802.11ax Design Challenges

Mani Krishnan Venkatachari

Wi-Fi: An integral part of the wireless landscape

At the center of connected home

Opening new frontiers for wireless connectivity

Wireless Display

Peer-to-peer

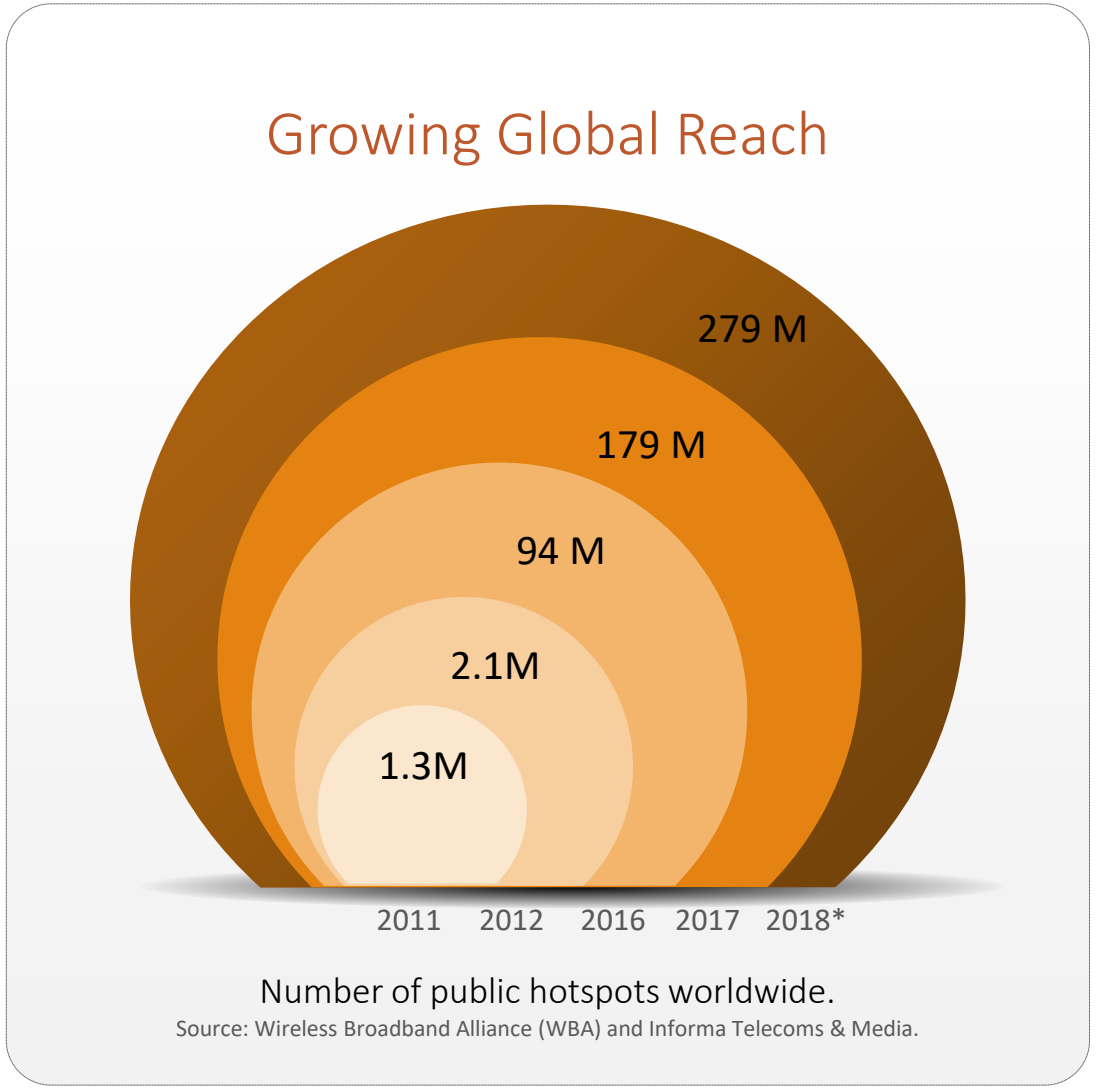
Indoor Location

