AIRHEADS meetup

aruba
a Hewlett Packard Enterprise company

802.11ax and 802.11ad Sneak Peek

Technology overview and Aruba's early products

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#ArubaAirheads

802.11ax : High Efficiency Wi-Fi

Overview & Aruba roadmap

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GOALS OF 802.11ax TASK GROUP

Increase average throughput per station by at least 4x in a dense deployment scenario (think: 100+ clients/AP, 2500sqft or less per AP)	Even higher peak throughputs, while also efficiently enabling very large amounts of simple, low-bandwidth and low-cost devices (IOT)	Enable client devices to achieve significant power savings (battery life!)	Enabling more robust and longer range outdoor links

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WHY YOU SHOULD CARE ABOUT 802.11ax?
IMPROVED EXPERIENCES!

PROBLEMS IT WILL SOLVE

Degraded client performance in dense WLAN use-cases with typical enterprise data traffic

Networks deployed now may not be ready to deal with the continued growth in client device numbers, their bandwidth demands, and the broad mix of client types

IMPROVEMENTS IT WILL DELIVER

Improved system efficiency and higher peak datarates, resulting in significantly increased average client performance

Significant power savings opportunities for client devices

Ability to provide optimized data pipes of varying bandwidths to broad range of client device types

Much more robust and longer-range outdoor links

CONCERNS

No client devices yet
– True, but they are coming soon, and being prepared is a good thing

Products not ready/stable yet
– True, but this is changing rapidly

Need to upgrade my wired network
- Not necessarily, and a gradual approach can be taken

It is (too) expensive
- Not really, the premium of 11ax over 11ac can be quite small

WHEN WILL 802.11ax BECOME A REALITY?

Ratification of the 802.11ax amendment expected by December 2019

Launch of 802.11ax WFA certification program (R1) expected by August 2019

Prerequisites: WPA3, MBO and ac/n

Key features in R1:
DL/UL-OFDMA (m),
DL-MU-MIMO (m*),
TxBF (m*), TWT (m),
20MHz-only STA (m),
160MHz (o)

Key features NOT in R1:
UL-MU-MIMO,
Spatial Reuse*, 80+80

Chipsets and drivers almost there

Early versions available now, mature solutions not quite there yet

Beware: some are not SW upgradable to 11ax compliance,
others come with early incomplete/unstable drivers

Client devices coming in 2019

Access Points coming soon, or “shipping” already

Switches

Multi-gigabit Ethernet (HPE Smart Rate, 802.3bz) available now on the Aruba 2930M, 3810 and 5400R switches

>30W PoE (802.3bt) coming soon

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ARUBA’S 802.11ax ROADMAP

Of course we want to be first or early to market with 802.11ax, Duh. It’s in our DNA. And it makes business sense	But with AP platforms that can pass full R1 WFA certification with software upgrades only, Not using prototype chipsets for throwaway platforms	And have the capabilities and performance to deliver the full potential of the 802.11ax promise, 802.11ax cannot be bolted onto existing hardware but needs to be built from the ground up	While ensuring business continuity through quality, stability and reliability, Futureproofing without the early adopter pain. Nobody can afford WLAN downtime	With differentiating features, both at the AP and system level, The new radio standard is just a small piece of the overall solution	At multiple price- and performance points 802.11ax adds value to all platform types and at all levels

ARUBA’S 802.11ax Campus AP LINEUP

AP-505
2x2 / 2x2
1Gbps
802.3af

AP-515
4x4 / 2x2
2.5Gbps / 1Gbps
802.3at

AP-535
4x4 / 4x4
5Gbps / 5Gbps
802.3at*

AP-555
8x8* / 4x4
5Gbps / 5Gbps
802.3bt*

802.11ax : High Efficiency Wi-Fi

Technology

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Standard Progression

Feature	802.11n	802.11ac	802.11ax
Bands	2.4 GHz and 5 GHz	5 GHz only	2.4 GHz and 5 GHz
Channels	20, 40 MHz	20, 40, 80, 80+80 MHz	20, 40, 80, 80+80 MHz
FFT Sizes	64, 128	64, 128, 256, 512	256, 512, 1024, 2048
Subcarrier spacing	312.5 kHz	312.5 kHz	78.125 kHz
OFDM symbols	3.2 usec	3.2 usec	12.8 usec
OFDM symbol cyclic prefix	0.8 or 0.4 usec	0.8 or 0.4 usec	0.8 or 1.6 or 3.2 usec
Highest modulation	64 QAM	256 QAM	1024 QAM
Spatial streams	1 – 4	1 – 8 (not implemented beyond 4)	1 – 8 (may be implemented)
Tx Beamforming	Yes but not implemented	Yes	Yes
MU MIMO	No	Yes DL	Yes DL and UL
OFDMA	No	No	Yes DL and UL
	HT	VHT	HE

Enhancements in 802.11ax

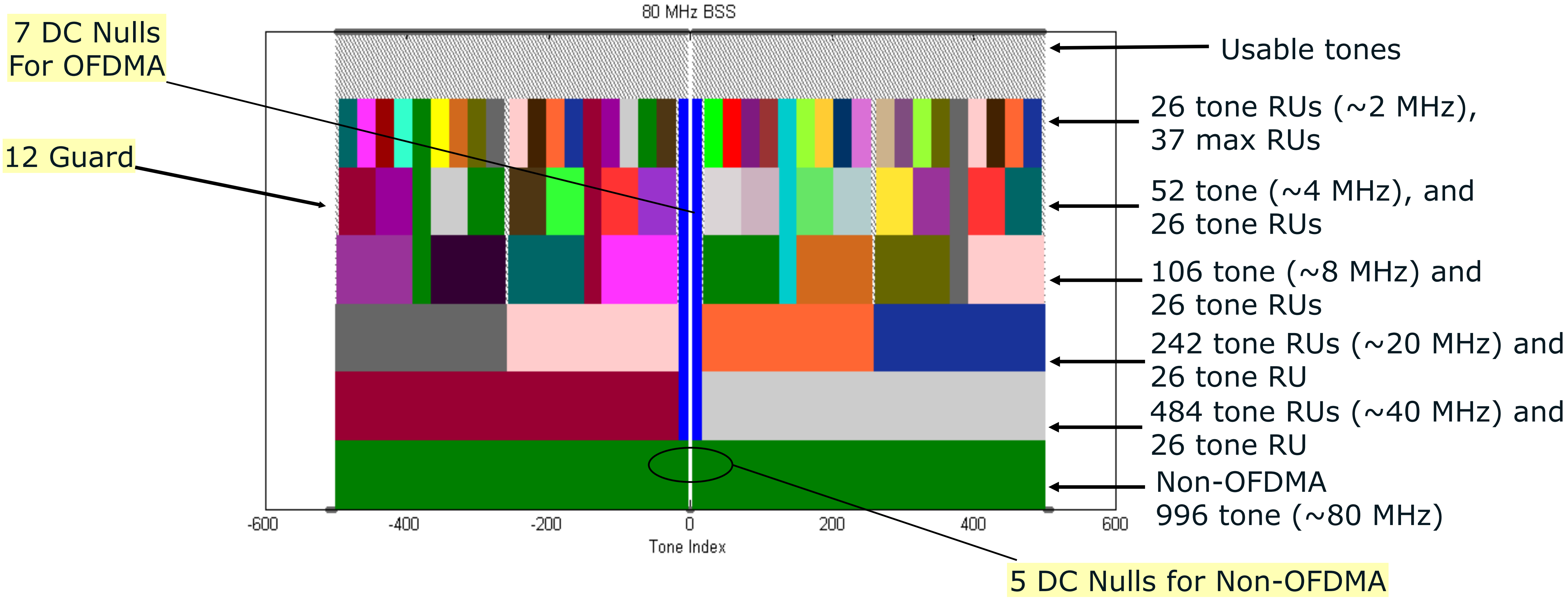
- OFDMA (Orthogonal Frequency Division Multiple Access)
  - Allows breaking up the channel (in frequency domain) for data to/from multiple clients simultaneously
  - Side-effect: longer symbol (in time) to allow more sub-carriers (in frequency) for more granularity (4x)
  - This improves sub-carrier usage efficiency (nuls, guard, pilot) and symbol usage efficiency (guard)
  - The results is a max datarate increase of about 20%
- 1024-QAM Modulation
  - Increases the max number of bits per symbol from 8 to 10 (+25%)
- MU-MIMO: Increase max number of simultaneous client devices to 8
- UL-MU: Support for both OFDMA and MU-MIMO in the Uplink direction
  - Note: Both DL and UL OFDMA are mandatory for 11ax WFA certification
- Spatial Reuse: Allow transmissions even if channel is “busy”
- Power Savings enhancements for client devices
- Enhancements for more robust and longer range outdoor links

