UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Information and Communication Technology

PERFORMANCE IMPROVEMENT OF MAC LAYER IN TERMS OF REVERSE DIRECTION TRANSMISSION BASED ON IEEE 802.11N

Ali Ahmad Milad

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ALI AHMAD MILAD

A thesis submitted in fulfillment of the requirements for the degree of doctor of philosophy

Faculty of Information and Communication Technology

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DECLARATION

I declare that this thesis entitled "Performance Improvement of MAC layer in terms of Reverse Direction Transmission Based on IEEE 802.11n " 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.

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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 Doctor of Philosophy.

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

DEDICATION

To my beloved mother and father

ABSTRACT

Medium access control (MAC) layer is one of the most prominent topics in the area of wireless networks. MAC protocols play a big role in improving the performance of wireless networks, and there are many challenges that have been addressed by the researchers to improve the performance of MAC layer in the family of IEEE 802.11. The physical data rate in IEEE 802.11n may reach 600 Mbps, this high data rate does not necessary transform into good performance efficiency, since the overhead at the MAC layer signifies that by augmenting PHY rates the effectiveness is automatically reduced. Therefore, the main objective of next generation wireless local area networks (WLANs) IEEE 802.11n is to achieve high throughput and able to support some applications such as TCP 100 Mbps and HDTV 20 Mbps and less delay. To mitigate the overhead and increase the MAC efficiency for IEEE 802.11n, one of the key enhancements at MAC layer in IEEE 802.11n is a reverse direction transmission. Reverse direction transmission mainly aims to accurately exchange the data between two devices, and does not support error recovery and correction; it drops the entire erroneous frame even though only a single bit error exists in the frame and then causes a retransmission overhead. Thus, two new schemes called (RD-SFF) Reverse Direction Single Frame Fragmentation and (RD-MFF) Reverse Direction Multi Frame Fragmentation are proposed in this study. The RD-SFF role is to aggregate the packets only into large frame, while RD-MFF aggregate both packets and frames into larger frame, then divided each data frame in both directions into subframes, Then it sends each subframe over reverse direction transmission. During the transmission, only the corrupted subframes need to be retransmited if an error occured, instead of the whole frame. Fragmentation method is also examined whereby the packets which are longer when compared to a threshold are split into fragments prior to being combined. The system is examined by simulation using NS-2. The simulation results show that the RD-SFF scheme significantly improves the performance over reverse direction transmission with single data frame up to 100%. In addition, the RD-MFF scheme improvers the performance over reverse direction transmission with multi data frames up to 44% based on network condition. These results show the benefits of fragmentation method in retransmission overhead and erroneous transmission. The results obtained by ON/OFF scheme takes into account the channel condition to show the benefits of our adaptive scheme in both ideal as well as erroneous networks. In conclusion, this research has achieved its stated objective of mitigation the overhead and increase the MAC efficiency for IEEE 802.11n. Additionally, the proposed schemes show a significant improvement over the reverse direction in changing network conditions to the current network state.

