



**Certified Wireless Network Administrator (CWNA)  
PW0-106**



Chapter 19  
Very High Throughput  
(VHT) and 802.11ac



### Chapter 19 Overview

- 802.11ac-2013 amendment
- 5 GHz only
- 20, 40, 80, and 160 MHz channels
- 256-QAM modulation
- Modulation and coding schemes
- Single-user MIMO



Certified Wireless Network Administrator: CWNA – PW0-106



## Chapter 19 Overview

- 802.11ac data rates
- VHT MAC
- Beamforming
- Infrastructure requirements
- 802.11ac in a SOHO or home
- Wi-Fi Alliance certification

Certified Wireless Network Administrator, CWNA – PW0-106 3



## 802.11ac-2013 Amendment

- Introduces Very High Throughput (VHT) technology with maximum transmission speed of 6.933 Gbps.
- Will be implemented in multiple phases
- Some of the features or capabilities may not exist yet in live product.

Certified Wireless Network Administrator, CWNA – PW0-106 4

Technology	802.11n	802.11ac
Frequency	2.4 GHz and 5 GHz	5 GHz only
Modulation	BPSK, QPSK, 16-QAM, 64-QAM	BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM
Channel widths	20 MHz, 40 MHz	20 MHz, 40 MHz, 80 MHz, 160 MHz
Spatial streams	Up to four	Up to eight on APs, up to four on clients
Short Guard Interval Support	Yes	Yes
Beamforming	Multiple types, both implicit and explicit, not typically implemented	Explicit beamforming with null data packets (NDPs)
Number of modulation and coding schemes (MCSs)	77	10
Support for A-MSDU and A-MPDU	Yes	Yes, all frames transmitted as A-MPDU
MIMO support	Single-user MIMO	Single-user MIMO and multiuser MIMO (MU-MIMO)
Maximum # of simultaneous user transmissions	One	Four
Maximum data rate	600 Mbps	6.933 Gbps

Certified Wireless Network Administrator: CWNA – PW0-106 5

Technology	802.11n	802.11ac
Frequency	2.4 GHz and 5 GHz	5 GHz only
Modulation	BPSK, QPSK, 16-QAM, 64-QAM	BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM
Channel widths	20 MHz, 40 MHz	20 MHz, 40 MHz, 80 MHz, 160 MHz
Spatial streams	Up to four	Up to eight on APs, up to four on clients
Short Guard Interval Support	Yes	Yes
Beamforming	Multiple types, both implicit and explicit, not typically implemented	Explicit beamforming with null data packets (NDPs)
Number of modulation and coding schemes (MCSs)	77	10
Support for A-MSDU and A-MPDU	Yes	Yes, all frames transmitted as A-MPDU
MIMO support	Single-user MIMO	Single-user MIMO and multiuser MIMO (MU-MIMO)
Maximum # of simultaneous user transmissions	One	Four
Maximum data rate	600 Mbps	6.933 Gbps

## 5 GHz Only

- In order to benefit from the faster data rates of 802.11n, companies have migrated to 5 GHz radios
- However, support for 2.4 GHz radios in older devices is still needed.
- Accomplished with dual-radio access points
- 802.11ac is designed to operate only in the 5 GHz band where much more frequency space is available.

Certified Wireless Network Administrator: CWNA – PW0-106 6

**SYBEX** **WILEY**

## 20, 40, 80, and 160 MHz Channels

- 802.11ac introduced two new channel widths: 80 MHz and 160 MHz
- The two 40 MHz channels that make up the 80 MHz channel must be adjacent.
- New 80 MHz channel consists of 242 subcarriers, of which 234 are used to transmit data, and 8 are used as pilot carriers
- 160 MHz channel is made up of two 80 MHz channels; however, the two 80 MHz channels do not have to be adjacent.
- 160 MHz channel consists of 484 subcarriers, with 468 used to transmit data, and 16 used as pilot carriers

