



Faculty of Information and Communication Technology

**NETWORK ENTRY PHASE OPTIMIZATION FOR WIMAX
NETWORK**

Mohamad Firdaus Bin Ghazali

Master of Science in Information and Communication Technology

2014

NETWORK ENTRY PHASE OPTIMIZATION FOR WIMAX NETWORK

MOHAMAD FIRDAUS BIN GHAZALI

**A thesis submitted
in fulfillment of the requirements for the degree of Master of Science
in Information and Communication Technology**

Faculty of Information and Communication Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2014

DECLARATION

I declare that this thesis entitle “Network Entry Phase Optimization for WiMAX Network” is the result of my own research except as cited in the references. This thesis has not been accepted for any degree and is not concurrently submitted in submission 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 in Information and Communication Technology.

Signature :

Supervisor Name :

Date :

ABSTRACT

In the last few years, there has been a large growth in wireless broadband communication including Worldwide Interoperability for Microwave Access (WiMAX) technologies. The network entry process in WiMAX is the first process for Subscriber Station (SS) to join the WiMAX network. It referred to the early procedure performed by SS to register with Base Station (BS) that controls the WiMAX network. Scanning to ranging procedure is part of several steps associated with network entry process. The problem of long channel scanning and collision in ranging process can lead to the delay to the access time for initialization and recovery of service between SS and BS connection. Most of the current approaches are focused on reducing the scanning time and optimizing the ranging process but nearly everyone has ignored the influence of system parameters setting. Through this research, a technique is proposed to be used for IEEE 802.16 WiMAX standard with consideration on WiMAX network entry system parameter settings. The simulation environment has been set up to test different configuration condition in WiMAX environment. The intention is to investigate and make recommendation for necessary configuration for IEEE 802.16 standard. Simulation are done using ns-3 simulator and the findings are presented. Simulation results indicate proposed optimum key parameter value of DCD Interval, UCD Interval and Initial Ranging Interval with effect on QoS parameters that will allow the WiMAX network to operate in a higher level of performance and environments.

ABSTRAK

Dalam beberapa tahun kebelakangan ini, telah terdapat pertumbuhan yang ketara di dalam bidang komunikasi jalur lebar tanpa wayar termasuk bagi teknologi Operasi Merentasi Seluruh Dunia bagi Akses Gelombang Mikro (WiMAX). Proses kemasukan dalam rangkaian WiMAX adalah proses pertama untuk Stesen Pelanggan (SS) menyertai rangkaian WiMAX. Ia merujuk kepada prosedur awal yang dilakukan oleh SS untuk mendaftar dengan Stesen Pangkalan (BS) yang mengawal rangkaian WiMAX. Prosedur pengimbasan hingga peluasan ialah sebahagian dari beberapa langkah yang berkaitan dengan proses kemasukan dalam rangkaian. Permasalahan pengimbasan saluran yang berpanjangan dan pelanggaran dalam proses peluasan boleh membawa kepada kelewatan masa akses bagi pengawalan dan pemulihan perkhidmatan antara sambungan SS dan BS. Kebanyakan pendekatan terkini tertumpu kepada mengurangkan masa pengimbasan dan mengoptimunkan proses peluasan tetapi hampir semua mengabaikan pengaruh penetapan parameter sistem. Melalui kajian ini, teknik dicadangkan untuk digunakan bagi standard IEEE 802.16 WiMAX ialah dengan mempertimbangkan penetapan parameter sistem pada kemasukan rangkaian WiMAX. Persekitaran simulasi telah diadakan untuk menguji keadaan konfigurasi yang berlainan dalam persekitaran WiMAX. Tujuannya adalah untuk menyiasat dan membuat cadangan untuk tatarajah yang diperlukan untuk standard IEEE 802.16. Simulasi dilakukan menggunakan simulator ns-3 dan penemuan dibentangkan. Keputusan simulasi menunjukkan nilai parameter optimum bagi Selang DCD, Selang UCD dan Selang Pengantara Awal yang dicadangkan dengan kesannya kepada parameter QoS yang akan membolehkan rangkaian WiMAX beroperasi di tahap prestasi dan persekitaran yang lebih baik.

ACKNOWLEDGEMENT

I would like to express appreciation to my supervisors Dr. Abdul Samad Shibghatullah, Assoc. Prof. Dr. Burairah Hussin and Prof. Dr. Shahrin Sahib for their guidance and excellent supervision. Special thanks to the staff in Faculty of Information and Communication Technology at Universiti Teknikal Malaysia Melaka for facilitating the process and for helping me throughout my research.

