UNIVERSITI PUTRA MALAYSIA

OPTIMAL CHANNEL ASSIGNMENT FOR MULTI-HOP WIMAX MESH NETWORKS

AHMED SHAIN HALEEM

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By

AHMED SHAIN HALEEM

Project Submitted to the School of Graduate Studies, University Putra Malaysia, in Fulfilment of the Requirement for the Degree of Master of Computer Science

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DEDICATION

To my wife, loving family and supervisor,

with a deep gratitude deep beyond what words can express.

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

OPTIMAL CHANNEL ASSIGNMENT FOR MULTI-HOP WIMAX MESH NETWORKS

By

AHMED SHAIN HALEEM

January 2016

Supervisor: Dr. Abdullah Muhammed

Faculty: Faculty of Computer Science and Information Technology

In this work, we study the problem of interference that affects quality of service (QoS) for diverse multimedia services which are the main concerns for WiMAX mesh networks and enhance the scheduling for multi-hop WiMAX mesh networks by assessing the optimal channel assignment. The objective of this study is to guarantee a throughput for individual stream in a multi-hop WiMAX mesh network. We study various scheduling algorithms with respect to the QoS constraints and come up with a framework which would help us to understand the optimal channel assignment and

enhance the scheduling in multi-hop WiMAX mesh networks. Our proposed method is able to produce good quality solutions for improving the scheduling scheme of multi-hop WiMAX mesh networks effectively to achieve QoS guarantees when compared with other QoS standard algorithms.

Abstrak Kertas Projek yang dikemukakan kepada Senat Universiti Putra Malaysia

Sebagai memenuhi keperluan untuk ijazah Sarjana Sains Komputer

PENUGASAN SALURAN YANG OPTIMAL UNTUK MULTI-HOP RANGKAIAN MESH WIMAX

Oleh

AHMED SHAIN HALEEM

Januari 2016

Penyella: Dr. Abdullah Muhammed

Fakulti: Fakulti Sains Komputer dan Teknologi Maklumat

Dalam kertas ini, kami mengkaji masalah gangguan yang menjejaskan kualiti perkhidmatan, atau *Quality of Service* (QoS) buat pelbagai perkhidmatan multimedia di mana ini adalah kebimbangan utama buat rangkaian mesh WiMAX dan kami juga mengkaji bagaimana untuk menambah baik penjadualan untuk rangkaian mesh WiMAX *multi-hop* dengan menilai penugasan saluran yang optimal.

Objektif utama kajian ini adalah untuk memastikan throughput untuk aliran individu di dalam multi-hop rangkaian mesh WiMAX. Kami juga mengkaji pelbagai algoritma penjadualan berkenaan dengan menimbang kekangan kualiti perkhidmatan (QoS) dan

mengemukakan satu rangka kerja yang boleh membantu kami untuk memahami penugasan saluran yang optimal dan menambah baik penjadualan di dalam rangkaian mesh WiMAX *multi-hop*.

Kaedah yang dicadangkan oleh kami mampu untuk menghasilkan penyelesaian yang berkualiti untuk menambah baik skema penjadualan rangkaian mesh WiMAX *multi-hop* dengan efektif untuk mencapai jaminan QoS, berbandi dengan algoritma standard QoS yang lain.

ACKNOWLEDGEMENT

I thank Allah for giving me this opportunity to embark on this wonderful journey. I have enjoyed the time that I have spent at Universiti Putra Malaysia a lot. And it has made me a better person for my future endeavors.

DECLARATION

This project paper with the title of Optimal Channel Assignment for Efficient Multi-Hop WiMAX Mesh Networks is fully prepared by Ahmed Shain Haleem and being submitted to the Faculty of Computer Science and Information Technology as the fullfilment of requirements for the Master of Computer Science. I hereby declare that the project paper is based on my original work except for quotations and citations that have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

Student's Name: AHMED SHAIN HALEEM Student's Signature:

Matric No: GS39836

Confirmation by,

Dr. Abdullah Muhammed

Faculty of Computer Science and Information Technology

Univeristi Putra Malaysia

Date:

