UNIVERSITI PUTRA MALAYSIA

# *ENHANCING THE MAC THROUGHPUT BY TWO SCHEMES OF FRAMES AGGREGATION WITH eA-MSDU IN WLANS*

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# ENHANCING THE MAC THROUGHPUT BY TWO SCHEMES OF FRAMES AGGREGATION WITH eA-MSDU IN WLANS

**By:**

**OSAMAH SAMER AL-DULAIMY**

Thesis submitted to the School of Graduate Student, University Putra Malaysia, in fulfilment of the requirement for the degree of Master of Computer Science

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## DEDICATION

I dedicate this thesis to God Almighty my creator, my strong pillar, my source of inspiration, wisdom, knowledge and understanding. I also dedicate this thesis to my family who has encouraged me all the way and whose encouragement has made sure that I give it all it takes to finish that which I have started. To a special and dear person who has been the source of my strength and has supported me throughout my study with many words of encouragement. To my friends for their endless support. Thank you. My love for you all can never be quantified. God bless you.

# ABSTRACT

Abstract of this thesis is presented to the Senate of University Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

**Enhancing the MAC Throughput by Two Schemes of Frames Aggregation with eA-MSDU in WLANs**

By:

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**June 2017**

**Supervisor: Dr. Kweh Yeah Lun**

**Faculty: Computer Science and Information Technology**

IEEE 802.11 is a set of media access control (MAC) and physical layer (PHY) specifications for implementing wireless local area network (WLAN) computer communication in the 900 MHz and 2.4, 3.6, 5, and 60 GHz frequency bands. They are created and maintained by the Institute of Electrical and Electronics Engineers (IEEE) LAN/MAN Standards Committee. IEEE 802.11n defines two schemes of frames aggregation: aggregate Mac Service Data Unit (A-MSDU) and aggregate Mac Protocol Data Unit (A-MPDU). They aimed at maximize utilizing WLAN PHY efficiency at MAC level, through sharing headers and timings overheads. Despite their efficiencies in enhancing the MAC throughput, the schemes are characterized with yet other overheads due to the aggregation. So to maximize the throughput gain, and also to utilize the efficiency of both of the scheme by merging them to co-work together in a scheme known as two-level aggregation, therefore, this research is carried out with the aim of minimizing the overhead due to the aggregation. An enhanced A-MSDU with minimal headers overhead, and an efficient two-level aggregation scheme utilizing the enhanced AMSDU are proposed. The eA-MSDU improved channel's utilization by up to 10% and 20% in terms of throughput increase. Results from the simulation show superiority of the proposed two-level aggregation in respect of throughput and overall channel utilization.

## ABSTRAK

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia

Sebagai memenuhi keperluan untuk ijazah Sarjana Sains.

**Enhancing the MAC Throughput by Two Schemes of Frames Aggregation with eA-MSDU in WLANs**

By:

**Osamah Samer AL-Dulaimy**

**June 2017**

**Pengerusi: Dr. Kweh Yeah Lun**

**Fakulti: Sains Komputer dan Teknolologi Maklumat**

IEEE 802.11 adalah satu set spesifikasi kawalan akses media (MAC) dan lapisan fizikal (PHY) untuk melaksanakan komunikasi komputer rangkaian kawasan setempat tanpa wayar (WLAN) dalam band frekuensi 900 MHz, 2.4, 3.6, 5 dan 60 GHz. Ia adalah diwujudkan dan dikendalikan oleh Jawatankuasa Piawaian LAN / MAN Institut Elektrik dan Elektronik Jurutera (IEEE). IEEE 802.11n mentakrifkan dua skim pengagregatan bingkai iaitu Unit Data Servis Mac agregat (A-MSDU) dan Unit Data Protokol Mac agregat (A-MPDU). Mereka bertujuan untuk memaksimumkan penggunaan kecekapan WLAN PHY pada tahap MAC, melalui perkongsian header dan masa overhed. Walaupun kecekapan mereka dalam meningkatkan daya pemprosesan MAC, skim ini dicirikan dengan overhed lain selain daripada

