IEEE802.11ax

- **IEEE802.11ax (WiFi 6)**

Review

- The usage of IEEE802.11ad
- The data rates of in IEEE802.11ad
- The new technologies in IEEE802.11ad

Market demands and new technology drive IEEE 802.11 innovation

- **Demand for throughput**
  - Continuing exponential demand for throughput (802.11ax and 802.11ay, 802.11be)
  - Most (50-80%, depending on the country) of the world's mobile data is carried on 802.11 (WiFi) devices
- **New usage models / features**
  - Dense deployments (802.11ax), Indoor Location (802.11az),
  - Automotive (IEEE Std 802.11p, Next Gen V2X), Internet of Things (802.11ah)
  - Low Power applications (802.11ba)
- **Technical capabilities**
  - MIMO (IEEE Std 802.11n, 802.11ac, 802.11ay) and OFDMA (802.11ax)
  - 60 GHz radios (802.11ay)
- **Changes to regulation**
  - TV whitespaces (IEEE Std 802.11af), Radar detection (IEEE Std 802.11h), 6GHz (802.11ax, 802.11be)
  - Coexistence and radio performance rules (e.g., ETSI BRAN, ITU-R)

802.11ax is focused on improving performance in dense environments

- Existing 802.11 WLAN systems serve dense deployments: 2019 Super bowl: 24TB* of data carried on WLAN network
- 802.11ax aims to further improve performance of WLAN deployments in dense scenarios
  - Targeting at least 4x improvement in the per-STA throughput compared to 802.11n and 802.11ac.
  - Improved efficiency through spatial (MU MIMO) and frequency (OFDMA) multiplexing.
- Dense scenarios are characterized by large number of access points and large number of associated STAs deployed in geographical limited region
  - e.g. a stadium or an airport.

Access to Internet, latest airlines' announcements, and digital media such as movies and sport events

* https://www.extremenetworks.com/resources/slideshare/wi-fi-engagements-from-super-bowl-liii/