Certified Wireless Network Administrator: CWNA – PW0-106 7

**SYBEX** **WILEY**

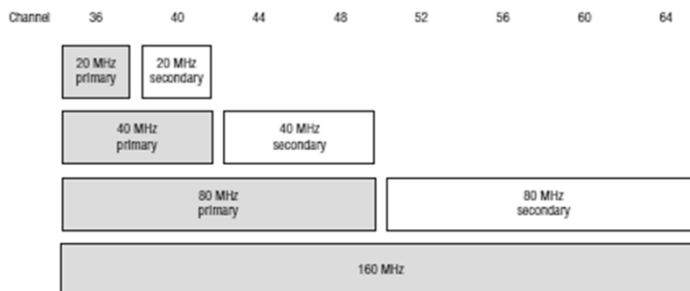
## 20, 40, 80, and 160 MHz Channels

Certified Wireless Network Administrator: CWNA – PW0-106 8

## Dynamic bandwidth operation

- 802.11ac feature that allows the AP to choose the channel width on a per-frame basis
- AP, operating at 80 MHz on channels 36, 40, 44, and 48, wants to transmit, it must first check to see if all four channels are available
- If one of the channels, such as 36, is currently being used, AP can transmit using a 40 MHz transmission on channels 44 and 48
- Allows 802.11ac devices to adapt to the environment while transmitting on the widest available channel.
- Channel selection for a single radio can require the selection of up to four channel groupings.
- Becomes much more difficult and important when choosing channels for multiple APs

## Single AP 160 MHz channel plan



**SYBEX** **WILEY**

## Two APs, 160 MHz channel plan

The diagram illustrates the channel plan for two APs (AP1 and AP2) across channels 36 to 64. The channels are labeled as 36, 40, 44, 48, 52, 56, 60, and 64. The diagram shows four levels of channel aggregation:

- 20 MHz primary:** AP1 (channels 36-40) and AP2 (channels 60-64).
- 40 MHz primary:** AP1 (channels 36-48) and AP2 (channels 56-64).
- 80 MHz primary:** AP1 (channels 36-56) and AP2 (channels 56-64).
- 160 MHz:** AP1 and AP2 (channels 36-64).

