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Understanding RF in a Wireless First World

Mark Krischer, Principal Wireless Architect
BRKEWN-1065



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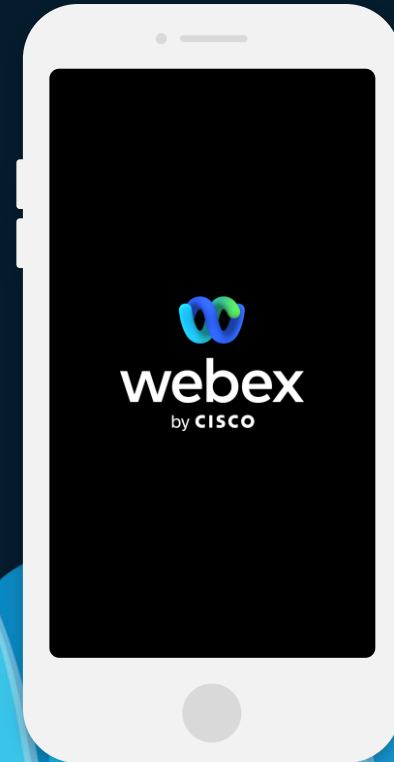
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Agenda

- RF Fundamentals
 - Three Dimensions of Wireless Performance
 - Wi-Fi 6 and Wi-Fi 7 Enhancements
- Implications for Wireless Network Design
 - Optimising for Client Roaming Behaviour
 - RF Planning and Site Surveys
 - Optimising for Low Latency Applications



Radio Frequency Fundamentals

- Frequency and Wavelength

- $f = c / \lambda$

- c = the speed of light in a vacuum

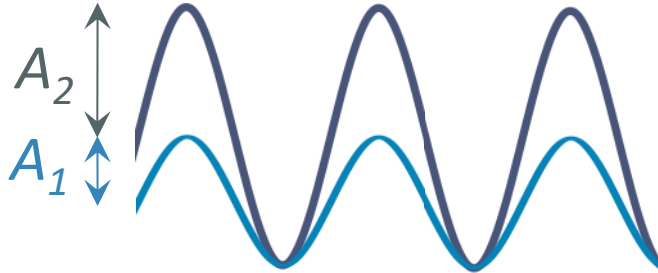
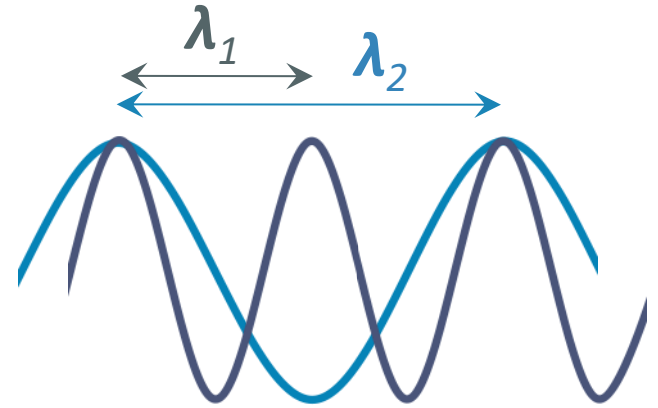
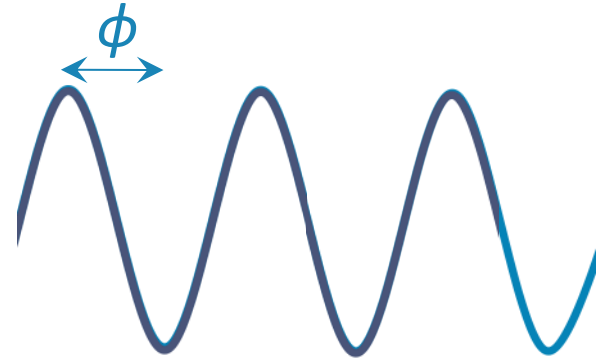
- $2.45\text{GHz} = 12.3\text{cm}$

- $5.0\text{GHz} = 6\text{cm}$

- $6.0\text{GHz} = 5\text{cm}$

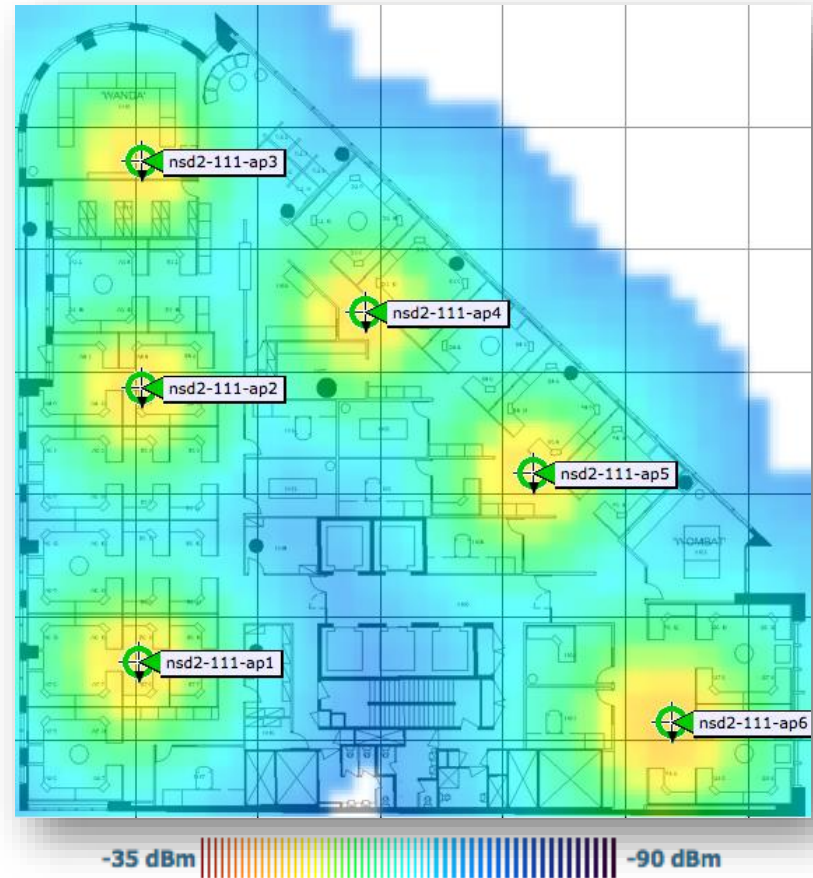
- Amplitude

- Phase



RF Mathematics

- dB is a logarithmic ratio of values (voltages, power, gains, losses)
 - We add gains
 - We subtract losses
- dBm is a power measurement relative to 1mW
- dBi is the forward gain of an antenna compared to isotropic antenna



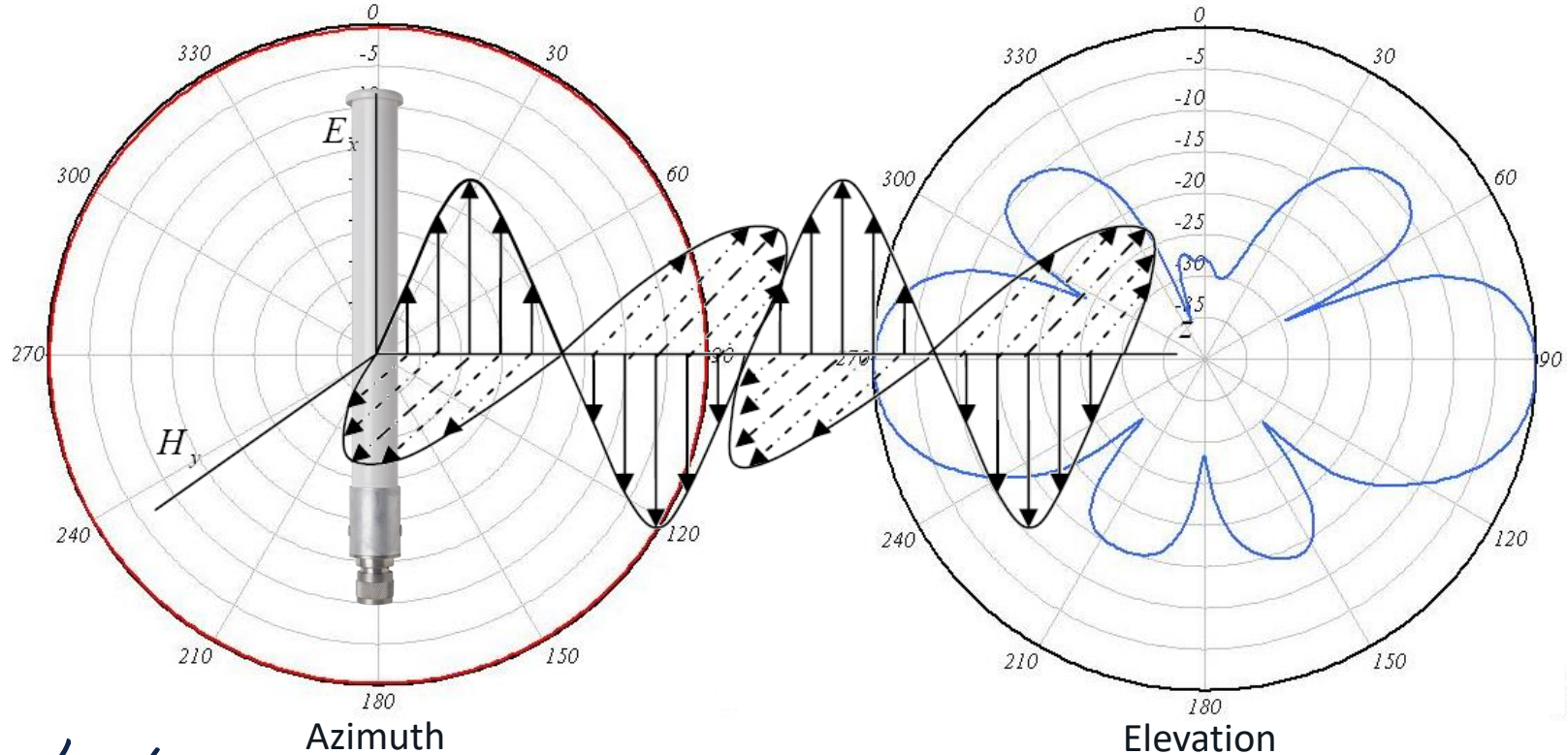
Interference and Signal to Noise Ratio

- Any RF signals other than what we want is interference
- SNR is a ratio
- The signal strength is a result of
 - Transmit power
 - Receive sensitivity
- Two Levers
 - Increase the signal
 - Or decrease the noise

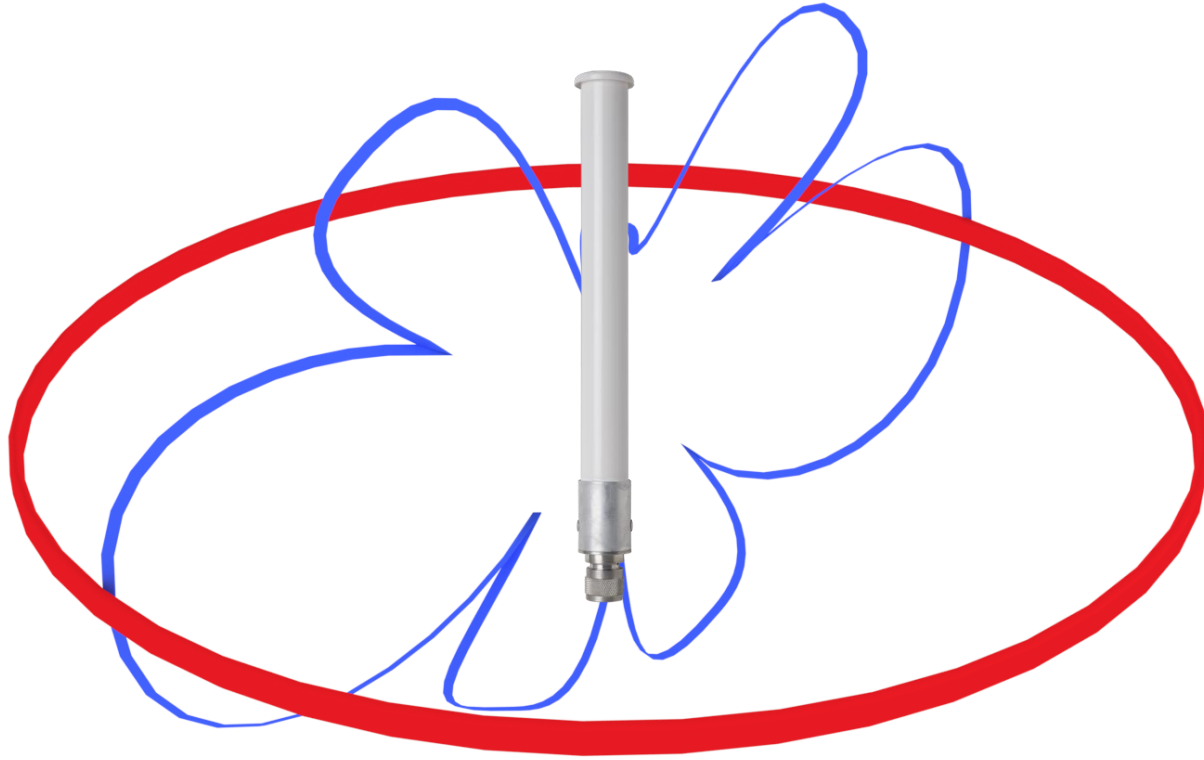


Antenna Design

Omnidirectional Antenna

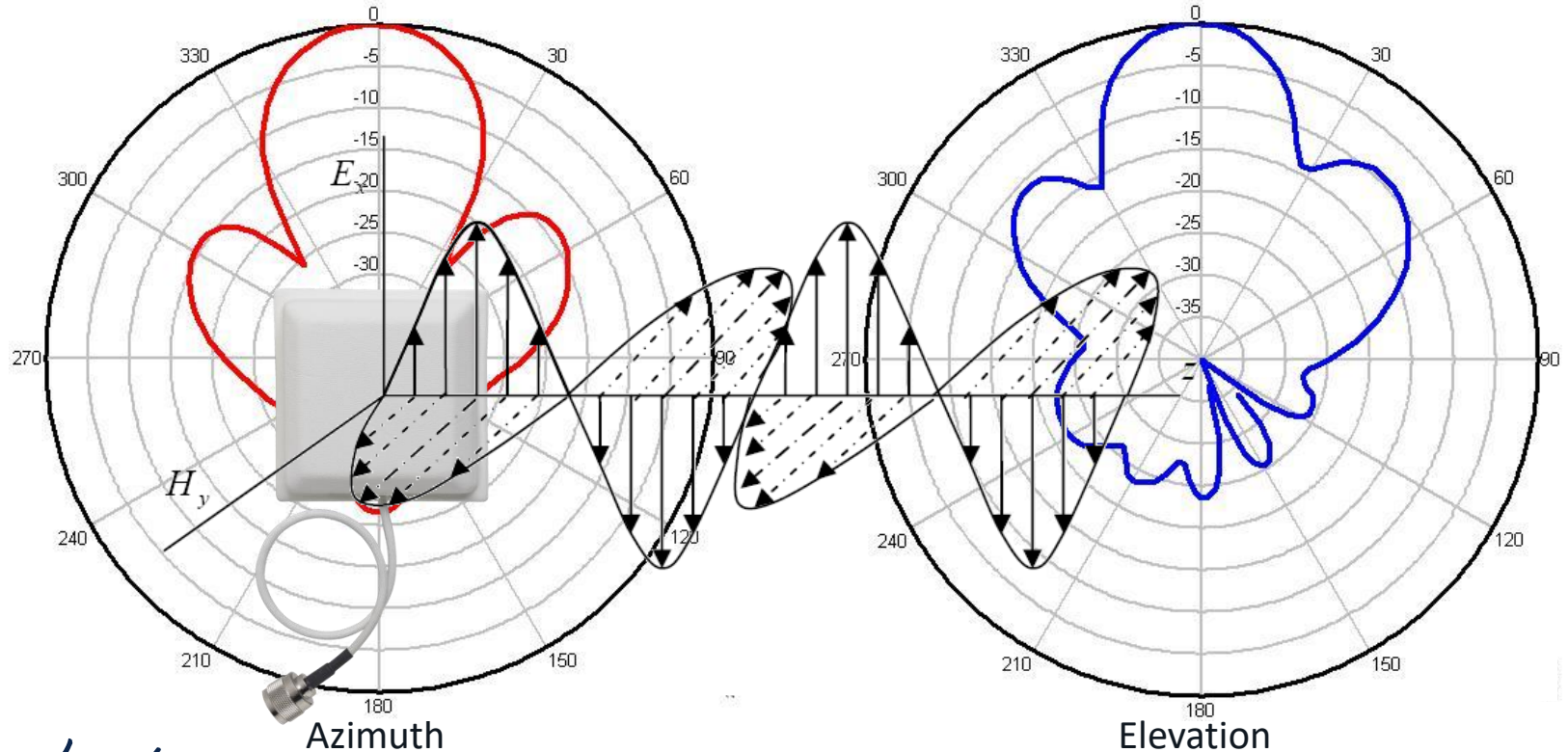


Azimuth and Elevation Planes

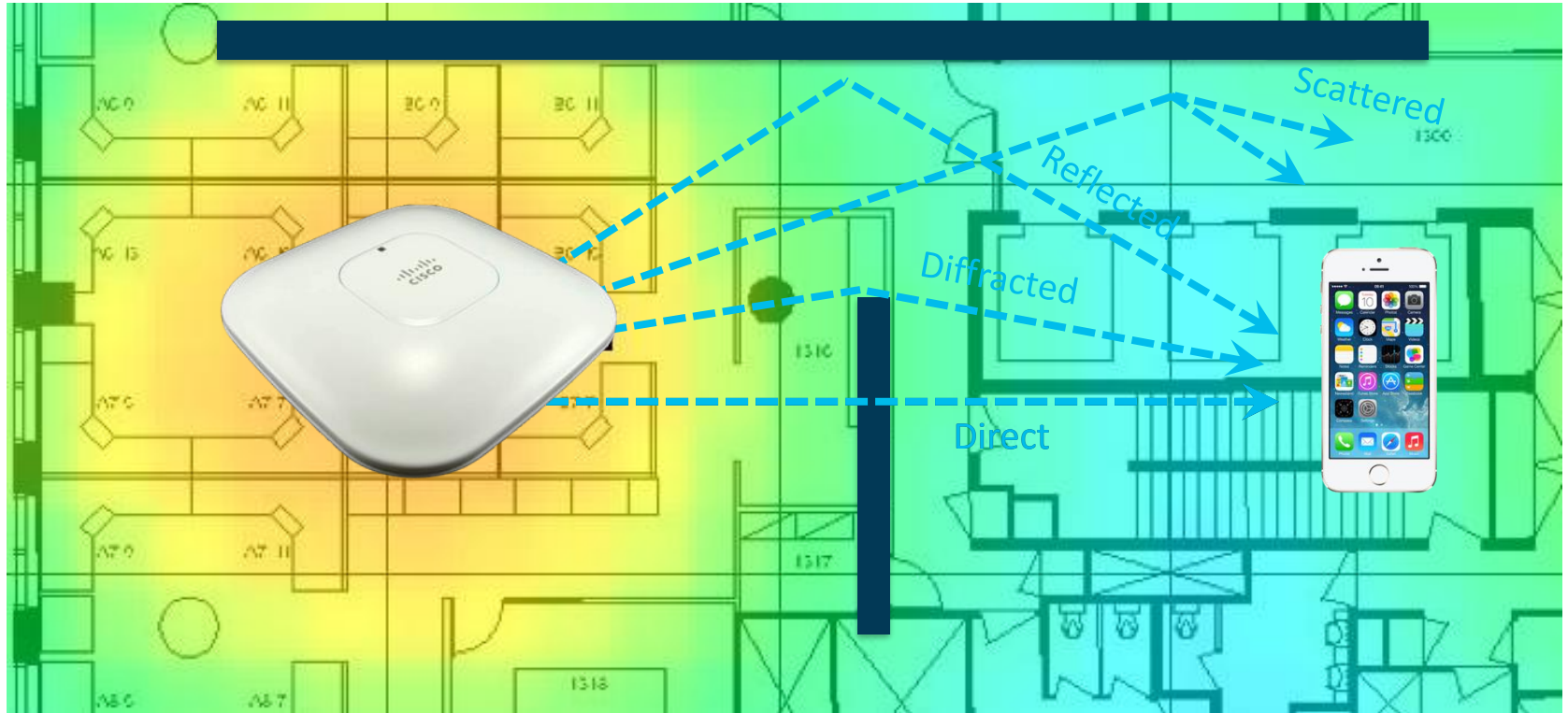


Antenna Design

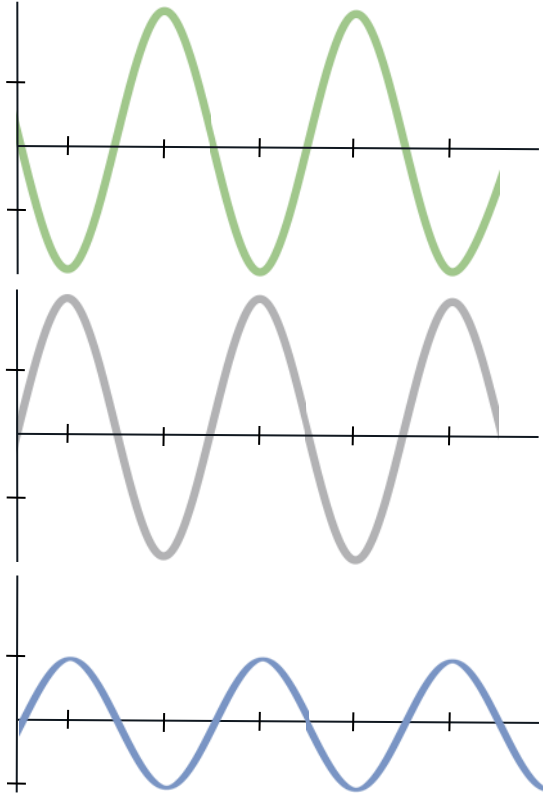
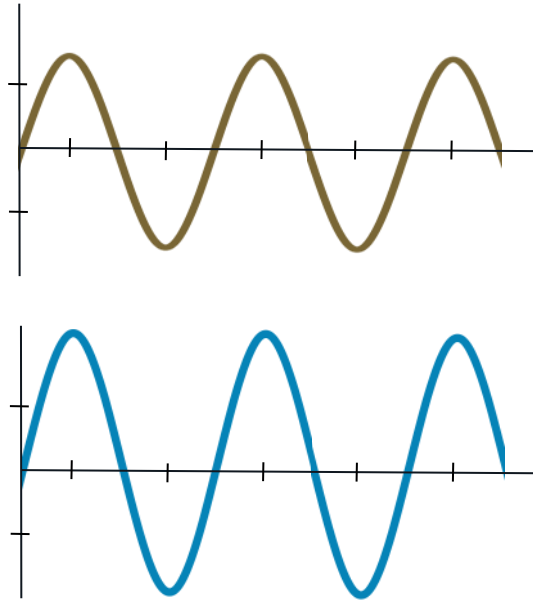
Directional Antennas



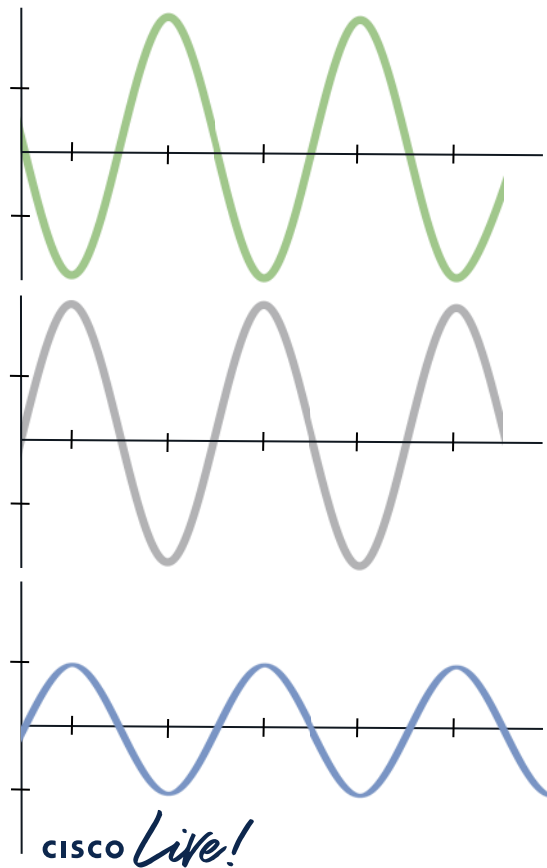
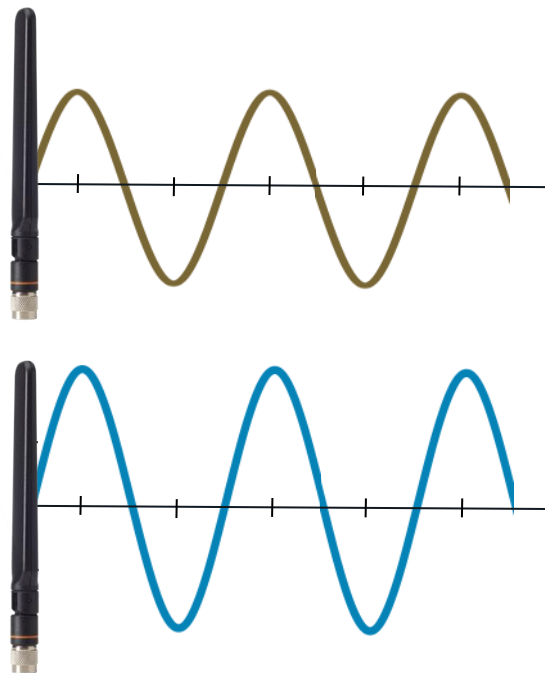
Multipath Propagation



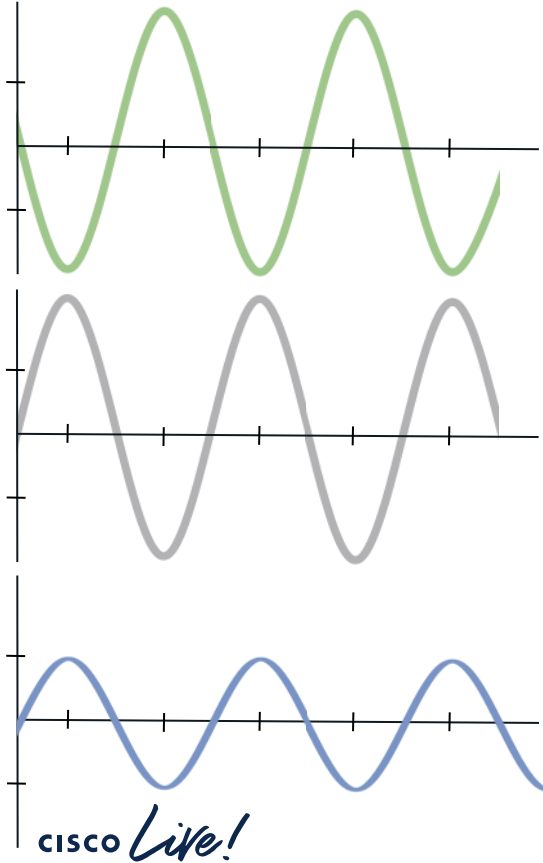
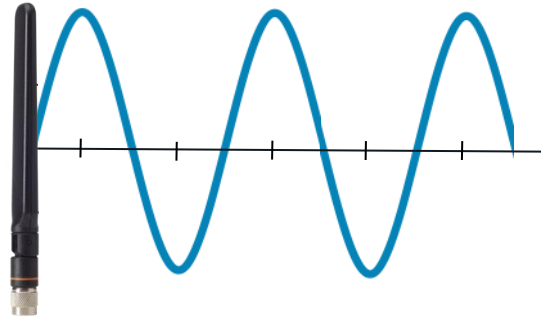
Destructive and Constructive Interference



