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IEEE 802.11ac: The New Gigabit Wi-Fi Standard

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ABSTRACT:- *With exponential growth of mobile subscribers , mobile data traffic has been projected to experience, with increasing demand for the bandwidth. To support the rate of growth there will be need for the device & standard capable of providing next generation mobile network that require high data rate to obtain video streaming, live gaming, voice over Wi-Fi ,database search, file transfer & other functions. For this the IEEE 802.11ac task group is working on the amendment that has goal of reaching maximum network throughput of atleast 1 Gbps on bands below 6GHz & continuing to support the legacy of 5GHz 802.11 devices. This paper introduces IEEE 802.11ac a very high throughput (VHT) wireless LAN standard & providing an overview of important features proposed in 802.11ac amendments. It also emphasis the importance in enterprise networking, including Multi user MIMO (MU-MIMO),channelization mechanism , technical details & its applications.*

KEYWORDS: **-** *Gigabit , IEEE 802.11ac , Wi-Fi , Wireless LAN , Wireless Communication.*

I. INTRODUCTION

IEEE 802.11ac is a new wireless networking standard in 802.11 family also known as Gigabit Wireless LAN, which is the latest Wi-Fi standard. This is build upon the 802.11n by improving data rate, reliability, robustness & RF bandwidth utilization. The IEEE 802.11ac has been proposed to enhance the throughput of IEEE 802.11n standard beyond Gigabit per second & Client capability which are increasingly demanded by Mobile Users. IEEE 802.11ac is the fifth generation in Wi-Fi networking standards and will bring fast, high quality video streaming and nearly instantaneous data syncing and backup to the notebooks, tablets, and mobile phones that have become our everyday companion The purpose of the 802.11ac amendment is to improve the Wi-Fi user experience by providing significantly higher throughput for existing application areas, and to enable new market segments for operation below 6 GHz including distribution of multiple data streams. With data rate over 1 Gbps and several new features, throughput and application-specific performance of 802.11ac promise to be comparable to that of existing wired networks. It is also known as Very High Throughput (VHT), 802.11ac achieves this purpose by building on the existing 802.11n technology. It also continues the long-existing trend towards higher data rates, to meet the growing application demand for Wi-Fi network capacity[2]. In 802.11ac several modifications have been proposed in order to reach gigabit throughput rate. In this paper we explore several features and enhancement that differentiate 802.11ac from previous standards in section I & II . Section III & IV discuss about channelization & Multi user MIMO mechanism & Application. Table 1 summarize the technology parameters of 802.11n and 802.11ac.

II. KEY FEATURES IEEE 802.11AC.

IEEE 802.11ac adopts several features and unique mechanisms to increase throughput, improve the user experience, and more. The key features of this new technology are:

1.1. Frequency Band of 5GHz.

As 802.11n, which operates in both the 2.4 GHz and 5 GHz RF bands, 802.11ac devices will operate only in the 5 GHz RF band. The choice to restrict usage in this band is mainly driven by the wider channel bandwidth requirements for 802.11ac. As the bandwidth increases, channel layout becomes a challenge, especially in the crowded and fragmented 2.4 GHz band. Even in the relatively expansive 5 GHz band, manufacturers will need to adapt automatic radio tuning capabilities to use the available resources wisely and conserve spectrum.

1.2. Modulation

IEEE 802.11ac uses Orthogonal Frequency-Division Multiplexing (OFDM) to modulate bits for transmission. While the modulation method is the same as that used in 802.11n, 802.11ac optionally allows the use of 256 QAM. This increases the number of bits per sub-carrier from 6 to 8, resulting in up to a 33% increase in PHY data rate.

1.3. Wider Channel Bandwidth

Compared to the legacy standard, IEEE 802.11ac operates exclusively in the 5-GHz band, which avoids interferences from many legacy devices as well as household appliances that operate at 2.4 GHz. In addition, there are more non overlapping channels at 5 GHz, which can be bonded together to obtain wider channels. IEEE 802.11ac adds 80- and 160-MHz (optional) channels into its specification, where the 80-MHz channel is formed by combining two adjacent 40-MHz channels, and the 160-MHz channel is built up by combining two adjacent or non-adjacent 80-MHz channels

1.4. System Performance

802.11ac will achieve a maximum single station throughput and multi-station aggregate throughput of more than 500 Mbps and 1 Gbps respectively. This is measured at the MAC data service access point (SAP), with no more than 80 MHz of channel bandwidth in the 5 GHz band. As the data rate requirement is at MAC rather than PHY, it implies that MAC efficiency must be addressed, not just an improvement to the PHY data rate.