802.11ax Categories of Enhancements

Spectral Efficiency & Area Throughput

1024 QAM
25% increase
in data rate

DL/UL MU-MIMO
w/ 8 clients

8x8 AP

2x increase
in throughput

Long OFDM
Symbol

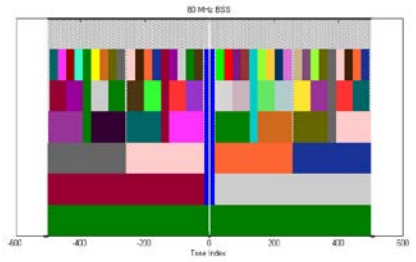
ac

ax

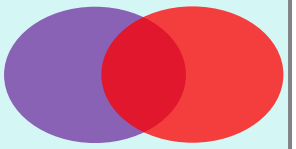
Up to 20%
increase
in data rate

High Density

OFDMA

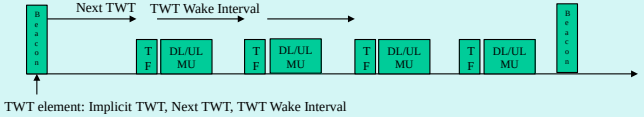


Spatial Reuse



Power Saving

Scheduled sleep and wake times



20 MHz-only clients

Outdoor / Longer range

Extended range packet structure

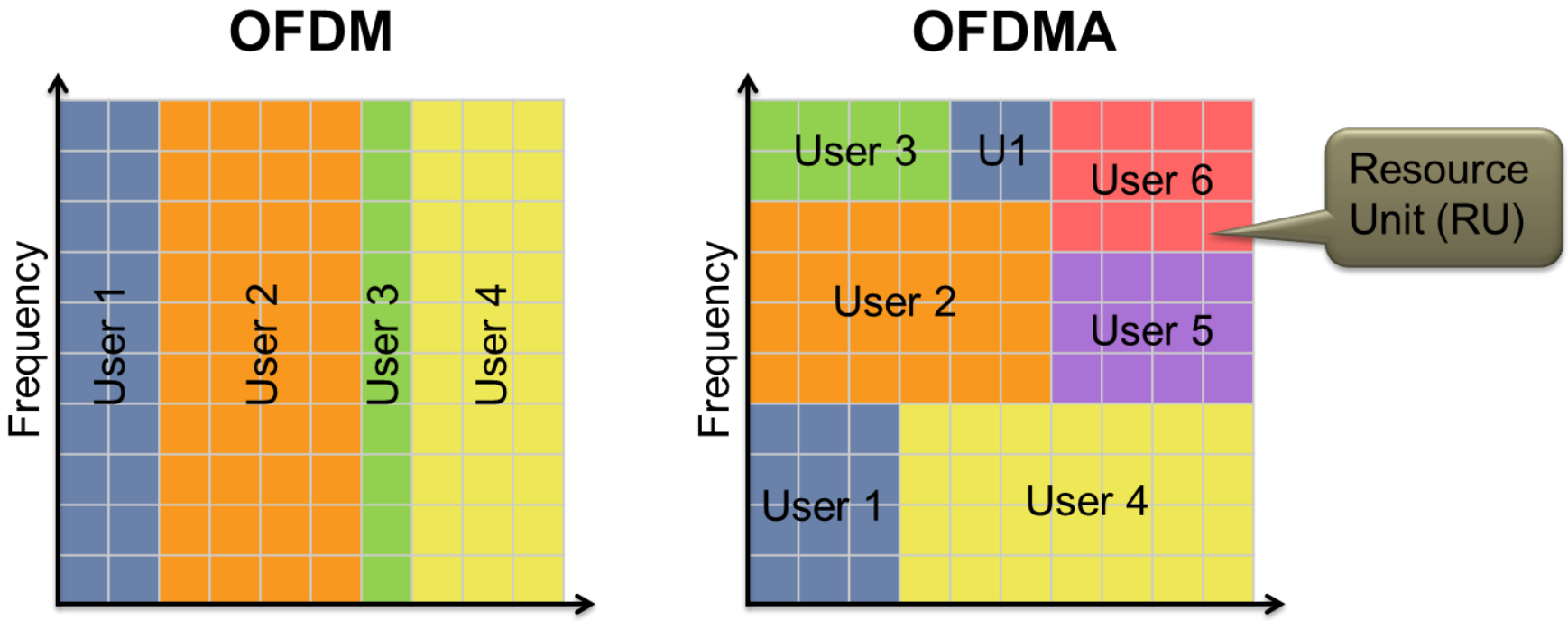
Enhanced delay
spread protection-
long guard interval

0.8us
11ac

1.6us 11ax

3.2us 11ax

OFDMA enables further AP customization of channel use to match client and traffic demands

