RADIO RESOURCE MANAGEMENT FOR MOBILE WiMAX NETWORK

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I dedicated this to my family with love and respect.

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ABSTRACT

Worldwide interoperability for Microwave Access (WiMAX) is one of the broadband wireless technologies that uses Orthogonal Frequency Division Multiple Access (OFDMA) and is anticipated to be a viable alternative to traditional wired broadband technique due to it is cost efficiency. It has been an emerging wireless broadband technology, in which the resources are limited. Thus, there is dramatic need to effectively manage the available resources and provide the necessary Quality of Service (QoS) for different traffic classes. Therefore, an effective admission control, scheduling and resource allocation are critical for the WiMAX network. The first contribution of this thesis is the development of link aware call admission control with service differentiation. The total link bandwidth is partitioned into portions such that each portion is dedicated to unique traffic. The amount of bandwidth dedicated to each portion is based on the probability mass function of the traffic arrival rate. A traffic can only be admitted when there is enough bandwidth in the portion allocated to that particular traffic. Firstly a two partitions call admission control is considered called dual partition call admission control. The scheme primarily partitioned the bandwidth into constant bit rate and variable bit rate traffics. Simulation result shows 63.63% increment in service flow acceptance and 21.42% reduction in blocking probability when compared to conventional call admission control. To accommodate handover services, partition base call admission control (PB CAC) is proposed. By allocating a third bandwidth portion for handover, service flow acceptance increased by 25%, with reduction of both blocking and dropping probability by 15.63% and 21.66% respectively. By using fuzzy logic in PB CAC, the dropping probability is reduced by 51.60%. The second contribution is the enhancement of the earliest deadline first (EDF) scheduling algorithm. The enhancement is based on the criterion for buffer selection in which the earliest deadline first scheduler should serve. The criterion for scheduling a packet depends on the queuing state and the QoS requirement of a particular service flow. The proposed algorithm utilizes link quality and is called link and queuing aware EDF scheduling algorithm (LQA-EDF). The modified algorithm outperformed the conventional EDF by about 5.77% in terms of throughput with fairness among service flows. The third contribution is the development of subcarrier and power allocation algorithm with aim of reducing the computational complexity. The allocation of subcarrier uses unsorted list technique by using biologically inspired algorithm which is based on particle swarm optimization. The power allocation employs the conventional water filling algorithm for optimal power distribution among users. The proposed technique has reduced the computational complexity by 31.2% compared to linear technique which uses sorted list and by 90.5% compared to root finding method