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LIST OF ABBREVIATIONS

WiMAX	Worldwide Interoperability for Microwave Access
IEEE	Institute of Electrical and Electronics Engineers
PHY	Physical
MAN	Metropolitan Area Network
ETSIH	European Telecommunications Standards Institute High Performance
OSI	Open Systems Interconnection
DSL	Digital Subscriber Line
WMN	Wireless Mesh Networks
SS	Subscriber Station
BS	Base Station
MAC	Media Access Control
NOLS	Non Line of Sight
LOS	Line of Sight
LAN	Local Area Network
QoS	Quality of Service
TCP	Transmission Control Protocol
PMP	Point to Multi point

OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
SDU	Service Data Units
TDMA	Time Division Multiple Access
BPSK	Binary phase-shift Keying
QPSK	Quadrature phase-shift Keying
QAM	Quadrature Amplitude Modulation
HOL	Head of Line
CID	Connection Identifier
RAN	Radio Access Network
MSH-CSCH	Mesh Centralized Scheduling
MSTR	Maximum Sustained Traffic Rate
MDFS	Maximum Degree First Select
VoIP	Voice over Internet Protocol
BFS	Breadth First Search
RAM	Random Access Memory
MS	Mobile Station

CHAPTER 1

INTRODUCTION

In the past few years we have witnessed the convergence and diversification of data services in the world of data communications and networking. The growth of data traffic is astounding. The convergence of several different types of services like for example voice, data and video services. But not only that, the convergence of bidirectional services with distributive unidirectional services, the convergence of narrow and broadband services and the convergence of wireline and wireless services is now an established trend that is augmented by the convergence of user terminals. The exponential growth of data traffic has led to the deepening of mobile wireless services like music, video and other forms of downloading and exchange, the convergence of communications in major fields like multimedia entertainment, business and mass broadcasting. The rise of mobile phone as the dominant form of communication in our society is hardly a revelation, the desktop is dying and mobile is winning in everything else. We are just starting to see just how dominant mobile devices have become (McDuling, 2015).

1.1 History of WiMAX

The IEEE 802.16 workgroup established the standard for physical (PHY) layer and MAC layer of the wireless MAN (Metropolitan Area Networks) to compose an operational network. The IEEE 802.16 technology requires the support of other components, therefore the WiMAX forum in April 2001, established to offer certification service for conformity and interoperability of broadband wireless access

products based on IEEE. The IEEE 802.16 work group established and agreed on the IEEE 802l16 WiMAX air interface specifications; hence the WiMAX forum is the propellant of technology and industry chain. Now the WiMAX is just a name for the IEEE 802.16 WiMAX technology with the air interference specification covering the 802.16d/e.

In (Pareit et al., 2012), authors describe the WiMAX Forum as an organization that certifies equipment that is complaint with the parameter values they have chosen in the IEEE 802.16 standard for the device assurance and interoperability. The WiMAX Forum has hundreds of members including mostly of WiMAX operators, parts and equipment vendors. It was founded in Jun 2001 to promote and certify wireless broadband equipment based on the IEEE 802.16 and ETSI HiperMAN (European Telecommunications Standards Institute High Performance Metropolitan Area Networks) to award manufactures with WiMAX Forum Certified label. First and second layer of Open System Interconnection model (OSI) reference model based on IEEE 802.16 is shown in Figure 1.