OFDMA

OFDMA

- 11ax Introduces the concept of Resource Units (RU)
- This is a concept adapted from LTE
- Allows for many parallel transmissions at once with each user getting a chunk of spectrum from 2 to 80 MHz wide
- 11ax symbol rate is 78.125 kSps vs 11n/ac at 312.5 kSps (4x)
  - This gives 4x as many tones as for 11ac but take 4x as long to transmit
  - Symbol duration goes from 3200 ns to T = 12800 ns
- New guard intervals for 11ax: 800 ns, 1600 ns and 3200 ns
  - 11n/ac: 400ns, 800ns
  - While longer the 800ns interval drops from 20% overhead to 6% overhead
  - 800 ns is T/16 or 6.25%, used to be T/5 or 20%. Even 400 ns was T/9 or 11.11%

80 MHz BSS



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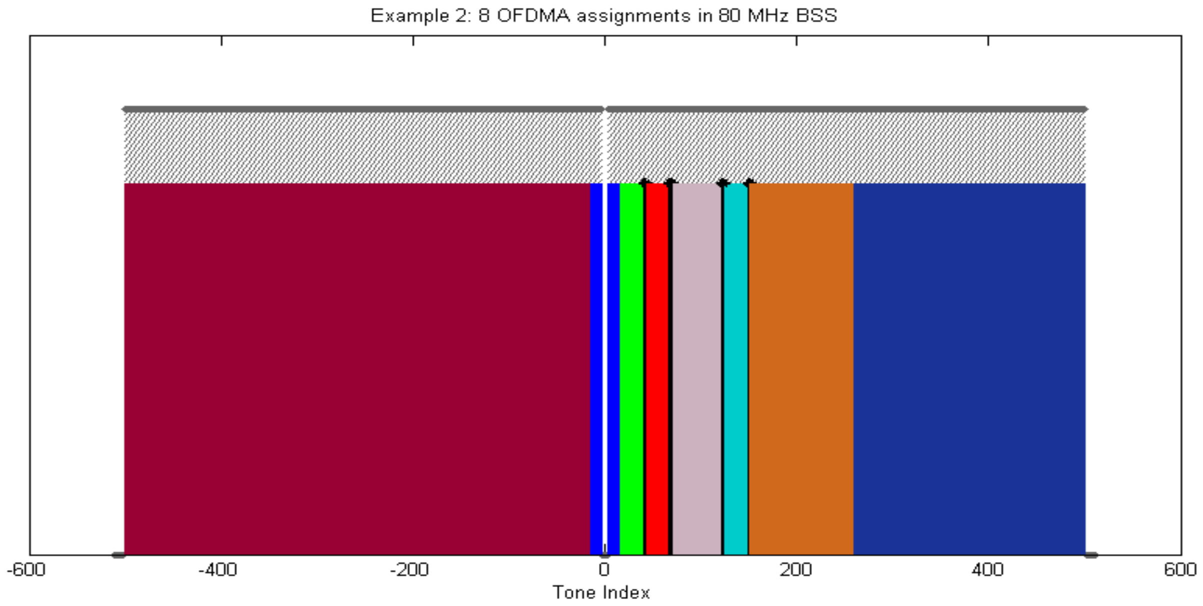
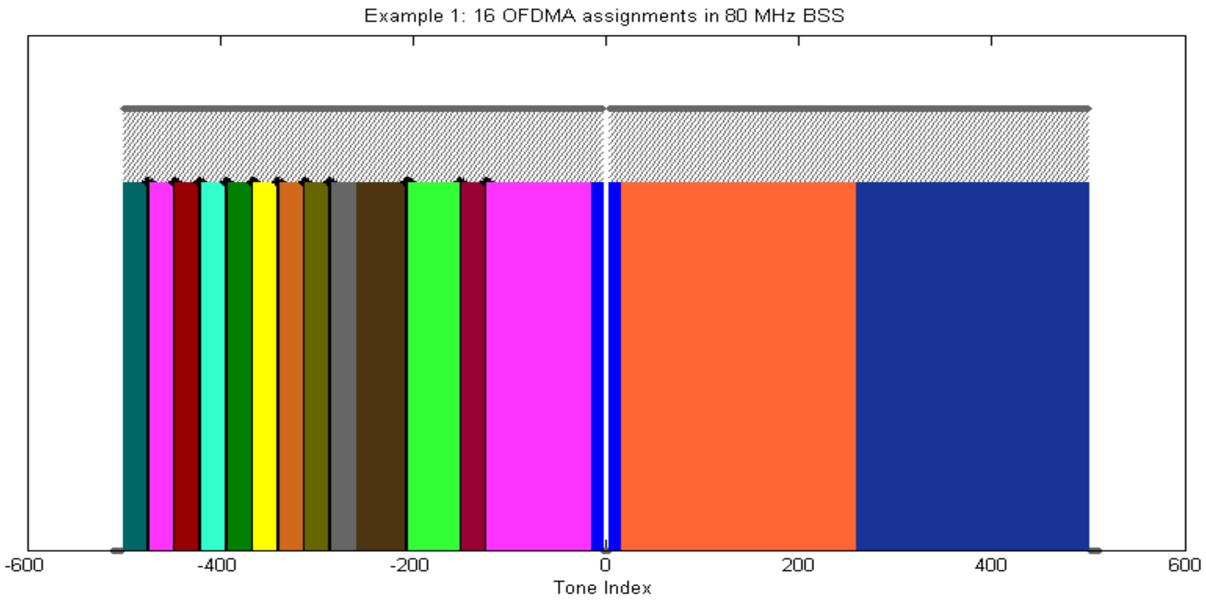
OFDMA Resource Unit Allocation Examples

8 OFDMA assignments in 80MHz BSS



16 OFDMA assignments in 80MHz BSS



RU assignments can vary packet to packet

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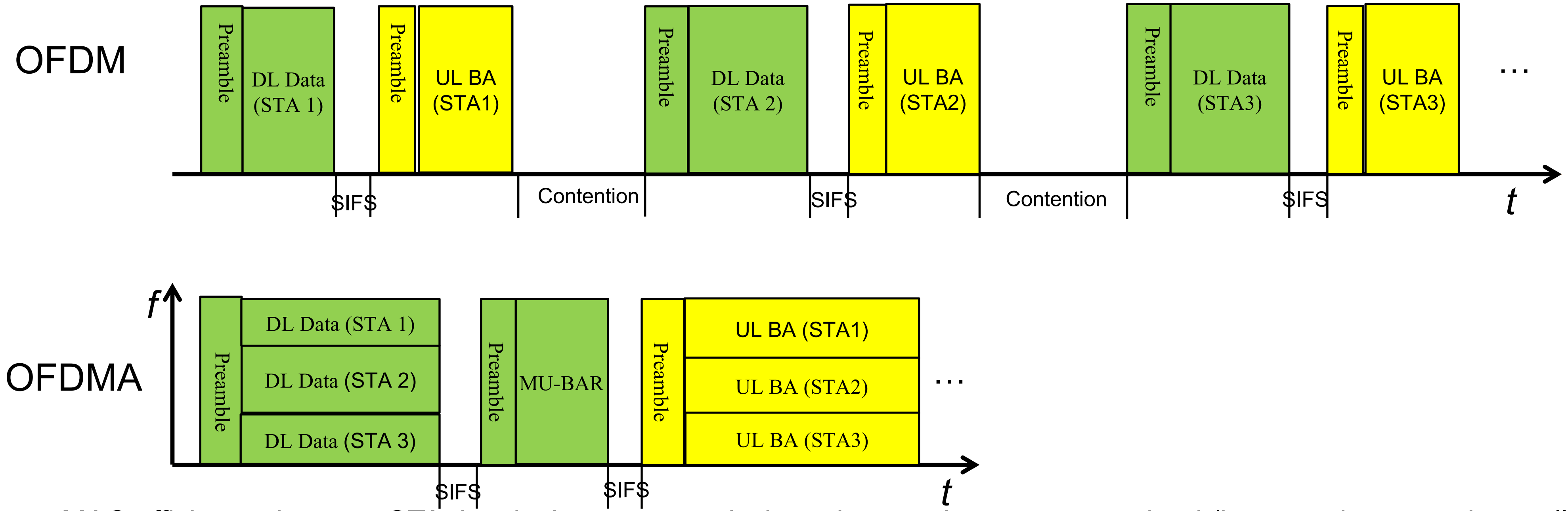
Orthogonal Frequency Division Multiple Access