1.5. Multiple Spatial Streams

802.11ac includes support for up to eight spatial streams, versus four in 802.11n. As in 802.11n, spatial multiplexing of multiple streams of data over the same frequencies takes advantage of the extra degrees of freedom provided by the independent spatial paths to effectively multiply channel capacity. The streams become combined as they pass across the channel, and the task at the receiver is to separate and decode them. Despite the complexity of this technique, manufacturers of 802.11n devices have learned to use the independent paths between multiple antennas to great effect, and can now effectively transpose this knowledge to the making of 802.11ac devices. It is likely that the first 802.11ac silicon will use multiple spatial streams.

1.6. Higher modulation and coding scheme

The 64-quadrature amplitude modulation (QAM) with 5/6 coding rate is the highest modulation and coding scheme (MCS) employed in IEEE 802.11n, which is extended to 256-QAMin IEEE 802.11ac.With 256-QAM, each symbol can carry eight information bits, increasing the number of transmitted bits per hertz. However, 256-QAM requires a higher signal-to-noise ratio at the receiving end in order to keep a low-bit error probability compared with other modulation schemes included in IEEE 802.11ac.

1.7. Coexistence

802.11ac amendment shall provide mechanisms that ensure coexistence between 802.11ac and 802.11a/n devices. It should be noted that 802.11ac is only required to be backward compatible and co-exist with 802.11a and 802.11n. This is due to the fact that 802.11ac devices only operate in the 5 GHz band.

1.8. Backwards Compatibility

802.11ac provides backwards compatibility with 802.11a and 802.11n devices operating in the 5 GHz band. This means that 802.11ac interworks with devices supporting 802.11a and 802.11n technologies & 802.11ac frame structures can accommodate transmission with 802.11a and 802.11n devices The backward compatibility of 802.11ac is a definite advantage of 802.11ac over alternative evolutionary technologies (such a 802.11ad) that also promise to increase data rate over 802.11n, but do not operate with existing WLAN devices.[6] Backward compatibility will ease adoption into the marketplace and ensure 802.11ac devices can seamlessly “plug into” existing WLAN networks.

1.9. Beamforming

Transmitter beamforming can be used to help increase throughput by improving the quality of the signal sent to wireless clients When this option is enabled, APs use beamforming techniques to optimize the signal strength for each individual wireless client station. Beamforming works by changing the characteristics of the transmitter to create a focused beam that can be more optimally received by a wireless station. With previous standards, such as 802.11n, APs can only transmit and receive Omni directional signals, which are susceptible to interference. IEEE 3802.11ac will support improved beamforming, which provide directional signal reception and transmission.

Table 1. Comparison of technology parameter of IEEE 802.11n and IEEE 802.11ac.

Technology Comparison		
Parameter	**IEEE 802.11n**	**IEEE 802.11ac**
Frequency Band	2.4GHz and 5GHz	5GHz only
Channel Width	20, 40MHz	20, 40, 80MHz or 160MHz optional
Multi-User MIMO	No	Yes
Spatial Streams	up to four	Maximum up to Eight
Modulation	64-QAM	256-QAM
Single Stream(1*1) Maximum Client Data Rate	150 Mbps	450Mbps
Three Stream(3*3) Maximum Client Data Rate	450Mbps	1.3Gbps

III. CHANNELIZATION

One of the most important enhancements to the 802.11ac amendment is the support for wider channels as well as both static and dynamic channel access. We dedicate this section to describe these 802.11ac features.

3.1. Channel Width Supported

The amendment mandates all devices to support 20, 40, and 80 MHz channels. In addition, it provides optional support for operation on 160 MHz channels. 80 and 160 MHz can be formed by a combination of two adjacent non-overlapping 40 and 80 MHz channels, respectively. The amendment also specifies that two non-adjacent 80 MHz channels can be used to form a 160 MHz one. More importantly, a device operating on non-contiguous 80+80 MHz should be capable of communicating with devices operating on contiguous 160 MHz if the former segments are placed in frequency to match the tone allocation of the latter case. In Figure 1 shows the channel allocation for the U.S. region.

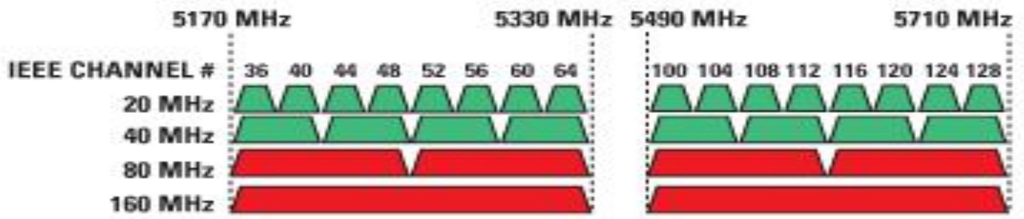

Figure 1 .Channel allocation in U.S. region.

