

**RESOURCE ALLOCATION FRAMEWORK FOR
DOWNLINK SUBFRAME OF MOBILE WiMAX**

ZAID GHANIMALI AL-AQEEDI

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**RESOURCE ALLOCATION FRAMEWORK FOR
DOWNLINK SUBFRAME OF MOBILE WiMAX**

By

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TABLE OF CONTENTS

	PAGE
THESIS DECLARATION	i
ACKNOWLEDGEMENTS	ii
TABLE OF CONTENTS	iii
LIST OF TABLES	vii
LIST OF FIGURES	viii
LIST OF ABBREVIATIONS	xi
LIST OF SYMBOLS	xv
ABSTRAK (MALAY)	xvii
ABSTRACT (ENGLISH)	xviii
CHAPTER 1 INTRODUCTION	
1.1 Introduction	1
1.2 Research Scope	4
1.3 Problem Statement	4
1.4 Research Objectives	5
1.5 Research Contributions	6
1.6 Thesis Outlines	7
CHAPTER 2 LITERATURE REVIEW	
2.1 Introduction	9
2.2 MAC and PHY Layers' Functions	10

2.2.1	MAC Layer	10
2.2.2	PHY Layer	12
2.3	OFDM Basics and OFDMA Subcarrier Permutations	14
2.4	Downlink Resources of Mobile WiMAX	17
2.5	Resource Allocation Management of Mobile WiMAX	19
2.6	Burst Allocation Based on Operator Demand	20
2.6.1	Frame Utilization Based on Data Burst Reshaping	21
2.6.2	Frame Utilization Based on Data Burst Fragmentation	27
2.7	Burst Allocation Based on User Demand	30
2.8	Frame Capacity and Overhead Reduction	34
2.9	Factors Influencing Burst Construction	37
2.10	Burst Allocation Algorithm Assessment and Comparison Methods	38
2.11	Burst Allocation Algorithm Objectives and Challenges	41
2.12	Summary	42

CHAPTER 3 SCHEDULER AND DOWNLINK RESOURCE ALLOCATION OF MOBILE WiMAX

3.1	Introduction	44
3.2	OFDMA PHY layer Frame and Slot structure	45
3.2.1	Downlink Subframe	49
3.2.1.1	Frame Overhead and Downlink Management Message	50
3.2.1.2	Downlink Data Bursts	52
3.3	Burst Allocation algorithm Criteria	53
3.4	Scheduling Goals and Burst Allocation Algorithm Mechanisms	56
3.5	Impact of Burst Allocation Algorithm on Mobile WiMAX Performance	61

3.6	Burst Allocation Algorithm Based on PUSC	64
3.7	Summary	66

CHAPTER 4 NOVEL SEQUENTIAL BURST ALLOCATION ALGORITHM

4.1	Introduction	68
4.2	Novel Burst Allocation Algorithm (SBA)	69
4.2.1	Sequential Burst Allocation Algorithm (SBA) Mechanism	70
4.2.2	SBA Algorithm	74
4.2.3	SBA Overhead Modification	77
4.2.4	Downlink Subframe Utilization Analytical Model	79
4.2.4.1	Modeling of Std-B Allocation Algorithm	80
4.2.4.2	Modeling of SBA	84
4.3	SBA Simulation Model	88
4.4	Performance Metrics	91
4.5	Comparison Evaluation of SBA Algorithm	93
4.6	A new Method of Overall Performance Assessment and Comparison	93
4.7	Summary	96

CHAPTER 5 RESULTS AND DISCUSSION

5.1	Introduction	98
5.2	Performance Evaluation	98
5.2.1	Unallocated and Unused Wastage Slots Per Downlink Subframe	99
5.2.2	Frame Overhead	102
5.2.3	Number of Users Per Downlink Subframe	103
5.2.4	Information Rate	104