ABSTRAK

Keantarakendalian seluruh dunia untuk akses gelombang mikro (WiMAX) adalah salah satu teknologi jalur lebar tanpa wayar yang menggunakan bahagian frekuensi tidak bertindih pelbagai akses (OFDMA) dan dijangka akan menjadi alternatif yang berdaya maju kepada teknik tradisional jalur lebar berwayar disebabkan kosnya yang efisien. WiMAX telah menjadi teknologi jalur lebar tanpa wayar yang baru muncul, di mana sumber-sumbernya adalah terhad. Oleh itu, terdapat keperluan yang dramatik untuk menguruskan sumber-sumber yang sedia ada secara efisien dan menyediakan Kualiti Perkhidmatan (QoS) untuk kelas trafik yang berlainan. Justeru itu, kawalan kebenaran masuk yang efektif, penjadualan dan pengagihan sumber adalah kritikal bagi rangkaian WiMAX. Sumbangan pertama tesis ini adalah pembangunan kawalan panggilan kebenaran masuk pautan sedar dengan perbezaan perkhidmatan. Jumlah pautan lebar jalur dibahagikan kepada beberapa bahagian dengan setiap bahagian dikhaskan kepada trafik yang unik. Jumlah lebar jalur yang dikhaskan kepada setiap bahagian adalah berdasarkan kebarangkalian fungsi jisim kadar ketibaan trafik. Trafik hanya akan diterima masuk apabila terdapat lebar jalur yang cukup di dalam bahagian yang telah diagihkan untuk trafik tersebut. Pertamanya, dua bahagian kawalan panggilan masuk dipertimbangkan yang dipanggil dua bahagian kawalan panggilan masuk (DP-CAC). Skim ini mengutamakan pembahagian lebar jalur untuk trafik kadar bit tetap dan trafik kadar bit berubah-ubah. Hasil simulasi menunjukkan peningkatan sebanyak 63.63% dalam penerimaan aliran perkhidmatan dan pengurangan 21.42% dalam kebarangkalian sekatan jika dibandingkan dengan kawalan kebenaran masuk panggilan konvensional. Untuk menempatkan perkhidmatan penyerahan, pembahagian-dasar kawalan panggilan masuk (PB-CAC) dicadangkan. Dengan mengagihkan bahagian ketiga lebar jalur untuk perkhidmatan penyerahan, penerimaan aliran perkhidmatan telah meningkat sebanyak 25%, dengan pengurangan kebarangkalian sekatan dan kebarangkalian jatuhan masing-masing sebanyak 15.63% dan 21.66%. Dengan menggunakan logik kabur di dalam PB-CAC, kebarangkalian jatuhan berkurangan sebanyak 51.60%. Sumbangan kedua adalah peningkatan algoritma penjadualan had waktu terawal yang pertama (EDF). Peningkatan dibuat berdasarkan kriteria pemilihan penyimpan di mana penjadual had waktu terawal yang pertama harus berkhidmat. Kriteria untuk penjadualan paket bergantung kepada status pengaturan dan keperluan QoS untuk aliran perkhidmatan tertentu. Algoritma cadangan menggunakan kualiti pautan dan dinamakan algoritma penjadualan dengan kesedaran pautan dan pengaturan had waktu terawal yang pertama(LQA-EDF). Algoritma yang telah diubahsuai mengatasi EDF konvensional sebanyak 5.77% dari segi kadar data yang dihantar dengan kesaksamaan di kalangan aliran perkhidmatan. Sumbangan ketiga adalah pembangunan algoritma sub-pembawa dan pengagihan kuasa dengan tujuan mengurangkan kerumitan pengiraan. Pengagihan sub-pembawa menggunakan teknik senarai yang tak teratur dengan menggunakan alat pengoptimuman yang diilhami dari biologi yang dipanggil teknik pengoptimuman zarah serangga. Pengagihan kuasa menggunakan algoritma pengisian air konvensional untuk taburan kuasa optimal di antara pengguna-pengguna. Teknik cadangan telah mengurangkan kerumitan pengiraan sebanyak 31.2% jika dibandingkan dengan teknik garis datar yang menggunakan senarai teratur dan mengurangkan kerumitan pengiraan sebanyak 90.5% jika dibandingkan dengan kaedah mencari punca.

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LIST OF ABBREVIATION

ACU	-	Admission Control Unit
AMC	-	Adaptive Modulation and Coding
AMR	-	Adaptive Multi-Rate
ARC	-	Average Reduce in Complexity
ATM	-	Asynchronous Transfer Mode
AWGN	-	Additive White Gaussian Noise
BE	-	Best Effort
BER	-	Bit Error Rate
BS	-	Base Station
BWA	-	Broadband Wireless Access
CA	-	Collision Avoidance
CAC	-	Call Admission Control
CB CAC	-	Conventional Call Admission Control
CBR	-	Constant Bit Rate
CC	-	Convolution Code
CD	-	Compact Disc
CDMA	-	Code Division Multiple Access
CID	-	Connection Identifier
CP	-	Cyclic Prefix
CPU	-	Central Processing Unit
CPS	-	Common Part Sublayer
CQICH	-	Channel Quality Indicator Channel
CRA	-	Contention Resolution Algorithm
CS	-	Carrier Sense / Convergence Sub layer
DA	-	Demand Assignment
DL	-	Downlink
DL MAP	-	Downlink Mobile Application Part

