

# A Survey of Next Generation Gigabit WLAN Standard: IEEE 802.11ac.

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## ABSTRACT

With rigorous increases in multimedia stations and applications, wireless infrastructure IEEE 802.11 WLAN standards are widely used. Delivery of excessive concentrated traffic over bequest WLAN standards pretends the functioning by being not simpatico with the resources. Directing to the eminent network throughput, an IEEE WLAN standard has been evolved apprehended as IEEE 802.11ac with ideal data rate up to 1 Gbps. This standard has a capability of using 160 MHz bandwidth, so to utilize it as a whole is always a challenging task due to numerous other standards overlapping the allocated bandwidth. In this survey, we present a brief survey of the IEEE 802.11ac standard with its ancestor IEEE 802.11n standard. Particularly we concentrate on the MAC layer enhancements and the recent invention of the standards. Lastly, we conclude the various authors' innovatory thoughts with their advancements and restriction for acquiring the IEEE 802.11ac standard in ameliorating manner.

## 1. INTRODUCTION

Wireless local area communicating has an enormous maturation in the last few years with the rigorous amendments in IEEE 802.11 standards for meliorate wireless technology. The first coeval of high throughput wireless LAN networks is recognized as IEEE 802.11n standard which was developed and introduced in 2009 achieve 130 Mbps. To improve the standards and enhance the network throughput, new rectifications for IEEE 802.11standards are under developments known as IEEE 802.11ac. It aims to reach 1Gbps with affirming multi-user access proficiencies with the hypothesis of transmitting in the 80GHZ or 160GHZ band which renders the chance for much wider band channel capacity. IEEE 802.11ac operates over 5GHz band, here more non-overlapping channels are usable for design tractability than have been uncommitted in the 2.4GHz range used by IEEE 802.11b and its advancements IEEE 802.11g and IEEE 802.11n which can run in any of two bands. IEEE 802.11ac acting as a "fifth generation" WLAN standards works either on 80 MHz and 160 MHz wide channel spectrum. for this, it uses channel bonding technique where 20 MHz channels combine together to obtain wide bandwidth in the available spectrum. The concept of channel bonding in WLAN was firstly introduced in IEEE 802.11n standards. It allowed two consecutive 20 MHz channels to get aggregates or obtaining 40MHz channel width. Its Successor 802.11ac advances this technology to maximize 160 MHz. Below sections are divided as follows, in section 2 the common technologies of 802.11n and 802.11ac has been discussed. In section 3, focus on 802.11ac amendments is done. In section 4, we emphasize on the MAC enhancements of the 802.11ac. In section 5, we give a brief of the researches done on MAC access mechanism for getting high throughput and supporting best effort QoS.

## 2. KEY TECHNOLOGIES OF IEEE 802.11N AND ITS ENHANCED IEEE 802.11AC STANDARD

IEEE 802.11ac standard is an amendment of an IEEE 802.11n, and it adopts the following technologies from 802.11n.

### 1) Channel bonding:

In this technology, two consecutive channels width resides within a given spectrum gets aggregates to increase the channel range which in turn increases the network throughput of wireless networks.

### Multiple Input, Multiple Output (MIMO):

In this technology, it uses multiple pairs of transmitters and receivers for more network communication at the simultaneous time. MIMO technology has an advantage of multipath causes due to the concept of instinctive radio- wave phenomenology. Due to use of multipath, transmitted signal bounce off the walls, ceilings and many more other obstacles, which leads this signal to reach antenna by multiple times through unlike angles with variation in time slots. It leads to enhance network throughput.

### Beamforming:

Through this process, the wireless transmitter will preferentially direct its signal strength towards the destinations, which in turn increase the SNR ration and decrease the communication latency.

### Air time acceptable:

It forbids the network functioning from "dropping off" to the transmission bandwidth of the legacy device present on the network. For example, Whenever a IEEE 802.11a station conjoining a 5GHz spectrum, the 802.11ac device more farseeing degrades an 802.11ac device functioning in the spectrum of 5GHz bandwidth, a 5GHz-band 802.11n station will be anticipated to demean its performance due to above causes.