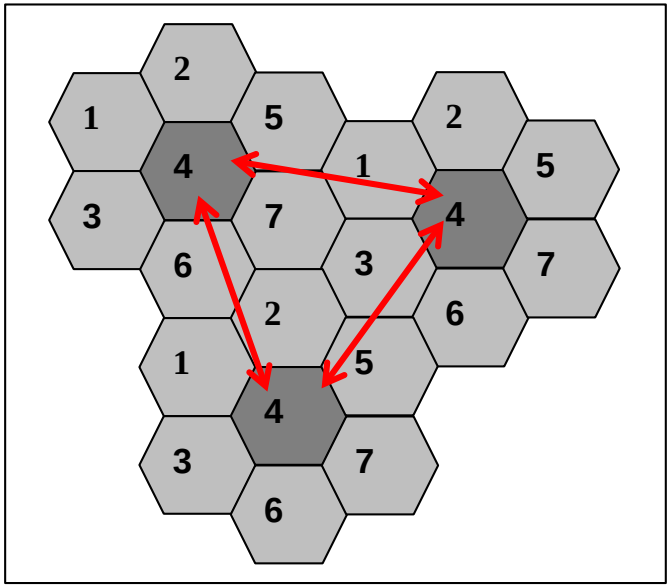


Increased efficiency for (high percentage of traffic) short data frames

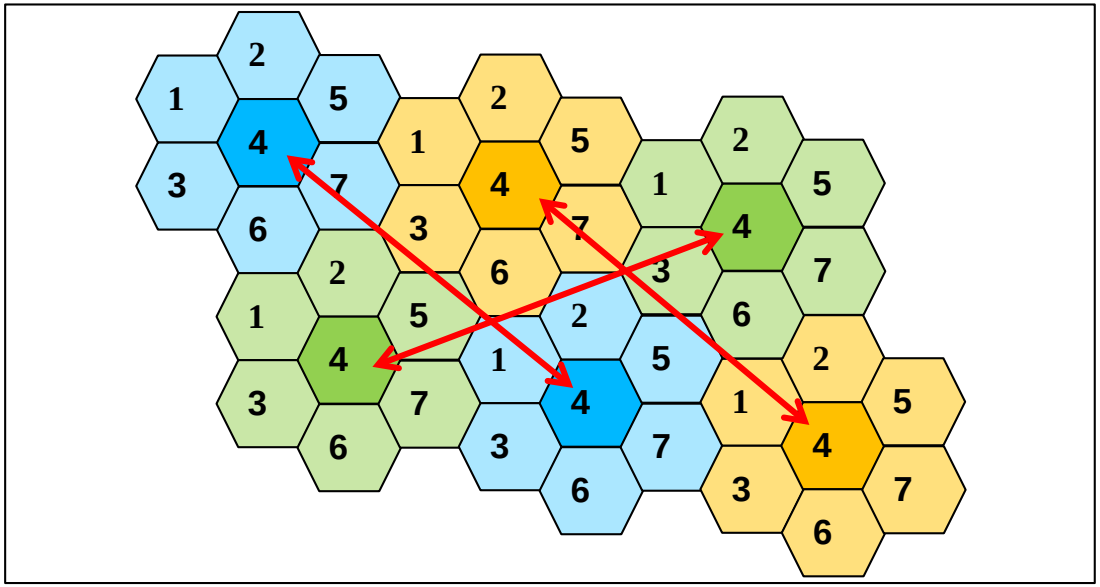
6

BSS Coloring enables additional channel re-use

All same-channel BSS block

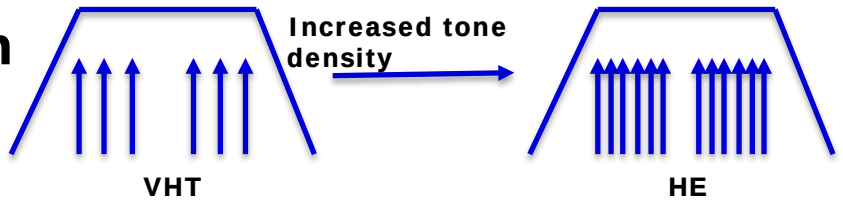


Same-channel BSS only block on Color Match



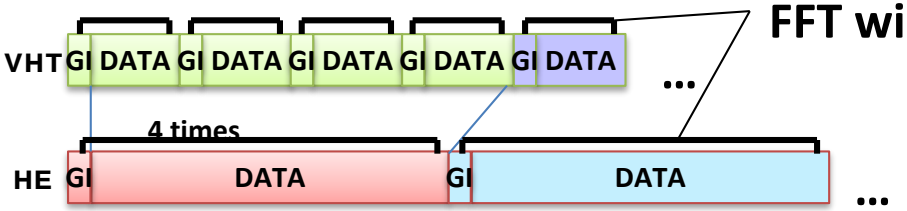
802.11ax Increases link efficiency

Frequency domain (~5% gain)



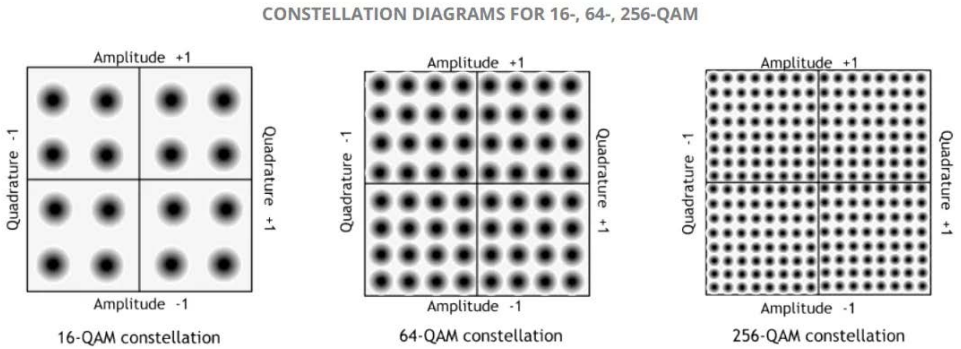
Squeeze more tones in around DC and edge