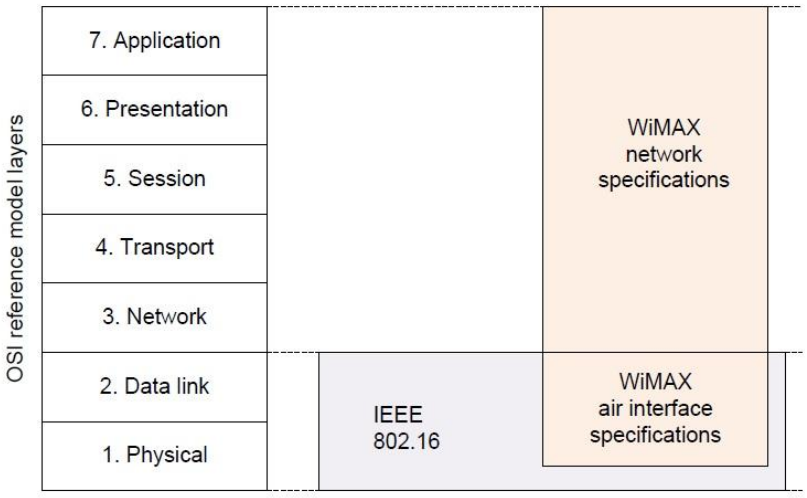

Figure 1. Relationship between 802.16 and WiMAX with OSI model

1.2 Architecture of WiMAX

The number of mobile data users has been rising due to the increased users and the need for high speed data access. The Worldwide Interoperability for Microwave Access (WiMAX) is a wireless communications technology that aims to provide wireless data over long distances in variety of ways as an alternative to cable and DSL (Digital Subscriber Line), it is based on IEEE 802.16 and ensures network the best available quality of service is adequate for mobile data users. The IEEE 802.16 is a set of telecommunication technology standard aimed at providing wireless access over long distances in a variety of ways – from point to point links to full cellular access as shown in Figure 1. It covers a huge area of several kilometers and a WiMAX base station can provide broadband wireless access in range up to 50 km for fixed stations and 5 to 15 km for mobile stations with a maximum data rate of up to 70 Mpbs compared to IEEE 802.11a (Wireless Technology) with about 54 Megabits per second (Mbps) to a couple of hundred meters (So-In et al., 2009).

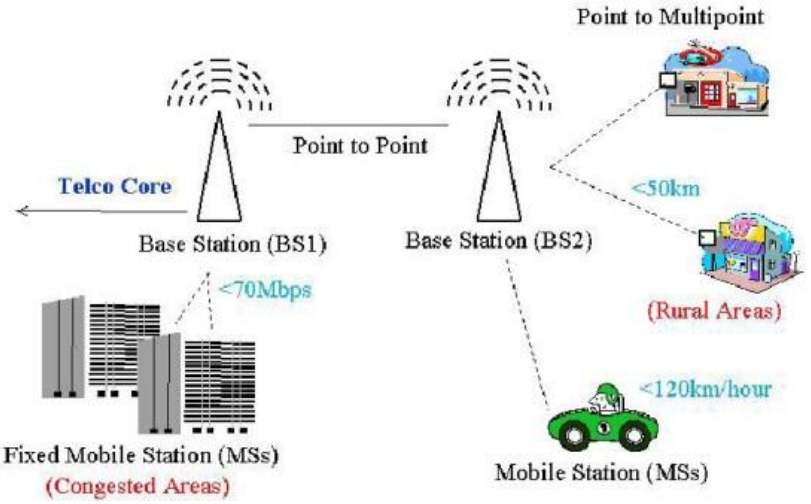

Figure 2. WiMAX deployment Scenarios

The WiMAX technology like the 802.11 is based on the use of Base Stations (BS) that are part of a wired network. A cell is referred to as the geographic area the base station covers. Base stations can serve a single cell or use multiple directional antennas to facilitate multiple cells. Cells usually don't have hard boundaries, they overlap each other. Even if they overlap, a mobile device can communicate with multiple base stations. This is similar to the 802.11 architecture. However, the phone is in communication with just one base station. When the phone beings to leave a cell, it will move into an area of overlap with other cells. This happens when current base station senses a weakening signal from the phone and it assigns control of the phone to another base station which is receiving the strongest signal. If the phone is in a call at the time, the call will be shifted to a new base station which is referred to as a handoff (So-In et al., 2009).

1.3 WiMAX Mesh Networks

Wireless Mesh Networks (WMN) are nodes connected to neighboring nodes. WMNs offer multiple redundant communication paths throughout the network. Whenever a link fails, the network automatically routes messages through alternate paths. WMN is any wireless network having a network topology of either a partial or full mesh topology. Even in adverse conditions devices in WMN cooperate with each other in transmitting packets through the network. WMNs are believed to be self-configuring and self-healing networks. WMNs can be integrated with other networks such as IEE 802.15 and 802.16.

Figure 3 shows WiMAX mesh networks allow traffic to be routed through and between Subscribers Stations (SS) also called Mesh SS (nodes have direct links called

neighbours), by passing BS (nodes connecting network to backhaul). The SS is also called “one-hop” and together they form a neighborhood (Mesh). An extended neighborhood is called “two-hop”, which includes all the neighbors of the neighborhood. The traffic direction towards the mesh BS is “uplink” and the traffic direction away from the mesh BS is “downlink”.