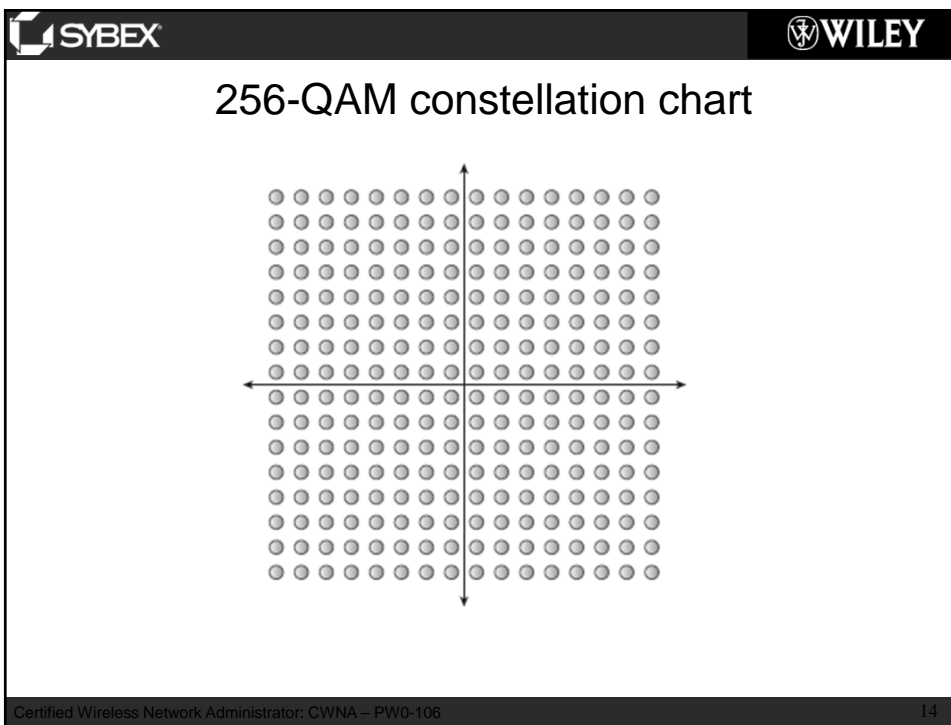
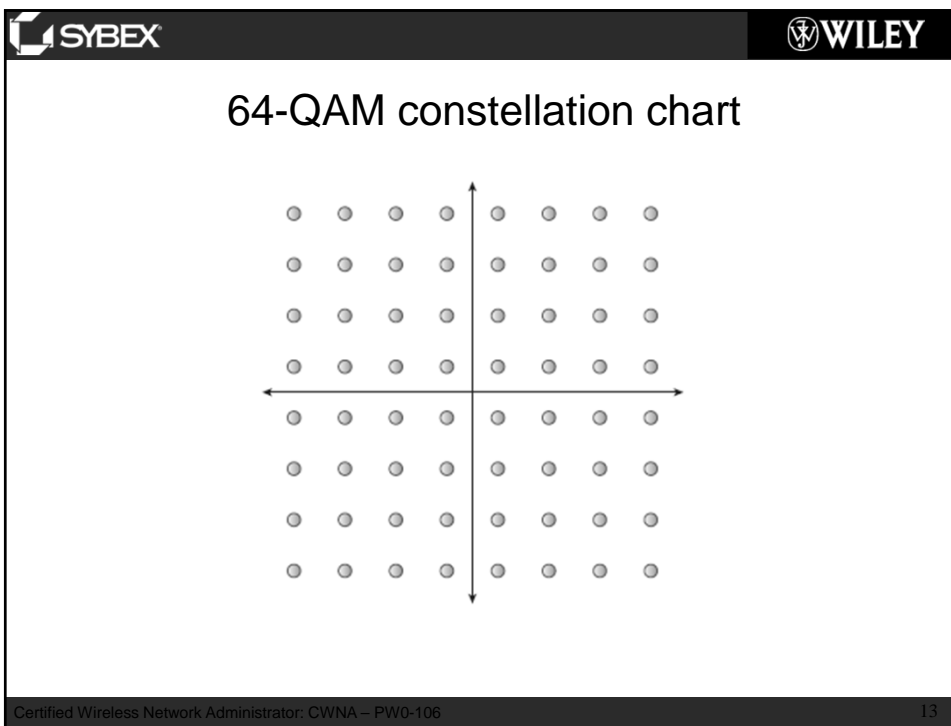
Certified Wireless Network Administrator, CWNA – PW0-106 11



**SYBEX** **WILEY**

## 256-QAM Modulation

- Introduced with the 802.11ac amendment
- Identifies 256 unique values, using 16 different levels of phase shift and 16 different levels of amplitude shift
- For comparison , 64-QAM identifies 64 unique values and using eight different levels of phase shift and eight different levels of amplitude shift
- 256-QAM is more sensitive to noise and interference.
- 802.11ac receiver performance requires about 5 dB of additional gain as compared to 64-QAM.

Certified Wireless Network Administrator, CWNA – PW0-106 12





## Modulation and Coding Schemes

- 802.11n (HT) defined 77 different modulation and coding schemes
- 802.11ac simplified this by defining only 10 MCS options
- The first eight modulation and coding schemes are mandatory; however, most vendors will support the last two, which provide 256-QAM modulation

Certified Wireless Network Administrator: CWNA – PW0-106
15



## 802.11ac Modulation and Coding Schemes

VHT MCS value	Modulation	Code rate (R)	20 MHz data rate (Mbps)
0	BPSK	1/2	7.2
1	QPSK	1/2	14.4
2	QPSK	3/4	21.7
3	16-QAM	1/2	28.9
4	16-QAM	3/4	43.3
5	64-QAM	2/3	57.8
6	64-QAM	3/4	65.0
7	64-QAM	5/6	72.2
8	256-QAM	3/4	86.7
9	256-QAM	5/6	96.3*

\*MCS 9 is not supported for 20 MHz channels, only 40 MHz, 80 MHz, and 160 MHz.