DP CAC	-	Dual Partition Call Admission Control
DSA	-	Dynamic Service Addition
DSA-ACK	-	Dynamic Service Addition Acknowledgement
DSC	-	Dynamic Service Change
DSD	-	Dynamic Service Deletes
EDF	-	Earliest Deadline First
ertPs	-	Extended Real Time Polling Service
GPC	-	Grant per Connection
GPSS	-	Grant per Subscriber Station
FCH	-	Frame Control Header
FDD	-	Frequency Division Duplex
FEC	-	Forward Error Coding
FFT	-	Fast Fourier Transforms
FIFO	-	First In First Out
FM- EDF	-	Fixed Modulation Earliest Deadline First
FUSC	-	Fully Used Sub Channel
FZ CAC	-	Fuzzy Logic Call Admission Control
HO	-	Handover Service/Handover Bandwidth
HSR	-	Handover Service Request
HTTP	-	Hyper Text Transfer Protocol
IFFT	-	Inverse Fast Fourier Transform
IEEE	-	Institute of Electrical and Electronics Engineers
ISI	-	Inter Symbol Interference
LQA-EDF	-	Link and Queuing Aware Earliest Deadline First
LOS	-	Line of Sight
LU	-	Lower and Upper Triangle
MAC	-	Medium Access Control
MAC CS	-	MAC Convergence Sub layer
MAC CPS	-	MAC Common Part Sub Layer
MAC PDU	-	MAC Protocol Data Unit
MAP	-	Mobile Application Part
Mbp	-	Maximum Blocking Probability

MCD	-	Media Content Download
Mdp	-	Maximum Dropping Probability
MPEG	-	Moving Picture Expert Group
MSP	-	Music and Speech
NPEDF	-	Non-Preemptive Earliest Deadline First
nrtPs	-	None Real Time Polling Service
NLOS	-	None Line of Sight
OFDM	-	Orthogonal Frequency Division Multiplex
OFDMA	-	Orthogonal Frequency Division Multiple Access
OSI	-	Open System Interconnect
PB CAC	-	Partition Base Call Admission Control
PEDF	-	Preemptive Earliest Deadline First
PER	-	Packet Error Rate
PMP	-	Point to Multi-Point
PRB_p	-	Percentage Reduce in Blocking Probability
PRD_p	-	Percentage Reduce in Dropping Probability
PSO	-	Particle Swarm Optimization
P/S	-	Parallel to Serial
PUSC	-	Partially Used Sub Channel
QAM	-	Quadrature Amplitude Modulation
QoS	-	Quality of Service
QPSK	-	Quadrature Phase Shift Keying
RR	-	Round Robin
RRA	-	Random Reservation Access
RS	-	Relay Station
RC_{2m}	-	Reduction in Complexity for Even User
rtPs	-	Real Time Polling Service
SC	-	Single Carrier
SF	-	Service Flow
SFID	-	Service Flow Identification
$SF_{improve}$	-	Service Flow improved
S-OFDMA	-	Scalable Orthogonal frequency division

		multiple Access
SNR	-	Signal to Noise Ratio
SS	-	Subscriber Station
TDD	-	Time Division Duplex
TDMA	-	Time Division Multiple Access
TSF	-	Total Service Flow
TUSC	-	Tile Used Sub Channel
TV	-	Television
UGS	-	Unsolicited Grant Service
UL	-	Uplink
UL MAP	-	Uplink Mobile Application Part
VBR	-	Variable Bit Rate
VC	-	Video Conference
VoIP	-	Voice over Internet Protocol
WAN	-	Wide Area Network
WB	-	Web Browsing
Wi-Fi	-	Wireless Fidelity
WFQ	-	Weighted Fair Queuing
WiBro	-	Wireless Broadband
WiMAX	-	Worldwide interoperability for Microwave Access
WLAN	-	Wireless Local Area Network
WMAN	-	Wireless Metropolitan Area Network
WPAN	-	Wireless Personal Area Network

