabled (not using AP Groups to control where SSID’s are enabled)

Case Study – Poor HD Optimisation

Open

Secure

BSSID	Beacon Airtime	Vendor	SNR	Device Name	Signal	Noise	Channel	Channel Width	Band	Channel Utilization
<Multiple values>	5.612 ms		38 dB		-47	-85	1, 6, 11, 48, 112, 124	20, 40, 80 MHz	2.4, 5 GHz	85%
<Multiple values>	4.804 ms		40 dB		-47	-87	1, 6, 11, 48, 112	20, 40, 80 MHz	2.4, 5 GHz	83%
38:FF:36:9D:63:A8	0.204 ms		40 dB		-47	-87	6	20 MHz	2.4 GHz	83%
38:FF:36:9D:7E:58	0.204 ms		33 dB		-61	-94	6	20 MHz	2.4 GHz	74%
38:FF:36:9D:85:F8	0.196 ms		24 dB		-63	-87	1	20 MHz	2.4 GHz	76%
34:8F:27:84:8B:D8	0.204 ms		23 dB		-64	-87	11	20 MHz	2.4 GHz	76%
38:FF:36:9D:82:C8	0.204 ms		23 dB		-64	-87	11	20 MHz	2.4 GHz	69%
38:FF:36:9D:63:AC	0.104 ms		20 dB		-67	-87	48	40 MHz	5 GHz	39%
38:FF:36:9D:7F:D8	0.204 ms		19 dB		-68	-87	6	20 MHz	2.4 GHz	82%
38:FF:36:9D:7E:28	0.204 ms		16 dB		-69	-85	6	20 MHz	2.4 GHz	79%
38:FF:36:9C:6A:D8	0.204 ms		18 dB		-69	-87	1	20 MHz	2.4 GHz	77%
38:FF:36:9D:84:F8	0.204 ms		12 dB		-73	-85	6	20 MHz	2.4 GHz	82%
38:FF:36:9D:7F:F8	0.204 ms		12 dB		-75	-87	11	20 MHz	2.4 GHz	78%
38:FF:36:9C:76:9C	0.104 ms		11 dB		-76	-87	48	40 MHz	5 GHz	37%
38:FF:36:9D:7E:5C	0.104 ms		11 dB		-76	-87	48	40 MHz	5 GHz	31%
38:FF:36:9D:82:CC	0.108 ms		10 dB		-77	-87	112	40 MHz	5 GHz	43%
38:FF:36:9C:65:88	0.204 ms		16 dB		-78	-94	11	20 MHz	2.4 GHz	77%
38:FF:36:9C:74:98	0.204 ms		8 dB		-79	-87	1	20 MHz	2.4 GHz	76%
34:8F:27:84:8D:A8	0.204 ms		15 dB		-79	-94	6	20 MHz	2.4 GHz	69%
34:8F:27:84:8B:DC	0.208 ms		8 dB		-79	-97	112	40 MHz	5 GHz	51%

<http://www.adriangranados.com/apps/wifi-explorer>

Case Study – Poor HD Optimisation

Open		Secure								
BSSID	Beacon Airtime	Vendor	SNR	Device Name	Signal	Noise	Channel	Channel Width	Band	Channel Utilization
<Multiple values>	5.612 ms		38 dB		-47	-85	1, 6, 11, 48, 112, 124	20, 40, 80 MHz	2.4, 5 GHz	85%
<Multiple values>	4.804 ms		40 dB		-47	-87	1, 6, 11, 48, 112	20, 40, 80 MHz	2.4, 5 GHz	83%
38:FF:36:9D:63:A8	0.204 ms		40 dB		-47	-87	6	20 MHz	2.4 GHz	83%
38:FF:36:9D:7E:58	0.204 ms		33 dB		-61	-94	6	20 MHz	2.4 GHz	74%
38:FF:36:9D:85:F8	0.196 ms		24 dB		-63	-87	1	20 MHz	2.4 GHz	76%
34:8F:27:84:8B:D8	0.204 ms		23 dB		-64	-87	11	20 MHz	2.4 GHz	76%
38:FF:36:9D:82:C8	0.204 ms		23 dB		-64	-87	11	20 MHz	2.4 GHz	69%
38:FF:36:9D:63:AC	0.104 ms		20 dB		-67	-87	48	40 MHz	5 GHz	39%
38:FF:36:9D:7F:D8	0.204 ms		19 dB		-68	-87	6	20 MHz	2.4 GHz	82%
38:FF:36:9D:7E:28	0.204 ms		16 dB		-69	-85	6	20 MHz	2.4 GHz	79%
38:FF:36:9C:6A:D8	0.204 ms		18 dB		-69	-87	1	20 MHz	2.4 GHz	77%
38:FF:36:9D:84:F8	0.204 ms		12 dB		-73	-85	6	20 MHz	2.4 GHz	82%
38:FF:36:9D:7F:F8	0.204 ms		12 dB		-75	-87	11	20 MHz	2.4 GHz	78%
38:FF:36:9C:76:9C	0.104 ms		11 dB		-76	-87	48	40 MHz	5 GHz	37%
38:FF:36:9D:7E:5C	0.104 ms		11 dB		-76	-87	48	40 MHz	5 GHz	31%
38:FF:36:9D:82:CC	0.108 ms		10 dB		-77	-87	112	40 MHz	5 GHz	43%
38:FF:36:9C:65:88	0.204 ms	Ruckus Wireless	16 dB		-78	-94	11	20 MHz	2.4 GHz	77%
38:FF:36:9C:74:98	0.204 ms	Ruckus Wireless	8 dB		-79	-87	1	20 MHz	2.4 GHz	76%
34:8F:27:84:8D:A8	0.204 ms	Ruckus Wireless	15 dB		-79	-94	6	20 MHz	2.4 GHz	69%
24:9E:27:84:8B:D8	0.228 ms	Ruckus Wireless	9 dB		-79	-87	112	40 MHz	5 GHz	51%