Certified Wireless Network Administrator: CWNA – PW0-106
16





## MIMO types

- 802.11n uses single-user MIMO (SU-MIMO)
- 802.11ac, a new form of MIMO was introduced: multi-user MIMO (MU-MIMO)
- 802.11n amendment allows up to four spatial streams of data to be transmitted, most 802.11 n APs support 3
- 802.11ac amendment doubles the total number of supported spatial streams to eight
- 802.11ac access point chipsets that are expected to support MU-MIMO will most likely be 4 × 4:4 radios

Certified Wireless Network Administrator: CWNA – PW0-106
17

## 802.11ac Data Rates factors

MCS	20 MHz data rate	Spatial stream multiplier	Channel width multiplier
0	7.2	× 1 (1 streams)	× 1.0 (20 MHz)
1	14.4	× 2 (2 streams)	× 2.1 (40 MHz)
2	21.7	× 3 (3 streams)	× 4.5 (80 MHz)
3	28.9	× 4 (4 streams)	× 9.0 (160 MHz)
4	43.3	× 5 (5 streams)	
5	57.8	× 6 (6 streams)	
6	65.0	× 7 (7 streams)	
7	72.2	× 8 (8 streams)	
8	86.7		
9*	96.3		

\*MCS 9 is not supported for 20 MHz channels, only 40, 80, and 160.

Certified Wireless Network Administrator: CWNA – PW0-106
18

**SYBEX** **WILEY**

## VHT MAC

- 802.11a, 802.11n and 802.11ac radios all use the same preamble and can calculate how long to wait before they can transmit.
- All 802.11ac frames are transmitted using the Aggregate MAC Protocol Data Unit (A-MPDU) frame format, even if only a single frame is being transmitted
- 802.11ac can use RTS/CTS to perform dynamic bandwidth operations
- Sends an RTS frame using a method known as a non-HT duplicate frame.
- If all requested channels are available, and if Station receives the RTS frames, it will transmit four CTS frames

Certified Wireless Network Administrator: CWNA – PW0-106 19

**SYBEX** **WILEY**

## The need for dynamic bandwidth Operation

### Interfering laptops

The diagram shows two overlapping circles representing the coverage areas of two access points, AP1 and AP2. AP1 is on the left and AP2 is on the right. The overlapping area in the center contains two laptops, Station1 and Station2. AP1 is associated with channels 36(P), 40, 44, and 48. AP2 is associated with channels 44(P) and 48. The overlap of the circles indicates that the channels used by AP1 and AP2 overlap, specifically channels 44 and 48, which can cause interference for the stations in the overlapping area.

Certified Wireless Network Administrator: CWNA – PW0-106 20

**SYBEX** **WILEY**

## Dynamic bandwidth operation

- Using RTS/CTS
- When AP1 receives all four CTS frames, it knows that all four channels are available

The diagram illustrates a successful dynamic bandwidth operation across four channels: CH36, CH40, CH44, and CH48. On each channel, the sequence of frames is: AP1 RTS, Station1 CTS, AP1 data, and Station1 block ACK. Vertical arrows labeled 'SIFS' indicate the time between the end of one frame and the start of the next. Below the frame sequence, a timeline shows the duration of the RTS and CTS frames on each channel, with the CTS duration value being longer than the RTS duration value.

21



**SYBEX** **WILEY**

## What happens if all four channels are not available?

- When AP1 receives the CTS frames, it performs a 40 MHz data transmission on channels 36 and 40.
- Station1 then responds with two block ACK frames.

The diagram shows a scenario where channels 44 and 48 are unavailable. On channels CH36 and CH40, the sequence of frames is: AP1 RTS, Station1 CTS, AP1 data, and Station1 block ACK. On channels CH44 and CH48, the AP1 RTS frames are shown, but the subsequent CTS frames and data transmission are blocked by a grey area labeled 'Channels busy due to interference'. Below the frame sequence, a timeline shows the duration of the RTS and CTS frames on each channel. For CH44 and CH48, the CTS frames are marked as 'unsuccessful'.



