The Assessment of Channel Bonding and Aggregation on WLANs

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Abstract:
To improve throughput IEEE 802.11ac is one of the newest variants of WLANs that use modulation and coding schemes (MCS), channel bonding, and frame aggregation. Channel Bonding permits wireless appliances to work at 40 MHz channels with replicating their bandwidth from standard 20 MHz channels in a 5 GHz band. With the increase in channel width, data rate is improved but non-overlapping channels decreased. Frame integration allows concatenation and posting of multiple frames within a single channel. In this paper, we have analyzed the throughput in two scenarios, Channel bonding as well as aggregation with Channel Bonding. The simulation results confirm that the channel bonding performs superior to aggregation with Channel Bonding in terms of throughput.

Keywords: Channel Bonding, 802.11ac, Throughput, MCS

1. Introduction

In recent years IEEE 802.11 networks provide easy internet access to a variety of communiqué equipment like smartphones, cameras, and HDTV [1]. To meet the high demand for new applications the WLAN standard is amended as 802.11ac which is capable of providing high data rates of 600 Mbps in 2.4 GHz as well as 5 GHz band.

WLAN standard 802.11ac is defined for 5 GHz band and bears data levels equal to 7 Gbps while 802.11ad is distinct for 60 GHz band and can broadcast at 6.8 Gbps and having distinctive range of just 10 meters [2]. 802.11ac [3] uses new modulation and coding (MCS) schemes, channel Bonding, and frame aggregation to achieve highest level of data. 802.11ac continues to be further supported by modern devices [4]. Frame aggregation is used to improve MAC efficiency [5]

Effective throughput increases and transmission overhead is reduced by using the frame integration feature. This feature can be very useful when there is a large amount of data to be exported (for example large file downloads). In the A-MPDU aggregation, the MAC layer will have a large number of frames to be exported that can be calculated within the A-MPDU. Although one cannot benefit from frame aggregation in other real-time applications. Because in such applications a small amount of data is generated from time to time which can only be adjusted inside a solo framework and does not need an A-MPDU. So the MAC must send each individual continuously and access the channels from time to time. So in current networks, A-MPDU-enabled and disabled conditions make sense Channel bonding allows for the transmission of wide channels of 20 MHz formed by 2-8 channels. The 802.11ac channel is known as the very high channel and can carry 160 MHz transmissions.

In channel bonding transmission rate is improved but the amount of non-overlapping channels is decreased. Consequently, European 5 GHz band has 19 non-overlapping 20 MHz channels or only two 160 MHZ channels. Within areas where only a few networks are available, the spectrum is less commonly used and may be organized in the form of wider channels, and in densely populated areas the level of collision may increase due to the several networks sharing the same medium. Thus it is advisable to divide the available WLANs into a narrow channel in a dense area to avoid collisions.

The reason for using narrow channels in crowded areas is overhead where the frame assembly is not used. Overhead contains more due to Back off time, PPDU over, and Acknowledgment overhead. Between these overheads Back off overhead (Short interframe space and Slot time) and PPDU are temporary and independent of the channel width. Apart from this the acknowledgment is always transmitted to the 20 MHz channel and does not rely on the channel width. Therefore, the higher effect is more suitable for wide channels where the A-MPDU is disabled and it is helpful to employ more self-governing transmission in slim channels than a single broadcast on a broad channel.

In our work, we examine throughput in two cases as the function of distance which is using channel bonding and Aggregation with Channel Bonding. The replication outcome illustrates that the throughput in the channel bonding exceeds that in the case of Channel Bonding with aggregation. The remaining paper is ordered as goes after. The next segment deals with the study of channel bonding. After that, we introduce 802.11ac in segment 3. We provide segment 4 to describe the experimental setup, the proposed work in section 5, Performance evaluation in 6, and finally conclusion.