<http://www.adriangranados.com/apps/wifi-explorer>

Common High Density Optimisation Mistakes



- ❑ AP-to-AP transmit power imbalance (causes “Magnet” / overloaded AP’s) *TPC*
- ❑ 2.4 GHz to 5 GHz 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*

Troubleshooting

Favorite Tools

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



Wi-Fi Hawk



WCAE



WLAN Poller

[Intuitibits](#) Tools (Mac)



WiFi Explorer



AirTool



WiFi Signal

Tethabyte WinFi (Windows)



[WinFi](#)

Packet Capture & Analysis Tools



Metageek [Tonic](#)



[Wireshark](#)



(Article)
[Analyzing Wireless Packet Captures](#)

Site Survey Tools



[Ekahau Pro](#) & [Sidekick](#)



[Hamina Network Planner](#)

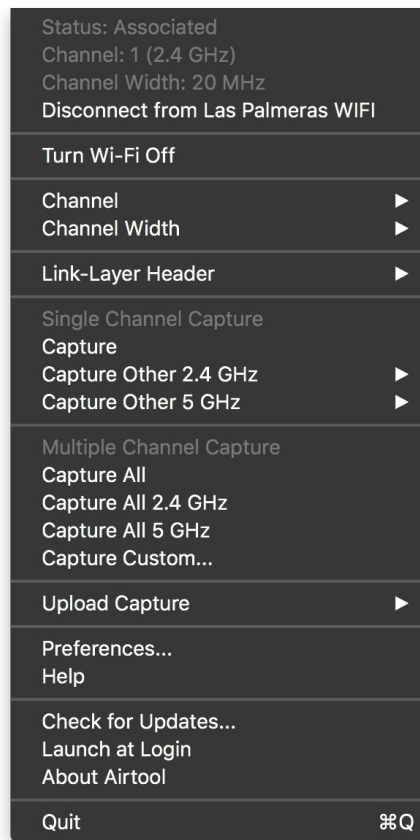
NetOps, AIOps, DevOps Tools



[Cisco DNA Center Assurance](#)