Many thanks to current and former fellow researchers of the Research and Development Lab of Faculty of Information and Communication Technology, especially Najwan, Taqwan, Fikri, Sandy, Fahmi, Mohamad and Affandy for their assistance in my research work.

Finally, I would like to extend my greatest indebtedness to my family, especially my mother, Fauziah Ab. Rahman for supporting my academic ambition and for continuous encouragement throughout my studies.

TABLE OF CONTENTS

DECLARATION	i
APPROVAL	ii
ABSTRACT	iii
ABSTRAK	iv
ACKNOWLEDGEMENT	vii
TABLE OF CONTENTS	viii
LIST OF TABLES	x
LIST OF FIGURES	xi
LIST OF EQUATIONS	xii
LIST OF APPENDICES	xv
LIST OF ABBREVIATIONS	
LIST OF PUBLICATIONS	
 CHAPTER	
1. INTRODUCTION	1
1.1 Background Introduction	1
1.2 Background of the Research Problem	2
1.2.1 What May Help	3
1.3 Research Aim and Objectives	4
1.4 Research Methodology	5
1.5 Thesis Outline	8
1.6 Summary	9
 2. LITERATURE REVIEW	11
2.1 Introduction	11
2.1.1 Chapter Objective	11
2.1.2 Chapter Outline	11
2.2 The WiMAX MAC Layer	12
2.2.1 MAC Common Part Sub Layer	14
2.2.2 Network Entry and Initialization	14
2.2.3 Initial Scanning for Channel	15
2.2.4 Ranging	20
2.3 The Scanning and Ranging Problem in WiMAX Network Entry	20
2.3.1 Long Channel Scanning	21
2.3.2 Collision in Ranging Process	21

2.4 The Current Works on WiMAX Network Entry	22
2.4.1 Reduce Scanning Time	23
2.4.2 Optimization of Ranging Process	27
2.4.3 Others	30
2.4.4 Critiques of the Current Approaches	31
2.5 Research Question	32
2.6 Summary	33
3. THE PROPOSED TECHNIQUE	34
3.1 Introduction	34
3.1.1 Chapter Objective	35
3.1.2 Chapter Outline	35
3.2 Issues in Proposed Technique	35
3.2.1 Relationship between Network Entry and WiMAX System Parameter Setting	36
3.2.2 How the WiMAX System Parameter affect the WiMAX Network Performance	36
3.3 Overview of the Proposed Technique	36
3.3.1 DCD Interval modifications	37
3.3.2 UCD Interval modifications	38
3.3.3 Initial Ranging modifications	40
3.4 Summary	41
4. SIMULATION ENVIRONMENT EXPERIMENTS	42
4.1 Introduction	42
4.1.1 Chapter Objective	42
4.1.2 Chapter Outline	42
4.2 Network Simulation	43
4.3 Network Simulator	45
4.3.1 Network Simulator 3 (ns-3)	45
4.4 NS-3 WiMAX Module	46
4.4.1 DCD and UCD messages	51
4.4.2 Network Entry and Initialization	52
4.5 IEEE 802.16 Network Simulation Scenario Setup	54
4.5.1 Simulation Scenario	56
4.5.2 Evaluation Setup	57
4.5.3 Simulation Parameters	58
4.6 Evaluation Metrics	65
4.6.1 Throughput	65
4.6.2 Average Delay	66
4.6.3 Jitter	67
4.6.4 Packet Loss	67
4.7 Summary	68
5. SIMULATION RESULTS AND ANALYSIS	69
5.1 Introduction	69

5.1.1 Chapter Objective	69
5.1.2 Chapter Outline	69
5.2 Results for DCD Interval Configuration	70
5.3 Results for UCD Interval Configuration	76
5.4 Results for Initial Ranging Interval	83
5.5 Summary of Results and Analysis	90
5.6 Summary	93
 6. SUMMARY AND CONCLUSION	 94
6.1 Introduction	94
6.2 Summary	96
6.3 Conclusion	97
6.4 Summaries of Contributions	98
6.5 Limitations of Research	99
6.6 Further research	99
 REFERENCES	 101
 APPENDICES	 113