22



## Beamforming

- Can occur from the AP to the client, or vice versa.
- Multiple radio chains in the AP transmit the same information through different antennas.
- APs time their transmissions so that the waves of all of the antennas arrive at the receiving radio at the same time and in phase with each other.
- Results in a signal increase of approximately 3 decibels
- Increase in signal strength can move the communications between the radios to a higher data rate

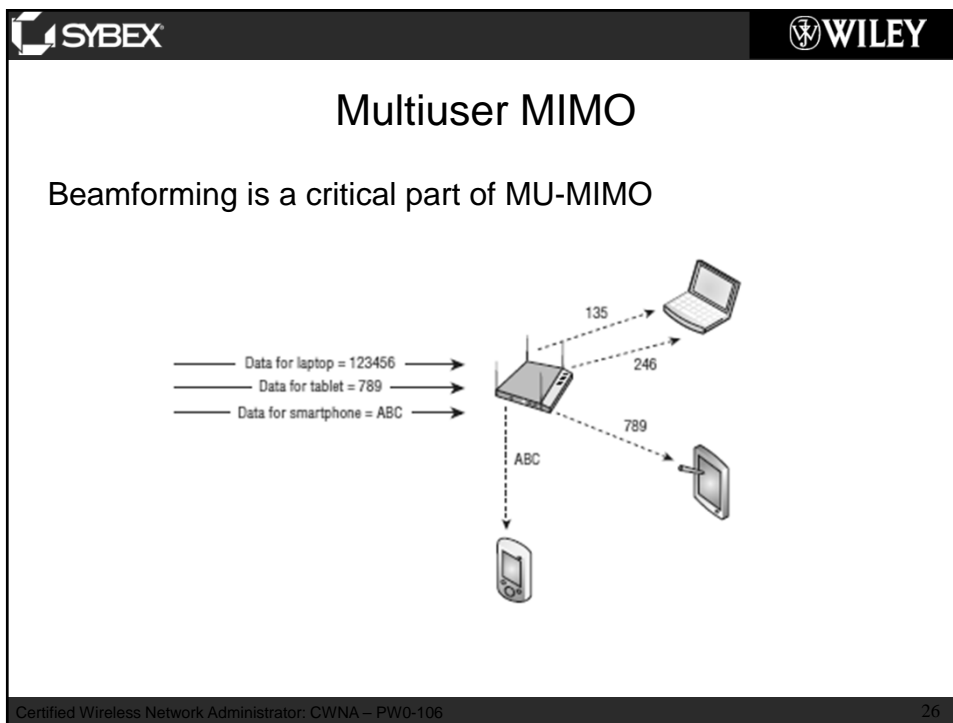
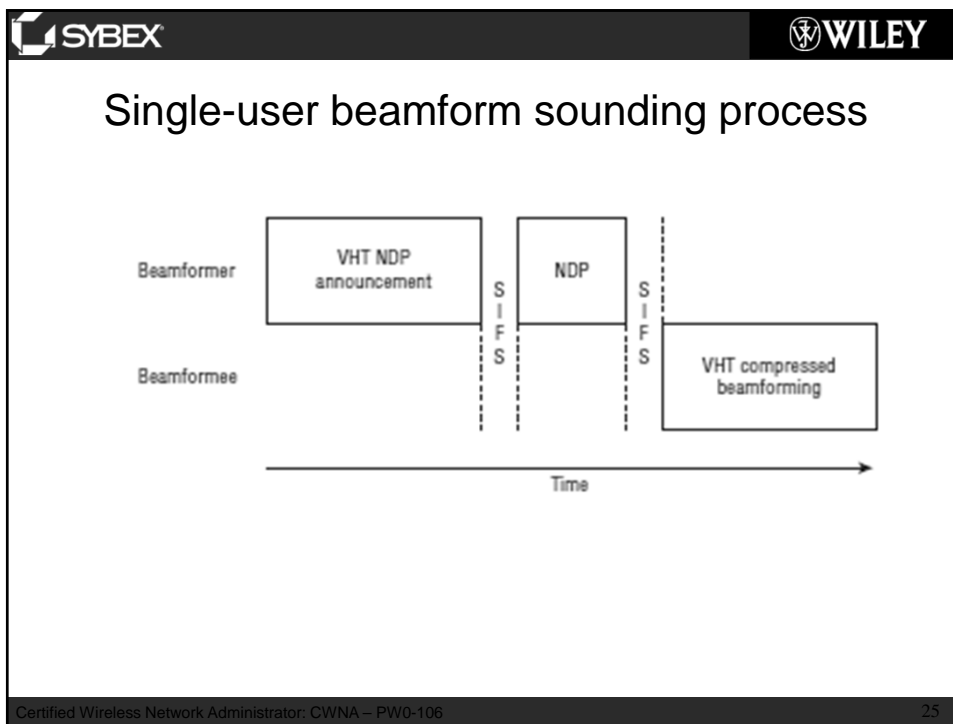
Certified Wireless Network Administrator: CWNA – PW0-106 23



