Wi-Fi 6E

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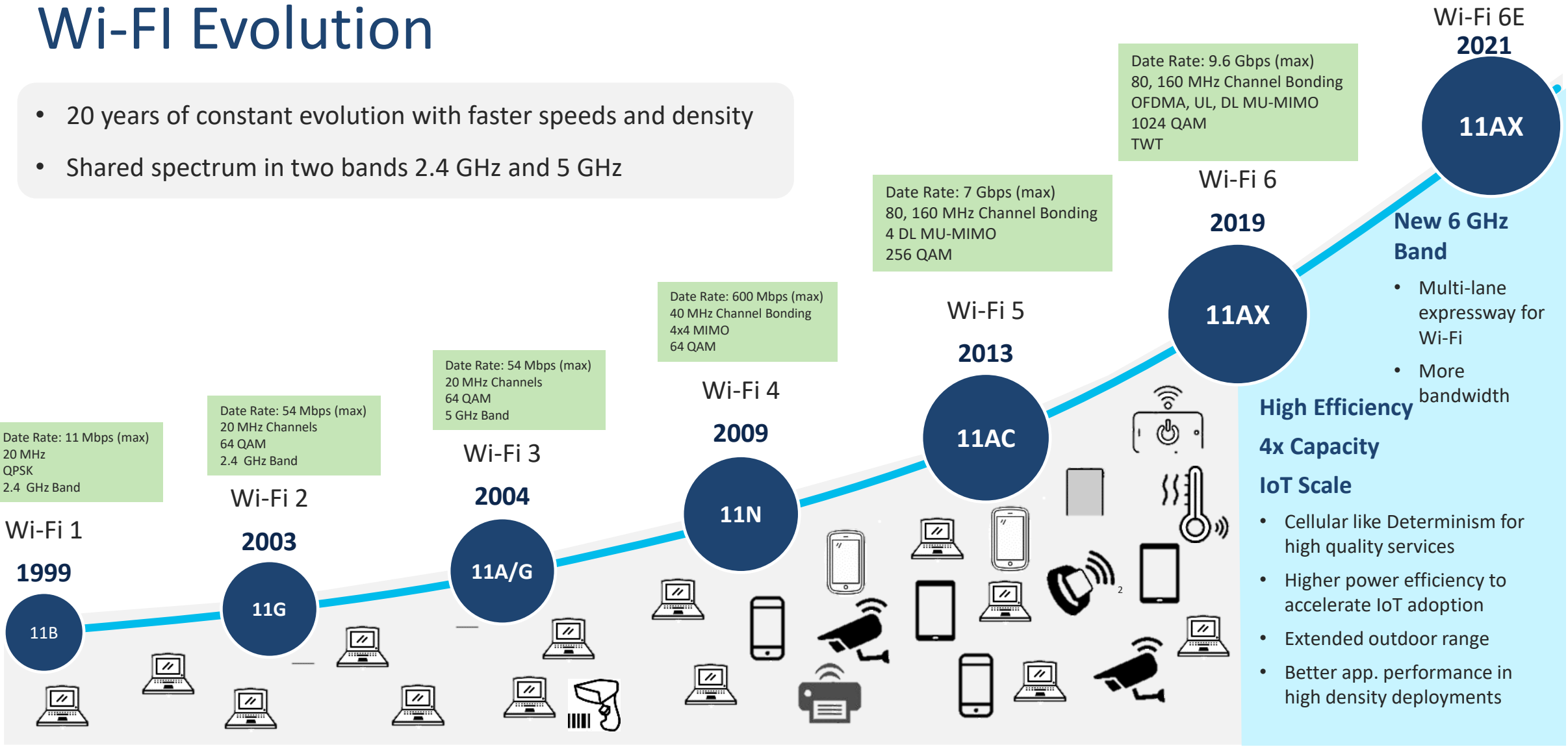
Wi-FI Evolution

- 20 years of constant evolution with faster speeds and density
- Shared spectrum in two bands 2.4 GHz and 5 GHz



Wi-Fi 6E

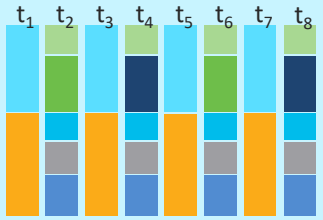
Wi-Fi 6 and 6GHz are friends

802.11ax

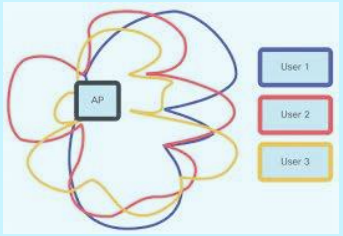
1024 QAM

BSS Coloring

OFDMA



DL, UL MU-MIMO



TWT

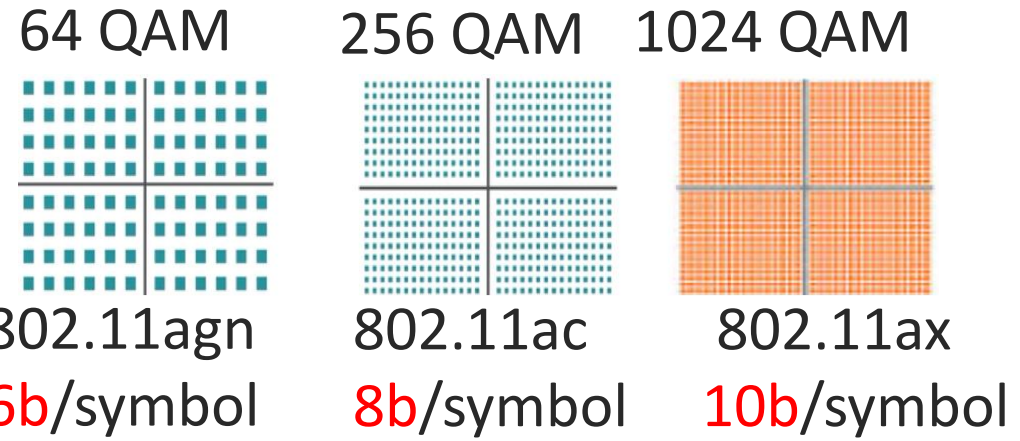
- Additional Spectrum
  - 1200MHz (5.925 GHz to 7.125 GHz) in US
  - 500 MHz (5.925 GHz to 6.425 GHz) in EU
- Wider Channels
- Clean RF
- No Slow Devices
- Security Upgrade
- 6 GHz WLAN Discovery
- Air Time Efficiency

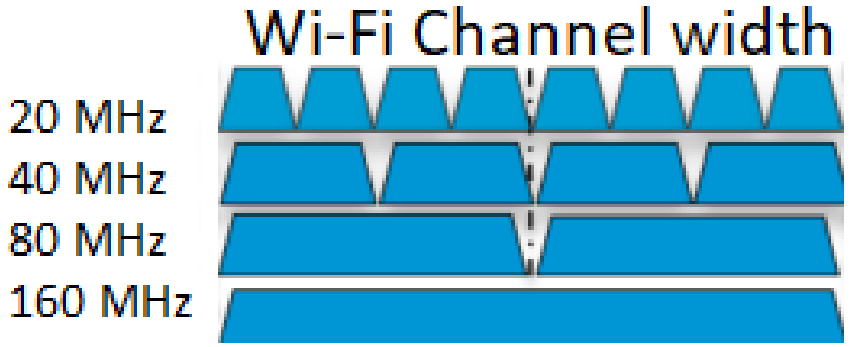
802.11ax is all about High Efficiency Wireless

These improvements are RF enhancements to make EVERY microsecond “ON THE AIR” matter.

- .11ax High Efficiency Wireless (HEW) is all about optimizing the time spend “ON THE AIR” and how much information is on the air during any given Micro Second “uS”
- **Four things determine Air Time efficiency**
  1. **Data Rate (Modulation Density) or QAM - (how many Bit’s per Radio Symbol) 64 QAM is more robust but 1024 QAM is a lot faster**
  2. **Number of Spatial Streams & Spatial reuse (introduction of OFDMA and Resource Units)**
  3. **Channel Bandwidth – How Many Frequencies can we modulate at one time**
  4. **Protocol Overhead – Preamble/Ack/BA, Guard Interval “GI” etc.**

Modulation Density Gains





Note: Channel Bonding reduces range as the power is spread out with each additional 20 MHz adding a 3 dB penalty in SNR and the greater the QAM the harder it is for the receiver to decode therefore it is more sensitive to noise.

.11ax Data-rate Chart for 1 Spatial Stream

Complex Modulation, Guard Interval and channel bonding is key to single radio performance.

Modulation and coding schemes for single spatial stream

MCS index[a]	Modulation type	Coding rate	Data rate (in Mb/s)[b]							
			20 MHz channels		40 MHz channels		80 MHz channels		160 MHz channels	
			1600 ns GI[c]	800 ns GI	1600 ns GI	800 ns GI	1600 ns GI	800 ns GI	1600 ns GI	800 ns GI
0	BPSK	1/2	4(?)	8.6	8(?)	17.2	17(?)	36	34(?)	36(?)
1	QPSK	1/2	16	17	33	34	68	72	136	144
2	QPSK	3/4	24	26	49	52	102	108	204	216
3	16-QAM	1/2	33	34	65	69	136	144	272	282
4	16-QAM	3/4	49	52	98	103	204	216	408	432
5	64-QAM	2/3	65	69	130	138	272	288	544	576
6	64-QAM	3/4	73	77	146	155	306	324	613	649
7	64-QAM	5/6	81	86	163	172	340	360	681	721
8	256-QAM	3/4	98	103	195	207	408	432	817	865
9	256-QAM	5/6	108	115	217	229	453	480	907	961
10	1024-QAM	3/4	122	129	244	258	510	540	1021	1081
11	1024-QAM	5/6	135	143	271	287	567	600	1134	1201