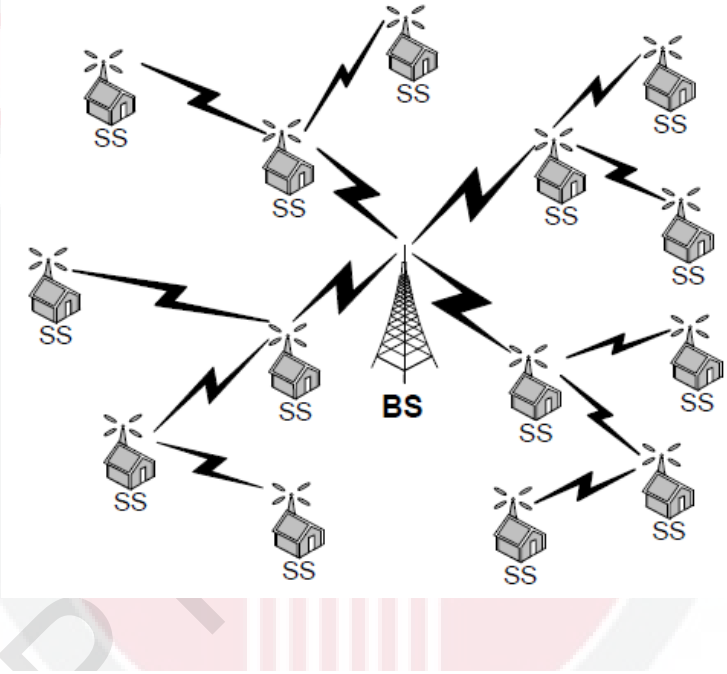

Figure 3. Mesh Architecture

1.4 Scheduling and Operation in WiMAX Mesh Networks

There are two algorithms that WiMAX Mesh use for scheduling; centralised and distributed. In the centralised scheduling the mesh BS collects a request call from all the mesh SS within the domain. Centralised Mesh scheduling consists of information made by the BS and publicly announced to all the surrounding nodes. The neighbouring nodes do likewise until all cooperating nodes obtain the message. The BS decides how much

resource would be allocated for both uplink and downlink and give the decision with the requesting mesh SS.

In the case of distributed scheduling, all of the nodes and BS organise their transmission and propagate the schedule that includes vacant resources and requests. Distributed scheduling uses a mesh mode which is utilised between two communicating nodes by using a single link. The QoS (Quality of Service) parameters on each message basis rather than for each link. In this mesh mode the Time Division Duplexing (TDD) is supported.

The mesh nodes operate on 48-bit Media Access Control (MAC). After a node is certified by the BS a node will receive a identification of 16-bit. The node assigns an 8-bit Link identification for each link that is authorized and created. WiMAX mesh model represents a hexagonal shape with mobile station at every edge of the hexagon.

1.5 Advantages of WiMAX Mesh Networks

Some of the advantage of using mesh networks is the self-healing ability that enables the network to be up and running even if one of the devices fails. There are multiple paths for the client devices to communicate with. Moreover it can locate the paths with low overload and avoid jams also stay away from hindrance using non line of sight (NLOS). WiMAX also works with line of sight (LOS) as well. This provides aggressive user throughput and increases QoS for multimedia traffic. It offers lower infrastructural expense with scaling itself to contain more users. Ultimately, WMSs are vigorous in light of the fact that they are not reliant on a solitary source.

We have similar technologies like 3G and 4G, but why do we need WiMAX? It is like the evolution of the mobile phones. At first most people said that they don't need it. But now everyone is either tethered to a Wi-Fi hotspot or a Digital Subscriber Line (DSL) connection. Or a more simple answer would be to get high speed broadband like internet access on the move. Broadband connections provides high speed networks but are attached to Local Area Network (LAN) systems, which means that it is not portable. And also Wi-Fi has much smaller distance. Cellular networks provide internet access but their speed is limited and is relatively costly. Therefore to overcome these problems WiMAX is going to play a vital role in the future of telecommunication and networking.

1.6 Motivation

The IEEE 802.16 (WiMAX) does not have a standard scheduling mechanism; it has been left for implementation. The main aim of WiMAX is to provide the best available QoS for the mobile data service users. According to the study by (Gabale et al., 2013) there are three main restraints while considering scheduling; 1) Inter dependence between routing and scheduling: to find a feasible path for scheduling flow; 2) Obstruction free or feasible link scheduling; 3) Satisfy QoS requirements.

