Wi-Fi6/802.11ax

Diving Deeper

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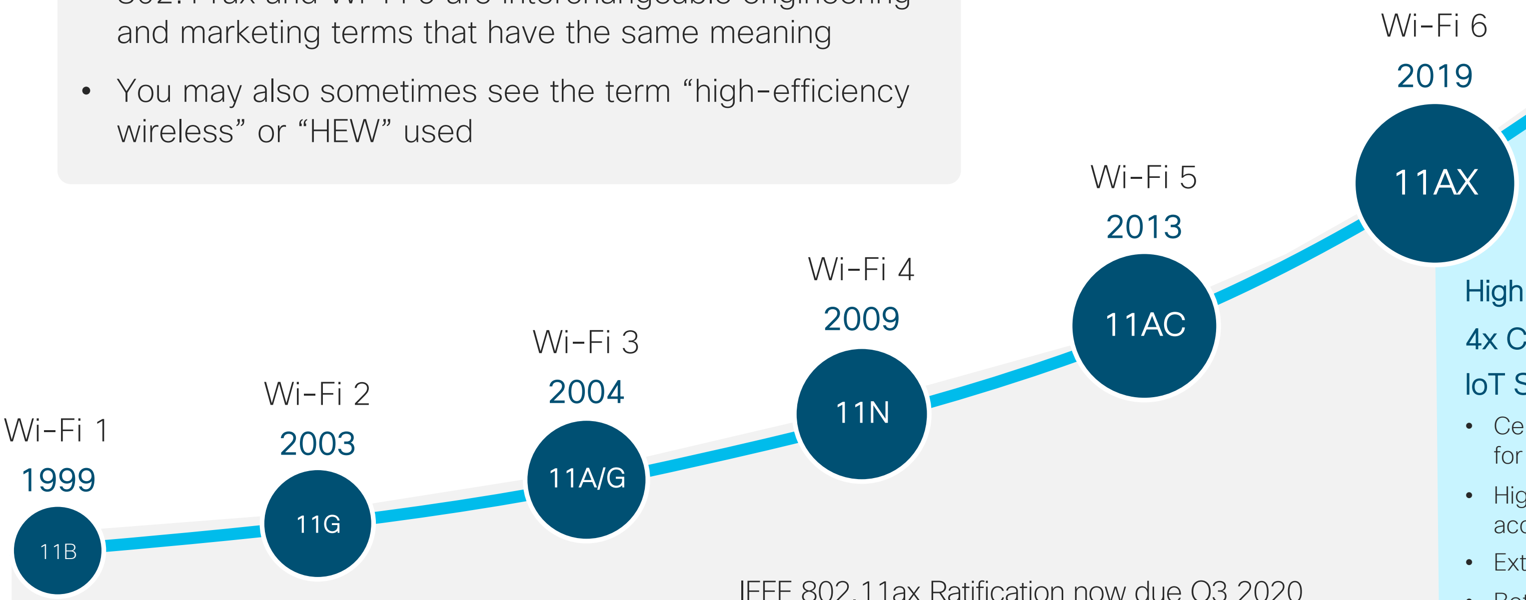
802.11ax (Wi-Fi 6)

You make customer experience **possible**

What is Wi-Fi 6 (or 11ax)?

IEEE Advancing Technology for Humanity — 802.11ax
Wi-Fi Alliance — 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

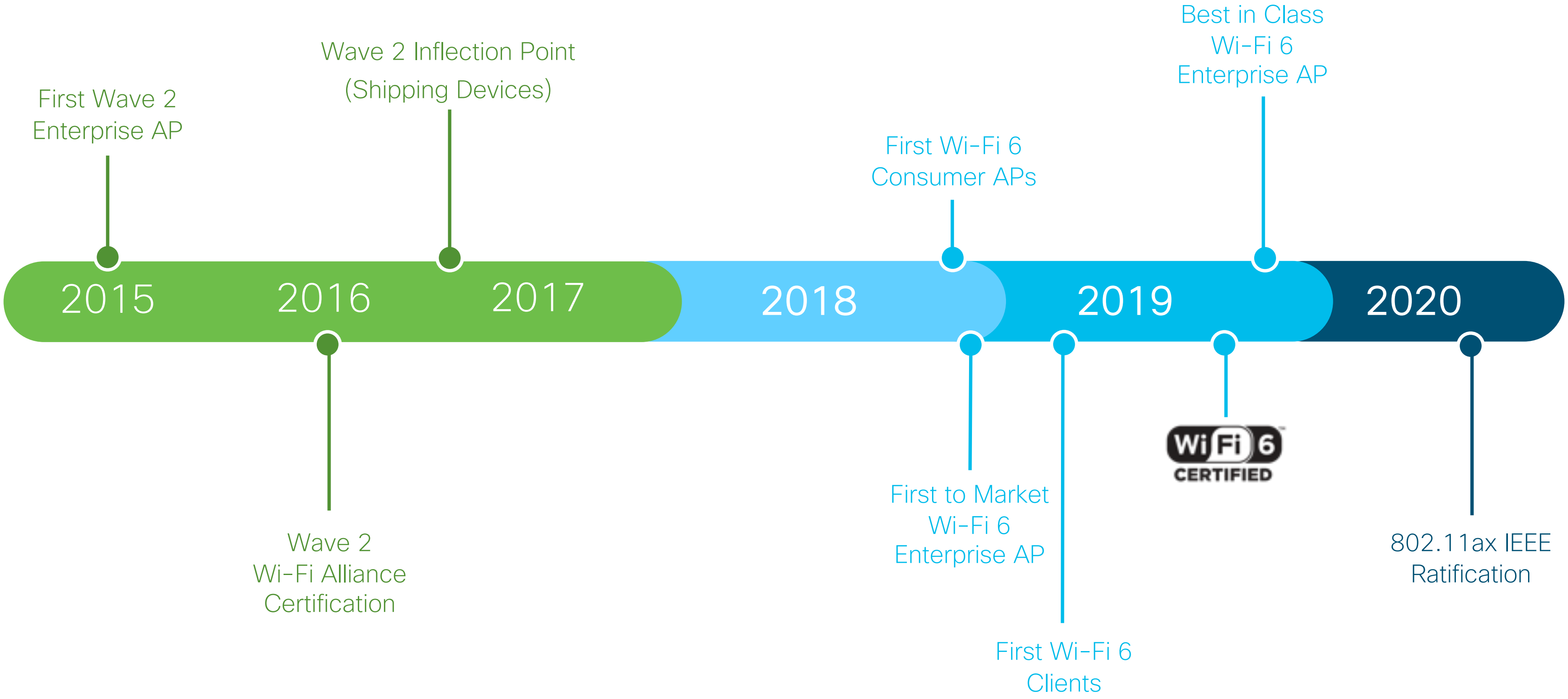
High Efficiency

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

Wi-Fi Evolution



...and clients are already here!