For Your Reference

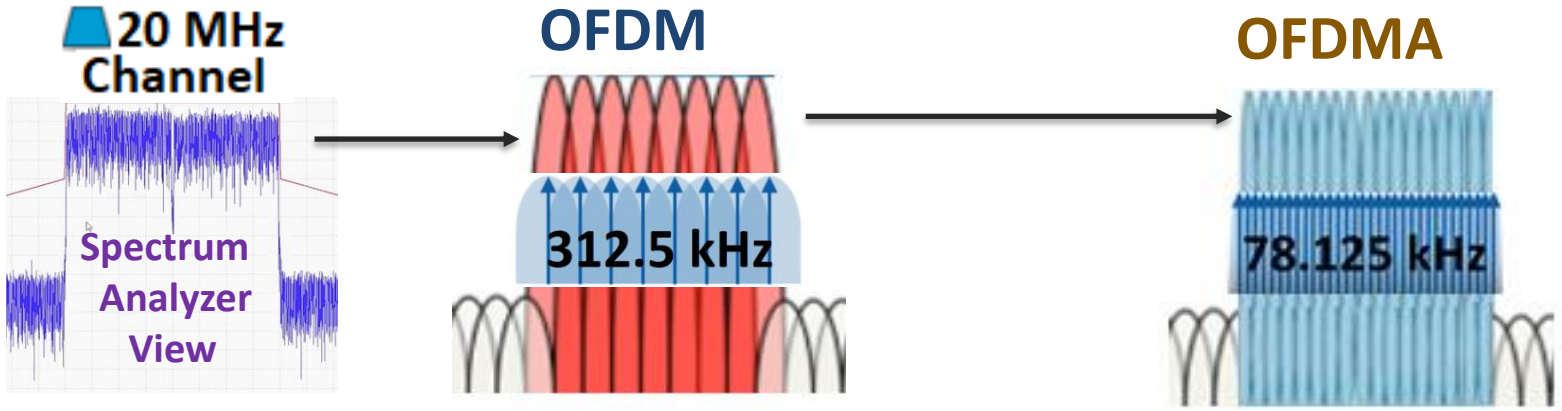
Up to 1.2Gb with 1 radio, up to 11 Gb* with 8 radios @ 160 MHz

***Devices were presented at CES 2018 with a top speed of 11Gbit/s**

Source https://en.wikipedia.org/wiki/IEEE_802.11ax

Understanding an OFDM and **OFDMA**

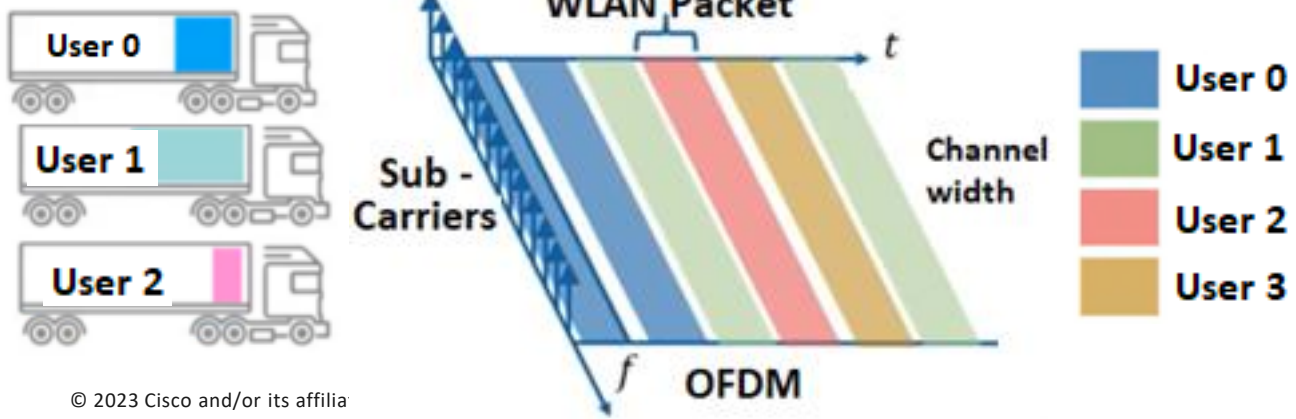
Both divide into sub-channels (carriers) but **OFDMA has more and the concept of Resource Units.**

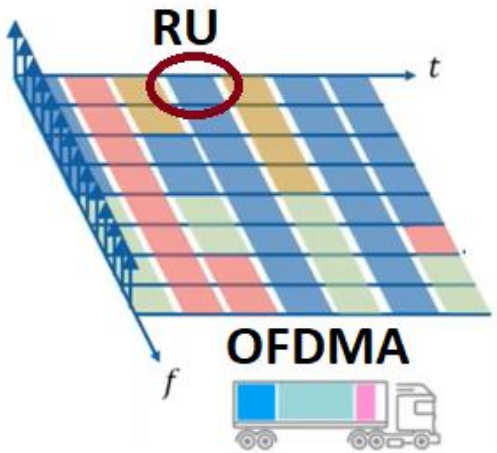


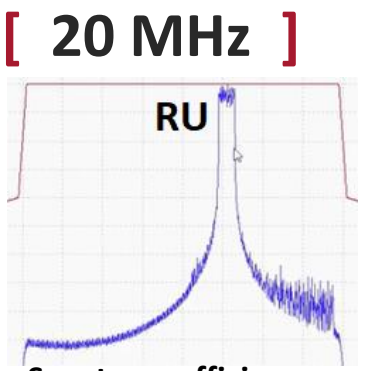
OFDMA divides the same 20 MHz spectrum into many more smaller subcarriers that can carry small packets faster.. Using Resource Units (RU) it allows each subcarrier to handle multiple users

OFDM divides the available spectrum into sub-channels that can be independently modulated and demodulated but each subcarrier has data for only one user at a time - OFDMA = more users at a time.

Take-away – all packets big and small get processed MUCH FASTER





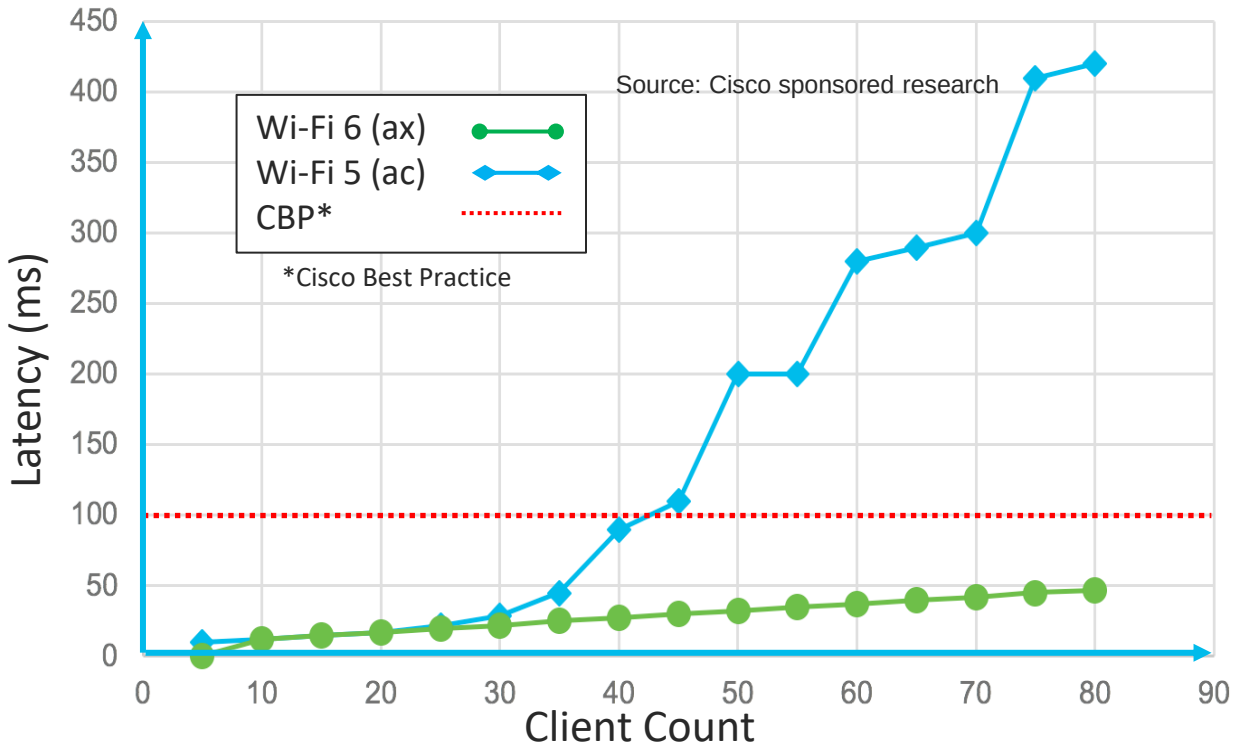


Spectrum efficiency

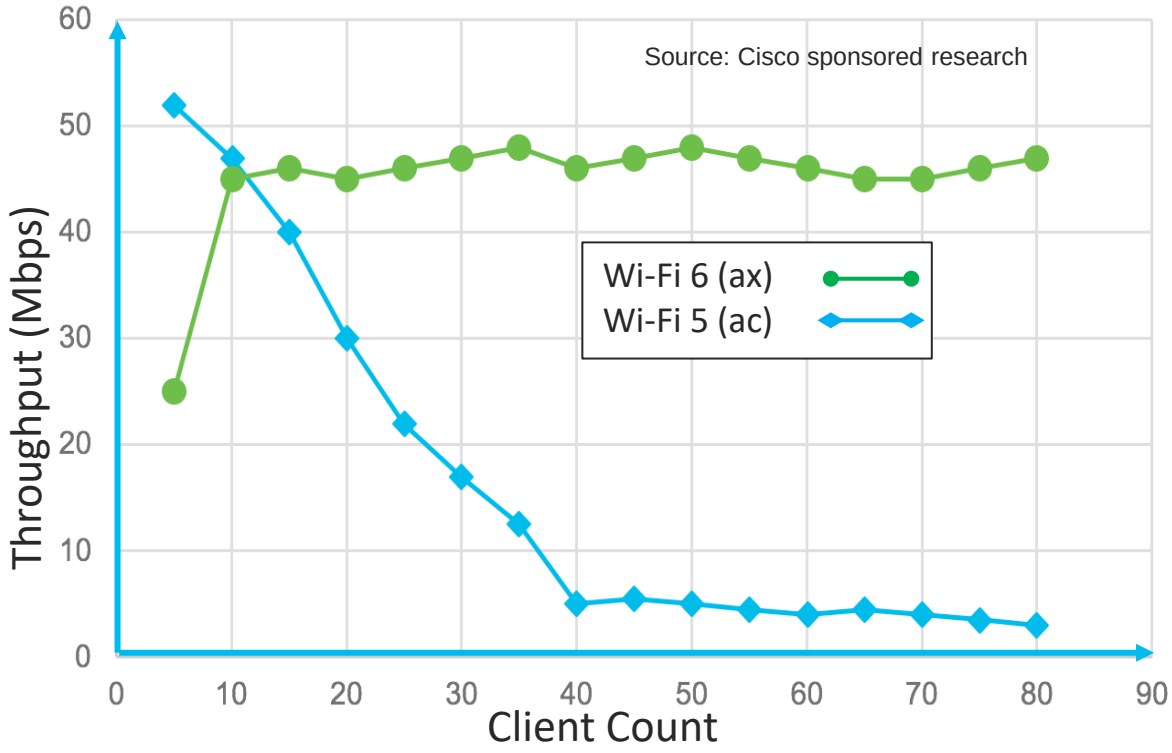
802.11ax (OFDMA) provides determinism at scale:

Enabling high-quality voice/video/data services cost effectively

Linear **VOICE** delay



Consistent **DATA** throughput

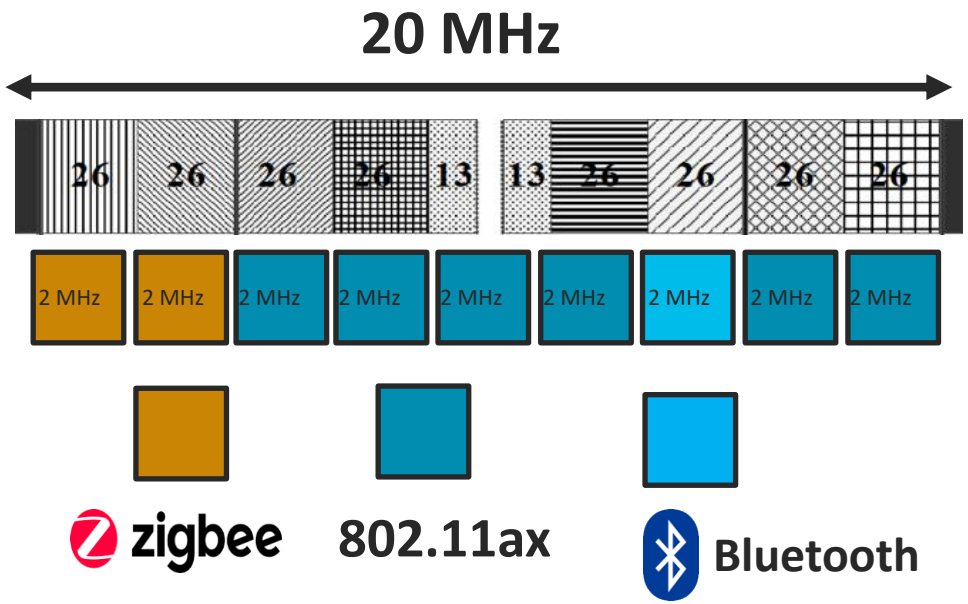


Wi-Fi 6 is not only cost-effective & ubiquitous but is now capable of delivering SLAs

802.11ax RU & Target Wake Time Benefits for IoT

Better Battery Life and co-existence via RF efficiency improvements

- **802.11ax RUs and TWT available in 2.4/5G GHz for IoT**
- **Thanks to 2 MHz channels, Coexistence with other 2.4 GHz IOT technologies is much more effective**
- **Any Channel can be left blank (no 802.11ax) to allow other technologies to operate**



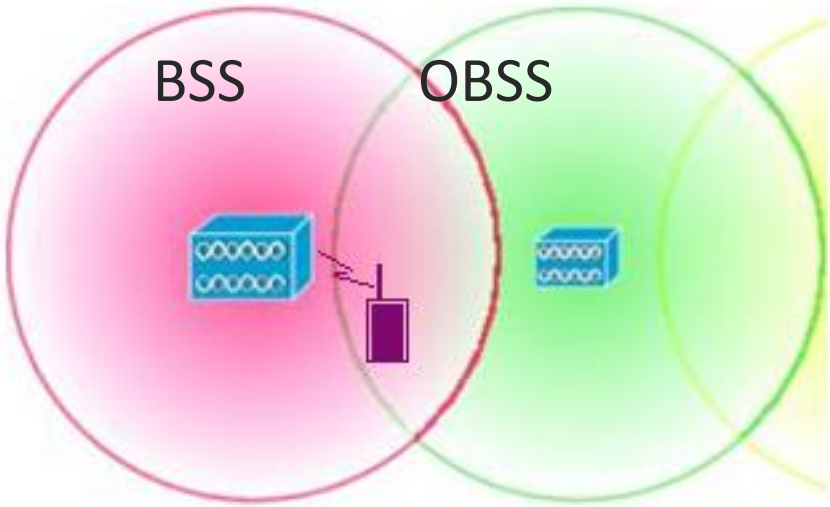
Target Wake Time

Target Wake Time (TWT) provides an effective mechanism to schedule transmissions in time.

Phones and IoT devices can sleep conserving battery life and then wake to take advantage of multi-user transmissions, and coexist in high-density RF environments with ease.

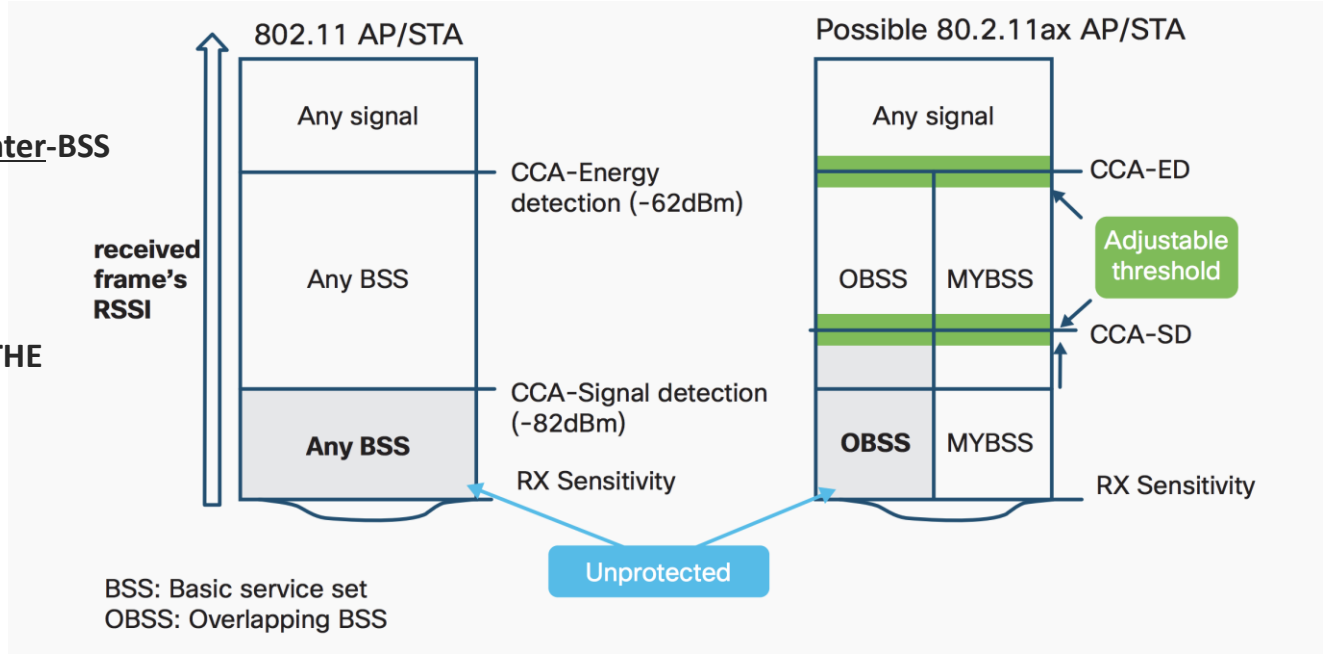
BSS Coloring – Spatial Reuse & addressing interference

Basic service Set “BSS” and Overlapping Basic Service Set “OBSS”



- **BSS Color** – All devices within a BSS send the same value (color), which will be different than other nearby BSSs (or OBSSs)
  - Each BSS (AP) uses a different “color” (6 bits in the preamble)
  - Each user (station) learns its BSS color upon association, allowing it to identify other BSS’s as OBSS
  - Stations detecting the same BSS color (intra-BSS) use a lower RSSI threshold for deferral which reduces Intra BSS collisions
  - Stations detecting a different BSS color (Inter-BSS) use a higher RSSI threshold, which allows more simultaneous transmissions
- OBSS Packet Detection is dynamic and managed by the AP
- If a station reduces its TX power, the device *can* raise its CCA thresholds and transmit ☺
  - TX Power reduction is based on Sounding Packets
  - Effectively RF locating the Client within the cell
  - The closer the client is to the AP, LOWER it’s transmitted power can be