2. RELATED WORK

The authors in [6] systematically estimate throughput of 802.11ac networks using channel Bonding, frame aggregation (A-MPDU and A-MSDU), and spatial diversity. However, it does not provide results for spectrum usage and does not guarantee their methodical model. In [6,7] authors' exposure to diverse performance metrics can affect performance of channel Bonding on 802.11n networks, by differentiating 20 MHz and 40 MHz channels in different locations as well as circumstances. The authors demonstrate that the performance of a broad channel can appreciably influence when a channel is common to numerous networks and stations. The authors afterward made suggestions for binding decisions. Nevertheless, they test individual channels and do not check all spectrum usage. Also, the author's learning was restricted to 802.11n which couldn't include 802.11ac. In [8] the authors explained binding to a channel inside 802.11ac has much lower effectiveness with the tiny frame size. It’s due to fact that the new enhancement means lengthy overhead than 802.11ac. The broadcast time of such overhead not rely on channel width and greatly influences the efficiency of broad channel. On the way to tackle this issue, the authors put forward a novel scheme of parallel transmission for primary and secondary channels. The aforementioned scheme ameliorates the increased use of a specified broad channel and does not match up to the output of wide channel with that of most constricted channels. In, [9] authors examined network throughput in a variety of scenarios by making an allowance for overlapping and non-overlapping channels of random widths. The domino effect obtained from aforesaid work proved that the spectrum consists of non-overlapping channels giving very high throughput. On the other hand, this study is still looking at other scenarios with a smaller proportion of contending stations. Also, it does not give an obvious indication of whole spectrum usage during noteworthy cases. The authors of [10] present the investigational work, concentrating on 802.11ac usage as well as power expenditure of Smartphones with no interruptions; this study is about performance of channel bonding (up to 80 MHz) as practiced through four dissimilar smartphones models. One single study [11] gives some motivating outcomes together with a test of channel bonding, still just enfolds precise and restricted scenarios. The former two works confirm that increasing channel width reduces channel throughput. Though, the authors do not reflect the impact of wide channels on the spectrum as a whole. In [12], author looks at the 802.11ac WLAN running on an 80 MHz channel where each one of its secondary channels lives on 802.11ac legacy networks. The former study reveals that static selection of 80 MHz for entire transfers (i.e. transfers of 80 MHz frames while the complete 80 MHz channel is inactive whereas any 20 MHz channel is active) gives restricted throughput when legacy networks are loaded with reasonable traffic.

Additionally, author exhibits that choice of dynamic range (e.g. choosing 80, 40, or 20 MHz does not work in the transmission where access is available) exceeds the static selection considerably and gives good enough input in identical conditions. Although, there is no estimation of throughput for an aggregated spectrum. Various other studies [13 - 16] show the functionality of a few of the new 802.11ac features, including channel binding. However, their most ordinary drawback is the lack of a comprehensible analysis of the event of channel bonding taking place with a wide channel. Moreover, a few of those authors spotlight the throughput of a particular wide channel and attempt to get the most out of it in weird environments with a sufficient number of network deployments. Although good radio spectrum planning is required to make full use of attained throughput, we consider it essential to calculate the performance of the spectrum as a function of existing channels as well as widths.

The authors [17] studied the channel bonding utilized by 802.11ac to enhance data transfer rates and concluded that the management of many narrow channels remains a fine alternative in the crowded environment and heavily overloaded networks. Although the authors looked at the significant scenarios in this test and could not think about specific scenarios, like a heavily overloaded network in the company of supplementary networks with the restricted load.

In our work, we examine the throughput in two cases as the function of distance that is using channel bonding and aggregation with channel bonding. For conveying role of this paper simulation has been done, using Network Simulator 3 (NS3 (NS-3 Simulator, http://www.nsnam.org/) representing the throughput as a function of distance at different distances of 10, 20…40 meters with Five different MCS (high data rates) and in crowded surroundings.