Experience: Wi-Fi 6 (802.11ax)

What is the big deal?

Higher data rates

- 1024-QAM for up to 9.6 Gbps per radio and single-antenna speeds of 1.2 Gbps
- 8x8:8SS
- Enables next-generation 4K/8K and AR/VR video

Increase in overall network capacity

- 3x to 4x more throughput than 802.11ac via OFDMA
- Up to 4x capacity gain in dense scenarios with BSS coloring
- Multiuser MIMO gains on all client types

Reduced latency and greater reliability

- Scheduled uplink and downlink OFDMA for deterministic "cellular-like" latency, reliability, and QoS
- Optimized for IoT scale with hundreds of devices per AP

Improved power efficiency

- Up to 3x better battery life with Target Wake Time (TWT)
- New coding structure and signaling procedures for better transmit and receive efficiency

For more information, see: https://www.cisco.com/c/en/us/products/collateral/wireless/white-paper-c11-740788.html

Efficiency!

Speed and performance YES! But, it needs to be better for all users and also use the spectrum efficiently.

- AirTime efficiency is about how utilised a channel is at any given time.
  - We want our devices to get on and off the channel as quickly as possible
  - Throughput and frame aggregation only gets us so far, and does not help small packet and/or latency-sensitive applications i.e. VoWi-Fi
  - High density of clients = longer intervals between transmit opportunities → increasing jitter and latency

- 4 things influence AirTime efficiency
  1. Data Rates (Constellation Density – how many bits per Radio Symbol per second) **1024 QAM**
  2. # Spatial Streams – Spatial reuse **>4 SS, MU-MIMO, BSS Colouring**
  3. Channel Bandwidth – How many frequencies can we modulate at one time **Subcarriers, RUs &**
  4. Protocol Overhead – Preamble/Ack/BA, Beacons .etc **OFDMA is the game changer**

Wi-Fi 6 - Enhancements

For your reference

Uplink and Downlink Orthogonal Frequency Division Multiple Access (OFDMA): Increases network efficiency and lowers latency for high demand environments

Packet latency improvements

Multi-User Multiple Input Multiple Output (MU-MIMO): allows more data to be transferred at once and enables an access point to transmit to a larger number of concurrent clients at once

Channel Reuse With BSS Color

Parallel processing: enables greater capacity by allowing MU-MIMO and OFDMA to function in UPLINK and DOWNLINK mode

Parallel transmissions

1024 Quadrature Amplitude Modulation Mode (1024-QAM): increases throughput in Wi-Fi devices by encoding more data in the same amount of spectrum

Faster Speed more Radios and 1024 QAM

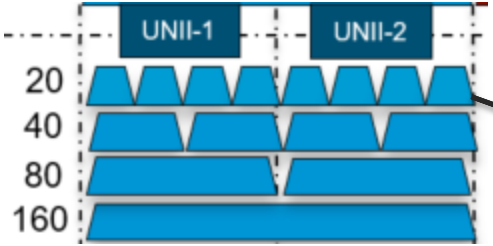
Target Wake Time (TWT): significantly improves battery life in Wi-Fi devices, such as Internet of Things (IoT) devices

Better Battery Life

Understanding OFDMA

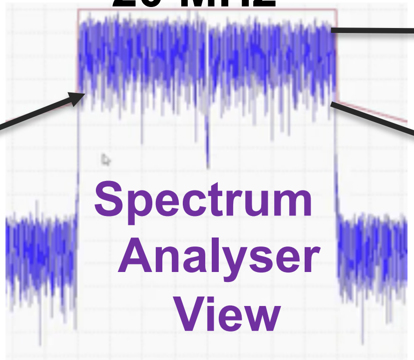
Understanding OFDM – RF Modulation Carrier

- .11ax uses OFDM but also implements OFDMA for High Efficiency Wireless

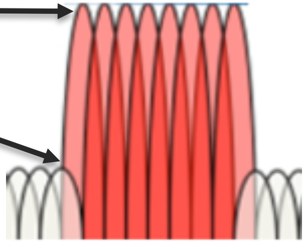


20 MHz Channel

20 MHz



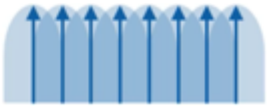
20 MHz



OFDM divides the available spectrum into sub-carriers that can be independently modulated and de-modulated

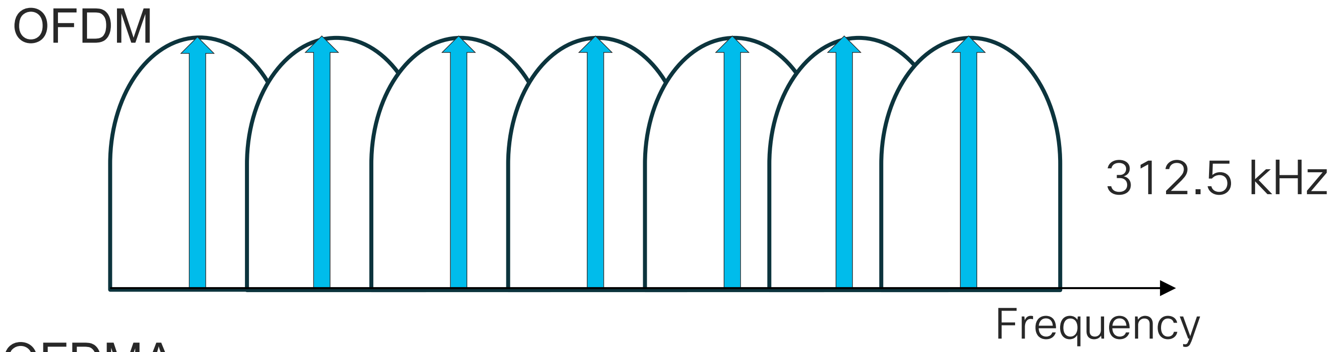
The technology works by splitting the radio signal into multiple smaller sub-carriers that are then transmitted simultaneously at different frequencies to the receiver.