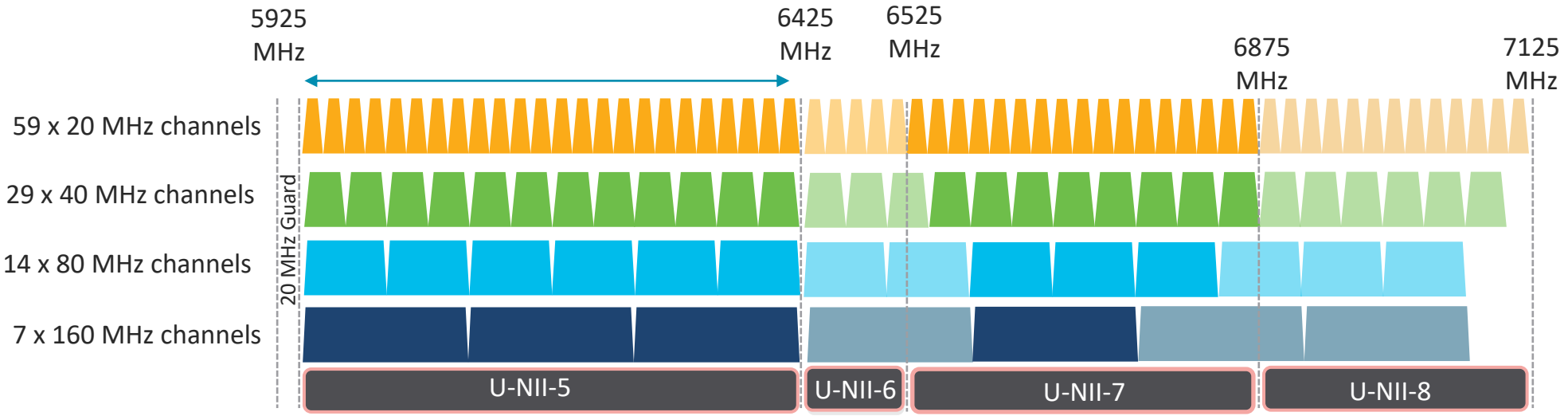
Benefit - Overcomes the problem of Clear Channel Assessment limitations



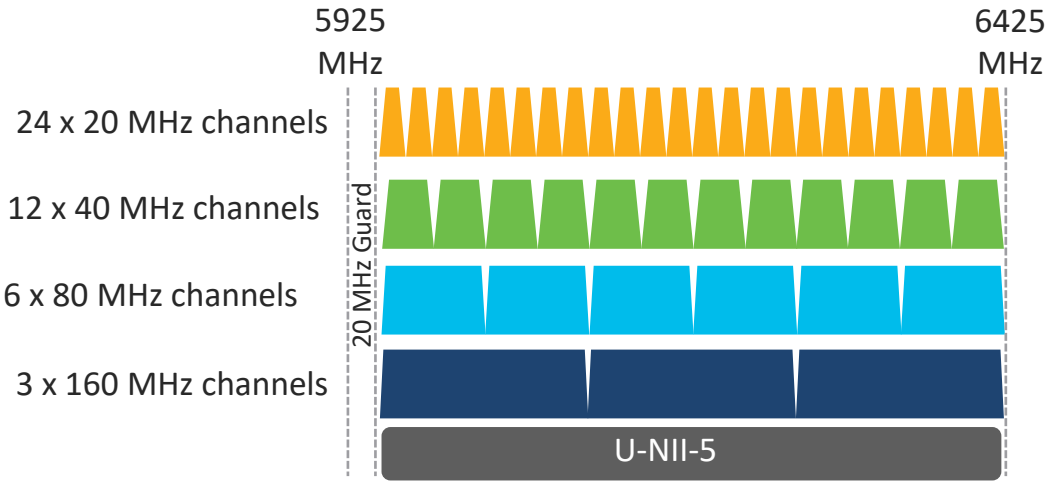
Wi-Fi 6E – 6GHz Around the World

The new 6 GHz band :

United States
1200 MHz

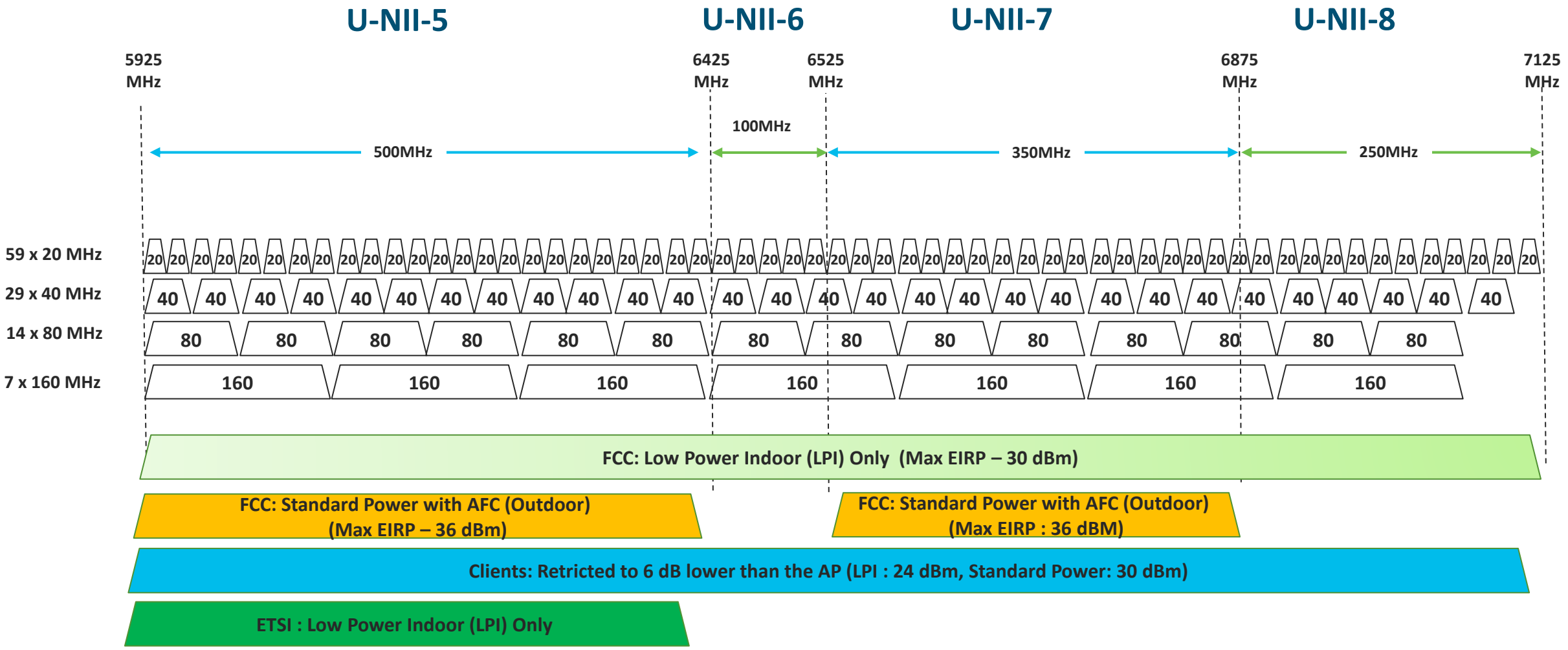


Europe/CEPT
500 MHz



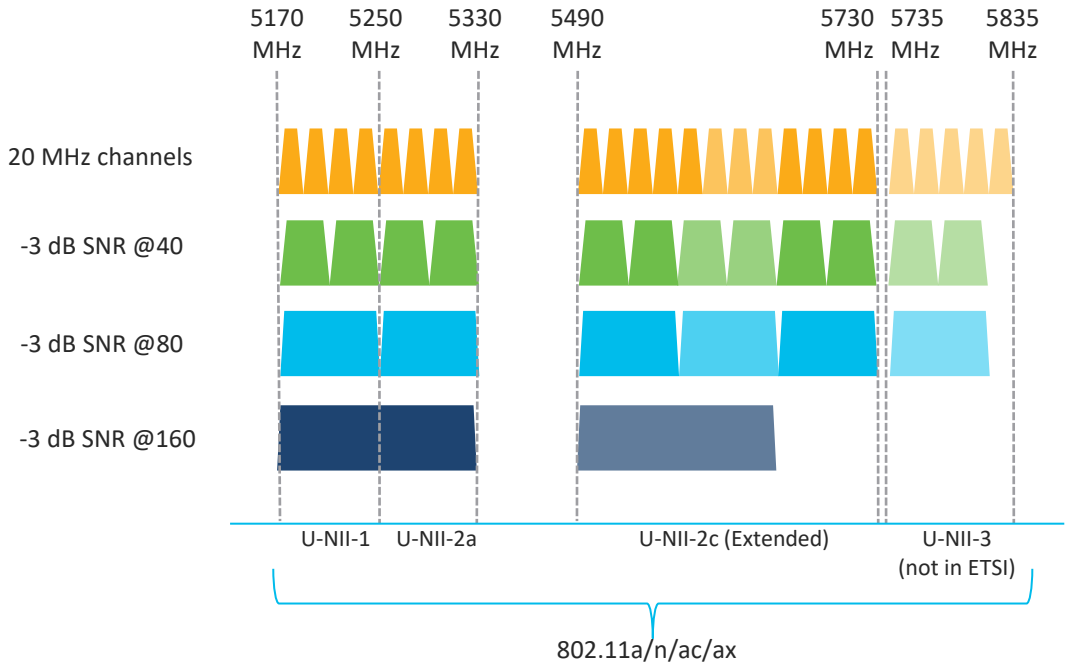
5955 – Central Frequency of the first 20 MHz channel
→ Starting at 5925 MHz +
20 MHz of guard band +
10 MHz to get to the center of the first 20 MHz channel

6GHz Spectrum- Equipment Classes & Regulations

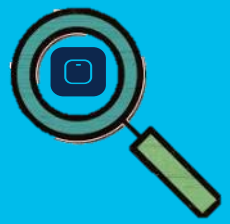


Bonded Channels and Noise 5 GHz vs 6 GHz

- A wider channel creates more noise
- Increased noise – decreases SNR
- In 5 GHz, every doubling of a channel width takes a corresponding 3 dB hit in SNR,
- A 3 dB reduction in SNR is equivalent to a 3 dB decrease in the RSSI performance wise
- Wi-Fi 6 E power rules in PSD of 5 dBm/MHz increases the EIRP as the channel gets wider
- This off-sets the corresponding SNR loss
- Comparing Effective EIRP – 6 GHz favors wider channels