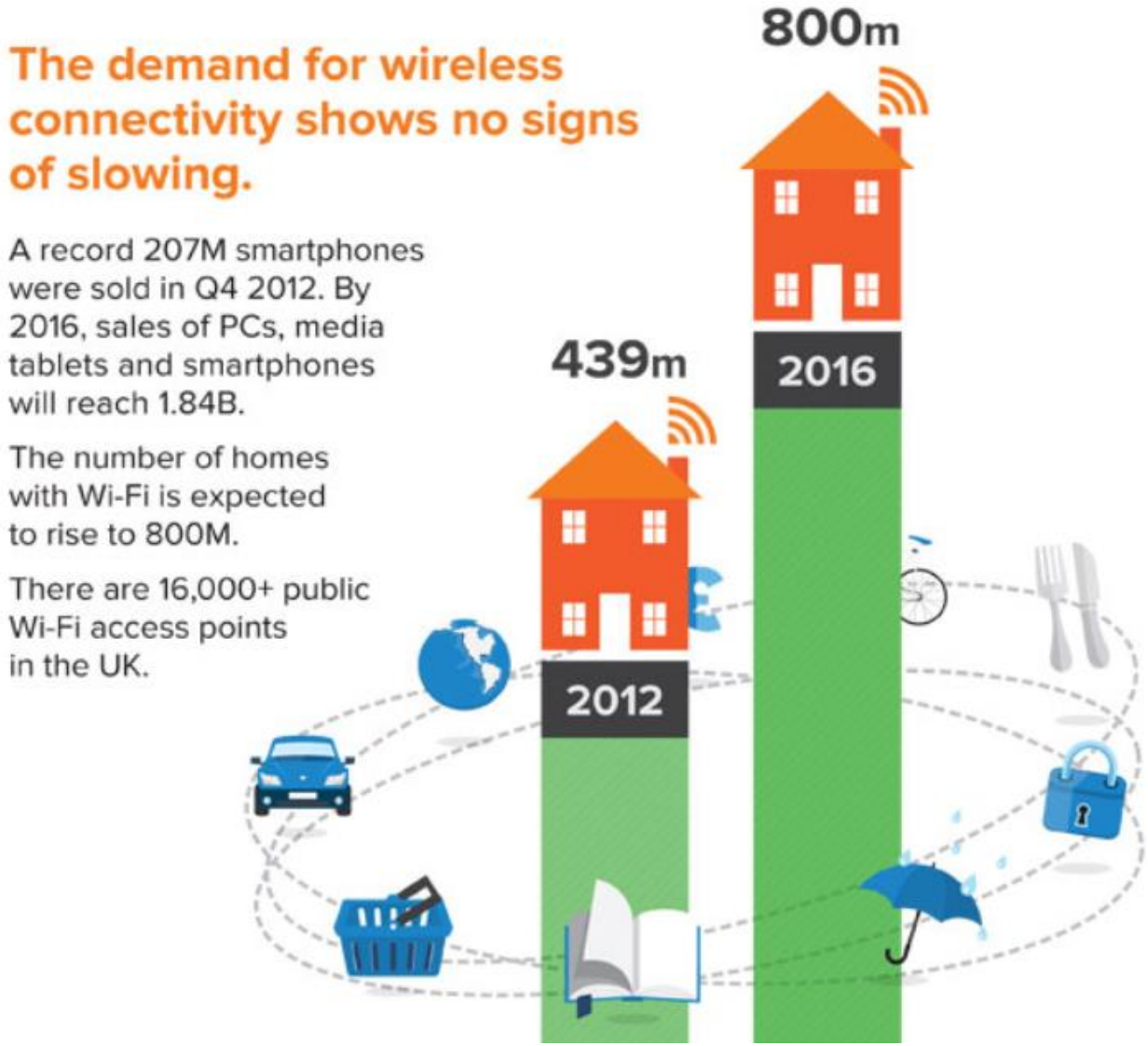
Wi-Fi supported in all smart devices

The universal technology in smart connected homes

Leveraging ubiquity of indoor Wi-Fi for many new applications and services

Wi-Fi is becoming ubiquitous





Source: Wireless Broadband Alliance (WBA)