– Issue: MAC efficiency drops as STA density increases and when short packets are transmitted (increase in contention, collision, IFS, preambles)

– Aggregation in 11n combines short packets in TIME from a single user, DL MU-MIMO in 11ac combines different users SPATIALLY, OFDMA combines different users together in FREQUENCY

– OFDMA does NOT increase the maximum PHY rate

– Downlink OFDMA: AP groups users to maximize downlink transmission efficiency

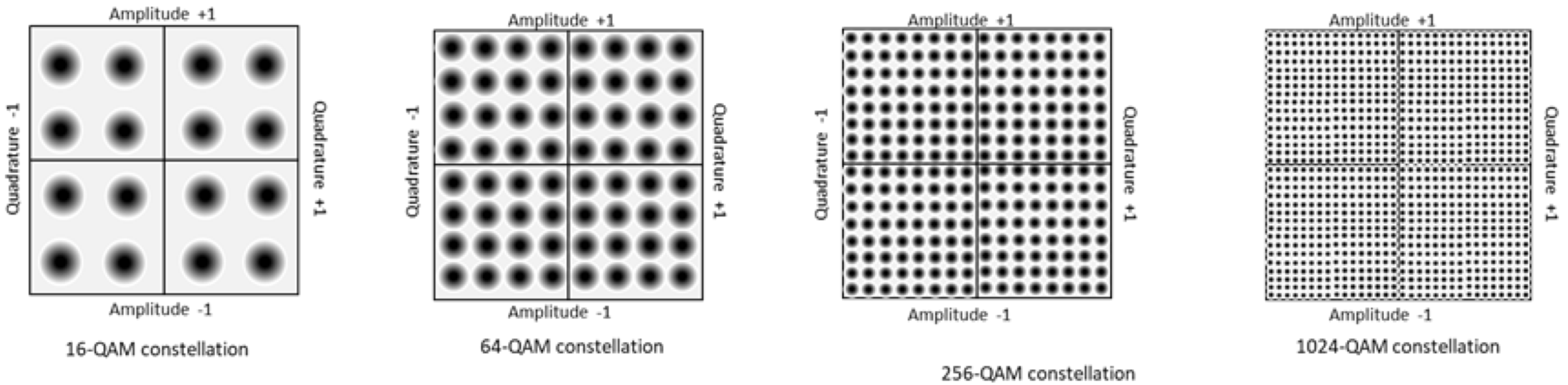
– Uplink OFDMA: Users are grouped together and transmit in sync to AP to maximize uplink transmission efficiency

– Transmit power can be adjusted per resource unit (RU) in either UL or DL to improve SINR for specific users

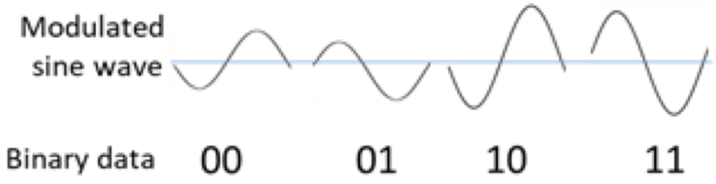
1024-QAM Modulation

Extending modulation depth to 1024 QAM

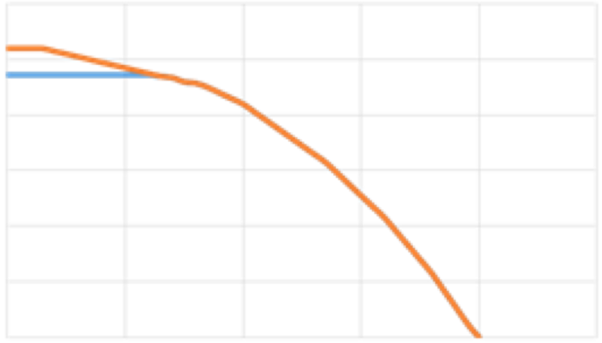
1024-QAM modulation



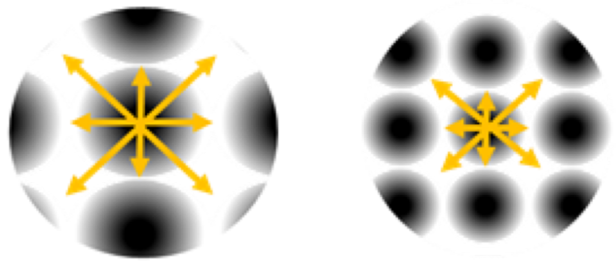
Constellation diagrams for 16-, 64-, 256, 1024-QAM



Sine wave representation of 4-QAM



Rate vs range before and after 1024-QAM



Decreased error margin

Understanding datarates

How do I get to the data rate for a given MCS and RU?

- Basic Symbol Rate
  - Baud Rate = 78.125 KSps
- Basic Symbol Duration
  - t = 1/78125 = 12.8 µs = 12800 ns
- Cyclic Extension

– 800 ns (11ax Short)	6% Overhead	13600 ns total
– 1600 ns (11ax Medium)	11% Overhead	14400 ns total
– 3200 ns (11ax Long)	20% Overhead	16000 ns total

- Bits Per Tone

– BPSK	1
– QPSK	2
– 16 QAM	4
– 64 QAM	6
– 256 QAM	8
– 1024 QAM	10

Resource Unit Structure

	RU 26	RU52	RU106	RU242	RU484	RU996
Number of Tones	26	52	106	242	484	996
Number of Pilots	2	4	4	8	16	16
Data Carrying Tones	24	48	102	234	468	980
Symbol Rate (kSps)	78.125	78.125	78.125	78.125	78.125	78.125
Raw Rate 1024 QAM	18.75	37.5	79.6875	182.8125	365.625	765.625

– Raw Rate: Data Carrying Tones * Symbol Rate * Modulation bits/symbol

– Then apply MCS (forward error correction) coding

– Then apply Guard Interval Overhead

RU 26 MCS and Data Rates

RU Width	2.0 MHz			Include Guard Interval		
RU26	**Raw Rate**	**Coding**	**After Code**	**0.8 usec**	**1.6 usec**	**3.2 usec**
MCS 0 BPSK	1.875	1/2	0.94	0.88	0.83	0.75
MCS 1 QPSK	3.75	1/2	1.88	1.76	1.67	1.50
MCS 2 QPSK	3.75	3/4	2.81	2.65	2.50	2.25
MCS 3 16 QAM	7.5	1/2	3.75	3.53	3.33	3.00
MCS 4 16 QAM	7.5	3/4	5.63	5.29	5.00	4.50
MCS 5 64 QAM	11.25	2/3	7.50	7.06	6.67	6.00
MCS 6 64 QAM	11.25	3/4	8.44	7.94	7.50	6.75
MCS 7 64 QAM	11.25	5/6	9.38	8.82	8.33	7.50
MCS 8 256 QAM	15	3/4	11.25	10.59	10.00	9.00
MCS 9 256 QAM	15	5/6	12.50	11.76	11.11	10.00
MCS 10 1024 QAM	18.75	3/4	14.06	13.24	12.50	11.25
MCS 11 1024 QAM	18.75	5/6	15.63	14.71	13.89	12.50

Data rate for each RU

			RU26 2.0 MHz	RU52 4.1 MHz	RU106 8.3 MHz	RU242 18.9 MHz	RU484 37.8 MHz	RU996 77.8 MHz
MCS 0	BPSK	1/2	0.9	1.8	3.8	8.6	17.2	36.0
MCS 1	QPSK	1/2	1.8	3.5	7.5	17.2	34.4	72.1
MCS 2	QPSK	3/4	2.6	5.3	11.3	25.8	51.6	108.1
MCS 3	16 QAM	1/2	3.5	7.1	15.0	34.4	68.8	144.1
MCS 4	16 QAM	3/4	5.3	13.2	28.1	51.6	103.2	216.2
MCS 5	64 QAM	2/3	7.1	14.1	30.0	68.8	137.6	288.2
MCS 6	64 QAM	3/4	7.9	15.9	33.8	77.4	154.9	324.3
MCS 7	64 QAM	5/6	8.8	17.6	37.5	86.0	172.1	360.3
MCS 8	256 QAM	3/4	10.6	21.2	45.0	103.2	206.5	432.4
MCS 9	256 QAM	5/6	11.8	23.5	50.0	114.7	229.4	480.4
MCS 10	1024 QAM	3/4	13.2	26.5	56.3	129.0	258.1	540.4
MCS 11	1024 QAM	5/6	14.7	29.4	62.5	143.4	286.8	600.5