Note: The wider the channel, the more sub-channels available however, range is reduced because the **<u>same amount of power</u>** is now **<u>spread across wider spectrum</u>** – so receiver has to work harder to hear the weaker signal.



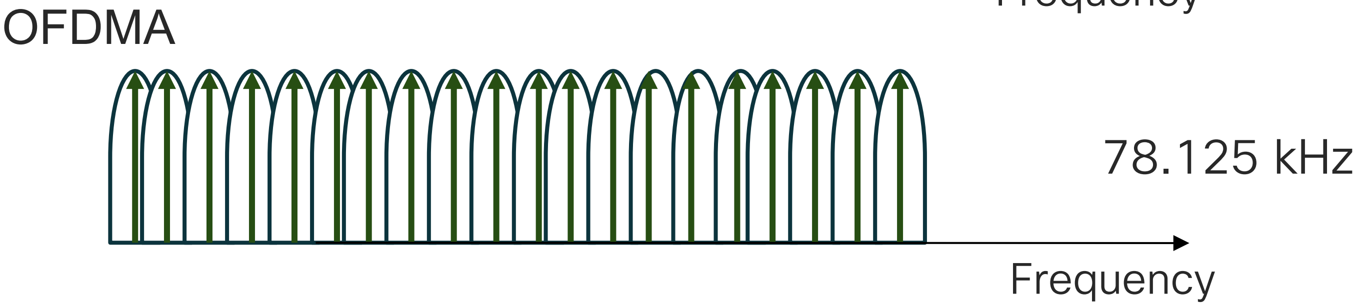
Subcarrier spacing is 312.5 kHz apart and protected by a Guard Interval (short or long)*

Higher Capacity: Sub-Carrier Spacing



Symbol Time: 3.2 us

# of subcarriers: 64



Symbol Time: 12.8 us

# of subcarriers: 256

NEW: Pilot Sub-carriers used for synchronization between TX/RX

32% improvement in throughput due to increase in # of sub-carriers

Understanding OFDMA resource units

For your reference

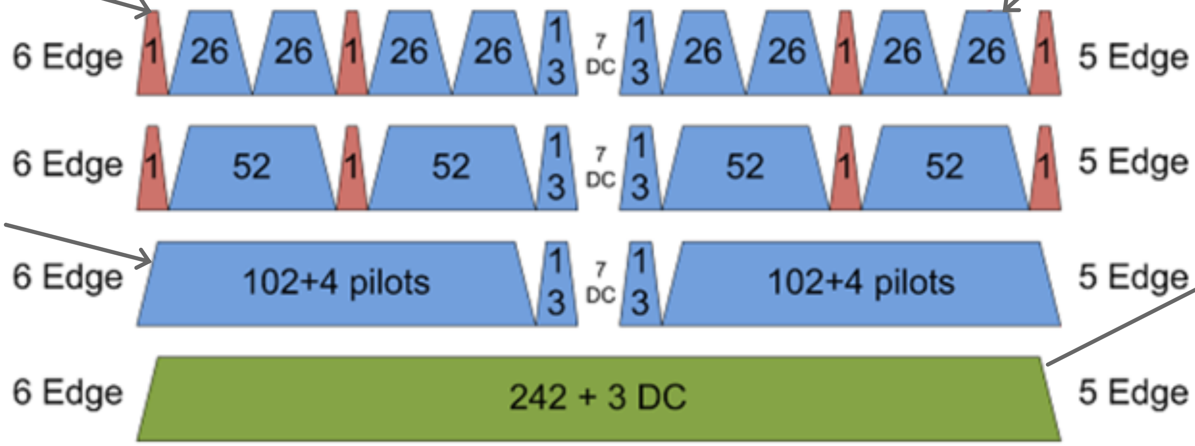
Each RU can be a different modulation scheme or coding rate determined by control information, scheduling etc.

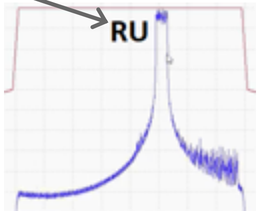
Up to 9 users per 20 MHz
Tiny RUs ideal for IoT

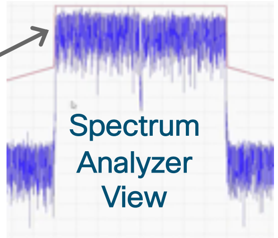
RU's are indexed

20 MHz Channel RUs

Min. RU size
For MU-MIMO







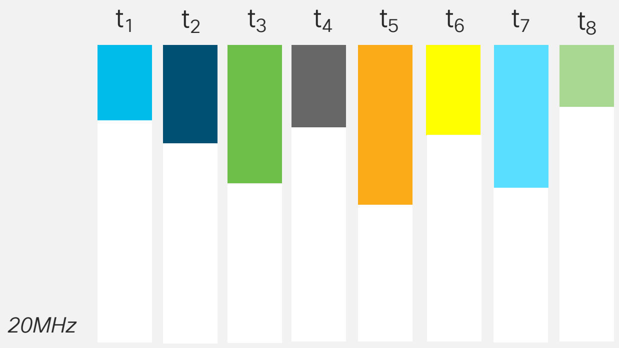
20 MHz

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

OFDMA – Using subcarriers more efficiently

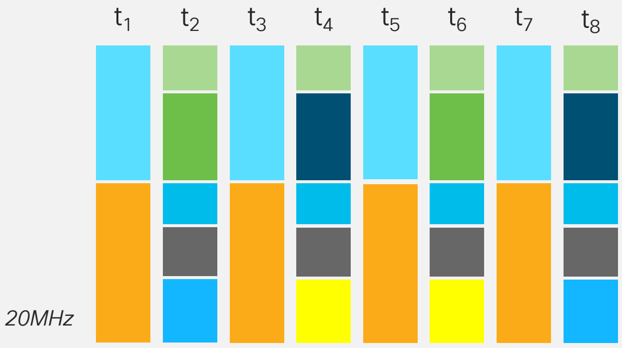
Maximizing client count – lowering latency

OFDM



- Each User gets 1 time slot – whole channel bandwidth
- Each User must wait t_8 before Next TX_op
- As more clients Join the cell, Latency – Jitter Increases
- QOS only manages TX_op – someone has to wait

OFDMA



- Multi user Packet makes flight more efficient
- Also provides much more regular and consistent TX_op
- Deterministic nature – miss this truck – no worries here comes another “meaning the truck” is always leaving “full”… net result is lower latency