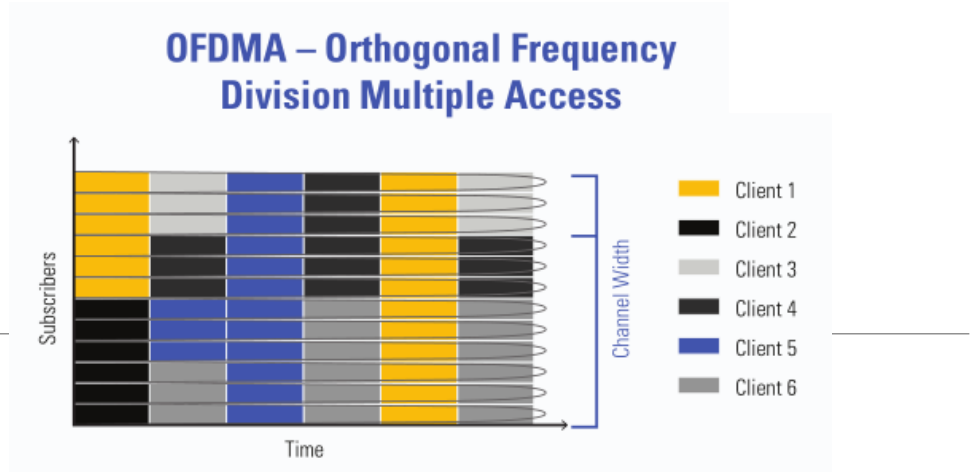
Wifi Standards Evolution

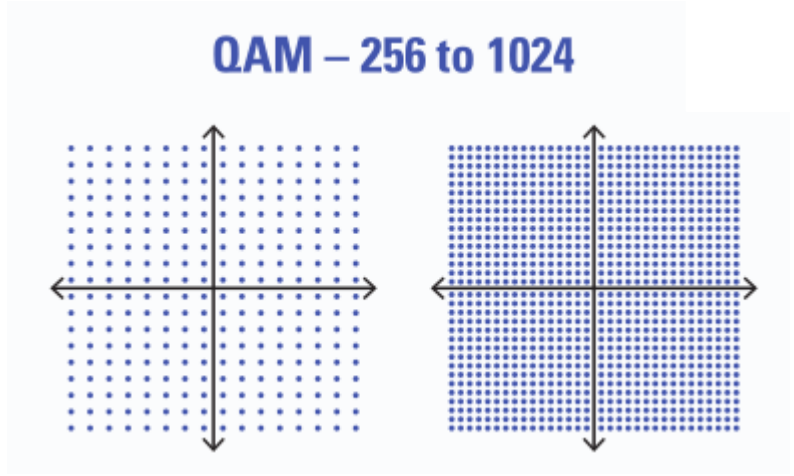
3 Dimensions	802.11 / 11b	802.11 a/g	802.11n	802.11ac
Spectrum	2.4GHz Band	2.4 GHz and 5GHz 20MHz Channel	2.4 and 5GHz Bands 20 and 40 MHz Channels	5GHz Band 20,40,80 and 160 MHz Channels
Spatial Dimension			Up to 4x4 MIMO (Single User) Spatial Multiplexing	Up to 8x8 MIMO (Multi User) Transmit Beamforming
Modulation	Direct Sequence Spread Spectrum (DSSS)	Orthogonal Frequency Division Multiplexing OFDM	Up to 64 QAM OFDM	Up to 256 QAM OFDM