5.2.5	Gross Data Transfer Rate	105
5.2.6	Downlink Subframe Utilization	106
5.2.7	Power Consumption	107
5.3	Performance Analysis	109
5.3.1	Transmission Time Delay	110
5.3.2	Fragmentation	112
5.3.3	SBA Complexity	114
5.3.4	Utilization Efficiency Behavior of SBA Algorithm	116
5.4	Comparison Evaluation of SBA algorithm	118
5.4.1	Basic Resource Utilization Results	118
5.4.1.1	Operator's Demands Algorithms	119
5.4.1.2	User's Demands Algorithms	123
5.4.2	Overall Performance Assessment and Comparison	125
5.5	Summary	127
CHAPTER 6 CONCLUSION AND FUTURE WORK		
6.1	Conclusions	129
6.2	Future Work	132
REFERENCES		134
LIST OF PUBLICATIONS AND AWARDS		142

LIST OF TABLES

No.		PAGE
2.1	FUSC/PUSC/AMC permutation subcarriers distribution for different FFT sizes	16
3.1	Mobile WiMAX resource allocation goals and mechanism	59
4.1	Parameter setup for SBA	90
4.2	Assessment questions explanation	94
4.3	Addressing the evaluation questions	95
5.1	Overall performance assessment results	126

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LIST OF FIGURES

No.		PAGE
2.1	IEEE Std. 802.16 protocol reference model	11
2.2	Functional stages of WiMAX PHY layer	13
2.3	Subcarriers distribution within OFDM symbol	14
2.4	Conceptual scheme of distributed and adjacent permutation showing sequence number of the subcarrier frequency	15
2.5	Downlink resources (slot) of Mobile WiMAX	18
2.6	Downlink user resources (burst) of Mobile WiMAX.	18
3.1	A sample TDD frame structure for Mobile WiMAX	47
3.2	Slot structures of three types of subcarrier permutation (a) FUSC, (b) PUSC and (c) AMC	48
3.3	OFDMA downlink PHY PDU structure	49
3.4	DL-MAP structure of Mobile WiMAX TDD frame	51
3.5	A sample Mobile WiMAX OFDMA downlink subframe structure for TDD mode	54
3.6	Example of burst allocation procedure of Std-B	65
4.1	SBA resource allocation procedure which describe slot allocation unit called Allocation Slot (AS)	70
4.2	Downlink subframe resource allocation using SBA algorithm	72
4.3	AS concept to minimize burst fragmentation	74
4.4	SBA algorithm flowchart	75
4.5	Modified overhead structure of Mobile WiMAX TDD frame	78

5.1	Percentage of unallocated slots vs. different MAC PDU sizes	100
5.2	Percentage of unused slots vs. different MAC PDU sizes	101
5.3	Percentage of total wasted slots vs. different MAC PDU sizes	102
5.4	Percentage of overhead slots vs. different MAC PDU sizes	103
5.5	Average numbers of users per downlink subframe vs. different MAC PDU sizes	104
5.6	Downlink data allocation efficiency and information rate vs. different MAC PDU sizes	105
5.7	Total allocated slots and the achieved gross data transfer rate vs. different MAC PDU sizes	106
5.8	Downlink subframe utilization ratio for data, overhead and wastage (unused and unallocated slots)	107
5.9	Example of downlink subframes for Std-B and SBA algorithms	109
5.10	Average required numbers of frames for transfer 1 Mbits of data vs. different MAC PDU sizes	111
5.11	Average framing time for 1 Mbits of data vs. different MAC PDU sizes	111
5.12	Average framing time for 10 Mbits of data vs. different data sizes	112
5.13	Average number of users and average number of fragments per downlink subframe vs. different bursts sizes	113
5.14	Average numbers of users vs. utilization percentage of the downlink subframe for SBA algorithm	114
5.15	Downlink subframe utilization efficiency for three different bandwidth sizes vs. MAC PDU sizes	117
5.16	Average number of burst fragments for three different bandwidth sizes vs. MAC PDU sizes	118

5.17	Average downlink subframe utilization efficiency vs. different number of users	120
5.18	Example of downlink subframes of eOCSA and SBA algorithms using two repetition of overhead	122
5.19	Example of downlink subframes of eOCSA and SBA algorithms using four repetition of overhead	123
5.20	Average downlink subframe utilization efficiency vs. different number of users	124

