UNIVERSITI PUTRA MALAYSIA

IMPROVEMENT OF CENTRALIZED ROUTING AND SCHEDULING USING CROSS-LAYER DESIGN AND MULTI-SLOT ASSIGNMENT IN WIMAX MESH NETWORKS

ALI ZUHAIR ABDULAMEER AL-HUMAIRI

IMPROVEMENT OF CENTRALIZED ROUTING AND SCHEDULING USING CROSS-LAYER DESIGN AND MULTI-SLOT ASSIGNMENT IN WIMAX MESH NETWORKS

By

Ali Zuhair Abdulameer Al-Humairi

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

April 2009

Dedicated to

My dearest Parents and Brothers

For their extraordinary love and their endless care

Thank You

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

IMPROVEMENT OF CENTRALIZED ROUTING AND SCHEDULING USING CROSS-LAYER DESIGN AND MULTI-SLOT ASSIGNMENT IN WIMAX MESH NETWORKS

By

Ali Zuhair Abdulameer Al-Humairi

April 2009

Chairman: Associate Professor Nor Kamariah Noordin, PhD

Faculty : Engineering

WiMAX (Worldwide Interoperability for Microwave Access) based wireless mesh network (WMN) aims to provide broadband wireless last-mile access. It is easy to deploy, has high speed data rate for large spanning area and is the key technology for the next generation wireless networking. The WiMAX mesh network is developed with the use of base station (BS) as the main controller for all the subscriber stations (SSs). This thesis proposes an optimized strategy namely cross-layer design in routing algorithms used find the best route for all SSs and scheduling algorithms, used to assign a time slot for each possible node transmission. The cross-layer design here is relying on the routing information in network layer and the scheduling in the medium access control (MAC) layer. This thesis also proposes a centralized scheduling algorithm that can avoid the collision by constructing routing path with multi-slot single transceiver system for WiMAX mesh networks. In our proposal, each node has one transceiver that can be tuned to any of the channels in the multi-slot assignment. The design parameters such as the number of the neighboring nodes, hop count to the BS, number of children per node, slot

reuse, fairness, load balancing, quality of services (QoS) and node identifier (ID) are considered. Results of analysis show that the proposed algorithms significantly improve the system performance in the aspects of length of scheduling by 30.9%, channel utilization ratio (CUR) by 50.1%, throughput of the system by 49.7%, and the end to end average transmission delay by 56.7% as compared to the MC algorithm.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PERBAIKAN BAGI PENGHALAAN DAN PENJADUALAN TERPUSAT MENGGUNAKAN REKABENTUK LAPISAN-SEBERANG DAN PENUGASAN ALURAN-BERBILANG DALAM RANGAKAIAN JEJARING WIMAX

Oleh

Ali Zuhair Abdulameer Al-Humairi

April 2009

Pengerusi: Prof. Madya Nor Kamariah Noordin, PhD

Fakulti : Kejuruteraan

WiMAX (Worldwide Interoperability for Microwave Access) berasaskan wayarles rangkaian jejaring (WMN) bertujuan untuk menyediakan capaian batuan-terakhir wayarles jalurlebar. Ianya mudah dilaksanakan dengan kadar data yang tinggi untuk jangkauan keluasan yang besar, adalah merupakan topologi utama untuk rangkaian generasi wayarles akan datang. Rangkaian jejaring WIMAX dibangunkan dengan menggunakan stesen dasar (BS) sebagai pengawal utama untuk semua stesen pengguna (SS). Tesis ini mencadangkan strategi yang optimum iaitu rekabentuk lapisan seberang dalam algoritma penghalaan yang digunakan untuk mencari laluan yang terbaik untuk semua stesen pengguna (SS), dan algoritma penjadualan yang digunakan untuk menetapkan slot masa bagi setiap penghantaran nod yang berkemungkinan. Rekabentuk lapisan sebarang ini bergantung kepada informasi penghalaan dalam lapisan rangkaian dan penjadualan dalam lapisan kawalan medium capaian (MAC). Tesis ini juga mencadangkan algoritma

