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

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Kun Qian

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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 uncertainly 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**
HIPERLANS	**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**
ITU-T	**International Telecommunications Union – Telecommunications**
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**
NAODA	**Network Application Optimization and Deployment Analysis**
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 Faire 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.

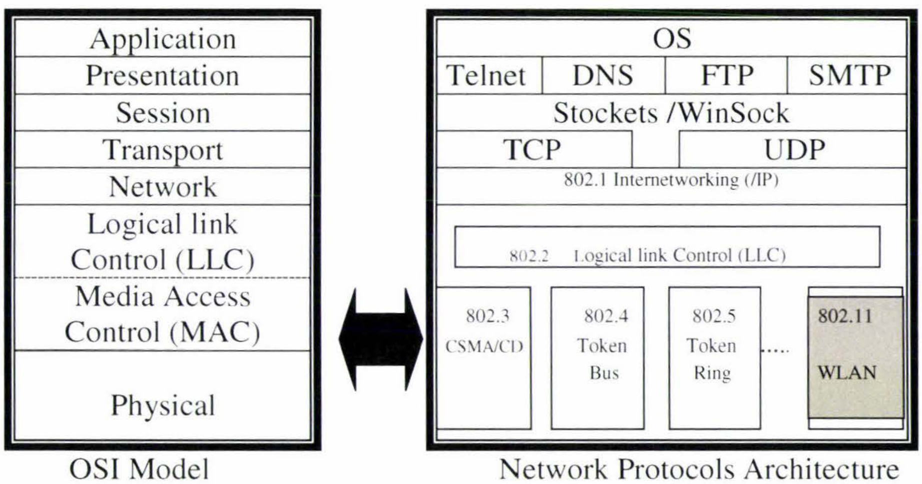

Figure 1-1 802.11 WLAN protocols in Network Architecture

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 finial 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 OoS 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.