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Evaluation of Frame Aggregation in Giga-bit WLANs

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***Abstract*—Recently, the very high throughput (VHT) IEEE 802.11ac amendment has emerged as the fifth generation of wireless local area networks (WLANs). Enhancements to the physical and MAC layers have been defined which elevate the data rate to 6.933 Gbps. The 802.11ac amendment extends the frame size from 8000 bytes to approximately 11454 bytes, which increases the ability to aggregate frames from upper layers. Moreover, frame aggregation is employed in 802.11ac which states that all MAC protocol data units (MPDU) must use the aggregate MPDU (A-MPDU) format. In this paper we evaluate the techniques of frame aggregation adopted by IEEE 802.11ac. In particular, we study the impact of frame aggregation on the system throughput. Simulation results show that frame aggregation is a powerful mechanism in terms of increasing system throughput through reducing overhead in MAC layer.**

***Index Terms*—802.11ac, frame aggregation, A-MSDU, A-MPDU.**

I. INTRODUCTION

The IEEE 802.11 based wireless LAN has gained a great success for data and multimedia applications in hotspots, university campuses, hospitals, and enterprises. As a step towards achieving very high throughput (VHT), the IEEE 802.11ac amendment [1] has been introduced that provides data rates up to 6.933 Gbps in the 5 GHz band. Enhancements are introduced mainly in physical and MAC layers. In order to achieve very high throughput, higher order modulation schemes, wider channel bandwidths, and multiple spatial streams are modifications introduced in the physical layer [2]. On the other hand, MAC frame aggregation mechanisms are the enhancements defined for efficient MAC layer that provides better channel utilization. The 802.11ac amendment defines two basic frame aggregation mechanisms to be used in transmission at the MAC layer. These mechanisms are: Aggregate MAC service data unit (A-MSDU) and Aggregate MAC protocol data unit (A-MPDU). In addition, 802.11ac extends the frame size from 8000 bytes to approximately 11454 bytes, which allows aggregating more frames from upper layers [3]. The frame aggregation techniques significantly reduce the overhead by sharing the physical header for several aggregated frames and inter-frame spacing when accessing the channel.

In this paper, we study the impact of frame aggregation mechanisms introduced by the IEEE 802.11ac amendment on system performance.

The rest of the paper is organized as follows. Section II provides an overview of the frame aggregation mechanisms defined in the IEEE 802.11ac amendment. Related work is also summarized in section II. Simulation techniques and setup along with simulation parameters are presented in section III. Results and discussions are reported in section IV. Conclusion to our work is presented in section V.

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II. BACKGROUND AND RELATED WORK

A. *Frame Aggregation Mechanisms*

The MAC service data unit (MSDU) is defined as the transmission unit used at the MAC layer which is received from higher layers. The MAC protocol data unit (MPDU), on the other hand, is the frame passed from the MAC layer to the physical layer [4]. In other words, MSDU is the input to the MAC layer, whereas MPDU is the output of the MAC layer. The IEEE 802.11ac amendment defines two basic forms of frame aggregation: A-MSDU and A-MPDU to be used in transmission [1].

A-MSDU: the idea behind aggregate MSDU (A-MSDU) lies on concatenating several MSDUs. However, the aggregation of a single A-MSDU completes when a predefined maximal limit of A-MSDU is reached [3].

The structure of MSDU comprises MSDU header that contains destination address (DA), source address (SA), and the MSDU length. This header is followed by the MSDU from higher layer and padding bytes, as depicted in Fig. 1. However, aggregating MSDUs into an A-MSDU causes performance degradation in cases where channel is error prone. In this case, if any MSDU inside the A-MSDU is corrupted, the entire A-MSDU needs to be retransmitted [4].

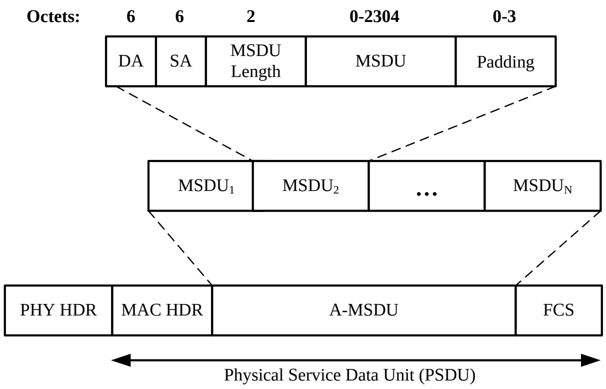

Fig. 1. An Aggregate MSDU

A-MPDU: the principle of aggregate MPDU is to join multiple MPDUs with a single physical header. The A-MPDU takes place after the MAC header encapsulation procedure.