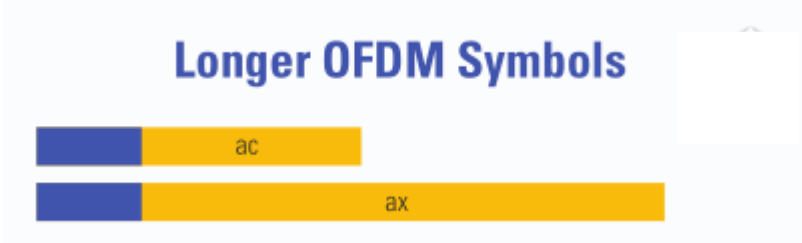
The Newest Standard

PHY spec - 11ac vs 11ax

Parameter	IEEE 80 2.11ac	IEEE 802.11ax Draft 0.4
Spectrum	<6 GHz, excluding 2.4 GHz	Between 1 and 6 GHz
Bandwidth	20 to 160 MHz	20 to 160 MHz
Modulation	BPSK to 256 QAM	BPSK to 1024 QAM
FFT size	64 to 512	256 to 2048
OFDM symbol duration	3.2µs + 0.8/0.4 µs GI	12.8µs + 0.8/1.6/3.2µs GI
Pilot sub-carriers	4/6/8/16	2/4/6/8/16
Subcarrier spacing	312.5 kHz	78.125 kHz (smaller value to increase range/coverage for OFDMA systems)
Number of spatial streams	1 to 8	1 to 8
MIMO	SU and DL-MU	SU and DL-UL-MU
Guard interval	Long and short	Long, additional guard interval durations for outdoor channels, short guard not available
Backward compatibility	IEEE 802.11a/n	IEEE 802.11a/b/g/n/ac
Mechanism to reduce power consumption	NA	TWT