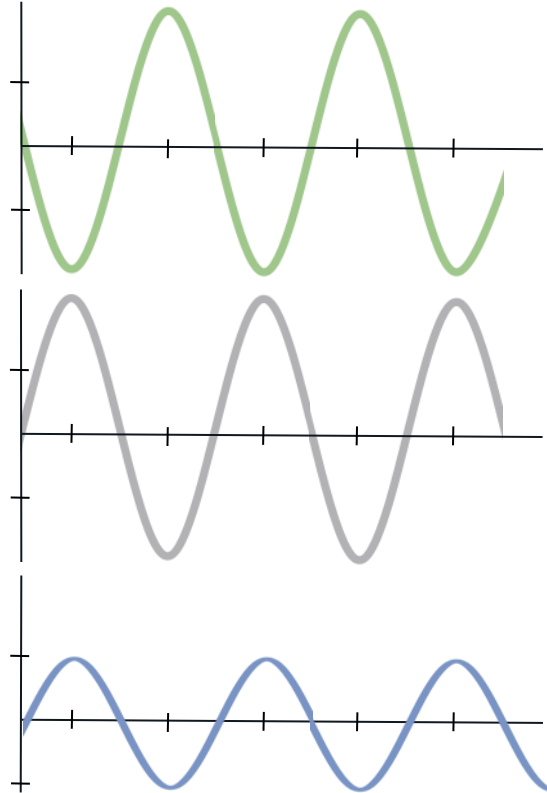
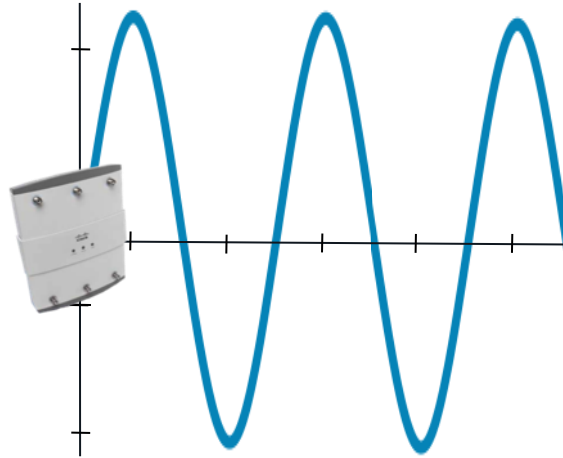
Antenna Diversity



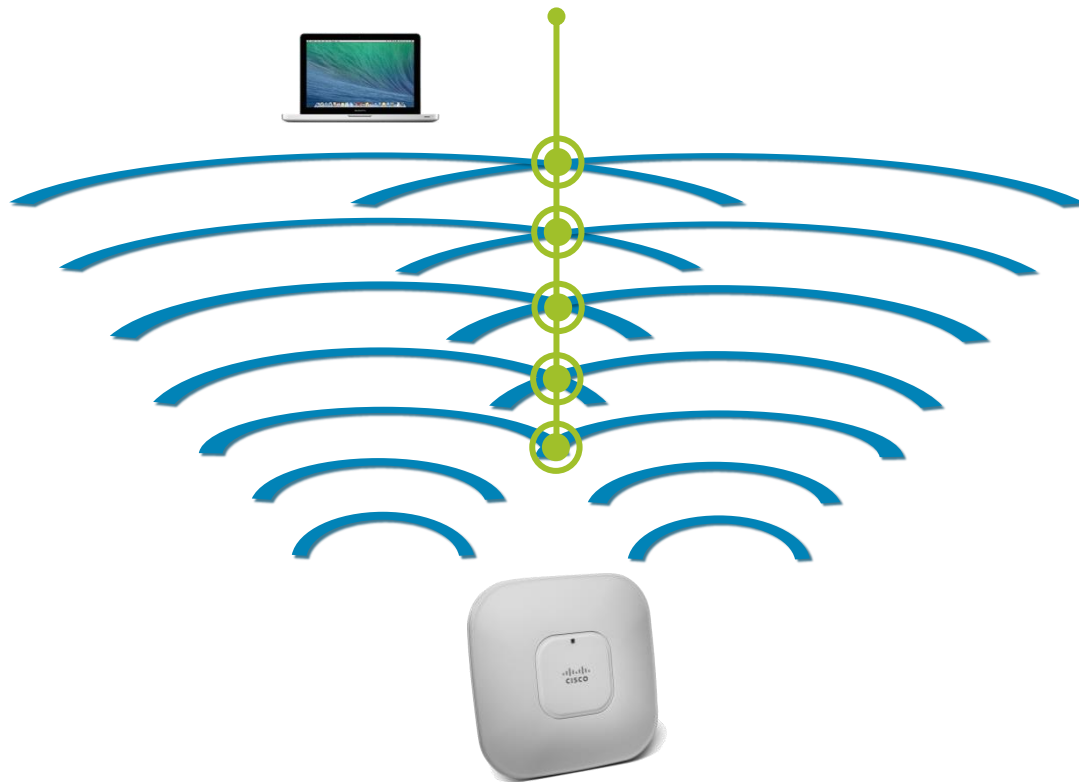
Antenna Diversity



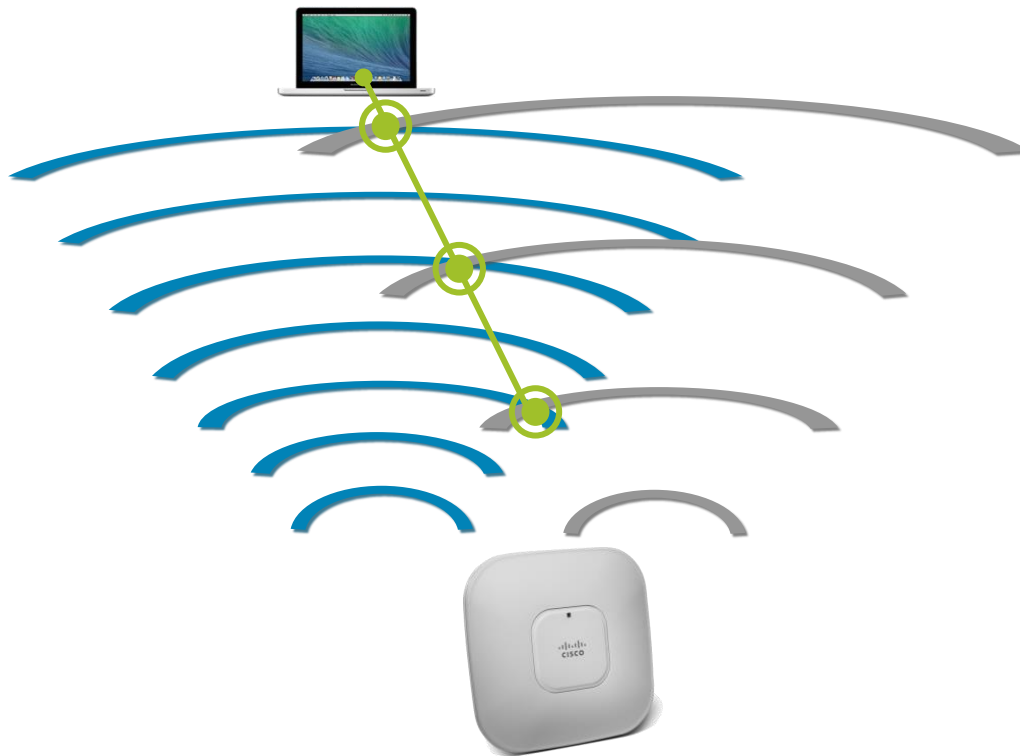
Diversity Combining



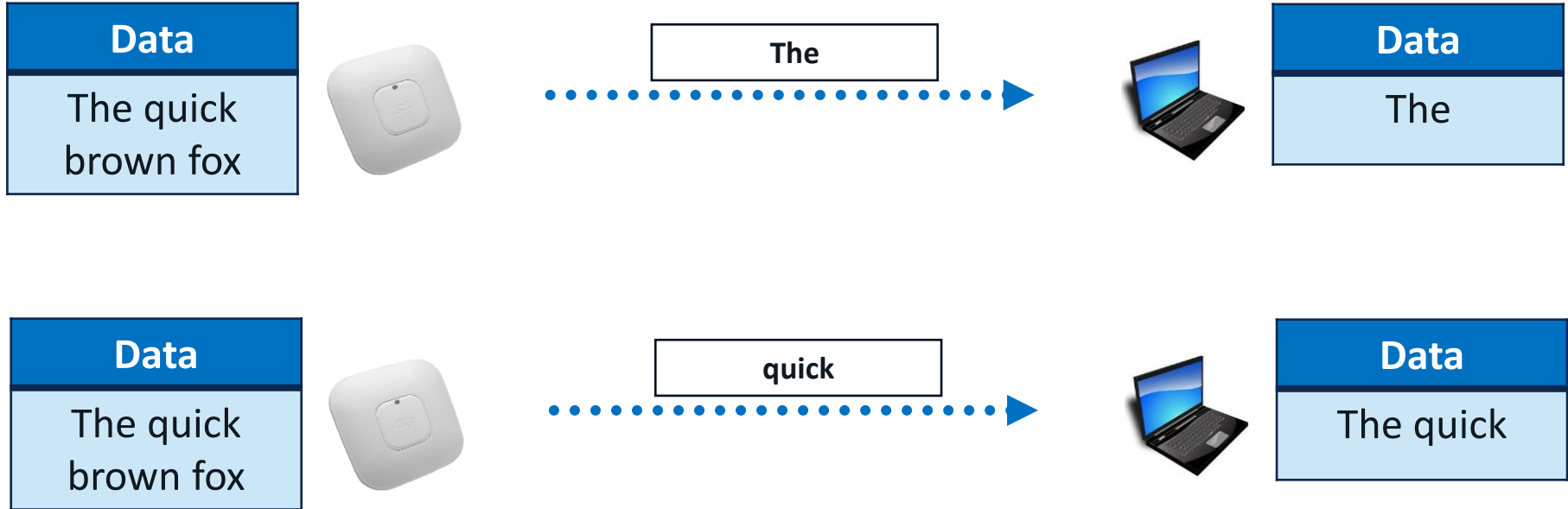
Transmit Beamforming



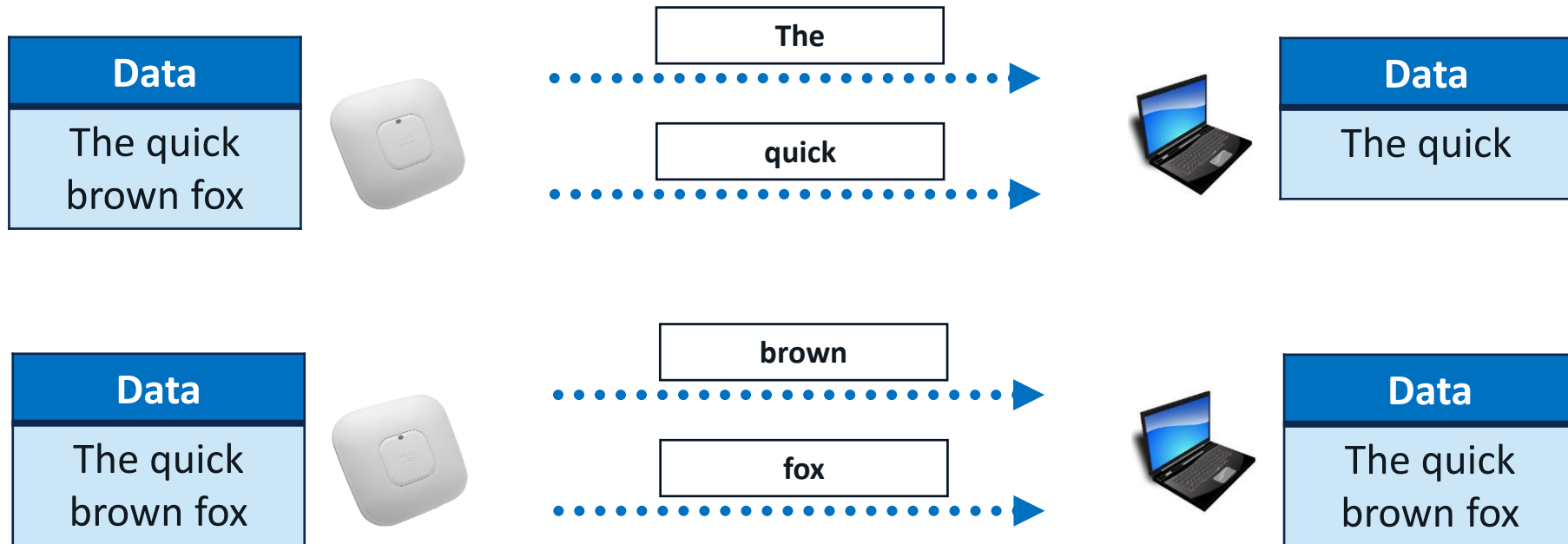
Transmit Beamforming



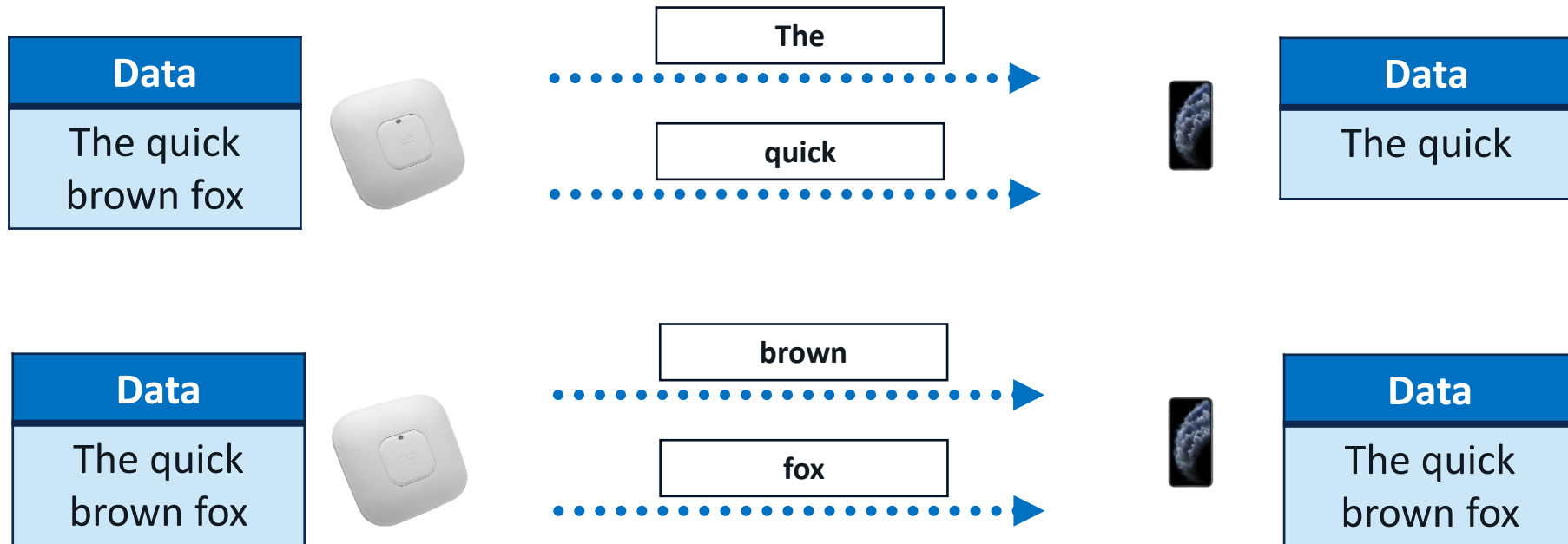
Spatial Multiplexing



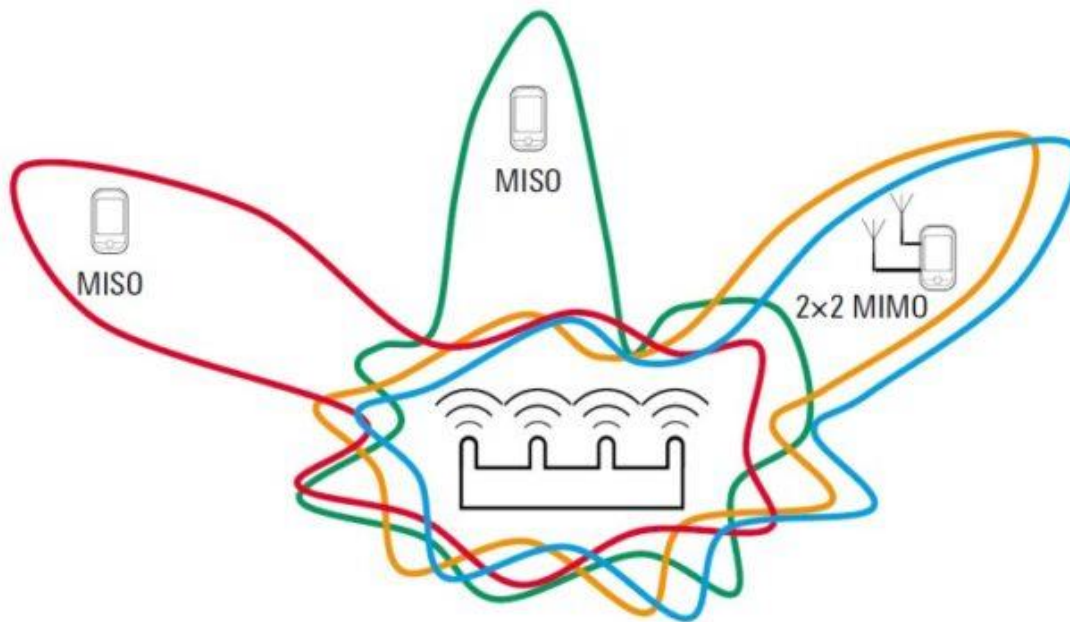
Spatial Multiplexing



Spatial Multiplexing

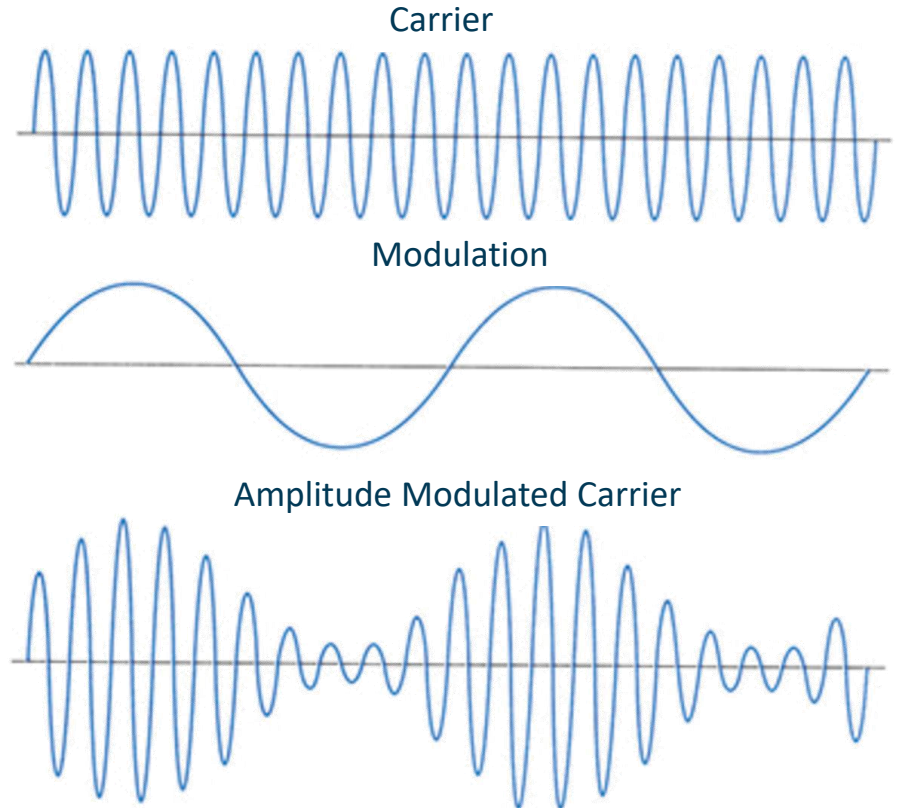


Multi-User MIMO



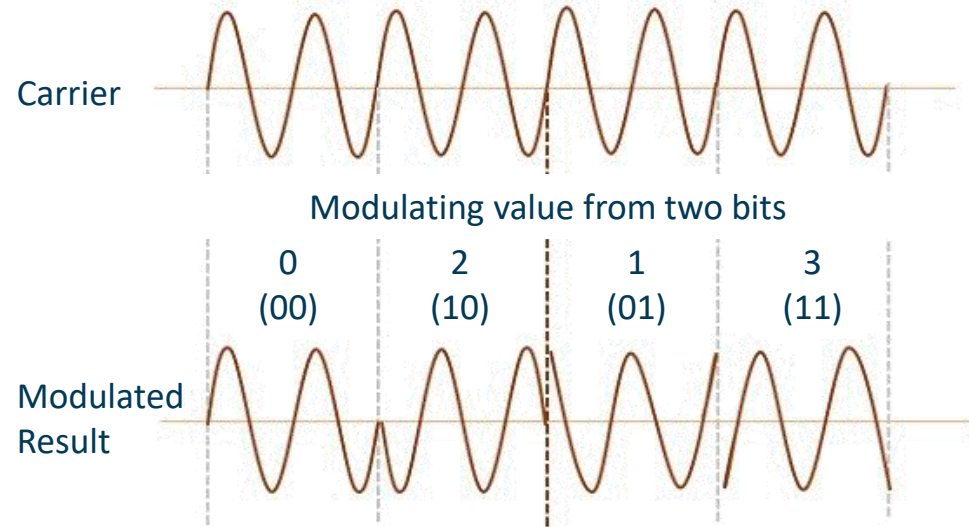
Digital Modulation

- Three basic methods
 1. Modulate the Amplitude
 2. Modulate the Frequency
 3. Modulate the Phase

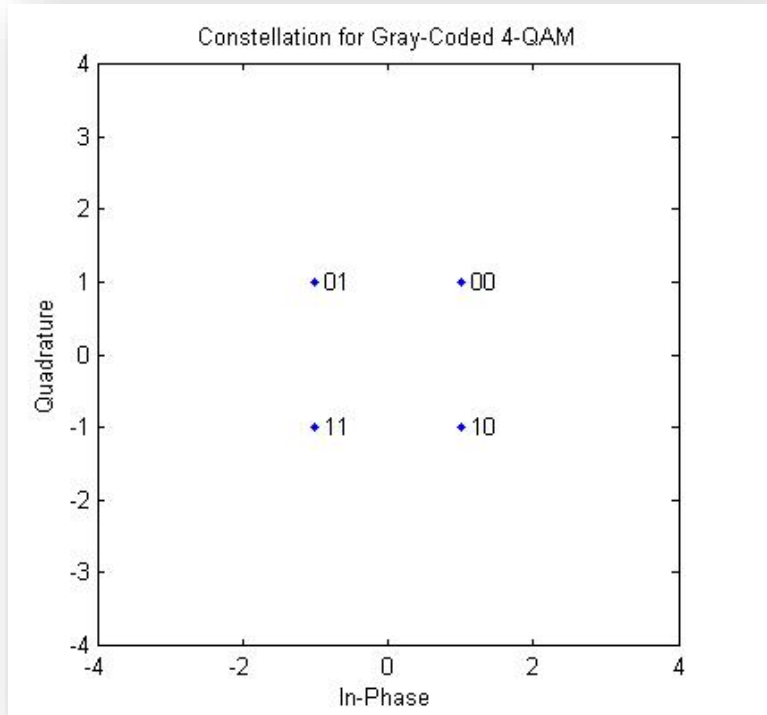


Digital Modulation

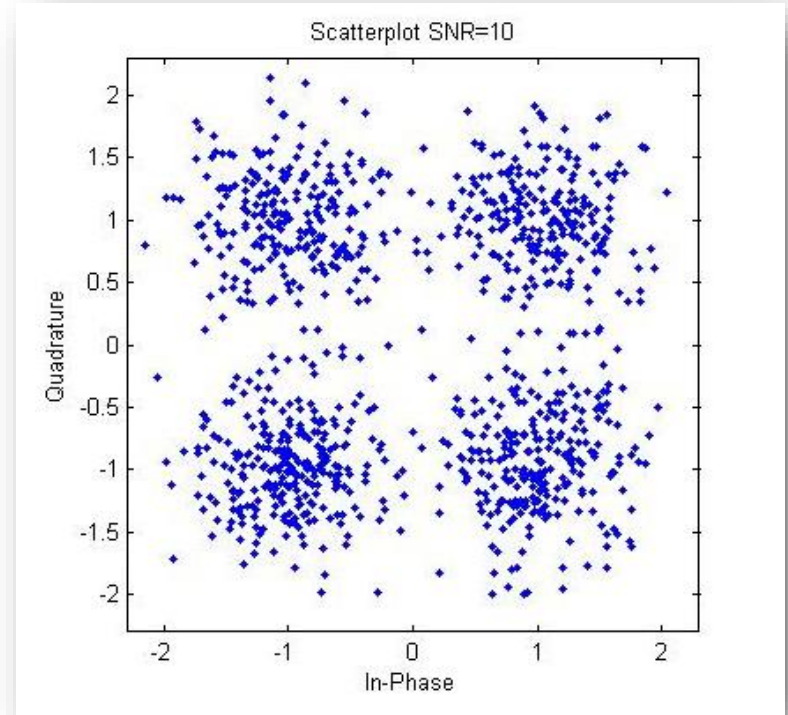
- Quadrature Phase Shift Keying (QPSK)
 - Each possible shift represents 2 bits
- Quadrature Amplitude Modulation (QAM)
 - Symbols are a combination of amplitude and phase
 - High Spectral Efficiency
 - Difficult to demodulate in the presence of noise



