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**A STUDY OF QOS SUPPORT FOR REAL
TIME MULTIMEDIA COMMUNICATION
OVER IEEE802.11 WLAN**

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requirements for the degree of
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Abstract

Quality of Service (QoS) is becoming a key problem for Real Time (RT) traffic transmitted over Wireless Local Area Network (WLAN). In this project the recent proposals for enhanced QoS performance for RT multimedia is evaluated and analyzed. Two simulation models for EDCF and HCF protocols are explored using OPNET and NS-2 simulation packages respectively. From the results of the simulation, we have studied the limitations of the 802.11e standard for RT multimedia communication and analysed the reasons of the limitations happened and proposed the solutions for improvement.

Since RT multimedia communication encompasses time-sensitive traffic, the measure of quality of service generally is minimal delay (latency) and delay variation (jitter). 802.11 WLAN standard focuses on the PHY layer and the MAC layer. The transmitted data rate on PHY layer are increased on standards 802.11b, a, g, j, n by different code mapping technologies while 802.11e is developed specially for the QoS performance of RT-traffics at the MAC layer.

Enhancing the MAC layer protocols are the significant topic for guaranteeing the QoS performance of RT-traffics. The original MAC protocols of 802.11 are DCF (Distributed Coordination Function) and PCF (Point Coordinator Function). They cannot achieve the required QoS performance for the RT-traffic transmission. IEEE802.11e draft has developed EDCF and HCF instead. Simulation results of EDCF and HCF models that we explored by OPNET and NS-2, show that minimal latency and jitter can be achieved. However, the limitations of EDCF and HCF are identified from the simulation results. EDCF is not stable under the high network loading. The channel utilization is low by both protocols. Furthermore, the fairness

index is very poor by the HCF. It means the low priority traffic should starve in the WLAN network. All these limitations are due to the priority mechanism of the protocols.

We propose a future work to develop dynamic self-adaptive 802.11e protocol as practical research directions. Because of the uncertainty in the EDCF in the heavy loading, we can add some parameters to the traffic loading and channel condition efficiently. We provide indications for adding some parameters to increase the EDCF performance and channel utilization. Because all the limitations are due to the priority mechanism, the other direction is doing away with the priority rule for reasonable bandwidth allocation.

We have established that the channel utilization can be increased and collision time can be reduced for RT-traffics over the EDCF protocol. These parameters can include loading rate, collision rate and total throughput saturation. Further simulation should look for optimum values for the parameters. Because of the huge polling-induced overheads, HCF has the unsatisfied tradeoff. This leads to poor fairness and poor throughput. By developing enhanced HCF it may be possible to enhance the RI polling interval and TXOP allocation mechanism to get better fairness index and channel utilization. From the simulation, we noticed that the traffics deployment could affect the total QoS performance, an indication to explore whether the classification of traffics deployments to different categories is a good idea. With different load-based traffic categories, QoS may be enhanced by appropriate bandwidth allocation Strategy.

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Glossary

3G	Third-generation
AAS	Arbitrary Antenna System
ABR	Available Bit Rate
AC	Access Categories
ADPCM	Adaptive Differential Pulse Code Modulation
AGC	Automatic Gain Control
AIFS	Arbitrary Inter-Frame Spacing
AP	Access Point
ARQ	Automatic Repeat Request
BAD	Broad-Address
BE	Best Effort
BEB	Binary Exponential Backoff
BER	Bit Error Rate
BK	Background Traffics
BSS	Basic Service Set
BSSID	Basic Service Set Identity
BSSID	Basic Service Set ID
BTS	Base Transaction Station
BWA	Broadband Wireless Access
CA	Collision Avoidance
CAP	Controlled Access Period
CAS	Channel-Associated Signal
CBR	Constant Bit Rate
CCA	Clear Channel Assessment
CCK	Complementary Code Keying
CDMA	Code Division Multiple Access
CELP	Code Excited Linear Prediction
CF	Contention Period
CF	Compensating Fiber
CFP	Contention Free Period
CIR	Channel Impulse Response
CMOS	Complementary Metal Oxide Semiconductor
CP	Contention Period
CPE	Customer Premises Equipment
CRC	Cyclic Redundancy Check
CS/CCA	Carrier Sense/Clear Channel Assessment