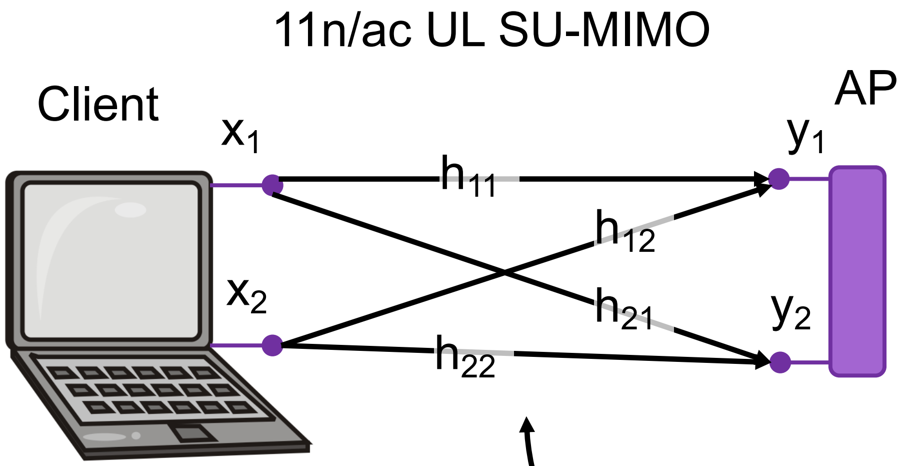
*800ns Guard Interval

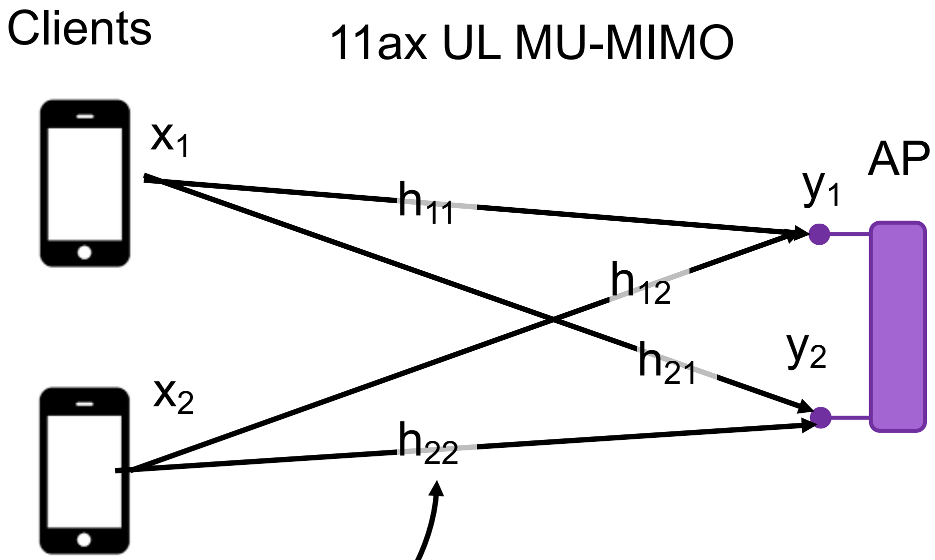
MU-MIMO

Multi-User MIMO

- 802.11ac introduced DL MU-MIMO, but we're experiencing the following issues:
  - Many client devices are single antenna, and many two antenna clients switch to single stream mode for DL MU-MIMO for protection against interference
    - With 4 antenna AP, gains compared to Single User are modest
    - Even if we built an 8 antenna AP, groupings are limited to 4 users
  - Channel sounding responses from the users are transmitted serially in time resulting in high overhead
  - TCP/IP on downlink with TCP ACK on uplink is impaired with no UL MU enhancement
- UL MU-MIMO was initially considered in 11ac, but not included due to implementation concerns
- 802.11ax MU-MIMO enhancements
  - UL MU-MIMO
    - Sounding frames, data frames, etc can be grouped among multiple users to reduce overhead and increase uplink response time
  - Groups expanded to eight users for both DL and UL
    - Now even with devices in single stream mode, MU-MIMO throughput can be doubled or tripled over single user operation

Uplink Multi User-MIMO





$$y_1 = \sqrt{\rho/2}\,h_{11}x_1 + \sqrt{\rho/2}\,h_{12}x_2 + z_1$$

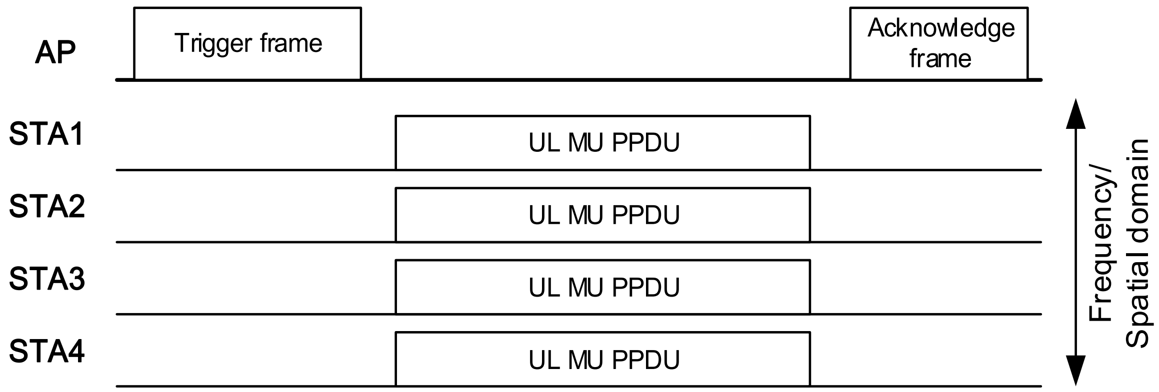
$$y_2 = \sqrt{\rho/2}\,h_{21}x_1 + \sqrt{\rho/2}\,h_{22}x_2 + z_2$$

- UL MU-MIMO is mathematically equivalent to UL SU-MIMO
- Why not included in 11ac? To maintain mathematical equivalency in practice requires time synchronization, frequency alignment, and power normalization between all clients in an MU group
- Protocol to address this has been added to 11ax for both UL OFDMA and MU-MIMO (trigger frame)

UL MU Operation

Basic Frame Exchange Sequence for UL MU transmissions

- New Trigger control frame
  - Specifies the length of the UL window
  - Specifies the users that may send during the UL window
  - Allocates resources for the UL-MU PPDUs:
    - RU allocation
    - Spatial stream allocation
    - MCS to be used by the user
  - Supports transmission time, frequency, sampling symbol clock, and power pre-correction by the participating users
- UL MU transmission may be OFDMA or MU-MIMO
- Acknowledgement frame can be
  - DL MU transmission with individually addressed BlockAck frames
  - New "Multi-STA BlockAck" frame contained in Legacy frame or HE MU PPDU
- Trigger frame can be used as a Beamforming Report Poll, MU-BAR, MU-RTS, Buffer Status Report Poll, Bandwidth Query Report Poll…



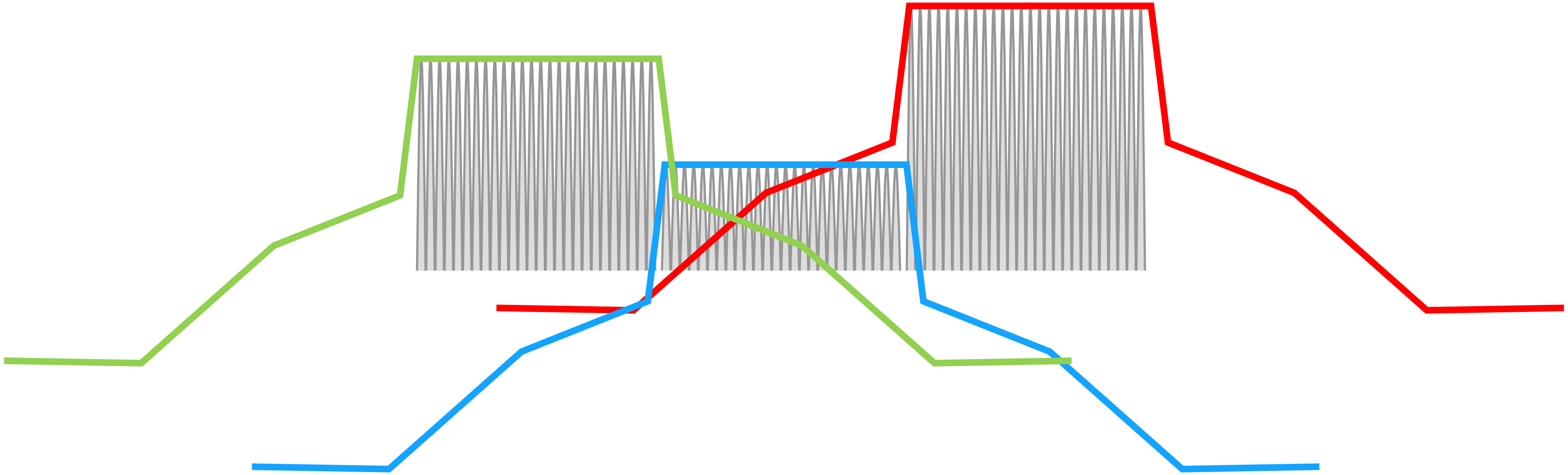
Tx Power Control

– In 802.11ax you will have multiple clients at different distances transmitting at the same time

– This can result in OFDMA blocks showing up at different power levels

– Without power control users that are further away would have there signal swamped by adjacent radio

  – This has the side benefit of increasing battery life for the nearby clients.