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LIST OF ABBREVIATIONS

AMC	Adaptive Modulation and Coding
ARQ	Automatic Repeat Request
AS	Allocation Slots: smallest unit of resources used by SBA algorithm
AS-column	Allocation Slots-column
ATM	Asynchronous Transfer Mode
BE	Best Effort
BFPS	Burst Fragmentation Packing and Scheduling
BLER	Block Error Rate
BOSS	Burst Overlapping and Scheduling Scheme
BS	Base Station
CAC	Call Admission Control
CC	Convolutional Code
CID	Connection Identifier
CP	Cyclic Prefix
CPS	Common Part Sublayer
CQI	Channel Quality Indication
CQICH	Channel Quality Indicator Channel
CRC	Cyclic Redundancy Code
CS	Convergence Sublayer
CTC	Convolutional Turbo Code
DCD	Downlink Channel Descriptor
DIUC	Downlink Interval Usage Code
DLFP	Downlink Frame Prefix

DL-MAP	Downlink Map
DL-MAP_IE	Downlink Information Element
DLRMS	Downlink Resource Management Scheme
DSL	Digital Subscriber Line
EDBA	Efficient Downlink Bandwidth Allocation
eMax.Rect.	enhanced Maximum Rectangle-based burst allocation
eOCSA	enhanced One Column Striping with non increasing Area first mapping
ERT-VR	Extended Real-Time Variable Rate
FCH	Frame Control Header
FDD	Frequency Division Duplex
FEC	Forward Error Correction
FFT	Fast Fourier Transform
Frag.-IE	Fragment- Information Element
FTP	File Transfer Protocol
FUSC	Full Usage of Subchannels
GMH	Generic MAC Header
GSA	Greedy Scheduling Algorithm
HTTP	Hypertext Transfer Protocol
IE	Information Element
IEEE	Institute of Electrical and Electronics Engineers
IFFT	Inverse Fourier transform
IP	Internet Protocol
LAN	Local Area Network
LDPC	Low Density Parity check Code
LTE	Long Term Evolution

MAC	Media Access Control
MATS	Mapping with Appropriate Truncation and Sort
Mbps	Mega Bit per Second
MCS	Modulation and Code Scheme
MRBA	Maximum Regret Band Allocation
MS	Mobile Stations
N_CID	Numbers of Connection Identifier
NLOS	Non-Line-Of-Sight
NP	Nondeterministic Polynomial time (NP-complete problem is a class of decision problems defined in computational complexity theory)
nrtPS	non-real-time Polling Service
OBBP	Orientation-Based Burst Packing
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
P	Polynomial time (P-complete problem is a class of decision problems that provide an answer in polynomial time)
PDA	Personal Digital Assistant
PDU	Protocol Data Unit
PHY	Physical Layer
PMP	Point-to-Multipoint
PUSC	Partial Usage of Subchannels
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
RB	Resource Block

RTG	Receive-transmit Transition Gap
rtPS	real-time Polling Services
SAP	Service Access Point
SBA	Sequential Burst Allocation
SDRA	Sample Data Region Allocation algorithm
SDU	Service Data Unit
SFID	Service Flow Identifier
SINR	Signal-to-Interference-plus-Noise Ratio
SNR	Signal-to-Noise Ratio
Std-B	Standard-Based
TCP	Transmission Control Protocol
TDD	Time Division Duplexing
TTG	Transmit-receive Transition Gap
UCD	Uplink Channel Descriptor
UGS	Unsolicited Grant Services
UL-MAP	Uplink Map
UL-MAP IE	Uplink Information Element
VoIP	Voice Over IP
WiMAX	Worldwide Interoperability for Microwave Access