CSMA/CD	Carrier Sense Multiple Access with Collision Detection
CW	Contention Window
DA	Destination Address
DARPA	Defense Advanced Research Projects Agency
DBPSK	Differential Binary Phase Shift Keying
DAC	Distributed Admission Control
DCF	Distributed Coordination Function
DDN	Digital Data Network
DE	Discard Eligibility
DED	Discrete Event Driven
DEM	Discrete Events Machine
DFS	Dynamic Frequency Selection
DFS	Distributed Fair Scheduling
DFT	Discrete Fourier Transform
DIFS	DCF Inter-Frame Space
DQPSK	Differential Quadrature Phase Shift Keying
DS	Distribution System
DSS	Distribute Service System
DSSS	Direct Sequence Spread Spectrum
DTIM	Delivery Traffic Indication Map
EDCA	EDCF Admission Control
EDCF	Enhance DCF
EENAD	End to End Network Architecture Design
ERP	Extended Rate PHY
ESS	Extend Service Set
FCC	Federal Communications Commission
FCS	Frame Check Sequence
FEQ	Frequency Domain Equalizer
FFT	Fast Fourier Transform Algorithm
FHSS	Frequency Hopping Spread Spectrum
FSK	Frequency Shift Keying
FSM	Finite State Machine
FSO	Free Space Optics
FTAM	File Transfer, Access, and Management
FWT	Fast Walsh Transform
GAD	Group-Address
GFSK	Gaussian Frequency Shift Keying
GPRS	General Packet Radio Service
GPS	Generalized Processor Sharing

HC	Hybrid Coordinator
HCCA	HCF Controlled Channel Access
HCF	Hybrid Coordination Function
HEC	Header Error Control
HIPERLAN S	High-Performance Radio Local Area Networks
HomeRF	Home Radio Frequency
HTTP	Hyper Text Transport Protocol
IE	Information Element
IEEE	Institute of Electrical and Electronics Engineering
IETF	Internet Engineering Task Force
IFFT	Inverse FFT
IntServ	Integrated Service
IR	Infra-Red
ISI	Intersymbol interference
ISM	Instrumentation, Scientific, and Medical
ISO	International Organization for Standardization
ITU	International Telecommunication Union
	International Telecommunications Union –
	Telecommunications
ITU-T	
LAN	Local Area Network
LD-CELP	Low Delay CELP
LLC	Link Layer Control
LMDS	Local Multipoint Distribution Service
LOS	Line-of-Sight
LSB	Least Significant Bit
MA	Multiple Access
MAC	Medium Access Control
MIB	Management Information Base
MIMO	Multiple-Input Multiple-Output
MMDS	Multichannel Multipoint Distribution Service
MPDU	MAC Protocol Data Unit
	Network Application Optimization and Deployment
	Analysis
NAODA	
NAV	Network Allocation Vector
NLOS	No-Line-of-Sight
NS	Network Simulation
OFDM	Orthogonal Frequency Division Multiplexing
OSI	Open System Interconnection
PBCC	Packet Binary Convolutional Coding