MU Performance

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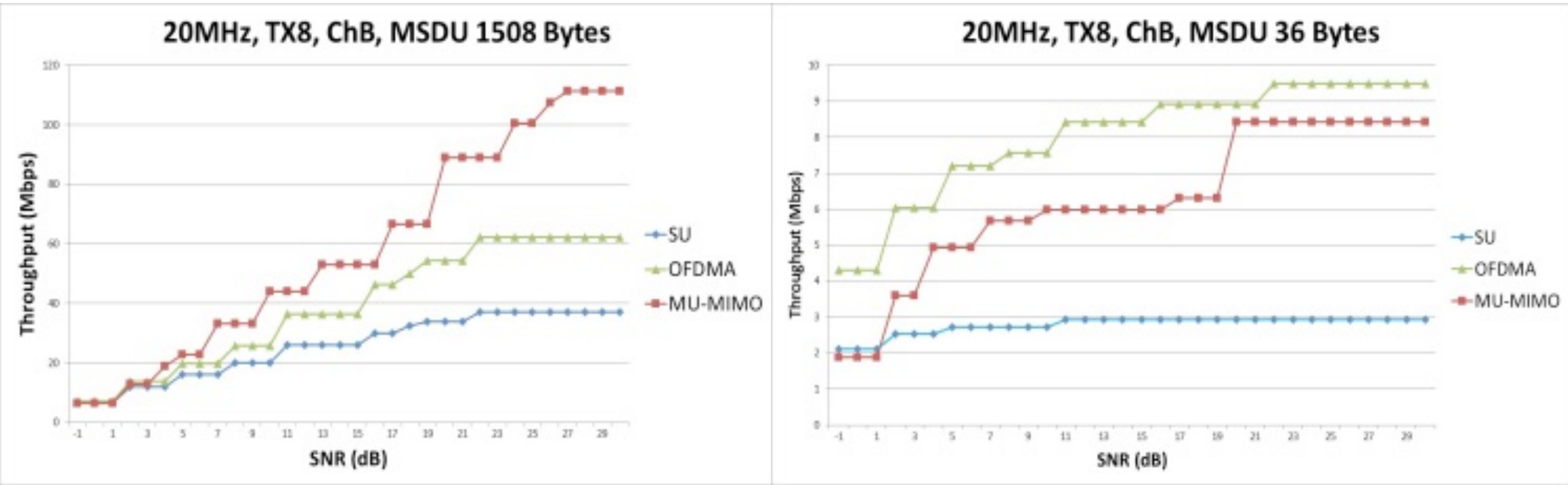
Downlink MU Performance

Analysis Results for DL



Observations

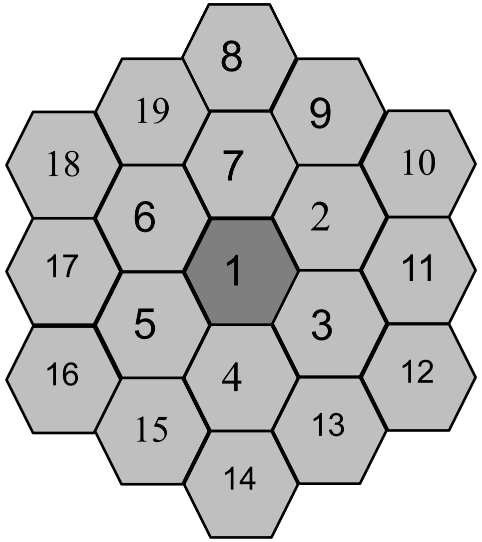
- Packet size:
  - Large packet: MU-MIMO is the most efficient at high SNR ranges
  - Small packet: OFDMA is the most efficient over entire SNR range
- SNR: At low SNRs, OFDMA always outperforms MU-MIMO

Spatial Reuse

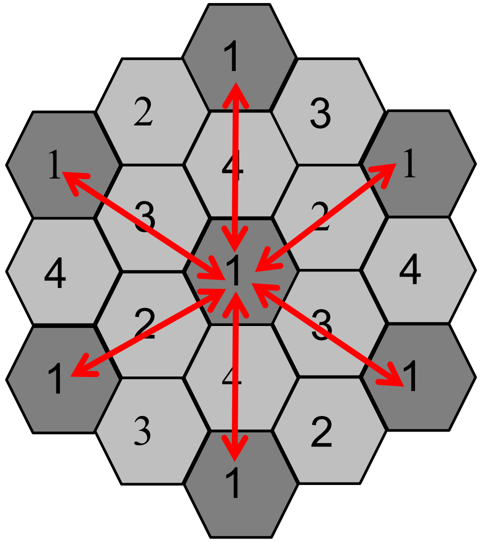
BSS Coloring

- To increase capacity in dense environment with wider (less) channels, we need to increase frequency reuse between BSS's
  - However, with existing medium access rules, devices from one BSS will defer to another co-channel BSS, with no increase in network capacity
- BSS Coloring was a mechanism introduced in 802.11ah to assign a different "color" per BSS, which will be extended to 11ax
- New channel access behavior will be assigned based on the color detected

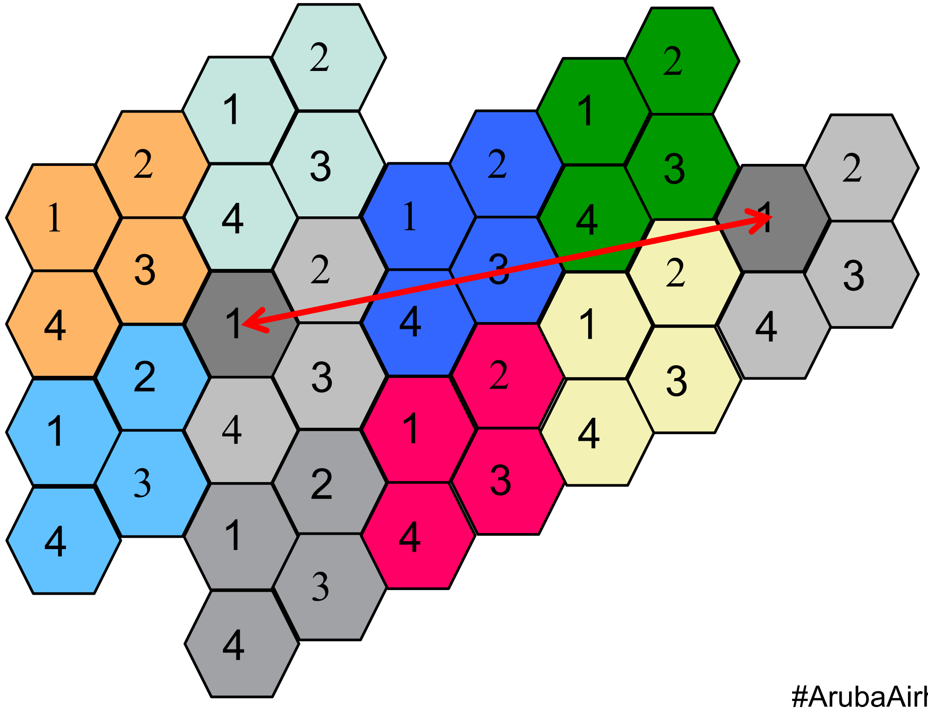
Low Frequency Reuse (w/ 20 MHz channels)