ABSTRAK

Lapisan Kawalan Capaian Media (KCM) adalah salah satu topik yang paling penting dalam bidang rangkaian wayarles. Protokol-protokol MAC memainkan peranan besar dalam meningkatkan prestasi rangkaian wayarles, dan pelbagai cabaran pernah dikemukakan oleh para penyelidik bagi meningkatkan prestasi lapisan Kawalan Capaian Media (MAC) dalam kumpulan IEEE 802.11. Kadar data fizikal dalam IEEE 802.11n boleh mencapai 600 Mbps. Kadar data yang tinggi ini tidak semestinya ditransformasikan ke efisiensi berprestasi tinggi. Ini adalah kerana overhed di lapisan MAC menunjukkan bahawa dengan penambahan kadar lapisan fizikal (PHY), keberkesanan secara automatiknya berkurangan. Oleh itu, objektif utama bagi rangkaian setempat wayarles (WLANs) generasi akan datang IEEE 802.11n adalah untuk mencapai daya pemprosesan yang tinggi dan menyokong aplikasi-aplikasi seperti TCP 100 Mbps and HDTV 20 Mbps serta mengurangkan penundaan. Untuk mengurangkan overhed and meningkatkan efisiensi MAC untuk IEEE 802.11n, salah satu faktor peningkatan di lapisan MAC dalam IEEE 802.11n adalah transmisi arah songsang. Transmisi arah songsang bertujuan menukar data antara dua peranti dengan tepat, dan tidak menyokong pemulihan dan pembetulan ralat. Ia akan mengabaikan keseluruhan rangka yang mengelirukan walaupun disebabkan hanya oleh ralat bit dalam rangka dan menyebabkan overhed transmisi kembali. Maka, dua skema baru yang dikenali sebagai Fragmentasi Rangka Tunggal Arah Songsang (RD-SFF) dan Fragmentasi Berbilang Rangka Arah Songsang (RD-MFF) dicadangkan dalam penyelidikan ini. Peranan RD-SFF adalah untuk mengumpulkan paket-paket dalam rangka yang besar, manakala RD-MFF mengumpulkan kedua-dua paket dan rangka besar ke dalam rangka yang lebih besar. Kemudian ia membahagikan setiap rangka data dalam kedua-dua arah kepada sub-rangka dan menghantar setiap sub-rangka melalui transmisi arah songsang. Jika berlaku ralat semasa transmisi, hanya sub-rangka yang korup perlu ditransmisikan dan bukan keseluruhan rangka. Kaedah fragmentasi juga diuji di mana paket-paket yang lebih panjang berbanding dengan ambang batas akan dibelah menjadi fragmen-fragmen sebelum digabungkan. Sistem ini diuji menggunakan simulasi NS-2. Keputusan simulasi menunjukkan yang skema RD-SFF dengan jelasnya meningkatkan prestasi berbanding dengan transmisi arah songsang dengan rangka bit tunggal sehingga 100%. Selain itu, skema RD-MFF meningkatkan prestasi berbanding dengan transmisi arah songsang dengan rangka berbilang data sehingga 44% berdasarkan kondisi rangkaian. Keputusan yang diperolehi menunjukkan kelebihan kaedah fragmentasi dalam overhed transmisi semula dan transmisi beralat. Keputusan yang diperolehi melalui skema ON/OFF mempertimbangkan kondisi saluran bagi menunjukkan kelebihan skema penyesuaian ini dalam rangkaian unggul dan rangkaian beralat. Secara kesimpulan, kajian ini telah mencapai objektifnya untuk mengurangkan overhed and meningkatkan efisiensi MAC untuk IEEE 802.11n. Tambahan pula, skema-skema baru yang dicadangkan ini menunjukkan peningkatan yang jelas berbanding dengan arah songsang dalam kondisi rangkaian yang berubah ke kondisi rangkaian semasa.

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LIST OF ABBREVIATION

A-MPDU	Aggregate MAC Protocol Data Unit
A-MSDU	Aggregate MAC Service Data Unit
AC	Access Category
ACK	Acknowledgment
ADDBA	Add Block Acknowledgement
AFR	Aggregation Fragment Retransmission
AP	Access Point
ARQ	Automatic Repeat Request
BA	Block Acknowledgment
BAR	Block Acknowledgment Request
BER	Bit Error Rate
Bi-MCMAC	Bidirectional Multi-Channel MAC
BiPAC	Bidirectional Packet Aggregation and Coding
BT	Bidirectional Transmission
BTA	Block Transmission and Acknowledgment
CBR	Constant Bit Rate
CCK	Complementary Code Keying
CS	Carrier sense
CSMA/CA	Carrier Sense Multiple Access and the Collision Access
CSMA/CD	Carrier Sense Multiple Access and the Collision Detection
CTS	Clear To Send
CW	Contenation Window
DA	Destination Address
DCF	Distributed Coordination Function
DELBA	Delete Block ACK
DIFS	Distributed Inter-Frame Space
EDCA	Enhanced Distributed Channel Access
FCS	Frame Check Sequence

HDTV	High Definition Television
HT	High Throughput
HTC	High Throughput Control
IEEE	Institute of Electrical and Electronics Engineers
IFS	Inter Frame Space
LLC	Logic Link Control
MAC	Medium Access Control
MIMO	Multiple-Input Multiple-Output
MPDU	MAC Protocol Data Unit
MSDU	MAC Service Data Unit
NAV	Network Allocation Vector
NS-2	Network Simulator 2
OFDM	Orthogonal Frequency Division Multiplexing
PHY	Physical
PCF	Point Coordination Functions
PCO	Phased Coexistence operation
PIFS	PCF Inter-Frame Space
PLCP	Physical Layer Convergence Procedure
PPDU	PLCP Protocol Data Unit
PSDU	PLCP Service Data Unit
PSMP	Power saves Multi Poll
QoS	Quality of Service
QBSS	QoS Basic Service Set
QSTA	QoS Station
RA	Receiver Address
RD	Reverse Direction
RDF	Reverse Direction Data Flow
RDG	Reverse Direction Grant
RD-MFF	Reverse Direction - Multi Frame Fragmentation
RD-SFF	Reverse Direction – Single Frame Fragmentation
RED	Randomized, Efficient, and Distributed
RIFS	Reduce Inter-Frame Space
RF	Radio frequency
RTS	Request To Send