Time domain (~15% gain)



Guard interval (GI) overhead reduced

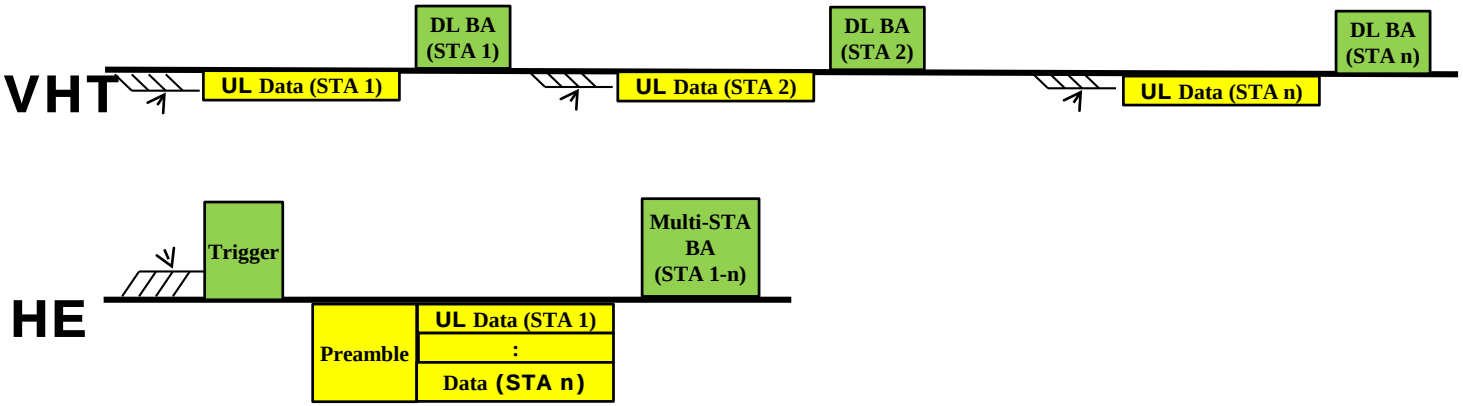
Modulation (~25% gain)



+ 1024-QAM

8

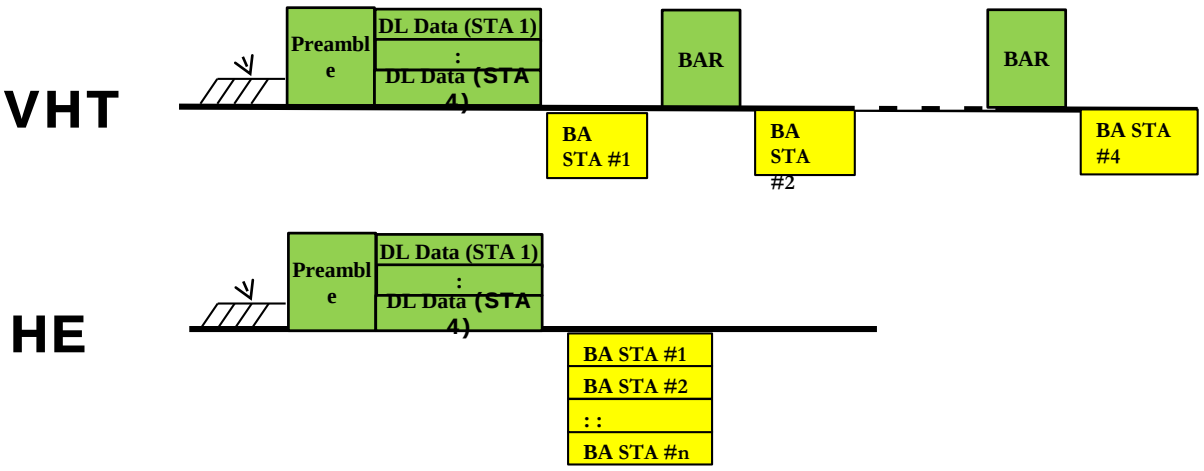
UL/DL multi-user links in 802.11ax will support more efficient UL data