Modulation, SNR and Data Rates

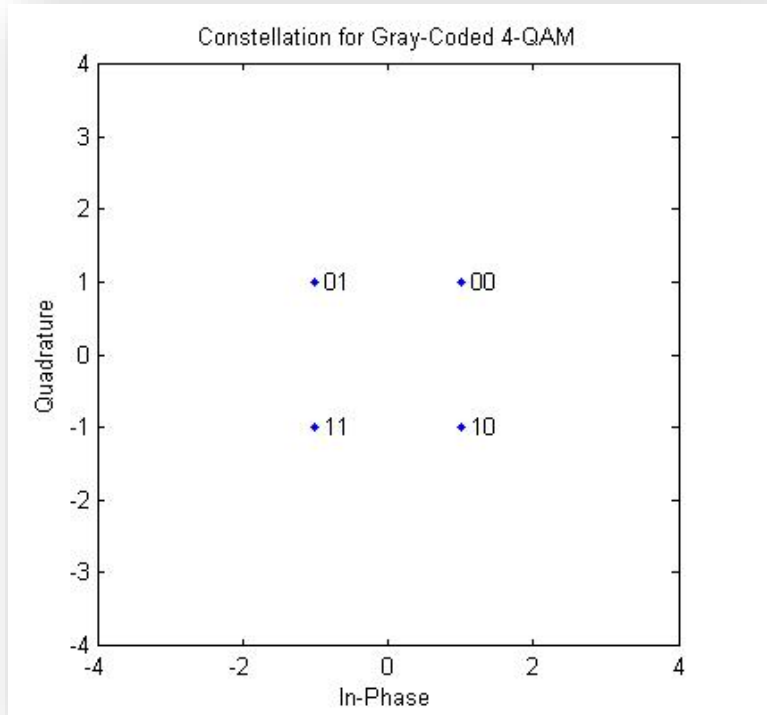


4-QAM

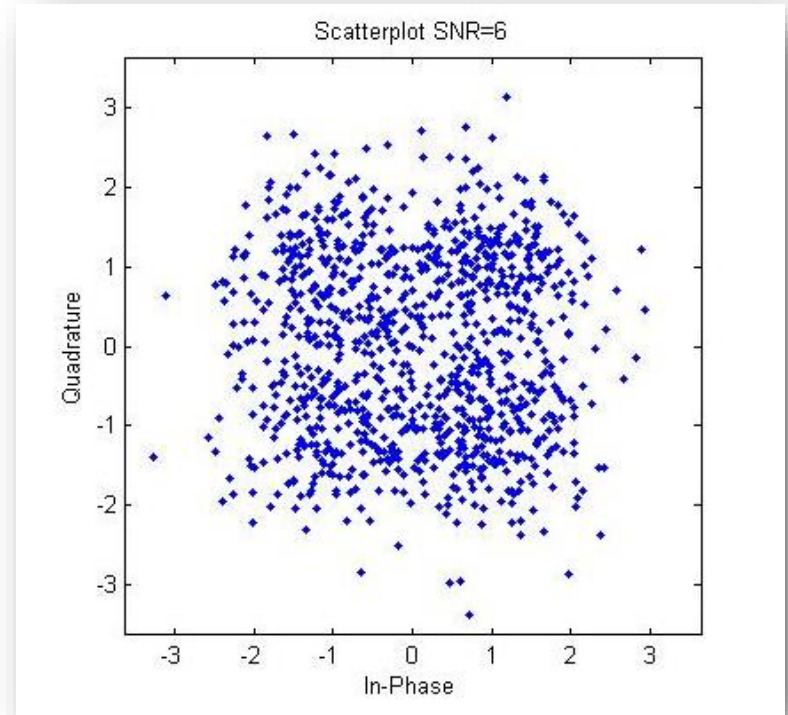


SNR=10

Modulation, SNR and Data Rates

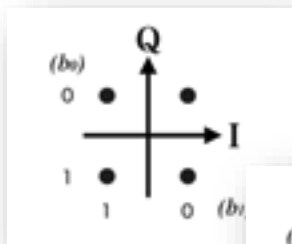


4-QAM

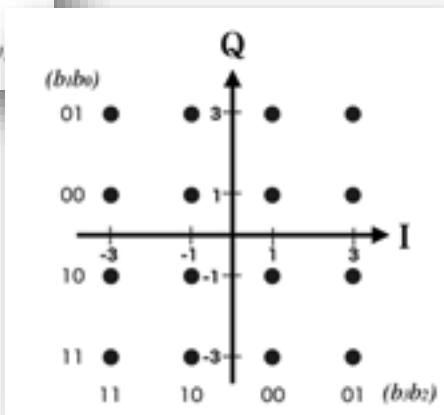


SNR=6

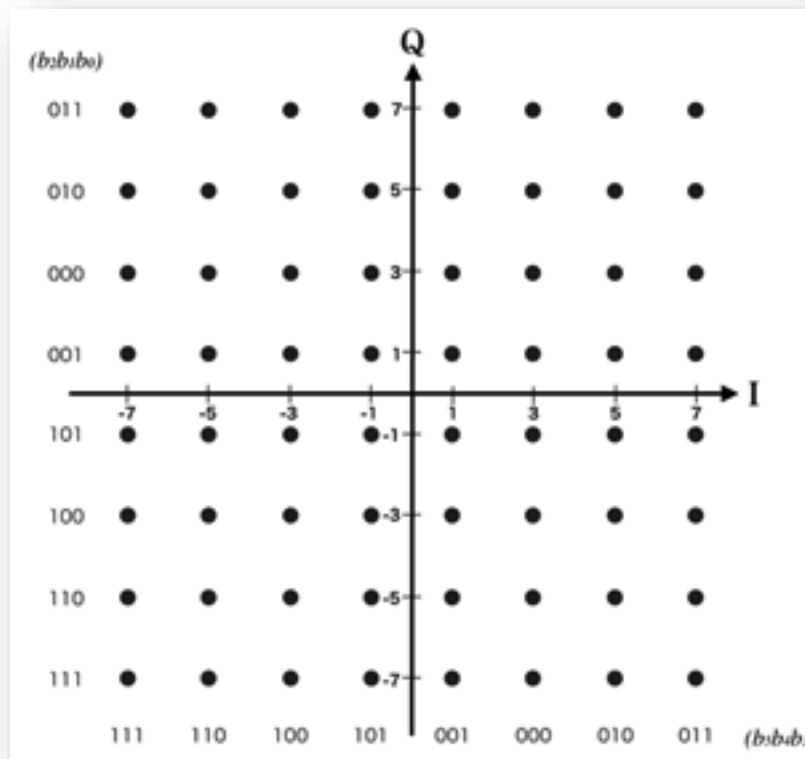
Rate vs Range and the Laws of Physics



4-QAM

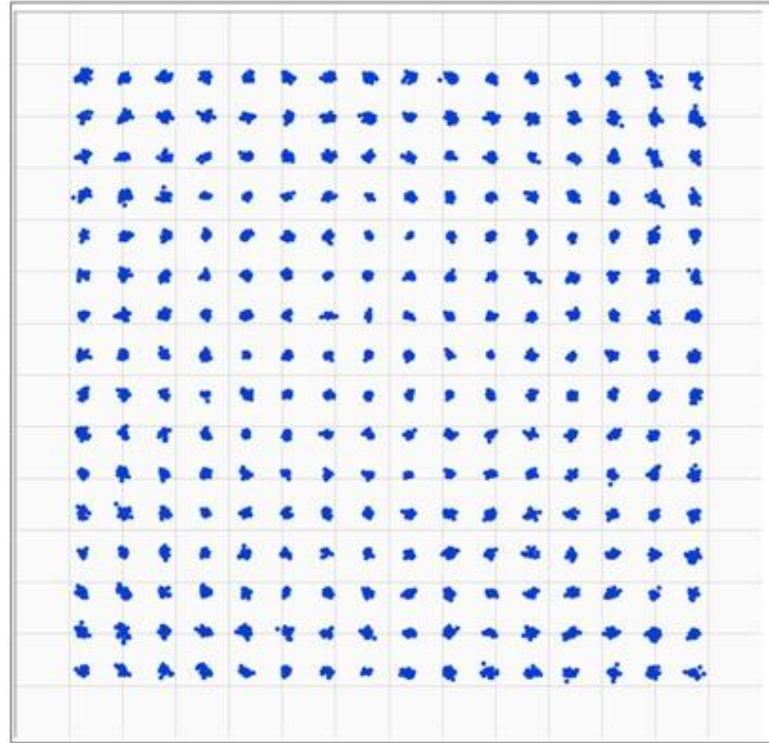


16-QAM



64-QAM

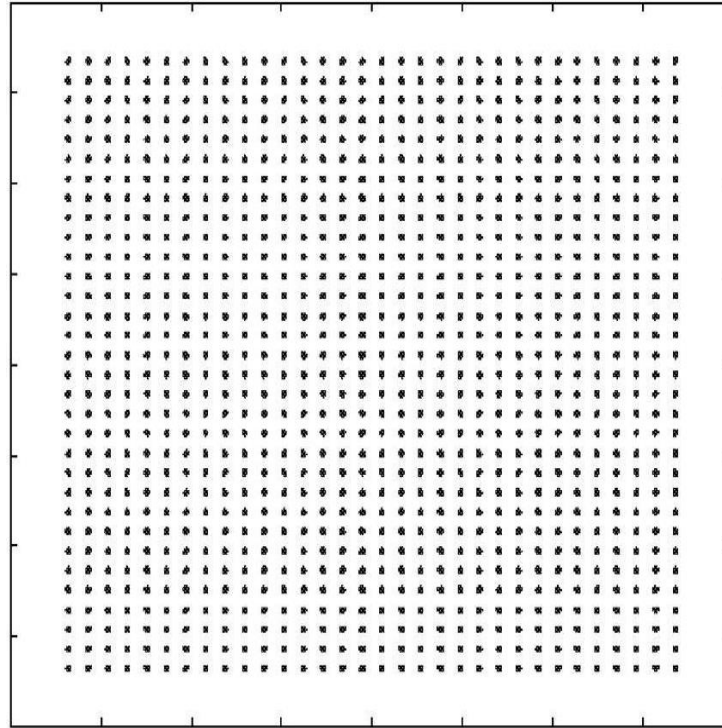
Rate vs Range and the Laws of Physics



256-QAM Constellation

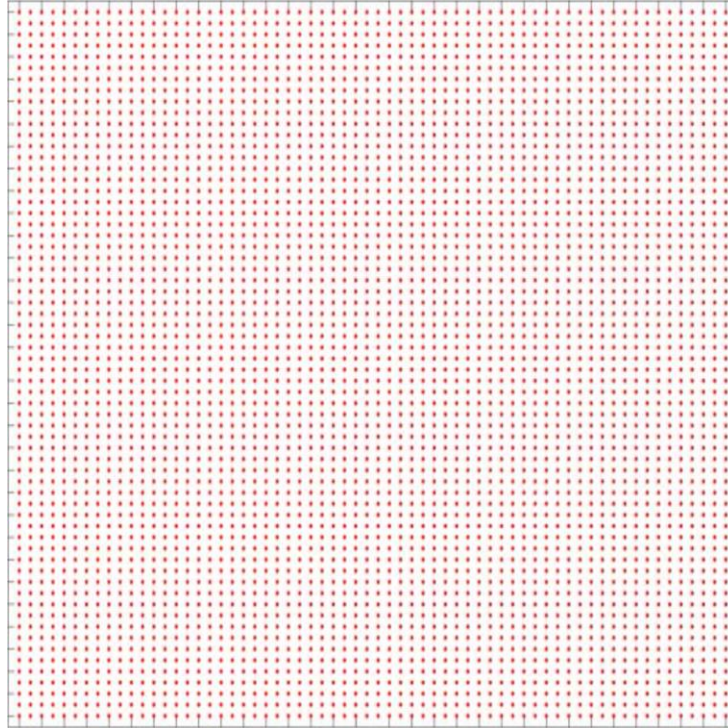


Rate vs Range and the Laws of Physics



1024-QAM Constellation

Rate vs Range and the Laws of Physics



4096-QAM (12 bits/symbol)

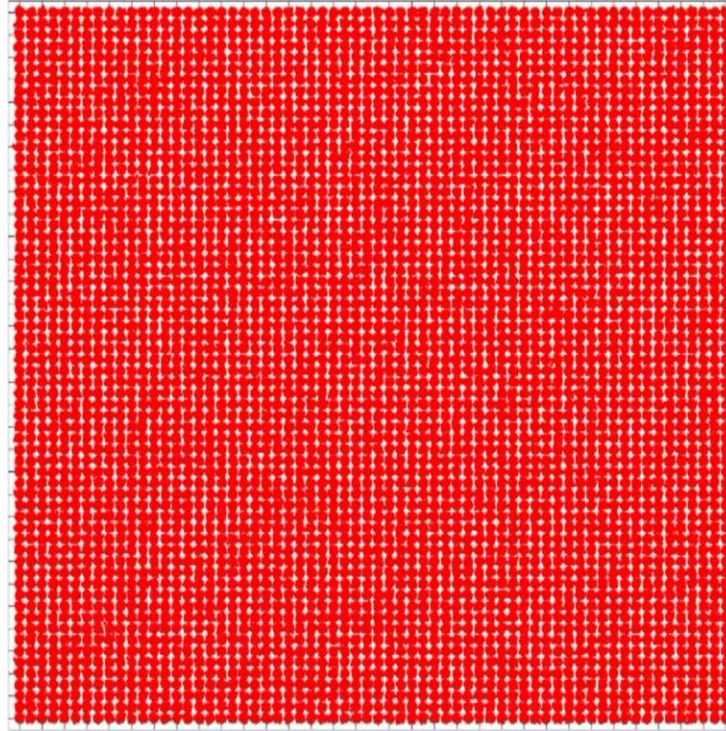
Relationship Between Modulation and SNR

Protocol and Channel Width	MCS Value Achieved by Clients at Various Signal to Noise Ratio (SNR) Levels													
	0	1	2	3	4	5	6	7	8	9	10	11	12	
IEEE 802.11b 20 MHz	None	None	None	None	MCS 0	MCS 0	MCS 0	MCS 1	MCS 1	MCS 1	MCS 1	MCS 2	MCS 2	MC
IEEE 802.11ag 20 MHz	None	None	MCS 0	MCS 0	MCS 1	MCS 2	MCS 2	MCS 2	MCS 2	MCS 3	MCS 3	MCS 4	MCS 4	MC
IEEE 802.11n 20 MHz	None	None	MCS 0	MCS 0	MCS 0	MCS 1	MCS 1	MCS 1	MCS 1	MCS 2	MCS 2	MCS 3	MCS 3	MC
IEEE 802.11n 40 MHz	None	None	None	None	None	MCS 0	MCS 0	MCS 0	MCS 1	MCS 1	MCS 1	MCS 1	MCS 2	MC
IEEE 802.11ac 20 MHz	None	None	MCS 0	MCS 0	MCS 0	MCS 1	MCS 1	MCS 1	MCS 1	MCS 2	MCS 2	MCS 3	MCS 3	MC
IEEE 802.11ac 40 MHz	None	None	None	None	None	MCS 0	MCS 0	MCS 0	MCS 1	MCS 1	MCS 1	MCS 1	MCS 2	MC
IEEE 802.11ac 80 MHz	None	None	None	None	None	None	None	None	None	MCS 0	MCS 0	MCS 0	MCS 1	MC
IEEE 802.11ac 160 MHz	None	None	None	None	None	None	None	None	None	None	None	None	MCS 0	MC

13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
MCS 2	MCS 2	MCS 2	MCS 3	MCS 3	MCS 3	MCS 3	MCS 3	MCS 3	MCS 3	MCS 3	MCS 3	MCS 3	MCS 3	MCS 3	MCS 3	MCS 3	MCS 3	MCS 3
MCS 4	MCS 4	MCS 5	MCS 5	MCS 5	MCS 6	MCS 6	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7
MCS 3	MCS 3	MCS 4	MCS 4	MCS 4	MCS 5	MCS 5	MCS 6	MCS 6	MCS 6	MCS 6	MCS 6	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7
MCS 2	MCS 3	MCS 3	MCS 3	MCS 3	MCS 4	MCS 4	MCS 4	MCS 5	MCS 5	MCS 6	MCS 6	MCS 6	MCS 6	MCS 6	MCS 7	MCS 7	MCS 7	MCS 7
MCS 3	MCS 3	MCS 4	MCS 4	MCS 4	MCS 5	MCS 5	MCS 6	MCS 6	MCS 6	MCS 6	MCS 6	MCS 7	MCS 7	MCS 7	MCS 7	MCS 8	MCS 8	MCS 9
MCS 2	MCS 3	MCS 3	MCS 3	MCS 3	MCS 4	MCS 4	MCS 4	MCS 5	MCS 5	MCS 6	MCS 6	MCS 6	MCS 6	MCS 6	MCS 7	MCS 7	MCS 7	MCS 7
MCS 1	MCS 1	MCS 2	MCS 2	MCS 3	MCS 3	MCS 3	MCS 3	MCS 4	MCS 4	MCS 4	MCS 5	MCS 5	MCS 6	MCS 6	MCS 6	MCS 6	MCS 6	MCS 7
MCS 0	MCS 1	MCS 1	MCS 1	MCS 1	MCS 2	MCS 2	MCS 3	MCS 3	MCS 3	MCS 3	MCS 4	MCS 4	MCS 4	MCS 5	MCS 5	MCS 6	MCS 6	MCS 6

32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
MCS 3	MCS 3	MCS 3	MCS 3	MCS 3	MCS 3	MCS 3	MCS 3	MCS 3	MCS 3	MCS 3	MCS 3	MCS 3	MCS 3	MCS 3	MCS 3	MCS 3	MCS 3	MCS 3
MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7
MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7
MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7	MCS 7
MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9
MCS 8	MCS 8	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9
MCS 7	MCS 7	MCS 7	MCS 8	MCS 8	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9
MCS 6	MCS 6	MCS 7	MCS 7	MCS 7	MCS 7	MCS 8	MCS 8	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9	MCS 9

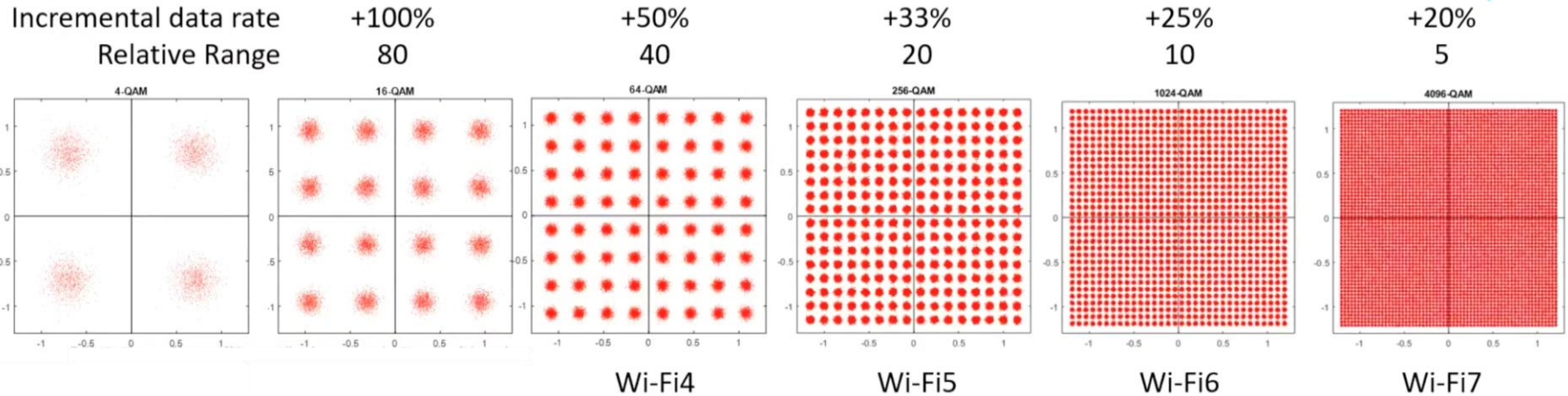
Increased Sensitivity to Noise



SNR=43

Increasing Throughput and Decreasing Range

Each increment in constellation size reduces range by approx. 50%



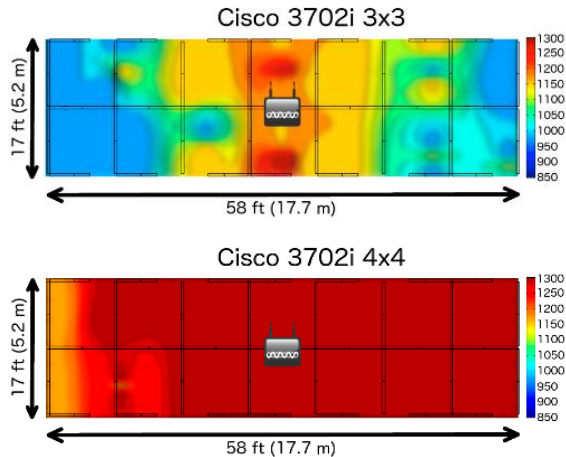
Implications of Poor Cell Design

17	0.039879000	172.31.255.101	172.31.255.103	UDP	1420	34	-35 55 dB	54.0	Source port: 50857	Destination port: search-agent
18	0.040266000	172.31.255.101	172.31.255.103	UDP	1420	34	-35 55 dB	54.0	Source port: 50857	Destination port: search-agent
19	0.040648000	172.31.255.101	172.31.255.103	UDP	1420	34	-34 56 dB	54.0	Source port: 50857	Destination port: search-agent
20	0.041938000	172.31.255.101	172.31.255.103	UDP	1420	34	-34 56 dB	54.0	Source port: 50857	Destination port: search-agent
21	0.042217000	172.31.255.101	172.31.255.103	UDP	1420	34	-29 61 dB	36.0	Source port: 50857	Destination port: search-agent
22	0.043444000	172.31.255.101	172.31.255.103	UDP	1420	34	-29 61 dB	12.0	Source port: 50857	Destination port: search-agent
23	0.043445000		Cisco_0a:04:2e (RA)	802.11	40		-45 45 dB	12.0	Acknowledgement, Flags=.....C	
24	0.043850000	172.31.255.101	172.31.255.103	UDP	1420	34	-34 56 dB	54.0	Source port: 50857	Destination port: search-agent
25	0.044245000	172.31.255.101	172.31.255.103	UDP	1420	34	-34 56 dB	54.0	Source port: 50857	Destination port: search-agent
26	0.044641000	172.31.255.101	172.31.255.103	UDP	1420	34	-34 56 dB	54.0	Source port: 50857	Destination port: search-agent
27	0.045023000	172.31.255.101	172.31.255.103	UDP	1420	34	-35 55 dB	54.0	Source port: 50857	Destination port: search-agent
28	0.045750000	172.31.255.101	172.31.255.103	UDP	1420	34	-29 61 dB	36.0	Source port: 50857	Destination port: search-agent
29	0.046223000	172.31.255.101	172.31.255.103	UDP	1420	34	-29 61 dB	36.0	Source port: 50857	Destination port: search-agent
30	0.047450000	172.31.255.101	172.31.255.103	UDP	1420	34	-29 61 dB	12.0	Source port: 50857	Destination port: search-agent
31	0.047450000		Cisco_0a:04:2e (RA)	802.11	40		-47 43 dB	12.0	Acknowledgement, Flags=.....C	

- Based on received AP signal strength, client transmits at 54 Mbps
- Client signal strength at the AP is too low, and AP does not send the acknowledgement
- Client continues to decrease the data rate and retransmit
- AP finally acknowledges the packet has been received at 12Mbps

Transmit and Receive Diversity

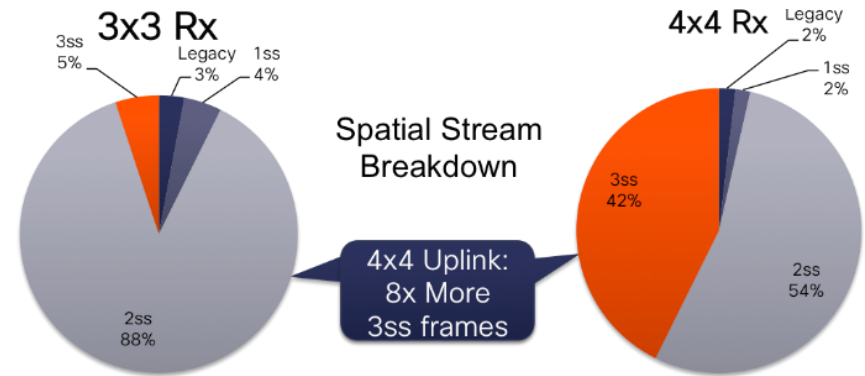
- Transmit Diversity improves signal strength at the client



- Results in a 15% improvement by making MCS m8/m9 usable

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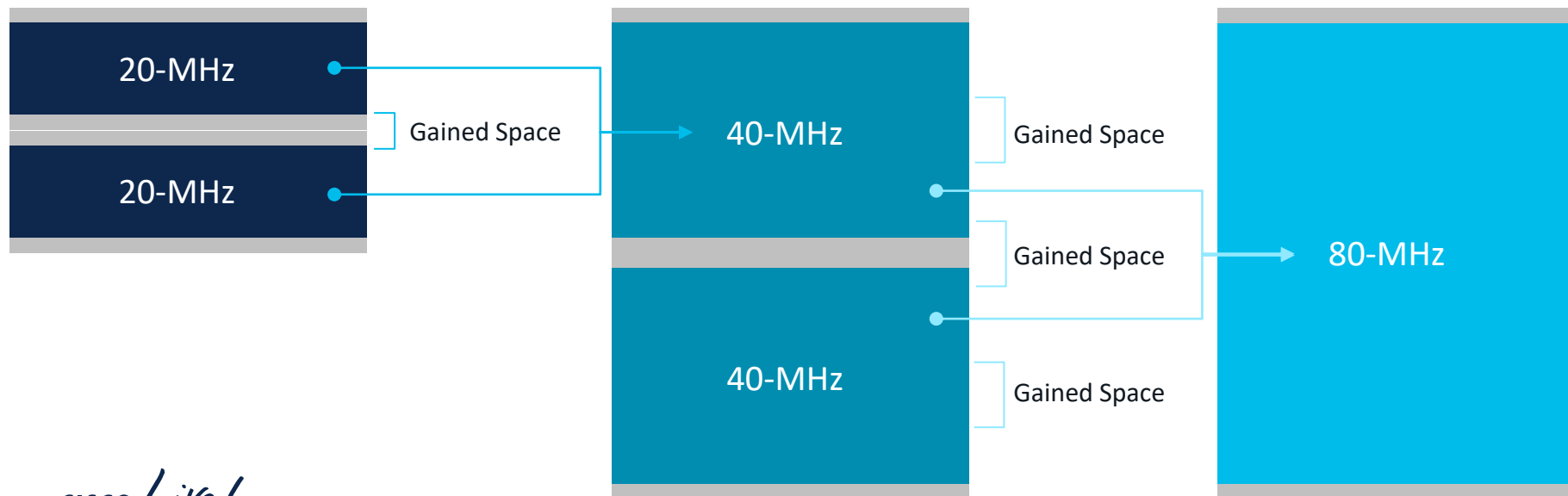
- Receive Diversity improves ability to receive 3SS frames from the client



- N+1 is necessary to deliver spatial multiplexing benefits



Channel Aggregation



Wi-Fi Spectrum

2.4 GHz Channels

80 MHz

ISM Band $2407 + 5 \times \text{Ch. Number}$ Wavelength 12.5cm - 4.9" to 12.0cm - 4.7"

Qty	Channel	1	6	11
3	Center Freq	2.412	2.437	2.462

5 GHz Channels

500 MHz

Frequency $5000 + 5 \times \text{Ch. Number}$ Wavelength 5.8cm - 2.3" to 5.1cm - 2.0"

Radio Band Center Freq		DFS Channels								DFS Channels																	
		U-NII-1				U-NII-2a				U-NII-2c (Extended)												U-NII-3					
		5.180	5.200	5.220	5.240	5.260	5.280	5.300	5.320	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	
Qty										TDWR																	Qty
25	20 MHz	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	25
11	40 MHz	38		46		54		62		102		110		118		126		134		142		151		159		11	
5	80 MHz	42				58				106				122				138				155				5	
2	160 MHz	50								114												165 was ISM, now U-NII-3				2	

Wi-Fi Spectrum

2.4 GHz Channels

80 MHz

ISM Band	2407 + 5 X Ch. Number	Wavelength	12.5cm - 4.9" to 12.0cm - 4.7"
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Channel	1	6	11
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Center Freq	.412	.437	.462
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5 GHz Channels

500 MHz

Frequency	5000 + 5 X Ch. Number	Wavelength 5.8cm - 2.3" to 5.1cm - 2.0"
------------------	-----------------------	--

Radio Band Center Freq	DFS Channels										DFS Channels										Qty							
	U-NII-1					U-NII-2a					TDWR					U-NII-3												
	5160	5200	5250	5280	5300	5300	5320	5350	5370	5390	5400	5420	5450	5480	5500	5500	5520	5550	5580	5600	5600	5620	5650	5680	5700	5720		
20 MHz	36	40	44	48	52	56	60	64	68	72	100	104	108	112	116	120	124	128	132	136	140	144	148	149	153	157	161	25
40 MHz	38		46		54	62					102		110		118	126			134	142			150		158		11	
80 MHz		42				58						106				122				138				155			5	
160 MHz			50											114														