## 3. IEEE 802.11ac AMENDMENTS

**1) Wider Channels**

An IEEE 802.11ac standard supports two new channel bandwidth i.e. 80 MHz and 160MHz bandwidth. Similar to 802.11n, broader channel leads to more network speed and throughputs. Due to less existence of single 160 MHz wider bandwidth, ac works on two casts of 160 MHz channel i.e. a whole one 160 MHz bandwidth spectrum or combination of two consecutive 80 MHz channel block and provides the same network functionality. IEEE 802.11ac standards follow bare approach to group consecutive 20 MHz channel to reform 40 MHz, similarly consecutive 40 MHz channel to reform 80 MHz bandwidth and consecutive 80 MHz channel to reform 160 MHz as evidenced in figure 1:

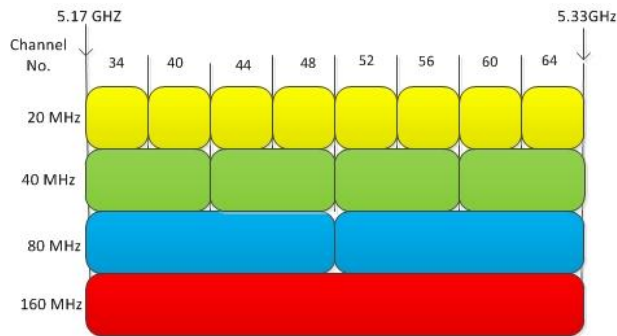


Fig. 1. IEEE 802.11ac bandwidth allotments for 20, 40, 80 and 160 MHz

**2) Primary and Secondary Channels**

Due to the presence of merely five usable 80 MHz bandwidth, it creates problem to 80 MHz bandwidth supported system to avert interference from other station residing on any one of 20MHz or 40 MHz channel bandwidth. Imbrications broadcasting stations facing more troubles for 80 MHz channel bandwidth systems. Due to this problem, the nearby station has to apportion the same channel with neighbour stations. It leads to access to the medium using time-sharing principle. The main disadvantage of 80 MHz spectrum is that before its station transmits all the residing 20 MHz channel must be clear; otherwise, it will not allow the station to transmit. Thus any legacy device using 20 MHz or 40 MHz will block the 802.11ac station from transmitting which in turn increases the network latency, and it may have to wait enormous time to get the access of wireless medium. The above problem faced by the interlacing of different variants of channel bandwidth is shown in figure 2:

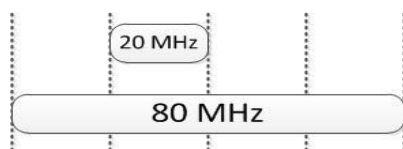


Fig. 2. Two Interference Scenarios

In a given network, if 802.11n stations are in access which leads to less availability of 80 MHz wider channel bandwidth. In this scenario two 802.11ac station works on the same 80 MHz bandwidth. For this one station selects its one primary bandwidth (20MHz) from a lower portion of 40 MHz in the spectrum of 80 MHz and another selects its one primary bandwidth (20MHz) from an upper portion of 40 MHz in the spectrum of 80 MHz. It leads to the 802.11n station to work on

20MHz or 40 MHz as per the availability at the same time another station can also communicate over 20 MHz or 40 MHz simultaneous. Thus 802.11ac has the foreside view of the client to see the whole 80 MHz as a whole or in different 20MHz slots. This concept is shown in figure 3:

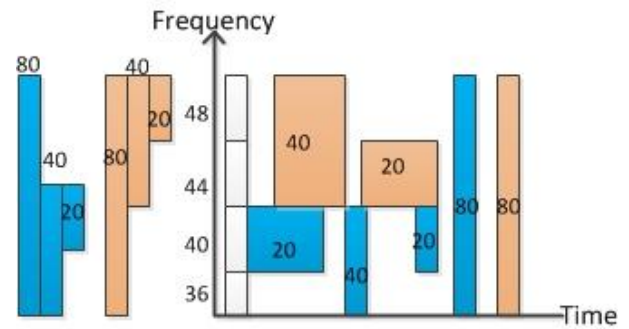


Fig. 3. Simultaneous transmissions of 2 stations over 80 MHz with having individual principal 20MHz subchannels