3. PRELIMINARIES

1.1. Use this style for level two headings

3.1. PRESENTATION OF 802.11AC AMENDMENT

802.11ac permits networks for working on channels wider than 20 MHz widths. The broad channel is formed by combining 2, 4, or 8 dissimilar channels of 20 MHz, divided into primary and secondary channels. For range available, 20 MHz primary, 20 MHz seconds, 40 MHz primary, 40 MHz secondary, 80 MHz primary, and 80 MHz secondary channels are obtainable. The 40 MHz and 80 MHz main channels include 20 MHz primary and 20 MHz secondary, 40 MHz primary and 40 MHz secondary channels, correspondingly. Figure 1 exhibits this arrangement.

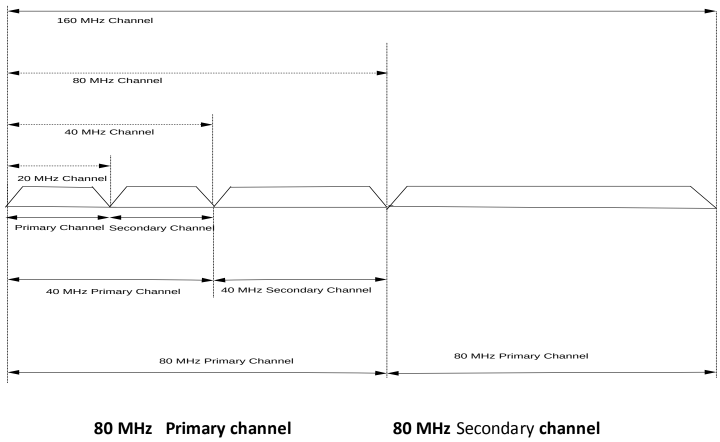

Figure1. Primary and secondary channels in 802.11ac [17]

We recall that broad channel must proficient to function at individual primary channels. As a result, the station operating at 40 MHz is striving to access its primary channel (eg the primary 20 MHz channel). The station defers its transmission when the primary channel is busy. Alternatively, we get it and it is possible to either 1) broadcast a 40 MHz frame if the secondary channel was not working for the duration of PIFS before the communication started, or 2) broadcast a 20 MHz frame if not

Figure 2 shows a situation somewhere the station is striving used for limited access to a 40 MHz channel. In the initial discovery of the primary channel (e.g. Backoff Time 1 - BT1), secondary channel was eventful for duration of preceding PIFS. Therefore, station begins transmitting at 20 MHz channel. After that station waits for a while and wins the primary channel. Since the secondary channel was not working on behalf of the duration of PIFS (Point interframe space) break before the end of BT2, station is starting to transmit at 40 MHz channel at this time.

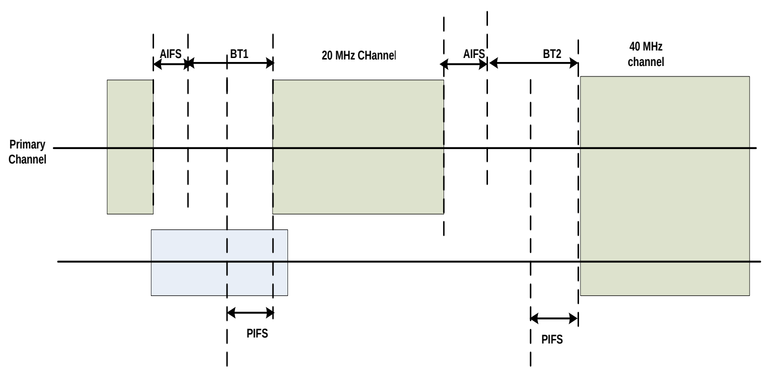

Figure2. Channel access and transmission in 40 MHz WLAN [17]

Usually, the station must work under one of the subsequent set of laws [3], relying on the size of the channel:

- Broadcast frame of 160 MHz if the secondary channel, secondary channel 40 MHz, and secondary channel 80 MHz are active during PIFS before attainment of primary channel;
- Broadcast a frame of 80 MHz if secondary channel and secondary 40 MHz channels are not working during PIFS before primary channel is detected;
- Broadcast a 40 MHz frame if secondary channel is not working in favour of duration of PIFS before primary channel was detected;
- Sends 20 MHz frame to primary channel as soon as received;
- Resumes channel entrée effort when the primary channel is full of activity

As per the standard [3]), 40, 80, or 160 MHz WLAN is supposed to employ the identical primary and secondary channels of additional presented networks where probable. Also, the 20 MHz WLAN not supposed to be work on the secondary channel of the presented network. These constraints headed towards the conclusion that the idyllic arrangement of a wide channel is: the identical primary as well as secondary channels for the entire WLANs. It means acquiring a primary channel escort towards acquiring all secondary channels. Consequently, during an idyllic deployment scenario, networks will either send at the largest width or reschedule their transmissions. In this work Authors just think about this perfect scenario (e.g. a 160 MHz network either dispatch 160 MHz frames or reschedules its broadcast and resumes the channel entrée effort.

The understandable effect of binding channels reduces amount of non-overlapping channels. 802.11ac is distinct in support of a 5 GHz band. The diverse band arrangement as a function of the channel width in the European band is shown in Fig. 3. They have been obtained as per Tables E-2 and [1, 3]. It can be seen that there are 20 other 20 MHz channels in the European 5 GHz band, with the subsequent numbers: 149, 153, 157, 161, 165, 169, 173, 177, and 181. However, they cannot be utilized for channel bonding. Fig. 3 indicates a total of 19 overlapping channels of 20 MHz, but only 9×40, 4×80, or 2×160 MHz channels.

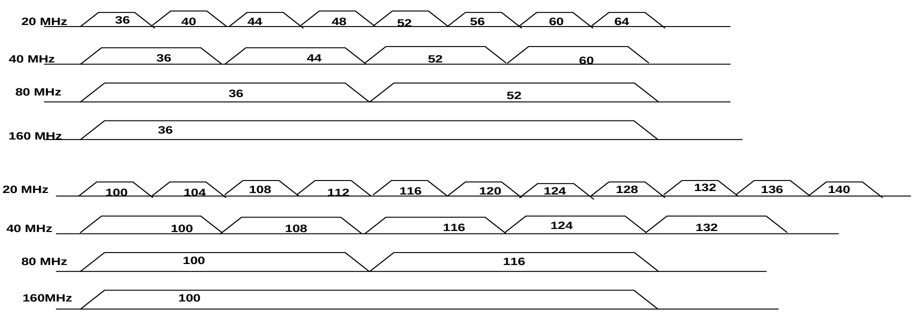

Figure3. Channelization of the European 5 GHz band [17]

Increasing the bandwidth enables channels to broadcast further information and improves the output of a specific WLAN. Conversely, the number of accessible channels is declining. Within congested WLAN applications, several networks may require for sharing the same wide channel, resulting in increased contention over medium access and consequently increase the level of collision.

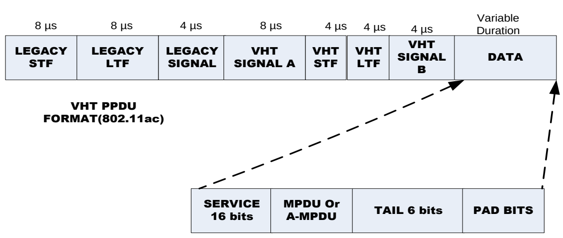

Figure4. VHT PPDU format [17]

In A-MPDU several MAC frames are incorporated within the integrated MPDU, and then this A-MPDU is moved within the PHY framework (ie PPPU) as shown in Figure 4. The utilization of A-MPDU was primarily defined by 802.11n with a maximum length of 65535 Bytes. However; development of VHT improves this boundary to 1048575Byte (approximately 1 MB). The novel boundary based on the PPDU duration of 5484 µs.