PC	Point Coordinator
PCF	Point Coordination Function
PDA	Personal Digital Assistants
PDO	Protocol Development and Optimization
PF	Persistence Factor
PHY	Physical Layer
PIFS	Priority Inter-Frame Space
PLCP	Physical Layer Convergence Protocol
PLW	PSDU Length Word
PMD	Physical Medium Dependent
PN	Pseudo-Noise
POTS	Plain Old Telephone Service
PPDU	PLCP Protocol Data Unit
PSDU	PLCP Service Data Unit
PSF	PLCP Signal Field
QAM	Quadrature Amplitude Modulation
QAP	Quality Access Point
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
QSTA	Quality Station
RA	Receiver Address
RF	Radio Frequency
RSI	Required Service Interval
RSVP	Resource Reservation Setup Protocol
RT	Real Time
RTP	Real time Transport Protocol
RTS/CTS	Request to Send/Clear to Send
SA	Source Address
SAD	Single-Address
SAP	Service Access Point
SCFQ	Self-Clocked Fair Queue Model
SFD	Start of Frame Delimiter
SFQ	Start-Time Fair Queuing
SI	Service Interval
SIFS	Short Interframe Space
SLA	Service Level Agreement
SLA	System Literary Analysis
SLSND	System Level Simulation for Network Devices
SNA	System Network Architecture

SNR	Signal-to-Noise Rate
SRTS	Synchronous Residual Time Stamping
STA	Wireless Station
STC	Space Time Code
SWAP	Share Wireless Application Protocol
TA	Transmitter Address
TC	Traffic Classes
TBTT	Target Beacon Transmit Time
TCP	Transport Control Protocol
TDM	Time Division Multiplexing
TDMA	Time Division Multiple Access
TOS	Type of Service
TSPEC	Traffic Specification
TU	Time Unit
TXOP	Transmission Opportunity
UDP	Universal Data Gram Protocol
U-NII	Unlicensed National Information Infrastructure
UWB	Ultra Wide Band
VBR	Variable Bit Rate
VFRAD	Voice Frame Relay Access Device
VINT	Virtual Internet Test-bed
VMAC	Virtual MAC
VOATM	Voice Over Asynchronous Transfer Mode
VOFR	Voice Over Frame Relay
VOIP	Voice Over Internet Protocol
VS	Virtual Source
WAP	Wireless Application Protocol
WEP	Wired Equivalent Privacy
Wi-Fi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access)
WLAN	Wireless Local Area Network
WM	Wireless Medium
WMAN	Wireless Metropolitan Area Network
WPAN	Wireless Personal Area Network

CHAPTER 1

INTRODUCTION

1.1 BACKGROUNDS

With the explosive growth of the IP-based network, Quality of Service (QoS) is becoming a key issue for Real Time (RT) traffic transmitted over Wireless Local Area Network (WLAN).

Because IEEE802.11 technology can provide cheap and flexible wireless access capability, more and more vendors believe that it will play an important role in the future wireless communication system.

In the past, IEEE802.11 just provided better quality of service for the conventional data transmission. After all, WLAN has different architecture against wired LAN: its transmission medium is by radio frequency (RF) or Infra-Red (IR). These results into lower bandwidth and higher loss rate or bite error rate (BER). The original 802.11 standard is designed for best-effort data transmission. However, real-time voice, audio and video traffic are successfully transmitted over wired IP-based network today. It requires *WLAN* to provide good QoS performance for the RT-traffic. More and more people began to research performance of RT-traffic over WLAN with enhanced QoS.

1.2 SCOPE AND OBJECTIVES OF THE THESIS

Figure 1-1 presents the main network protocol architecture. IEEE802.11 WLAN covers Physical layer and the MAC layer of the Data Link layer. The QoS performance of RT-traffic is related with every layer of the network architecture. While this study is focused on the PHY layer and MAC sub-Layer of the OSI (Open System Interconnection) standard.

WLAN PHY layer is required to transmit a bit stream over physical Wireless mediums. The physical layer has two sub-layers called PLCP (Physical Layer Convergence Protocol) and PMD (Physical Medium Dependent) [1]. There are three types of physical

layers. Two of them are used a radio frequency and one is for infrared. The PLCP sublayer provides a carrier sense signal, called clear channel assessment (CCA) and provides a common PHY service access point (SAP) independent of transmission technology. The PMD is the layer responsible for the modulation and encoding/decoding of the signal. The PLCP and PMD sub-layers vary based on 802.11 types [2]. There are four basic PHY concepts and building blocks in the different PMDs that each 802.11 PHY provides. They are scrambling, coding, interleaving, symbol mapping and modulation. The different symbol mapping and modulation is the main difference among the IEEE802.11 protocols based PHY layer.