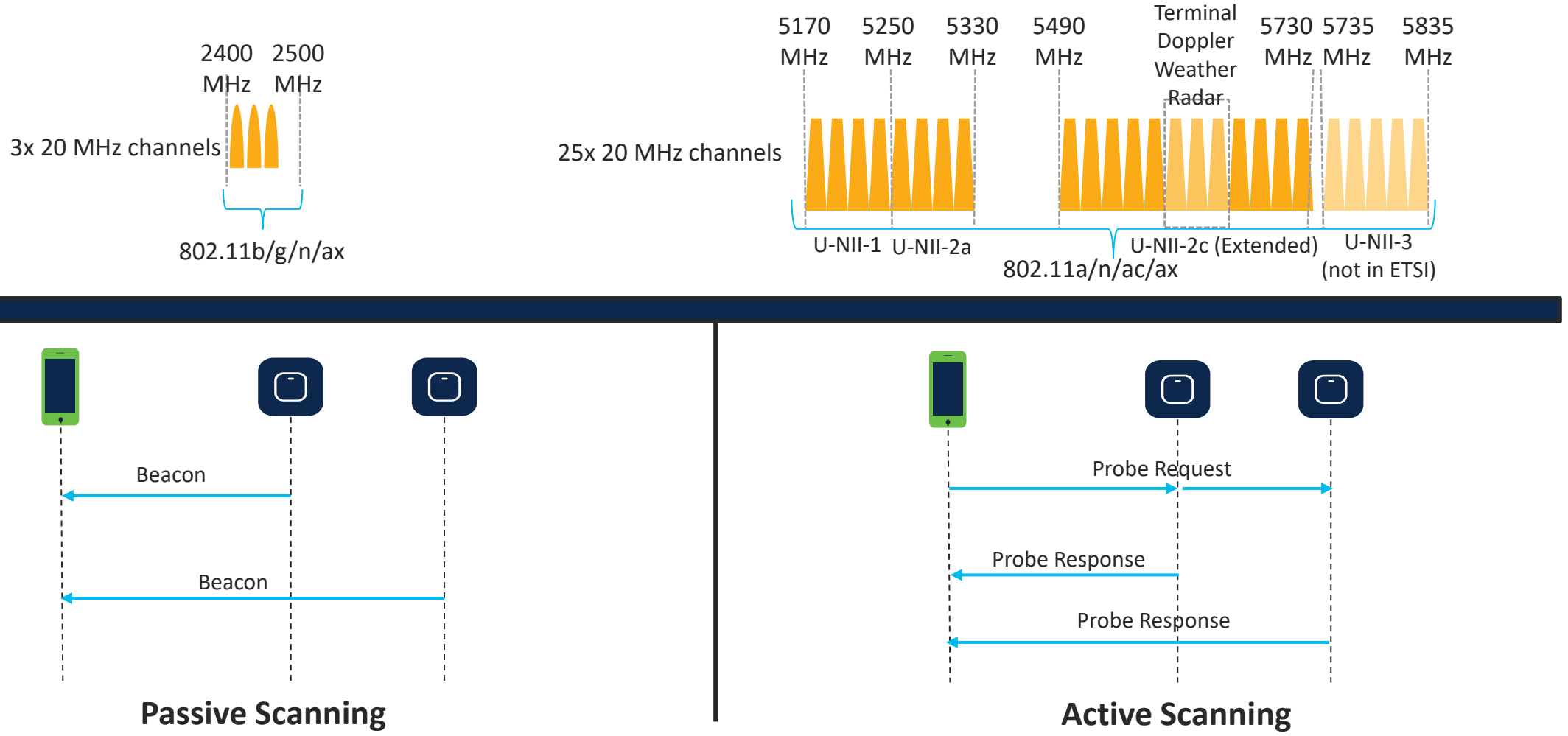
	Effective EIRP Improves as needed			
	20 MHz	40 MHz	80 MHz	160 MHz
5 GHz, U-NII-1	23 dBm	20 dBm	17 dBm	14 dBm
6 GHz. U-NII-5	18 dBm	21 dBm	24 dBm	27 dBm



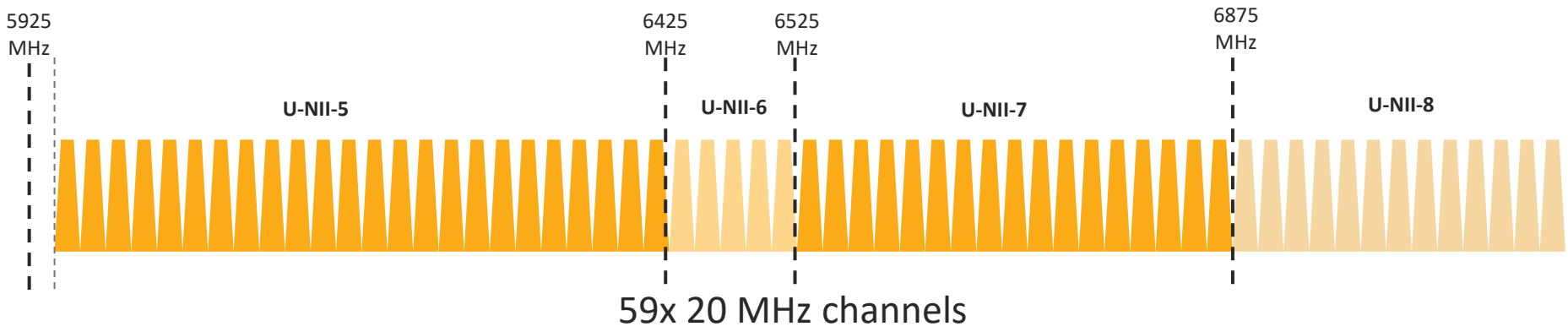
Wi-FI 6E – AP Discovery

AP Discovery by Wireless Clients – Legacy Methods

- Hunt and seek method to scan Basic Service Sets or for APs



Why Legacy Scanning Methods won’t scale in 6 GHz ?



- A Whopping 59 x 20 MHz Channels!
- Wi-FI Clients can send only Probe Requests on 20 MHz Channels
- 6 seconds to passive scan all 59 channels.

Wi-FI 6E - New AP Discovery Mechanisms

Out of Band

Reduced Neighbor Report

(Preferred Method)

Co-located Discovery

In Band

Multiple BSSID Beacon Frames

Passive Scan:

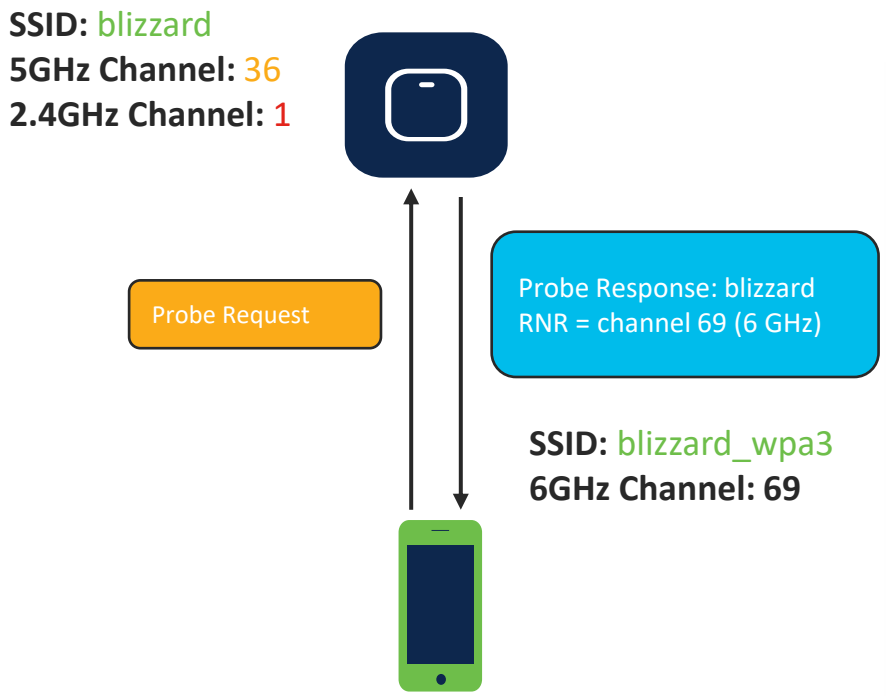
- Fast Link Setup (FILS) Discovery Announcement Frames
- Unsolicited Probe Response Frames

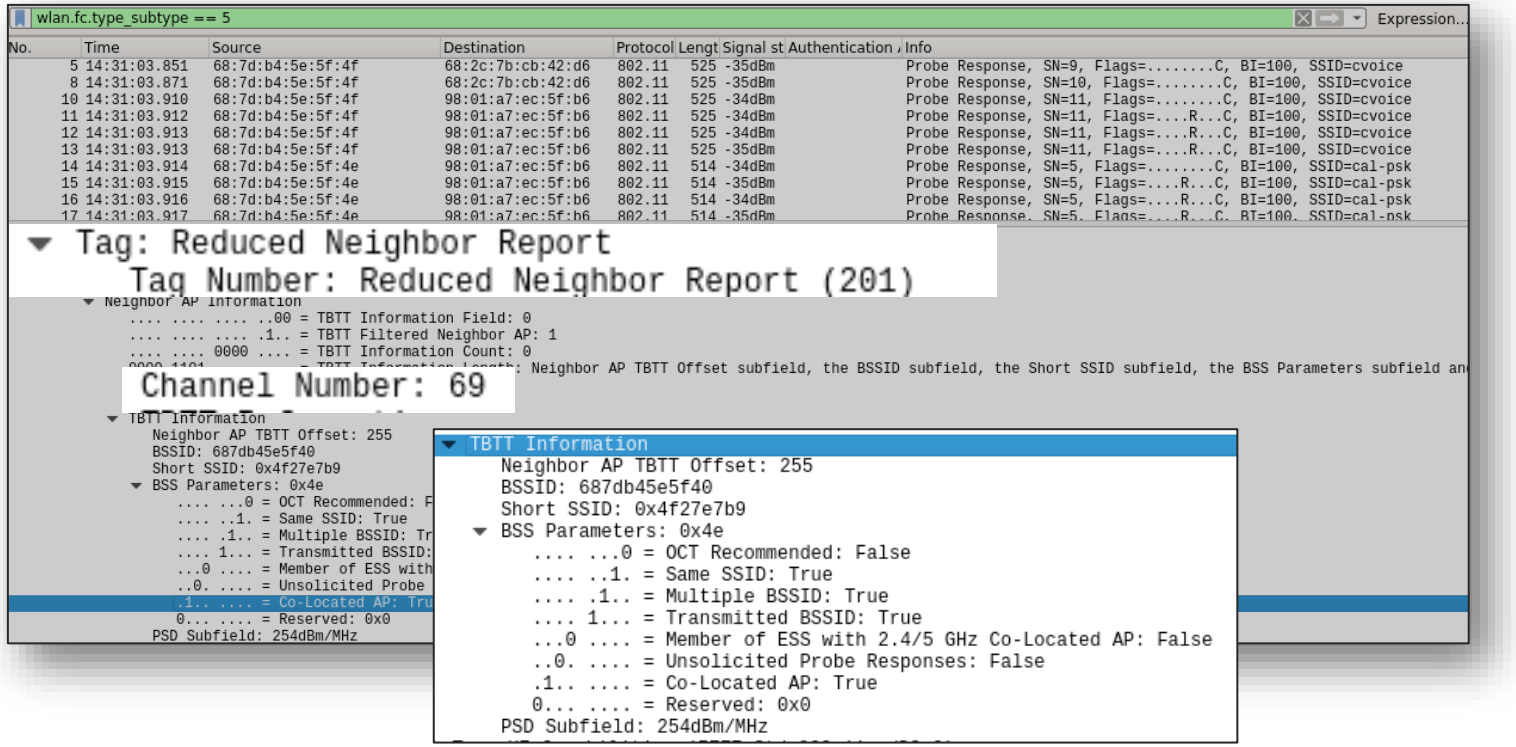
Active Scan:

- Preferred Scanning Channels (PSC)

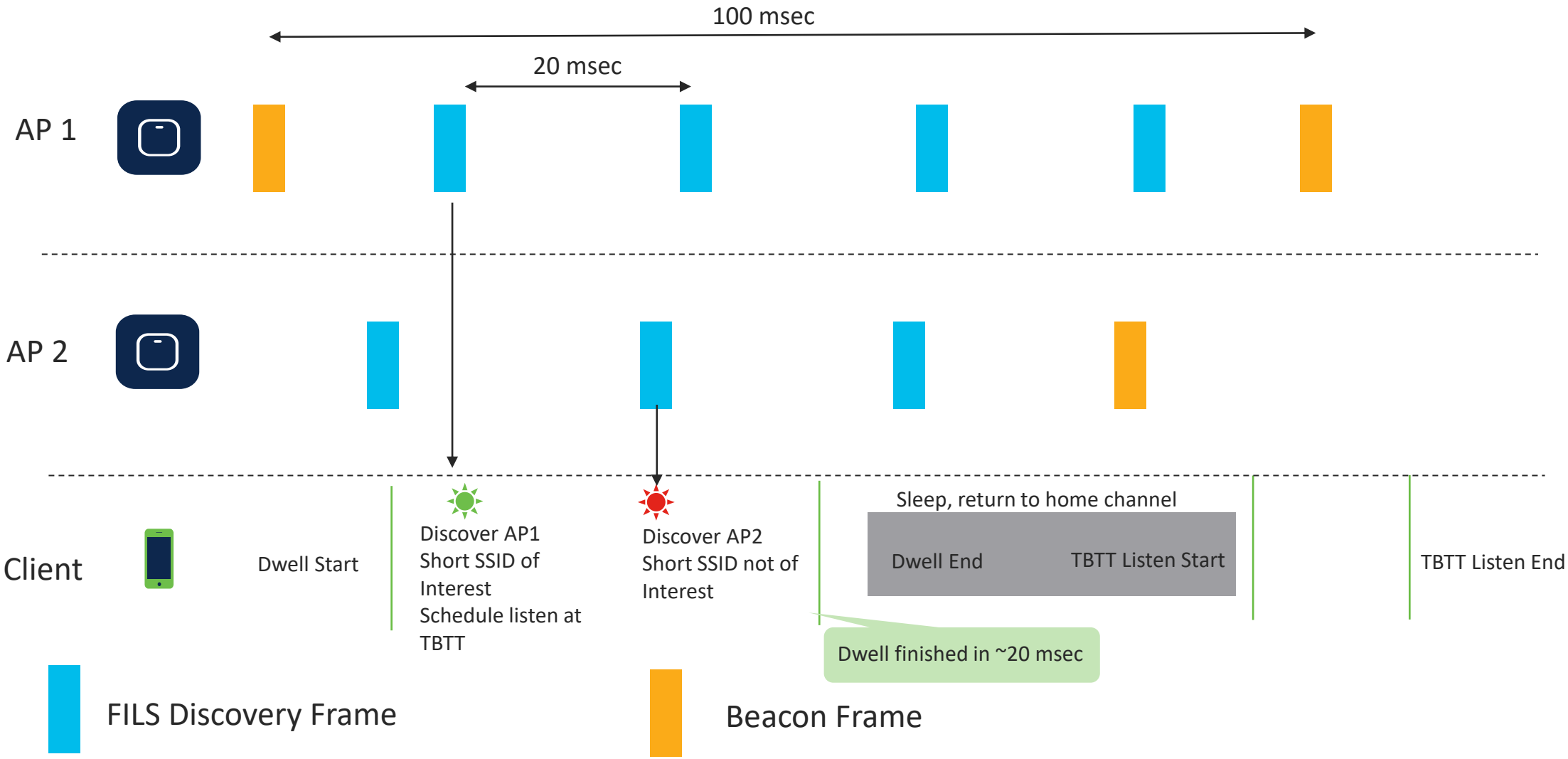
Reduced Neighbor Report

- Co-located “Neighbor” 6 GHz radio information in Beacon and Probe Response of 2.4 and 5 GHz radios.





Fast Initial Link Setup (FILS) Discovery Frames



Unsolicited Broadcast Probe Response

Reduces Probe Request Overhead

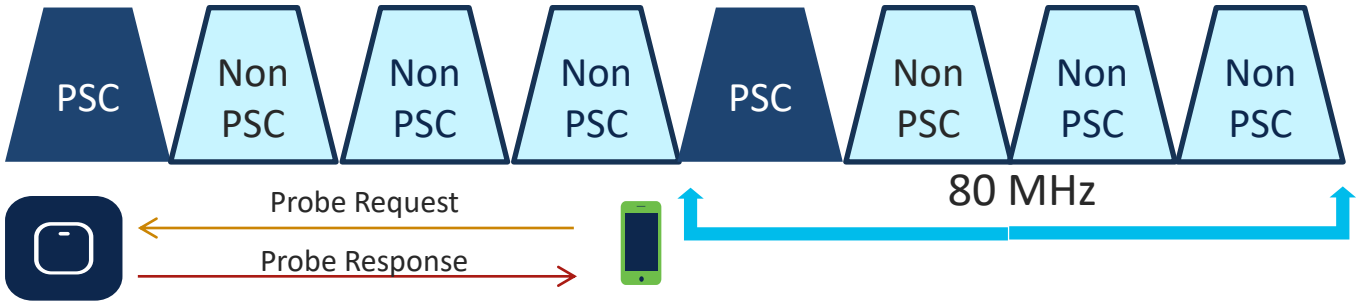
Broadcast probe response every 20 msec

Contains detailed information as a Beacon

Helps Avoid Probe Storm

Preferred Scanning Channels (PSC)

- Every fourth 20MHz channel designated for active probing by Wi-Fi 6E Clients; restricts scanning to 15 channels, instead of 59.
- PSC channels serve as the primary channel for channel bonding in 80 MHz



PSC Channel List:
5, 21, 37, 53, 69, 85, 101, 117, 133, 149, 165, 181, 197, 213 and 229

Wi-FI 6E – Deployment Considerations

Out of Band Discovery

Only Through RNR

FILS and UBPR Disabled

Most likely Deployment

In Band Discovery

Discovery through FILS or UBPR

Default: FILS

Least likely Deployment

Wi-Fi 6E – Security

Wi-Fi 6E Security

Wi-Fi 6E up levels security with WPA3 and OWE

WPA3 and Enhanced Open Security made mandatory for Wi-Fi 6E certification.

No backward compatibility with Open and WPA2 Security.

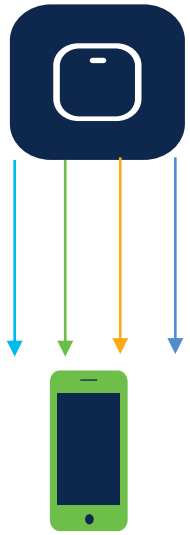
Requires Protected Management Frame (PMF) in both AP and Clients.

Wi-Fi 6E Security Deployment Considerations

- Layers of Wi-Fi Security
  - Clients with WPA2/WPA/Open continue to operate in 2.4 and 5 GHz bands.
  - 6 GHz operates exclusively with WPA3 and Enhanced Open Security
- Use of different SSIDs for 6 GHz band

2.4 & 5 GHz Bands

SSID: employees
(WPA2-Enterprise)
SSID: employees-wpa3
(WPA3-Enterprise)
SSID: guest
(WPA2-Personal)



6 GHz Band

SSID: employees-wpa3
(WPA3-Enterprise)
SSID: guest-wpa3
(WPA3-Personal/H2E *)

**Note: Only H2E is the supported SAE in 6GHz Band*

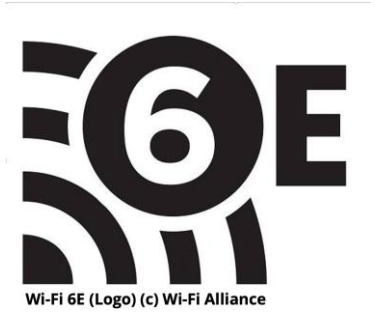
Wi-Fi 6E Design Guidance

Best Practices

What's the difference 5 vs 6 GHz LPI?

