UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Electronic and Computer Engineering

ADAPTIVE TRAFFIC PRIORITIZATION ALGORITHM OVER AD HOC NETWORK USING IEEE 802.11e

Ammar bin Anuar

Master of Science in Electronic Engineering

2016

ADAPTIVE TRAFFIC PRIORITIZATION ALGORITHM OVER AD HOC NETWORK USING IEEE 802.11e

AMMAR BIN ANUAR

A thesis submitted in fulfillment of the requirement for the degree of Master of Science in Electronic Engineering

Faculty of Electronic and Computer Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2016

DECLARATION

I declare that this thesis entitled “Adaptive Traffic Prioritization Algorithm Over Mesh Network Using IEEE 802.11e Standard” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	....
Name	:	....
Date	:	....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science Electronic Engineering.

Signature	:	....
Supervisor Name	:	....
Date	:	....

ABSTRACT

This thesis proposes an adaptive traffic prioritization algorithm over ad hoc network using IEEE 802.11e standard that defines a set of Quality of Service enhancements for wireless LAN applications through modifications to the Media Access Control (MAC) layer. The IEEE 802.11e standard aims to provide enhancements that allow traffic with specific requirements to be treated differently from normal traffic. Enhanced Distributed Channel Access (EDCA) is a fundamental and mandatory contention-based channel access method of IEEE 802.11e which delivers traffic based on differentiated Access Category (ACs). Each AC has its own queue and set of EDCA parameter values. Although IEEE 802.11e has been widely implemented in commercial hardware, the EDCA parameters are normally preset with some default values recommended by the standard. By default, the values of EDCA parameters are not open for changes. This has limited the performance as from literature review, a proper EDCA parameter manipulation will improve the network throughput performance. However, most existing research works on IEEE 802.11e EDCA parameter optimization are done either analytically or in simulated environments and hence are unable to provide its effectivenes in realistic scenarios. This is largely due to the several hurdles associated with real-life implementations which prohibit them to do so, such as hardware limitations, software restrictions, coding bugs in the wireless cards driver and so on.These challengess form part of the motivations behind this work. This thesis first investigates the impacts of EDCA parameters on the network performance and link conditions using open source software and commercially available hardware in ad hoc mode. An adaptive prioritization scheme (APS) is then proposed. The results obtained show that the proposed APS algorithm can improve the single-AC throughput performance up to 10.82% when compared to static EDCA. In dual-AC scenario, APS can improve the throughput performance up to 9.93% as compared to static EDCA, while another scheme in existing literature, R-AIFSN shows inconsistency in throughput performance. It is also found that the improvement is more significant in terms of the queue occupancy.

ABSTRAK

Tesis ini membentangkan penyesuaian algoritma prioriti trafik melalui rangkaian mesh menggunakan standard IEEE 802.11e. Tujuan utama IEEE 802.11e standard adalah menyediakan trafik dengan keperluan khusus untuk dilayan secara berbeza daripada trafik normal. Peningkatan Edaran Channel Akses (EDCA) adalah satu kaedah akses saluran berdasarkan pemahaman asas dan mandatori IEEE 802.11e yang menghantar trafik berdasarkan Kategori Akses berbeza (PB). Setiap AC mempunyai giliran sendiri dan juga nilai-nilai parameter EDCA yang berbeza. Walaupun IEEE 802.11e telah diaplikasikan secara meluas, parameter EDCA biasanya tetap berdasarkan nilai yang telah ditakrifkan dalam standard IEEE 802.11e. Secara default, nilai parameter EDCA tidak dibuka untuk perubahan. Walau bagaimanapun, terdapat keperluan untuk mengubah nilai EDCA parameter dalam keadaan tertentu. Berdasarkan kajian literatur, pelarasan EDCA parameter yang tept akan merubah maksimum truput sesuatu trafik. Dalam kesusasteraan, kebanyakan kerja-kerja penyelidikan yang berkaitan dengan IEEE 802.11e dilakukan, sama ada secara analitik atau oleh simulasi. Ini adalah disebabkan oleh beberapa masalah yang berkaitan dengan pelaksanaan realistik, seperti batasan perkakasan, gangguan, noise latar belakang, kekangan perisian dan tidak kurang juga, pengekodan pepijat dalam driver kad wayarles. Walau bagaimanapun, hasil dari simulasi sahaja sukar untuk membuktikan keberkesanannya dalam senario realistik. Di samping itu, kajian IEEE 802.11e berdasarkan platform simulasi tidak dapat disahkan tepat berbanding keputusan yang diperolehi dari kajian sebenar. Bahagian pertama dalam tesis ini telah dilaksanakan bertujuan untuk menyiasat kesan parameter EDCA terhadap prestasi rangkaian dan pautan kondisi dengan menggunakan perisian sumber terbuka dan perkakasan boleh didapati secara komersial dalam rangkaian mesh sebenar. Kedua karya ini menilaian kaedah yang dicadangkan, skim prioriti adaptif (APS) dengan IEEE 802.11e statik dalam rangkaian mesh sebenar. Keputusan yang diperolehi daripada kerja ini menunjukkan bahawa algoritma DPS boleh meningkatkan prestasi AC tunggal sehingga 9.36% untuk sasaran AC berbanding statik EDCA. Dalam dua scenario AC,peningkatan lebih ketara pada penggunaan barisan, sementara itu dari segi truput pula peningkatan sehingga lebih 9,93% manakala keputusan R-AIFSN pula menunjukkan ketidakselarasan truput.