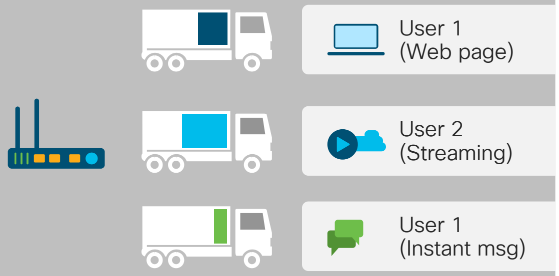
User 1 – Telemetry | User 2 – Voip | User 3 – Video | User 4 – Voip | User 5 – Data | User 6 – IoT | User 7 – Data | User 8 – Voip

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**

Device only improvements vs whole cell/network:

OFDM vs. OFDMA and sub-carriers

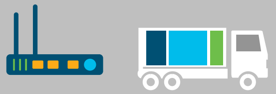
OFDM



- Fixed overhead – Independent of payload size
- Uses full channel bandwidth – Per user

Device only improvements vs Whole cell/network:
OFDM vs. OFDMA and sub-carriers

OFDMA

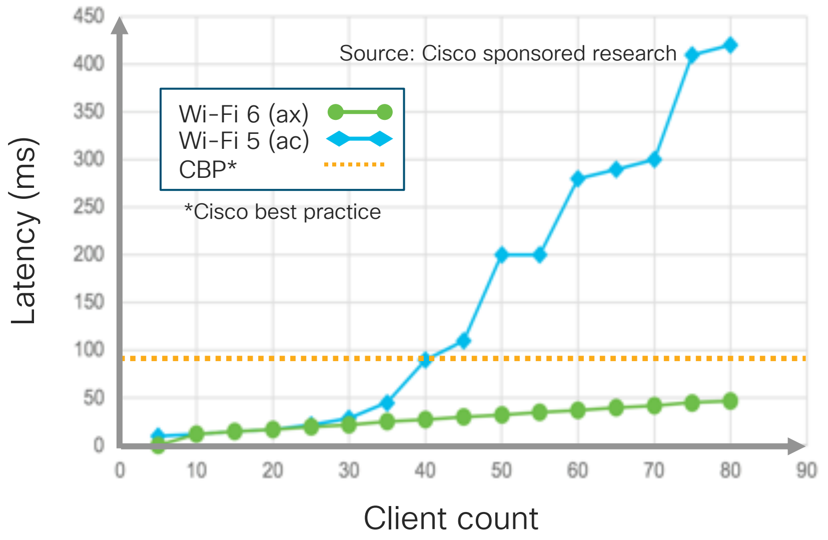


- Creates
- Playload
- Efficiency

- Overhead – Amortized between users
- Efficient use of Resources
- Scales resources for different traffic mix (IM vs Download)
- Increases overall Efficiency

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)

.11ax data-rate chart for 1 spatial stream

New 1024 QAM introduces a 25% performance in throughput with single radio

For your reference

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

OFDMA is Multi-User

....now overlay MU-MIMO

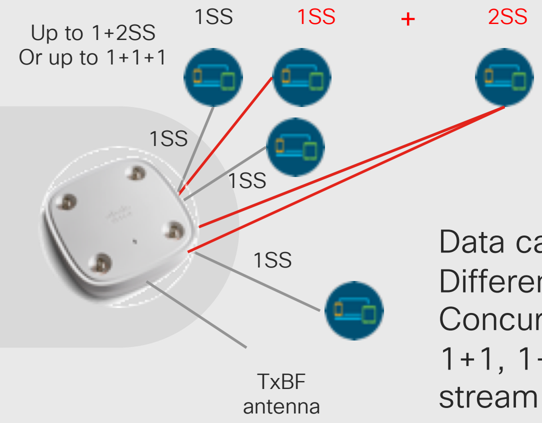
Multi-User MIMO (MU-MIMO) .11ac wave-2

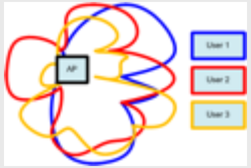
Performs TxBF, while nulling and also sending similar size data packets using 4th antenna TxBF

Each Wave-2 client sends CSI (Channel State Information) about how to best beam-form to it.

The AP then determines how it will beam-form **and null** to each of the 2-3 clients and then clusters these “ideal” clients into groups.

On a per-packet-basis each member of a group receives a similar size packet at the same time (downstream).

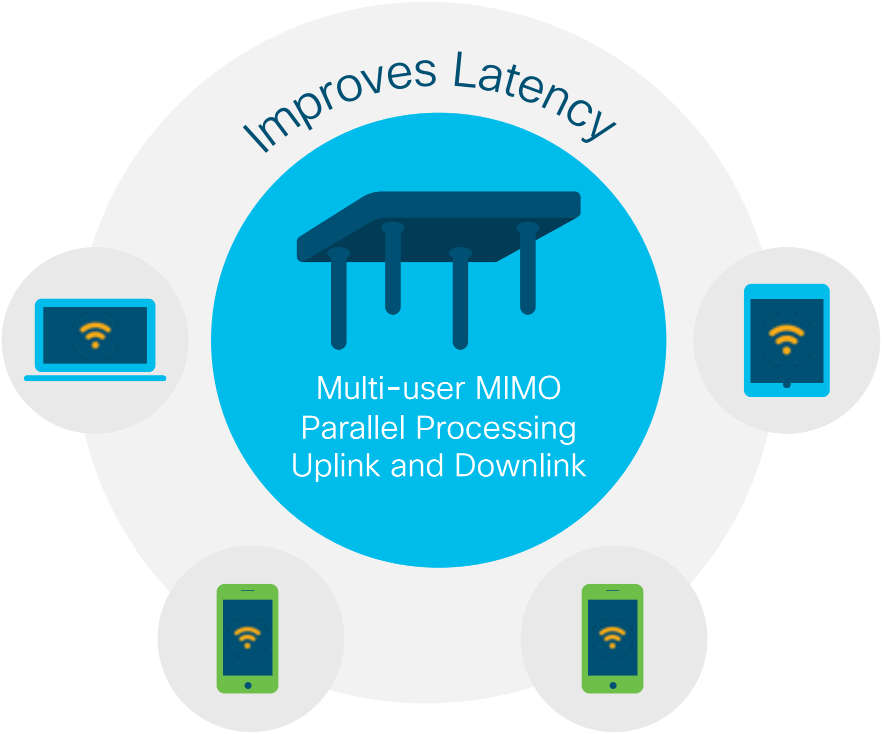




Data can be directed to Different clients in Concurrent streams in a 1+1, 1+1+1 or 1+2 stream combinations

AP is using the **fourth antenna** to beam-form and null. In reality the clients are ideally spaced apart **around the AP** and not clustered together like the diagram depicts.