3.2. Modulation and Coding Scheme

The Modulation Coding Scheme is a Combination of modulation, coding scheme, guard interval, channel width. With the Amendment in IEEE WLANs from 802.11a to 802.11n, the New features have been added and more data rates are available) [18]. The table for 802.11ac and 802.11n is given below.

HT MCS	VHT MCS	Modulation	Coding	20 MHz			
				Data rate		MIN SNR	RSSI
				800ns	400ns		
1 spatial stream							
0	0	BPSK	1/2	6.5	7.2	2	-82
1	1	QPSK	1/2	13	14.4	5	-79
2	2	QPSK	3/4	19.5	21.7	9	-77
3	3	16 QAM	1/2	26	28.9	11	-74
4	4	16 QAM	3/4	39	43.3	15	-70
5	5	64 QAM	2/3	52	57.8	18	-66
6	6	64 QAM	3/4	58.5	65	20	-65
7	7	64 QAM	5/6	65	72.2	25	-64
	8	256 QAM	3/4	78	86.7	29	-59
	9	256 QAM	5/6			31	-57

Table 1.802.11n and 802.11ac MCS, SNR and RSSI [18]

4. EXPERIMENTAL SETUP AND PERFORMANCE METRICS NETWORK DESIGN

Wireless network design is shown in figure 4 that is configured as a MIMO network in which multiple transmitters (Txs) and receivers (Rxs) between the access point and Client are considered at a different distance (d).

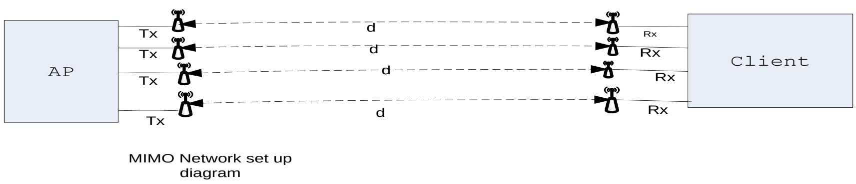

Figure5. MIMO Network set up Diagram

We have utilized modulation coding schemes indexed MSC3,MCS4,MCS5,MCS6 andMCS7.We have used two scenarios Channel Bonding and aggregation with channel boding and measured throughput with respect to distance under mentioned scenarios.

Performance Metric

To analyze the performance of the network we have selected performance metrics as Throughput.

Throughput

It is described as the number of bits transferred (in Mbps) from the access point to the user in the network

$$\text{Throughput} = \frac{(\text{Total Packet} * \ \text{Payload Size})}{(\text{Simulation Time})}$$

5. PROPOSED WORK

In our proposed work we have considered modulation coding schemes MCS3, MCS 4, MCS5, MCS6, and MCS7 which is defined by 802.11ac at a different distance ranging from 0,10,20,….,40 and estimate the throughput for the two scenarios denoted as Channel bonding and Aggregation with Channel Bonding.

6. PERFORMANCE EVALUATION

We employ ns3 [19] for estimating the outcome of channel bonding and aggregation on throughput. We have considered the simulation configuration of Table 2. We have taken a payload size of 1500 Bytes. We set different distances on behalf of each modulation coding scheme (MCS0-MCS10) to compute the throughput.