LIST OF SYMBOLS

A_n	-	Normalized channel amplitude
B	-	Available link bandwidth
b_m	-	Data rate per subcarrier per slot
$b_{m,n}$	-	Capacity of subcarrier *n* on user *m*
CB_t	-	Bandwidth allocated to CBR traffics
c_r	-	Coding rate
d	-	SS distance from BS
$d_{m,n}$	-	Indicator of subcarrier *n* on user *m*
d_o	-	Reference distance
$E(i)$	-	Relative energy of multipath
f	-	Transmission frequency
F_d	-	Frame duration in second
f_{max}	-	Maximum Doppler shift
F_s	-	Sampling frequency
$\mathrm{G_b}$	-	BS antenna gain
G_r	-	SS antenna gain
h	-	SS antenna height
h_b	-	BS antenna height
$H_{m,n}$	-	Channel to noise ratio of subcarrier *n* on user *m*
HO	-	Handover service / Handover bandwidth
$I_{n,i}$	-	In phase of channel *i*
k		number of partitions
$\mathrm{L_{imp}}$	-	Implementation loss
m	-	Modulated symbol
M,m	-	Number of users
N	-	Number of subcarrier
$N_{bit,f}$	-	Number of bits per frame

NC	-	Network capacity
NF	-	Receiver noise figure
N_m	-	Set of subcarriers assign to user m
N_o	-	Noise power spectrum density
N_{OFDM}	-	Number of OFDM symbol in the down link/frame
N_s	-	Number of subcarrier per seconds
N_{sc}	-	Total number of subchannels in the downlink frame
N_{slot}	-	Number of slots per SS
$N_{slot,pusc}$	-	Number of slots in one PUSC downlink frame
$N_{slot,sec}$	-	slots per second
N_{sub}	-	Number of subcarrier per slots
N_{used}	-	Data subcarrier
$O(.)$	-	Computational Complexity
P	-	Admitting vector
P_{loss}	-	Median Path loss
$p_{m,n}$	-	Power assign to subcarrier n on user m
P_t	-	BS Transmission Power
$Q_{n,}i$	-	In quadrature of channel i
R	-	Repetition factor
R_{cbr}	-	Bandwidth allocated to CBR traffic with relay
R_m	-	SS data rate
$R_{rly(cbr)}$	-	Bandwidth allocated to CBR at relay station
$R_{rly(vbr)}$	-	Bandwidth allocated to VBR at relay station
R_{ss}	-	Receiver sensitivity
R_{sus}	-	Sustainable traffic rate
R_{vbr}	-	Bandwidth allocated to VBR traffic with relay
s	-	Shadowing effect
S_{cap}	-	Data rate per slot
SN	-	Frame serial number
$\mathrm{SNR}_{\mathrm{RX}}$	-	Received signal to noise ratio
T	-	Service flow vector
T_f	-	Number of frame per seconds
U	-	Bit rate vector

v	-	velocity of light
VB_t	-	Bandwidth allocated to VBR traffics
y_{FZ}	-	Bandwidth controlled by fuzzy logic
α, α_1	-	Bandwidth partition control variable
α_o	-	Input angles of the wave
$\beta_{m,n}$	-	Signal to noise ratio of subcarrier n on user m
γ	-	Path loss exponent
ε, ε_1	-	RS partition variable
ζ	-	Best effort buffer control
θ_o	-	Normalized channel phase shift
λ	-	Wave length
λ_m	-	Predetermine values assign to users
φ	-	Channel gain
$\varphi_{m,n}$	-	Channel gain of subcarrier n on user m
χ	-	Lagrangian multiplier

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CHAPTER 1

INTRODUCTION

1.1 Background

Achieving high data rates in global wireless communication is complex with the present increment in bandwidth demand by different service classes. High data rates for wireless local area networks, such as the Wi-Fi (IEEE 802.11) family of standards, became commercially flourishing around 2000 [1]. Wide area wireless networks, such as cellular systems, are still designed and used primarily for low rate voice services. Even though there are various promising technologies, the reality of a wide area network servicing users with high data rates through realistic bandwidth and power utilization, while maintaining high coverage and quality of service has yet to be achieved [3, 4].