LIST OF TABLES

TABLE	TITLE	PAGE
3.1	DCD Interval Parameters	39
3.2	UCD Interval Parameters	40
3.3	Initial Ranging Interval Parameters	41
4.1	Comparison of link-level and system level simulation tools	44
4.2	Serviced layer by each simulator	44
4.3	Modulation and coding rates and corresponding data rate	54
4.4	Simulation Fixed Parameters	69
4.5	Simulation Variables Parameters	60
4.6	Set of Experiment for DCD Interval	61
4.7	Set of Experiment for UCD Interval	62
4.8	Set of Experiment for Initial Ranging Interval	63
4.9	Set of Experiment for New Proposed Optimum Value with Effect on QoS	63
5.1	New Propose Value with Effect on QoS Parameters	90

LIST OF FIGURES

FIGURE	TITLE	PAGE
1.1	Research Methodology	7
1.2	Summary of Chapter One	10
2.1	IEEE 802.16 MAC Layer	13
3.1	The Structure of Chapter Three	35
3.2	The Proposed Technique for WiMAX Network Entry Phase Optimization	37
4.1	Class Diagram of IEEE 802.16 WiMAX Module	48
4.2	IEEE 802.16 MAC Frame	50
4.3	Block Diagram of NS-3 WiMAX Module	51
4.4	Simulation Experiment Methodology	55
4.5	Point to Multipoint WiMAX structure	56
4.6	Simulation Setup for Set of Experiments	64
4.7	Simulation Setup Topology	64
4.8	Simulation of DCD Interval, UCD Interval and Initial Ranging Interval	65
5.1	Variation of Throughput to DCD Interval	70
5.2	Variation of Delay for DCD Interval	71
5.3	Variation of Jitter for DCD Interval	71
5.4	Variation of Packet Loss for DCD Interval	72
5.5	Relationship between Throughputs and DCD Interval	72
5.6	Relationship between Average Delay and DCD Interval	74
5.7	Relationship between Average Jitter and DCD Interval	75
5.8	Relationship between Packet Loss and DCD Interval	76
5.9	Variation of Throughput for UCD Interval	77

5.10	Variation of Delay for UCD Interval	77
5.11	Variation of Jitter for UCD Interval	78
5.12	Variation of Packet Loss for UCD Interval	79
5.13	Relationship between Throughput and UCD Interval	79
5.14	Relationship between Average Delay and UCD Interval	80
5.15	Relationship between Average Jitter and UCD Interval	81
5.16	Relationship between Packet Loss and UCD Interval	83
5.17	Variation of Throughput for Initial Ranging Interval	84
5.18	Variation of Delay for Initial Ranging Interval	84
5.19	Variation of Jitter for Initial Ranging Interval	85
5.20	Variation of Packet Loss for Initial Ranging Interval	85
5.21	Relationship between Throughput and Initial Ranging Interval	86
5.22	Relationship between Average Delay and Initial Ranging Interval	87
5.23	Relationship between Average Jitter and Initial Ranging Interval	88
5.24	Relationship between Packet Loss and Initial Ranging Interval	89
5.25	Effect on Throughput	91
5.26	Effect on Average Delay	92
5.27	Effect on Average Jitter	92
5.28	Effect on Packet Loss	93

LIST OF EQUATIONS

EQUATION	TITLE	PAGE
Equation 1	Throughput Calculation	66
Equation 2	Average Delay	66
Equation 3	Average Jitter	67
Equation 4	Packet Loss	67

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	The script for ns-3 used for PMP network environment	113
B	The script for ns-3 used for BS configurations	120
C	The script for ns-3 used for UDP based video streaming configurations	145
D	Screenshot of Sample Transmitted Packets from ns-3 Simulation	149
E	Screenshot of Sample Received Packets from ns-3 Simulation	150

LIST OF ABBREVIATIONS

AAS	Adaptive Antenna System
AMC	Adaptive Modulation and Coding
ATM	Asynchronous Transfer Module
BE	Best Effort
BPSK	Binary Phase Shift Keying
BRH	Bandwidth Request Header
BS	Base Station
BW	Bandwidth
BWA	Broadband Wireless Access
CBR	Constant Bit Rate
CC	Convolutional Coding
CID	Connection Identifier
CP	Cyclic Prefix
CQICH	Channel Quality Indicator
CR	Contention Ratio
CRC	Cyclic Redundancy Check
CS	Convergence Sublayer
CTC	Convolutional Turbo Coding
DAC	Digital to Analogue Converter
DCD	Downlink Channel Descriptor
DL	Downlink
FCH	Frame Control Header
FDD	Frequency Division Duplex
FEC	Forward Error Correction
FFT	Fast Fourier Transform
FRF	Frequency Reuse Factor