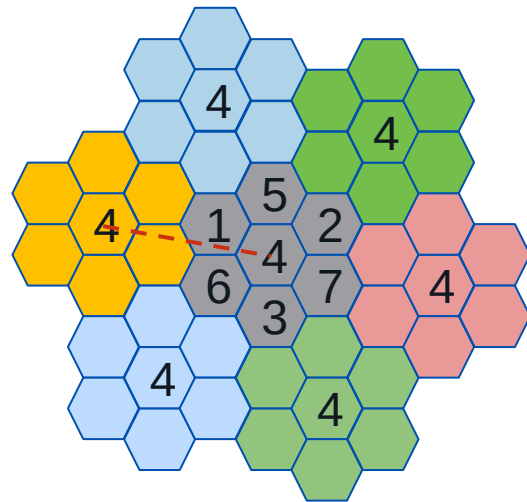
145 was GSM, now U-NII-3

6 GHz Channels

1,200 MHz

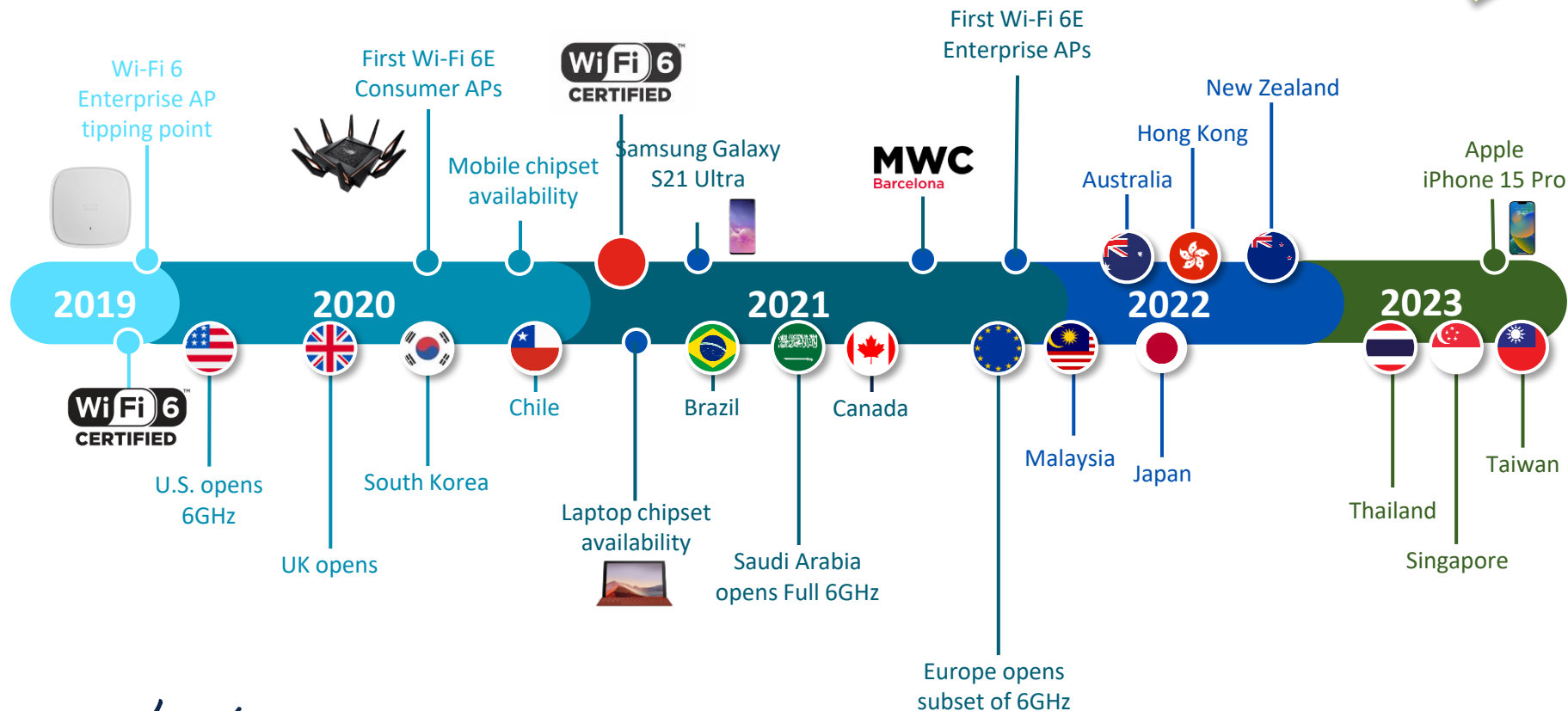
FCC - USA 5950 + 5 X Ch. Number Wavelength 5.1cm - 2.0" to 4.2cm - 1.6"

Low Power Indoor	5dBm/MHz - Net EIRP 18dBm																																								3dBm/MHz - Net EIRP 16dBm																																								0dBm/MHz - Net EIRP 13dBm																																																																															
	UNII-5																																								UNII-6																																								UNII-7																																								UNII-8																																							
	Center Freq																																								Center Freq																																								Center Freq																																								Center Freq																																							
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Standard Power AP	36dBm with Automated Frequency Coordination (AFC)																																								36dBm with Automated Frequency Coordination (AFC)																																								36dBm with Automated Frequency Coordination (AFC)																																								36dBm with Automated Frequency Coordination (AFC)																																							
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FYI

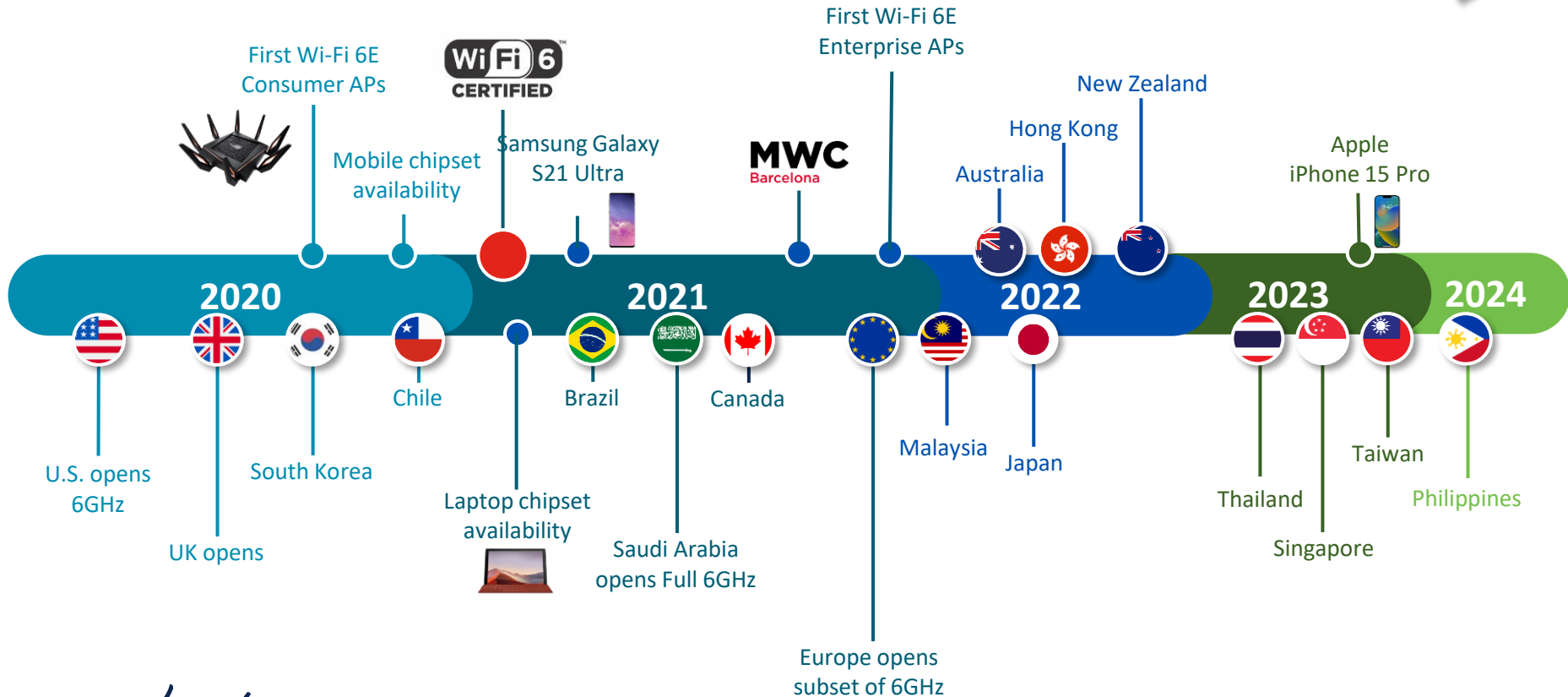
The Road to 6GHz



The Road to 6GHz



FYI



6GHz Device Classes



Low Power Indoor

- Indoor Only
- Integrated Antenna Required
- Can use up to 1200 MHz
- Wired Power



Client Devices

- Indoor or Outdoor
- Only Indoor under control of LPI AP
- 6 dBm lower power than AP



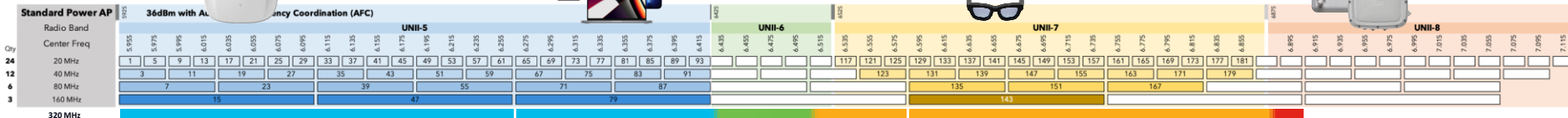
Very Low Power

- Mobile Indoor or Outdoor
- Limited Range
- UNII-5 and UNII-7 Only
- Does not require AFC



Standard Power

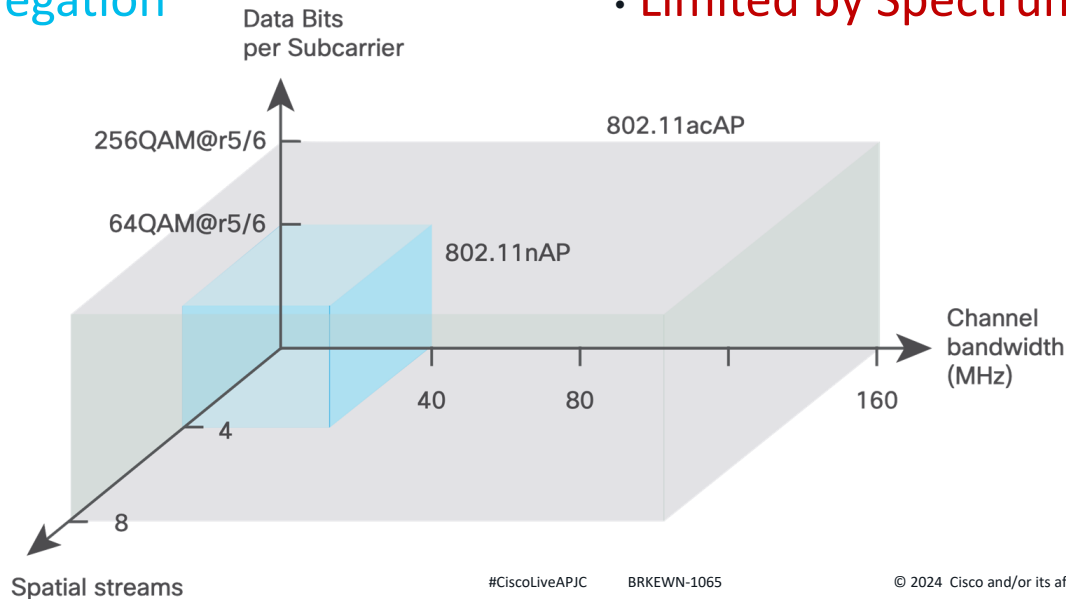
- Indoor or Outdoor
- Integrated or External Antenna
- UNII-5 and UNII-7 Only
- Requires AFC



cisco Live!

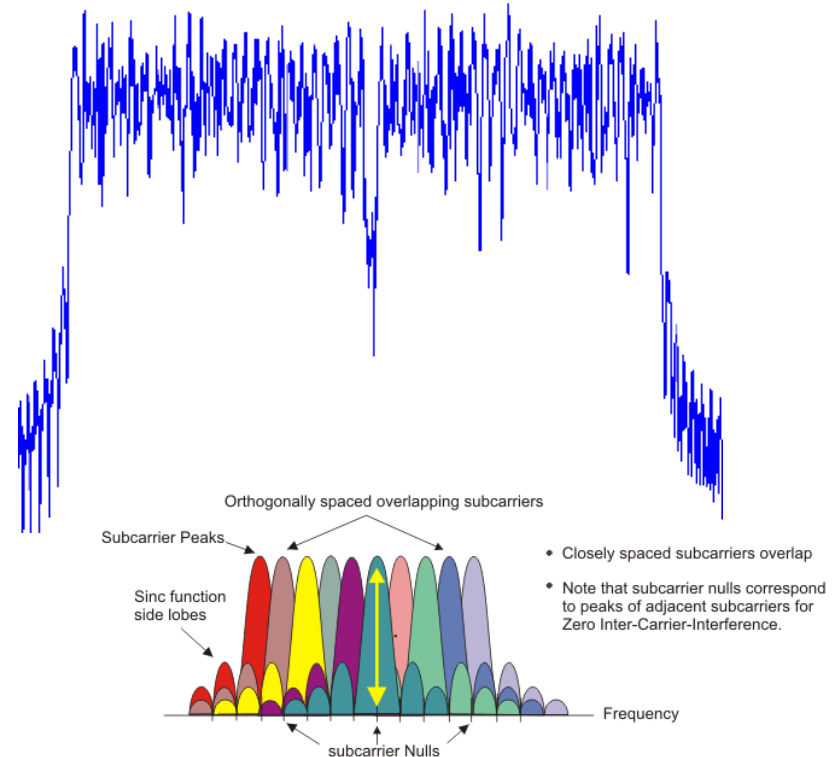
Three Dimensions to Wi-Fi Performance

- Spatial Multiplexing
- Digital Modulation
- Channel Aggregation
- Limited by Client Capability
- Limited by SNR
- Limited by Spectrum Availability



Multi-Carrier Modulation

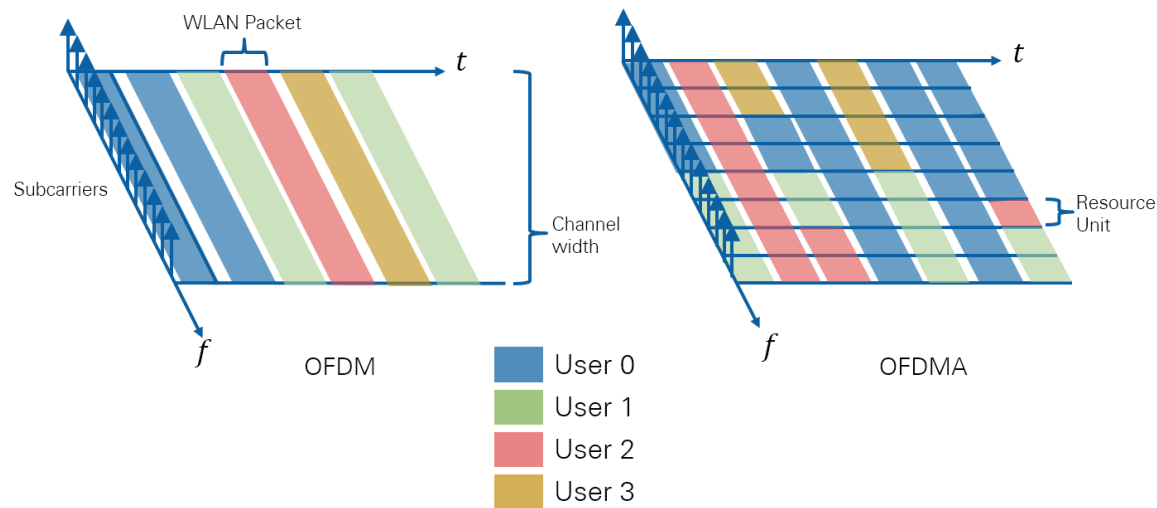
- Orthogonal Frequency Division Multiplexing (OFDM)
- Combines modulation and multiplexing techniques to further improve spatial efficiency
- The transmission channel is divided into subchannels or subcarriers
- To avoid overlap between subcarriers, they are orthogonal (at 90° angle) to one another
- Modulation techniques such as QPSK or QAM are then used in each subcarrier





Improving Spectrum Efficiency

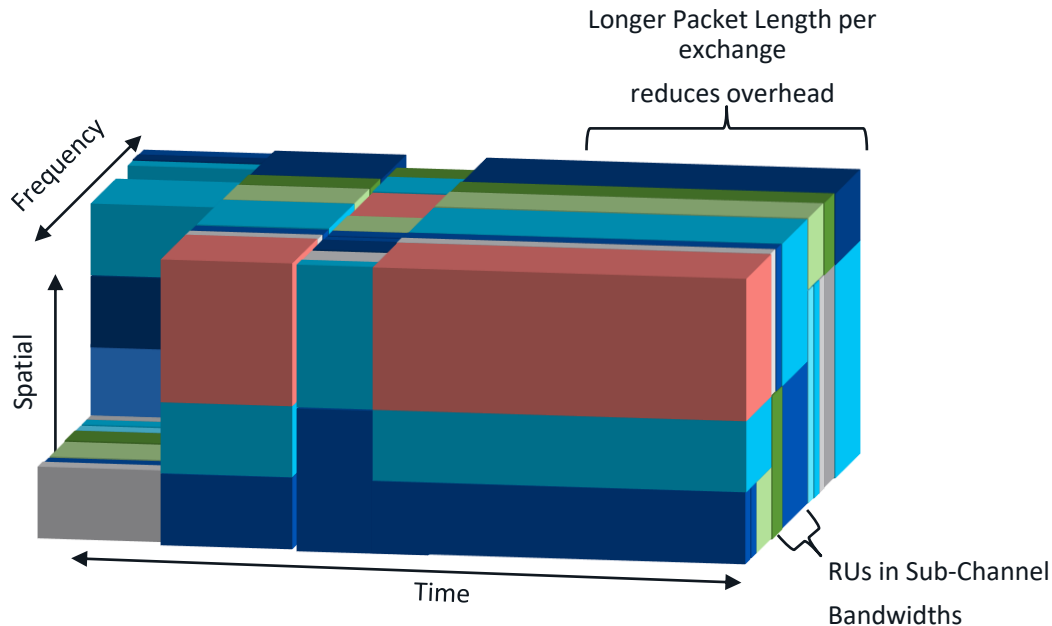
Orthogonal Frequency Division Multiple Access



FYI

OFDMA Concepts

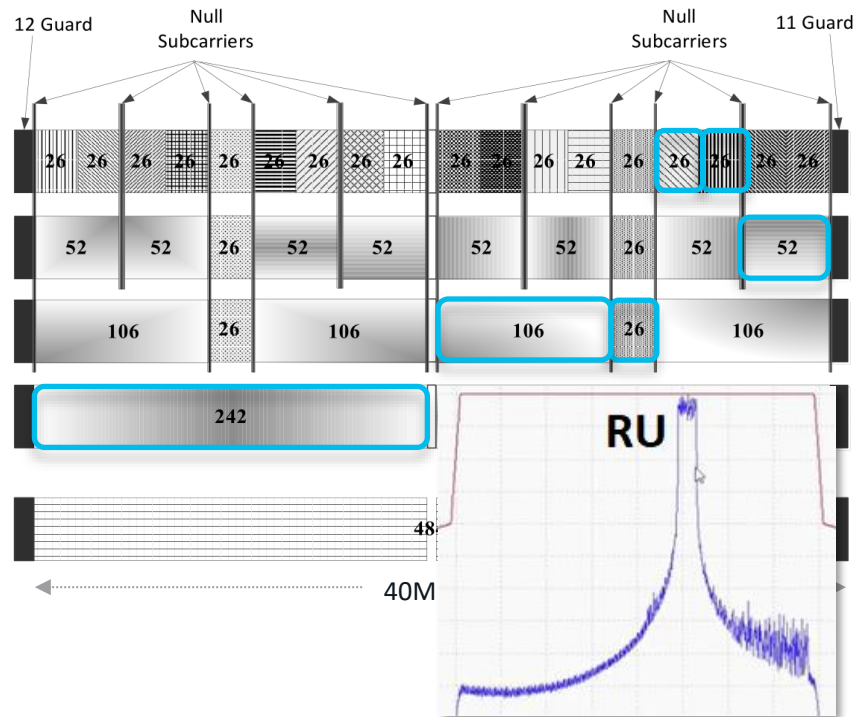
- Spatial Dimension
 - Multi-User
- Frequency Dimension
 - Sub-Channel Bandwidths
- Time Dimension
 - Scheduled Transmissions
- Variable Frequency Bandwidth per receiver
- Variable MCS per receiver





Resource Units

Orthogonal Frequency Division Multiple Access



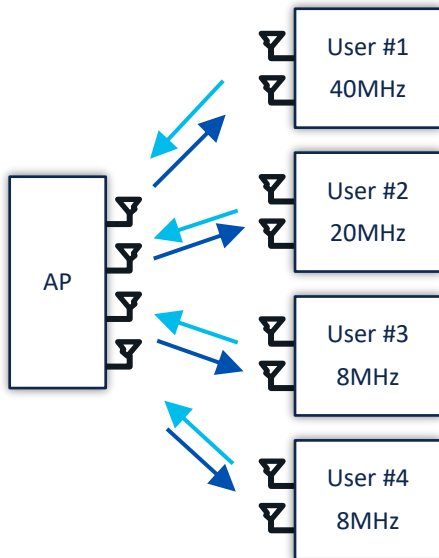
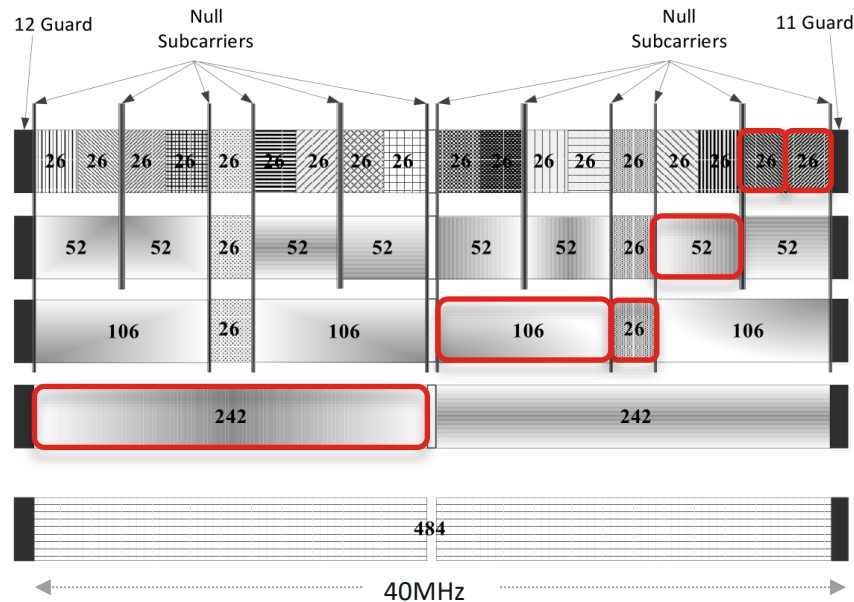
FYI

Resource Units

DL and UL OFDMA

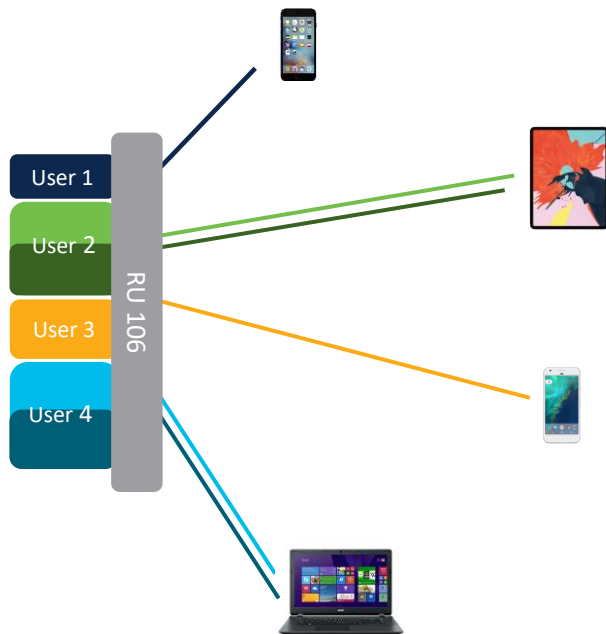
- Users can be assigned different Resource Unit bandwidths

- 2MHz
- 4MHz
- 8MHz
- 20MHz
- 40MHz
- 80MHz
- 160MHz



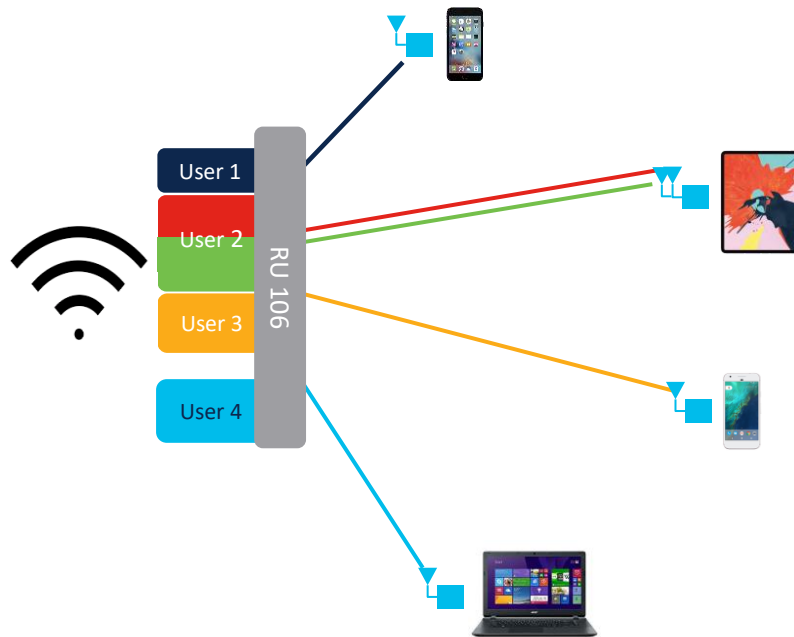


OFDMA and MU-MIMO

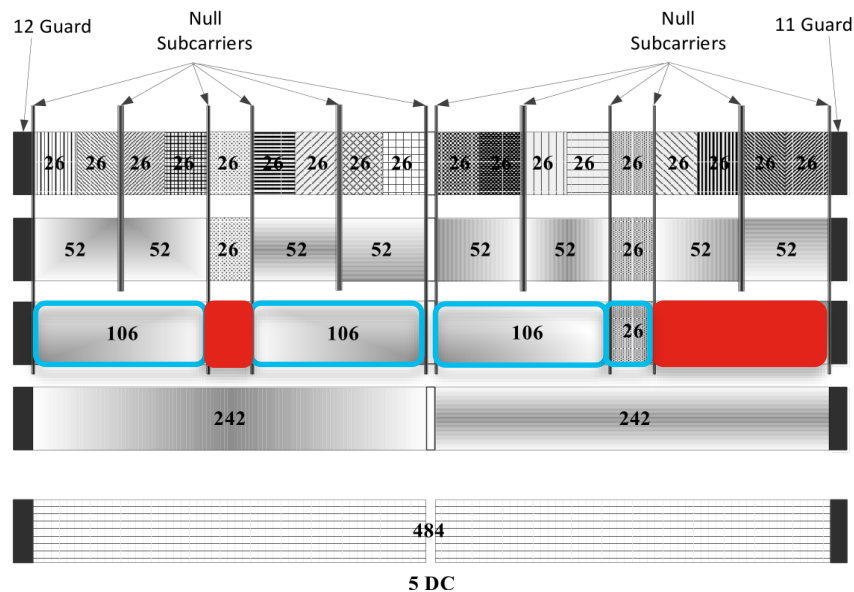


OFDMA and MU-MIMO

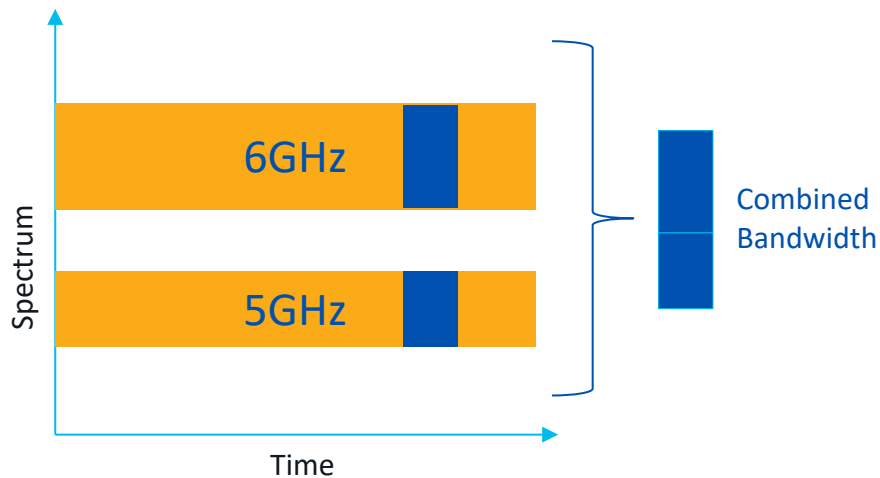
- Within OFDMA – any RU 106 or Larger can multiplex up to 8 SS split between users– DL/UL MU-MIMO
- Within the same 802.11ax frame, some RU's can be SU and others MU
- A 40 MHz BW signal has 4x RU106



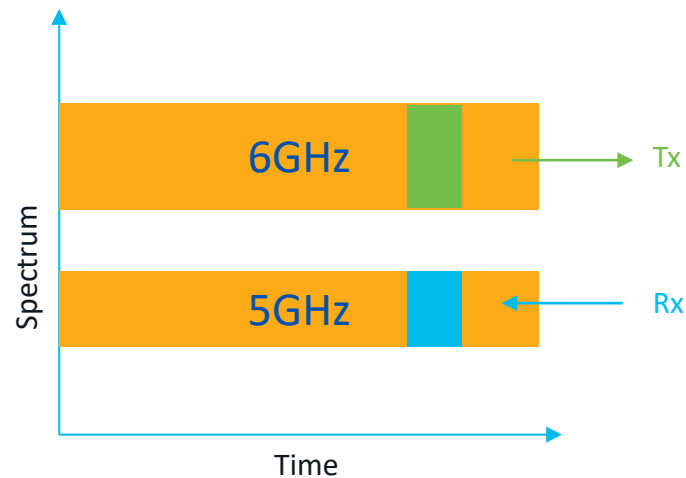
Puncturing



Multi-Link Operation



Multi-Band Aggregation



Multi-Band Full Duplex

FYI

Different Perspectives

AP

AP understands its own RF environment and the success of downstream traffic

AP sees client upstream data rate and the 'retry' bit, but can only infer why there is a difference

AP has visibility of neighbouring cells their client load

Client

Client has limited awareness of other clients in the cell

Client has limited awareness of neighbouring cells

Client has no awareness of cell edge location or next cell conditions

Providing the AP with the Client Perspective

What is this client?