Packet Captures

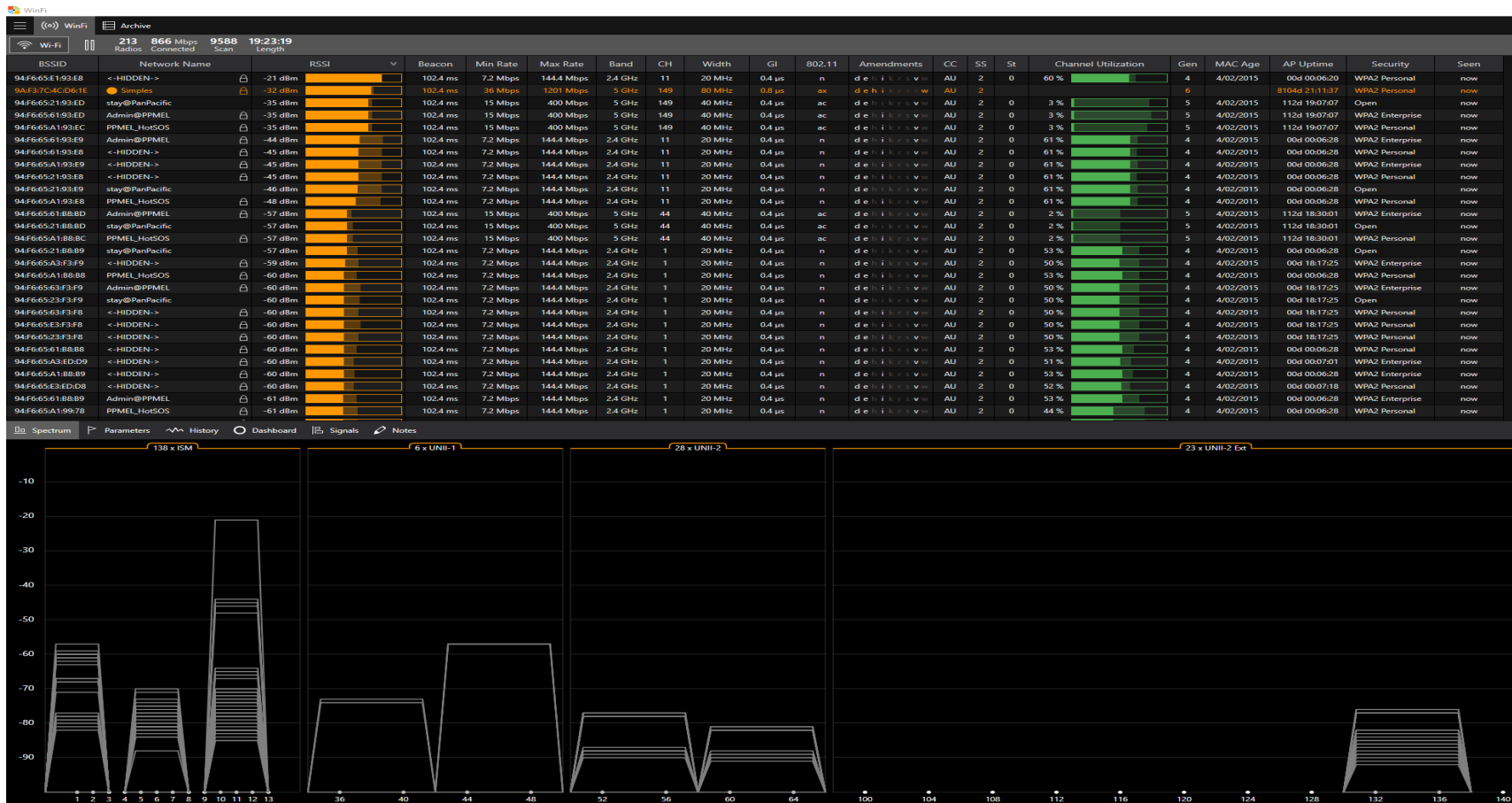
- OmniPeek/Wireshark
 - For packet captures of the WLAN, including beacons and other management traffic
 - Helpful for troubleshooting of problems at the source
- AirTool
 - Free app for Mac – simplifies packet capture process
 - <https://www.adriangranados.com/apps/airtool>



Ekahau Sidekick



<https://www.ekahau.com/products/sidekick/overview/>



<https://www.tethabyte.com/>

Metageek Tonic

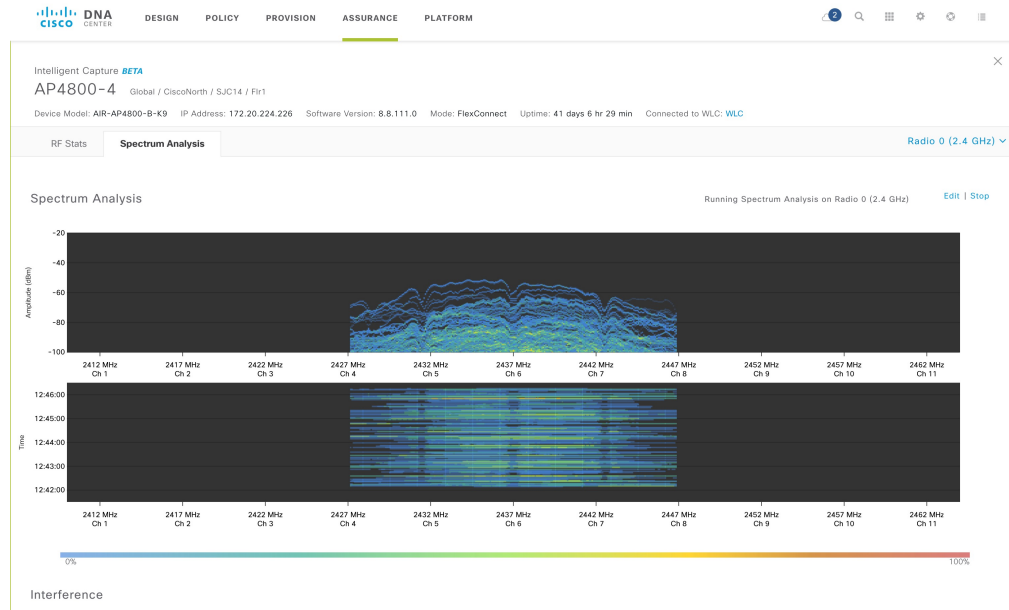


<https://www.metageek.com/tonic/>

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”