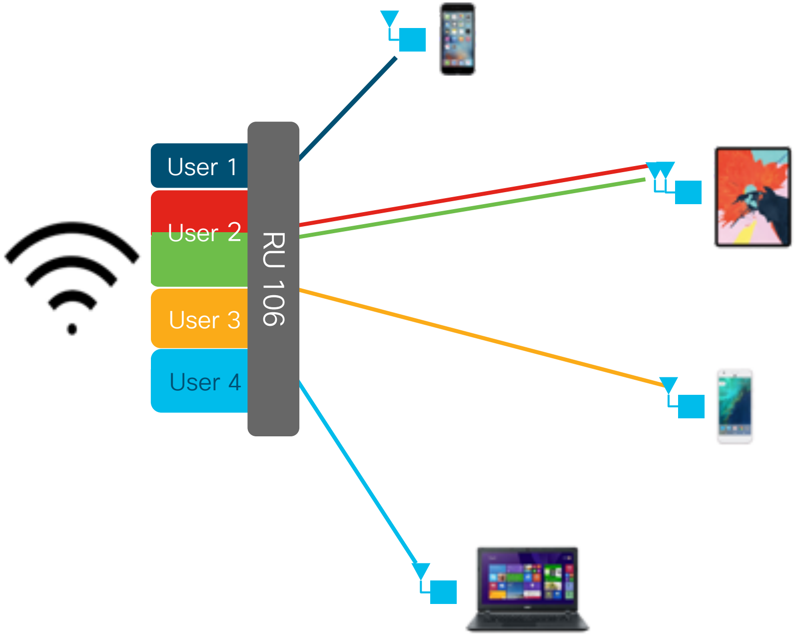
Wi-Fi 6 enhancements to Multi-User MIMO



- MU-MIMO is a requirement for Wi-Fi 6
- 8 MU-MIMO transmissions (users in a group) up from 4
- MU Station UL and DL ACKs come back in parallel *USING OFDMA*
- 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

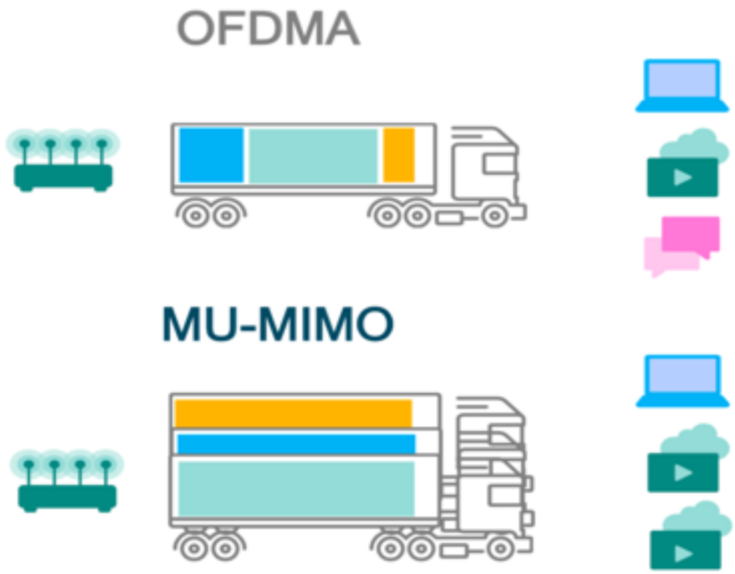
OFDMA and MU-MIMO

- 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
  - Clients send Buffer Status Reports (BSRs) to AP in QoS Data or QoS Null frames
  - AP then determines SS/MCS/Tx Power
- OFDMA Back-off OBO
- Operating Mode Indication (OMI)
  - Client can request change to RU/BW/SS
  - Can opt out of MU operation
- UL-OFDMA Random Access



OFDMA and MU-MIMO are complementary

Utilized based on the type of application being served



MU-MIMO is similar to multiple trucks serving users simultaneously

- OFDMA increases efficiency
- OFDMA reduces latency
- Ideal for low-bandwidth applications

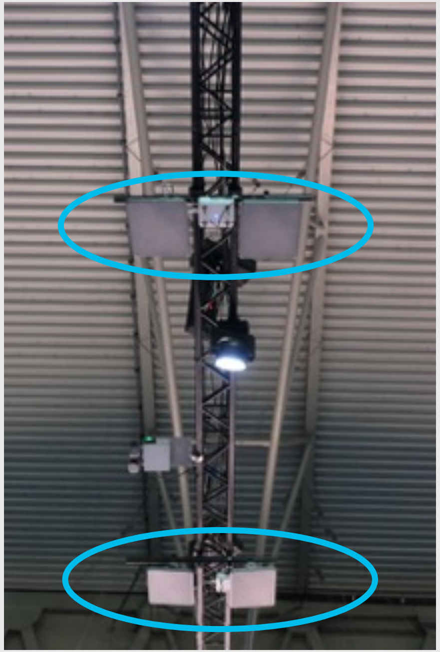
- MU-MIMO increases capacity
- MU-MIMO results in higher speeds per user
- Ideal for high-bandwidth applications