3.2. Primary and Secondary Sub-Channels

Similar to 802.11n, channels consisting of 40 MHz or wider always require a primary 20 MHz wide sub-channel Additionally, 80 MHz channels have a primary 40 MHz which includes the primary 20 MHz sub-channel and a secondary 40 MHz sub-channel. The same applies to 160 MHz and 80+80 MHz channels, which consist of a primary 80 MHz and a secondary 80 MHz sub-channels. In Figure 2 we depict this relationship between the primary and secondary sub channels based on the different bandwidth options. In all cases, the primary sub-channel is used for carrier sensing in order to guarantee no other device is transmitting.[10]

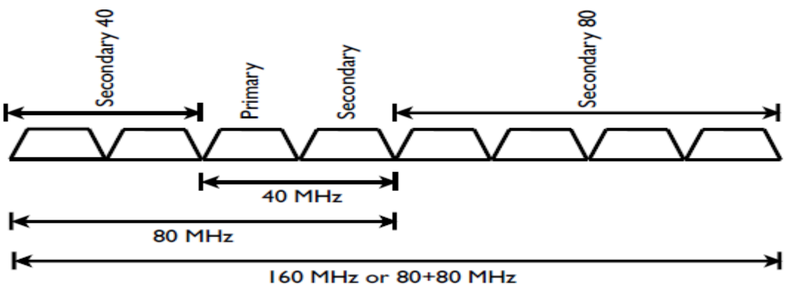

Figure 2. Primary and Secondary channel selection

The presence of the 20 MHz primary sub-channel is also necessary to guarantee coexistence and backward compatibility with legacy 802.11 devices. Only the primary sub-channel performs full Clear Channel Assessment (CCA), which involves packet detection starting with the preamble. In contrast, the secondary sub-channel is not required to perform full CCA. The CCA sensitivity of the primary sub-channel is -82 dB for a valid 802.11 20 MHz signal, -79 dB for a valid 802.11 40 MHz signal, -76 dB for a valid 80 MHz signal and -73 dB for a 160 MHz one. On the other hand, for the secondary sub-channel the sensitivity was improved from -62 dB to -72 dB for both 20 and 40 MHz channels, compared to 802.11n (and -69 dB for 80 MHz channels), an 802.11ac device should detect whether the primary sub-channel is busy within 4 µs with a probability greater than 90%. In contrast, on the secondary sub-channel the device has up to 25 µs to detect if it is busy with the same probability.

3.3. Static and Dynamic Channel Access

802.11ac extends the channel access policies proposed in 802.11n to the case of 80 and 160 MHz channels. In order for an 802.11ac station to be able to transmit an 80 MHz Physical Layer Convergence Procedure Protocol Data Unit (PPDU) two conditions must be true: (i) the primary channel follows EDCA (Enhanced Distributed Channel Access) rules so it needs to be idle for DIFS (Distributed Coordination Function Inter-Framing Spacing) plus the back off counter duration, and (ii) all three secondary sub-channels must have been idle for a duration of PIFS (Point Coordination Function Inter-Framing Spacing) immediately preceding the expiration of the back off counter. In the case that any of the secondary sub-channels is busy, the station can follow either static or dynamic channel access rules as dictated in 802.11n.[14] Static Channel Access – Consider an 802.11ac station trying to transmit on 80 MHz If the secondary sub channel is busy the station will choose a random back off period within the current contention window size to restart the contention process and attempt only until no interferer is present in any of the sub-channels. Notice that with a large number of legacy stations, the probability of accessing the medium with such a wide channel will be diminished. Dynamic Channel Access – The 802.11ac station may attempt to transmit over a narrower channel using 20 or 40 MHz instead. This will depend on each sub channel's CCA. This is clearly a more flexible approach that allows for more efficient resource allocation because the station can still transmit over a fraction of the original bandwidth. All transmissions always have to include the primary channel in order to inform the receiver of which channels the transmitter will use.

IV. MULTI-USER MIMO (MU-MIMO)

With MIMO based on spatial division multiplexing (SDM) in 802.11n, one device transmits multiple data streams to another device. In 802.11ac DL MU-MIMO, an access point (AP) simultaneously transmits data streams to multiple client devices. For example, consider an AP with 6 antennas, a handheld client device with one antenna (STA1), a laptop client device with two antennas (STA2), and a TV set top box client device with two antennas (STA3). An AP can simultaneously transmit one data stream to STA1, two data streams to STA2, and two data streams to STA3. This is illustrated in Figure 3.