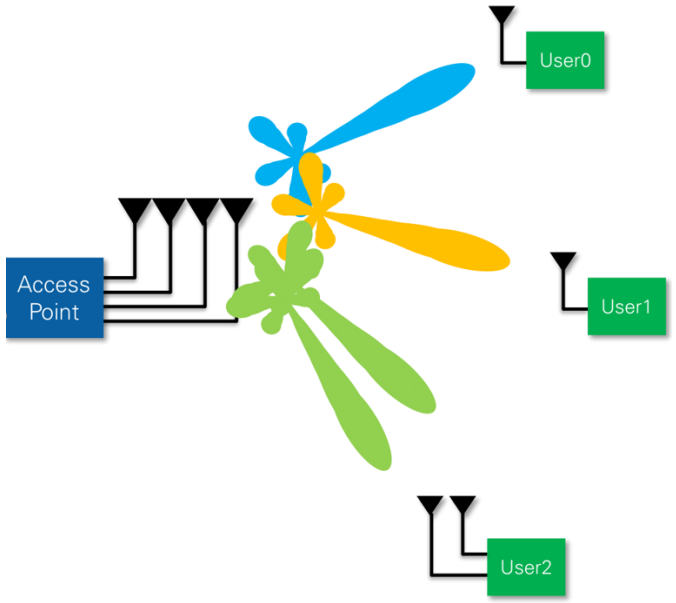




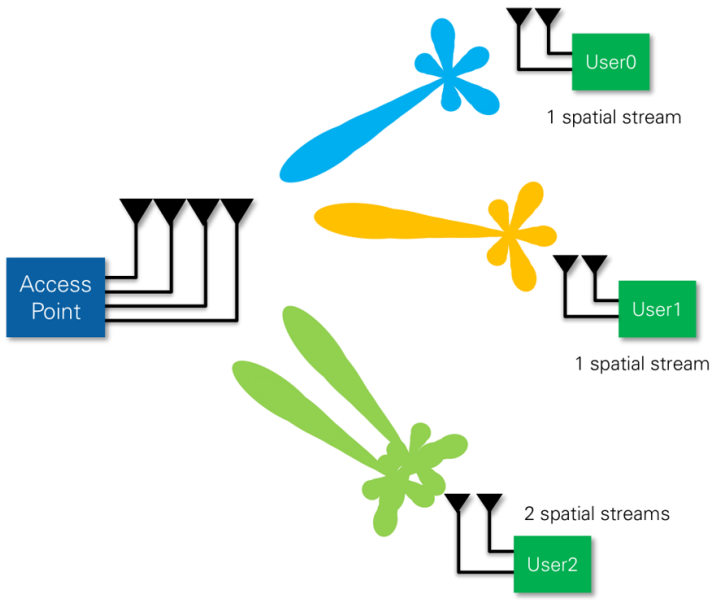


Source: Aerohive, IEEE

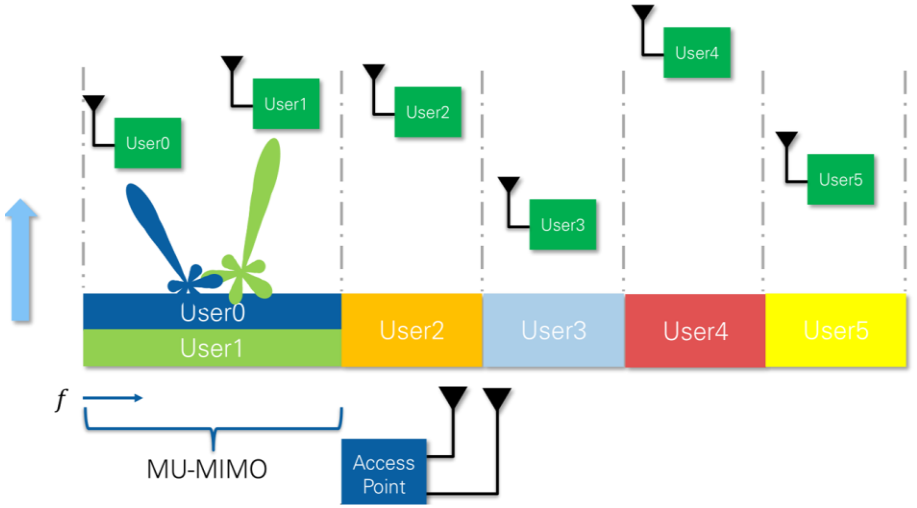
MU-MIMO – Beam Forming - OFDMA



MU-MIMO - Downlink



MU-MIMO - Uplink



OFDMA and MU-MIMO - Downlink

- Users are separated in spatial domain
- All users use same frequency spectrum

- Users are multiplexed in both Frequency and spatial domain

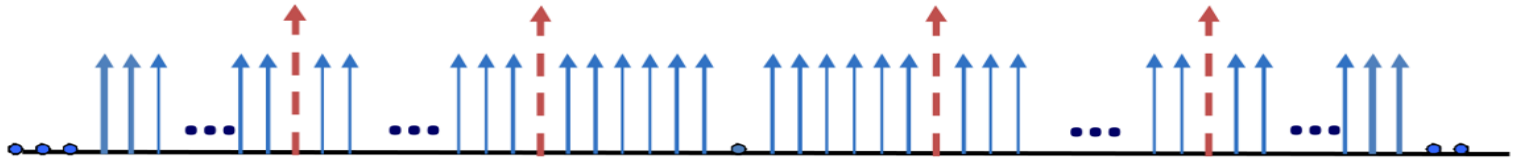
802.11ax and 11ac – MU-MIMO vs OFDMA

MU MIMO	OFDMA
Users multiplexed in Spatial Domain	Users multiplexed in Frequency Domain
Downlink - First added in 802.11ac Uplink - Newly added in 802.11ax	Newly added in 802.11ax
Maximum Number of Users • 802.11ac: 4 • 802.11ax: 8	Maximum Number of Users: 9 in 20 MHz, 18 in 40 MHz, 37 in 80 MHz, 74 in 160 MHz
Maximum Number of Streams per user • 802.11ac: 4 • 802.11ax: 4	Maximum Number of Streams per user: 4