- Lots of chatter regarding how 6 GHz compares to 5 GHz
  - Path Loss - 6 GHz will not go as far as 5 GHz ✔
  - Cell Size – Will be smaller at 6 GHz compared to 5 GHz @ same configuration ✔
  - Absorption / Reflectance – 6 GHz will behave differently through materials ✔

Yup, assuming LPI and Same Power Level….BUT:



Wi-Fi 6E (Logo) (c) Wi-Fi Alliance

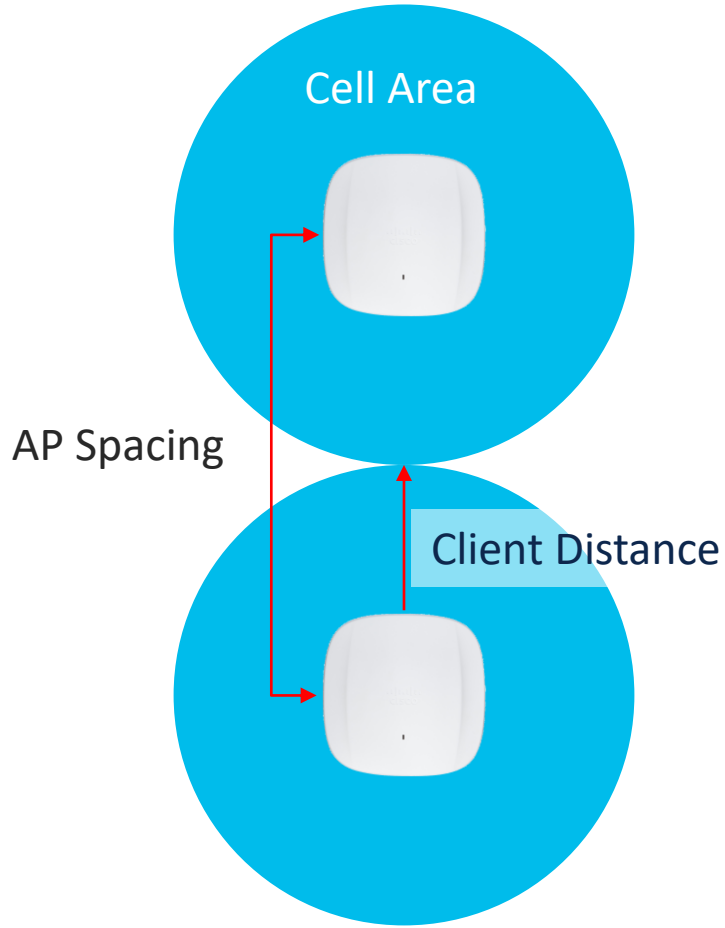
Wi-Fi 6E (Logo) (c) Wi-Fi Alliance

And, That's a Good Thing

Dimensioning 5 GHz

Cell Area/Coverage	AP Spacing 1 AP every	Max Client Distance to AP
1k ft^2/92m^2	36 f /11 m	18 f / 5.5 m
1.2k ft^2/111m^2	40 f /12 m	20 f / 6 m
1.5k ft^2/140 m^2	44 f /13.5 m	22 f / 6.7 m
2K ft^2/185 m^2	50 f /15.2 m	25 f / 7.6 m
2.8K ft^2/260 m^2	60 f /18.2 m	30 f / 9.1 m

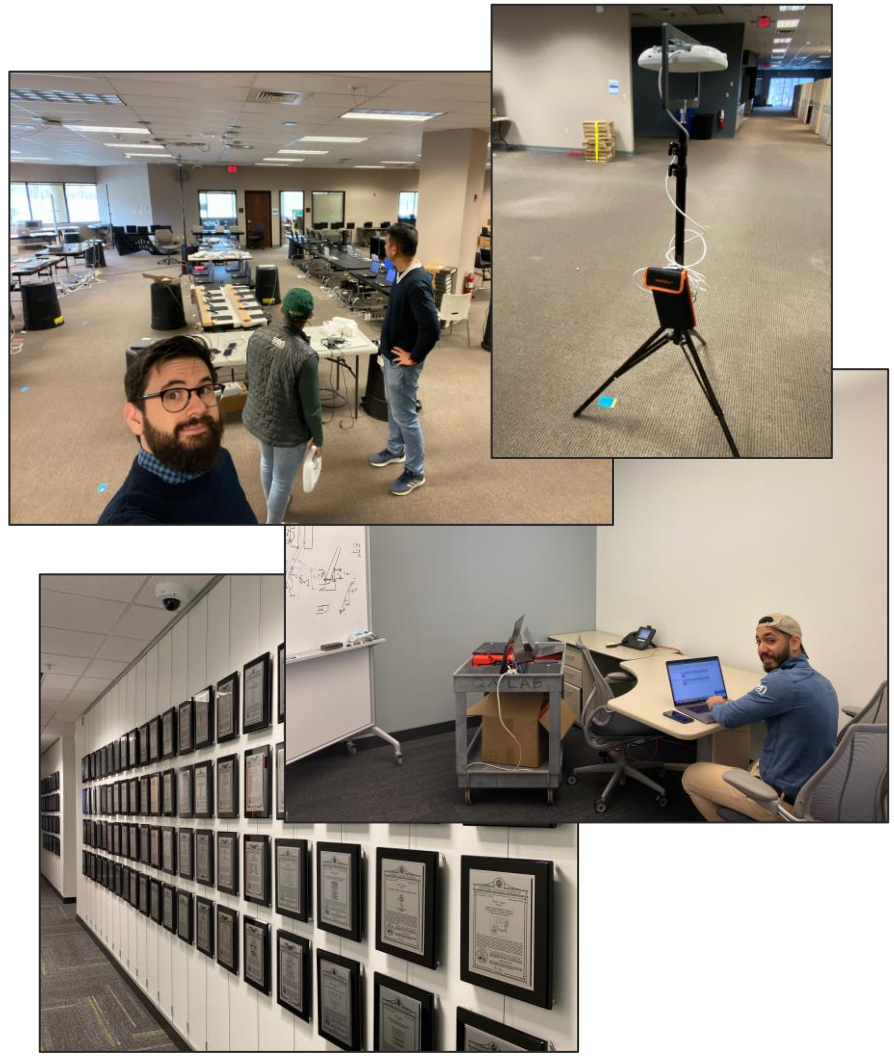
Cell Edge/ Clients 20-25 feet (6-7.5 meters)

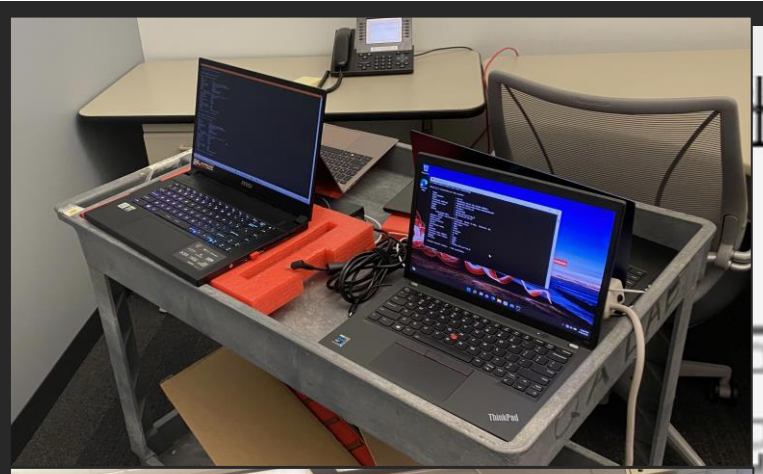


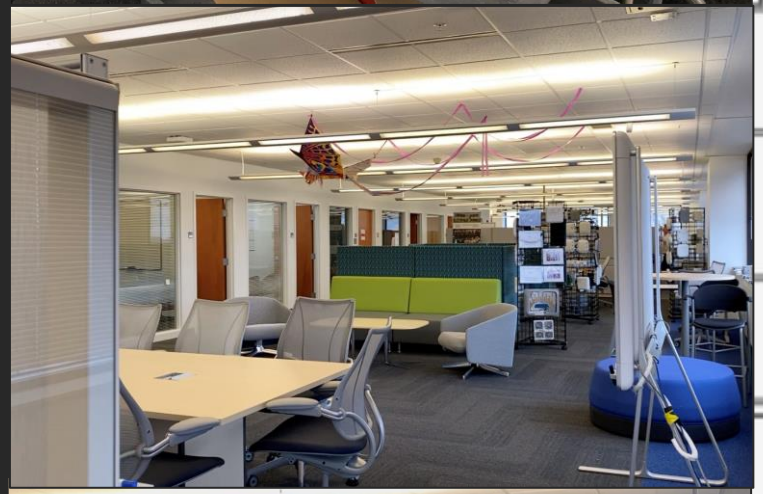
For more information on channel planning and AP density see:
Cisco High Density AP/Deployment
https://www.youtube.com/watch?v=c8w6Mfck0nQ

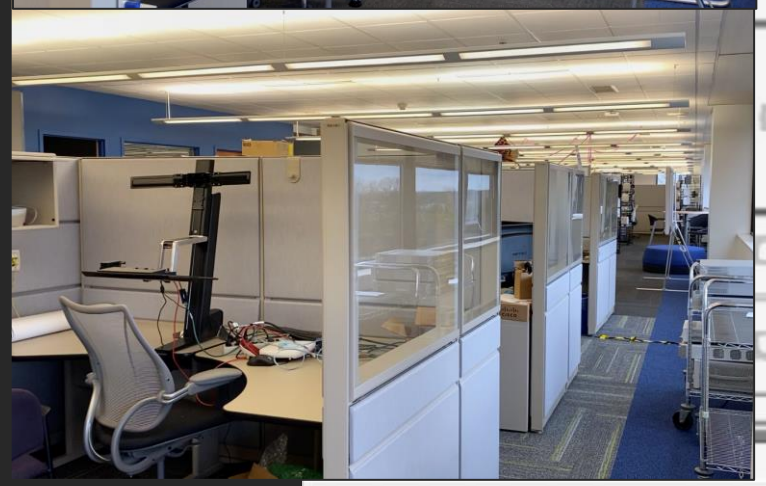
We Tested 2 Way's

1. Propagation for 6 GHz as it compares to 5 GHz propagation
   - Use clients to record RSSI @ 5 and 6 GHz measuring at 12 points across the Richfield, OH Cisco offices
     - ❖Office construction is full height cubes, mixed with open space, and sheet rock walls/solid doors in surrounding offices
   - Compare 5 GHz and 6 GHz readings from the same device at each point
   - Compare Ekahau Site Survey/sidekick values
2. Range vs Rate testing for 5 GHz vs 6 GHz
   - Compare 5 vs 6 GHz implementation on Various clients
   - Demonstrate effectiveness of a practical coverage plan









