Wi-Fi6 update

IX Forum 14

Flavio Correa – flcorrea@cisco.com

Technical Solutions Architect

CCIE Wireless #38913

Agenda

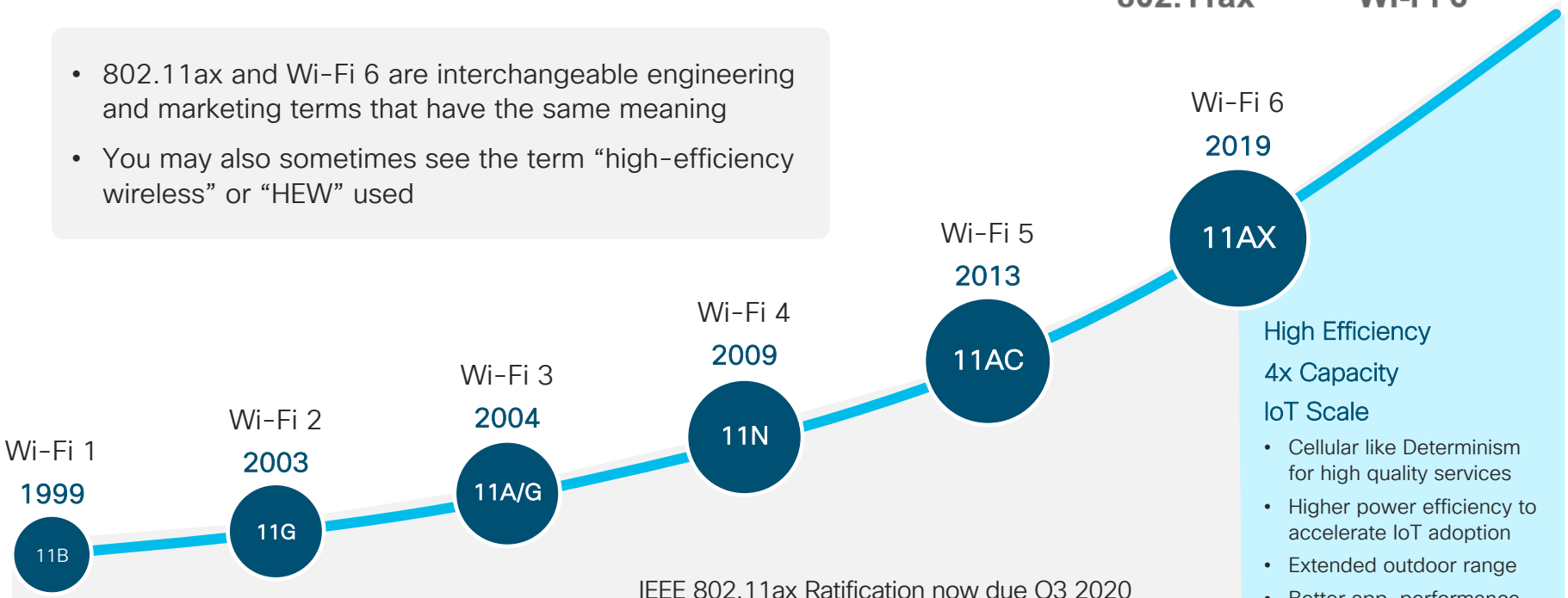
- Como chegamos até aqui?
- Benefícios e o que muda com o Wi-Fi6
- Status da solução e adoção no mercado
- Wi-Fi6E e nova alocação de espectro não licenciado

How did we get here?

802.11ax

Wi-Fi 6

- 802.11ax and Wi-Fi 6 are interchangeable engineering and marketing terms that have the same meaning
- You may also sometimes see the term “high-efficiency wireless” or “HEW” used



IEEE 802.11ax Ratification now due Q3 2020
WFA Wi-Fi 6 certification Q3 2019

High Efficiency

4x Capacity

IoT Scale

- Cellular like Determinism for high quality services
- Higher power efficiency to accelerate IoT adoption
- Extended outdoor range
- Better app. performance in high density deployments

What Wi-Fi6 brings to the table?

Increased Data Rates

Higher Modulation (Up to 1024 QAM)

Reduced latency

Uplink Resource Scheduling (OFDMA)

Greater IoT Coverage

Deterministic Capacity (OFDMA)

Higher Density

Efficient Spectral Re-use (BSS Coloring)

Power Efficient

Flexible low-power scheduling (Target Wake Time)

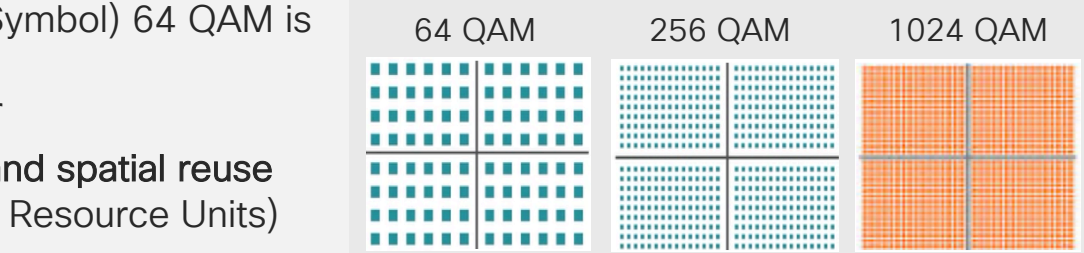
Faster Speeds | Optimized Capacity | IoT Ready

Wi-Fi 6 is all about high efficiency wireless

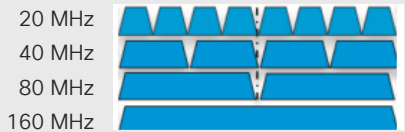
Four things determine Air Time Efficiency

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 and spatial reuse** (introduction of OFDMA and Resource Units) and UL/DL MU-MIMO
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



Wi-Fi channel width



.11ax data-rate chart for 1 spatial stream

What is the maximum theorical Wi-Fi6 throughput

MCS Index	Modulation type	Coding Rate	Data rate (in Mb/s)							
			20 MHz channels		40 MHz channels		80 MHz channels		160 MHz channels	
			1600 ns GI	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[1]	8.6	8[1]	17.2	17[1]	36	34[1]	36[1]
1	QPSK	1/2	16	17.2	33	34.4	68	72.1	136	144
2	QPSK	3/4	24	25.8	49	51.6	102	108.1	204	216
3	16-QAM	1/2	33	34.4	65	68.8	136	144.1	272	282
4	16-QAM	3/4	49	51.6	98	103.2	204	216.2	408	432
5	64-QAM	2/3	65	68.8	130	137.6	272	288.2	544	576
6	64-QAM	3/4	73	77.4	146	154.9	306	324.4	613	649
7	64-QAM	5/6	81	86	163	172.1	340	360.3	681	721
8	256-QAM	3/4	98	103.2	195	206.5	408	432.4	817	865
9	256-QAM	5/6	108	114.7	217	229.4	453	480.4	907	961
10	1024-QAM	3/4	122	129	244	258.1	510	540.4	1021	1081
11	1024-QAM	5/6	135	143.4	271	286.8	567	600.5	1134	1201

Up to **1.2Gb with 1 radio**, up to 10 Gb* with 8 radios @ 160 MHz

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

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

1024-QAM 40 MHz Channel

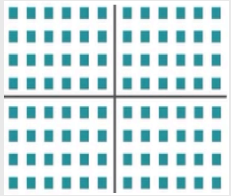
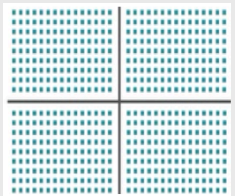
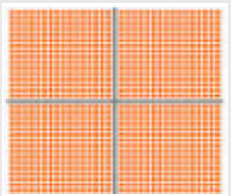
How far can 1024-QAM go?