Ref: https://www.techspot.com/article/1769-wi-fi-6-explained/

BSS Coloring and Spatial Reuse

Spatial reuse today – Prior to Wi-Fi 6

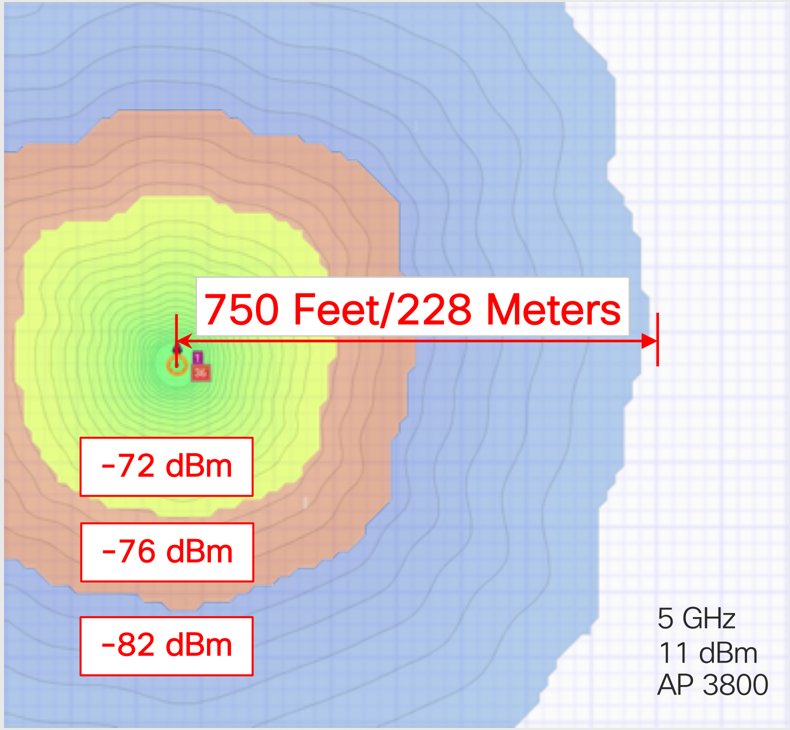
- Today, any other Wi-Fi station above -82 dBm means channel is busy and we must defer (back off)
  - LBT – Listen Before Talk
- Implementations generally in a range of about 4 dB (-78 to -82) to provide conditional exceptions (noise floor)
- This range has been overly cautious due to fears of co-channel interference which can and does impact overall capacity if not designed correctly
- In high client density implementations, we often design for -60 dBm cell edges to maintain SNR in very noisy environments
- A lot of expensive hardware (antennas, design) is used to isolate one cell from another on the same channel and maintain capacity and throughput



802.11 contention mechanism – Listen before talk and the contention zone

- Using 10 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



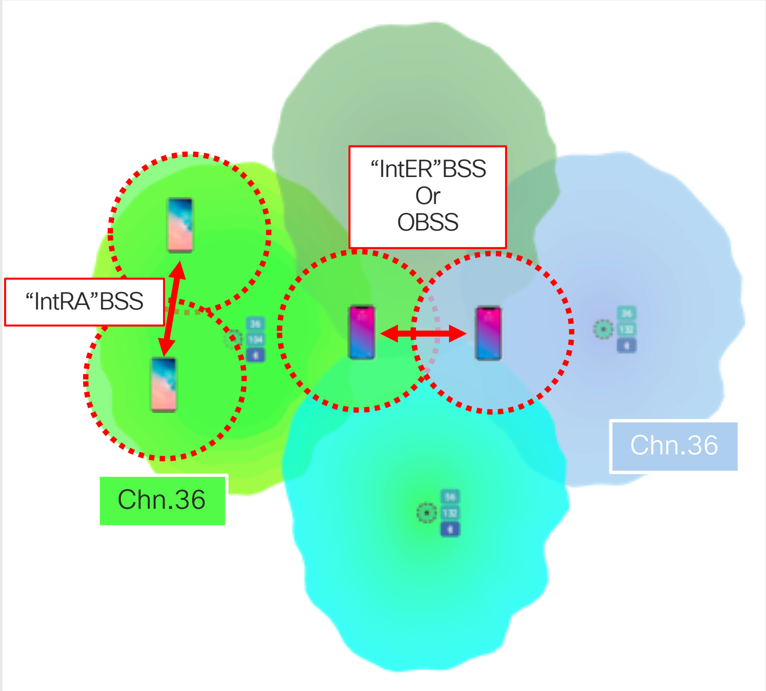
BSS Coloring – Spatial Reuse

Basic service set "BSS" and the overlapping basic service set "OBSS"

- BSS Color – All devices within a BSS send the same value (color). ("Intra-BSS")
- Each user (station) learns its BSS's color upon association
- Stations detecting the same BSS color (intra-BSS) *may be offered a lower CCA threshold for Access (Higher Contention) default -82 dBm
- Stations detecting a different BSS color may be able to use a higher CCA threshold (lower contention) i.e -81 to -62 dBm
- OBSS-PD enables variable contention window based on neighbours and operational power levels

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

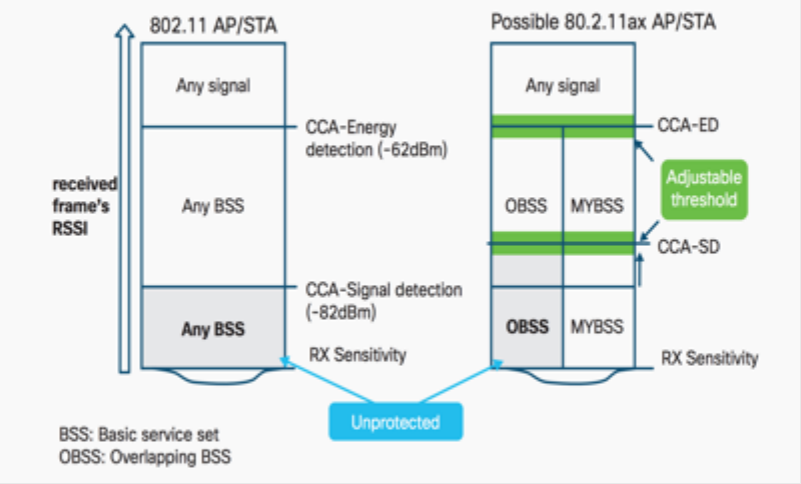
*RRM via supported OBSS-PD will determine and recommend



BSS Coloring – Spatial Reuse and OBSS-PD

Manage the Noise – get more simultaneous TX Opportunities!

- OBSS Packet detection is dynamic and managed by the AP
- If a station reduces its TX power, the device **can** raise its **inter**-BSS 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, THE LOWER it's transmitted power can be while maintaining SNR and acceptable Data-Rates



Benefit - Overcomes the problem of Clear Channel Assessment limitations –

TWT – Target Wake Time

802.11ax Target Wake Time Benefits for IoT

Better Battery Life and co-existence via RF efficiency improvements

Target Wake Time

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.