The WiMAX (Worldwide inter-operability for microwave access) Forum is formed to solve this problem and to promote solutions based on the IEEE802.16 standards. The target of the IEEE802.16 Forum [1] is to design a wireless communication system that incorporates the most promising new technologies in communications and digital signal processing for achieving a broadband internet access for nomadic or mobile users over a wide or metropolitan area. It is important to note that WiMAX systems have to face similar challenges just like the existing cellular systems, and their eventual performance will be bounded by similar laws of physical and information theory [4]. The WiMAX forum which is formed in 2001 completed the standard and approved for fixed application in 2004, while the standard for mobile WiMAX is completed in 2005 [1-3]. The IEEE802.16e is the name for the mobile WiMAX by the IEEE and is designed to enable pervasive, high-speed mobile internet access to a very large coverage area of several kilometers at data rate of about 75Mbps [1-4].

1.2 Broadband Wireless Network

A large number of wireless access technologies exist; other systems are still under design [3]. These technologies can be distributed over different network families, based on the network scale. Figure 1.1 shows the wireless network categories, with most famous technologies for each type of the network.

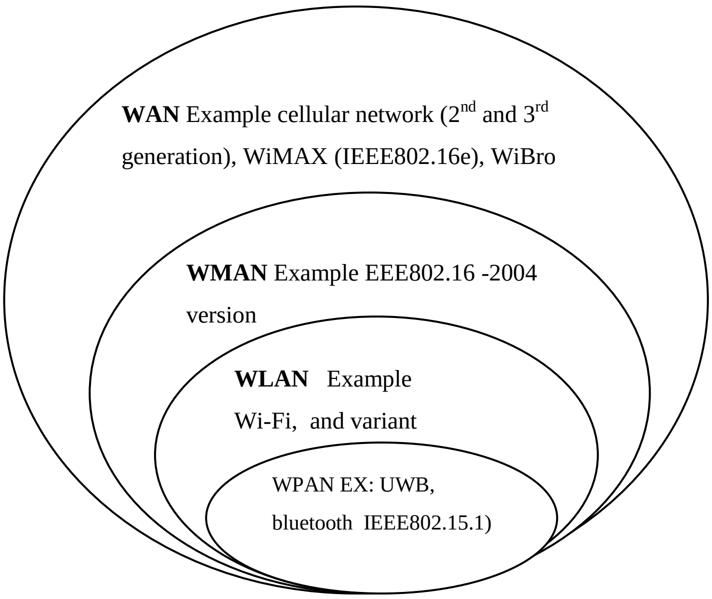

Figure 1.1 Wireless network categories

WiMAX IEEE802.16e being one of the WAN categories provides flexible and easy deployment solution to high-speed communications and supports a variety of services utilizing advanced multiple access techniques [1]. This means that the network will be able to accommodate users with different traffic classes and quality of services (QoS) requirements. As a key component of the state of the art IEEE 802.16e standard is accessed by means of Orthogonal Frequency Division Multiple Access (OFDMA) which supports broadband access infrastructure based wireless networks. The technology of OFDMA is based on OFDM as such it inherits immunity to inter-symbol interference and frequency selective fading like OFDM. It also increases multi-user diversity by acting the channel fading as a channel randomizer [1-3]. Its performance depends on the ability to provide efficient resource allocation, which is limited by the scarce radio spectrum.

A good radio resource allocation scheme should adapt to wireless fading channel, as well as improves the spectrum efficiency and satisfies active users with different traffic classes. With OFDM, the prescribed bandwidth is divided to multiple orthogonal frequency bands called subcarriers [1, 3-4]. These subcarriers are allocated to subscriber station (SS) by the base station (BS). The allocated subcarriers may be distributed or adjacent. In WiMAX, a group of these subcarriers forms a subchannel which can be accessed at different OFDM symbols called slot and this slot is the minimum resource that can be allocated to a SS [1]. The WiMAX frame is divided into uplink and downlink sub frame, BS accesses the SS in the downlink while the reverse is the case in the uplink. Both the downlink and uplink are either multiplexed in time using the time division duplex (TDD) or in frequency using frequency division duplex (FDD) [1]. In FDD, simultaneous communication is achieved by using different subchannels. In time division duplex, the communication is achieved using the same subchannels in different time slots. In the TDD mode, the downlink and uplink are separated by transmit receive transition gap (TTG) and the uplink and subsequent frame are separated by receive transmit transition gap (RTG) [1]. The throughput of the downlink or uplink is proportional to the number of subcarriers allocated to the corresponding SS, as well as the achievable rate of each subcarrier [2-4].