- Single-antenna devices (smart-phone) should see MCS10-11 with 40 dB SNR

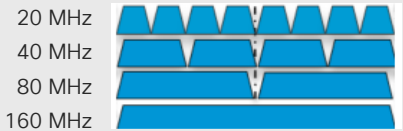
Four things determine “Air Time Efficiency”
Wi-Fi’s 1-5 have delivered on 3 of these….

1. Data rate (Modulation density)
2. Number of spatial streams
3. Channel bandwidth
4. Protocol overhead

Modulation density gains

64 QAM	256 QAM	1024 QAM
		
802.11agn 6b/symbol	802.11ac **8b/symbol**	802.11ax **10b/symbol**

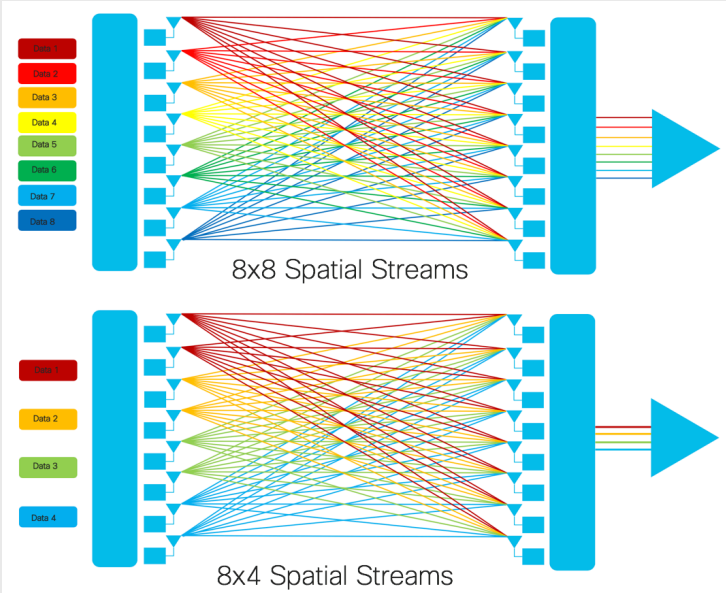
Wi-Fi channel width



Wi-Fi 6 Spatial Streams – Up from 4 to 8 SS

100% more to Work with!

- Spatial reuse is not new, however we have twice as many with 802.11ax
- Spatial multiplexing allows for a 1-1 increase in the spectrum under ideal conditions – MU-MIMO x 8? – More later….
- Higher modulation densities require higher SNR to protect against corruption
- 802.11ax provides 8 SS which can be mixed and matched to reinforce signal and increase SNR for any other SS's data

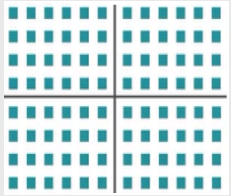
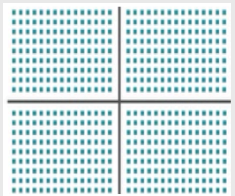
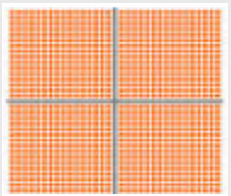


The Fundamentals of Spatial Streams – TechWise TV
https://www.youtube.com/watch?v=EeK4ISiN0Dw

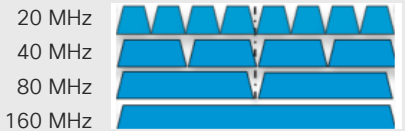
Four things determine “Air Time Efficiency”
Wi-Fi’s 1-5 have delivered on 3 of these….

1. Data rate (Modulation density)
2. Number of spatial streams
3. Channel bandwidth
4. Protocol overhead

Modulation density gains

64 QAM	256 QAM	1024 QAM
		
802.11agn 6b/symbol	802.11ac **8b/symbol**	802.11ax **10b/symbol**

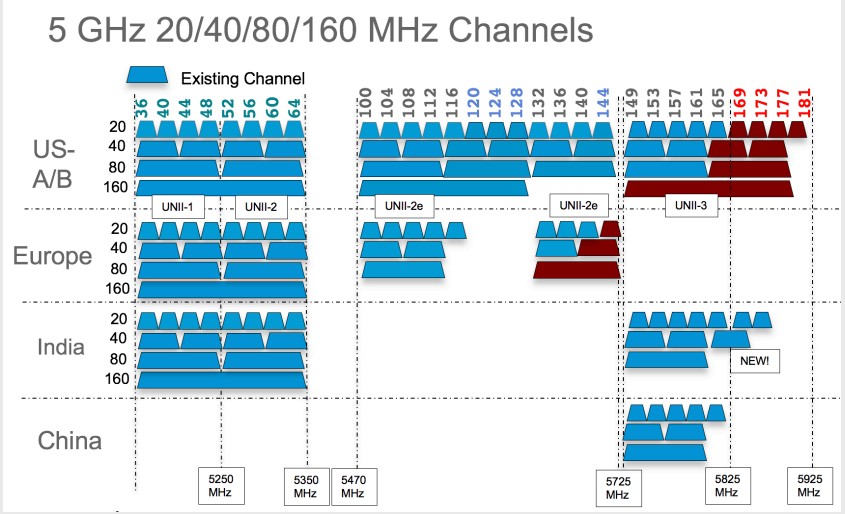
Wi-Fi channel width



Channel Bonding – 20/40/80/80+80

Wi-Fi 6 Maintains Wi-Fi 5's abilities

- Channel bonding enables OFDM and OFDMA to increase the amount of throughput per frame by bonding existing 20 MHz channel assignments together to create very wide 40/80/160 or 80+80 MHz channel
- Each bonded 20 MHz channel comes with a 3dB SNR penalty because of the wider channel
- 80 MHz channels on Dual 5 Ghz AP's consume 8 channels per AP placement – the net result if, not careful, is the same N=3 channel re-use as 2.4 GHz band and heavy loss due to co-channel interference
- In a drag race, 80 MHz is pretty impressive
- Most installations are about driving a bus – not racing dragsters



The Fundamentals of Spatial Streams – TechWise TV
https://www.youtube.com/watch?v=EeK4ISiN0Dw

More spectrum is coming with Wi-Fi6E!

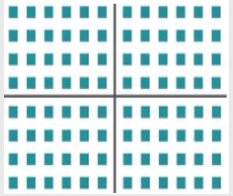
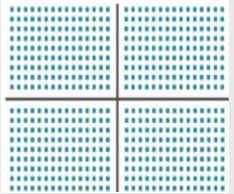
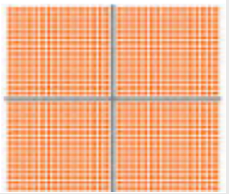
Four things determine “Air Time Efficiency”

Wi-Fi’s 1-5 have delivered on 3 of these….