- Form factor (phone/tablet/laptop)
- Hardware chipset
- Software OS/drivers

What is the client's perspective?

- AP RSSI
- Neighbour AP RSSI
- Retries

Where did the client go?

- 802.11 “standard” reasons
- User intervention
- Upper layer reasons

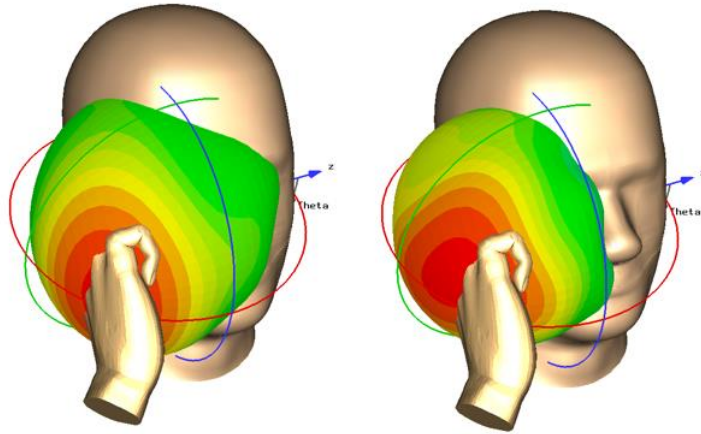
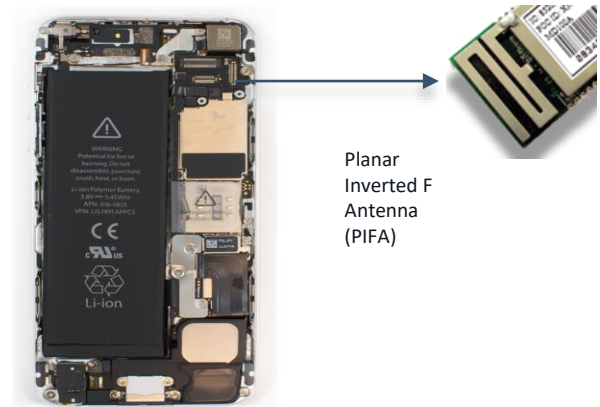
What does the AP know?

- Neighbour list
- AP load

Spot the Difference



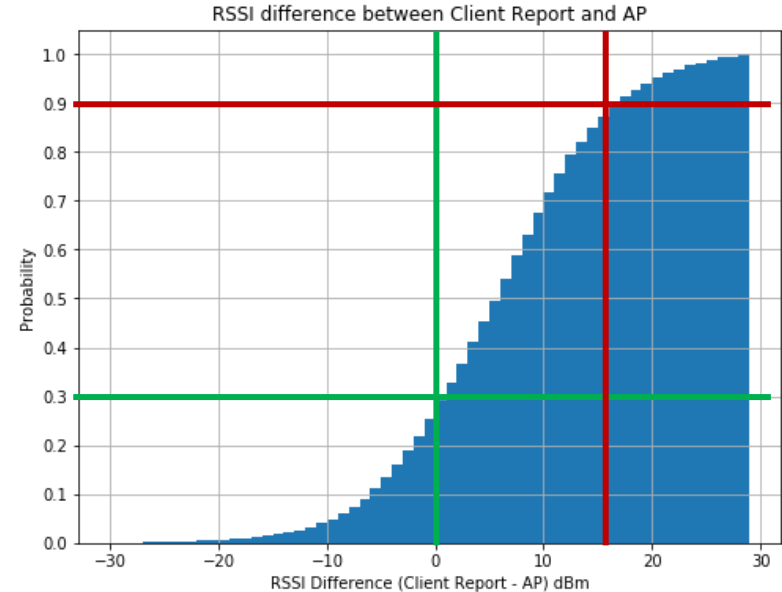
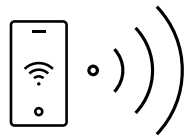
Client Position and Attenuation



Planar
Inverted F
Antenna
(PIFA)

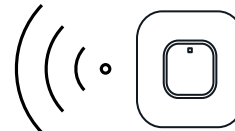
Device Disparity

- Six months aggregated view of the network designed “from the ceiling”
 - AP power set with “AP to AP” in mind (max tx power)
 - RSSI seen by the AP is lower than that seen by Client
- RSSI difference is significant
 - 50% of the time the RSSI is 6 dB less
 - 90% of the time the RSSI is 15 dB less

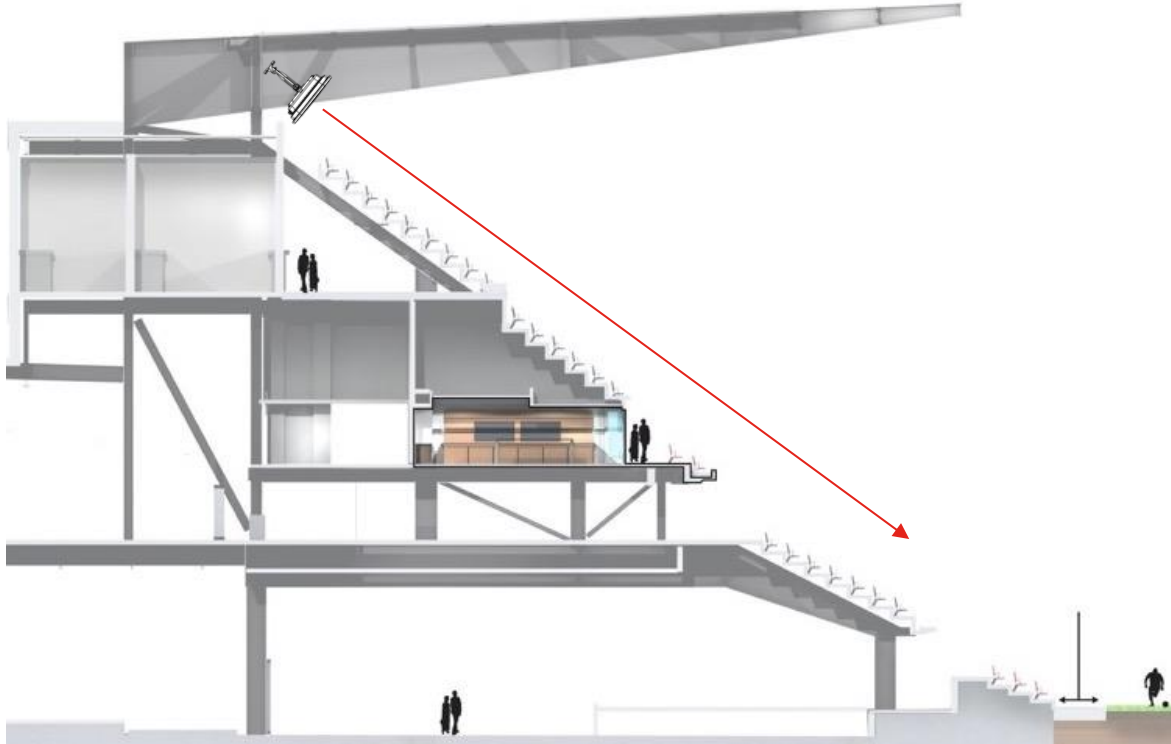


I see you at -
56 dBm

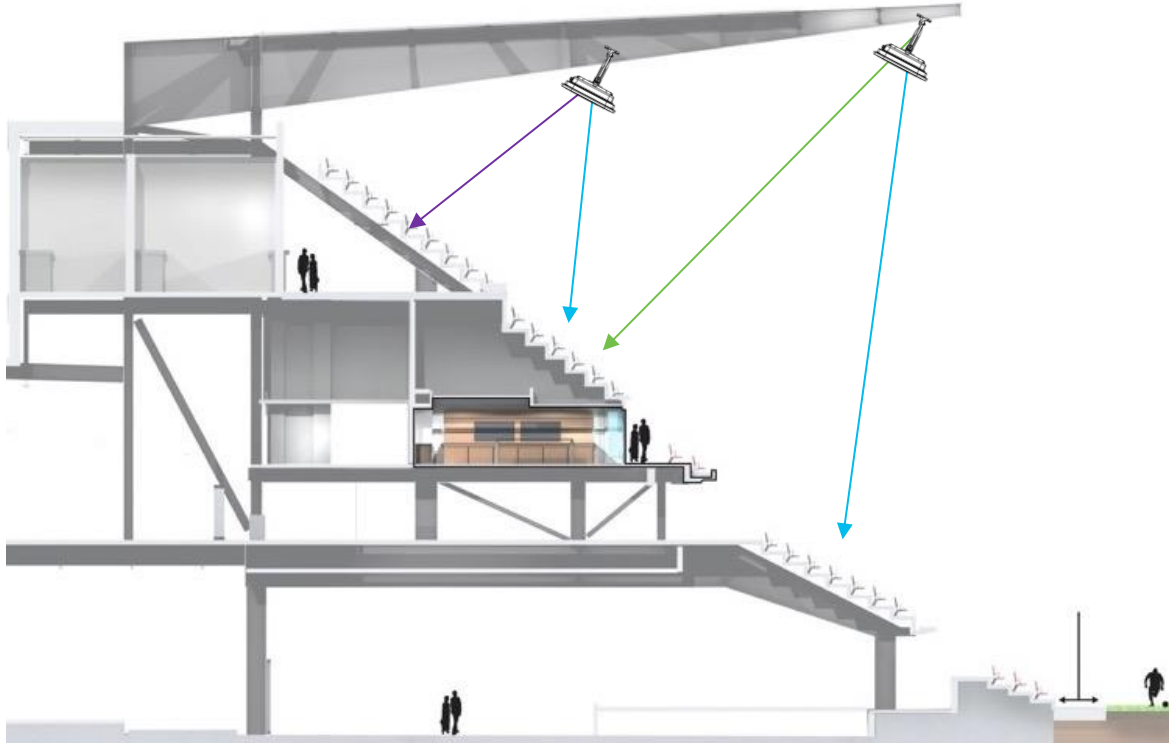
I see you at -
62 dBm



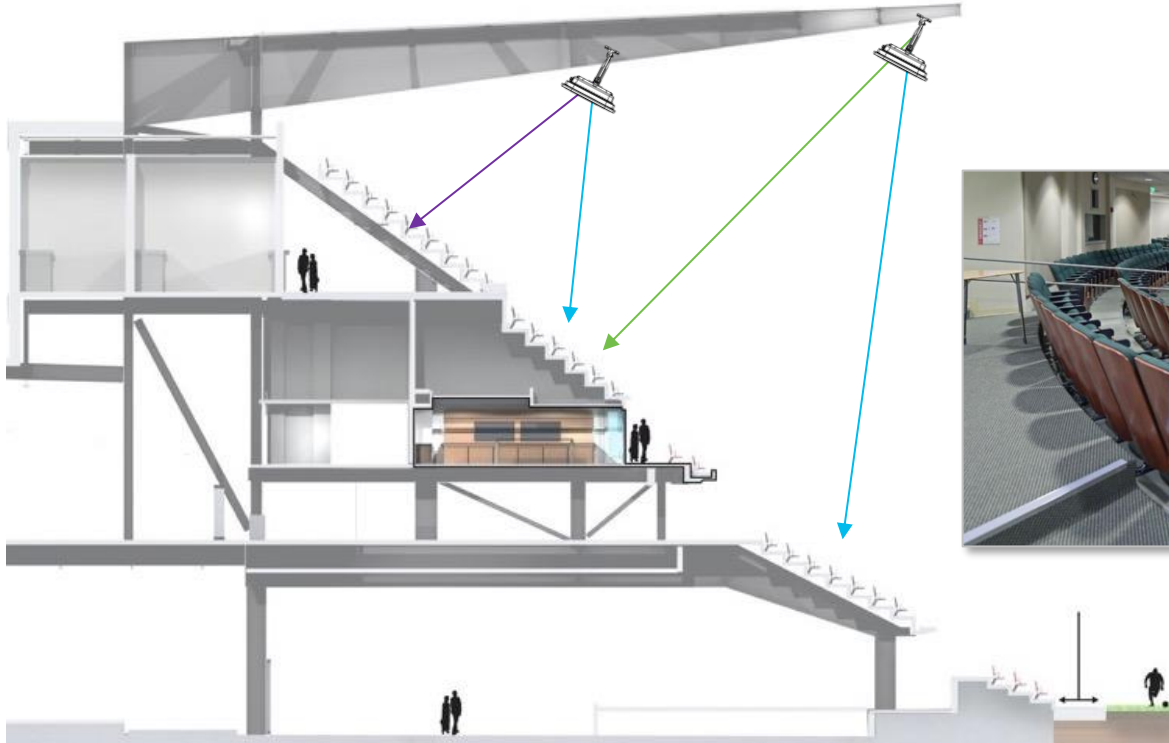
Antenna Positioning and Coverage



Antenna Positioning and Coverage



Antenna Positioning and Coverage



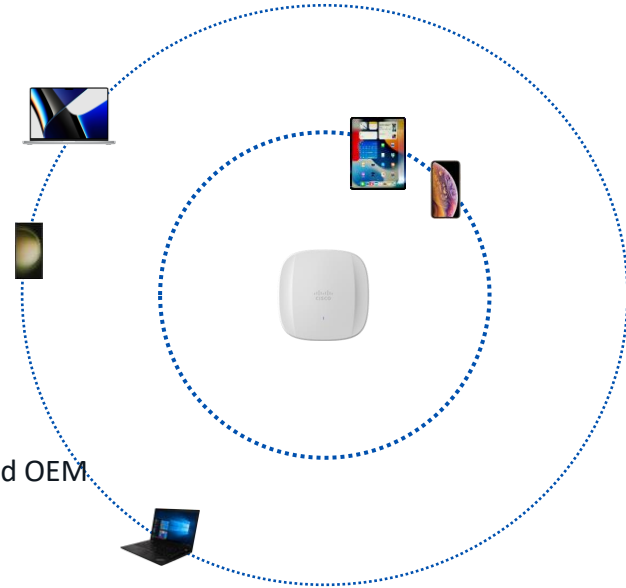
Client Roaming Logic

iOS devices start scanning at -70dBm
Roam to AP if 8dB better when active
Roam to AP if 12dB better when idle

macOS devices start scanning at -75dBm
Roam to AP if 12dB better

Samsung devices start scanning at -75dBm
Samsung devices start scanning at -65dBm if channel utilisation is at 70%
Roam to AP if 10dB better

Intel laptops scanning trigger depends on the antenna type and OEM
Typically between -65dBm and -75dBm
Roaming aggressiveness also varies, between 5dB and 20dB



Mac OS Roaming Logic: <https://support.apple.com/en-us/HT206207>

Samsung Roaming Logic: <https://docs.samsungknox.com/admin/knox-platform-for-enterprise/kbas/kba-115013403768.htm>

Client Analytics

- On a Cisco Network, after association, client sends an unsolicited, encrypted action frame with vendor-specific subtype
- Apple
 - Platform (“iPhone 15”)
 - OS (“iOS 17.1.1”)
- Samsung
 - Platform (“Galaxy 22 Ultra”)
 - OS (“Android 14.1”)
 - Manufacturer Build (“Samsung v5.917”)
 - SP Build (“AT&T v4.1.17”)
- Intel (AX200 and later)
 - Hardware model (“AX210”)
 - Driver version (“iOS 17.1.1”)
 - OS (“Win 11.0.12”)
 - AC/DC voltage (“AC”)



☐	Status	Description	Last seen	Usage	Device type, OS	IPv4 address	Policy
☐	Wireless	Karas-MacBook-Air-3	Apr 24 15:03	811.8 MB	Mac OS X	192.168.10.17	Normal
☐	Wireless	DAHUCABY-M-C9V9	Apr 24 15:03	1.70 GB	Apple iPhone	192.168.10.7	Normal
☐	Wireless	iPhone-3	Apr 24 15:03	4.40 GB	iPhone 13, iOS15.6.1	192.168.10.15	Normal
☐	Wireless	DH-iPad-Air					

Status	last seen Nov 25 20:44
SSID	blizzard
Access point	SFO12-3-AP22 topology
Splash	N/A
User	ksahin@cisco.com (802.1X login)
Device type, OS	Apple iPad Pro, iOS17.1.1
Capable Wi-Fi standards	802.11ax - 2.4, 5, and 6 GHz, 802.11r, Fastlane capable details
Tools	history packet capture disconnect client

Detail Information Jan 3, 2023 11:52 AM	
Device Info	Connectivity RF iOS Analytics
Information	
Device Type	iPad Pro (11 inch) (2nd gen)
Operating System	iOS 13.5.1
User Name	--
Host Name	WTMEs-iPad
MAC Address	3C:7D:0A:CC:D1:DF
IPv4 Address	10.70.1.95
IPv6 Address	fe80::cf8:8ee:9011:c255
Status	Connected
VLAN ID	70
Association Protocol	Wi-Fi 6
Protocol Capability	Wi-Fi 6



802.11 Reason Codes

- 802.11 says “why” one side terminates the connection
 - ~70 possible reasons
 - Reasons are only “L1 or L2”
 - No OS or upper layer event considered
 - No user action considered

Table 9-49—Reason codes

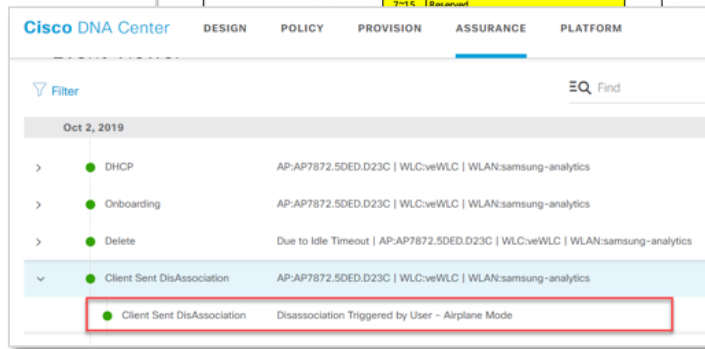
Reason code	Name	Meaning
0		Reserved
1	UNSPECIFIED_REASON	Unspecified reason
2	INVALID_AUTHENTICATION	Previous authentication no longer valid
3	LEAVING_NETWORK_DEAUTH	Deauthenticated because sending STA is leaving (or has left) the BSS
4	REASON_INACTIVITY	Disassociated due to inactivity
5	NO_MORE_STAS	Disassociated because AP is unable to handle all currently associated STAs
6	INVALID_CLASS2_FRAME	Class 2 frame received from nonauthenticated STA
7	INVALID_CLASS3_FRAME	Class 3 frame received from nonassociated STA

FYI

Understanding Client Behaviour

- Apple, Intel and Samsung clients will send additional reason codes upon disassociation
- Apple adds 9 upper layer reasons
 - DHCP failed
 - EAP timed out
 - 802.1X failed
 - Device is idle
 - Captive portal security failed
 - Decryption failed
 - Wi-Fi interface disabled
 - User triggered disassociation
 - AP triggered disassociation
- Samsung enhances the Apple reason codes with more details

STEP 1 Reason [15:8]		Additional Reason Code [15:0]		STEP 3 Reason [3:0]	AP	STA
0	Reserved	0-15	Reserved	0-15	Reserved	
1	User Triggered Disconnect	0	Unspecified			0
		1	Power Off or Wi-Fi Off			0
		2	Connect to other AP			0
		3	Remove AP profile			0
		4	Airplane mode On			0
2	L2 Connection	5-15	Reserved	0-15	Reserved	0
		0	Unspecified			0
		1	Association			0
3	4-Way Handshake	2-15	Reserved	0-15	Reserved	0
		0	Unspecified			0
		1	M1 for 4-Way Handshake			0
		2	M2 for 4-Way Handshake			0
		3	M3 for 4-Way Handshake			0
		4	M4 for 4-Way Handshake			0
		5	M1 for Groupkey Handshake			0
4	DHCP Fail	6	M2 for Groupkey Handshake			0
		7-15	Reserved			0
		0	Unspecified			0
		1	Time Out			0
		2	Time out after Roaming			0
		3	Lease Expired (no response for renew)			0
		4	Nak in renew			0
		5	Renew lease wrong IP			0
		6	Internal error			0
		7-15	Reserved			0



iOS and Samsung Analytics

FYI

Detail Information Jan 3, 2023 11:52 AM

Device Info Connectivity RF iOS Analytics

Information

Device Type	iPad Pro (11 inch) (2nd gen)
Operating System	iOS 13.5.1
User Name	--
Host Name	WTMEs-iPad
MAC Address	3C:7D:0A:CC:D1:DF
IPv4 Address	10.70.1.95
IPv6 Address	fe80::cf8:8ee:9011:c255
Status	Connected
VLAN ID	70
Association Protocol	Wi-Fi 6
Protocol Capability	Wi-Fi 6

Device Info Connectivity RF iOS Analytics

Neighbor APs (6)

Search Table

BSSID	AP Name	Channel	RSSI (dBm)	Location	Time
AC:4A:56:AE:92:CD	Assurance_9130_3	48	-49	Global/San Jose/Building 14/F	
A4:53:0E:7D:42:AD	SJC14-TME-AP10	52	-80	Global/San Jose/Building 14/F	
6C:8D:77:2E:04:2D	SJC14-F1-9164-3	100	-75	Global/San Jose/Building 14/F	
10:F9:20:FD:68:8D	SJC14-F1-9166-1	116	-61	Global/San Jose/Building 14/F	

6 Records Show Records: 10 < 1 >

The diagram illustrates a central mobile device (represented by a smartphone icon) connected to six access points (APs). The connections are color-coded: green for positive RSSI values and red for negative RSSI values. The RSSI values are as follows:

- SJC14-TME-AP9 (10:B3:C6:24:B7:4D) to mobile: -54 dBm (green)
- SJC14-TME-AP10 (A4:53:0E:7D:42:AD) to mobile: -80 dBm (red)
- SJC14-F1-9166-1 (10:F9:20:FD:68:8D) to mobile: -61 dBm (green)
- SJC14-F1-9164-3 (6C:8D:77:2E:04:2D) to mobile: -75 dBm (red)
- SJC14-TME-AP11 (10:B3:C6:24:9E:6D) to mobile: -65 dBm (red)
- Assurance_9130_3 (AC:4A:56:AE:92:CD) to mobile: -49 dBm (green)

Cisco DNA Center DESIGN POLICY PROVISION ASSURANCE PLATFORM

Filter EQ Find

Oct 2, 2019

- > DHCP AP:AP7872.5DED.D23C | WLC:veWLC | WLAN:samsung-analytics
- > Onboarding AP:AP7872.5DED.D23C | WLC:veWLC | WLAN:samsung-analytics
- > Delete Due to Idle Timeout | AP:AP7872.5DED.D23C | WLC:veWLC | WLAN:samsung-analytics
- > Client Sent DisAssociation AP:AP7872.5DED.D23C | WLC:veWLC | WLAN:samsung-analytics
- > Client Sent DisAssociation Disassociation Triggered by User - Airplane Mode

FYI

Intel Device Analytics

Station Information

Reports: Hardware model, OS version, driver version, manufacturer, voltage, system model

Helps troubleshoot and identify Intel devices based on their specific attributes

Low RSSI

Reports: When RSSI is below -75dBm for 5 mins, Last Reported Time

Identify sticky client issues and understand why a roam has not triggered

Neighboring APs

Reports: Top 5 APs based on RSSI, Roaming Reasons, Missed Beacons and 11v Recommendations

Provides a client-side view of the network and the reason for a roam

Temporary Disconnects

Reports: When a client disconnection is due to a Missed Beacon

Helps understand why a client has disconnected from the network

Unknown APs

Reports: Reports a list of APs not part of Neighboring AP report

Helps troubleshoot issues with non-valid IEs and see why AP is not responding

Failed APs

Reports: Reports invalid IEs in Beacons, Probe Responses and Association Responses

Used to identify and flag rogue BSSIDs

Intel Connectivity Analytics

FYI

Detail InformationJun 2, 2022 3:19 PM

Device InfoConnectivityRFIntel Connectivity Analytics

Information

Device Type	Dell Inc. Inspiron 5406 2n1
Operating System	Windows 10
User Name	--
Host Name	OTA-wind11-156-USDT
MAC Address	A4:6B:B6:40:37:51
IPv4 Address	40.235.10.11
IPv6 Address	2000:40:235:0:352b:c7c7:c720:322b (7)
Status	Connected
VLAN ID	2435
Association Protocol	Wi-Fi 6E
Protocol Capability	Wi-Fi 6E
L3 Virtual Network	--

Connection Information

Detail InformationDec 17, 2020 10:16 AM

Device InfoConnectivityRFIntel Connectivity Analytics

Roam EventsView All Roam Events in Event Viewer

Reason Code: Low RSSISelected AP: AP9120.1234BSSID: 6C:B2:AE:C7:AB:00RSSI: -50 dBm