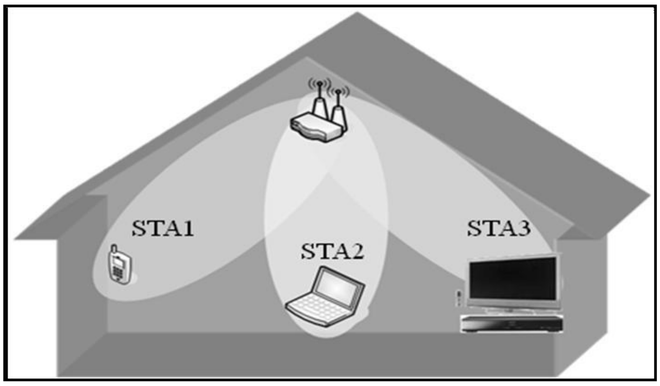

Figure 3. Example of Downlink Multi User MIMO Network.

The primary advantage of DL MU-MIMO is that client devices with limited capability (few or one antenna) do not degrade the network capacity by occupying too much time on air due to their lower data rates. With DL MU-MIMO, network capacity is based on the aggregate of the clients of the simultaneous transmission. However, this benefit comes with increased cost and complexity [2]. From a PHY perspective, the AP should have more antennas than total number of spatial streams for diversity gain. In addition, the AP requires channel state information from each of the clients participating in the DL MU-MIMO transmission in order to form the antenna weights. With DL MU-MIMO, the antenna weights are much more sensitive to changes in the channel.

In the case of transmit beamforming, if the antenna weights are stale, the system performance degrades to the case without transmit beamforming. However with DL MU-MIMO, if the antenna weights do not accurately match the channel, the streams to one client introduce interference to the other clients, leading to negative signal-to-interference-plus-noise ratio. Therefore channel state information must be higher resolution and more frequently updated. To constrain the dimensions of the system to a manageable size, 802.11ac defines that the maximum number of users in a transmission is four, the maximum number of spatial streams per user is four and the maximum total number of spatial streams is eight.

V. APPLICATION

The single-link and multi-station enhancements supported by 802.11ac can improve the performance and user experience in well-known WLAN applications, and enable several new ones, particularly in the following markets:

5.1. Mobile Application

The increased data rate and higher energy efficiency of 802.11ac are ideal for applications in mobile entertainment devices such as music players, handheld gaming devices, and wireless-enabled cameras and camcorders. Without adding too much to the limited power consumption availability of these devices, 802.11ac can enable, for example, the rapid synchronization and backup of large data files between these devices and a personal computer (PC) or tablet. Due to constraints in term of both power consumption and physical space, it is likely that first generations of these devices will use only SISO or 2x2 MIMO 802.11ac chipsets.

5.2. Portable Computing

Portable computing devices such as PCs, laptops, slates and tablets, are obvious ideal candidates for 802.11ac. The growing number of wireless applications supported by these devices, and the increasing demand for faster connectivity by their users, will be the key drivers for adoption of 802.11ac. Portable computing devices will use 802.11ac, as mentioned, for rapid synchronization and backup of large data files with other 802.11ac-enabled devices, or for the streaming of HD video and other content.

5.3. Home Entertainment

802.11ac can be used in TVs, Set-Top Boxes, and Networked Game Consoles to enable in-home distribution of HDTV and other content, including simultaneous streaming of HD video to multiple clients throughout the home.

5.4. The Enterprise

Wi-Fi is becoming as important at work as it is in the home. Some offices already have nearly as many Wi-Fi access points as printers or copiers. With IEEE 802.11ac, coverage can be accomplished with fewer devices, even while transmission rates increase. Among those benefiting from this more efficient Wi-Fi networking technology will be the many office workers using mobile devices, either their own or ones that have been supplied by the IT department. These devices have caused a spike in enterprise demand for Wi-Fi, an increase that IEEE 802.11ac can easily accommodate. The new IEEE 802.11ac standard will also be useful for companies experimenting with new seating arrangements, such as “virtual teams,” in which workers don't use the same desk every day but assemble themselves into ad hoc groups that are determined by the job that needs doing. Traditional wired Ethernet networks don't always give enterprises the flexibility they need to support these constantly-evolving workplace layout.[9]

VI. CONCLUSION

In this paper we represent a detailed description of important enhancement proposed in 802.11ac amendment. The IEEE 802.11ac represent the fifth generation of IEEE 802.11 WLAN Standard and is expected to deliver a data rate connection three times that of 802.11n and also identify the changes to channelization technique and multi user MIMO capabilities for reaching gigabit wireless transmission. Many of algorithm of 802.11n are being reused but enhanced with 802.11a ,which makes technology easy to work with existing networks. 802.11ac will be backward compatible with 802.11n networks operating in the range of 5GHz and offers improvements in Wi-Fi reliability, throughput and range.

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