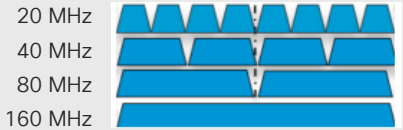
1. Data rate (Modulation density)
2. Number of spatial streams
3. Channel bandwidth
4. Protocol overhead

Wi Fi 6™

Modulation density gains

64 QAM	256 QAM	1024 QAM
		
802.11agn 6b/symbol	802.11ac **8b/symbol**	802.11ax **10b/symbol**

Wi-Fi channel width

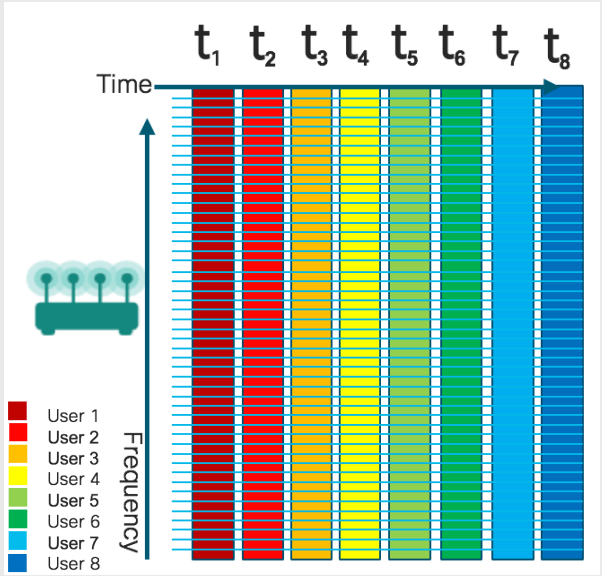


OFDMA – Multiple Access Phy IS the game changer!

So, What's Wrong with OFDM you say?

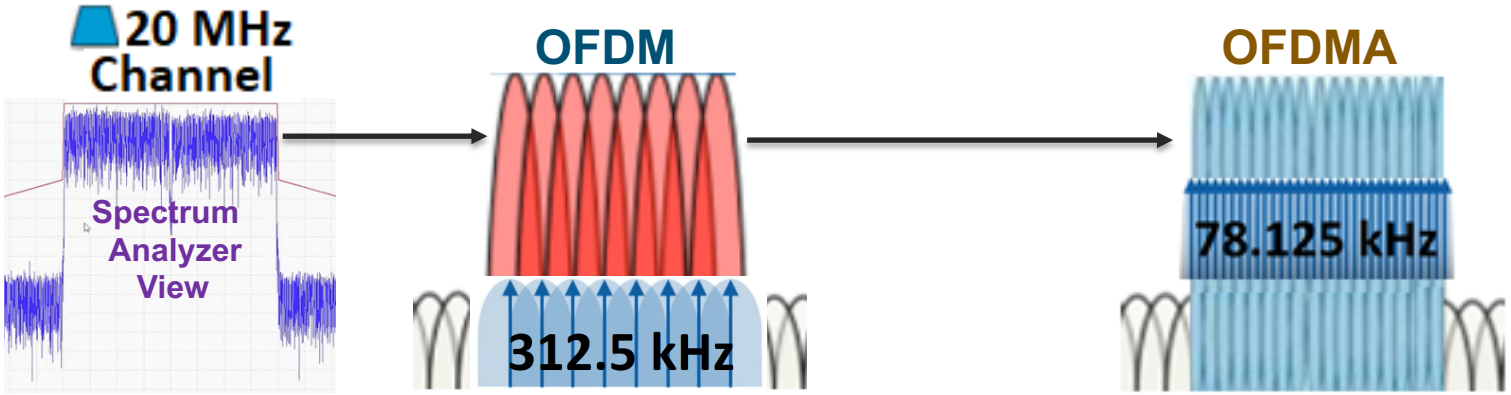
Nothing really- It's a dear old friend, But.....

- OFDM has made fantastic strides in throughput, and capacity
- Design methodologies and the technology have evolved by leaps and bounds
- OFDM (Wi-Fi's 1-5) only supports one Client PPDU per Frame. Each Clients data must have it's own Framing, this is inefficient and leaves Airtime on the table.
- As more Clients join the cell, latency will increase – Inevitably
- Today, we compensate with over design



Deconstructing OFDM and OFDMA

OFDM and OFDMA populate a 20 MHz channel using sub-carriers but OFDMA has More



- **"OFDM" channel is divided by Larger subcarriers which are not individually addressable**
- **"OFDMA" channel Sub-Carriers can be grouped into individually addressable "Resource Units", user data can be "Multiplexed" onto a Frames RU's**

All packets big and small get processed MUCH FASTER

Understanding OFDMA Resource Units

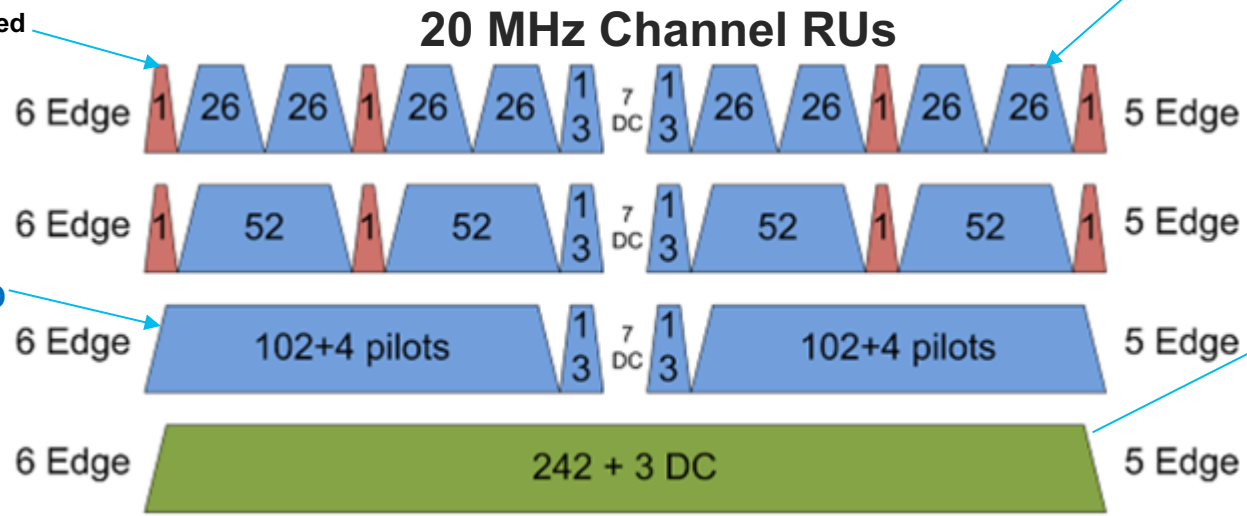
For your reference

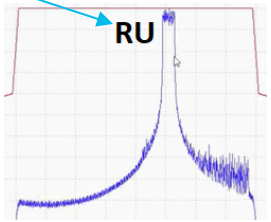
Each RU can be a different modulation scheme or coding rate determined by control information, scheduling etc.

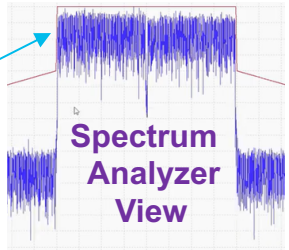
Up to 9 users per 20 MHz
Tiny RUs ideal for IoT

RU's are indexed

Min. RU size For MU-MIMO







20 MHz

http://www.ni.com/white-paper/53150/en/

Higher Efficiency: Requires a Design Philosophy

OFDM Today

- When a client has data to transmit, it's given the whole channel, to support bursty data
- As data rates go up, PHY/MAC (preamble, back-off, Ack/BA, any RTS/CTS, etc) overheads don't diminish
- Aggregation can only take us so far
- Example – 87% of frames less than 320 bytes
  - Voice – average 100 bytes
- More clients – also results in longer intervals between Tx-Ops – increasing jitter (latency)

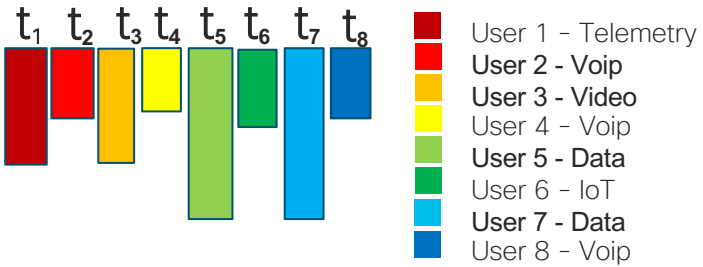
Topic / Item	Count	Average	Min val	Max val	Rate (ms)	Percent
Packet Lengths	105198	225.52	14	1623	1.6173	100%
0-19	14274	14.00	14	14	0.2194	13.57%
20-39	10605	26.89	20	39	0.1630	10.08%
40-79	1122	64.11	40	79	0.0172	1.07%
80-159	6447	115.83	80	159	0.0991	6.13%
160-319	59472	283.61	160	319	0.9143	56.53%
320-639	12440	363.13	320	636	0.1913	11.83%
640-1279	326	892.03	640	1278	0.0050	0.31%

87.37% of Frames =<320 bytes of data!