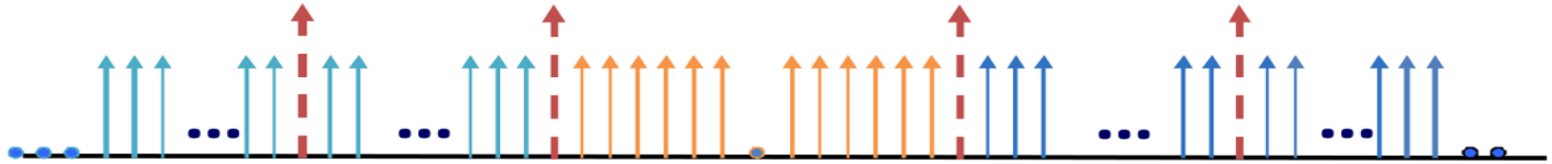
MU-MIMO – DL only vs UL and DL

DL MU-MIMO	UL and DL MU-MIMO
Single Transmitter – Only AP Does Tx	Multiple Transmitters in UL MU-MIMO – Both AP and individual STAs
Only Sounding and Steering Sequence before MU Beam-forming	Additional HE-Trigger Frame required before Scheduling UL Transactions
No unique Receiver Complexity for AP	More Complex Receiver at AP end – Time and Frequency Sync requirement, different received power, etc.
AP determines its rate and power per User.	Added AP processing also to determine STAs Rate and power parameters.
No Antenna restriction on the STA side. AP can do DL MU-MIMO with 1x1 STA	STA requires minimum 2 Antenna for even 1SS UL MU-MIMO
Simple Modelling for Lab Validation	Modelling is not straight forward and need to go to real use-case.

802.11ax – OFDM vs OFDMA



OFDM Transmission – entire spectrum to single user



OFDMA Transmission – contiguous subcarrier chunks (Resource Units (RUs)) to different users

- An OFDMA building block is called Resource Unit (RU).
- RU sizes: 26, 52, 106, 242, 484, 996 tones (subcarriers)
- Pilot subcarriers
  - 26-tone with 2 pilots
  - 52-tone with 4 pilots
  - 106-tone with 4 pilots
  - 242-tone with 8 pilots
  - 484-tone with 16 pilots
  - 996-tone with 16 pilots

HE20 with 7DC for OFDMA

802.11ax – OFDM vs OFDMA – Design Challenges

- High susceptibility to frequency and clock offsets in OFDMA
  - Wifi does not have Clock synchronization across users as mandated in LTE.
- Increased Power Consumption across every level
  - Chip Power Consumption increases due to the Design Complexity – FFT Size, More Streams/Chains/users, etc.
  - Overall System Power consumption increase due to the tighter Front-End Specs.
  - System Design Complexity to maintain and not degrade the RF performance.
- Scheduling and Rate Control Challenges with Resource Allocations.
- Decision making challenges of using OFDMA vs MU-MIMO – Both are supported in 11ax.
- Validation Challenges
  - Modelling Channels and Channel conditions for OFDMA – Indoor/Outdoor – Short/Long Range.
  - How to test the Max User configuration ? – Up to 74 users

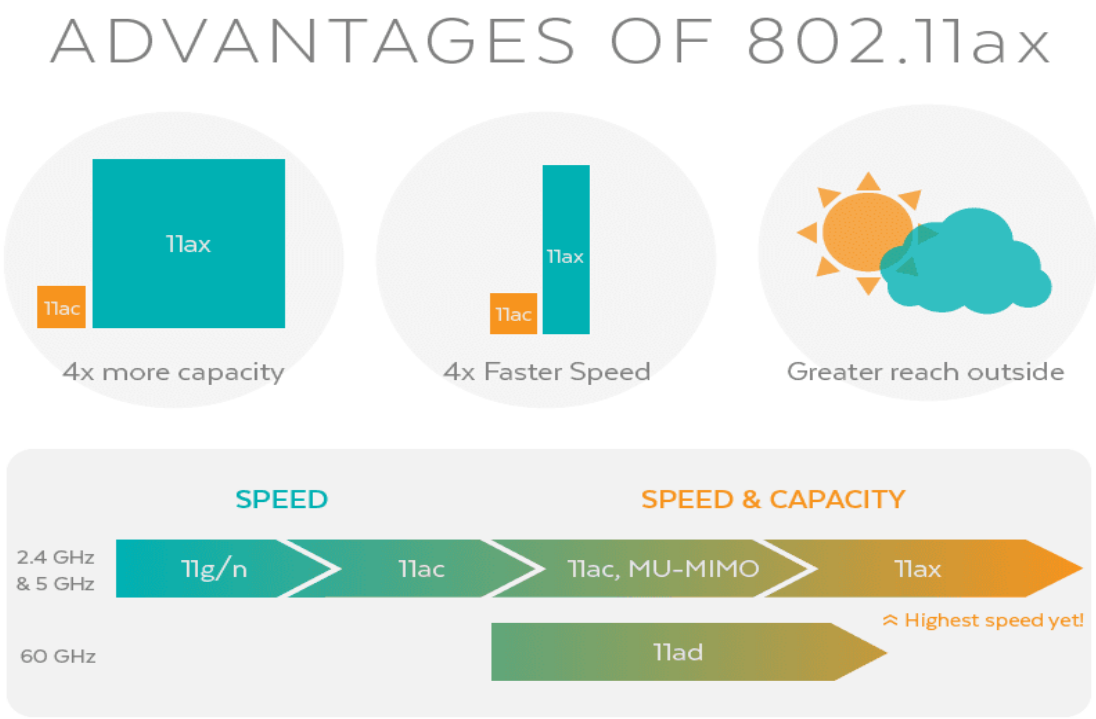
802.11ax – Chip and System Design Challenges - Nutshell