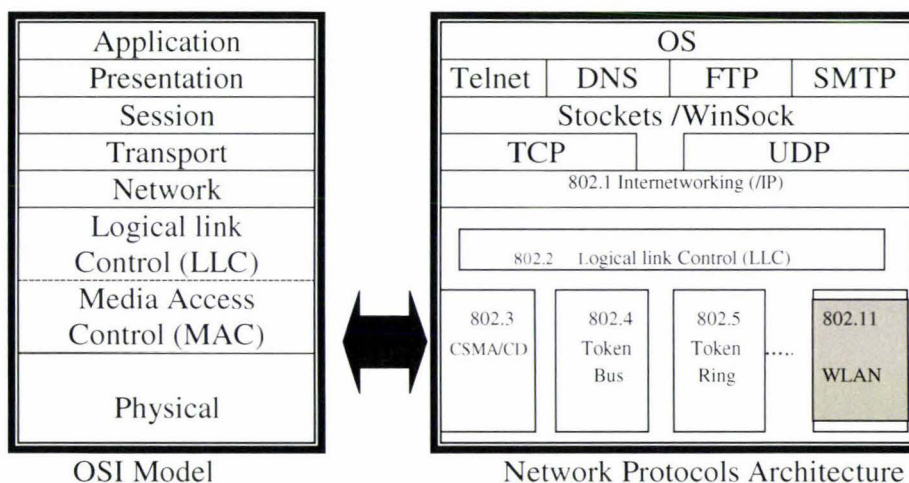


Figure 1-1 802.11 WLAN protocols in Network Architecture

According to Shannon’s Law, the capacity of the signal transmission speed rate is directly proportioned to the transmission bandwidth [3]. It became a base design idea for QoS enhancement exploring the physical layer of WLAN. 802.11b, 802.11a, 802.11g, 802.11h and 802.11n increase the data rate from 1 Mbps to more than 100 Mbps with different symbol mapping and modulation technologies [4].

From figure 1-1, the Data Link layer includes the LLC sub-layer and MAC sub-layer, 802.11 WLAN does not cover the LLC sub-layer. The 802.11 MAC layer provides functionality to allow reliable data delivery for the upper layers over the wireless PHY media. The data delivery itself is based on an asynchronous, best-effort, connectionless

delivery of MAC layer data. The 802.11 MAC provides a controlled access method to the shared wireless media.

Originally, the 802.11 MAC layer mechanism is based on CSMA/CA (Carrier Sense Multiple Access with Collision Avoid). It has two approaches: Distributed Coordination Function (DCF) and Point Coordination Function (PCF) [5]. DCF does not support any QoS guarantees for RT-traffic and PCF has limitations leading to poor RT-traffic QoS performance. Recently, different kinds of QoS enhancement schemes for both infrastructure and ad-hoc modes have been proposed for 802.11 MAC layer. On the basis of these results, the 802.11 group was drafted a protocol 802.11e for RT-traffic QoS over WLAN and final published on 21 November 2005.

Generally, the MAC technology is the key for the QoS performance of RT-traffic over WLAN 802.11[6]. In the WLAN 802.11 family, the 802.11e is being drafted specially to deal with the QoS question.