OFDMA – Using Subcarriers more efficiently

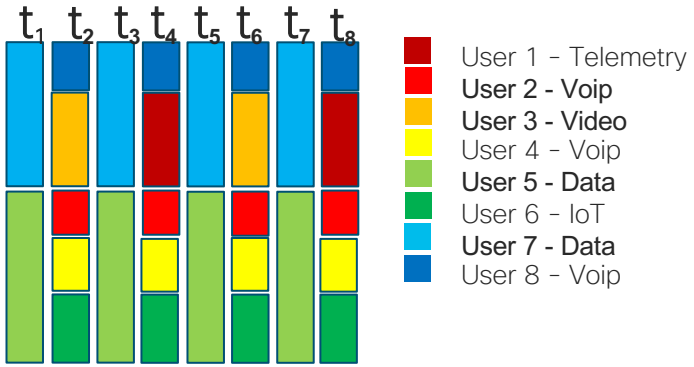
Maximizing Client Count – Lowering Latency

OFDM



- Each User gets 1 time slot – and uses the whole channel bandwidth
- In this example with 8 users, each User will wait t_8 before Next Tx_op (Assuming no QOS)
- As more clients Join the cell, Latency –and Jitter Increases

OFDMA



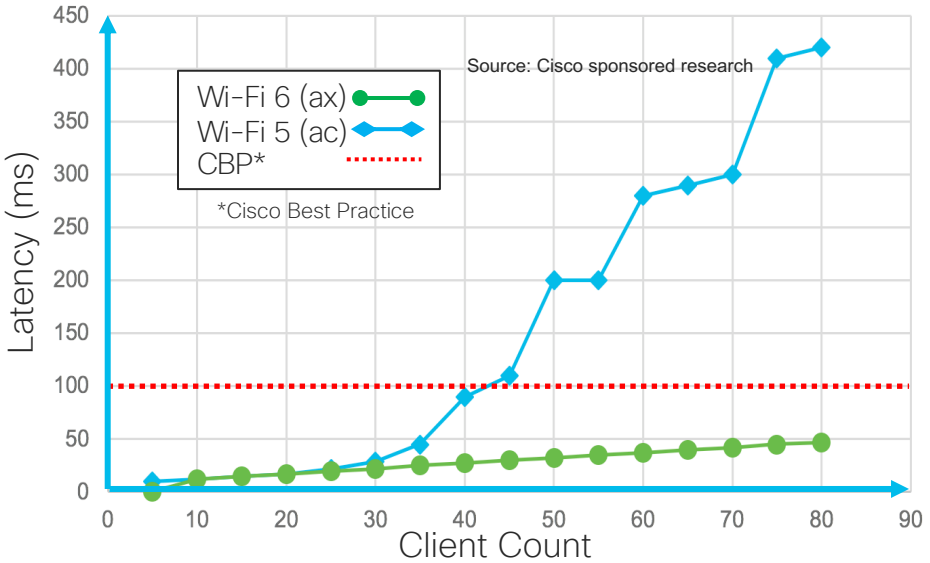
- Multi user Packet makes flight more efficient
- Much more regular and consistent TX_op
- Deterministic nature –
- Multiplexing Users onto Single frames, reduces overhead, and Latency

Each subcarrier is a transport - Latency goes up when subcarriers go out “half empty”… OFDMA solves this by allowing multi-user packets to go out on one subcarrier

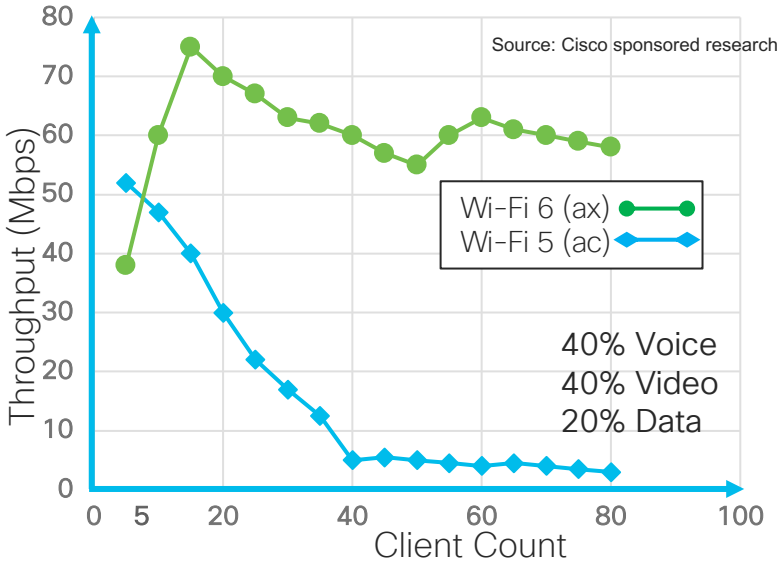
802.11ax (OFDMA) provides determinism at scale:

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

Linear **VOICE** delay



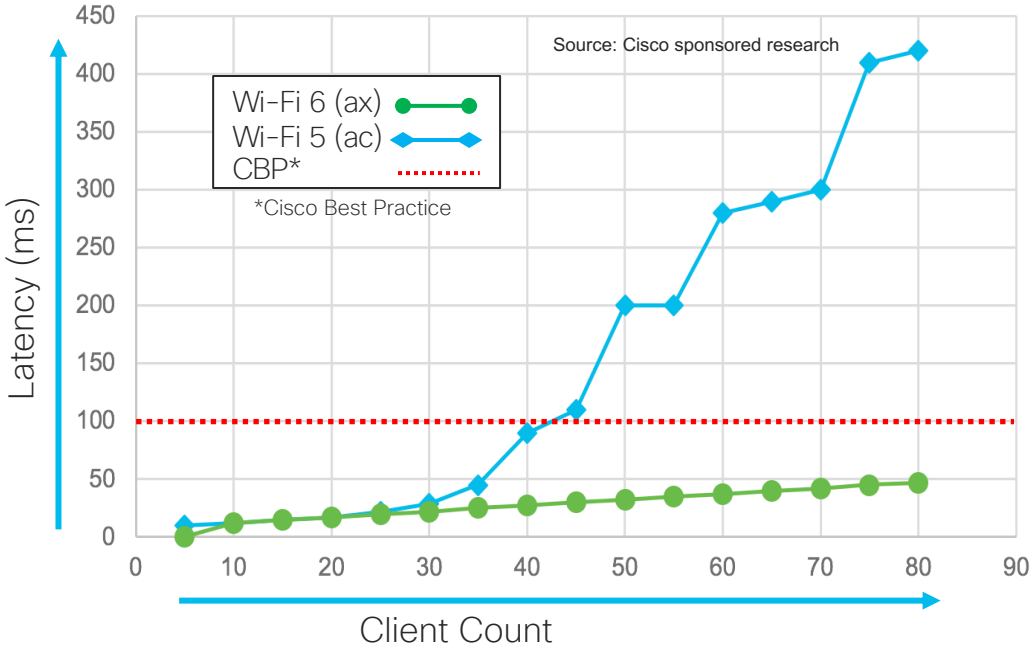
Consistent **DATA** throughput



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

802.11ax provides higher VOICE/VIDEO capacity

Lower latency at increased density



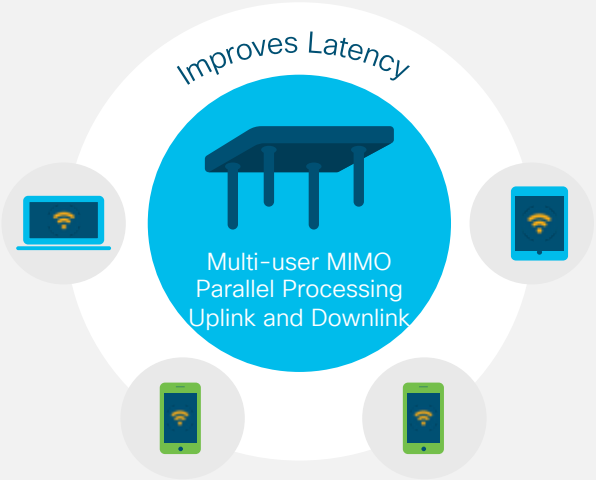
- With 11ac, as density (Clients/AP) increase from 25 (e.g. class room) to 50 (e.g. conference hall), latency increases 4x from an acceptable 50ms (99%-ile) to an unacceptable 200ms – unusable service!
- By leveraging OFDMA, delay is bounded to 50ms up to 75 Clients/AP resulting in 2- 3x the VOICE user capacity with high quality

Wi-Fi 6 can achieve up to 3x the VOICE capacity over 11ac in High-Density (HD)

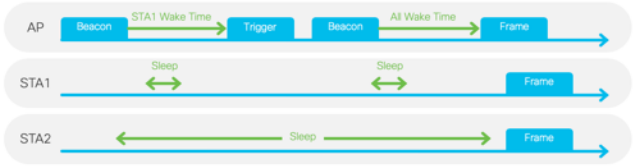
Other interesting new capabilities of Wi-Fi6

Wi-Fi 6 additional enhancements

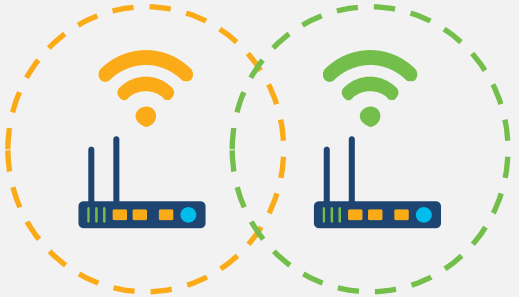
Multi-user MIMO



Target Wake Time



BSS Coloring



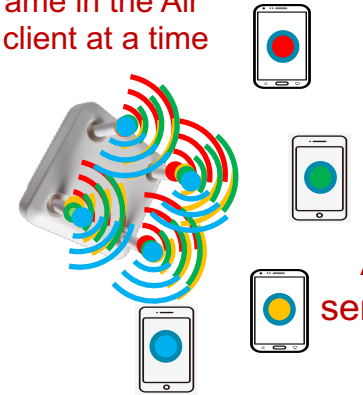
Multi-User MIMO (MU-MIMO) introduced 11ac Wave-2

How does it work? Why is it an advantage?

SU – MIMO vs. MU - MIMO

This is Single-User MIMO
SU-MIMO

Only one Frame in the Air to any One client at a time



Effective # SS is limited to the # of SS available on the client

All Spatial Steams send the same data

This is Multi-User MIMO
MU-MIMO

Up to 1+2 SS
Or 1+1+1

Max 3SS simultaneously

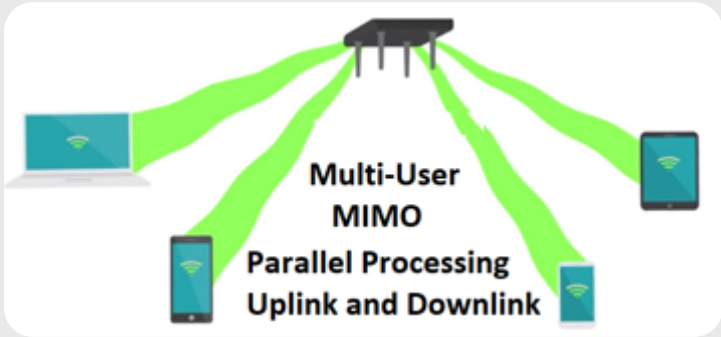
Data can be directed to Different clients in Concurrent streams in a1+1, 1+1+1 or 1+2 stream combination

Wi-Fi 6 enhancements to Multi-user MIMO

The previous slides for .11acW2 holds true for .11ax
However there are **NEW** supported features:

- MU-MIMO is now supported in Uplink
- 8 MU-MIMO transmissions (users in a group) up from 4
- AP calculates a channel matrix for each user and simultaneous steer beams to different users (creating groups and managing)
- Each MU-MIMO transmission may have its own MCS rate
- Larger RU frames 106 and above are used for MU-MIMO
- MU and SU-MIMO is decided by AP w/MU- favoring larger packets

Improves latency

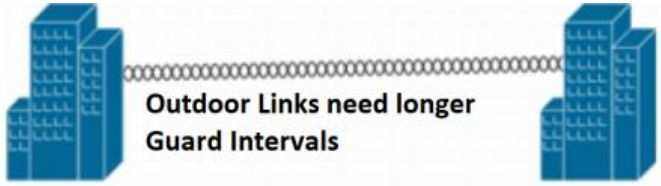


IoT Benefits using Wi-Fi 6

More IoT devices coming on line everyday – Strong need for 2.4 GHz

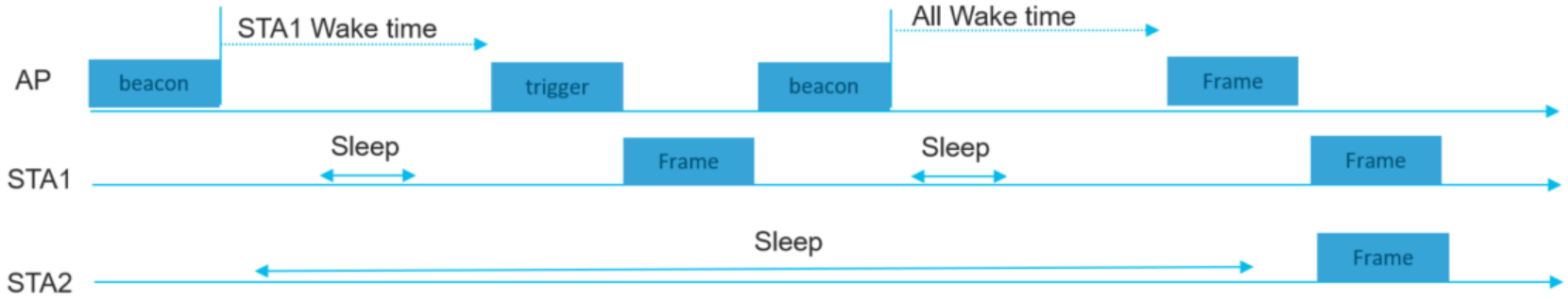
- Superior battery life for IoT and mobile devices – Using Target Wake Time
- Parallel Processing for Spectrum Efficiency MU-MIMO
- Small Packet aggregation (using OFDMA) for reduced latency
- Longer Guard interval for greater range outdoor links
- BSS Coloring helps increase channel reuse
- Better spectrum coexistence with other technologies e.g. Bluetooth, Zigbee