Grace.Smith

24 Hours



7/10 CLIENT DETAILS

Dec 5, 2022 3:20 PM - Dec 6, 2022 3:20 PM

Device: Apple-iPad OS: Apple-iPad MAC: 6C:19:C0:BD:87:C9 IPv4: 10.30.100.27 IPv6: fe80::7e46:85ff:fe20:1cd6 L3 Virtual Network: -- L2 Virtual Network: -- VLAN ID: 120 Status: Connected Capability: 11ac Last seen: Dec 6, 2022 3:20:40 PM Connected Network Device: AP4800 SSID: @CorpSSID [View All Details](#)

Issues Onboarding Path Trace Application Experience Device Info Connectivity RF iOS Analytics User Defined Network Event Viewer

Issues (7)

- P1** Application
Network Latency for Application 'webex-meeting' is Above the Threshold Value of 262ms.
Instance Count: 23 Dec 6, 2022 3:20 PM
- P1** Application
Network Latency for Application 'ms-office-365' is Above the Threshold Value of 262ms.
Instance Count: 35 Dec 6, 2022 3:20 PM
- P1** Onboarding
Wireless client took a long time to connect (SSID: @CorpSSID, AP: AP4800, Band: 2.4 GHz) - Excessive time due to Association failures
Instance Count: 57 Dec 6, 2022 3:20 PM
- P2** Connected
Wireless client experiencing poor RF conditions on SSID '@CorpSSID'
Instance Count: 48 Dec 6, 2022 3:20 PM
- P3** Application

Show Records: 10 < 1 >

[Resolved Issues](#) [Ignored Issues](#)

Detail Information Dec 6, 2022 3:20 PM

Device Info Connectivity RF **IOS Analytics** User Defined Network

Neighbor APs (3)

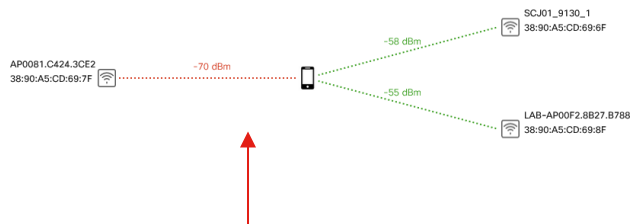
[Export](#)

Search Table



BSSID	AP Name	Channel	RSSI (dBm)	Location
38:90:A5:CD:69:8F	LAB-AP00F2.8B27.B788	165	-55	Global/North America/USA/California/San Jose/SJC01/Fir-SJC1-1
38:90:A5:CD:69:7F	AP0081.C424.3CE2	162	-70	Global/North America/USA/California/San Jose/SJC01/Fir-SJC1-1
38:90:A5:CD:69:8F	SCJ01_9130_1	161	-58	Global/North America/USA/California/San Jose/SJC01/Fir-SJC1-1

Show Records: 10 < 1 >



Client Disassociation Details (144)

[Export](#)

Search Table



Time	Disassociation Reason	Disassociated AP	Session Duration	AP Location
Dec 6, 2022 3:14 PM	User triggered disassociation	SCJ01_9130_1	--	Global/North America/USA/California/San Jose/SJC01/
Dec 6, 2022 3:09 PM	Device idle	SCJ01_9130_1	--	Global/North America/USA/California/San Jose/SJC01/
Dec 6, 2022 3:04 PM	Device idle	SCJ01_9130_1	--	Global/North America/USA/California/San Jose/SJC01/
Dec 6, 2022 2:59 PM	User triggered disassociation	SCJ01_9130_1	--	Global/North America/USA/California/San Jose/SJC01/

Show Records: 10 < 1 2 3 4 5 ... 15 >





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Thursday	9:30am – 4:00pm
Friday	10:30am – 1:30pm

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Thank you

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The background is a vibrant, abstract graphic featuring a spectrum of colors from red and orange on the left to blue and green on the right. The colors are arranged in a series of overlapping, wavy bands that create a sense of movement and depth. A bright, white, starburst-like light source is positioned on the right side, from which rays of light emanate across the entire scene, enhancing the dynamic and energetic feel of the design.

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