SIFS	Short Inter-Frame Space
SA	Sender Address

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1 Milad, A. A., Bin Muhamad Noh, Z., Shibghatullah, A. S., and Algaet, M. A. Design a novel reverse direction transmission using piggyback and piggyback with block ACK to improving the performance of MAC layer based on very high speed wireless lans. Information & Communication Technologies (ICT), 2013 IEEE Conference on; 263-266. (Published).

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CHAPTER 1

INTRODUCTION

1.0 Background

A wireless LAN (WLAN) enables communication between devices by radio waves. WLANs are popular because of their convenience, cost efficiency, ease of installation, and ease of integration with other networks. However, WLANs are undesirable in some circumstances or with some types of applications because of the limitations of this technology. Security, range, speed, and reliability are the obstacles that prevent WLANs from fully competing with wired technology. Successive IEEE 802.11 standards and amendments have been proposed to address these limitations and reengineer wireless concepts in terms of physical and logical aspects.

1.1 Family of IEEE 802.11

Significant developments have recently been achieved in IEEE802.11 WLAN (WG Committee, 2009). WLANs have become popular, and their importance has been realized. IEEE 802.11 WLANs are widely accepted as a technology that matches IEEE 802.3 (high-speed Ethernet) for handheld and portable gadgets. The success of WLAN is attributed to its effectiveness in increasing data transfer rates while maintaining reasonably minimal cost. IEEE 802.11, 802.11b, and 802.11a/g are able to offer data rates of up to 2, 11, and 54 Mbps respectively. Moreover, IEEE 802.11n, a modified version with high throughput and speed improvement, is implemented by the IEEE 802.11 Working Group. IEEE 802.11a, 11b, 11g, 11e, and 11n offer data rates with high speed and diverse physical layer

(PHY) specifications, whereas IEEE 802.11n offers a high throughput instead of high data rates with PHY and improvements in medium access control (MAC) (Jain-Shing 2006).

In IEEE 802.11b Jong-Ok and Murakami (2006) PHY standard specification for WLANs, the 2.4 GHz radio band is available and three channels are supported at 11 Mbps per channel. The PHY standard for WLANs also exists in IEEE 802.11a but has a limited radio band in 5 GHz, thus implying that 802.11a is incompatible with 802.11b/g. Moreover, it includes eight channels and the highest rate of the PHY is approximately 54 Mbps per channel. In IEEE 802.11g, a definite new standard of the PHY for WLANs exists in the 2.4 GHz radio band. The PHY also includes three available channels in 802.11g with a maximum rate of 54 Mbps per channel. Thus, the 802.11g standard can support a variety of orthogonal frequency division multiplexing methods (Ho et al. 2003), (Drilo and Flatz 2003), (Al-Banna et al. 2006), (Al-Banna et al. 2007). However, given its backward compatibility with 802.11b, 802.11g can support the modulation of complementary code keying. Thus, the emergence of IEEE 802.11n technology has significantly supported multimedia applications, such as high definition television (HDTV), at 20 Mbps.

IEEE 802.11e is a MAC layer version that was extended from the 802.11 standard for quality of service (QoS) specifications. Nevertheless, the present 802.11 MAC does not have the capacity to differentiate services because it handles all upper-layer traffic in a similar manner. The utilization of IEEE 802.11-based WLANs has increased to support many applications using TCP, HDTV, and VoIP. Extremely fast speed WLANs is possible and the PHY rate may reach 600 Mbps to obtain high efficiency at a MAC layer (Ferre et al. 2004).

The increase in physical rate can result in an increase in transmission at the MAC link, thus causing an increase in overhead. In IEEE 802.11, the throughput does not scale well with increasing physical rate. However, in IEEE 802.11n, the throughput should achieve 100 Mbps at a MAC layer. To achieve a wide performance enhancement or improvement, the causes MAC of inefficiency should be identified. In this study, we intend to increase the efficiency of IEEE 802.11n-based MAC layer.