Each MPDU consists of MPDU header which comprises MPDU length and cyclic redundancy check (CRC) field for verifying authenticity of the 16 preceding bits, as illustrated in Fig. 2. Upon reception, de-aggregation process is performed. It checks the MPDU header for errors depending on the CRC field [4].

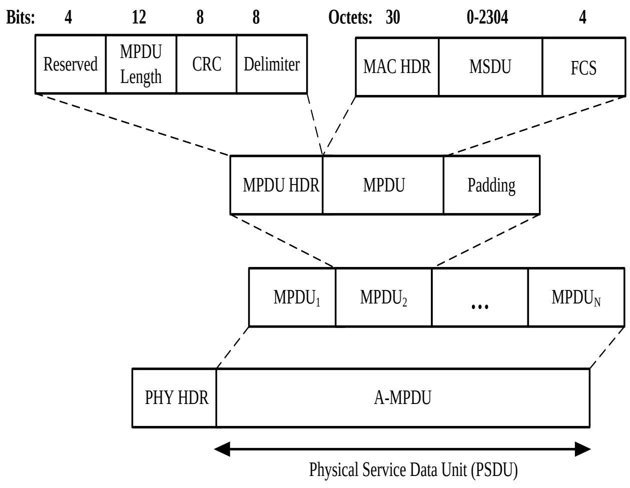

Fig. 2. An Aggregate MPDU

B. *Related Work*

Investigating the performance of 802.11ac has grabbed the attention of many researchers in the wireless field. In [2], a theoretical model is proposed to examine the throughput of PHY and MAC layers of the 802.11ac. Simulation results are relatively close to the results of the theoretical model. Similarly, a performance study of 802.11ac is presented in [4]. The simulation results show that using frame aggregation increases channel utilization and enhances system performance. The authors of [5] provide a comparison between 802.11n and 802.11ac. The results show that under specific consideration, the 802.11ac enhances the system throughput by 28%. The authors of [6] introduce a mechanism of aggregate MPDU using fragmented MPDUs with compressed block acknowledgement. This mechanism can eliminate overhead caused by MPDU padding, which in turn increases the system throughput. A cross-layer aggregation scheme is proposed in [7]. This scheme is a tradeoff between channel diversity exploitation in WLAN multichannel and robustness to collisions. The authors of [8] have examined the MAC enhancements for downlink MU-MIMO transmission. Basically, the authors introduce a mechanism of enhancing the transmission opportunity (TXOP) and the backoff procedure. A frame aggregation scheme for 802.11ac is introduced in [9]. The performance of the network is studied under non-saturated conditions. Their discussions show that queue length and number of active nodes have a significant influence on the system performance. Based on [10], the authors of [11] proposed a theoretical model to study the performance of the IEEE 802.11ac distributed coordination function (DCF) of the MAC layer in presence of hidden nodes. The paper concludes that using legacy RTS/CTS handshake mechanism has some shortcomings that need to be addressed to cope with the new 802.11ac features. The authors of [12] provide a survey on the impact of physical and MAC enhancements on transport and application layer protocols. A comparison between 802.11n and 802.11ac is also considered in [12]. In addition, the authors specify some challenges for 802.11ac in order to support higher layers protocols.

III. SIMULATION SETUP

We have used the Jemula 802.11ac simulator [13] to study the impact of frame aggregation defined in 802.11ac on system throughput. Jemula 802.11ac kernel is an open source JAVA library that constitutes a kernel for event-driven stochastic simulation that is prepared to simulate real-time systems. The simulation core consists of three main packages called kernel, statistics and plot [13]. Physical and MAC layers parameters used in our simulation are presented in Table I. Several scenarios have been constructed where each scenario is run for 20 seconds. Each scenario is run for 10 times and we have calculated the average values to obtain stable results.

Table I
PHY and MAC Parameters

Parameter	Value
Slot time	9 μs
T_{DIFS}	34 μs
T_{SIFS}	16 μs
MAC HDR Length	36 bits
Min PHY HDR Time	40 μs
Max PHY HDR Time	68 μs
CW_{min}	32
CW_{max}	1024
$Propag_{Delay}$	1 μs
Max MSDU Size	2304 bytes
Max MPDU Size	11454 bytes
ACK length	14 bytes
Block ACK length	64 bytes

IV. RESULTS AND DISCUSSIONS

Our aim is to study the effect of frame aggregation mechanisms introduced in 802.11ac on system throughput. We calculate the aggregate throughput for the network for the following different scenarios.