penjadualan terpusat yang dapat mengurangkan gangguan dengan membina laluan penghalaan dengan sistem aluran berbilang penghantar-penerima tunggal bagi rangkaian jejaring WiMAX. Dalam cadangan kami, setiap nod mempunyai satu penghantar-penerima yang boleh ditalakan kepada mana-mana saluran dalam penugasan aluran berbilang. Parameter rekabentuk seperti gangguan dari penghantaran nod kejiranan, bilangan loncatan ke BS, bilangan anak setiap nod, penggunaan-semula aluran masa, keadilan, keseimbangan beban, kualiti perkhidmatan dan identiti nod telah dipertimbangkan. Analisis keputusan menunjukkan algoritma yang dicadangkan telah menambahbaik prestasi sistem dalam aspek masa penjadualan sebanyak 30.9%, nisbah penggunaan saluran sebanyak 50.1%, keluaran sistem sebanyak 49.7%, dan lengahan penghantaran hujung-ke-hujung sebanyak 56.7% berbanding dengan algoritma MC.

ACKNOWLEDGMENTS

In the name of Allah, the Most Beneficent, the Most Merciful

I would like to express my heartiest thanks to my supervisor Associate Professor Dr. Nor for her guidance, patience, advice and devotion of time, throughout my research. She taught me how to be a researcher with her wonderful personality. I have the honor to work under her supervision and I will ask Allah to keep her safe, and support her with good health and the power to help the students with the knowledge and her scientific abilities. I am forever indebted to her for excellent guidance.

I would like also to extend my thanks to my co-supervisors Associate Professor Sabira Khatun, and Dr. Alyani Ismail for their support.

My gratitude also goes to all other faculty members especially Dr. Michael, who has taught me during my first year of my study at UPM and to all my colleagues in the wireless laboratory for their encouragement and motivations.

Finally, I would like to thank my family for their unconditional care until I reach to this point, without their continuous support and precious prayers I could not have been able to finish my research. I know their blessings will always be with me in all my endeavors and I dedicate this success to them. Thanks my beloved family.

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

Nor Kamariah Noordin, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Alyani Ismail, PhD
Assistance Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Sabira Khatun, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

HASANAH MOHD. GHAZALI, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 9 July 2009

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

_____

ALI ZUHAIR ABDULAMEER AL-HUMAIRI

Date: 5 June 2009

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

3G	Third Generations
AVG	Average Transmission Delay
BS	Base Station
BWA	Broadband Wireless Access
CDS	Coordinated Distributed Scheduling
CN	Candidate Node
CCS	Coordinated Centralized Scheduling
CUR	Channel Utilization Ratio
DSL	Digital Subscriber Line
FIFO	First In First Out
E1	European Telecommunications Standard for 2 Mbit/s
FDD	Frequency Division Duplexing
ID	Identifier
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
LAN	Local Area Network
LIFO	Last In Last Out
LOS	Line Of Sight
MAC	Medium Access Control layer
MAN	Metropolitan Area Network
Mb/s	Megabit per second
MPMP	Multi Point to Multi Point

MSH-CSCF	Mesh Centralized Scheduling Configuration
MSH-CSCH	Mesh Centralized Scheduling
MSH-DSCH	Mesh Distributed Scheduling
MSH-NCFG	Mesh Network Configuration
MSH-NENT	Mesh Network Entry
NIST	National Institute of Standards and Technology
NLOS	Non Line Of Sight
NWEST	National Wireless Electronics Systems Testbed
OFDMA	Orthogonal Frequency Division Multiple Access
OFDM	Orthogonal Frequency Division Multiplexing
Opt.	Optional
OSI	Open Systems Interconnect
PC	Personal Computer
PHY	Physical layers
PMP	Point to Multi Point
PTCP	Point to Consecutive Point
PTP	Point to Point
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
rx-rx	receiver-receiver
rx-tx-rx	receiver transmitter-receiver
SCa	Single Carrier for lower frequency
SC	Single Carrier for higher frequency

SS	Subscriber Station
T1	Digital Signal 1
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
THR	Throughput of System
tx-rx	transmitter-receiver
tx-rx-tx	transmitter-receiver-transmitter
tx-tx	transmitter-transmitter
UDS	Uncoordinated Distributed Scheduling
WAN	Wide Area Network
Wi-Fi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access
WirelessHUMAN	Wireless High speed Unlicensed Metropolitan Area Network
WirelessMAN	Wireless Metropolitan Area Network
WMNs	Wireless Mesh Networks
WSN	Wireless Sensor Network