FTP	File Transfer Protocol
FUSC	Fully Used Sub-Carrier
GM	Grant Management
GMH	Generic MAC Header
GSM	Global System for Mobile communications
HARQ	Hybrid Automatic Repeat Request
HHO	Hard Hand-Off
HSPA	High Speed Packet Access
HTTP	Hyper Text Transfer Protocol
IE	Information Element
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
ISI	Inter-Symbol Interference
LOS	Line Of Sight
LTE	Long Term Evolution
MAC	Medium Access Control
MAP	Media Access Protocol
MAU	Minimum Allocation Unit
MDHO	Macro Diversity Hand Over
MIMO	Multiple Input Multiple Output
NF	Noise Figure
NLOS	Non Line-of-Sight
OCR	Overall Coding Rate
OFDM	Orthogonal Frequency Division Multiplex
OFDMA	Orthogonal Frequency Division Multiple Access
OSR	Over Subscription Ratio
P2P	Peer to Peer
PDU	Packet Data Unit
PHY	Physical Layer Protocol
PL	Path Loss
PUSC	Partially Used Sub-Carriers
QAM	Quadrature Amplitude Modulation

QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
RF	Radio Frequency
RSSI	Received Signal Strength Indicator
rtPS	Real Time Polling Service
SDU	Service Data Unit
SIMO	Single Input Multiple Output
SNIR	Signal to Noise + Interference Ratio
SNR	Signal to Noise Ratio
SS	Subscriber Station
TDD	Time Division Duplex
TDM	Time Division Multiplexing
UCD	Uplink Channel Descriptor
UL	Uplink
UMTS	Universal Mobile Telephone System
VBR	Variable Bit Rate
VoIP	Voice over IP
WiMAX	Worldwide Interoperability for Microwave Access

LIST OF PUBLICATIONS

Mohamad Firdaus Ghazali, Abdul Samad Shibghatullah and Shahrin Sahib. (2010). WiMAX: Network Entry Phase Optimization for Bandwidth Improvement Solution. 4th International Symposium on Broadband Communication, ISBC 2010, Melaka, Malaysia, 11 – 14 July 2010.

Mohamad Firdaus Ghazali, Abdul Samad Shibghatullah and Shahrin Sahib. (2010). Investigating the Network Entry Phase Optimization in WiMAX Network. Seminar of Information Technology 2010, SIT 2010, Melaka, Malaysia. 27 October 2010.

CHAPTER 1

INTRODUCTION

1.1 Background Introduction

The Worldwide Inter-operability for Microwave Access (WiMAX) is a telecommunication technology based on IEEE 802.16 standard (IEEE 2012). WiMAX supports two types of network topologies which is Point-to-Multipoint (PMP) and Mesh (Kejie Lu et al. 2008). In PMP, the link connection is only between Base Station (BS) and Subscriber Station (SS). The standard was designed to evolve with media access control (MAC) layer consists of three sub layers. They are the service specific convergence sub layer (CS), MAC common part sub layer (CPS), and the security sub layer (Maode Ma and Yan Zhang 2008).

The main functionalities of the MAC CPS are including network entry, connection management, Quality of Service (QoS) control, air-link control, Protocol Data Unit (PDU) operation, mobility and power management, and multicast and broadcast service (Ming Wu, Fei Wu, and Changsheng Xie 2008). This thesis is particularly concern with network entry.

Network entry process as part of MAC CPS sub layer is the first step for Subscriber Station (SS) joining the WiMAX network. It referred to the early procedure subscriber SS perform to register themselves with the Base Station (BS) that controls the 802.16 network (Bum-Gon Choi et al. 2009). There are several steps associated with network entry such as scanning to ranging, intersection of SS's and BS's capabilities, authentication and

authorization, SS registration and connection establishment (Pero Latkoski and Borislav Popovski 2009).

The scanning to ranging steps usually affected with delay and service disruptions between SS and BS. This is caused by long channel scanning and collision in ranging process. This research focuses on the mandatory steps of scanning to ranging (Pero Latkoski and Borislav Popovski 2009) and propose a WiMAX system parameter setting to manage the effect of long channel scanning and collision in ranging process. The relationship between scanning to ranging steps and WiMAX system parameters setting will be considered. Assessment on WiMAX parameter setting has been used in other problem domain such as Denial of Service (DoS) vulnerabilities of WiMAX network (Juan Deng, Richard R. Brooks, and James Martin 2012), and geolocating of WiMAX station based on timing adjustment ranging parameter (Don E. Barber Jr. 2009).