**3) 256-QAM**

IEEE 802.11ac communicates a serial of symbol, which constitutes a unique bit pattern. For legacy standards, WLAN transmits six bits in a symbol sequence. By implementing to a greater extent complex modulation scheme which resides more data bit streams, it's got possible to send 8 bit per symbol which leads to thirty percentage gain. 256 QAM extents can be used for practical applications.

**4) More spatial streams and multi-user MIMO (MU-MIMO)**

In legacy standard IEEE 802.11n, they can transmit multiple spatial streams at erstwhile aimed to a single direction. In this concept, only a single station receives the data at a particular time which are individually destined frame. This is also known as single user Multiple Input Multiple outputs. In IEEE 802.11ac multi-user multiple input – multiple output has been introduced. Here an Access Point is capable of transmits multiple frames to the different station with a different address on the same time over the same spectrum bandwidth.

**4. MAC LAYER ENHANCEMENTS**

**1) RTS/CTS operation for wider bandwidth**

IEEE 802.11ac standards works on either 80 or 160 MHz is still adequate to allow IEEE 802.11a and IEEE 802.11n station to join the network. The beacon frames are transmitting on a primary channel (20 MHz) which resides in the 80MHz bandwidth. The Access Point and all station transmit and receive on the primary channel that overlaps and draws out virtual carrier sense from the frames that they received. Nevertheless, the Access Point could be nigh former uncoordinated Access Point. Those Access Points can be legacy either of IEEE 802.11a or IEEE 802.11n standards, and their associated primary channel will be one of 20 MHz spectrum among the 80 MHz spectrum of that 802.11ac Access Point. Due to these different access points and their belonging stations has a separate virtual carrier sense; therefore they can transmit at dislike times on others subchannels. As the IEEE 802.11ac has a wide channel, it leads to a more similar situation with the IEEE802.11n. To overcome this, IEEE802.11ac has an enhanced Ready to send / Clear to send mechanism. It is used to determine whether a

channel bandwidth is free and if not then how much is free (20MHz/40MHz/80MHz). This is shown in figure 4:

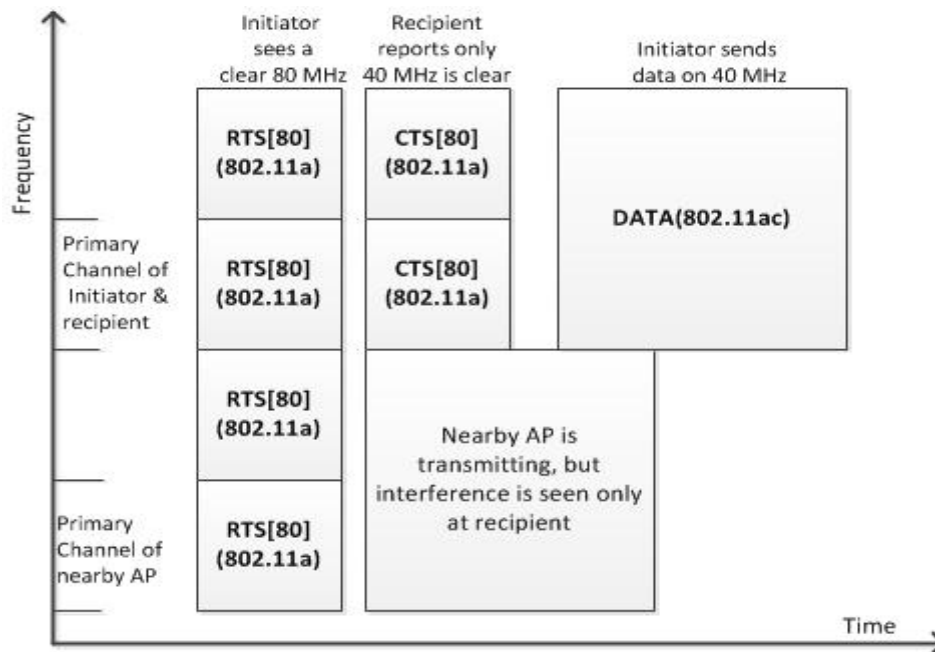


Fig. 4. RTS/CTS Enhanced with Bandwidth signalling with no interference

Whenever IEEE 802.11ac station air the RTS frame, first of all, this station has to check out that the 80 MHz channel is free along with the surrounding stations, then RTS frame is sent as a PLCP Protocol Data Unit (IEEE 802.11a) format, and at final stage like 802.11a communication format (20MHz primary channel) is spread over three times to fulfill the whole 802.11ac spectrum (80MHz/160MHz). Then all the surrounding stations whether they are of IEEE 802.11a, IEEE 802.11n or IEEE 802.11ac station, received the RTS frame on their primary channel. Then their virtual carrier sense and they set or unset the busy status. This is shown in figure 4. For full-bodied protocol contriving, the counter bandwidth of ready to send is accounted within the IEEE802.11a PLCP Protocol Data Unit. For this, IEEE802.11ac will have to some design mechanism to maintain legacy standard compatibility. For this scrambling,

the sequence is used to encode bandwidth denotation. The association and group flag in transmitter address in ready to send frame is encoded for an individual to the whole group. If the device transmits the ready to send a response with clear to send, then receiver station checks out that is anyone is transmitting in the surrounding. Whether it may be on stations primary spectrum or any overlapped 20 MHz channel over its whole 80 MHz/160MHz bandwidth. If any surrounding station uses the constituent of the channel, then the receiver will be responsive on the free and usable 20 MHz subchannel and also describes free subchannel in the clear to send PLCP Protocol Data Unit. Here 20MHz, 40 MHz, 80 MHz is considered as usable subchannel where transmitting device can transmit RTS, CTS and data. This is shown in figure 5.