The main objective of the thesis is to present and evaluate the QoS performance of RT traffic over the IEEE802.11 WLAN, focusing on the MAC layer of protocol. For studying the RT-traffic's QoS enhancement in 802.11WLAN, it gives a survey and analysis for the architecture and the mechanism from current 802.11 WLAN and some QoS enhancement proposals. This thesis attempts to find the limitations of the upcoming 802.11e, proposes and studies some solutions for enhancing the QoS performance of RT-traffic. The main contributions are as follows:

- A critical study of performance evaluation of the RT-traffic over QoS based on the original IEEE802.11 protocols.
- An in-depth analysis of the current proposed ideas for the MAC layer to enhance performance of RT-traffic over WLAN.
- Performance evaluation of the RT-traffic with QoS enhancement for the upcoming 802.11e protocol.
- Analysis and simulation performance of the RT-traffic. Analysis and simulation of the original IEEE802.11MAC protocols and PHY layer protocols for enhancement of QoS.

- Explore the EDCF model by OPNET and the HCF model by NS-2
- Analysis and simulation of the QoS performance of the RT-traffic based on the EDCF and HCF.
- Limitations analysis and resolution proposes of the upcoming 802.11e for RT-traffic QoS performance over WLAN.

In order to cover the above topics, the thesis is divided into eight chapters. The outline of the chapter is given in the next section.

1.3 OUTLINE OF THE THESIS

Chapter 1 provides the technology background and overview of the thesis. It presented the Scope and object and outline of the thesis. The main sub-topics of this thesis are issued. The outline of the thesis is given.

Chapter 2 introduces some detail for the WLAN characteristic. Meanwhile, it provides the basic knowledge for IEEE802.11 and compares the current wireless scheme to illustrate what is the advantage and disadvantages for traffic transmission.

Chapter 3 provides basic concepts of the QoS and RT-traffic used in this thesis. It presents the basic measured factors of QoS in the network for the following chapters. It analyses the QoS performances of RT-traffic against best-effort data traffic. The chapter presents the RT-traffic concept and its QoS requirements. It analyses the detail of the parameters and finally, explains the wired QoS technologies to fetch up the same topic in the next chapter for WLAN.

Chapter 4 describes the issues of WLAN QoS, it illustrates traffic over MAC layer and analyses the existing protocols: DCF and PCF. Finally, based on the mechanisms, it determines the limitations for RT-traffic QoS over WLAN.

Chapter 5 focuses on the QoS enhancement based on 802.11 WLAN. It continues to study MAC layer protocols. Based on the challenges in MAC layer, the chapter analyses

the advantages and disadvantage for some proposed enhancement schemes based on PCF and DCF. In fact, the upcoming 802.11e exactly is based on these proposed schemes. Based on these analyses, the chapter illustrates the upcoming 802.11e for RT-traffic QoS performance. It analyses the mechanism of 802.11e from the AC definition, AIFS, back-off mechanism, TXOP-EDCF and admission control for EDCF. The chapter also analyses the access occur, admission control and the algorithm schedule of 802.11e draft for HCF.

Based on the above knowledge and analysis, the ways are three methods to study the 802.11e physically. The three methods are: mathematical analysis method, experimental method and simulation method. After analyses, we decide to employ the simulation method to study the protocol.

In chapter 6, we explore the models of the EDCF and HCF by OPNET and NS-2 respectively. We simulate the protocols to measure the QoS for RT-traffic performance over WLAN. The chapter focuses on analyzing delay, jitter, and throughput and packet loss rate. These key QoS factors covered by 802.11 protocols without some measures are just for high layer in OSI system. As we know, the RT-traffic are the time-sensitive traffic; delay is the most important factor.

In chapter 7, based on the data of the simulation in chapter 6, we do further analysis for the topic. Because nowadays the upcoming 802.11e is unstable in some cases, the chapter attempts to find the limitations in the 802.11e. By the mathematical model analysis, the chapter presents some relationships among the parameters in the 802.11e mechanism. At the end of this chapter, some prediction of the RT-traffic over WLAN and some proposals for solution to the 802.11e limitations are given.

Chapter 8 gives the conclusion for the thesis. It presents the contributions of this thesis in this research field and gives some research direction for further work related to QoS performance of RT-traffic over 802.11 WLAN.