Increased Frequency Reuse (w/ 80 MHz channels) - All same-channel BSS blocking



Same-channel BSS only blocked on Color Match



Spatial Reuse Channel Access Rules

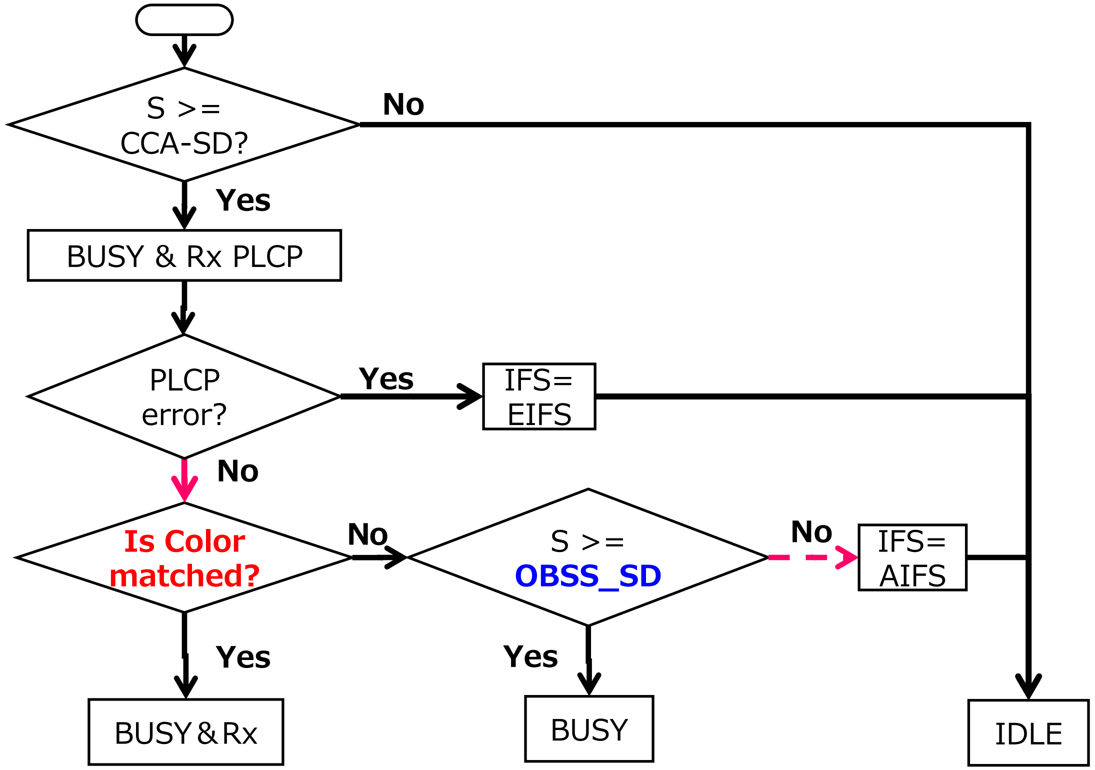
– BOTH the AP and clients can now differentiate between intra-BSS frames and OBSS frames with use of BSS Color bits and apply less sensitive CCA threshold to OBSS frames

  – Higher CCA value leads to more simultaneous transmissions, but potentially lowers SINR

  – The goal is to increase the reuse, while not causing a significant reduction to selected MCS due to interference

– Adaptive CCA

  – 802.11 signal detect and TXPWR threshold may be adjusted dynamically by both AP and clients



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Adaptive CCA and TPC

UE Tx (dBm)	OBSS_PD (dBm)
10	-71
11	-72
12	-73
13	-74
14	-75
15	-76
16	-77
17	-78
18	-79
19	-80
20	-81
21	-82

AP Tx (dBm)	OBSS_PD (dBm)
14	-71
15	-72
16	-73
17	-74
18	-75
19	-76
20	-77
21	-78
22	-79
23	-80
24	-81
25	-82

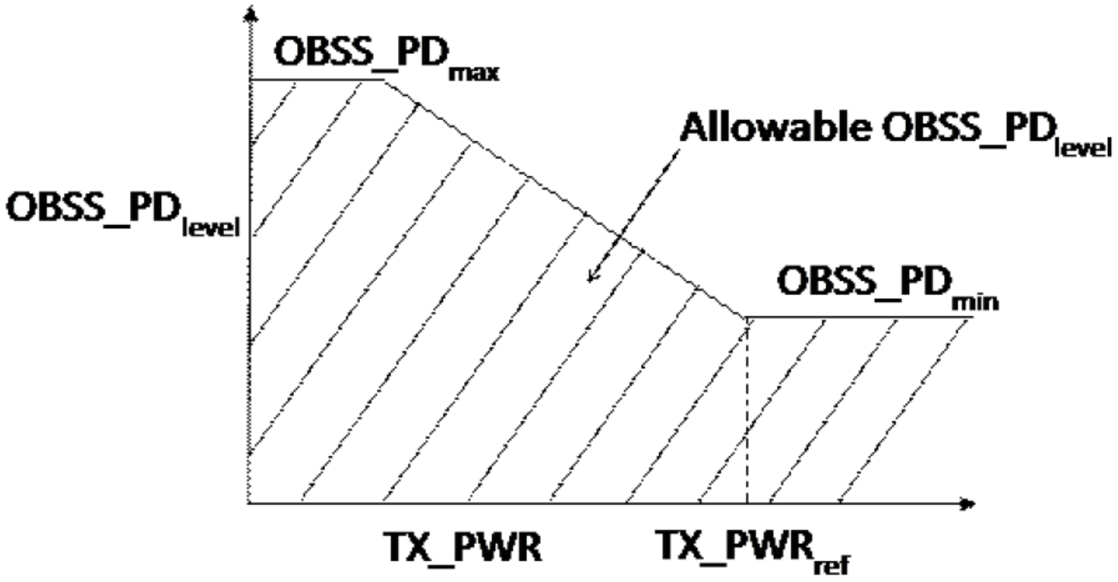


Figure 25-7—Illustration of the adjustment rules for OBSS_PD and TX_PWR

$$\text{Allowable } OBSS\_PD_{level} \le max(OBSSPD_{min}, min(OBSSPD_{max}, OBSSPD_{min} + (TXPWR_{ref} - TXPWR)))$$

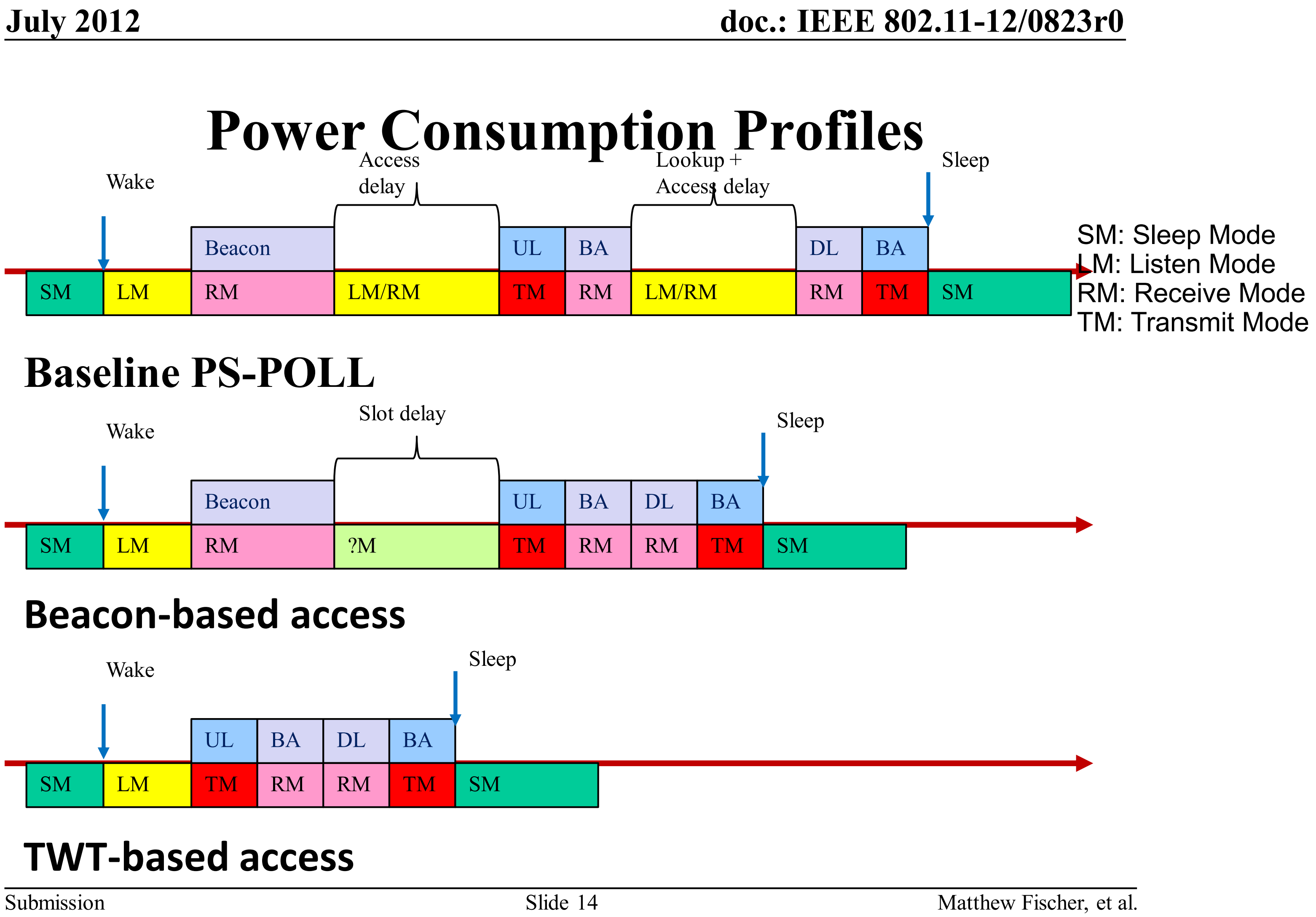
$TXPWR_{ref}$ = 21 dBm for non-AP STAs or for AP STAs with 1 and 2 spatial streams and $TXPWR_{ref}$ = 25 dBm for AP STAs of 3 spatial streams or more.