Table .2 Simulation parameter

Parameter	Value
Simulator version	Network Simulator (NS3.29)
Error rate model	Nist Error Rate Model
Wi-fi Type	Wi-Fi phy standard 80211n 5GHz
Frequency	5.0 GHz
Short Guard Interval	True
Channel Bonding	True
Propagation loss model	Friis Propagation Loss Model
Mobility	Constant Speed
Payload	1500 Byte
Channel Propagation Delay Model	Constant Speed Propagation Delay Model
MIMO Antennas n Streams	1-8
MIMO Max Supported Tx Spatial Streams n Streams	1-8
MIMO Max Supported Rx Spatial Streams n Streams	1-8
IP Version	IPV4

Table3. Throughput of Modulation coding scheme (HT MCS3 QAM 16) at different distance using channel bonding only and Aggregation with Channel Bonding

Distance (m)	Channel Bonding	Aggregation with Channel Bonding
0	47.9091	48.7617
10	48.5115	48.6528

20	47.3461	9.5012
30	47.6056	1.12365
40	0	0

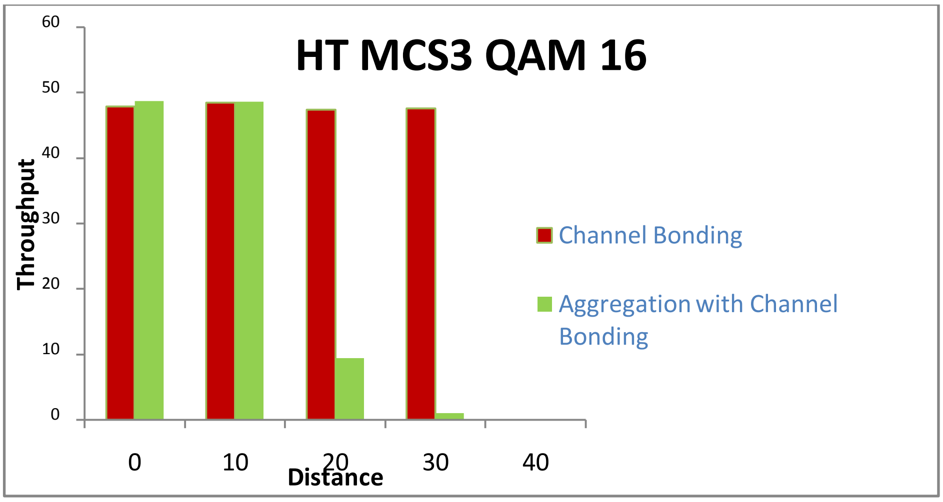

Figure 6.Throughput Vs Distance using Channel Bonding and Aggregation with channel bonding for HT MCS3 QAM 16

Figure 6 shows that channel bonding outperforms the Aggregation with Channel Bonding as the Distance increases. It is evident that at a distance of 30m Channel Bonding achieves 47.6 Mbps throughput as compared to 1.12 Mbps using Aggregation with Channel Bonding.

Table4. Throughput of Modulation coding schemes (HT MCS4 QAM 16) at different distance using channel Bonding only and Aggregation with Channel Bonding

Distance (m)	Channel Bonding	Aggregation with Channel Bonding
0	72.7151	70.4354
10	72.1637	70.7412
20	69.8237	13.6992
30	11.35	9.13283
40	0	0