Last 5 Reported ErrorsView All Reported Errors in Event Viewer

Last 5 Temporary Disconnection ReportsView All Temporary Disconnection Reports

Last 5 Low RSSI ReportsView All Low RSSI Reports

> June 11, 11:56 AM
10 Access Points

> June 11, 10:58 AM
8 Access Points

June 11, 11:53 AM
Access Point: AP9120.1236
BSSID: 6C:B2:AE:C7:AB:00

June 11, 11:50 AM
Access Point: AP9120.1236

June 11, 10:34 AM
Access Point: AP9120.1239
BSSID: 6C:B2:AE:C7:AB:00
RSSI: -80 dBm

June 11, 10:17 AM

Event Viewer

FilterExportGo to Global Event Viewer

Event is Roam Report

May 9, 2022

>	Intel	Roam Report	9:25:35.935 PM	RSSI: -47 dBm AP: OTA-9136B-17E0 Reason Code Low RSSI Type: Device Analytics - Intel
>	Intel	Roam Report	8:55:33.628 PM	RSSI: -47 dBm AP: OTA-9136B-17E0 Reason Code Better AP Type: Device Analytics - Intel
>	Intel	Roam Report	8:25:32.200 PM	RSSI: -47 dBm AP: OTA-9136B-17E0 Reason Code Other Type: Device Analytics - Intel
>	Intel	Roam Report	7:55:30.066 PM	RSSI: -47 dBm AP: OTA-9136B-17E0 Reason Code 11xforce Type: Device Analytics - Intel
>	Intel	Roam Report	7:25:28.241 PM	RSSI: -47 dBm AP: OTA-9136B-17E0 Reason Code Other Type: Device Analytics - Intel
>	Intel	Roam Report	7:25:28.241 PM	RSSI: -47 dBm AP: OTA-9136B-17E0 Reason Code Other Type: Device Analytics - Intel
>	Intel	Roam Report	6:55:27.112 PM	RSSI: -46 dBm AP: OTA-9136B-17E0 Reason Code Low RSSI Type: Device Analytics - Intel
>	Intel	Roam Report	6:25:26.366 PM	RSSI: -47 dBm AP: OTA-9136B-17E0 Reason Code Better AP Type: Device Analytics - Intel
>	Intel	Roam Report	5:55:24.129 PM	RSSI: -46 dBm AP: OTA-9136B-17E0 Reason Code Other Type: Device Analytics - Intel

Showing 1 - 9 of 48

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#CiscoLiveAPJC

BRKEWN-1065

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66

Device Analytics

FYI

		Intel	Apple	Samsung
What is the client type?	Catalyst 9800	Device Analytics > Advertise PC Analytics support	Automatic	Device Analytics > Advertise support
	Meraki Dashboard	Automatic Cannot be disabled	Automatic Cannot be disabled	
How does the client see the network?	Catalyst 9800	Automatic at (re)association if PC Analytics is enabled Also sent dynamically	Automatic at (re)association	Automatic at (re)association if Device Analytics is enabled Also sent dynamically
	Meraki Dashboard	Automatic Cannot be disabled	Automatic Cannot be disabled	
Why did the client leave?	Catalyst 9800	Automatic if Advertise PC Analytics support enabled	Automatic	Automatic if Device Analytics is enabled
	Meraki Dashboard	Automatically on, cannot be turned off	Automatically on, cannot be turned off	
For better client experience	Catalyst 9800	Enable 802.11k/v and Device Analytics > Share Data with Client. Cisco sends the STA info about AP to tune its algorithms to understand what is a good AP		
	Meraki Dashboard			



Minimum Software Support Matrix

	Meraki	WLC Type	WLC Version	Catalyst Center
Intel Connectivity Analytics	MR29	IOS XE	17.6.1	2.3.3
		AireOS	N/A	N/A
Apple Analytics	MR27	IOS XE	16.12.1s	2.2.1
		AireOS	8.5	2.2.1
Samsung Analytics	MR31*	IOS-XE	17.1.1	2.2.1
		AireOS	N/A	N/A

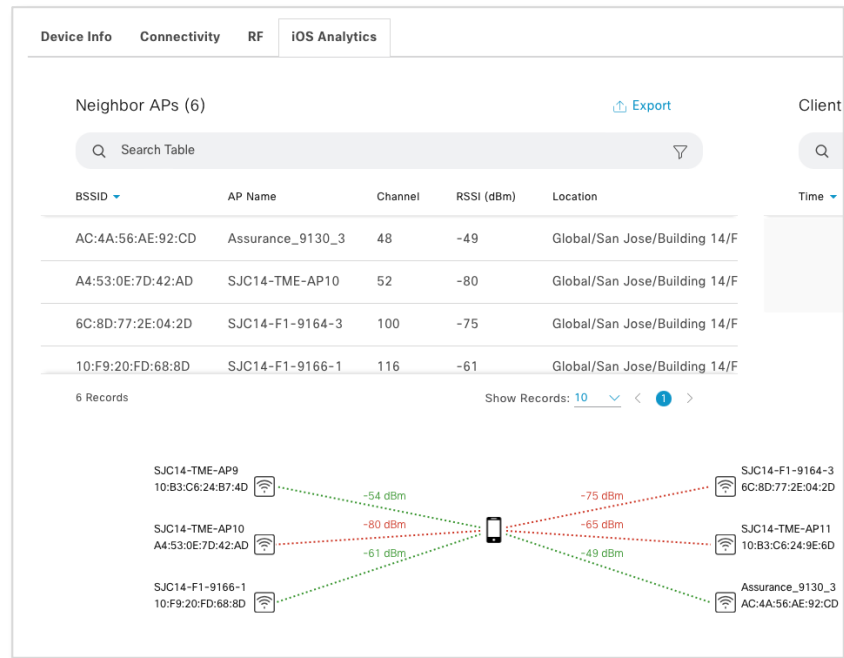


Intel Hardware and Software Matrix

Cisco Access Point Hardware		Intel Chipset	
All Wave 2, Catalyst Wi-Fi 6/6E APs		AX200, AX201, AX210, AX211, AX411	
Cisco IOS XE WLC Software	Cisco AireOS WLC Software	Cisco Catalyst Center	Intel Driver Software
17.6.1	N/A	2.3.3	22.50.1
Cisco IOS XE WLC Hardware			
Embedded Wireless Controller on the AP and Switch			
C9800-CL			
C9800-L			
C9800-40 / C9800-80			
CW9800-M / CW9800-H1 / CW9800-H2			

The Client Perspective of the Network

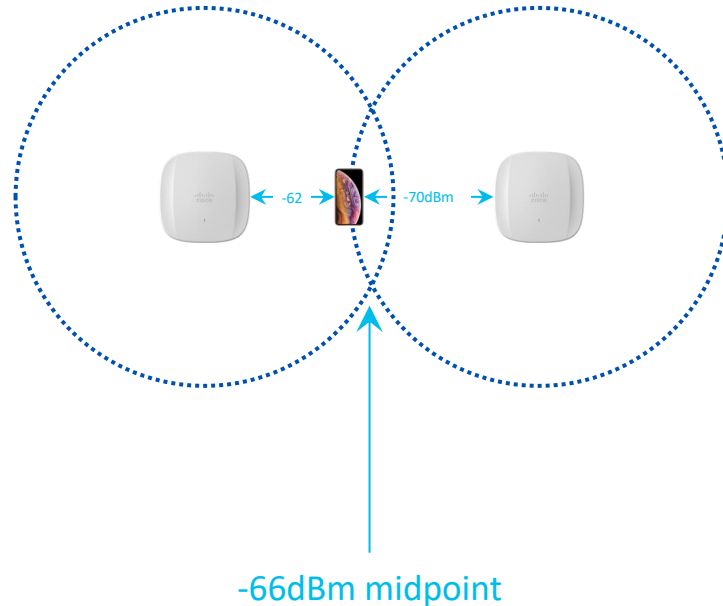
- Apple
 - After sending client details, iOS/macOS device sends an 802.11k unsolicited beacon report with a list of BSSID/channel/RSSI for the current SSID
- Intel
 - After sending client details, Intel clients sends an unsolicited 802.11k beacon report
 - AP can ask for an updated report, or instruct client to perform an active or passive scan
- Samsung
 - After receive client details, the AP automatically requests an 802.11k beacons report
 - AP can ask for an updated report, or instruct client to perform an active or passive scan



Samsung details are not yet supported in Meraki Dashboard

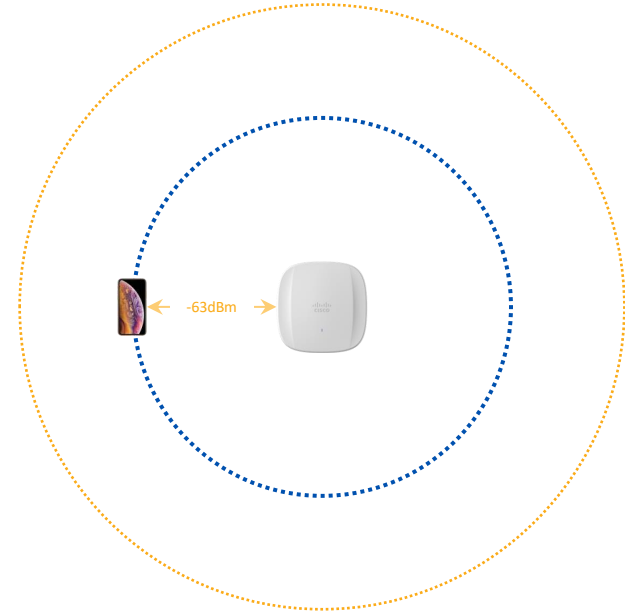
Cell Edge is Defined from the Client Perspective

- If the average client starts to look for a new AP at -70dBm, it better find one at -62dBm



Cell Edge is Defined from the Client Perspective

- If the average client starts to look for a new AP at -70dBm, it better find one at -62dBm
- Beware of 5GHz to 2.4GHz roams
 - At similar power, a 2.4GHz signal will be heard at 7dBm better than 5GHz



Cell Edge is Defined from the Client Perspective

- If the average client starts to look for a new AP at -70dBm, it better find one at -62dBm
- Beware of 5GHz to 2.4GHz roams
 - At similar power, a 2.4GHz signal will be heard at 7dBm better than 5GHz
 - Reduce 2.4GHz transmit power to maintain similar coverage



FYI

Designing for Cell Overlap

- The 6dB Rule
 - Half the distance = +6dB
 - Twice the distance = -6dB

← Distance $d/2$
-60dBm →



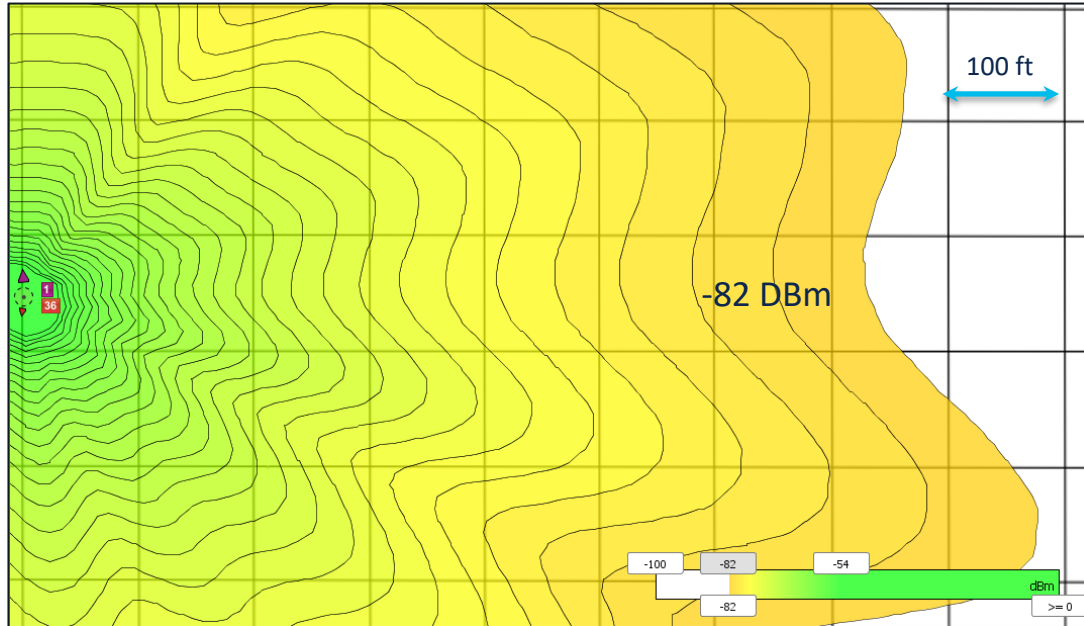
Distance d
-66dBm



Distance $2d$
-72dBm

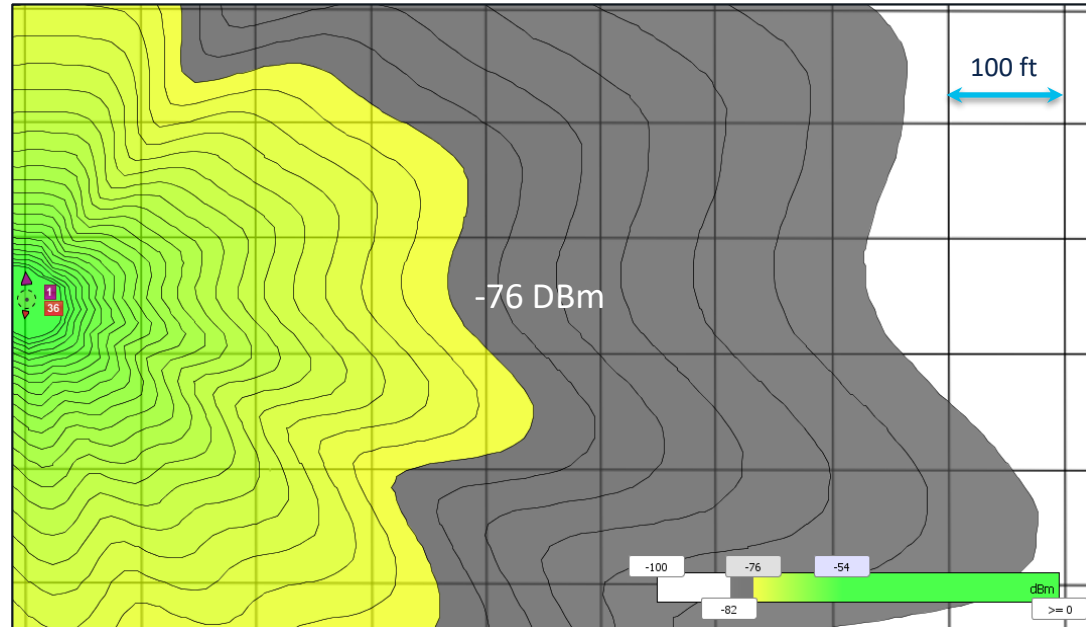
Managing the Cell Edge

- Using Tx Power
 - Cutoff -82 dBm



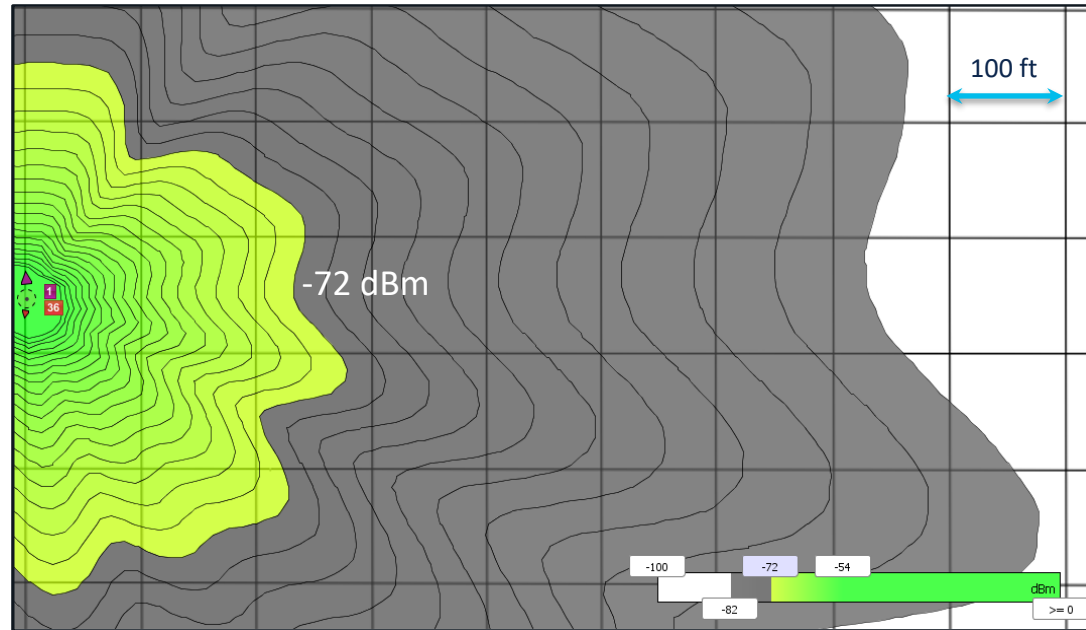
Managing the Cell Edge

- Using Tx Power
 - Cutoff -82 dBm
 - Cutoff -76 dBm



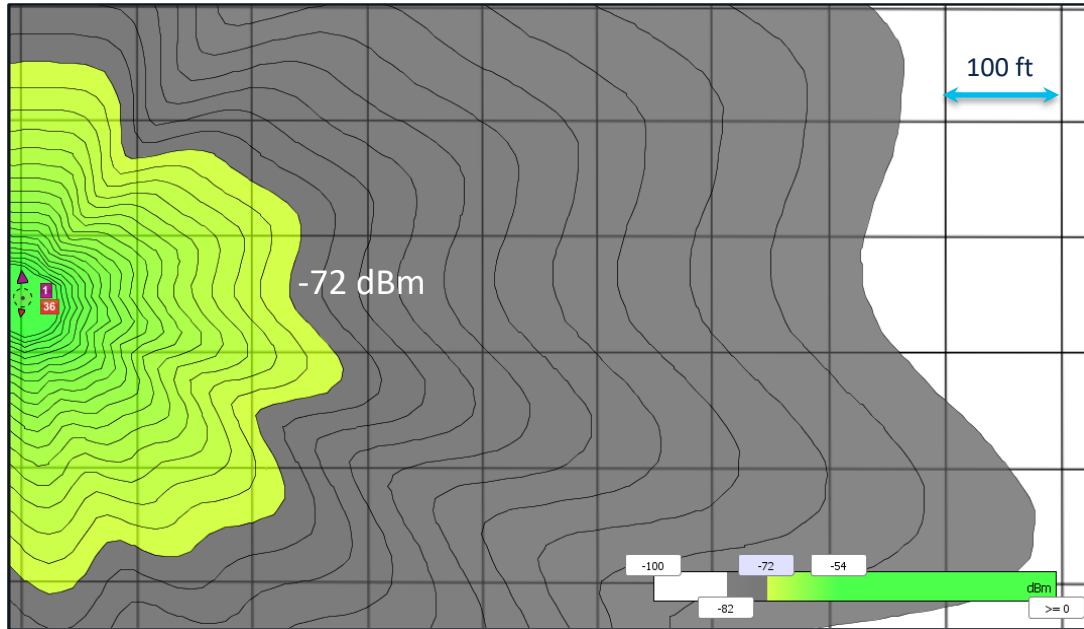
Managing the Cell Edge

- Using Tx Power
 - Cutoff -82 dBm
 - Cutoff -76 dBm
 - Cutoff -72 dBm



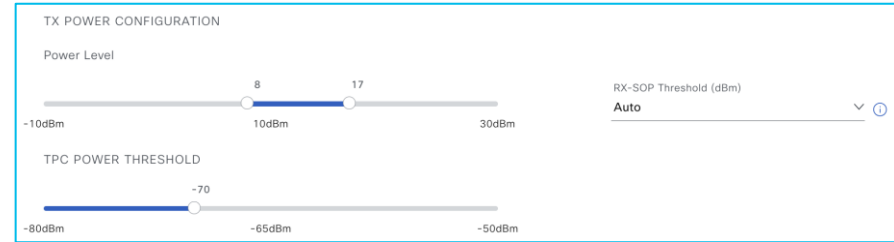
Managing the Cell Edge

- Using Tx Power
 - Cutoff -82 dBm
 - Cutoff -76 dBm
 - Cutoff -72 dBm
- High Gain Directional Antennas
- Mandatory Data Rates
- Receiver Start of Packet (RX-SOP)



Cell Edge as Defined by the AP Transmit Power

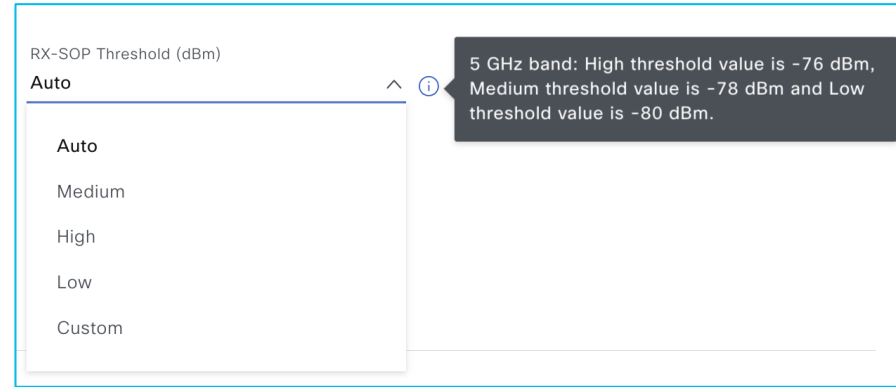
- Client Power Levels
 - Laptops: 20-23dBm
 - Modern Phones and Tablets: 17dBm
 - Older and Cheaper Phones: 11-14dBm
- The ideal AP max power level should be set to match your worst client max power
 - Assume a 3dB margin
 - For most modern clients assume the worst value to be 14dBm
 - Resulting in AP max power level of 17dBm



Cell Edge as Defined by Receiver Start of Packet

- RX-SOP Threshold

- Determines the signal level in dBm at which the AP will demodulate and decode a packet
- Increase RX-SOP
 - Decrease radio sensitivity
 - Reduce cell size
- Auto setting uses the radio default threshold
- Custom can be used for fine tuning in very specific areas



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

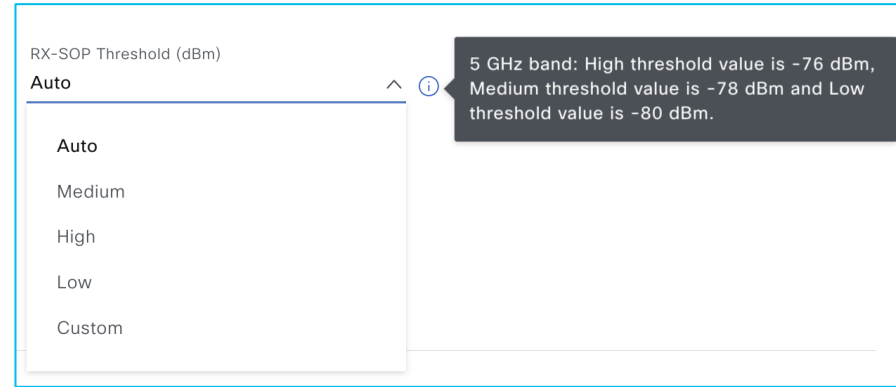
You should only use this option if you have a clear understanding of the nuances of RX-SOP and have conducted a site survey.

[Proceed](#) [Hide this option](#)

Cell Edge as Defined by Receiver Start of Packet

- RX-SOP Threshold

- Determines the signal level in dBm at which the AP will demodulate and decode a packet
- Increase RX-SOP
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Radio Resource Management and AutoRF

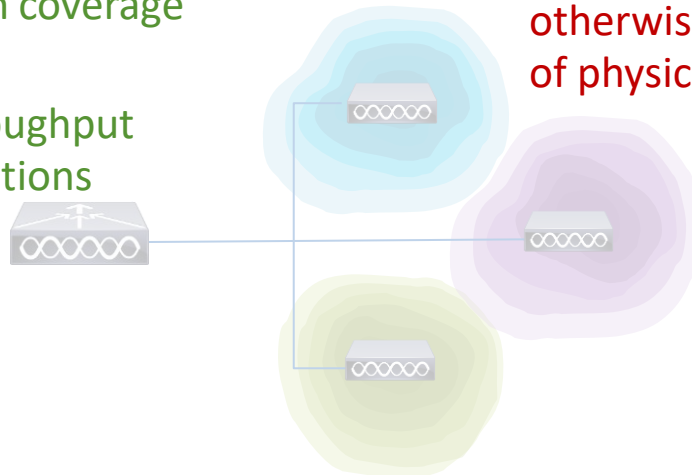
Dynamic Channel Allocation · Dynamic Bandwidth Selection · Transmit Power Control · Coverage Hole Detection

• What It Does

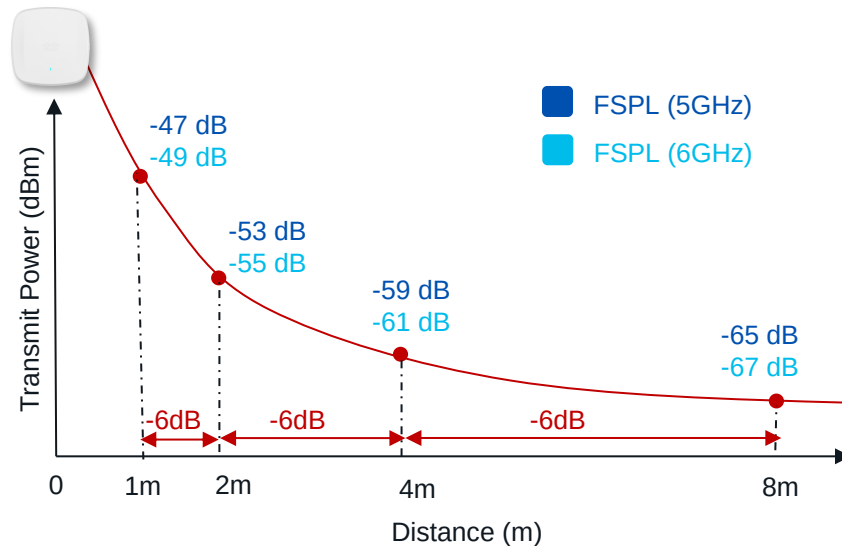
- Dynamically balances the RF environment and mitigates changes
- Monitor and maintain coverage for all clients
- Provides optimal throughput under changing conditions

• What It Doesn't Do

- Substitute for a site survey
- Correct a poor RF design
- Manufacture spectrum or otherwise counteract the laws of physics...