Empty for My Access Points on 2.4 5 Both Options

35-40 Feet (12 m)
-58.5 dBm 5 GHz
-58.5 dBm 6 GHz

50-70 Feet (21 m)
-60 to -65 dBm 5 GHz
-60 to -66 dBm 6 GHz

25-30 Feet (9m)
-57.5 dBm 5 GHz
-55.5 dBm 6 GHz

0-20 Feet (6m)
-56.5 dBm 5 GHz
-55.5 dBm 6 GHz

#8 @59 ft
#9 @70 ft
#7 @50 ft
#6 @35 ft
#5 @28 ft
#11 @40 ft
#10 @55 ft
#4 @17 ft
#2 @18 ft
#12 @30 ft
#3 @9 ft
1
36@40
#1 @25 ft

PL=Power Level

5 GHz PL 3 (15 dBm), 36 @ 40

6 GHz PL 1 (18 dBm), 5 @ 80

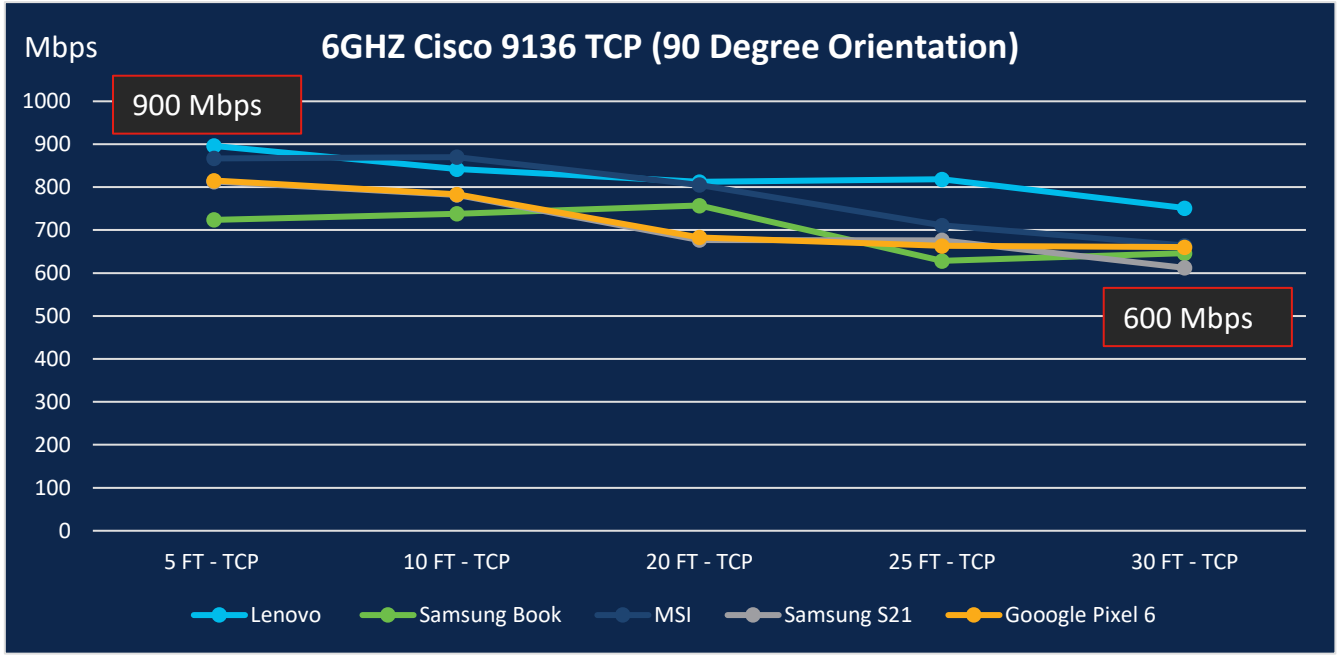
*RSSI values = Average of all 5 devices

2. Range vs Rate Performance

- At Enterprise densities (1.2-2K f^2) Cell boundary is ~25 Feet (7 m) max from AP
- Testing 5 clients TCP throughput @ 5 and 6 GHz
- Test Range uses Cisco C9136 –B configured for 5 GHz PL 4 (11 dBm), 36@40 and 6 GHz PL 2 (14 dBm), 5@80
- Data gathered at 5,10,20,25, and 30 foot (1.5,3,6,7.5,9 m) distances from the AP
- All devices 2ss @ 5 and 6 GHz

Test Results at 6 GHz

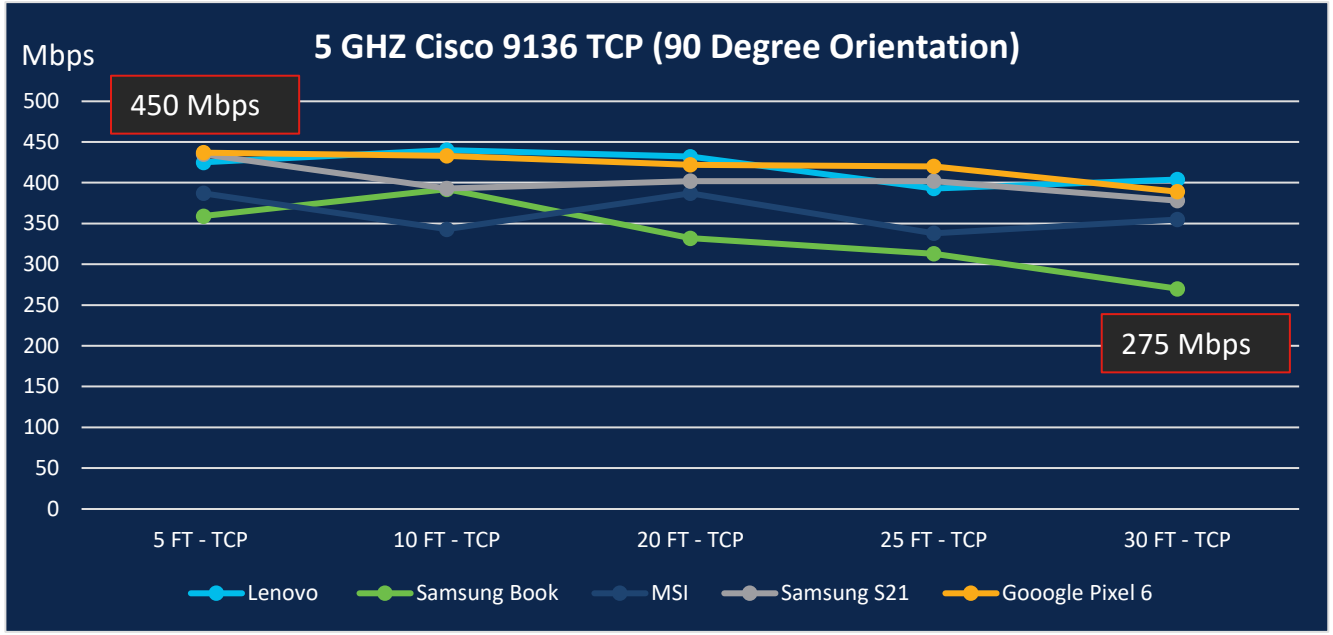
- Clients included Lenovo, Samsung Book, MSI Laptops and Samsung S21 and Google Pixel 6 Smart Phones
- Throughput was between 900 and 600 Mbps across the distance range
- For individual devices - 25% throughput difference between the near and far end of the range



1.5,3,6,7.5,9 meters

Test Results at 5 GHz

- At 5 GHz with 40 MHz cells
- Throughput was between 440 and 275 Mbps across the distance range
- Avg 13% throughput difference between the near and far end of the range



1.5,3,6,7.5,9 meters

Where are we then on 5 and 6 GHz assumptions?

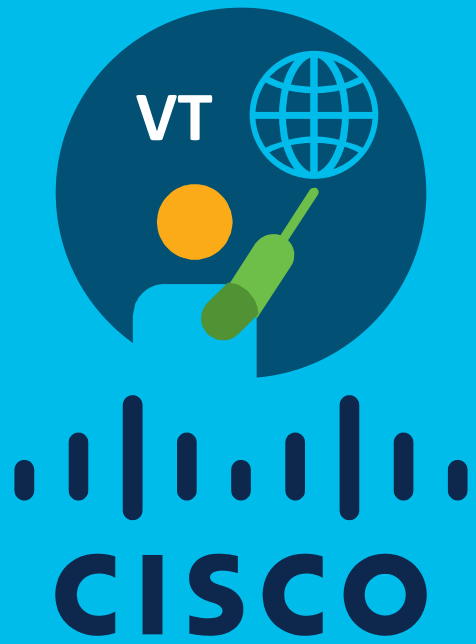
Q1: Can a co-resident LPI 6 GHz radio provide the same coverage as the 5 GHz cell while dramatically increasing capacity?

A1: Yes – in many installations

Q2: Can a one for one replacement of Wi-Fi 6/5 APs with LPI Wi-Fi 6E APs be achieved?

A2: Yes. *Assuming 1.2 – 2k f^2 average AP density, carpeted office normal ceiling (3-4 m /10-12 ft), sheetrock walls/cubes etc.

- 5 GHz network with RRM operating at power levels 3-4? >then equal 5 and 6 GHz coverage is possible with a one for one AP replacement in both ETSI and FCC. Assuming 80 MHz channel in FCC and 40 MHz channel in ETSI/UK
- Edges and less dense Areas need to be identified and augmented.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