2.4 GHz No longer a junk band – It simply needs to work



Target Wake Time – Putting Devices to Sleep

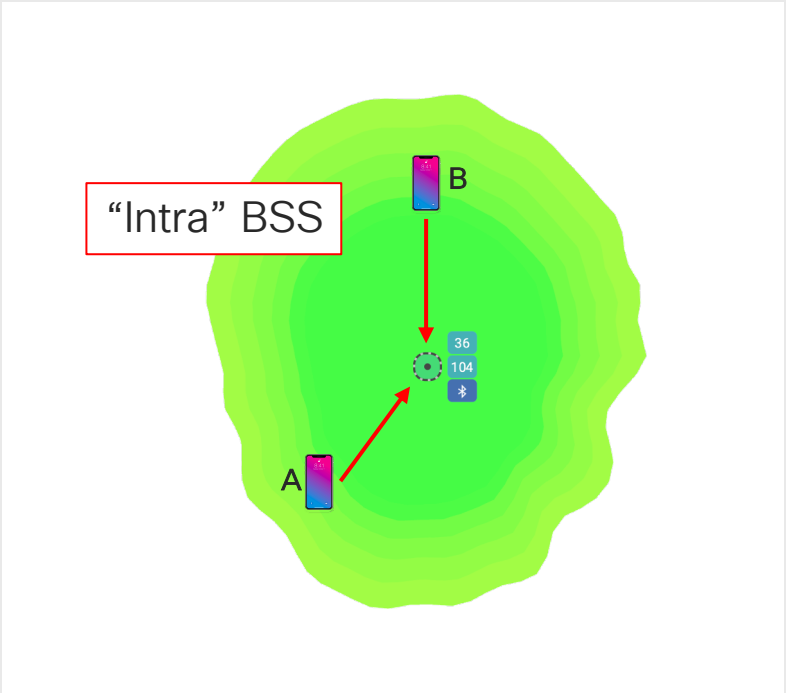
- With Target Wake Time (TWT), the AP can schedule phones and IoT devices sleep for long durations **(up to 5 years)** and then wake the individual device up.
- Devices can be configured to wake up as a group to communicate at the same time sharing the channel for increased network capacity and reduced battery drain.
- Use of BSS Color field and UL/DL flag in preamble to enable intra PPDU power Saving



Wi-Fi Contention and Spatial Reuse

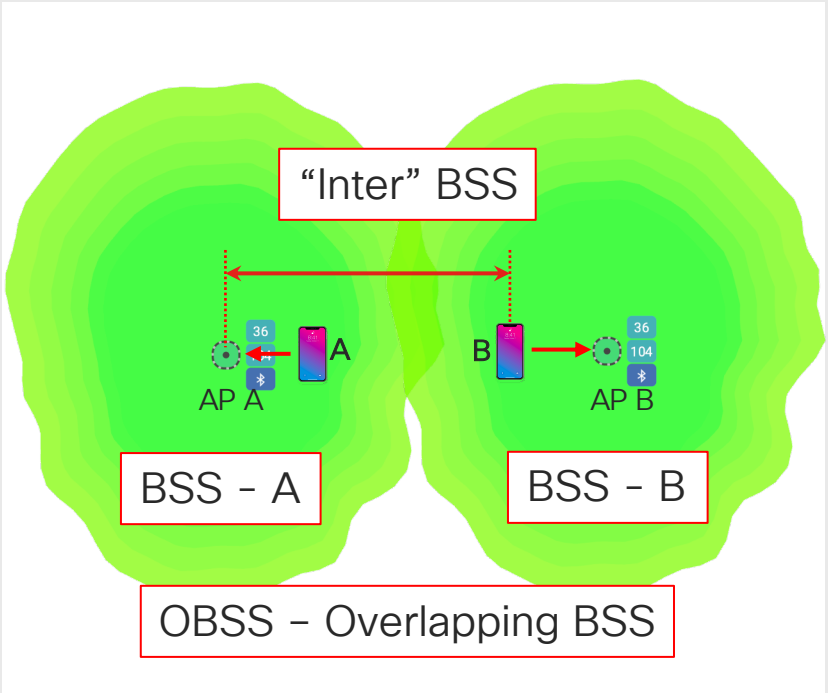
Why is BSS coloring important?

- Two stations associated to the same AP can not both talk to the same AP at the same time, they will “Interfere” with one another at the AP’s receiver
- To prevent this Wi-Fi uses a “contention mechanism” – CCA (Clear Channel Assessment)
- If Sta A listens to the channel – and can hear anyone at or above -82 dBm – then the channel is in use and Sta A must back off and try again
- In this way – stations will all take turns using the channel and avoid harmful or destructive interference
- An AP and all the Stations associated to it are considered a BSS as all the stations



Wi-Fi Contention and Spatial Reuse
Why is BSS coloring important?

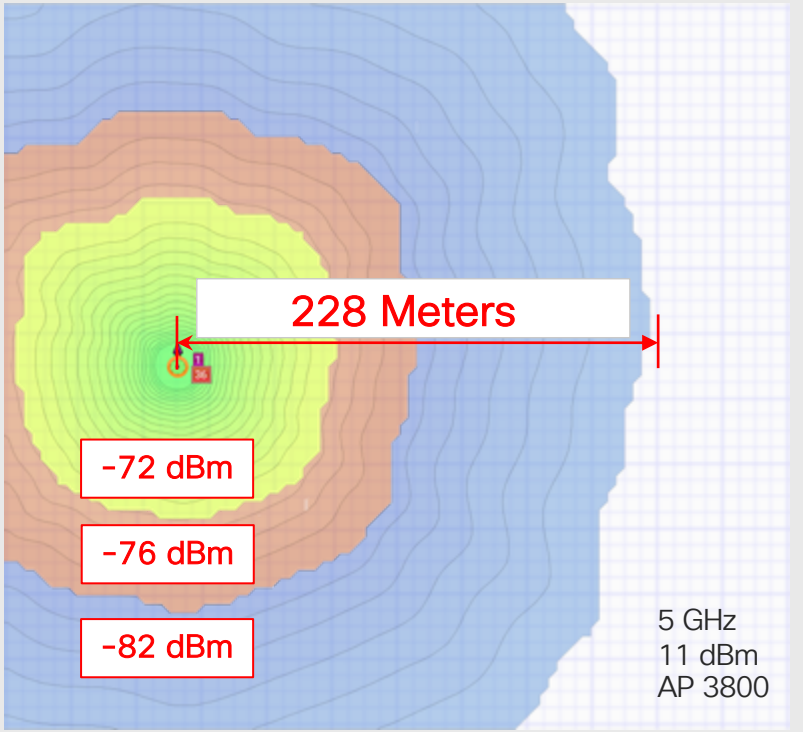
- What if 2 Sta's are talking to two different AP's on the same channel but are close enough to hear one another
- In Wi-Fi 1-5, this still causes all stations that are close enough to hear one another above -82 dBm to back off and take wait for a clear channel
- Realistically though, Sta A and Sta B are close enough to their respective AP's to both Tx at the same time without interfering at their intended receivers
- AP A is far enough from Sta B, and AP B is far enough from Sta A that both transmissions would be successful without one interfering with the other
- In Wi-Fi 1-5 though – there is only the Channel defined as a shared medium, there is no concept of individual BSS's
- BSS A and B form an Overlapping BSS or OBSS



802.11 contention mechanism – Listen before talk and the contention zone

- Using 11 dBm Tx power
  - Cutoff -82 dBm
  - Cutoff -76 dBm
  - Cutoff -72 dBm
- Managed today using:
    - High gain directional antenna's
    - RX-SOP (changing the start of packet threshold)
    - Data rates in use

See the 2018 Wireless High density client density design guide
https://cs.co/9001D47PT