CHAPTER 1

INTRODUCTION

WiMAX which stand for worldwide interoperability for microwave access is an emerging broadband wireless access (BWA) system with optimized delivery of fixed, nomadic, portable and mobile wireless connections on a metropolitan area networks (MANs). It is an alternative and a complementary solution for the extension of a fiber-optic backbone. The core of WiMAX technology is specified by the Institute of Electrical and Electronic Engineers (IEEE) 802.16 standard that provides specifications for the medium access control (MAC) and physical (PHY) layers. The term WiMAX was created by the WiMAX forum that promotes conformance and interoperability of the standard. WiMAX or IEEE 802.16 [1], is a standardized wireless version of Ethernet which is intended primarily as an alternative to wire technology such as cable modems, digital subscriber line (DSL) and digital signal 1/European telecommunications standard (T1/E1) links to provide broadband access to customer premises. This application is called wireless last mile broadband because it is the final transmission distance of delivering connectivity from a service provider main network to a customer place. The 802.16 standard is large, complicated but offers many options and extensions, hence the term interoperability of the wireless systems. In particular, one extension for the fixed wireless technology known as 802.16a or commonly called as WiMAX mesh network and its later version 802.16d become the focus of much industry attention because it is the easiest and most useful to implement. In addition to the point to multi-point (PMP) mode, some WiMAX standards support mesh mode. Mesh mode provides a more robust

broadband access topology, enables direct communication between the nodes. Nodes can relay their transmissions through other subscribers in mesh networks if they cannot directly reach a base station (BS).

This chapter provides a brief introduction to the WiMAX, motivations, problem statement, research challenges, objective, research scopes, and a brief methodology.

1.1 Motivations

A WiMAX mesh network introduces many special features which encourage researchers and developers to take advantage of, and some of them are:

- WiMAX will serve as a backbone for IEEE 802.11 wireless local area network (LAN) hotspots and cellular network hence extending the range of wireless fidelity (Wi-Fi) and cellular systems [2].

- WiMAX offers less expensive, easier to build infrastructure than the wire line backbones that DSL, cable, or T1 line systems currently provide [2]. In many rural areas especially in developing countries, there is no existence of wired infrastructure. IEEE 802.16 can be a better solution to provide communication services to those areas.

- WiMAX provides coverage for wide geographical area (with radius up to 30 miles) because it can operate in both condition, line of sight (LOS) [18] and

NOLS without severe distortion and multi-paths of the signal from buildings, weather and vehicles [3].

- WiMAX service offer to carry multiple kinds of technologies which comprised of fixed (in extension 802.16d) and mobile (in extension 802.16e) access wireless broadband connectivity.

- WiMAX is an open system; many algorithms are left for the vendor which opens the door to optimization, and connection between different units operating on different parts of the network [4].

- WiMAX has a strong support from industry companies such as Intel, Samsung and etc [6].

- WiMAX is supporting the mesh network which enables devices to act as relays; passing signals from one device to another until it reaches the BS [5]. This helps to extend the range of the BS [7].

- The WiMAX mesh standards enable direct communication between the nodes and hence reduce dead zone while increasing the global throughput by the use of multi-hops. [7].

1.2 Problem Statement

Many researchers tried to come out with suitable solutions to one of the problems in WiMAX mesh networks that is dealing with the conflicting neighbouring WiMAX mesh nodes. The transmission from any nodes can be conflict with all the neighboring nodes.

In this thesis, a multi-channel assignment algorithm is proposed to increase the slot reuse in the networks, and centralized scheduling algorithm is proposed to avoid the effects of collision from neighboring nodes. The most important issue in WiMAX mesh system that need consideration in routing and scheduling algorithms are fairness, load balancing, concurrent transmission, slot reuse, and the relay model. Hence, the design of the proposed algorithms considers all these parameters and at the same time also considers number of the neighboring nodes.

Another issue in constructing the routing path is to find the best route between the sender and the receiver in the network. The proposed design of the routing algorithm also try to select the best route for each node to the BS with the least number of neighboring node in the network by considering the load balancing between the nodes. Cross layer design is also considered as an optimization method to ensure transmission and reception of data at most optimum level.