## Explicit Beamforming

- 802.11ac only uses explicit beamforming
- Requires support by both the transmitter and receiver
- Uses an interactive calibration process to identify how to perform the transmission using the multiple radio chains
- Known as channel sounding.
- Beamformee processes each OFDM subcarrier and creates feedback information
- Uses the feedback matrix to calculate a steering matrix that is used to direct the data transmission to the beamformee

Certified Wireless Network Administrator: CWNA – PW0-106 24



**SYBEX** **WILEY**

## Multiuser Beamforming

- With single-user MIMO, beamforming is used to focus a signal to a client
- With MU-MIMO, the task of beamforming is not just performed for transmitting to a single client, it's performed for transmitting to up to four clients at a time.
- AP uses the feedback matrix from each of the beamformees to create a single steering matrix.

Certified Wireless Network Administrator, CWNA – PW0-106 27

**SYBEX** **WILEY**

## Multiuser beamform sounding process

The diagram illustrates the multiuser beamforming sounding process over time. It involves a Beamformer and three Beamformees (1, 2, and 3). The process is as follows:

- Beamformer:**
  - Starts with a **VHT NDP announcement**.
  - Followed by **NDP** (Null Data Packet).
  - Then **Beamforming report poll**.
  - Finally another **Beamforming report poll**.
- Beamformee 1:**
  - Receives **VHT compressed beamforming (beamformee 1)** during the first NDP period.
  - Sends a **Beamforming report** during the first Beamforming report poll.
- Beamformee 2:**
  - Receives **VHT compressed beamforming (beamformee 2)** during the second NDP period.
  - Sends a **Beamforming report** during the second Beamforming report poll.
- Beamformee 3:**
  - Receives **VHT compressed beamforming (beamformee 3)** during the third NDP period.
  - Sends a **Beamforming report** during the third Beamforming report poll.

Certified Wireless Network Administrator, CWNA – PW0-106 28

**SYBEX** **WILEY**

## Beamformed transmissions in a MU-MIMO environment

Signal laptop = high  
Signal smartphone = null  
Signal tablet = null

Signal laptop = null  
Signal smartphone = high  
Signal tablet = null

Signal laptop = null  
Signal smartphone = null  
Signal tablet = high

Certified Wireless Network Administrator: CWNA – PW0-106 29

**SYBEX** **WILEY**

## MU-MIMO block acknowledgements

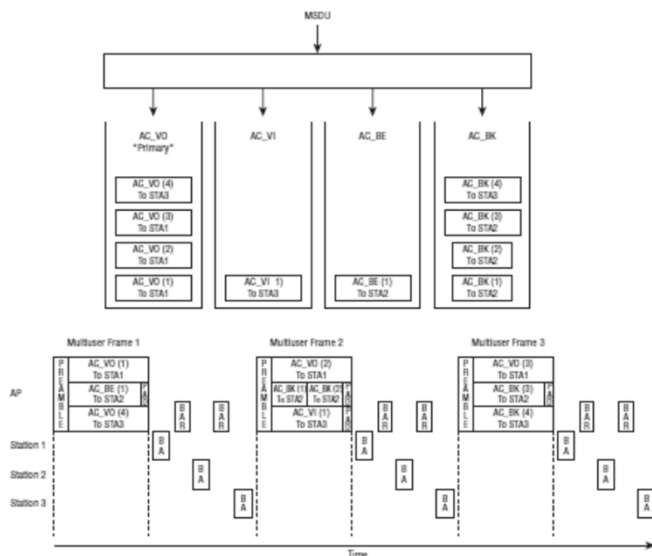
- AP sends a BAR frame to a user, waits for the block acknowledgment from that user, and then sequentially repeats the process with the other users.