- In a VHT UL sequence, STAs compete for medium access and send sequentially
- In an HE UL sequence, the AP triggers simultaneous transmissions in multiple STAs

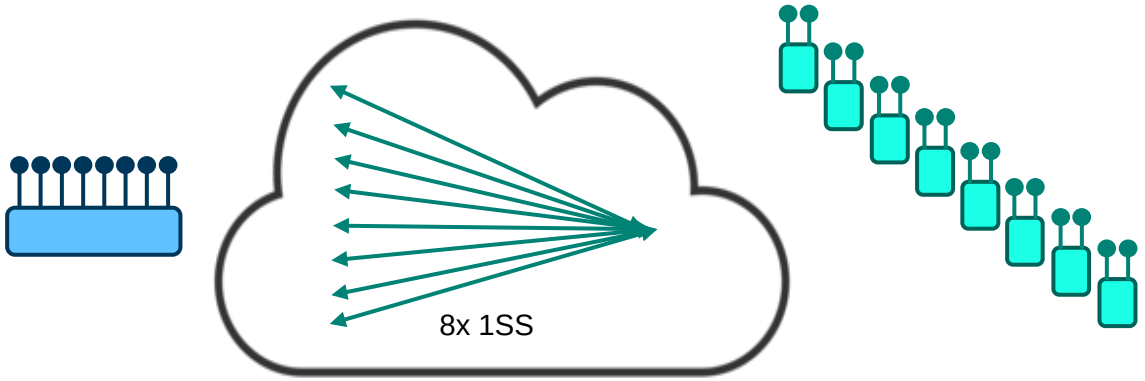
802.11ax Data exchange sequences: Multi-user downlink

- In a VHT DL MU sequence acknowledgements are serialized
- In an HE DL MU sequence acknowledgements are allocated UL resources and transmitted simultaneously



Uplink MU-MIMO

- **UL MU-MIMO was initially considered in 11ac, but not included due to implementation concerns**
- **Sounding frames, data frames, etc can be grouped among multiple users to reduce overhead and increase uplink response time**



Various features in 802.11ax will support improved outdoor operation

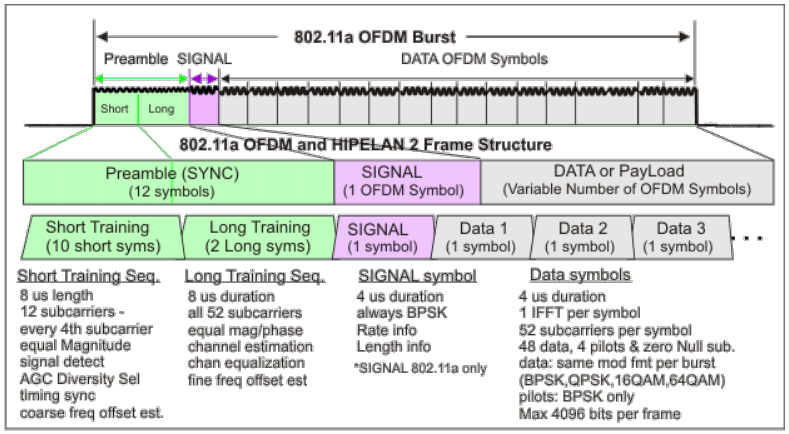
- Operates in higher delay spread channels than 11ac:
  - 11ac GI options: 0.4 µs and 0.8 µs
  - 11ax GI options: 0.8 µs, 1.6 µs and 3.2 µs
  - GI overhead mitigated with longer OFDM symbol
- Preamble includes repeated L-SIG
- Extended range preamble includes repeated HE-SIG-A
- Dual carrier modulation improves robustness in Data field

