802.11ax: Transforming Wi-Fi to bring unprecedented capacity & efficiency
The Wi-Fi landscape is rapidly changing
More devices & data

8 24 50
2012 2017 2022

Devices per household

Apps & services with diverse needs

Ranging from extremely low traffic to highly bandwidth intensive

Source: Connected devices—GSMA connected living 2015; Number of devices per household in home with a family of 4
Multiple interfering AP environment
- Shared channel usage

Wi-Fi usage extending to outdoors
- Urban hotspots
- Campus-wide coverage
Wi-Fi scales to support wide range connectivity needs

<table>
<thead>
<tr>
<th>Feature</th>
<th>11ad/ay</th>
<th>11ax/11ac MU-MIMO</th>
<th>11ah</th>
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<tbody>
<tr>
<td>User speed</td>
<td>Extremely high capacity and density</td>
<td>100s of Mbps</td>
<td>100s of kbps - 10s of Mbps</td>
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<tr>
<td>Coverage</td>
<td>Multi-Gigabit</td>
<td>Whole house</td>
<td>Campus</td>
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<tr>
<td>Battery life</td>
<td>In-space</td>
<td>Full day</td>
<td>Months/years</td>
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<td>Full day</td>
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Seamless transition
Wi-Fi powers the smart connected homes

HD / 4K video, screen mirroring, docking, and broadband

Computing and CE devices all over the house

Appliances, sensors, smart machines, and things

Smart router / gateway
Nerve center of connected home / local cloud

11ad/ay
Consistent Multi-gigabit experience

11ax /11ac MU-MIMO
Broadband for the whole house

11ah
Ultra low-power and extended range
Capacity
(The amount of data delivered to all users with appropriate QoS)
is going to be the defining character of Wi-Fi networks.
Capacity is the key metric to measure Wi-Fi performance
Moving away from simplistic theoretical peak speeds

Traditional approach
“theoretical peak speed”
- Works for single AP with few devices

New approach
Overall “capacity”
- Relevant for dense usage scenarios

802.11 g/n
802.11 ac
11ac MU-MIMO
802.11 ax
802.11 ad
802.11 ay
11ax

High efficiency Wi-Fi for high density connectivity

Up to 4x increase in capacity

Higher efficiency

Improved coverage & performance

¹Based on Qualcomm Technologies simulations: Up to 4x increase in median throughputs compared to 4x4 11ac Wave-2; Assumptions: 11ax with 8x8 AP and 2x2 clients; UL and DL MU-MIMO; increased OFDM symbol
11ax: Designed for high density connectivity

- Simultaneously serving lots of devices per AP
  - Few vs. dozens of devices
- Optimal performance in dense environments with many APs
  - Multiple APs on shared channels
- Uplink resource scheduling
  - vs. contention
- Efficiently serving multiple traffic types
  - Low traffic IM, IoT vs. 4k streaming/download
Technology building blocks of 11ax

8x8 MU-MIMO DL/UL
Long OFDM symbol
MU-MIMO and OFDMA expertise are key for success in 11ax

OFDMA DL/UL
1024 QAM
Extended range

Up link resource scheduling

2.4 GHz 5 GHz
More spatial streams

BSS color

MU-MIMO and OFDMA expertise are key for success in 11ax
Up to 4x increase in capacity
Extending the benefits of proven 11ac MU-MIMO

11ac MU-MIMO is already mainstream

- Up to 8x8 MU-MIMO in the downlink
  - Serving up to 8 simultaneous users (in downlink)
  - Up to 2x increase in capacity vs. 4x4

- Up to 8x8 MU-MIMO in the uplink
  - Serving up to 8 simultaneous users (in uplink)
  - Up to 8x increase in capacity vs. 1x1
  - Extremely useful for uplink heavy apps such as social media, content sharing (video, picture uploads, Periscope, etc)

- Higher MU-MIMO gain with more client devices per AP
8x8 MU-MIMO: Improved performance for 11ac devices

- Immediate coverage improvement for existing 11ac and legacy client devices
- Up to 4 downlink users with 2x2 configuration served simultaneously
- Realizes the benefits of 11ax during the 11ax client device ramp-up
- Overall capacity scales with the penetration of 11ax client devices
Up to 4x increase in capacity in dense scenarios

Based on Qualcomm Technologies simulations
Up to 4x increase in median throughputs in dense scenarios compared to 4x4 11ac wave 2
Assumptions: 11ax with 8x8 AP and 2x2 clients; UL and DL MU-MIMO; long OFDM symbol
Higher efficiency
OFDMA: Proven technology for efficient access
Foundation of global 4G LTE standard

- Fixed overhead independent of payload size
- Uses full channel bandwidth per user

- Overhead amortized among users
- Efficient use of resources
- Scales resources for different types of traffic (e.g. IM vs large download)
- Increases overall efficiency
OFDMA and MU-MIMO are complementary
Utilized based on the type of application being served

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

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

MU-MIMO is similar to multiple trucks serving users simultaneously
UL OFDMA & UL MU-MIMO

Scheduled UL access for increased capacity and efficiency

Contetion based resource allocation (11ac)

- Un coordinated resource management
- Devices all compete and try to get resource till they succeed
- Works well in single AP scenario

Scheduling based resource allocation (11ax)

- Up link resource allocation managed by AP
- A must for dense scenarios
- Increased capacity and better user experience
Resource scheduling significantly improves device battery life

**TWT : Target Wake Time**

- AP and devices negotiate and define specific times to access the medium
- Reduced contention and overlap between users
- Significantly increases the device sleep time to reduce power consumption
Improved coverage & performance
Enhancements that further improve capacity & efficiency

- 4x longer OFDM symbol
- Increased efficiency and higher rates
- Address outdoor use cases such as colleague campus and public venues

1024 QAM

- 10 bits per symbol vs. 8
- Gigabit Wi-Fi with only 2x2
- Up to 25% higher capacity vs. 256QAM

1 In certain conditions
>4x increase in speeds for users on the cell boundary

Based on Qualcomm Technologies simulations

> 4x increase in worst 5 percentile throughput in dense scenarios compared to 4x4 11ac Wave 2

Assumptions: 11ax with 8x8 AP and 2x2 clients; UL and DL MU-MIMO; long OFDM symbol
11ax use cases
11ax is a necessity for dense urban usage scenarios

E.g.: Apartment complexes, condominiums, and multi-dwelling buildings
11ax is key to enterprise-class use cases
E.g.: Next-gen e-classrooms, colleges and school campuses
11ax is critical for carrier networks for LTE traffic offload
Qualcomm Technologies is leading the Wi-Fi evolution
OFDMA and 11ac Wave-2 experience key to 11ax success

#1
First with MU-MIMO and 11ad
LTE/LTE Advanced technology & product leadership
>30 years of industry leadership in cellular

Wi-Fi leadership across segments

1Source: from IHS WLAN IC Extract Nov. 2016. Reflects shipments from 802.11X ICs (Baseband, RF / IF, but not PA) used in handsets, tablets, PCs (mobile and desktop), Enterprise and Consumer Access points, Carrier Gateways and Clients, Gaming devices/consoles, and other devices.
802.11ax: Next Gen Wi-Fi for the transformed landscape

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<td>Unprecedented increase in capacity to support more devices, more data and diverse needs</td>
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<td>Higher capacity and coverage enables new use cases and improve existing ones</td>
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<th>A must to meet capacity needs in homes</th>
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<td>Capacity to support connected homes.</td>
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<td>Leadership in MU-MIMO, 11ad, OFDMA &amp; strong proven heritage of cellular technology</td>
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Capacity is going to be the defining character of Wi-Fi performance
Thank you