pengagregatan. Dengan itu, bagi memaksimumkan peningkatan daya pemprosesan, dan juga menggunakan kecekapan kedua-dua skema dengan menggabungkan mereka untuk bekerjasama dalam satu skema yang dipanggil sebagai agregasi dua peringkat, maka, penyelidikan ini dijalankan dengan tujuan meminimumkan overhed disebabkan oleh pengagregatan. Peningkatan A-MSDU dengan overhed header minimal, dan skema agregasi dua peringkat cekap menggunakan AMSDU yang telah dipertingkatkan telah dicadangkan. Penggunaan saluran eA-MSDU meningkat sehingga 10% dan 20% dari segi peningkatan daya pemprosesan. Hasil dari simulasi menunjukkan keunggulan dari agregasi dua peringkat yang telah dicadangkan berkenaan dengan penggunaan dan penggunaan saluran keseluruhan.

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## APPROVAL

This thesis was submitted to the faculty of Computer Science and Information Technology of University Putra Malaysia and has been accepted as partial fulfilment of the requirement for the degree of Master of Computer Science. The members of the Supervisory Committee were as follows:

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# DECLARATION

I declare that the thesis is my original work, except for the quotation and citations, which have been duly, acknowledge. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at University Putra Malaysia or any other institution.



**Osamah Samer AL-Dulaimy**

Date: ______________________________

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| | |
|---|---|
| AAM | Adaptive Aggregation Algorithm |
| AC | Access Category |
| ACF | Adaptive Coordination Function |
| Ack | Acknowledgement |
| AFR | Aggregation with Fragment Retransmission |
| A-MPDU | Aggregate MAC Protocol Data Unit |
| A-MSDU | Aggregate MAC Service Data Unit |
| AP | Access Point |
| BACK | Block Acknowledgement |
| BER | Bit Error Rate |
| BO | Back-off |
| BSS | Basic Service Set |
| CBA | Compressed Block Acknowledgement |
| CSMA | Carrier Sense Multiple Access |
| CSMA/CA | Carrier Sense Multiple Access with Collision Avoidance |
| CSMA/CD | Carrier Sense Multiple Access with Collision Detection |
| CTS | Clear To Send |
| CW | Contention Window |
| DA | Destination Address |
| DCF | Distributed Coordination Function |
| DIFS | DCF Inter-Frame Space |
| DLL | Delay Lower Limit |
| DS | Distribution System |
| DTMC | Discrete Time Markov Chain Model |
| DTMC | Discrete Time Markov Chain Model |
| eA-MSDU | enhanced A-MSDU |
| EDCA | Enhanced Distributed Channel Access |
| EIFS | Extended Inter-frames Space |
| ESS | Extended Service Set |
| FCS | Frame Check Sequence |

| | |
|---|---|
| FER | Frame Error Ratio |
| FIFO | First in First out |
| GMAC | Group-based MAC |
| HT | High Throughput |
| IEEE | Institute of Electrical and Electronic Engineering |
| IFS | Inter-Frame Space |
| IP | Internet Protocol |
| ISM | Industrial Scientific and Medical |
| ISO | International Organization for Standardization |
| LLC | Logical Link Convergence |
| LPDC | Low Parity Density Coding |
| MAC | Media Access Control |
| mA-MSDU | modified A-MSDU |
| MIMO | Multiple Input Multiple Output |
| MPDU | MAC Protocol Data Unit |
| MSDU | MAC Service Data Unit |
| NAV | Network Allocation Vector |
| OFDM | Orthogonal Frequency Division Multiplexing |
| OSI | Open Systems Interconnection |
| OTCL | Object Oriented Transaction Command Language |
| PCF | Point Coordination Function |
| PCO | Phased Coexistence Operation |
| PDU | Protocol Data Unit |
| PHY | Physical |
| PIFS | Polling Inter-Frame Space |
| PLCP | PHY Layer Convergence Protocol |
| PPDU | PHY Protocol Data Unit |
| PSDU | PHY Service Data Unit |
| QoS | Quality of Service |
| RA | Receiver Address |
| RD | Reverse Direction |
| RDG | Reverse Direction Grant |
| RIFS | Reduced Inter-frames Space |