In frequency selective multipath fading environment, different subcarriers have diverse channel gains for the same SS, so the same subcarrier fades independently for different SSs [5-7]. Such diversity has motivated the design of dynamic mechanisms for allocating the resource in OFDM based wireless networks. In particular, a large body of research work is focused on the downlink subcarrier assignment and resource (bit and power) allocation schemes, aiming at maximizing link rate or minimizing transmit power [6, 7].

Many papers have been published on how these limited radio resources in WiMAX netwok can be allocated efficiently. While some research papers focus on how to provide efficient call admission control [6-10], others focused on efficient scheduling algorithm [11-17]. Other research papers target the assignment of subcarriers, bit and power [18-24]. Even though a lot of papers are published on call admission control, most of them do not have service differentiation and channel quality aware when admitting traffics [7-9]. Some works are channel aware but no service differentiation [10]. While some considered service differentiation but are channel unaware [38]. In scheduling, some papers considered cross layer design which has high complexity [11-13]. Scheduling based on channel quality is proposed in [10, 16] while in [15] utilizes the buffer queuing information for scheduling a packet.

Resources such as subcarriers, bits and power allocation are separately treated in some researcher works [18-30]. In an OFDMA system, the radio resource allocation problems in physical and medium access control (MAC) can be formulated as joint optimization problem for efficient allocation of the limited resource. In [39] call admission control and power allocations are treated together. In [25] resource allocation of subcarriers is proposed by assuming equal subcarrier allocation irrespective of the user data rate and channel quality. Equal power distribution to all subcarriers irrespective of the channel quality is assumed in [23]. In [26-27] ideal channel state information is assumed by using fixed modulation for all subcarriers to all users.

In the actual system, SSs have different data rate at different location from the BS so the approach in [23-27] above do not reflects the practical situation. Some realistic approaches are proposed in [18-22, 28-30] in order to reflect the actual system, by treating the subcarrier and power allocation separately. In [18, 22] users are allowed to set their data rate based on their QoS and by using proportional rate constraint each user data rate can be satisfied with constraint to the total transmit power. However, this leads to high computational burden at the BS. In [21] the computational complexity is reduced by minimizing the transmit power with constraint to user data rate but there is no flexibility to users even though they have different data rate. Computational complexity is reduced in [24] using Lagrangian dual decomposition which cannot be implemented in the real system. In [102], computational complexity is reduced by using same techniques in [21] with relay station deployment.

In wireless network like WiMAX, QoS is very important parameter to consider when admitting and allocating resources to SS. This is due to the fact that the traffics in WiMAX are heterogeneous in nature. Thus, the researches presented above on resource management may not be suitable in WiMAX network due to variations in the QoS parameters of the SSs in the network. In addition to this, WiMAX network supports adaptive modulation to cater for channel variation and none of the research mentioned above proposed call admission control which is channel aware with service differentiation or addressed the problem of the computational complexity of the resource allocation together with the flexibility of the data rate for the users.

WiMAX network is heterogeneous traffic wireless network that involves different users wired or wireless, from a real-time, data, voice users, to higher speed users and so on. The IEEE802.16e standard [1-2] have identified and classified the heterogeneous traffics expected in WiMAX into five service flows: Unsolicited grant service (UGS), Real time polling service (rtPs), non-real time polling service (nrtPs), best effort (BE) and extended real time polling service (ertPs). These traffics have different QoS and arrive to the network in Poisson process, from random locations within the coverage area of network. Thus, efficient radio resource management is needed.