LIST OF SYMBOLS

d_m	Actual data size in term of bits for user m
cq	Counter to calculate number of unallocated slots
ck	Counter to calculate number of unused slots
q	Counter to calculate top-end two slots of wastage per downlink subframe for SBA algorithm
F_x	Fixed size of frame overhead
k_m	Flag records number of unused slots for SBA algorithm
n_i	i^{th} subchannel
y_j	j^{th} OFDMA symbol
F	Mobile WiMAX frame composed of $N * Y$
K	Number of bits in DL- MAP fields precedes Information Element
δ	Number of bits in DL- MAP Information Element
λ	Number of bits in the fragment Information Element field
β	Number of bits in UL- MAP fields precedes Information Element
τ	Number of bits in UL- MAP Information Element
C	Number of bits per slot
B_m	Number of data slots allocated to user m
Fr_{IE}	Number of fragments per downlink subframe
y_{mL}	Number of OFDMA symbols related to user m
OV_m	Number of overhead slots related to user m
DB_s	Number of slots in data bursts area
n_{mH}	Number of subchannels related to user m
u_m	Number of unused slots within burst of user m

γ	Overhead repetition rank
R_m	Required number of data slots for user m
m	Single user deliver to the burst allocation algorithm
S_{DL_MAP}	Size of DL-MAP in term of bits
$S_{DL_MAP_{SBA}}$	Size of modified DL-MAP for SBA algorithm
S_{UL_MAP}	Size of UL-MAP in term of bits
S_{n_i, y_j}	Slots of i^{th} subchannel by j^{th} OFDMA symbol
$DB_{s-Bursts}$	Sum of all burst's slots allocated to M users within the downlink area
R_M	Sum of all data slots allocated to M users within downlink subframe
W	Sum of all unallocated slots within downlink area
u_{MSBA}	Sum of all unused slots produced by the SBA algorithm
u_M	Sum of all unused slots within the bursts of M users
$DB_{s-Bursts_{SBA}}$	Sum of bursts' slots allocated to M users within downlink area of SBA algorithm
W_{SBA}	Sum of unallocated slots produced by SBA algorithm
OV_s	Total number of slots in overhead area
DF_s	Total number of slots per downlink subframe area
N	Total number of subchannel per downlink subframe
M	Total number of users per downlink subframe
Y	Total number OFDMA symbol per downlink subframe
V_s	Variable size of frame overhead

KERANGKA PERUNTUKAN SUMBER UNTUK BINGKAI PAUT TURUN WiMAX MUDAH ALIH

ABSTRAK

Teknologi WiMAX mudah alih dijangka akan menjadi satu teknologi yang mendominasi dalam memenuhi keperluan sistem komunikasi tanpa wayar moden Mobile WiMAX yang merupakan sistem komunikasi jalur lebar tanpa wayar mudah alih berteraskan teknik OFDM dan menggunakan OFDMA versi capaian berbilang dalam menyampaikan data kelajuan tinggi.. Teknik capaian berbilang membolehkan ramai pengguna mencapai jumlah data yang tinggi melalui sumber saluran paut turun terhad. Pengurusan sumber pautan turun dikongsi ketat memberi kesan kepada prestasi mudah alih stesen pangkalan WiMAX, kerana peruntukan sumber pautan turun adalah keputusan yang kompleks yang memerlukan untuk kuantiti banyak aspek yang mempengaruhi prestasi pengendali rangkaian dan kepuasan pengguna. Pengurusan sumber pautan turun dikongsi ketat memberi kesan kepada prestasi mudah alih stesen pangkalan WiMAX, kerana peruntukan sumber pautan turun adalah keputusan yang kompleks yang memerlukan untuk kuantiti banyak aspek yang mempengaruhi prestasi pengendali rangkaian dan kepuasan pengguna.. Masalah utama yang biasanya timbul dalam pengurusan peruntukan sumber ialah pembaziran sumber akibat kesilapan pengurusan dalam algoritma peruntukan sumber yang berperanan untuk memaksimumkan penggunaan sumber. Pembaziran sumber boleh dilihat dengan penurunan prestasi keseluruhan sistem WiMAX mudah alih, memandangkan ia mengurangkan lebar jalur yang secara langsung menjejaskan pengguna sistem WiMAX mudah alih dan sebaliknya. Dalam tesis ini, satu reka bentuk baharu algoritma peruntukan sumber dinamik untuk stesen utama WiMAX mudah alih dicadangkan. Cadangan algoritma peruntukan ini dipanggil Algoritma Peruntukan Pecahan Berturut (SBA). Algoritma SBA yang dicadangkan ini akan tertumpu pada pengurangan pembaziran sumber dan meningkatkan kecekapan penggunaan sumber saluran paut turun. Algoritma SBA menggunakan kelebihan spesifikasi lapisan fizikal untuk memenuhi keperluan pengguna mudah alih, dan menggunakan sepenuhnya struktur saluran paut turun untuk mengurangkan maklumat berulang dalam overhead paut turun dan menyusun peruntukan sumber secara inovatif. Reka bentuk SBA memelihara keperluan pengguna dan mengurangkan penggunaan kuasa di stesen mudah alih. Penilaian, perbandingan, dan analisis prestasi menunjukkan SBA adalah algoritma mudah yang menyelesaikan kerumitan dan kekangan dalam memperuntukkan sumber pengguna dan paling ketara mengurangkan pembaziran sumber, yang secara langsung meningkatkan kadar pergerakan data dalam paut turun dan menyumbang dalam kualiti perkhidmatan sedia ada. Keputusan menunjukkan algoritma SBA mencapai 97.54% kecekapan penggunaan dalam saluran paut turun dan stabil dalam pelbagai parameter operasi yang membawa kepada peningkatan bilangan pengguna stesen utama dan meningkatkan kapasiti sistem. Dan mencadangkan cara baru untuk menilai prestasi keseluruhan dan perbandingan dengan peruntukan sumber algoritma. Hasil kajian menunjukkan bahawa algoritma SBA mencapai peratusan tertinggi (90.13%) daripada prestasi keseluruhan.