| | |
|---|---|
| RTS | Request To Send |
| SA | Source Address |
| SAP | Service Access Point |
| SDM | Spatial Division Multiplexing |
| SIFS | Short Inter-Frame Space |
| SISO | Single-Input Single-Output |
| STA | Station |
| STBC | Space-Time Block Coding |
| TA | Transmitter Address |
| TCP | Transmission Control Protocol |
| TDMA | Time-Division Multiple Access |
| TID | Traffic Identifier |
| TUL | Throughput Upper Limit |
| TXOP | Transmission Opportunity |
| UDP | User Datagram Protocol |
| VoIP | Voice over Internet Protocol |
| WEP | Wireless Equivalent Protocol |
| WFA | Wi-Fi Alliance |
| WLAN | Wireless Local Area Networks |
| WPA | Wi-Fi Protected Access |

# CHAPTER 1

# INTRODUCTION

## 1.1 Overview

This chapter will present a review of wireless area networks and a short background about this thesis' scope. This chapter will also provide the idea behind our research problem and the manner in which we addressed it, as well as our objective.

## 1.2 INTRODUCTION TO WLANS

Wireless LANs (WLAN) are becoming increasing everywhere because of the flexibility and the freedom they offer to the users. This is due to the fact that gives users the mobility to move around within a local area and still be connected to the network, the ease of installation and the use of laptops. Therefore, the WLAN is a network that usually extends an existing wired local area network and provides wireless network communication over short distances using radio or infrared signals.

In 1971 as it begun, where the first packet-based wireless network was created at the University of Hawaii. They named the network ALOHANET and the system included seven computers over four islands communicating with a central computer, without using phone lines, in a bi-directional star topology. WLAN devices were developed for commercial use after several years but these initial systems were expensive and because of this reason, the deployment was only feasible when running cable was difficult. Finally increased commercial interest was observed as a result of the advances in technology and the standardization of WLAN with IEEE 802.11, which led to cost reduction, resulting in a more convenient and feasible deployment of a wireless network. Then Wi-Fi Alliance (WFA) was formed in 1999 to certify interoperability between IEEE 802.11 devices, because of the mass production of different manufacturers. Therefore, WLANs are deploying in homes, businesses, small areas (hot spots) and know great growth.

Ethernet (802.3) influenced the initial version of IEEE 802.11 standard for wired LANs in 1997, adopting the distributed access protocol, carrier sense multiple access (CSMA) in MAC layer. For a quick review, all network architectures are based on a layered model called OSI (Open Systems Interconnection) model, designed by the International Organization for Standardization (ISO), as seen in Figure 1.1. The OSI model provides an extensive list of functions and services that can occur at each layer. It also describes the relation of each layer with the layers directly above and below it.