Certified Wireless Network Administrator: CWNA – PW0-106 30



## Quality of Service

- Core concepts and procedures of quality of service (QoS) remain the same with 802.11ac.
- Queuing and transmission of QoS frames is handled differently than in single-user wireless environments
- During the construction of each multiuser frame, lower-priority frames can piggyback with the higher-priority frame, providing they do not increase the time needed to transmit the primary data and providing the stations they are being sent to are spatially distinct.

## MU-MIMO and QoS







## Infrastructure Requirements

- Ethernet
  - Second phase of 802.11ac may require faster uplink technology than Gigabit Ethernet
- Power
  - Transitioning to PoE+ will be inevitable
  - Upgrading the network to provide 802.3at (PoE+) power of 30 watts is highly recommended and most likely will become a necessity



Certified Wireless Network Administrator, CWNA – PW0-106 33

## 802.11ac in a SOHO or Home

- Device Radios
  - To upgrade, you will need to purchase a dual-radio AP to continue to provide support for older 2.4 GHz devices.
- Data Flow/Usage
  - It is not likely that your Internet connection is fast enough to support the throughput that an 802.11ac AP can provide



Certified Wireless Network Administrator, CWNA – PW0-106 34



## 802.11ac in a SOHO or Home

- **Spatial Streams**
  - Operating 802.11ac multiple-spatial-stream devices along with single-spatial-stream devices, the single-stream devices will decrease the performance
- **Wider 802.11ac Channels**
  - Takes more power to process the data that is transmitted across wider channels
- **MU-MIMO**
  - Can only occur if the devices are spatially separated, since beamforming will not work properly if two devices are near each other.

Certified Wireless Network Administrator, CWNA – PW0-106 35



## Wi-Fi Alliance Certification

- Wi-Fi CERTIFIED ac products are tested for both the mandatory and optional baseline capabilities
- Wi-Fi CERTIFIED ac devices only operate in the 5 GHz frequency band.
- Wi-Fi CERTIFIED ac devices support both Wi-Fi Multimedia (WMM) quality-of-service mechanisms and WPA2/WPA2 security mechanisms

Certified Wireless Network Administrator, CWNA – PW0-106 36

Feature	Mandatory	Optional
Channel width	20, 40, 80 MHz	80, 80, 160 MHz
Modulation and coding	MCS 0-7	MCS 8,9
Spatial streams	One for clients, two for APs	Two to eight
Guard Interval	Long (800 nanoseconds)	Short (400 nanoseconds)
Beamforming feedback		Respond to beamforming sounding
Space-time block coding (STBC)		Transmit and receive STBC
Low-density parity check (LDPC)		Transmit and receive LDPC
Multuser MIMO		UP to four spatial streams per client, using the same MCS

Certified Wireless Network Administrator: CWNA – PW0-106

37

Feature	Mandatory	Optional
Channel width	20, 40, 80 MHz	80, 80, 160 MHz
Modulation and coding	MCS 0-7	MCS 8,9
Spatial streams	One for clients, two for APs	Two to eight
Guard Interval	Long (800 nanoseconds)	Short (400 nanoseconds)
Beamforming feedback		Respond to beamforming sounding
Space-time block coding (STBC)		Transmit and receive STBC
Low-density parity check (LDPC)		Transmit and receive LDPC
Multuser MIMO		UP to four spatial streams per client, using the same MCS

Certified Wireless Network Administrator: CWNA – PW0-106

38

## Chapter 19 Summary

- 802.11ac-2013 amendment
- 5 GHz only
- 20, 40, 80, and 160 MHz channels
- 256-QAM modulation
- Modulation and coding schemes
- Single-user MIMO

## Chapter 19 Summary

- 802.11ac data rates
- VHT MAC
- Beamforming
- Infrastructure requirements
- 802.11ac in a SOHO or home
- Wi-Fi Alliance certification