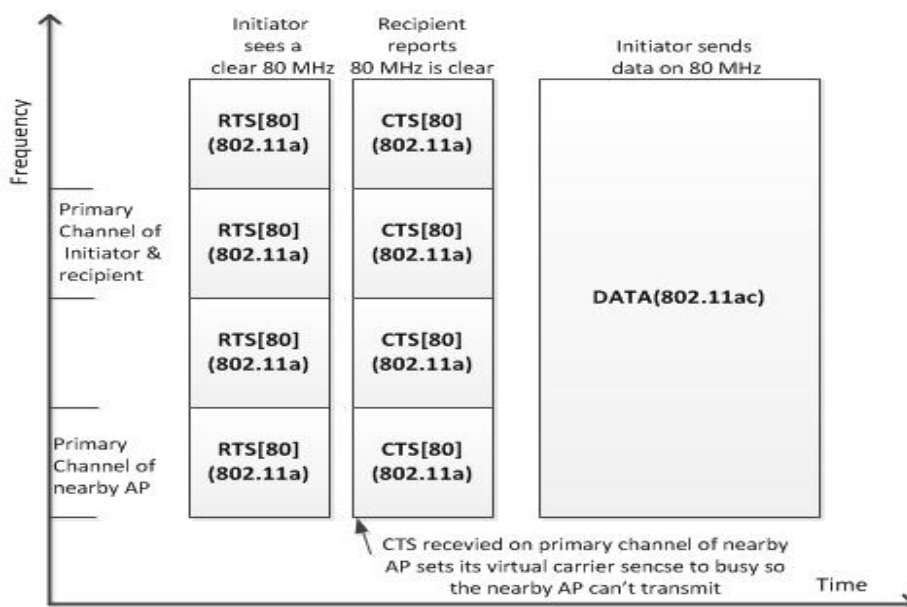


Fig. 5. RTS/CTS Enhanced with Bandwidth signalling with interference

**5) TXOP sharing**

A new technique known as Transmission Opportunity (TXOP) has been introduced as an enhanced feature in MAC layer of IEEE 802.11ac to defend n number of downlink communicating streams to n number of receiving station consecutively. In the legacy Enhanced Distributed Channel Access mechanism, during a station which holds the time slot transmits the frame belongs to a particular access category. Due to this even station holds time slot frames of different access category of that same station cannot be transmitted at the same time. The central concept behind the TXOP is to promote the station or access point to transmit simultaneously to multiple client stations. TXOP also enables the station to use their EDCA parameters to get in compete for the transmission slot. Whenever a station gets time slots (i.e. TXOP), it will decide its primary access category and secondary access category among the available 4 ACs for the simultaneous broadcasting the data. Due to this access point divides the ACs into two types of destination, one for primary destination and another for the secondary destination, which depends on the access category selected. In the TXOP scheme, a station has only one primary access category and can have multiple access category. This is shown in figure 6.

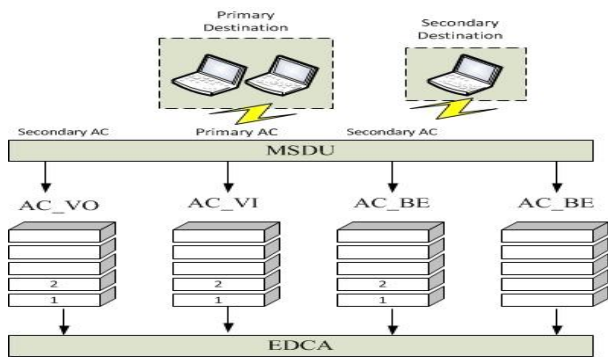


Fig. 6. Multi-User EDCA

In the above assumption and concept, the primary access category polls and decides to select secondary access category which can partake in TXOP. The primary channel will also decide the primary destination and secondary destination for the targeted transmission. But the TXOP duration (slot) is determined by TXOP EDCA parameters of primary access category. This time slot gets finished when the primary access category passes its time slot or ends it even some frames of secondary access category has been remaining. As shown in figure 6: Access Category of the video is treated as a primary access category which wants to transmit 2 MSDS frames for station-1 and station-2; therefore station-1 and station-2 is considered as a prime destination. Access category-Voice and Access category-Best effort are considered as a secondary destination. MSDU frame will be aggregated in A\_MPDU and transmit as A-MPDU. The downlink transmission of multiple frames sharing a TXOP is illustrated in Figure 7.

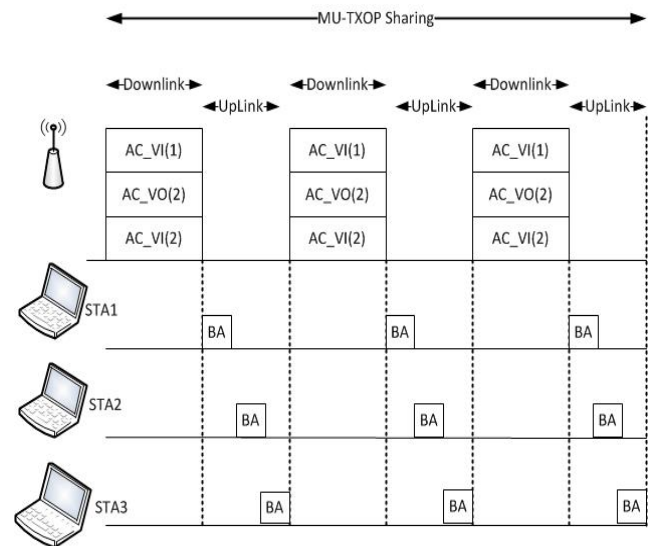


Fig. 7. DL MU-TXOP sharing mechanism

**6) Enhanced aggregation**

A new aggregation scheme is introduced in IEEE802.11ac where subframes get aggregated and transmitted in one packet to improve medium access control layer efficiency by reducing the header payload. This standard follows two eccentric aggregation one is A-MSDU, and another is A-MPDU. 802.11ac can combine both of the above aggregation (A-MSDU + A-MPDU). The header and data frames of this aggregation scheme is shown in figure 8:

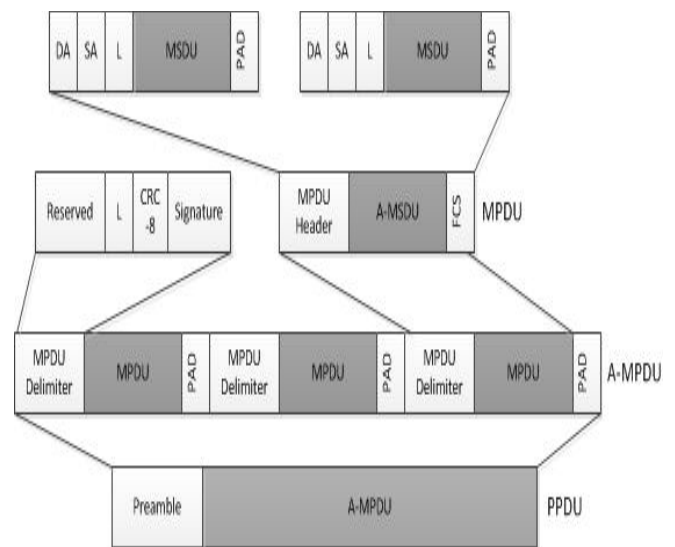


Fig. 8. Two-level aggregation Concept

MAC header overhead in legacy standards can be reduced by sending larger packets. The aggregation mechanism cuts down the time for overhead transmission and the holding back time due to random backoff period during the time slot of successive frame transmissions. The main concept of A-MSDU is to multiple aggregate MSDU in one unit belonging to the same destination. The packets received at upper MAC layer from logical link layer firstly gets buffered and then aggregated to form a single frame known as A-MSDU. MSDU data, MSDU subframe header and padding field, are comprised to create a single MSDU frame belonging to an A-MSDU. Subframe header is comprised of the destination

address, source address, and frame length, all together they represent MSDU data payload. A-MSDU aggregation scheme is acceptable only for the frames destined from the same source to the same destination.

After addition of Physical, MAC header and CS field to MSDU frame, it is ready to transmit. The main concept behind A-MPDU is to reduce the physical overhead by aggregating n number of MPDU subframes with a common PHY header field. For every MPDU frame, it consists of MPDU delimiter and the padding field. Such MPDUs are aggregated to form a single larger frame known as A-MPDU. Here in A-MPDU, all subframe must be destined to the same destination, but their originality of source may be the same or different. A-MPDU is aggregated or come in existence at the lower part of the MAC layer. Before the aggregated frame is passed to the physical layer for transmission, an MPDU delimiter is concatenated to every MPDU frame for identification of individual MPDU frame at receiving end. The above delimiter's length is of 32 bits. The integration of MPDU delimiter is MDU length field (12 bit), CRC field (8 bit), signature field (8 bit) and reserved field (4 bit). In which CRC is consisted of four reserved bits and used for validation of the frame headers. Due to the uneven length of MPDU frame, 0 to 3 bytes are used to round up the frame length to fixed 32-bit frame size. The below table 1 gives the length of frames in both 802.11n and 802.11ac.

TABLE I  
802.11AC AGGREGATION FRAME SIZES [3]

	802.11n	802.11ac
A-MSDU length (bytes)	7935	11426
A-MPDU length (bytes)	65535	1048579

**7) Block Acknowledgment**

As Downlink Multi User-MIMO packets are broadcasts at the same time destined for different stations, a robust acknowledgement scheme is required to support acknowledgement receipts from different station simultaneously. The new acknowledgement scheme must support by the legacy standard as the network environment is full of different rules working altogether.