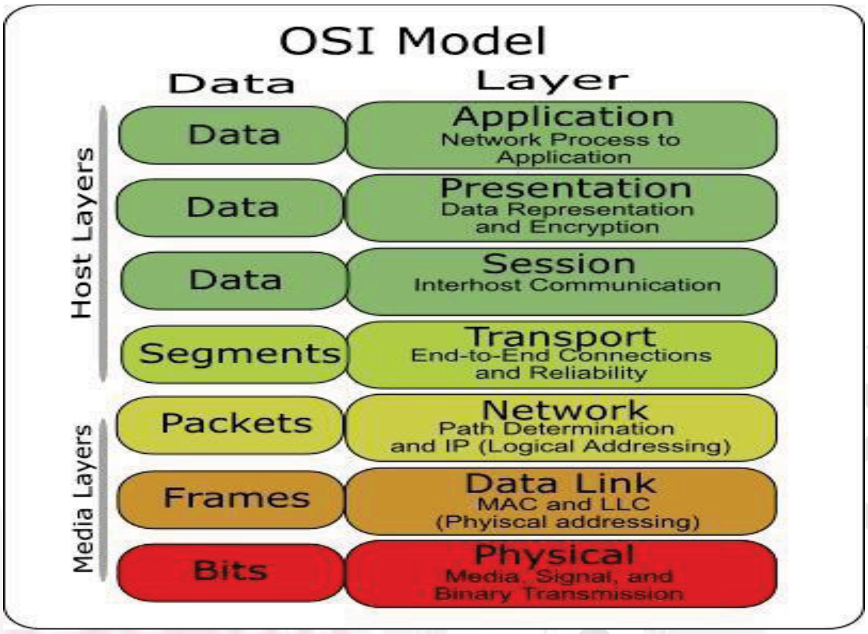


**Figure 1.1: OSI Model [46]**

The OSI Layers Physical and Data Link provide the necessary procedures to access the media and the physical means to send data over a network. Therefore, these two layers are also responsible for data rates, a connection or network accomplish and are the case study of the researchers for improving data rates.

The Data Link layer exchanges the data over a common medium and:

- Encapsulates the data units from the upper layers to frames and permits the access to the media
- Using media access control and error detection, it controls how data is placed/received onto/from the media

For further analyzed, the Data Link layer consists of two sub-layers:

The upper sub-layer called Logical Link Control (LLC) layer that encapsulates into frames the Network layer packets and identifies the Network layer Protocol (IP) and the lower one called Media Access Control (MAC), which physically addresses the frame (MAC address) and completes the creation of the frame as shown in Figure 1.2.

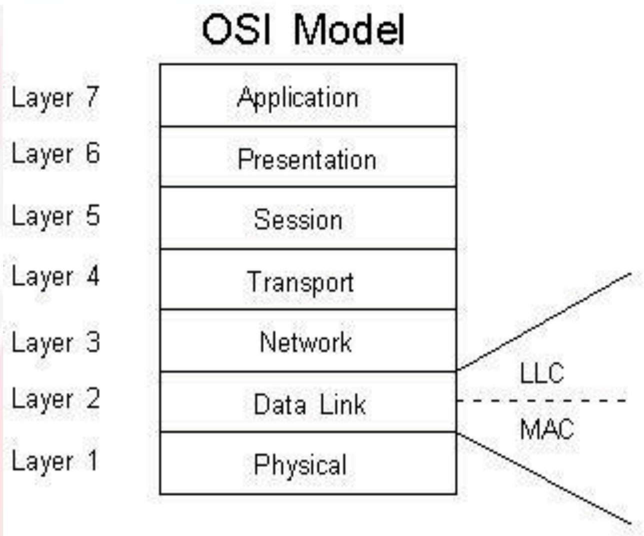


**Figure 1.2: Data Link Sub-layers: LLC, MAC [47]**

So getting back on how IEEE 802.11 works, CSMA is a MAC mechanism for medium access. Ethernet (802.3) is based on CSMA/CD (collision Detection), whereas IEEE 802.11-based WLANs use a similar mechanism known as carrier sense multiple access with collision avoidance (CSMA/CA). CSMA/CA is a protocol for carrier transmission in 802.11 networks. Unlike CSMA/CD (Carrier Sense Multiple Access/Collision Detect) which deals with transmissions after a collision has occurred, CSMA/CA acts to prevent collisions before they happen.

In CSMA/CA, as soon as a node receives a packet that is to be sent, it checks to be sure the channel is clear (no other node is transmitting at the time). If the channel is clear, then the packet is sent. If the channel is not clear, the node waits for a randomly chosen period, and then checks again to see if the channel is clear. This period is called the backoff factor, and is counted down by a backoff counter. If the channel is clear when the backoff counter reaches zero, the node transmits the packet. If the channel is not clear when the backoff counter reaches zero, the backoff factor is set again, and the process is repeated.

**IEEE 802.11n Standard**

IEEE 802.11 formed 802.11n working group in 1997 with the objectives of increasing both PHY rate and MAC layer throughput, and attaining data rate of at least 100Mbps, measured at MAC Service Access Point (SAP). To achieve these, 802.11 proposed series of improvements at both PHY and MAC layer.