ACKNOWLEDGMENT

The research work in this thesis was carried under Universiti Teknikal Melaka Malaysia (UTeM) and collaboration with MIMOS Berhad Research Center. The research facilities and equipment was provided by UTeM and MIMOS Berhad. I would like to express my appreciation to my main supervisor Dr. Soo Yew Guan who had guided me throughout this research on my main thesis writing and for his advice and support during this research. I would like to express my special thanks to my co-supervisor, Mr. Khairul Muzzammil Saipullah, who had open the way for me doing master by research. I am also very thankful to my industrial supervisor, Dr. Ng Seh Chun for his guidance, advice and motivation in performing the experiments for this research. Without their continued moral support and concern, this thesis would not have been presented here.

Besides that, thanks to my line manager in MIMOS, Dr. David Chieng for his advice on making this research work practical and guided me towards implementing some of my research outputs in future MIMOS' products. Also many thanks to my lecturer, Dr. Lim Kim Chuan, who have helped, guided and his willingness to do the knowledge sharing with me regarding this research. Finally, I would like to extend my gratitude to everyone who have been directly and indirectly invovled in the successful completion of this thesis especially to my wife, Nur Aidah Razman who has very understanding and keep giving motivation.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATION

AC	-	Access Category
ACK	-	Acknowledgement
AIFS	-	Arbitrary Interframe Spacing
AP	-	Access Point
APS	-	Adaptive Prioritization Scheme
BSA	-	Basic Service Area
BSS	-	Basic Service Set
CAP	-	Controlled Access Phase
CFP	-	Contention Free Period
CP	-	Contention Period
CSMA	-	Carrier Sense Multiple Access
CSMA/CA	-	CSMA with Collision Avoidance
CSMA/CD	-	CSMA with Collision Detection
CTS	-	Clear to Send
CW	-	Contention Window
DCF	-	Distributed Coordination Function
DIFS	-	Distributed Interframe Space

DSCP	-	Differentiated Services Code Point
DSSS	-	Direct Sequence Spread Spectrum
EDCA	-	Enhanced Distributed Channel Access
FHSS	-	Frequency Hoping Spread Spectrum
FTP	-	File Transfer Protocol
HC	-	Hybrid Coordinator
HCCA	-	HCF Controlled Channel Access
HCF	-	Hybrid Coordination Function
HWMP	-	Hybrid Wireless Mesh Protocol
IBSS	-	Independent Basic Service Set
IEEE	-	Institute of Electrical and Electronics Engineers
IP	-	Internet Protocol
LAN	-	Local Area Network
MAC	-	Medium Access Control
MCS	-	Modulation and Coding Scheme
MIMO	-	Multiple-input Multiple-output
NAV	-	Network Allocation Vector
OFDM	-	Orthogonal Frequency-Division Multiplexing
OLSR	-	Optimized Link State Routing Protocol
PC	-	Point Coordinator
PCF	-	Point Coordination Function
PHB	-	Per-hop Behaviour
PHY	-	Physical Layer
PIFS	-	PCF Interframe Space