1.3 Problem Statements

IEEE 802.16e, Mobile WiMAX, has the capability to support high transmission rates and QoS for different applications. Due to the limited resources in this network, efforts to improve resource utilization are vital issues. In order to effectively support the heterogeneous traffics expected in this network, great challenges are anticipated in the radio resource management entity. The resource management including call admission controls, scheduling controls, bandwidth and power allocation are essential in order to realize an efficient and optimum network performance.

1.4 Objectives of the Research

The research question is how to develop an efficient algorithm for call admission control, with effortless scheduling algorithm and low complex resource allocation algorithm for subcarriers, bit and power for WiMAX network. The following are the objectives of the thesis:-

1. To develop an efficient admission control technique based on service differentiation for WiMAX network.
2. To propose scheduling algorithm that satisfies the QoS requirements for WiMAX network.
3. To reduce the complexity in resource allocation technique and allows data rate flexibility in WiMAX network.

1.5 Scope of the Research

The scope of this research covers the admission control based on resources, dynamic resource allocation, and scheduling in the downlink of the base station of mobile WiMAX. The research focuses in the downlink in point to multipoint mode with centralized BS. In the call admission control, bandwidth is allocated based on grant per subscriber station (GPSS) so that all subscribers need to compete only once and once admitted they are assumed to adhere with their QoS. All admitted SSs are assumed to be active in the network throughout the simulation period. Channel quality per SS is assumed to be feedback by each SS to the BS. The admission control unit at BS computes the path loss experienced by each user. Erceg model is used to estimate the path loss which is translated into SNR. Users are assumed to be moving with low speed like pedestrian so that accurate channel state can be obtained. Thus, modulation scheme and coding rate can be chosen for each SS. The aggregate total number of slots required by each SS and each packet in the scheduling can be computed. Since different modulation techniques and coding rates exist in WiMAX for the sake of simplicity square *M*-modulation techniques is assumed with various coding rate.

The frequency selective multipath channel in resource allocation is modeled to consist of 6 independent Rayleigh multi-paths, with exponentially decaying profile. The fading channel will be assumed to be varying slowly. The resource allocation algorithm starts with two users and consequently users are added with different data rate requirements. The users can be from any type of service flow in mobile WiMAX.

1.6 Significant of the Research

Wireless communication is presently the leading communication technology with millions of subscribers. To satisfy and maintain these subscribers, there is need to have a very good and efficient way of providing good quality of services to these subscribers and at the same time try to optimize the available resources as the spectrum is limited. For example, when a conventional approach of admission control or resource allocation is implemented on the network, the resource may not be used efficiently and the subscriber's QoS may be affected which causes dissatisfaction to the SSs. WiMAX being a broadband wireless network is expected to provide services to different traffics with different QoS requirements. With efficient call admission control algorithm, scheduling and resource allocation algorithm, the QoS requirement will be guaranteed; this will attract more subscribers and hence network capacity will be optimized and the overall revenue generated by the service providers will increase.

1.7 Research Contributions

The following contributions are specifically achieved in this research;-

1. The partitioning for service differentiation in call admission control has improved the overall service flow acceptance compared to the approach that uses conventional call admission control in WiMAX.
2. The use of fuzzy logic in the handover partition of the call admission control has further reduced the overall dropping probability and increases the flow acceptance.
3. The use of channel quality, link and queuing aware earliest deadline first (LQA-EDF) scheduling algorithm increases the overall throughput compared to the conventional earliest deadline first scheduling algorithm in WiMAX.
4. The developed LQA-EDF scheduling algorithm has buffer management and maintains fairness among the service flow in WiMAX without starvation to non real time applications.

5 The use of particle swarm optimization technique for allocating subcarriers and power with flexible data rate has reduced the overall complexity of the resource allocation algorithm to $Mlog_{10}N$ for M users and N number of subcarriers. The proposed technique has reduced the central processing unit (CPU) time usage compared to root-finding method and linear search techniques adopted by some researchers.

1.8 Thesis Organization

The thesis is organized as follows;

Chapter 1 focuses on introduction, broadband wireless network, problems definition, research objective, scope and significant of the research work and finally the contributions of the research work.