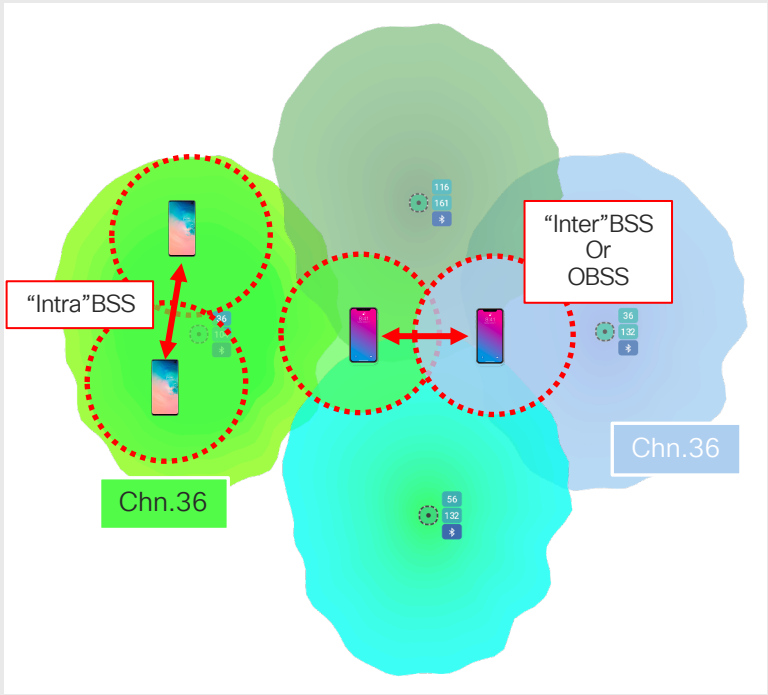
BSS Coloring – Spatial Reuse

Basic service set “BSS” and the overlapping basic service set “OBSS”

- All clients associated on a given AP are operating within the same BSS and will operate on the same BSS color (regardless of the SSID)
- Stations operating on a different AP, may have the same SSID and channel – but will be assigned a different color than mine.
- Each user (station) learns its BSS’s color upon association
- Stations detecting the same BSS color (intra-BSS)operate at the default (PD) CCA -82 dBm
- Stations detecting a different BSS color (Inter-BSS) *may be able to use a higher CCA threshold (lower contention i.e -81 to -62 dBm) through **OBSS-PD and re-use lost space

Every Client becomes a sensor reporting what they can hear from the floor - in realtime

*RRM will make the determination and assignment
**OBSS-PD Overlapping BSS – Packet Detection



Wi-Fi6 adoption and technology next steps

Wi-Fi 6 adoption is accelerating...

First Wi-Fi 6 device:
Samsung Galaxy S10

First Wi-Fi 6 laptops
powered by Intel: HP, Dell

Apple iPhone 11

Microsoft Surface Pro 7
Surface Laptop

2018 | 2019 Feb | Apr | Jun | Jul | Aug | Sep | Oct | 2020

C9115AX
C9117AX
C9120AX

Wi-Fi 6 WFA
Certification

Samsung Galaxy
Note 10

- Samsung S20
- Apple SE 2020
- Xiaomi Mi 10
- Samsung Fold
- OnePlus 8

Many other coming..

15USD WiFi6
Laptop Interface

And there is more coming soon... WiFi6E

More spectrum for Wi-Fi = larger channels

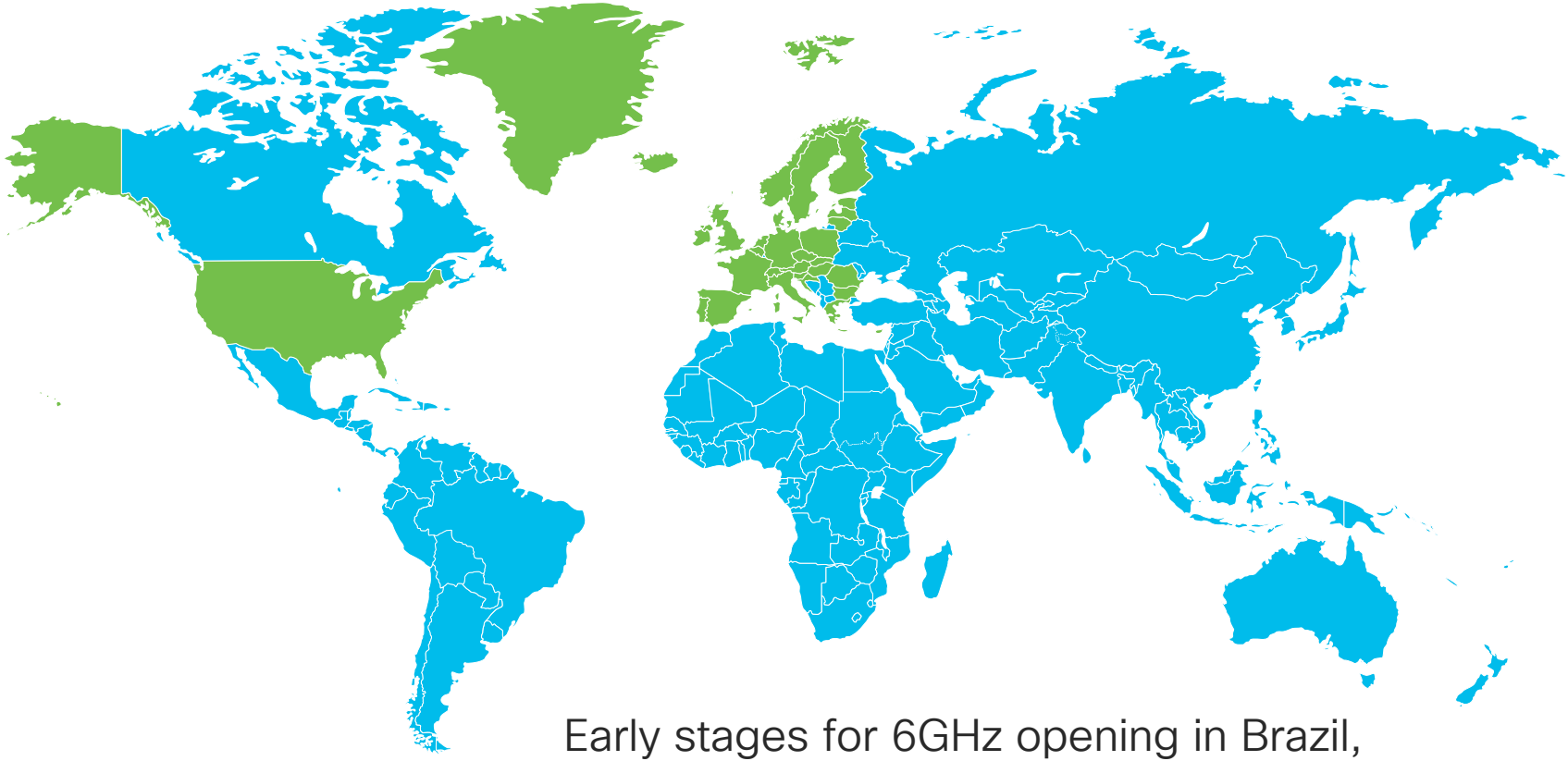
FCC unlocks a massive amount of bandwidth for next-gen Wi-Fi devices

April's unanimous vote opens up 1,200MHz of bandwidth in the 6GHz band for Wi-Fi use. New devices that can take advantage are coming later this year.