1.2 Background of the Research Problem

The problem during scanning to ranging steps in network entry will degrade the access time for initialization and recovery of service in WiMAX network. For example, a lengthy channel scanning will causes a service disruptions between the SS and BS (Jae-Kark Choi, Nan Hao, and Sang-Jo Yoo 2008) while the collision in ranging will lead to disconnection between SS and BS (Lidong Lin, Bo Han, and Weijia Jia 2006). As part of functionalities mechanism for network entry in MAC CPS, this could result unexpected delay and under utilization of WiMAX link (Hai L. Vu and Sammy Chan 2008).

Thus, how the effect of long channel scan and collision in ranging process during scanning to ranging steps in network entry is managed? One method is by “reduce scanning

time” (Zdenek Becvar and Pavel Mach 2010) and another is “optimization of ranging process” (Lidong Lin et al. 2007). Reducing scanning time approaches have had success in reduce a number of channels to scan so that fast scanning is achieved (Jae-Kark Choi, Nan Hao, and Sang-Jo Yoo 2008) and optimization of ranging process approaches was appealing in term of optimizing the connection probability and average connection delay (Namsuk Lee et al. 2010).

Other approaches also exist such as to upgrade the IEEE 802.16 protocol performance regarding the delay during subscriber network entry process (Pero Latkoski and Borislav Popovski 2009), analyzing the collision probability (Ben-Jye Chang, Ying-Hsin Liang, and Sung-Ju Hsieh 2010) and analytical modeling of network entry process (Matthias Hollick et al. 2007).

Most of the current approaches are primarily focused on modification of scanning and ranging procedure. All of these approaches correspond to the IEEE 802.16 standard but most of them are not easily implemented and have ignored the ability of WiMAX system parameter setting. Most of them also not considered to implicate with better communication system’s QoS for WiMAX network.

To the best of our knowledges, there are only 2 works of (Pero Latkoski and Borislav Popovski 2009) and (Matthias Hollick et al. 2007) that look at influence of WiMAX protocol parameter during network entry to deal with delay problem caused by long channel scanning and collision in ranging process.

1.2.1 What May Help?

The overview of the current approaches has shown that while these approaches may be relevant for the associated environments, they do not provide solutions that could help in both

process of scanning and ranging in WiMAX network entry. The question is, what is the appropriate technique that can be used to relate the specified process of scanning to ranging in network entry that can deal with the problem of long channel scanning and collision in ranging process?

Reduce the channel scan approaches are able to achieve a fast scanning process but this approaches may not guarantee SS to acquire precise information for association with BS. Optimization of ranging process may improve the connection but it will sometimes disregard the performance of WiMAX network traffic flows.

The main characteristic for a solution that we are looking for is the ability to be easily modified WiMAX network entry process. The capabilities of WiMAX system parameters settings, especially related to WiMAX network entry process is matched with our requirements. Thus, in this research we propose evaluate to WiMAX system parameters with consideration to scanning to ranging steps in WiMAX network entry. Details of the specified WiMAX network entry process are discussed in Chapter Two.

1.3 Research Aim and Objectives

The process of designing an efficient system model for network entry phase calls for study of innovative and useful techniques that can improve IEEE 802.16 networks. The aim of this research therefore is to predict the effect and influence of significant protocol parameters for joining the network. By doing so, it should show that appropriate protocol parameters are crucial for optimization of network entry process. The work in this research will focuses on the following objectives:

1. The first objective is to determine and gather information the current approaches in reducing the scanning time and optimize the ranging process of WiMAX network entry to tackle the problem of scanning to ranging steps delay. The reason for this is to learn from current approaches the mechanism in dealing with the issue of WiMAX network entry phase with regards to scanning to ranging steps.
2. The second objective is to propose a solution technique that can improve the effect of long channel scanning and collision in ranging process for scanning to ranging steps in WiMAX network entry phase. The aim is to propose a modification to the original setup of IEEE 802.16 system parameters setting.
3. The third objective is to analyze the proposed technique whether it can manage the problem of long channel scanning and collision in ranging process while improve the WiMAX system.

1.4 Research Methodology

The research methodology used in this research to accomplish the requirements for this thesis will include as follow as summarized in Figure 1.1:

1. The literature survey through related research is used to obtain information IEEE 802.16 network entry and initialization process capabilities. The information on delay of scanning, synchronization, and ranging process in WiMAX network entry phase and current approaches to deal with long channel scanning and collision in ranging is