Chapter 2 explains some of the important features in WiMAX, the quality of service provisioning, MAC and physical layer architectures. Literature review on call admission control, scheduling and resource allocation in WiMAX network are also presented.

Chapter 3 discusses on the designed framework of the proposed call admission control policy, scheduling algorithm and the resource allocation technique. The physical layer model and the resource allocation mathematical model are presented. The concept of Particle swarm optimization in resource allocation is also included.

Chapter 4 discusses on the proposed partition call admission control policy. The link aware CAC with service differentiation is explained thoroughly. A fuzzy logic implementation in the handover partitioning is developed. The algorithm is validated through simulation work in MATLAB and compared with conventional CAC in WiMAX network.

Chapter 5 presents link and queuing aware scheduling algorithm. The algorithm is based on the conventional EDF. The technique used to differentiate services for QoS provisioning in the algorithm is explained. Buffer management strategies in the algorithm are highlighted. The mathematical model of the proposed scheduling algorithm is validated through simulation in MATLAB.

The resource allocation algorithm using PSO optimization technique is presented in Chapter 6. The cost function of the resource allocation using the proposed technique is highlighted and the optimal power allocation using water filling algorithm is derived. The complexity of the system is analysed and compared with related optimization techniques. The computational time taken by the proposed algorithm is compared with other algorithm using MATLAB simulation flat form.

Chapter 7 consists of final conclusion and contributions made in this work. The areas for further studies are also highlighted.

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APPENDIX A

List of Publication from the Research

1 **D. S. Shuaibu**, S. K. Syed Yusof, N. M. Abdul- Latiff, S. H. S. Ariffin, R. A. Rashid and N. Fisal, "Bandwidth Allocation in WiMAX with Channel Quality and Fuzzy Logic Control Submitted to Journal Electrika Under Review

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6 **D.S. Shu'aibu** and S.K. Syed-Yusof,"Quality of Service Provision for Unsolicited Grant Service and Real Time traffics in WiMAX," International

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7 **D. S. Shuaibu** and S. K. Syed Yusof Slot Allocation Algorithm for Real Time and Non Real Time Traffics of Mobile WiMAX IEEE802.16e International Journal of Computer Applications (IJCA) Vol 8 No.7 October 2010. pg 12-16

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10 **D. S. Shuaibu**, S. K. Syed yusof and N. Fisal Capacity Utilization and Admission Control in the Downlink of Mobile WiMAX International Review on Computers and Software (I.Re.Co.S) Vol 5 No.2 March 2010. pg 193-199

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12 **Dahiru Sani Shuabu**, Sharifah Kamilah, Norshela Fisal and Yakub S Baguda, Simulation and Performance Analysis of Partial Usage Subchannels in WiMAX IEEE802.16e. International Journal of Recent Trends in Engineering (IJRTE)Vol 2. No. 5 Nov. 2009 pg 126-129.

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14 Y.S.Baguda, N. Fisal, S.H. Syed, S.K.Syed Yosuf, L.A.Latif, Rozeha A. Rashid and **Dahiru Sani** and Adaptive FEC Error control scheme for wireless video Transmission International Conference on Advanced Communication Technology ICACT Korea Feb 2010. Pp 565-569

15 **D.S. Shu'aibu**, S.K. Syed-Yusof, S.H.S. Ariffin, R.A. Rashid and Y.S. Baguda Call Admission Control in Mobile WiMAX IEEE802.16e with Dual

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16. **D.S. Shu'aibu**, S.K. Syed Yusof, N. Fisal and Y.S. Baguda An Efficient Method of Call Admission Control in Mobile WiMAX IEEE802.16e, Third International Graduate Conference on Engineering, Science and Humanity, (IGCESH 2010) 2-4 November 2010 Johor Bahru Malaysia .

17. **D.S. Shu'aibu**, S.K. Syed-Yusof and N. Fisal Link Aware Unsolicited Grant Packets Scheduling in Mobile WiMAX, International Conference on Modelling Simulation and optimization (ICMSAO2011) pp 1081-1085 April 2011