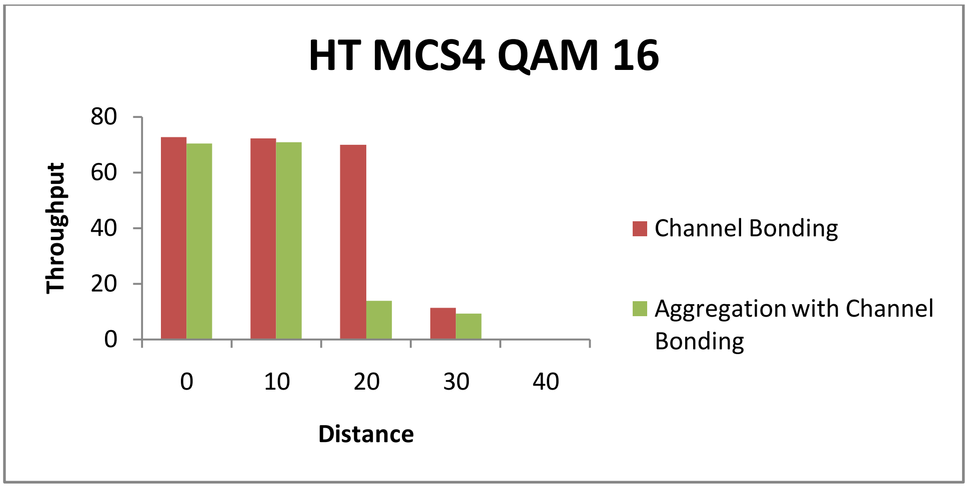

Figure 7.Throughput Vs Distance using Channel Bonding and Aggregation with channel bonding for HT MCS4 QAM 16

Figure 7 shows that channel bonding outperforms the Aggregation with Channel Bonding as the Distance increases. It is evident that at a distance of 30m Channel Bonding achieves 11.35 Mbps throughput as compared to 9.13 Mbps using Aggregation with Channel Bonding.

Table5. Throughput of Modulation coding schemes (HT MCS5 QAM 64) at different distance using channel bonding only and Aggregation with Channel Bonding

Distance (m)	Channel Bonding	Aggregation with Channel Bonding
0	95.1255	91.2518
10	95.3734	91.6364
20	22.8552	14.5611
30	0	0
40	0	0

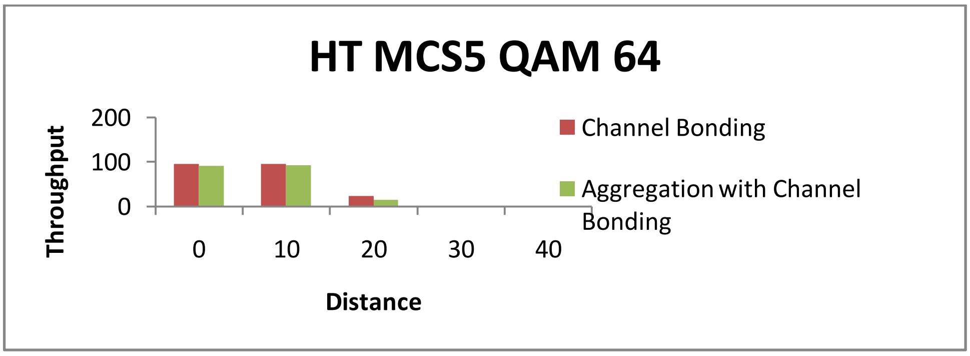

Figure 8.Throughput Vs Distance using Channel Bonding and Aggregation with channel bonding for HT MCS5 QAM 64

Figure 8 shows that channel bonding outperforms the Aggregation with Channel Bonding as the Distance increases. It is evident that at a distance of 20m Channel Bonding achieves 22.85 Mbps throughput as compared to 14.56 Mbps using Aggregation with Channel Bonding.

Table6.Throughput of Modulation coding schemes (HT MCS6 QAM 64) at different distance using Frame aggregation, channel Bonding and Aggregation with Channel Bonding

Distance (m)	Channel Bonding	Aggregation with Channel Bonding
0	105.528	101.483
10	105.885	100.911
20	0	0
30	0	0
40	0	0