A. *Channel Utilization without Aggregation*

In this scenario, we study the channel utilization in case the frame aggregation is not used. We vary the physical data rate from 50 to 300 Mbps. We use an average MAC protocol data unit (MPDU) of 1500 octets. The number of stations is fixed to 12 stations. Channel bandwidth is set to 40 MHz with 16-QAM modulation. As shown in Fig. 3, the channel utilization decreases with the increase of physical data rates. The MAC and PHY headers are transmitted with the basic physical rate which entails increment in the transmission time compared to the transmission of payload. Since the frame aggregation techniques are not used, each frame has its own MAC, PHY headers, inter-frame spacing, and ACK frame. This overhead causes the degradation of channel utilization as much time is spent in transmitting useless data.

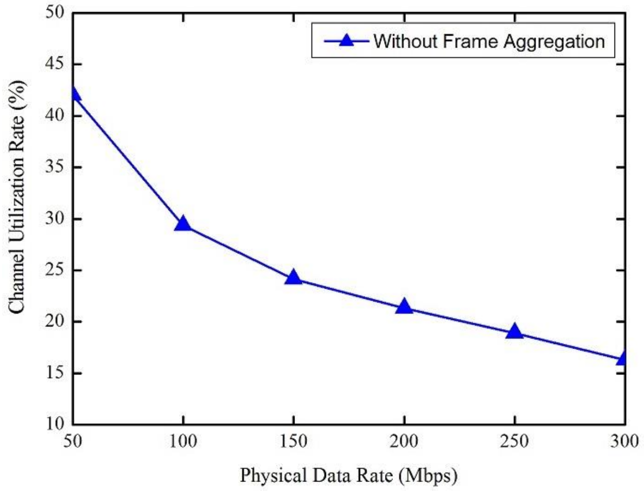

Fig. 3. Channel utilization in the absence of frame aggregation mechanisms

B. *The effect of A-MPDUs on Throughput*

In this scenario, we investigate the impact of utilizing A-MPDUs on system throughput. We use two physical data rates: 100 Mbps and 150 Mbps. Number of stations is fixed to 12 stations. We vary the number of MPDU that are aggregated into an A-MPDU. Each MPDU size is set to 2000 octets. Channel bandwidth is set to 40 MHz with 16-QAM modulation.

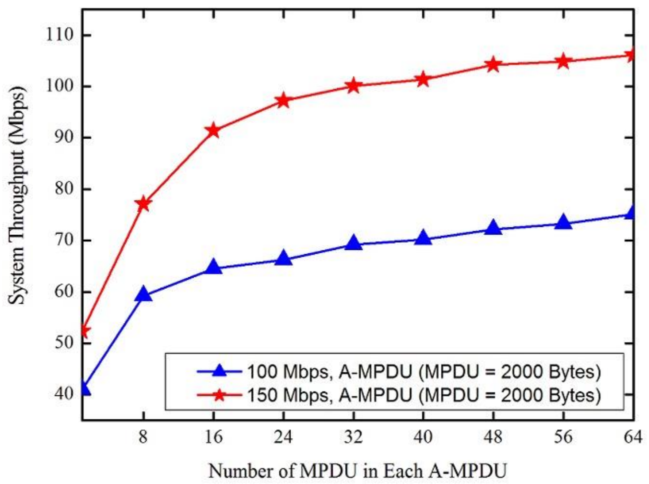

Fig. 4. The effect of A-MPDU on Throughput

The system throughput increases with increase of the number of MPDUs aggregated in an A-MPDU, as depicted in Fig.4. This ensures that frame aggregation enhances the overall system performance. This increase in throughput is mainly cause by reducing the overhead imposed by MAC and PHY headers, ACK frames, as well as inter-frame spacing. However, when using large frame sizes, the gain in the throughput is insignificant. This entails that larger frame sizes requires higher physical rates.

V. Conclusion

This paper evaluated the frame aggregation techniques defined in the IEEE 802.11ac amendment. Simulation results have shown that frame aggregation can effectively achieve better channel utilization. Frame aggregation enhances MAC efficiency by reducing overheads. However, special consideration must be taken to relate the frame sizes to the physical data rate.

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