Ry Crist April 29, 2020 5:15 a.m. PT

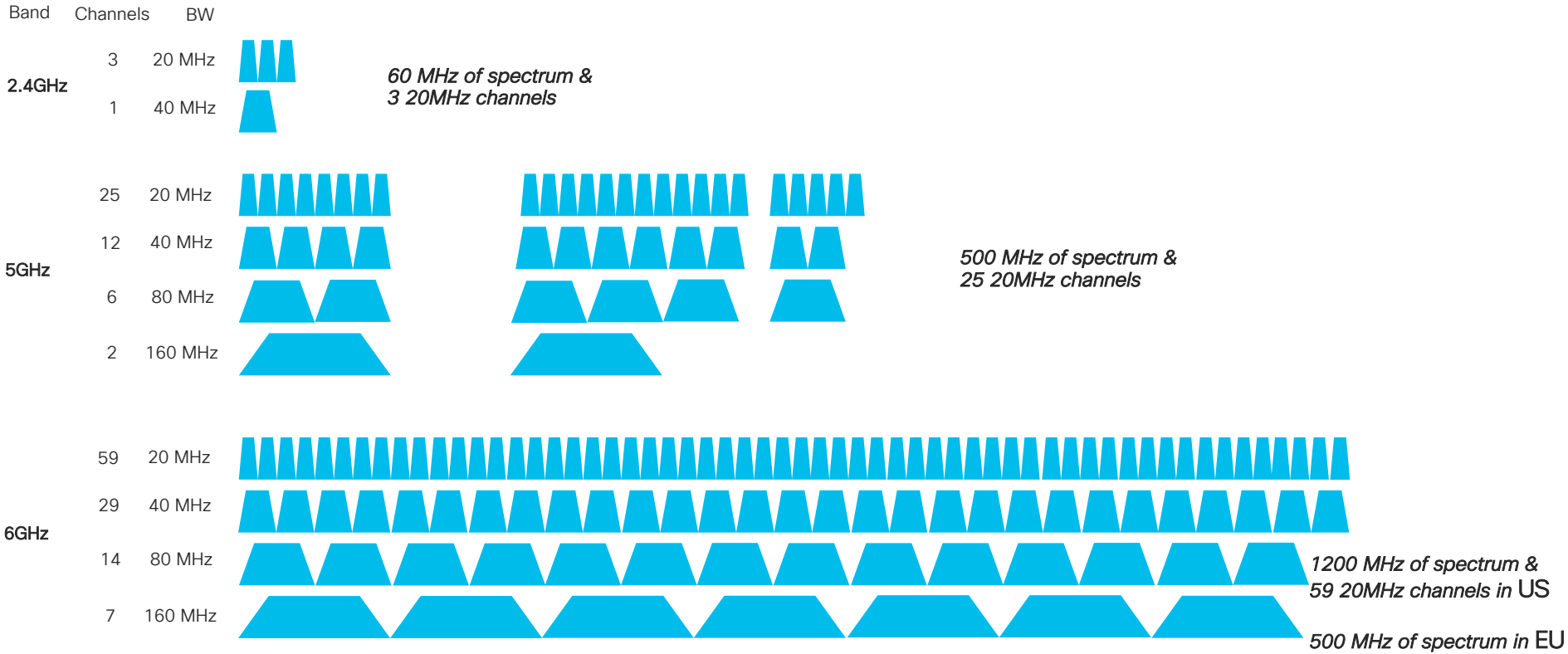
LISTEN - 03:50

US and EU opening up 6GHz band for Wi-Fi usage

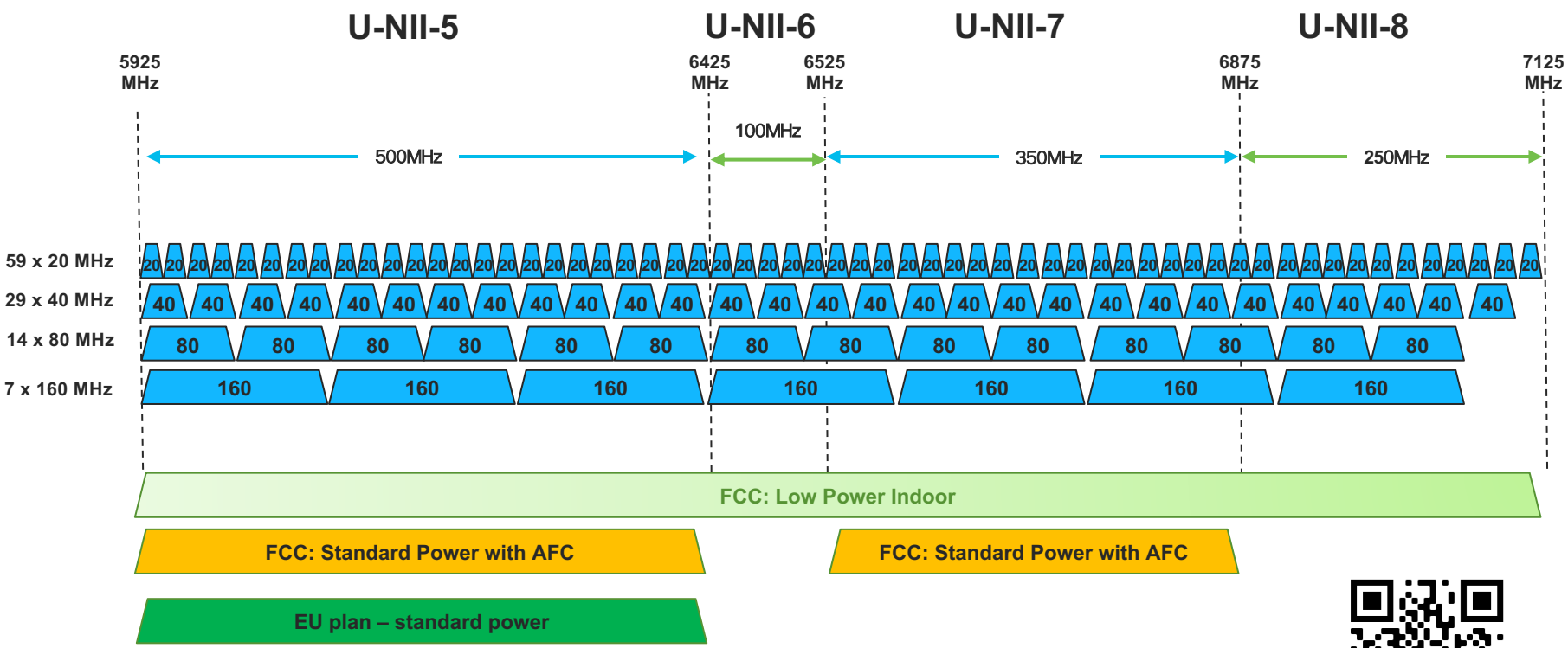


Early stages for 6GHz opening in Brazil, Canada, South Korea, Singapore

6GHz is the biggest Wi-Fi spectrum expansion ever



6 GHz Spectrum Availability



Painel: Alocação do Espectro 6GHz com ANATEL – Novembro 2020

https://youtu.be/qgNZ9s3cxbQ

Key take aways

- Wi-Fi6 is the 6th Wi-Fi generation of the technology
- As in previous generations more throughput is possible via more complex modulation schemes, wider channels and MIMO.
- However the most important change is the use of OFDMA that makes the protocol much more efficient with the capabilities to talk with multiple users in download and uplink.
- This makes the technology a much better option for realtime applications like voice and video, as well as better for higher density of users.
- Other capabilities like BSS coloring make channel reuse more efficient and the use of RU and TWT make Wi-Fi applicable for IoT application.
- Wi-Fi6E will bring mode spectrum to Wi-Fi, allowing the use of wider channels and also will not require design drawbacks like transition mode scenarios that impact in performance and security.
- “Long live the *Wi-Fi*”

Thank you