802.11ax meets the MAC/PHY requirements for 5G Indoor Hotspot test Environment

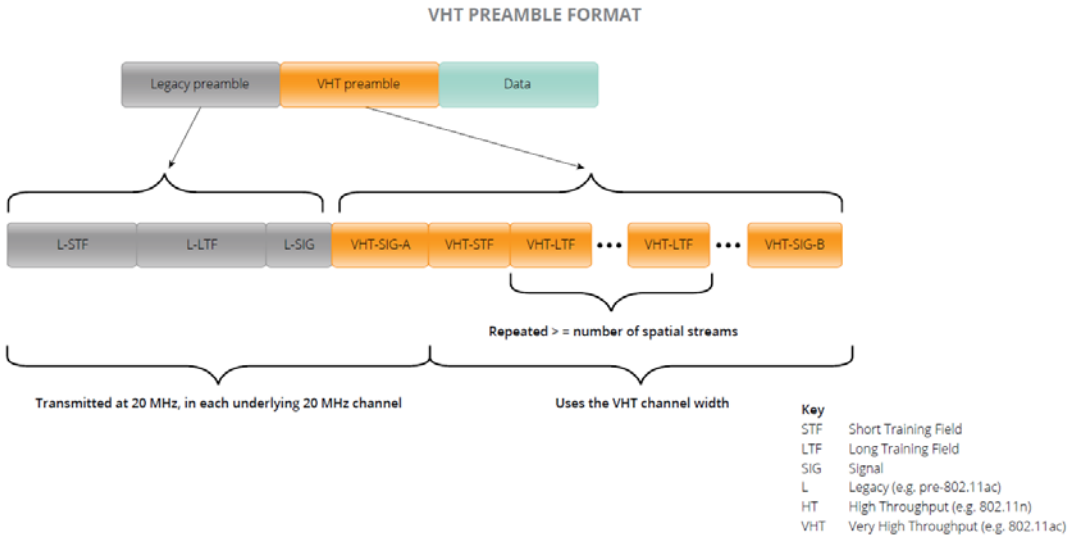
- **Analysis and simulations confirm that performance of IEEE 802.11ax MAC/PHY meet or exceed 5G requirements for the 5G Indoor Hotspot use case**
- **Similar studies are underway for the Dense Urban test environment**

	Metric	ITU-R Evaluation Method	Minimum Requirement	802.11ax Performance
1	Peak data rate	Analytical	DL/UL : 20/10 Gbps	DL/UL : 20.78 Gbps [Note 1]
2	Peak spectral efficiency	Analytical	DL/UL : 30/15 bits/s/Hz	DL/UL : 58.01 bits/s/Hz [Note 2]
3	User experienced data rate	Analytical for single band and single layer; Simulation for multi-layer	Not applicable for Indoor Hotspot	Not applicable
4	5th percentile user spectral efficiency	Simulation	DL/UL : 0.3/0.21 bits/s/Hz	DL/UL : 0.45/0.52 bits/s/Hz [Note 3]
5	Average spectral efficiency	Simulation	DL/UL : 9/6.75 bits/s/Hz/TRxP	DL/UL : 9.82/13.7 bits/s/Hz/TRxP [Note 3]
6	Area traffic capacity	Analytical	DL : 10 Mbit/s/m^2	Required DL bandwidth = 170 MHz with 3 TRxP/site. [Note 4]
7	Mobility	Simulation	UL : 1.5 bits/s/Hz	UL : 9.4 bits/s/Hz
8	Bandwidth	Inspection	100 MHz, scalable	20/40/80/80+80/160 MHz
9	User plane latency	Analytical	DL/UL : 4 ms	DL/UL : 80 us [Note 5]

802.11 PHY standards are backwards compatible with prior generations within a spectrum band



802.11a and HIPERLAN/2 Frame Structure



- 802.11a Preamble is included in 802.11a, 802.11n, 802.11ac, 802.11ax 5GHz encoded frames
- Very minimal common preamble provides backward compatibility and enables preamble detection at low energy levels for improved coexistence

New 802.11 Radio technologies are under development to meet expanding market needs and leverage new technologies

- 802.11ax – Increased throughput in 2.4, 5 (and 6) GHz bands. Increased efficiency.
- 802.11ay – Support for 20 Gbps in 60 GHz band.
- 802.11az – 2nd generation positioning features.
- 802.11ba – Wake up radio. Low power IoT applications.
- 802.11bb – Light Communications
- 802.11bc – Enhanced Broadcast Service
- 802.11bd – Enhancements for Next Generation V2X
- 802.11be – Extremely High Throughput

Class Quiz

- What is the drive for IEEE802.11ax?
- What is the maximum data rate in IEEE802.11ax?
- What are the new technologies in IEEE802.11ax?