QAM	-	Quadrature Amplitude Modulation
QoS	-	Quality of Service
RTS	-	Request to Send
SDM	-	Spatial Division Multiplexing
SIFS	-	Short Interframe Space
TBTT	-	Target Beacon Transmission Time
TID	-	Traffic Identifier
TS	-	Traffic Stream
TSPEC	-	Traffic Specification
TXOP	-	Transmission Opportunity
UDP	-	User Datagram Protocol
UP	-	User Priority
VoIP	-	Voice over Internet Protocol
WLAN	-	Wireless Local Area Network
WMN	-	Wireless Mesh Network
RTT	-	Round Trip Time
NTP	-	Network Time Protocol
PSNR	-	Peak Signal-to-noise Ratio
TCP	-	Transmission Control Protocol
IBSS	-	Independent Basic Service Set
BATMAN	-	Better Approach To Mobile Adhoc Networking
OS	-	Operating System

LIST OF PUBLICATIONS

Journals:

Anuar, A., Ng, S.C., Ting, A., Chieng, D., Chan, M. L., Soo, Y., and Lim, K.C.,. Tuning of EDCA parameters in 802.11e network – An experimental outcome. – *Submitted to Science Asia on May 2014.*

Conference papers:

Anuar, A., Ng, S. C., Chan, M. L., Torshizi, S. D. S., Chieng, D., Ting, A., Lim, K.C., and Soo, Y. Effects of rate control, bridging and antenna orientation on IEEE 802.11 n link performance: An experimental analysis. In IEEE, *IEEE Malaysia International Conference on Communications (MICC), 2013* (pp. 432-437), November 2013. *(Scopus)*

Anuar, A., Ng, S.C., Ting, A., Chieng, D., Chan, M. L., Soo, Y., and Lim, K.C.,. Tuning of EDCA parameters in 802.11e network – An experimental outcome. *Proceedings of the 3rd International Conference on Computer Science & Computational Mathematics (ICCSCM)* 2014 (pp 160-166).

CHAPTER 1

INTRODUCTION

1.1 Background

Quality of Service (QoS) is a demanding feature in wireless networks. Without QoS all types of traffic will be treated equally and hence real-time or time-critical applications will be affected when traffic congestion occurs. IEEE 802.11e (IEEE, 2005) was introduced in 2005 to provide better QoS for time-critical applications such as real-time video streaming and voice over internet protocol (VoIP) over IEEE 802.11 Wireless Local Area Networks (WLANs) (IEEE, 1999). In order to provide the QoS function, a new medium access control (MAC) scheme called enhanced distributed channel access (EDCA) is introduced. EDCA supports up to eight user priorities mapped into four access categories (ACs), i.e. voice (AC1), video (AC2), best-effort (AC3), and background (AC4). In each AC, there is a transmission queue to buffer the outgoing packets. In EDCA, four new parameters are introduced, i.e. minimum and maximum contention windows (CWmin and CWmax), arbitrary interframe spacing (AIFS) and transmission opportunity limit (TXOP limit). These parameters are used to control the waiting time of each packet before its transmission attempt and the duration allowed to occupy the channel. With EDCA, packets from different ACs are given different transmission priorities.

There is a need to change the EDCA parameters in response to different network conditions so that the network performance can be further optimized. This work therefore mainly focuses on developing an algorithm which is able to adapt the selected EDCA parameters according to network condition so that the traffic from different ACs can fully utilize the channel.

1.2 Problem with IEEE 802.11e

In IEEE 802.11e standard, EDCA parameters are preset with some default values. As shown in Figure 1.1, the default values enforce longer waiting time on the lower priority ACs (i.e. AC3 and AC4), and shorter waiting time on the higher priority ACs (i.e. AC2 and AC1). The Short Interframe Space (SIFS) provides the required interframe spacing in between frame exchanges. As for Arbitration Interframe Space (AIFS), some default values have been chosen with respect to the delay sensitivity of various traffic types. The EDCA parameters cause the lower priority ACs to have lower data transfer rate or throughput as compared with the higher ACs even though only traffics from lower priority ACs exists in the network. When this happens, the bandwidth is considered wasted.

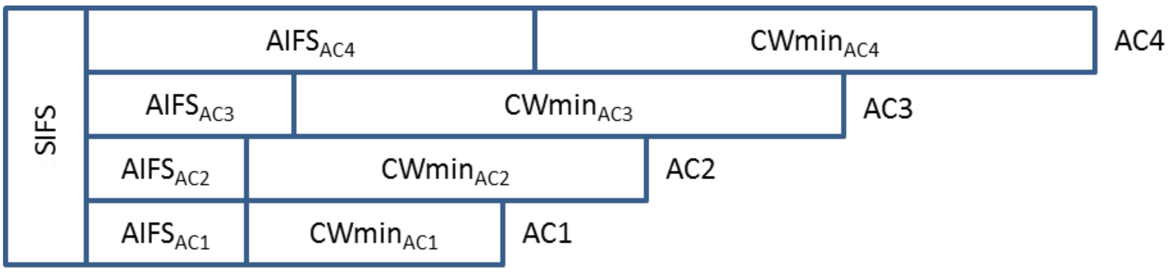

Figure 1.1 Different EDCA parameters values for different ACs

Bandwidth wastage is the condition where the channel not fully utilized by the network traffic. One way to overcome bandwidth wastage problem is to adaptively assign the traffic from lower AC to higher AC based on the network condition.