$OBSS\_PD_{min\_default} = -82$ dBm and $OBSS\_PD_{max\_default} = -62$ dBm.

Power Saving

Target Wake Time

- Target Wake Time (TWT) is a power saving mechanism in 802.11ah, negotiated between a STA and its AP, which allows the STA to sleep for periods of time, and wake up in pre-scheduled (target) times to exchange information with its AP
- 802.11ah TWT mechanism modified to support triggered-based uplink transmissions
- New Broadcast TWT operation added in 802.11ax to support non-AP STAs that have not negotiated any implicit agreement with HE AP



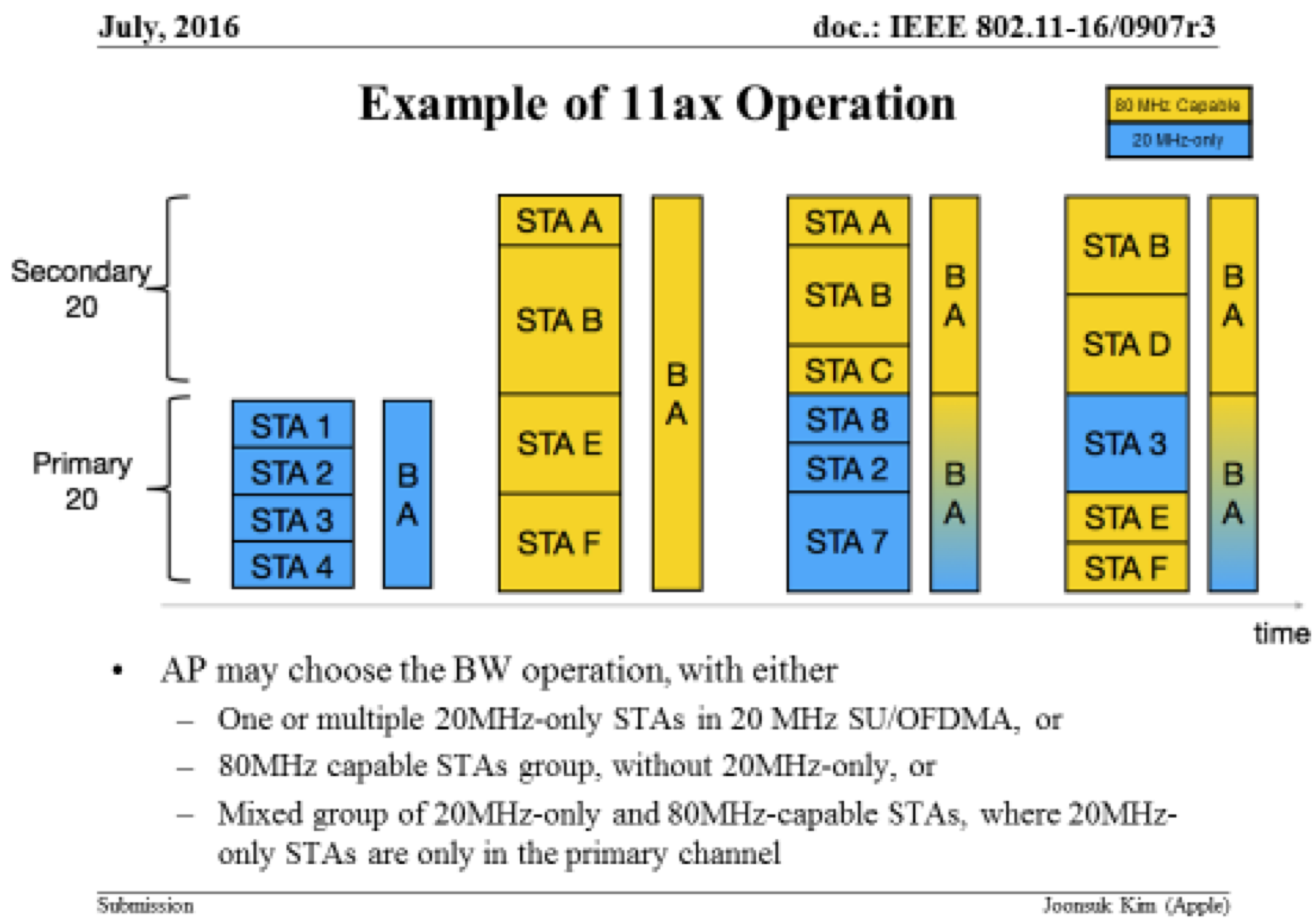
20 MHz-only Clients

– Provide support for low power, low complexity devices (IOT): wearable devices, sensors and automation, medical equipment, etc.

– Such devices do not need high bandwidth operation

– In actuality, this only applies to 5 GHz, as only 20 MHz support is mandatory in 2.4 GHz

  – “Normal” clients still required to support 80 MHz in 5 GHz



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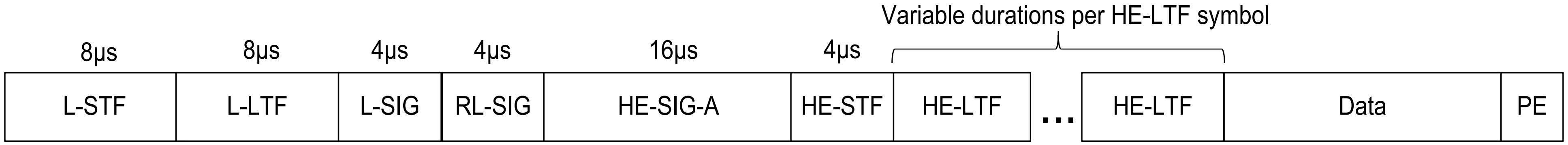
Outdoor Enhancements

Outdoor / Longer range features

- One of the goals of 802.11ax task group is to address improved performance in outdoor environment
  - One of the issues in an outdoor environment is propagation conditions with delay spreads potentially longer delays spreads than the 11a/n/ac guard interval of 0.8 usec
  - 802.11ax modifies the guard intervals options to 0.8, 1.6, and 3.2 usec
  - In an outdoor environment, there could be multipath bounces off high speed vehicles. A Doppler bit is included in the signal field to indicate TBD Doppler mode of transmission
- To expand the coverage and robustness of an outdoor hotspot
  - New extended range packet format with more robust (longer) preamble
    - L-STF/L-LTF/HE-STF/HE-LTF are boosted by 3 dB
    - L-SIG and HE-SIG-A are repeated twice
  - Dual Carrier Modulation (DCM) – replicate the same information on different subcarriers for diversity gain and narrow band interference protection, ~3.5 dB gain
  - Narrower transmission bandwidth for Data field – 106 tones (~8 MHz) can be used to reduce noise bandwidth