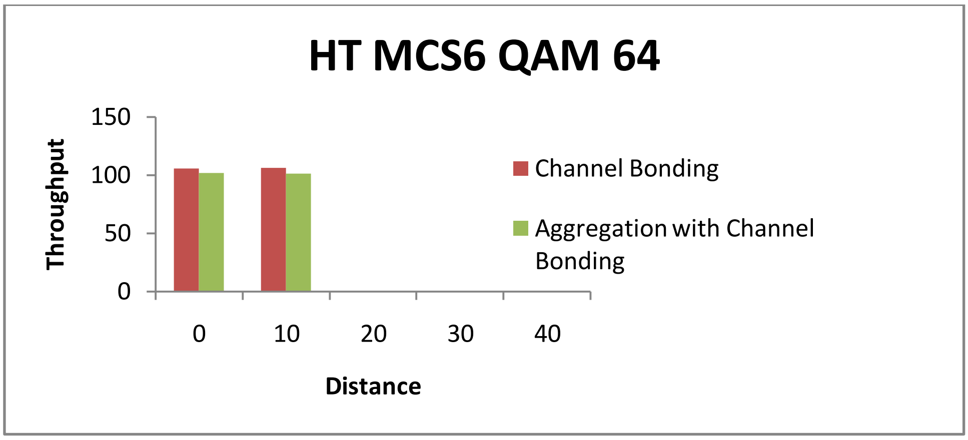

Figure 9.Throughput Vs Distance using Channel Bonding and Aggregation with channel bonding for HT MCS6 QAM 64

Figure 9 shows that channel bonding outperforms the Aggregation with Channel Bonding as the Distance increases. It is evident that at a distance of 10m Channel Bonding achieves 105.88 Mbps throughput as compared to 100.911 Mbps using Aggregation with Channel Bonding.

Table7. Throughput of Modulation coding schemes (HT MCS7 QAM 64) at different distance using channel Bonding and Aggregation with Channel Bonding

Distance (m)	Channel Bonding	Aggregation with Channel Bonding
0	117.816	111.033
10	116.442	110.609
20	0	0
30	0	0
40	0	0

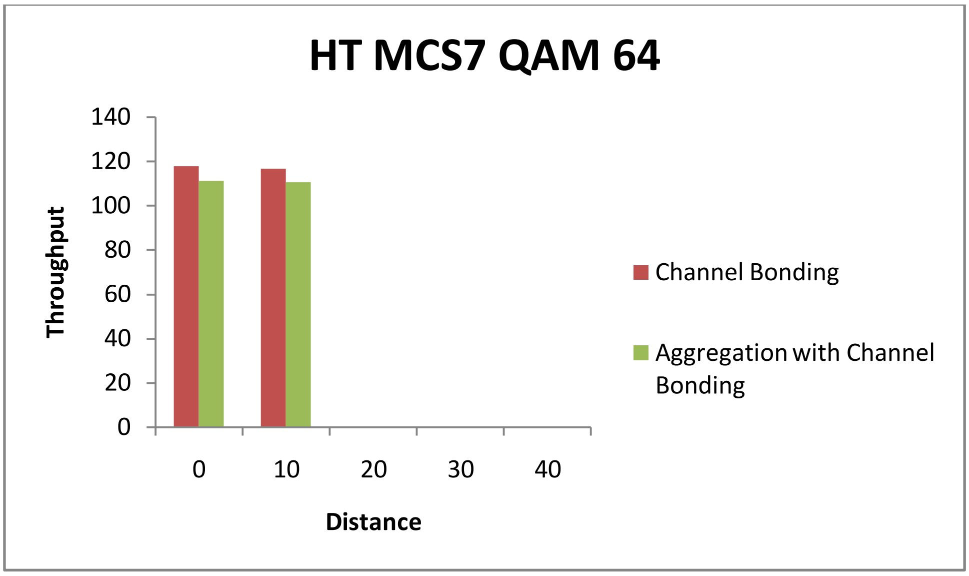

Figure 10.Throughput Vs Distance using Channel Bonding and Aggregation with channel bonding for HT MCS7 QAM 64

Figure 10 shows that channel bonding outperforms the aggregation with Channel Bonding as the Distance increases. It is evident that at a distance of 10m Channel Bonding achieves 116.44 Mbps throughputs as compared to 110.60 using aggregation and channel bonding.

CONCLUSION

We conclude that with increasing distance, better throughput is achieved using channel Bonding scenario for lower and higher modulation schemes compared to using aggregation scenario with channel bonding. We also notice that as we go from low to high MCS with further degradation of the throughput performance, we obtain a low throughput MCS for a greater distance compared to high MCS for both scenarios.

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