Although a significant amount of works have been done on improving network performance through dynamic EDCA parameters optimization, they were mostly carried out in a simulated environment. Very few works are actually looking into dynamic adaption of EDCA parameters value in the actual hardware in real-time. In fact, most commercial on the shelf and/or open source wireless platforms or systems are not capable of supporting such dynamic manipulation of EDCA parameters, especially for wireless nodes operating in ad hoc mode. Fortunately due to the work done by (Simon, 2012), real-time modifications of EDCA parameter are made possible in Linux based hardware with only one single command.

Since IEEE 802.11e can only provide four ACs which are preset at the source, mapping between IP layer QoS (DiffServ) and MAC layer QoS (IEEE 802.11e) is necessary in order to provide an end to end QoS. Since DiffServ is defined at the IP layer, user may tag the incoming traffic based on its IP address, port number so it can be assigned to the desired AC supported by IEEE 802.11e. As shown in Figure 1.2, data traffic from the higher layer is passed down to the MAC layer and during the process its DiffServ value is mapped into the respective IEEE 802.11e's AC. Some of the commercial routers support this DiffServ and IEEE 802.11e mapping but for the open source community (Linux), such mapping is limited to the certain hardware drivers, protocols, and Linux distributions. The detail operation of the IP layer and MAC layer QoS mapping in Linux open source is further discussed in Chapter 2.

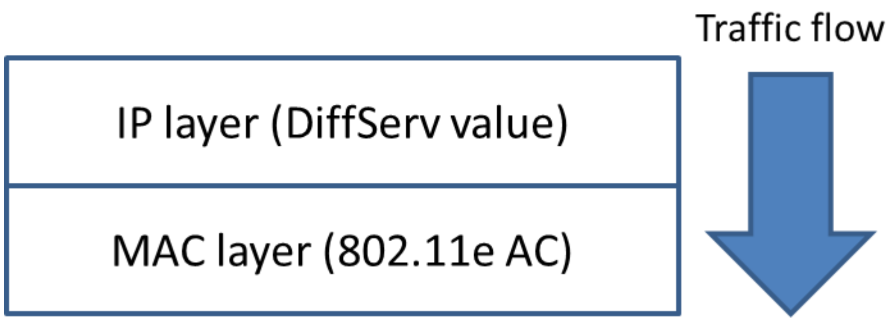

Figure 1.2 Mapping between IP layer DiffServ value and MAC layer 802.11e AC

1.3 Contribution

This research work provides better QoS for the wireless network specifically for multiple user networks with different types of traffics.

In this work, an Adaptive Prioritization Scheme (APS) is proposed for IEEE 802.11e WLANs, which can adaptively optimize IEEE 802.11e EDCA parameters in order to provide QoS according to network traffic condition. This work shows that the proposed scheme provides more granular and consistent performances as compared with static EDCA parameters used in the standard IEEE 802.11e. It also demonstrates better performances than the scheme proposed by (Gaur, S. & Cooklev, T., 2007), which is the closest scheme to APS according to existing literature.

Other contributions of this research work include better understanding of the effects of IEEE 802.11e parameters on the network performance under different loading scenarios. Such knowledge is critical when designing and implementing APS in the real hardware.

1.4 Problem Statement

During traffic congestion, AC3 has a lower maximum transfer rate as compared with AC2. Even there is only AC3 traffic in the network, the default EDCA parameters value for AC3 forces the packet with AC3 to wait longer than the packet with AC2. Furthermore, static EDCA parameters may lead to unsatisfactory performance for some stations and data streams. Shifting the traffic from lower priority AC to higher priority AC may increase the maximum transfer rate but in turn raises some other issues which will be explained later. The detail scenario is depicted in Figure 1.3. As shown, both file transfer protocol (FTP) traffic and user datagram protocol (UDP) traffic flow to node A as AC3 traffic. Due to that the throughput for both traffics are divided equally. At node A, since