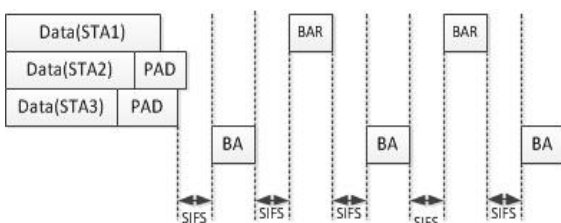


Fig. 9. DL MU MIMO Response Mechanism

As exemplified in figure 9, after an access point transmits a Down Link Multi-user – MIMO data, it applies block acknowledgement request (BAR) for the first station which is numbered 1. It is done so that first station replies forthwith to the DL MU-MIMO with a Block Acknowledgement (BA). Next Block Acknowledgement Request is used by an access point to poll out next second station. This will continuously be done till all the station gets polled in the transmission slot. This is done so that every station realizes that they are the part of multi-user transmission. This is done with a unique group ID in VHT-SIG-A.

**5. AN OVERVIEW OF 802.11AC RESEARCHES**

In this section, we have carried out a brief survey and review the various amendments done to IEEE 802.11ac standards by various researches for providing better network performance and QoS. In paper [6] authors depict the problem due to DL MU MIMO in WLAN. Authors suggest a CSMA/CA MAC protocol with three response mechanisms. This three response mechanism is used by an access point to accumulate acknowledgements from the station. The first response scheme is instanced in figure 10. In this polled response scheme, an access point transmits a block acknowledgement request (BAR) frame to each destination station, in turn, to request urgently block acknowledgements (BAs).

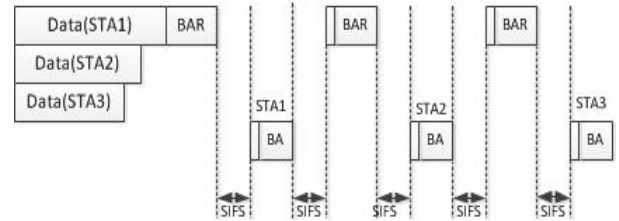


Fig. 10. CSMA/CA-based DL MU MIMO protocol with polled response

In paper [7], the authors discussed channel bounding in WLAN in brief. Authors suggest a MAC protection scheme to defeat the hidden node problem on secondary channels. As demonstrated in the figure. 11, an Access Points transmit duplicate RTS on every secondary channel which sensed as a free channel.

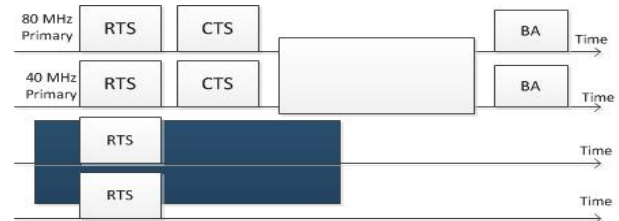


Fig. 11. MAC Protection for Dynamic BW operation

They show that the RTS/CTS frame is decoded only on primary channels, but they are duplicated over all available channels so that they can set NAV on all available channels. A problem is identified here that: Suppose there are two stations A and B. A wants to communicate with B, A sends RTS frame to B, but due to some other transmissions, B senses its 1st and 2nd 20 MHz channel busy, so it sends CTS on 3rd and 4th 20 MHz secondary channel. Therefore instead of waiting for the primary channel to become idle A can consider its 3rd or 4th as a primary channel and starts transmission.

Authors of [8] prove that Hybrid A-MSDU/A-MPDU aggregation has the best performance for both IEEE 802.11n and IEEE 802.11ac standards. They also comment that A-MSDU is more prone to channel error as it is transmitted within a single MPDU which implies that the entire A-MSDU has to be retransmitted if any bits within the A-MSDU are received false. Therefore the maximum size of A-MSDU is less than A-MPDU. Through numerical analysis, they demonstrate: A-MPDU is more robust to channel errors as compared to A-MSDU as each MPDU within an A-MPDU has own delimiter and FCS. So only a single MPDU has to retransmit in case of any transmission failure. They conclude that Hybrid A-MSDU/A-MPDU aggregation can be used to reduce MAC overhead by

MSDU aggregation and it is useful where consecutive small MSDU is required to transmit.