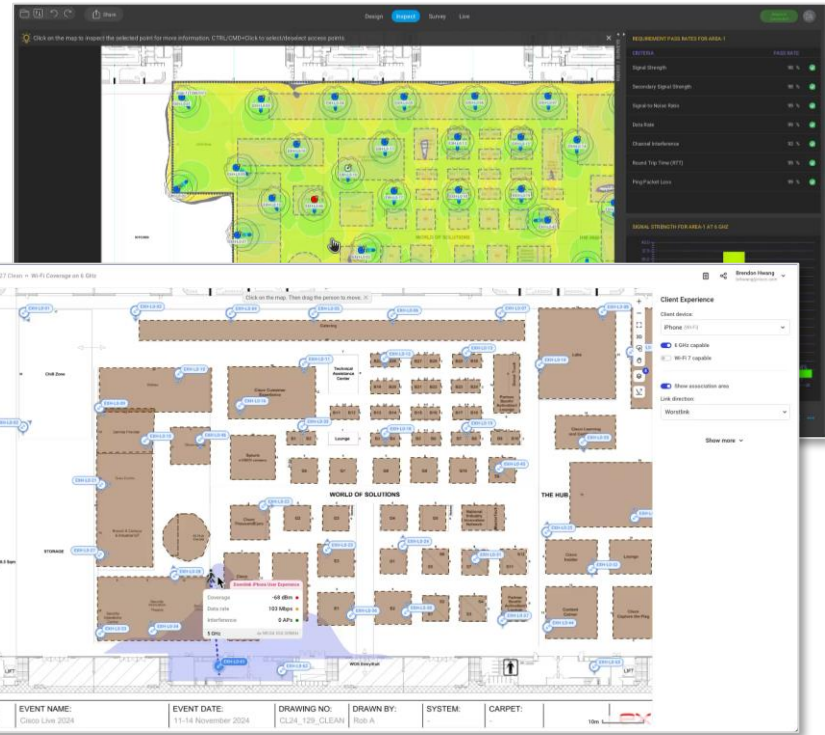
Designing for 6GHz



- Higher transmit power is necessary to balance 5GHz and 6GHz cells
- For existing networks at 5GHz, transmit power level is typically 11-15 dBm (PL3/4) depending on density
- This leaves room for 6GHz transmit power to be adjusted higher to match cell coverage

RF Planning Tools

- All models are wrong
- Some of them are useful
- Planning tools can help develop a preliminary design and identify potential deployment issues
- The model MUST be calibrated to ensure what you see is what you get
- Always remain conservative with power
 - Middle to lower end of the range should be selected
 - Many tools default to high power and can be very misleading
 - Coverage and capacity should be balanced



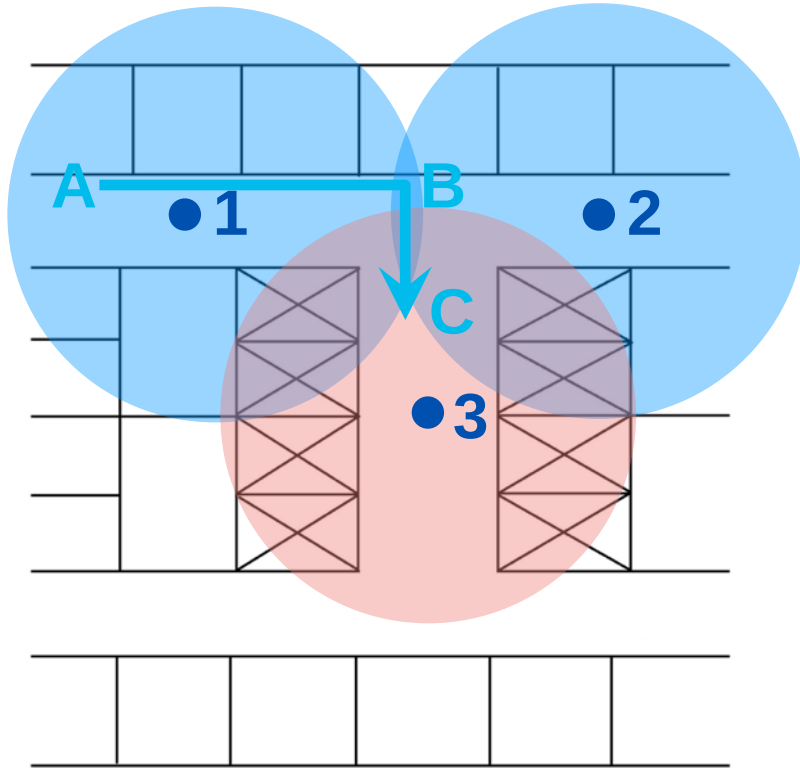
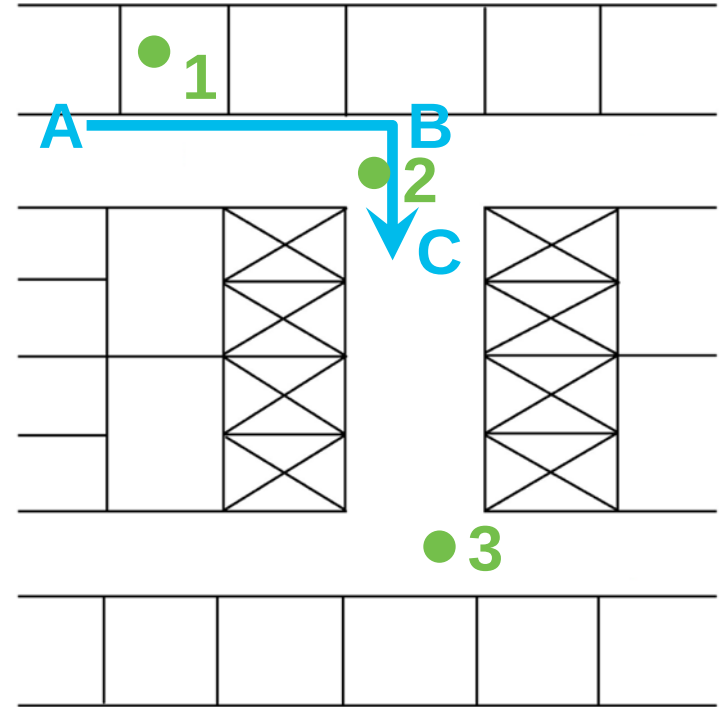
- Catalyst Center and Meraki Dashboard both support both Ekahau and Hamina project file import

Site Surveys

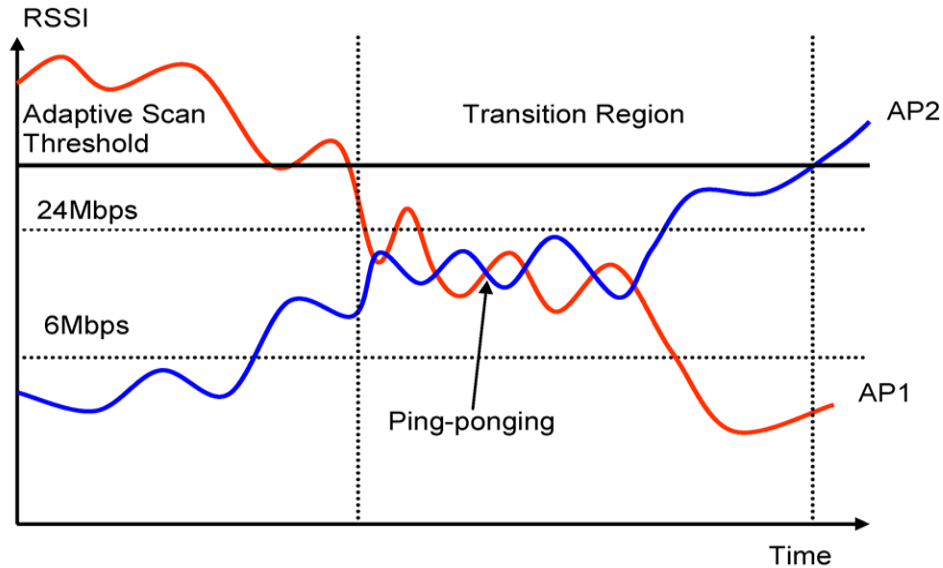
- Always verify predicted coverage with actual measurements
- Consider underlying requirements
 - Number of Users
 - Application Types
 - Location accuracy
- AP placement considerations
 - Consider environmentals
 - Characterise the -66 dBm edges
 - For location a minimum of three AP should be able to hear the device with a signal strength of -75 dBm or higher
- Understand existing spectrum use



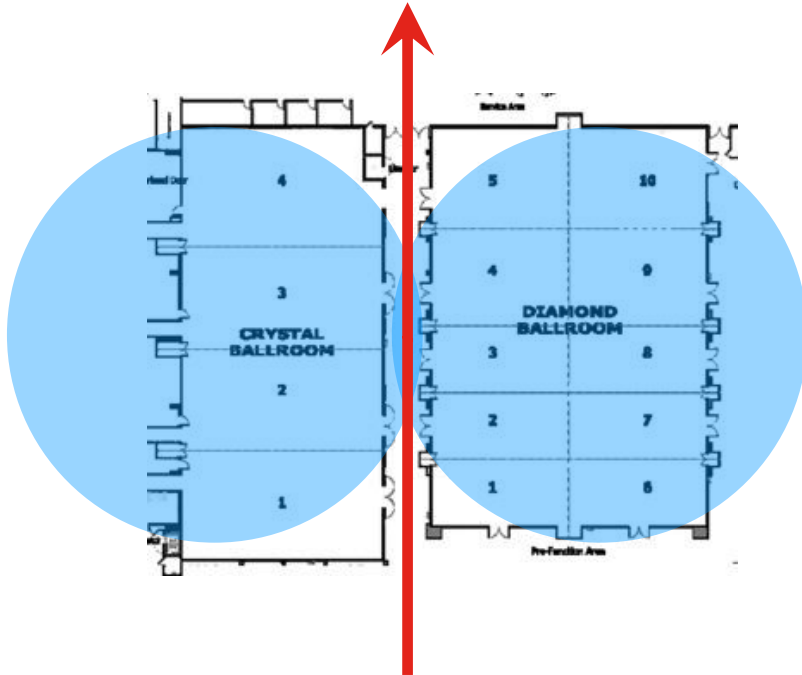
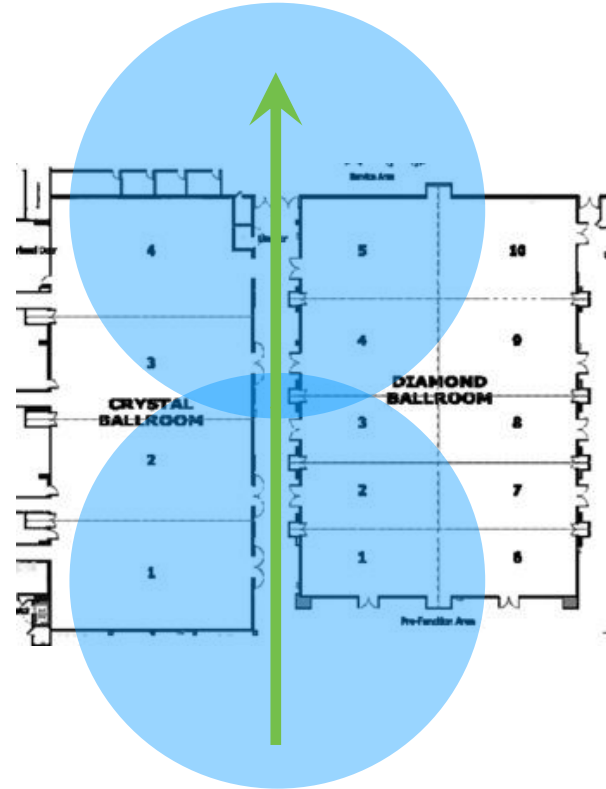
AP Placement and Roaming Optimisation



Avoiding Ping Pong Zones



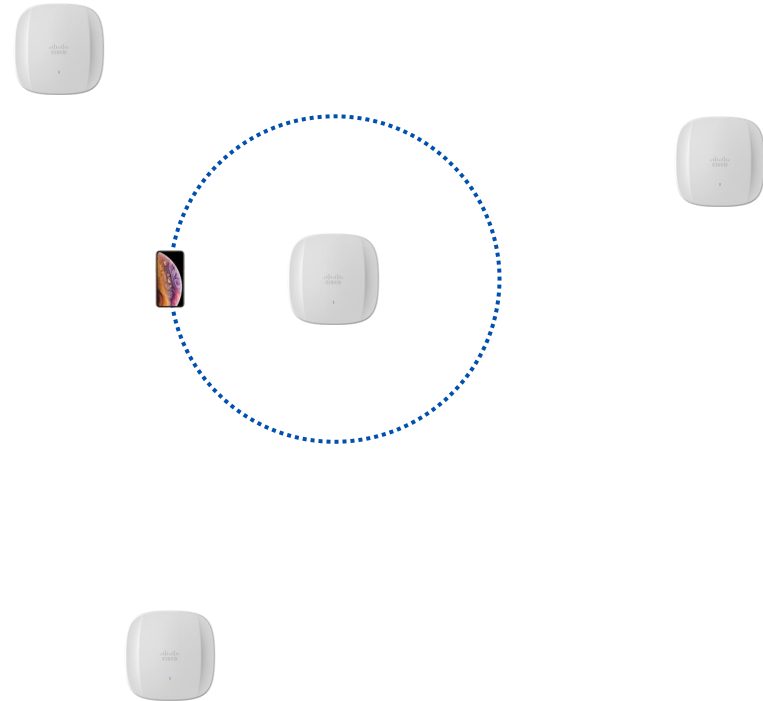
Avoiding Ping Pong Zones



BSS Transition with 802.11k and 802.11v

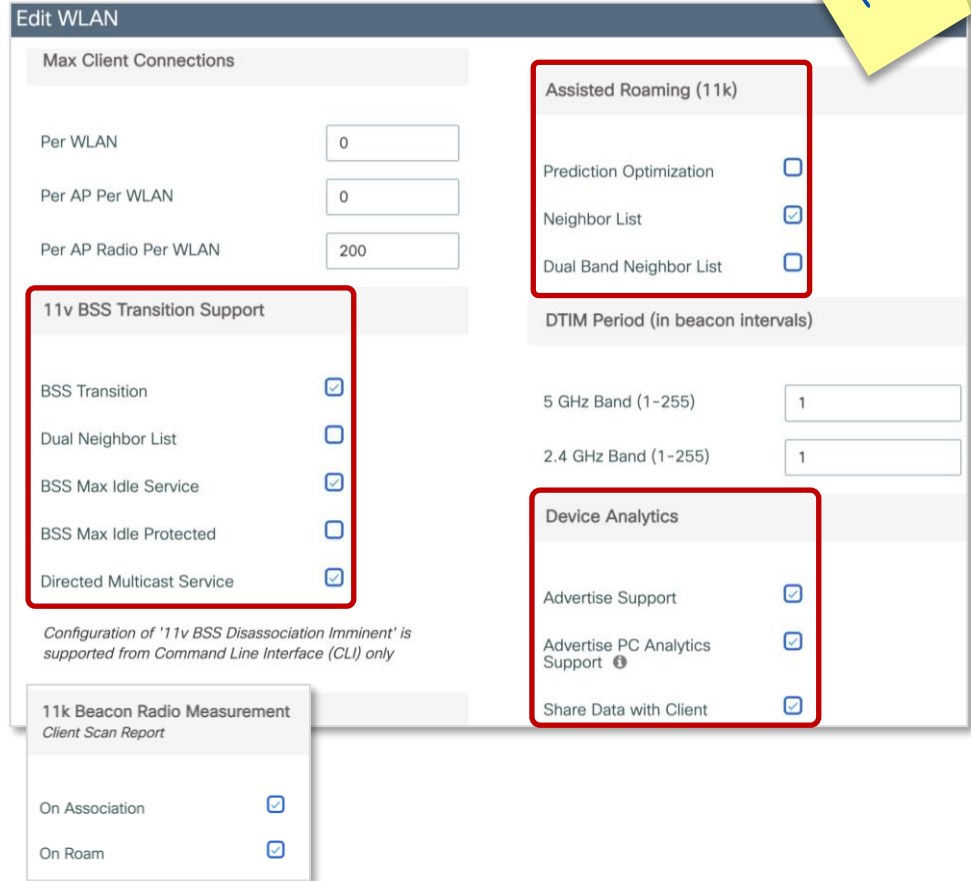
Multi-Band Operation

- 802.11k (Neighbour and Beacon Report)
 - Provides a list of the neighbouring APs
 - Reduces the number of channels the client needs to scan
- 802.11v (BSS Transition Management)
 - Solicited Request
 - Unsolicited Request
 - AP load too high
 - Client RSSI to low
 - DFS event
 - High Priority Request
 - Disassociation Imminent



Enabling Support

- Individually 802.11k & 802.11v
 - No downsides or impacts
- Enable Device Analytics
 - Advertise Support
 - Samsung Analytics
- Advertise PC Analytics Support
 - Intel Analytics
- Share Data with Client
 - Samsung onboard AI/ML optimiser
- Enable 11k client scan reports for Samsung and Intel clients



FYI

Edit WLAN

Max Client Connections

Per WLAN: 0

Per AP Per WLAN: 0

Per AP Radio Per WLAN: 200

11v BSS Transition Support

BSS Transition: ☒

Dual Neighbor List: ☐

BSS Max Idle Service: ☒

BSS Max Idle Protected: ☐

Directed Multicast Service: ☒

Configuration of '11v BSS Disassociation Imminent' is supported from Command Line Interface (CLI) only

11k Beacon Radio Measurement Client Scan Report

On Association: ☒

On Roam: ☒

Assisted Roaming (11k)

Prediction Optimization: ☐

Neighbor List: ☒

Dual Band Neighbor List: ☐

DTIM Period (in beacon intervals)

5 GHz Band (1-255): 1

2.4 GHz Band (1-255): 1

Device Analytics

Advertise Support: ☒

Advertise PC Analytics Support: ☒

Share Data with Client: ☒

Apple

Roaming optimisation support for Apple devices

Apple devices support these assisted roaming technologies:

Technology	802.11k	802.11r	PMKID	802.11u	802.11v
iPhone 5s or later	✓	✓	✓	✓	✓
iPad Pro 13-inch (M4)	✓	✓	✓	✓	✓
iPad Pro 9.7-inch or later	✓	✓	✓	✓	✓
iPad Air (1st generation) or later	✓	✓	✓	✓	✓
iPad (5th generation) or later	✓	✓	✓	✓	✓
iPad mini 2 or later	✓	✓	✓	✓	✓
Apple Vision Pro	✓	✓	✓	✓	✓
Mac with Apple silicon	✓	✓	✓	✓	✓
Intel-based Mac	✗	✗	✓	✓	✗



[Wi-Fi roaming support in Apple devices](#)

Samsung



Save roaming channels

- The purpose of roaming is to provide a seamless data experience. However, data may be muted while performing roaming scans. To remedy this, Samsung mobile devices support partial scanning for a more efficient roaming performance.
- For a partial scan, a mobile device maintains a list of channels containing the same SSID at every scan. During roaming, the device will only scan for the channels in this list instead of a full-channel scan. This helps the device to update the scan list at a much faster rate.
- For example, on Galaxy S series, an active scan takes 40ms and a passive scan (on DFS channels) takes 130ms. With this, a legacy full-scan takes about 2800ms to complete while a partial scan with 7 saved channels will only take about 280ms — a 90% improvement.

Enhanced roaming algorithm

Enabling Support

FYI

- Individually 802.11k & 802.11v
 - No downsides or impacts
- Enable Device Analytics
 - Advertise Support
 - Samsung Analytics
 - Advertise PC Analytics Support
 - Intel Analytics
- Share Data with Client
 - Samsung onboard AI/ML optimiser
- Enable 11k client scan reports for Samsung and Intel clients

The screenshot shows the 'Advanced Settings' page in Cisco Catalyst Center. The 'SSID Name' is 'SecureFastRoam'. Under 'MFP Client Protection', 'Optional' is selected. Under 'WLAN Timeouts', 'Session Timeout' is set to 180 seconds, 'Client Exclusion' is set to 300 seconds, and 'Client User Idle Timeout' is set to 300 seconds. A red box highlights the '11v BSS Transition Support' section, which includes 'BSS Max Idle Service' and 'Directed Multicast Service'. An overlay window titled 'Add Advanced SSID Configuration' is shown, displaying the 'Design Name' field and tabs for 'General', 'Client Data Rates', 'SSID Data Rates', and 'More'. The 'Device Analytics' section in the overlay shows three toggles: 'Share Data with Client', 'Advertise Support', and 'Advertise PC Analytics Support', all of which are enabled.

Advanced Settings

Configure the advanced fields to complete the configuration

SSID Name: SecureFastRoam

MFP Client Protection

☐ Optional ☐ Required ☒ Disabled

☒ 11k - Neighbor List

WLAN Timeouts

☒ Session Timeout

☒ Client Exclusion

☒ Client User Idle Timeout

11v BSS Transition Support

☒ BSS Max Idle Service

☒ Directed Multicast Service

Add Advanced SSID Configuration

This capability is used for configuring the advanced SSID parameters on the device

Design Name*

General Client Data Rates SSID Data Rates More ▾

Device Analytics (Not supported for AireOS)

☒ Share Data with Client

☒ Advertise Support

☒ Advertise PC Analytics Support

In (secs)* 180 Range is from 0 to 2147483647

In (secs)* 300 Range is from 15 to 100000

Device Analytics

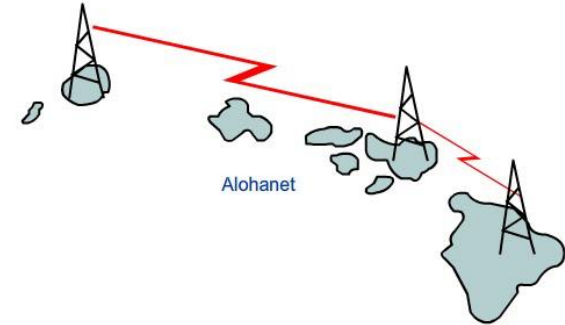
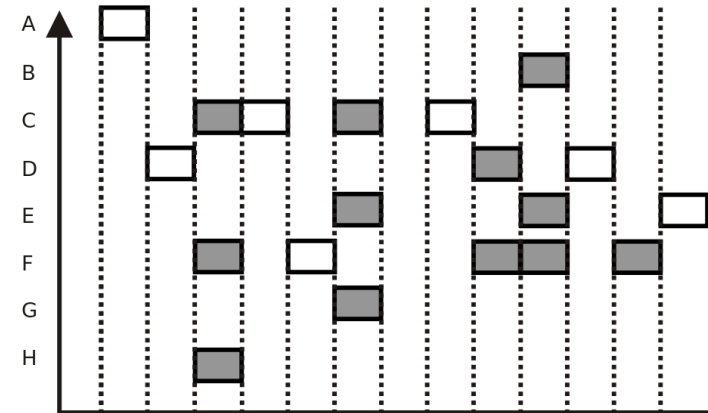
FYI

		Intel	Apple	Samsung
What is the client type?	Catalyst 9800	Device Analytics > Advertise PC Analytics support	Automatic	Device Analytics > Advertise support
	Meraki Dashboard	Automatic Cannot be disabled	Automatic Cannot be disabled	
How does the client see the network?	Catalyst 9800	Automatic at (re)association if PC Analytics is enabled Also sent dynamically	Automatic at (re)association	Automatic at (re)association if Device Analytics is enabled Also sent dynamically
	Meraki Dashboard	Automatic Cannot be disabled	Automatic Cannot be disabled	
Why did the client leave?	Catalyst 9800	Automatic if Advertise PC Analytics support enabled	Automatic	Automatic if Device Analytics is enabled
	Meraki Dashboard	Automatically on, cannot be turned off	Automatically on, cannot be turned off	
For better client experience	Catalyst 9800	Enable 802.11k/v and Device Analytics > Share Data with Client. Cisco sends the STA info about AP to tune its algorithms to understand what is a good AP		
	Meraki Dashboard			

Carrier Sense Multiple Access / Collision Detect

FYI

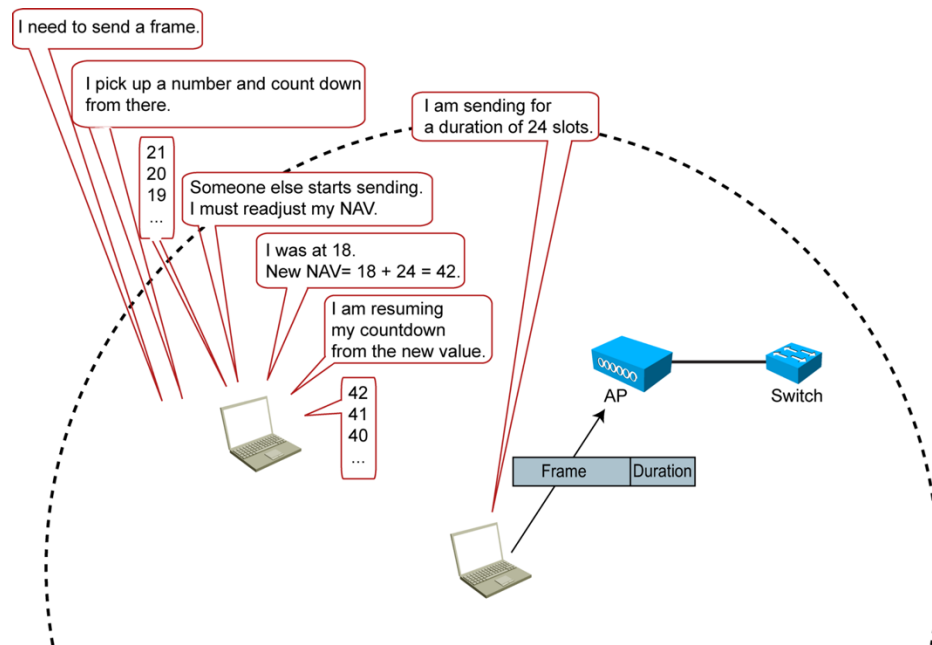
- Pure ALOHA
 - If you have data, send it
 - If you receive data while sending, there is a message collision and you must retransmit
- Slotted ALOHA
 - Stations only send at start of timeslot
 - Reduces collisions
- Clear Channel Assessment
 - Energy detection
 - Hidden Node Problem



Slotted ALOHA protocol (shaded slots indicate collision)

Carrier Sense Multiple Access / Collision Avoidance

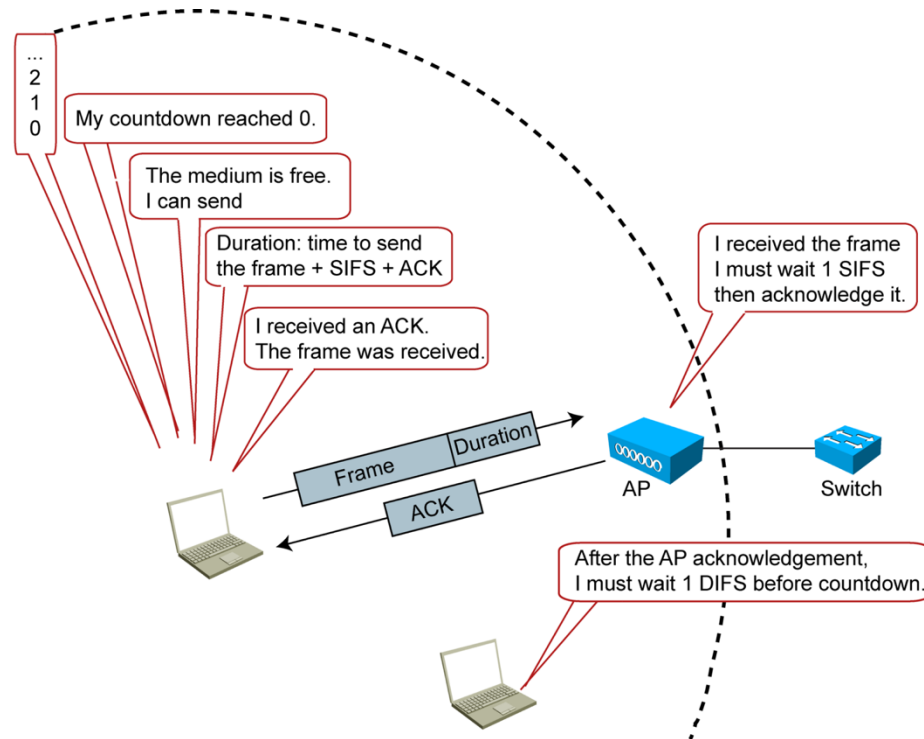
- Back-off Timer
 - Random number for countdown
- Contention Window (CW)
 - Backoff timer range
 - CWMin → CWMax
 - Differentiated back-off times to implement priorities
- Network Allocation Vector (NAV)
 - Total wait time before sending
 - Adjusted on energy detect