Major improvements at the PHY layer include channel expansion from 20MHz to 40MHz through bonding of two-20MHz channels; use Multiple Input Multiple Out-put (MIMO) and Orthogonal Frequency Division Multiplexing (OFDM) technologies to achieve either PHY data rate increase (through Spatial Division Multiplexing, SDM) or wider range (through Space-Time Block Coding, STBC); and channel beamforming. Principal enhancements at the MAC are introduction frames aggregation, in which multiple frames are transmitted at a time. Use of IEEE 802.11e TXOP technique to reverse-transmit data and an enhanced BACK scheme.

**Frames Aggregation**

IEEE 802.11n defines two standards of the frames aggregation schemes: the A-MSDU and the A-MPDU. A-MSDU logically works at upper level (initial stage) of MAC layer while A-MPDU at the lower level (later stage). A-MSDU aggregates MAC Service Data Units (MSDU) coming from the upper logical link convergence (LLC) layer, appends common MAC address and Frame Check Sequence (FCS), and transmits them as a unit in single DCF process. It thus reduces DCF activities that may otherwise be involved by the factor of individual frames aggregated. A-MPDU in the other hand aggregates multiple MSDUs after been processed by MAC (MAC Protocols Data Units, MPDU) into one PHY Service Data Unit (PSDU) and sends to PHY layer, where common PHY Layer Convergence Protocol (PLCP) header and preamble are appended and the frame is transmitted.

## 1.3 Problem Statement

IEEE 802.11 MAC architecture is based on the logical coordination functions that determine who and when to access the wireless medium at any time. In legacy 802.11 (prior to 802.11n) standards, there are two types of access schemes:

1. DCF– Distributed Coordination Function (mandatory) based on CSMA/CA.
2. PCF– Point Coordination Function (Optional) based on poll-response.

In 802.11n standard, Frame Aggregation was the most important MAC enhancement proposed which maximize throughput and efficiency. A-MSDU and A-MPDU frame aggregation schemes are the available methods to perform the frame aggregation. The main distinction between A-MSDU & A-MPDU is that the A-MSDU works at the upper part of MAC layer whereas the A-MPDU at the lower. However, huge aggregation overheads consume a large percentage of the cumulative aggregated data. So combining the two-level aggregation schemes would reduce the aggregation overheads and produce optimal efficiency.

## 1.4 Research Objectives

In this project, the objective is to implement an enhanced version of the A-MSDU with minimal header overheads and an efficient two level aggregation schemes utilizing the enhanced A-MSDU.

## 1.5 Research Scope

This project describes the A-MSDU and A-MPDU frame aggregation schemes defined by the IEEE 802.11n working group and the MAC throughput enhancement by the mandatory contention-based DCF. The two frame aggregation schemes will be combined into a two-level frame aggregation scheme to obtain optimal throughput efficiency. The network simulator (NS2) will be used to simulate the model.

## 1.6 Research Motivation

This research proposal is motivated to overcome the legacy 802.11 timing and headers overheads by means of aggregating multiple frames into a single frame. Only A-MSDU and A-MPDU aggregations that adopted by IEEE 802.11n working group. Applying the two level aggregation that have the potential additional efficiency through enhancing the overhead of the aggregation headers and cover the users' expectations by providing the optimal throughput of Wireless LAN technology.

## 1.7 Organization of Thesis

This research has five chapters. This first chapter provides a review of wireless local area networks and also presents a brief background of IEEE 820.11n standard and frames aggregation. Furthermore, this chapter presents the idea behind our research problem and the manner by which we have addressed it. We have also presented the research objective, scope and motivation in this first chapter. Brief descriptions of the remaining chapters are presented below:

Chapter two provides a brief background on the WLAN and IEEE standard, and also presents an explanation on the MAC function and frames aggregation with studies in literature that are related to them.

Chapter three presents the methodology and algorithm of our work and explanations of the used terminologies as well as software system requirements and simulation parameters that have been used for implementation.

Chapter four presents the proposed enhanced scheme (eA-MSDU) with its' frame structure. It will also present the results of the simulation with the implementation of the two level aggregation utilizing the enhanced A-MSDU. Chapter five presents the conclusion of the thesis and future work.

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