1.7 Problems Statement

In this paper, we study the problem of interference that affect quality of service (QoS) for diverse multimedia services which are the primary concerns for WiMAX mesh networks and enhance the scheduling for multi-hop WiMAX mesh networks by assessing the optimal channel assignment so that the transmission is free from

interference and set of transmission requests is fulfilled all the while using minimum or ideal number of channels. Interference factors such as lossy wireless links caused by concurrent transmissions on neighboring links and intra path interference caused by transmission on successive hops alongside a single path are challenges these networks deal with. Primarily, if a node has a single transmission of sending and receiving at the same time, there will be interference at that node. Also if the nodes have multiple radios transmissions and if two transmissions work on same channel in the meantime there will be interference as well.

(Seyedzadegan & Othman, 2010) indicates that wireless nodes do not reduce window sizes due to the mechanism of cumulative acknowledgment. For this reason, if uplink and downlink TCP flows coexist, the wireless nodes having uplink TCP flows tend to use most of the bandwidth. The key problem is the irregular space for each wireless node in the BS queue, that is, the number of wireless nodes and flows per wireless node are disproportionate to the BS queue size.

In the WiMAX mesh architecture, all of the Subscriber Stations (SS) are arranged in an organised ad hoc fashion and each SS can reach the BS through a multihop manner. Compared to the point to multi point architecture the mesh architecture covers a huge area like a city or large islands. Explicitly, different architectures possess different network characteristics and their own constraints, which make the WiMAX scheduling problem more challenging and interesting task. In the study (Liang et al., 2011) the following issues are highlighted as potential scheduling problems in WiMAX networks in point to multi point (PMP) and mesh architecture.

- Network throughput: the objective of WiMAX is to provide broadband network access, the control of overhead reduction and concurrent transmissions will help to enhance throughput.
- Quality of service (QoS): the IEEE 802.16 standards classify all traffics into five categories of QoS.
- Energy consumption: communication is an energy costly operation for mobile devices. A balance between their energy consumption and the overall network throughput is a crucial factor to be adjusted.

1.8 Project Objectives

. The project objectives are as follows:

- To study various scheduling algorithms with respect to the mentioned constraints and investigate how to achieve high guaranteed throughputs and fair access for individual flows in a multi-hop WiMAX mesh network.
- To propose an optimal channel assignment to improve the scheduling scheme of multi-hop WiMAX mesh networks effectively to achieve QoS guarantees.

1.9 Scope of Research

In a multi-channel single-transceiver system, one node can support only one channel in a certain time slot. Obviously, it is impossible to avoid primary interference. However, different nodes may operate on different channels to avoid secondary interference (Tang

et al., 2009). The scope of the research is based on the centralised scheduling algorithm with in the WiMAX network in multi-hop (multi point) mesh topology.

1.10 Hypothesis

The results of this study would help to achieve seamless interconnectivity with various user terminals, provide high quality wireless multimedia service to all types of IP enabled devices and also assist experiments on which protocols to be used and evaluate the design model in to building communities in rural areas and islands. Moreover (Akyildiz, 2005) claims that the improvement in throughput and QoS guarantees would provide support in the state of emergencies as well (police, fire brigade, ambulance etc.) by the help of self-healing, self-organising features of WiMAX mesh networks.

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BIO DATA OF STUDENT

Ahmed Shain Haleem, born and raised in the capital city of Male', Maldives on 5th February 1986. I started working in the government of Maldives in 2005 right after my A-levels at the Ministry of Environment. It was after a year at the ministry that I decided to take a career path in information technology. I saw the potential that IT personnel could bring to the work environment. Therein I pursed to achieve my higher studies in that field in 2006.

I achieved my Bachelor of Information Technology degree in 2009 at Kuala Lumpur Infrastructure University College now known as Infrastructure University Kuala Lumpur (Major in Network Technology). The same year I started working at the Environmental Protection Agency (EPA) of Maldives as a senior computer programmer with 3 subordinates. I gained so many experiences each day working as a team at EPA. Some of the projects that our team was involved in were to develop the website for EPA, create a database for EIA file tracking system and server configurations. We faced difficult times when we lost many data due to one of our backup hard disks in the file server failure due to some poor electricity in the building.

After almost 5 years in the position I decided to go and do my master's degree which bought me here to this wonderful place of Universiti Putra Malaysia. It was as almost I've forgotten that feeling of being a student, but the relentless effort and teachings from our dear lecturers that had rekindled my spirit for achieving even more than my masters. But for now I'm happy with where and what I have achieved. In the near future I intend to go and finish my PhD as well.