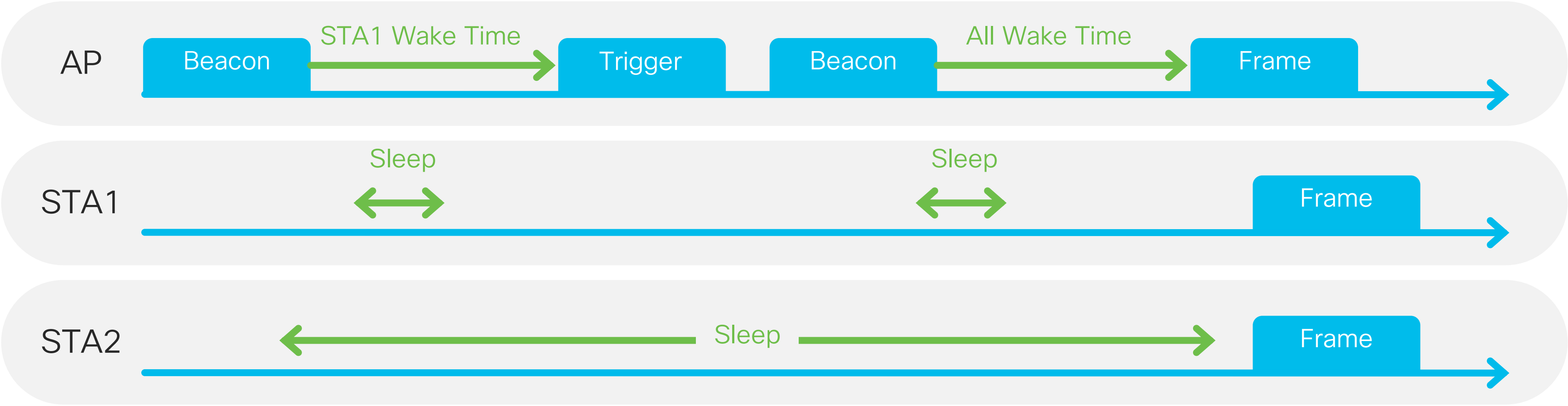


Image source: Broadcom

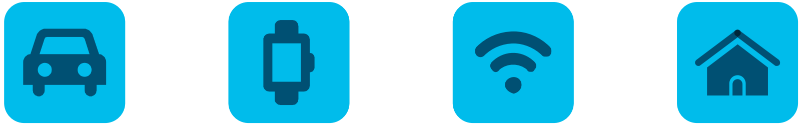
IoT – Wi-Fi 6 Enhancements

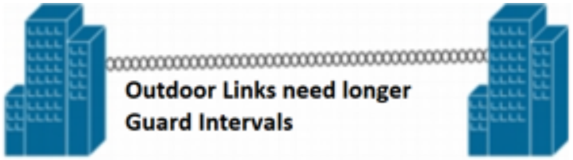
IoT benefits using Wi-Fi 6

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 (Uplink and Downlink)
- Small packet aggregation (using OFDMA) for reduced latency
- Longer guard interval for greater robustness for long-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**

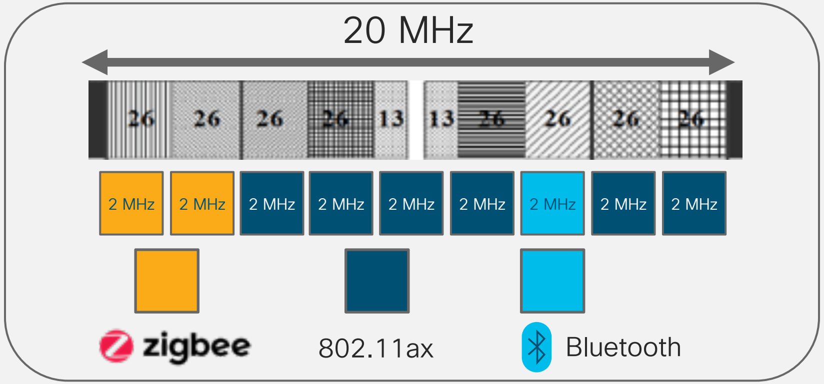




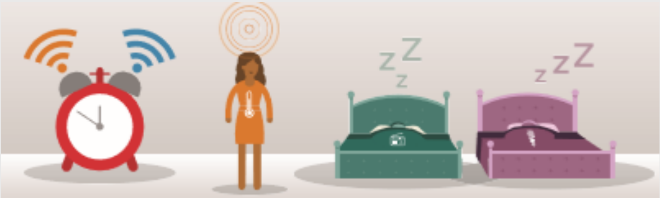
802.11ax RU and target wake time benefits for IoT

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 OFDMA) 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.

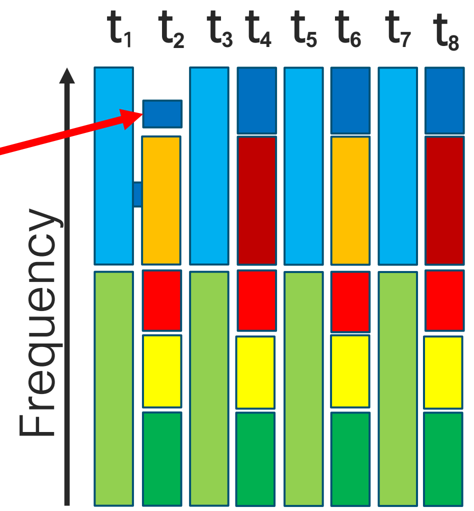
OFDMA Benefits for IOT

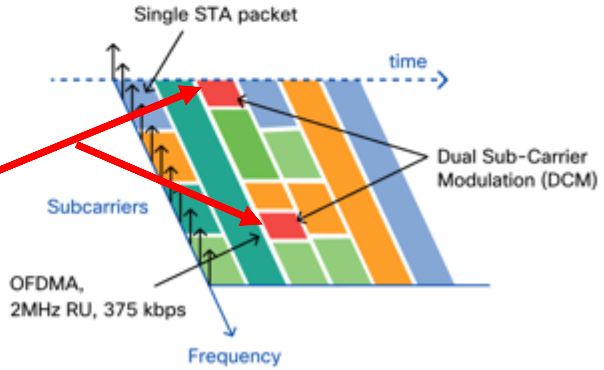
- OFDMA, 375 kbps Low Power, Low Throughput

- Using a single 2 MHz Resource Unit the AP and client can exchange **at 375 kbps** for low throughput and low power consumption ideal for IoT

- 802.11a/g/n/ac allowed only ~6-6.5 Mbps minimum, creating wasted bandwidth and higher RF power consumed.

- Longer Distance benefit as the power used for a 20 MHz channel could be concentrated into a single 2 MHz RU
  - Better Link Budget
  - No more cost to battery
  - **DCM (Dual Subcarrier Modulation)** RU can be repeated in another subcarrier for resiliency





Are you ready for Wi-Fi 6?

You make networking **possible**

.11ax Installations - What do you have installed today?