In [10] authors explained for dynamic bandwidth channel access in IEEE802.11ac, How IEEE 802.11a and IEEE 802.11n overlaps on IEEE 802.11ac networks, how to select the primary channel and Secondary channel CCA sensitivity. Selection of Primary channel should be made such that its secondary channels must support legacy stations. Improvements of secondary channel CCA (Clear channel assessment) sensitivity must be made. If IEEE 802.11ac secondary channel use CCA sensitivity of 802.11n, i.e. primary channel CCA threshold value is -82dBm and secondary channel CCA threshold value is -62dBm, then it can't support its legacy station which degrades their overall network performances.

Authors [11] conclude that the current Distributed Coordination Functions can't fully preserve the throughput performance of 802.11ac in a hidden node problem. So there is a need for enhancing the RTS/CTS scheme that can support multi-channel feature in OBSS hidden node problem.

In paper [12] author suggests the following design approach: Modify carrier sensing mechanism on a single channel, where an interfere yields to CTS transmission based on (i) RTS & CTS senders (ii) CTS sender and interfere. To alter the above design, they augment the CTS & modify the virtual and physical carrier sense mechanism. Semi-Synchronous scheme: split (in time) control & data phase has been introduced. During the control phase, CSMA-CA is used for RTS & CTS transmission along with SINR feedback to determine a transmission scheme. The control phase comprises of RTS, CTS, Pilot and CQI. The advantage of author schemes is that the links can be prioritized based on queue lengths and packet delays and interference estimation and rate adaption can be optimized if they are done after the exchange of all RTS and CTS packets in control phase.

Authors of [13] highlight the significant MAC enhancements for IEEE 802.11ac is TXOP sharing, which is applied to execute multiple downlink traffic streams to multiple receivers STAs simultaneously. The main problem is identified by them is that the MU-TXOP period is finished when Primary AC ends its transmission, even though secondary ACs has

more frames to transmit, which degrades the overall network and individual performances.

In paper [14], authors have discussed the basic working back off the process for 802.11ac standards. They also identified that all enhancements are done for backoff procedure of Primary AC in TXOP; therefore scheme can be made for secondary AC back off process, which may increase WLAN throughput.

In [15], authors performs a simulation-based analysis of IEEE 802.11ac & IEEE 802.11ax technologies, in which the BER performance degradation caused by CFO offset was found after a basic performance comparison done through simulation. The outcome of simulation shows that the level of BER is depending on the sub-carrier spacing and the used inner-modulation. The author also defines the IEEE 802.11ax as one of the upcoming technologies which primarily will be developed for the Industrial, Security & Medical (ISM) Band.

In [16] authors did comparison between the maximum throughputs of IEEE 802.11ax and IEEE 802.11ac in a single user operation mode and in UDP like traffic. The AP transmits continuously to a station using two-level aggregation In SU mode. Concerning IEEE 802.11ax two flavors are considered, using acknowledgment windows of 256 and 64 MPDUs respectively where IEEE 802.11ax outperforms IEEE 802.11ac by 29% and 48% in reliable and unreliable channels respectively. The authors depicts larger improvement in an unreliable channel is due to the larger number of MPDUs that IEEE 802.11ax enables.

## 6. CONCLUSION

We have provided a brief survey of IEEE 802.11ac WLAN standard. We focused on the key technologies of the standard mainly on the new MAC enhancements. For easy understanding, we highlighted the basic overview of legacy standards. Their new keen improvements make this standard very efficient in massively loaded traffic scenario as well as time-varying network resources. From our survey, we reason out that there is a need for better aggregation scheme and to solve out hidden node problem over wide bandwidth range at the MAC layer. As the station and traffic applications are increasing over the wireless technologies, it will be the area of research to provide better network efficiency.

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