<table>
<tr><th>Design Requirements</th><th>Challenges</th></tr>
<tr><td>• 1024 QAM – 10 Bits per Symbol</td><td>• Stricter IEEE EVM Spec – SU – -35dB EVM
• Tighter Phase Noise, PPM and other RF Requirements.
• Need advanced algorithms to mitigate and correct the Amplitude and Phase Imbalance on both Tx and Rx.</td></tr>
<tr><td>• DL MU-MIMO – More Multi-User Support – Up to 8MU / 8SS</td><td>• More Users – More Context and Channel information to be maintained in the PHY.
• Complex and Memory intensive Design.
• Grouping and Scheduling Challenges for SW.</td></tr>
<tr><td>• OFDMA DL – RU Allocation
<table>
<tr><th>BW</th><th>Users</th><th>BW</th><th>Users</th></tr>
<tr><td>20</td><td>9</td><td>80</td><td>37</td></tr>
<tr><td>40</td><td>18</td><td>160</td><td>74</td></tr>
</table>
</td><td>• Similar to MU – more context to be maintained.
• Transmit Power Control, Rate Control and Scheduling Challenges.
• MUBF with OFDMA-DL, increases the design implementation challenge multi-fold.</td></tr>
<tr><td>• OFDMA for Wifi</td><td>• Implementation of OFDMA in Contentious environment like Wifi.
• Wifi has relaxed RF Spec compared to LTE and stricter processing requirements.</td></tr>
</table>

802.11ax – Chip and System Design Challenges - Nutshell

Design Requirements	Challenges
• Large FFT Size – Upto 2048	• Design Complexity – More Area and Power consumption. • Transmitters to do the Carrier Frequency Offset (CFO) Correction during OFDMA-UL. • Rx Complexity due to Receiver receiving from multiple stations having different Transmit Power. • Higher Inter-Carrier Interference. • More Stringent RF and Front-end requirements. • Impacts the CFO and Sample Frequency Offset (SFO).
• OFDMA UL / UL MU-MIMO	
• Lower Sub-Carrier Spacing (78.125 KHz)	
• 8 Antenna Systems to take full use of the 11ax Features	• Antenna Isolation is a Key challenge. • Channel estimation and beam forming.
• Inter-operability Requirements	• Challenges of Interop always remain with many Wifi devices flooding the market with not all supporting all features.
• Higher Bandwidth – Back Haul requirements	• To fully utilize the higher Wifi BW, the back-haul need be of High Bandwidth (10G and above) – Can pose challenges with interference to Wifi through emissions.

Summary



DESIGN CHALLENGES COME WITH EVERY ADVANCEMENT OF TECHNOLOGY

ADVANTAGES OUTWEIGH THE CHALLENGES

WITH INCREASED WIFI PENETRATION, SPEED AND MORE USER SUPPORT IS THE NEED OF THE HOUR.


?
Q
&
A
!


THANK
YOU