HE extended range SU PPDU format

802.11ad : 60GHz Wi-Fi

Overview & Aruba roadmap

60GHz Market Current State

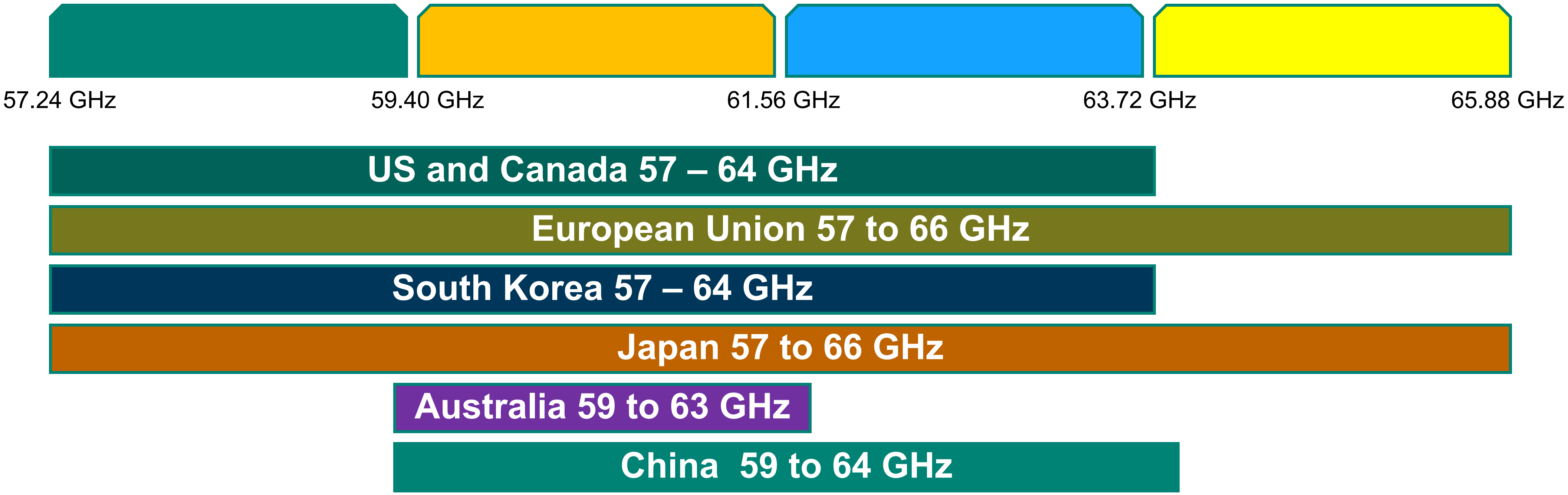
– It’s a sizeable market, with specialized players

– Traditional 60GHz links can be expensive

– Antennas are highly directional and require precise alignment by experts

– Long links have issues with rain induced fades

60 GHz Global Snapshot



Channel widths are 2.16 GHz
Symbol rate of 1.76 GSps

802.11ad: Old school in a big way

- Exploits significant chunks of spectrum at 60 GHz
- 2 to 8 GHz of spectrum is available around the world
- Oxygen Absorption spectrum adds challenges and benefits
- Uses simpler modulation techniques but on a massive scale
  - Single Carrier 1.76 GSps
  - BPSK/QPSK/16 QAM
  - Up to 4.5 Gbps on air data rate
- Chipsets will enable a dramatic shift to affordability and simplicity
  - Built-in scanning antenna capability

11ad

- Basic Symbol Rate
  - Baud Rate = 1.76 GSps
- Basic Symbol Duration
  - t = 1/1760000000 = 0.568 ns
- Cyclic Extension
  - None
- Bits Per Tone
  - BPSK 1
  - QPSK 2
  - 16 QAM 4

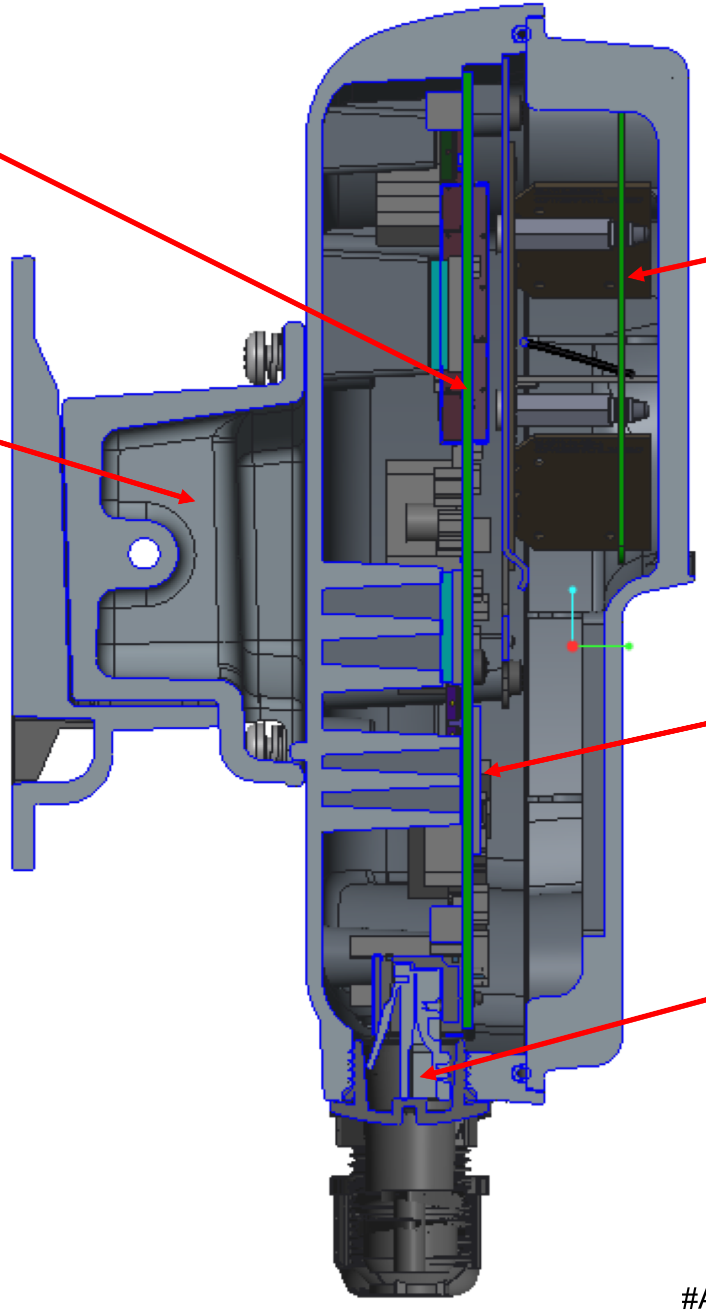
11ad Single Carrier Data Rates

		Bits per Symbol	Repeats	Raw Rate Mbps	Bit Padding	Coding Rate	Final Mbps
MCS 0	BPSK	1	32	55	512/512	1/2	27.5
MCS 1	BPSK	1	2	880	448/512	1/2	385
MCS 2	BPSK	1	1	1760	448/512	1/2	770
MCS 3	BPSK	1	1	1760	448/512	5/8	962.5
MCS 4	BPSK	1	1	1760	448/512	3/4	1155
MCS 5	BPSK	1	1	1760	448/512	13/16	1251.25
MCS 6	QPSK	2	1	3520	448/512	1/2	1540
MCS 7	QPSK	2	1	3520	448/512	5/8	1925
MCS 8	QPSK	2	1	3520	448/512	3/4	2310
MCS 9	QPSK	2	1	3520	448/512	13/16	2502.5
MCS 10	16 QAM	4	1	7040	448/512	1/2	3080
MCS 11	16 QAM	4	1	7040	448/512	5/8	3850
MCS 12	16 QAM	4	1	7040	448/512	3/4	4620

Symbol Rate **1.76 GSps**

AP-387 Overview and Attributes

- Outdoor hardened HW leveraging successful outdoor designs (270, 360 and 370 families)
- Reusing existing Aruba outdoor mount solutions
  - Ease of installation is a key differentiator
- Aggregating throughput of a 5 GHz and a 60 GHz radio
  - Allows for graceful degradation of the two links
  - 5 GHz is not impacted by weather
- Link is self acquiring so long as the radios are only crudely lined up
  - Eliminates the need for precision deployment
- 60 GHz radio leverages the scanning antenna capability built into the 11ad chipset solution
  - Scans a narrow beam +/- 40 horizontal and +/-10 degrees vertical
- Compact and cost-effective product, Aruba unified software (AOS & Instant)


Mainboard
Adapter
5G ANT
60G ANT
PoE port

Thank you!

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