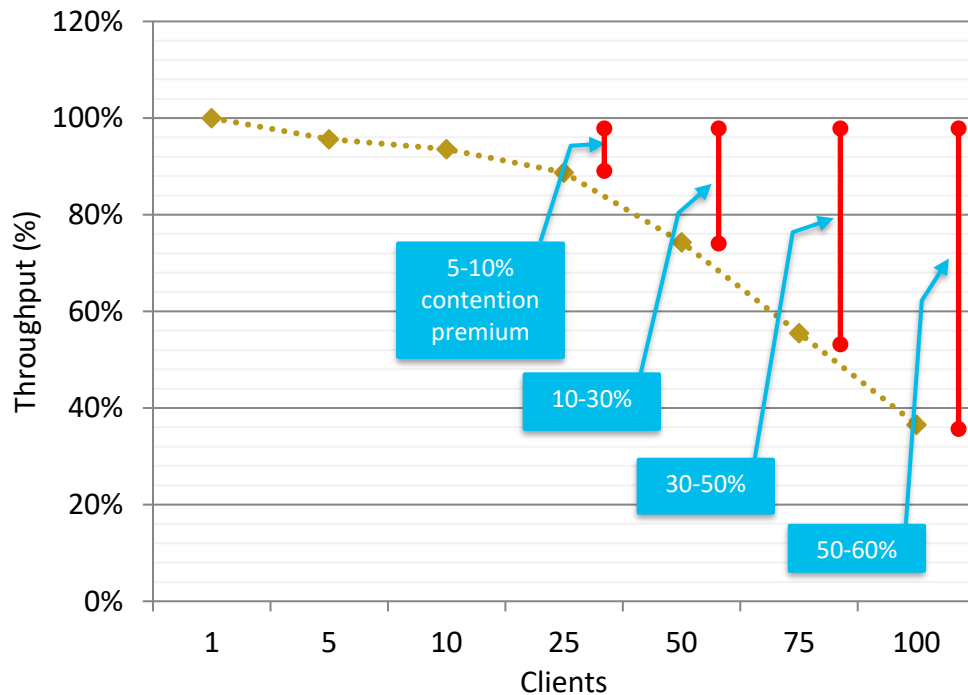
Carrier Sense Multiple Access / Collision Avoidance

FYI

- Short Interframe Space (SIFS)
 - Silence between unicast frame and ACK
- Acknowledgement (ACK)
 - Acknowledgement frame sent by receiver to confirm receipt of the packet
- Distributed Interframe Space (DIFS)
 - Silence between transmissions
- Arbitration Interframe Space (AIFS)
 - DIFS equivalent for 802.11e QoS

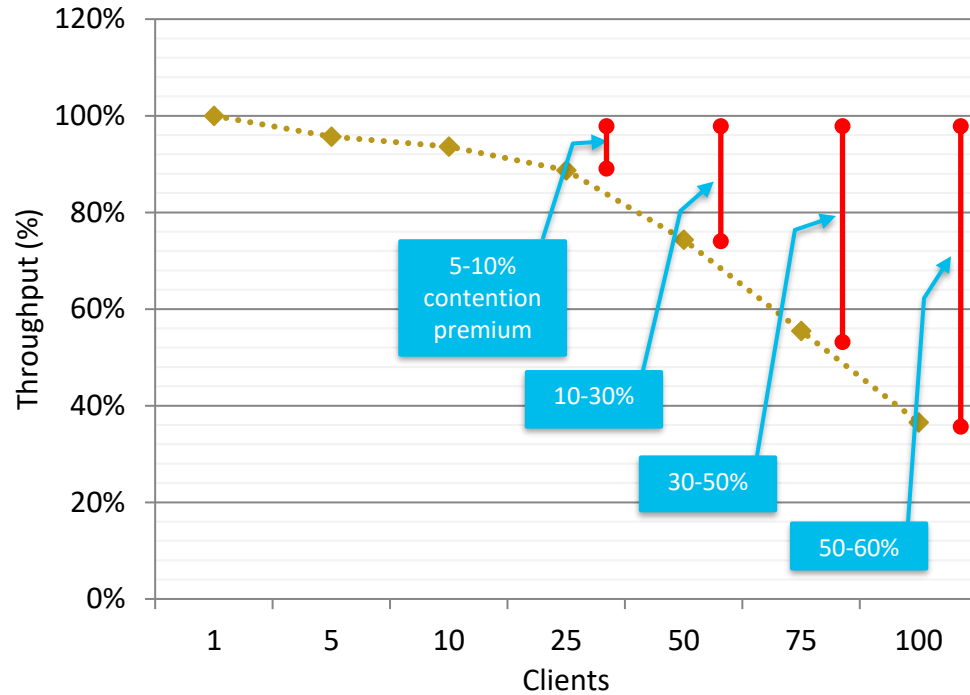


The Contention Breaking Point



- As more clients associate and transmit, WLAN contention increases for all clients
- Retries and back off windows increase
- Each station spends more and more time in the “waiting and listening” state
- This results in a significant decrease in per-station performance

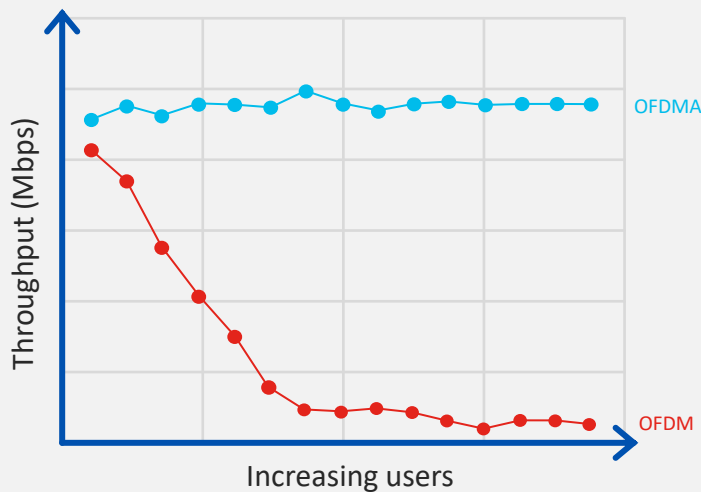
The Contention Breaking Point



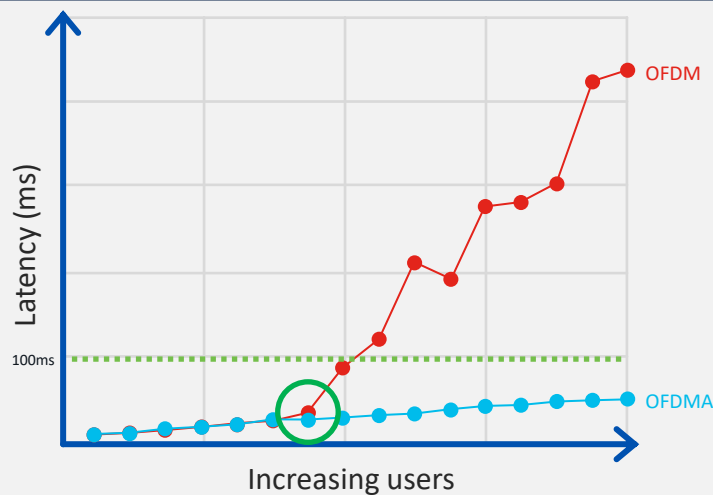


Deterministic Wireless

Consistent **Data** Throughput



Linear **Voice and Video** Delay

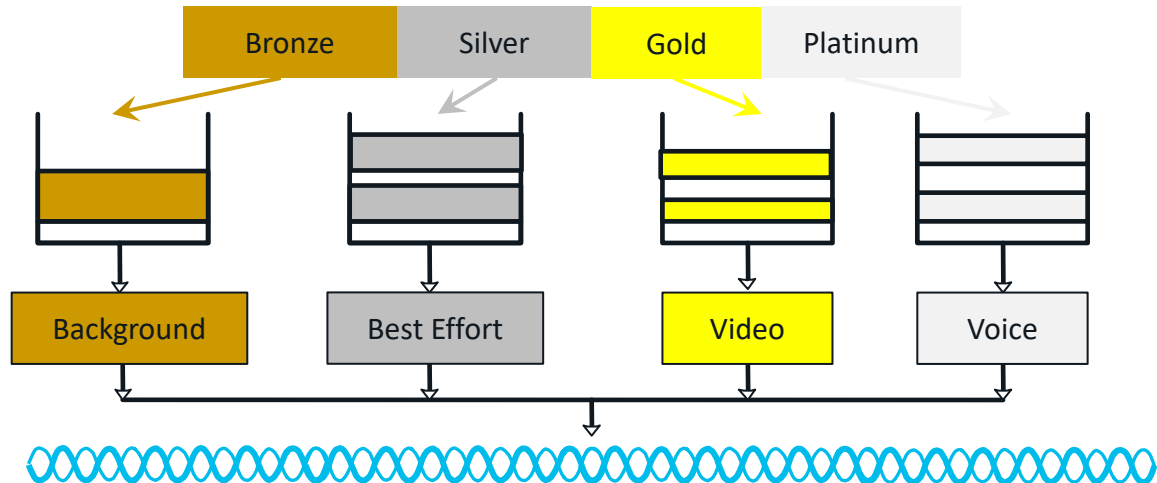


QoS Enhancements with 802.11e

Wireless Multi-Media

- Enhanced Distributed Channel Access (EDCA)

- EDCA established 4 queues known as Access Categories
- Each AC queue maintains different
 - Arbitration Inter Frame Spacing (AIFS) timers
 - Contention Window sizes
 - CWmin and Cwmax



IP DSCP to 802.11e User Priority Mapping



Internet Engineering Task Force (IETF)
Request for Comments: 8325
Category: Standards Track
ISSN: 2070-1721

T. Szigeti
J. Henry
Cisco Systems
F. Baker
February 2018

Mapping Diffserv to IEEE 802.11

Abstract

As Internet traffic wireless endpoints, aligned between wlr always the case by mappings from Diffe 802.11 User Priorit offered by the IETF treatment between w

IETF Diffserv Service Class	PHB	Reference RFC	IEEE 802.11 User Priority	Access Category
Network Control (reserved for future use)	CS7	RFC 2474	7 OR 0	AC_VO (Voice)
Network Control	CS6	RFC 2474	7 OR 0	AC_VO (Voice)
Telephony	EF	RFC 3266	6	AC_VO (Voice)
VOICE-ADMIT	VA	RFC 5865	6	AC_VO (Voice)
Signaling	CS5	RFC 2474	5	AC_VI (Video)
Multimedia Conferencing	AF41 AF42 AF43	RFC 2597	4	AC_VI (Video)
Real-time Interactive	CS4	RFC 2474	4	AC_VI (Video)
Multimedia Streaming	AF31 AF32 AF33	RFC 2597	4	AC_VI (Video)
Broadcast Video	CS3	RFC 2474	4	AC_VI (Video)
Low-Latency Data	AF21 AF22 AF23	RFC 2597	3	AC_BE (Best Effort)
OAM	CS2	RFC 2474	0	AC_BE (Best Effort)
High-Throughput Data	AF11 AF12 AF13	RFC 2597	0	AC_BE (Best Effort)
Standard	DF	RFC 2474	0	AC_BE (Best Effort)
Low-Priority Data	CS1	RFC 3662	1	AC_BK (Background)



DSCP



UP



IETF Traffic Class	PHB
Network Control	CS6
Voice (46), Voice-Admit(44)	EF,VA
Signaling	CS5
Multimedia Conferencing	AF4x
Real-time Interactive	CS4
Multimedia Streaming	AF3x
Broadcast Video	CS3
Low Latency Data	AF2x
OAM	CS2
High Throughput Data	AF1x
Standard (Best Effort)	DF
Low Priority Data	CS1

AC	UP
AC_VO	7
AC_VO	6
AC_VI	5
AC_VI	4
AC_VI	4
AC_VI	4
AC_VI	4
AC_BE	3
AC_BE	0
AC_BE	0
AC_BE	0
AC_BK	1

Voice

Video

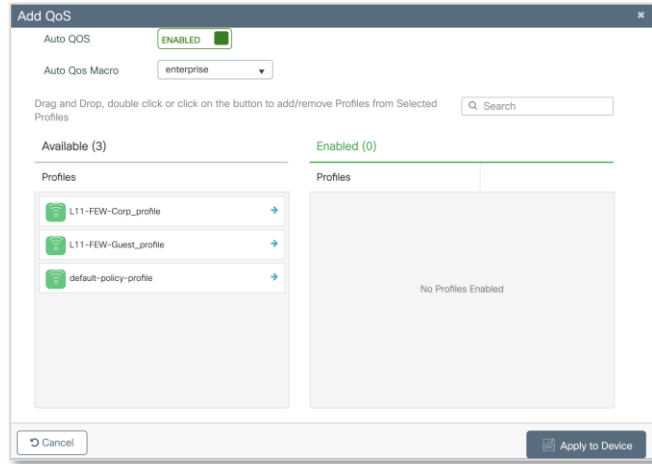
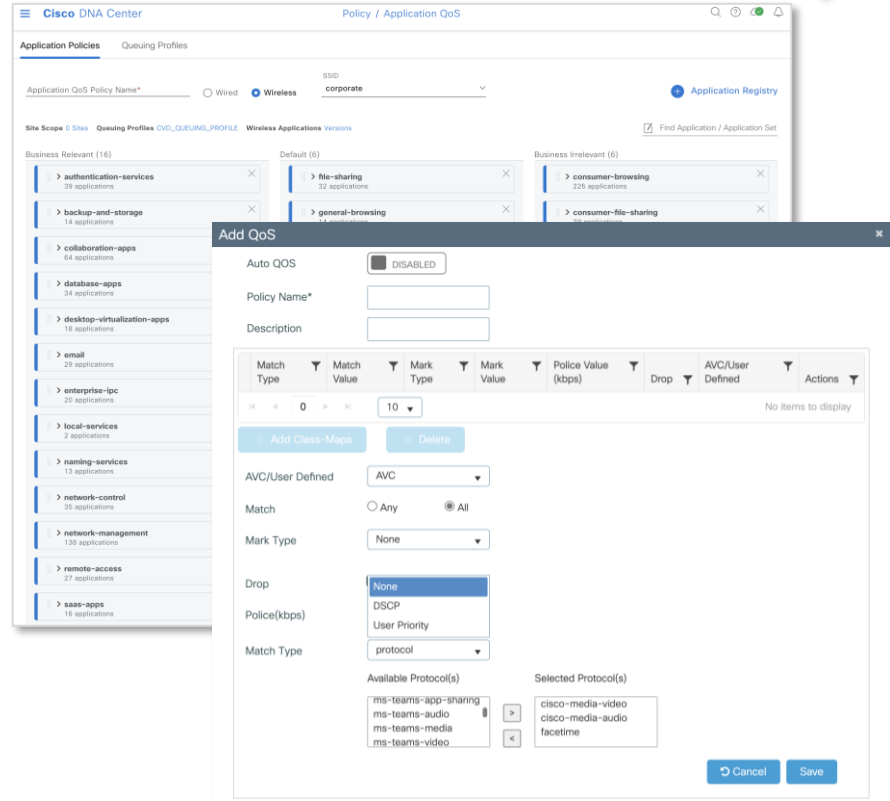
Best Effort

Background

Application Visibility and Control (AVC)

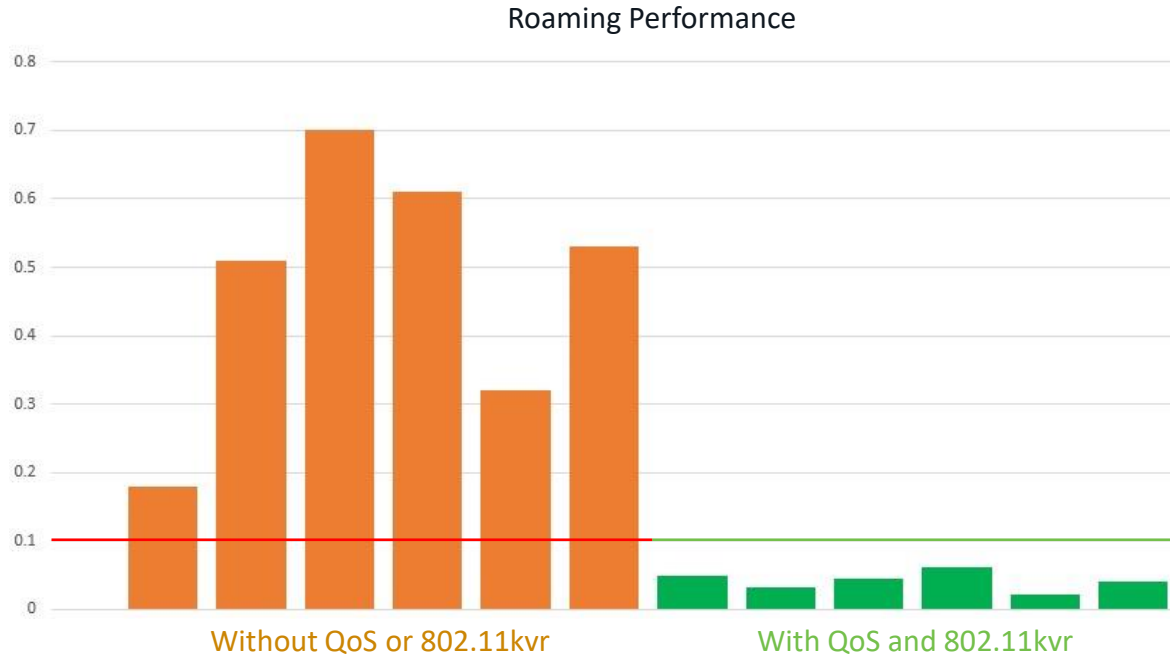
FYI

- AVC provides traffic visibility and ensures that marking stays consistent in both directions

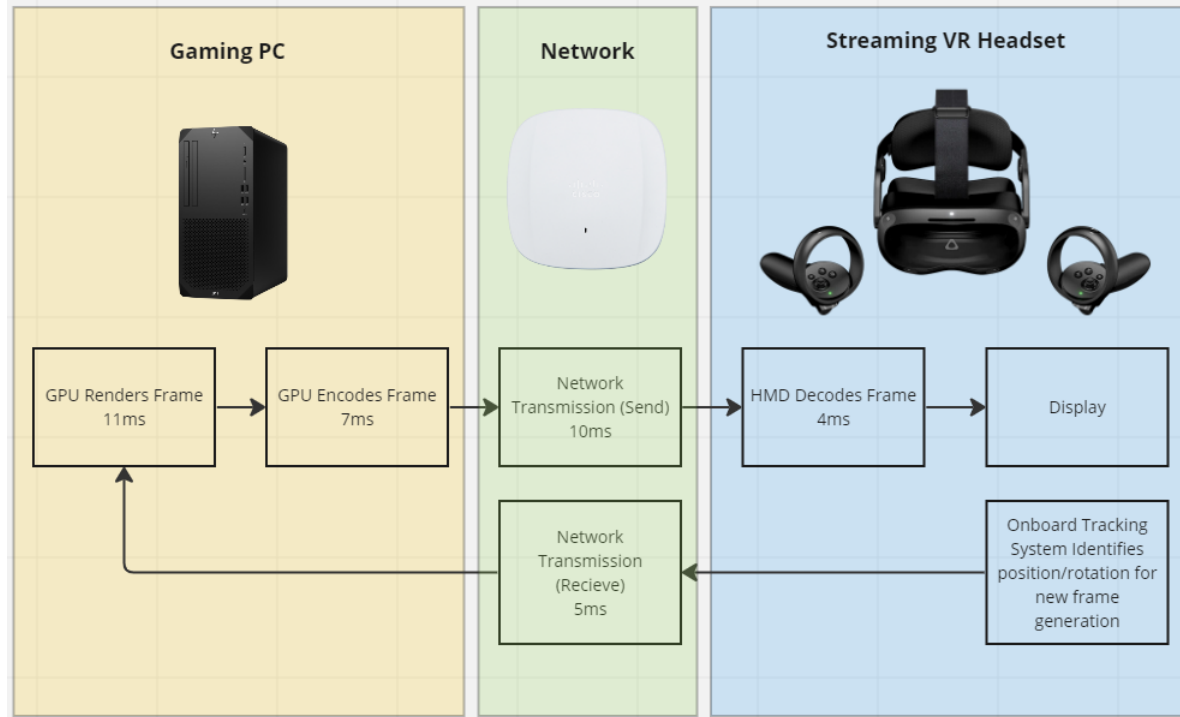


Putting it All Together

- Measuring time interval between last packet on previous AP and first packet on next AP for voice call while roaming



Designing for Virtual Reality Latency Requirements



FastLane+

Advanced Scheduling Request

- For traditional OFDMA, the client sends a periodic Buffer Status Report (BSR) with the amount of traffic in the buffer for each QoS queue
- FastLane+ allows for the client to send an Advanced Scheduling Request (ASR) to reserve bandwidth resources for latency-sensitive real-time voice and video applications

Add Advanced SSID Configuration

This capability is used for configuring the advanced SSID parameters on the device

Design Name*

Lock all ⓘ

GeneralClient Data RatesSSID Data RatesMore ▾

Miscellaneous (Not supported for AireOS)

☐

Media Stream Multicast-Direct ⓘ

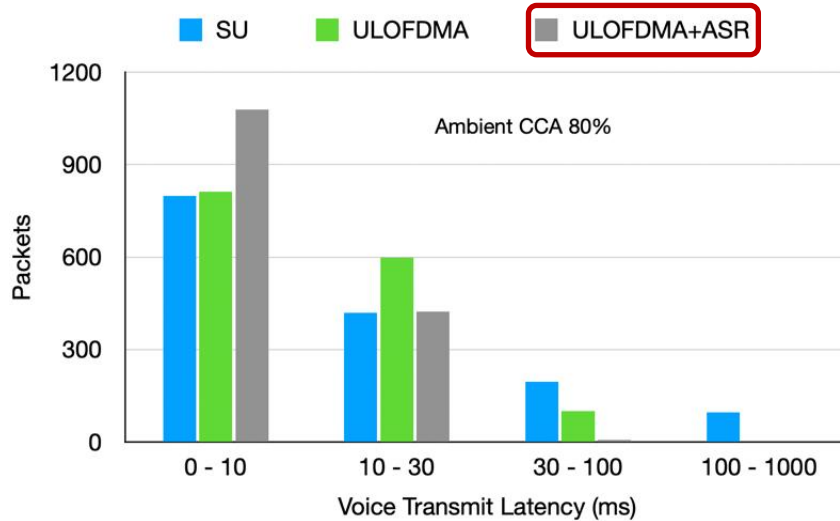
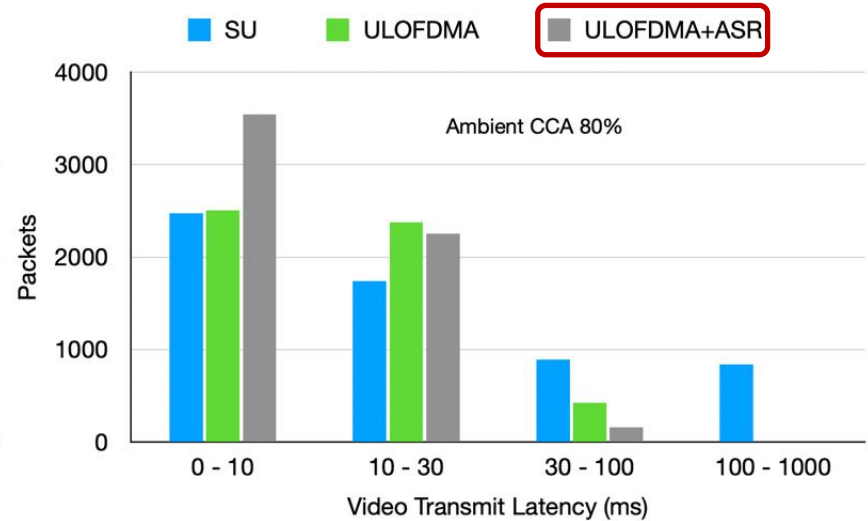
☒

802.11ac MU-MIMO ⓘ

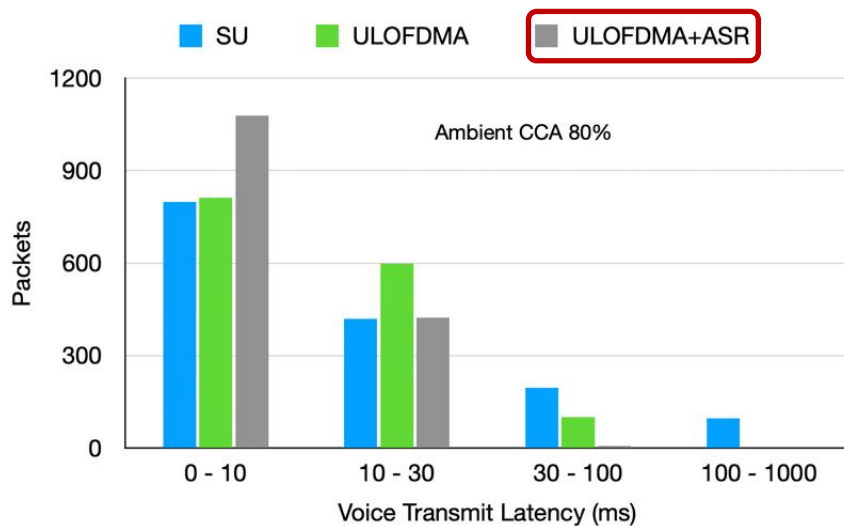
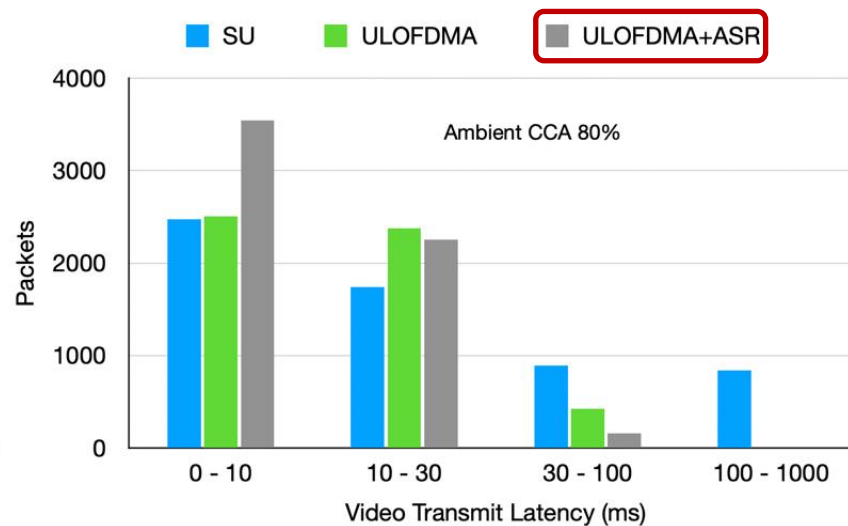
☒

Wifi To Cellular Steering ⓘ☒☒☐☐☒☐☐☐☒

FastLane+ Advanced Scheduling Requests



Triggered UL Access Optimisation



Wireless Network Design

- Two levers for improving signal quality
 - Increase the signal
 - Decrease the noise
- Three dimensions to Wi-Fi performance
 - Spatial Multiplexing
 - Digital Modulation
 - Channel Aggregation

Design with your clients in mind

- Consider client transmit power
- APs set to max transmit power is an indication something is wrong
- Ensure cell overlap to facilitate roaming
- Understand how APs hear each other along roaming pathways
- Enable available features to support seamless roaming and real-time applications
- Planning tools and site surveys are critical to success



Thank you

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Wednesday
10:30am – 11:30am



Experiences Amplified:
How AI Can Fuel Better Employee and Customer Experiences

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Room 106



Smart, Secure, Seamless:
Transforming Experiences with Next-Generation Networking

Level 2
Room 204



Harness a Bold New Era:
Transform Data Centre and Service Provider Connectivity

Level 2
Room 203



Securing User to Application and Everything in Between

Level 2
Melbourne Room 2



Unlocking Digital Resilience through Unified Observability

The HUB
Centre Stage

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- Book your one-on-one
Meet the Expert meeting
- 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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