1.2 IEEE 802.11n

IEEE 802.11n is a modified version of IEEE 802.11 with high throughput and speed and is used by the IEEE 802.11 Working Group. The primary aim of IEEE 802.11n is to provide high throughput rather than high rates, together with improvements in PHY and MAC (Xiao and Rosdahl, 2003). IEEE 802.11n provides many enhancements to reduce the overhead at the MAC layer. Frame aggregation merges a few frames into one large frame for transmission. Block acknowledgment (BA) is a block of data frames sent to the destination in sequence after the transfer of the block of data. The BA request (BAR) is sent from the sender to identify which frame has been received by the receiver. Thereafter, the BA is sent back to the sender. BA is naturally bidirectional and has a reverse direction (RD) data flow, which helps handle streams in traffic. A good example of this data flow is TCP traffic that has backward TCP ACK flow (Abraham et al. 2005).

1.3 Problem Statement

IEEE 802.11 WLAN has emerged as a dominant technology for wireless communication. In addition to the numerous applications and services over WLANs, the demand for faster and higher bandwidth WLANs has been growing rapidly. Many PHY extensions to the original IEEE 802.11 were specified to increase the data rate and meet these demands.

Most IEEE 802.11n proposals have stated that they endorse a physical data rate up to 600 Mbps. However, these high PHY rates do not necessarily transform into equivalent augmentation throughput at the upper layer because effectiveness is significantly decreased by augmenting PHY rates under MAC layer overhead; this phenomenon is a key function in Figure 1.1 (Ferre et al. 2004), (Xiao and Rosdahl 2003), (Li et al. 2009), (Abichar and Chang 2013), (Saif et al. 2011).

Improving the MAC layer is still insufficient to guarantee the high performance throughput of highly developed multimedia applications (e.g., HDTV, 20 Mbps). Furthermore, corrupted frames using large frame size are caused by packet aggregation, thus causing significant overhead when the channel is noisy (Ni et al. 2004). The whole data frame in the traditional transmission scheme has to be retransmitted even though only one part is lost (Li et al. 2009), (Chatzimisios et al. 2004).

In emerging 802.11n structures, MAC layer ACK frames are transmitted even though only a part of the data frame is missing. Therefore, differentiating frame losses from the error events caused by collisions is important to ensure the proper awareness of MAC layer operations. Similarly, on the basis of the aggregation with fragment retransmission (AFR) scheme, ACK can be lost even if the frame is received correctly. Thus, the AFR behaves similarly to the distributed coordination function (DCF) scheme (Li, 2007).

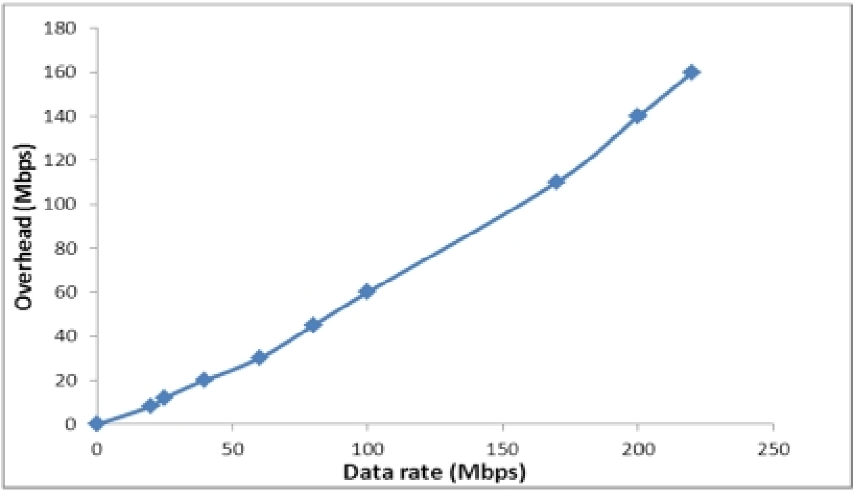

Figure 1.1: Overhead Compared With Data Rate (Xiao, 2004).

The existing bidirectional transmission using the piggyback structure triggered a decrease in the channel effectiveness and increases the delay of frame transmissions (Liu and Stephens, 2005), (Lee et al. 2007), (Mohammad and Muhammad, 2012). Therefore, the existing bidirectional transmission using the piggyback scheme with a single data frame and multi-data frames is still inadequate to guarantee high system performance in the MAC layer.

1.4 Research Objectives

This research mitigates the overhead and increase of MAC efficiency for very-high-speed WLAN IEEE 802.11n. The specific objectives of this study are as follows:

1. Design a new scheme for RD transmission with a single data frame in very-high-speed WLAN IEEE 802.11n.
2. Design a new scheme for RD transmission with multi-data frames in very-high-speed WLAN IEEE 802.11n.
3. Evaluate the performance of the proposal schemes by comparing with previous related works.