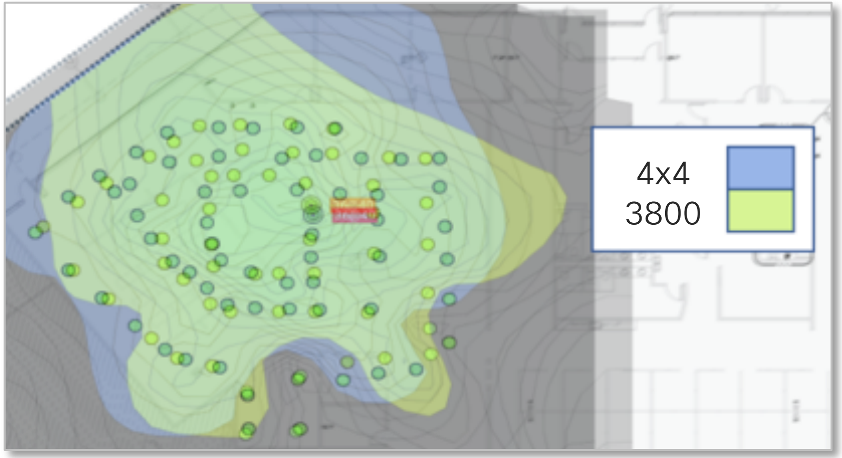
- Before refreshing to Wi-Fi 6 its time to do a review of your existing WLAN issues as well as identifying any new location, BLE or IoT requirements

- 1:1 replacement <u>assumes</u> the AP was installed in the best place to begin with?

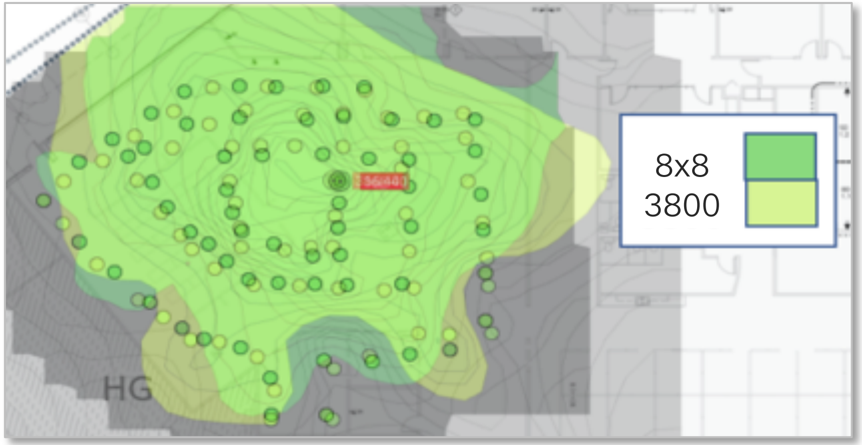
- While new Wi-Fi 6 features might be able to help mitigate a bad or poor design ***NOTHING BEATS*** reviewing what is in place now and ***INSTALL IT RIGHT the 1st time*** ☺

Upgrading Access Points 1:1 or another survey?

Access Points have always had similar heat maps – The design goal is to maintain a uniform coverage cell between products but improve the connection experience (faster speeds less retries). **Don't mix & match!**



AP-3800 & .11ax 4x4



AP-3800 and .11ax 8x8

- Keep Access Points mounted at least 2 metres away from each other
- Rule of thumb - **1 AP per 250m² or US 1 per 2500ft²** (data-grade deployment)

1024-QAM 40 MHz channel (314 Sq.meters)

Single-antenna devices (smart-phone) should see MCS10-11 (Gigabit speeds)

35%

faster than 11ac

Question to consider – are you ready for Wi-Fi 6?

- Ensure you are meeting requirements
  - Coverage, antennas
  - Capacity, dual 5 GHz
  - Channel widths
  - Data rates, basic rates
  - Applications & QoS
  - Always validate your design!
- Planning tool support
- Wired infrastructure
  - mGig (4x4:4 – 2.5G, 8x8:8 – 5G), cabling, UPoE/802.3bt
- Control Plane & Data Plane
  - Code support across APs
  - Central vs local switching
- Clients
  - Get rid of old b/g/a clients
  - Ensure drivers are up to date
  - Will they meet Wi-Fi Alliance certification – Mandatory vs Optional?
    - https://wikidevi.com/wiki/List_of_802.11ax_Hardware
- Troubleshooting tool support
  - Packet capture and analysis

Some useful Wi-Fi Tools

MacOS

- The Adrian Granados Trio
  adriangranados.com
  - Wi-Fi Signal – connection info, roaming
  - AirTool – Packet Captures
  - Wi-Fi Explorer – Visualisation of capabilities and channels

Windows

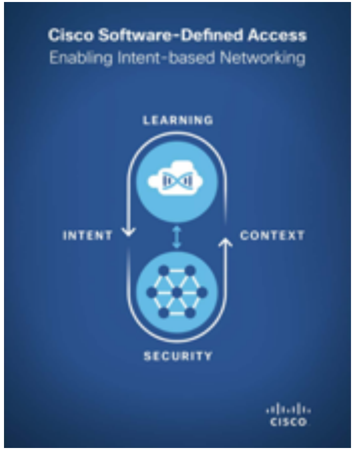
- inSSIDer – Visualisation of channels and high-level settings
- EyePA – Visualisation of frame analysis

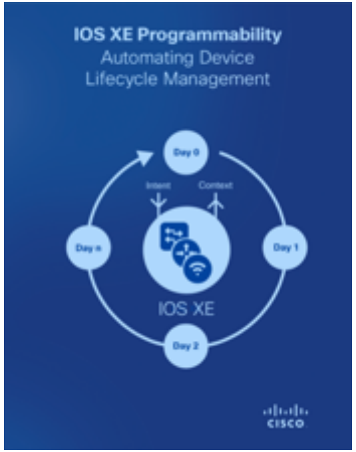
Ekahau Pro w/ Sidekick

- Predictive Designs
- Validation Surveys
- Spectrum Analysis
- Packet Captures
- Prime integration (watch this space)

Enterprise Networking Booksprints

Enterprise Wireless (Second Edition!) http://cs.co/wirelessbook
Cisco DNA Center Assurance http://cs.co/assurancebook
Catalyst 9000 Switching http://cs.co/cat9000book
Software Defined Access http://cs.co/sdabook
IOS-XE Programmability http://cs.co/programmabilitybook





Thank you ☺

Questions?

You make **possible**