RESOURCE ALLOCATION FRAMEWORK FOR DOWNLINK SUBFRAME OF MOBILE WiMAX

ABSTRACT

Mobile WiMAX technology is anticipated to be one of the technologies that dominate to meet the requirements of modern wireless communication systems, it is mobile broadband wireless communication system based on OFDM technique and it uses multiple-access version OFDMA to deliver high-speed data. Multiple-access technique allows many users to request high data rates in finite resources of the downlink channel. Management of shared downlink resources strictly affect the performance of mobile WiMAX base station, due to downlink resource allocation is complex decision which require to quantify many aspects that influence the performance of network operator and users' satisfaction. The main and common problem of the resource allocation management is the resource wastage, due to management flaw in resource allocation algorithm, which is responsible for maximizing the resources utilization. Resource wastage is directly translated to decline in the overall performance of Mobile WiMAX system, since it represents a bandwidth shortage which adversely affects all Mobile WiMAX system participants and vice versa. In this thesis a novel design of dynamic resource allocation algorithm for Mobile WiMAX base station is proposed. The proposed allocation algorithm is called Sequential Burst Allocation (SBA) algorithm. SBA algorithm focuses on minimizing the wasted resources to increase the utilization efficiency of the downlink channel resources. SBA algorithm takes advantages of the physical layer specification to satisfy mobile users' requirements, and utilizes downlink channel structure to reduce the redundant information in the downlink overhead and to manipulate resource allocation in innovative method. SBA design preserves users' priorities and minimizes power consumption at mobile stations. The performance evaluations, comparisons and analysis showed that SBA is a low complexity algorithm that overcomes the restriction and difficulties of allocating users' resources and achieves significantly minimization in resource wastage, which increases data transfer rate in the downlink direction to contribute in supporting the presented quality of service. Results showed that SBA algorithm achieves 97.54% utilization efficiency of the downlink channel and stable performance under various operating parameters, which lead to increase number of users per base station and enhance system capacity. A new method of overall performance assessment and comparison for resource allocation algorithms is proposed. It showed that SBA algorithm achieves the highest percentage (90.13%) of overall performance.

CHAPTER 1

INTRODUCTION

1.1 Introduction

The Worldwide Interoperability for Microwave Access (WiMAX) is a standard for broadband wireless technology. WiMAX enables the delivery of last mile wireless broadband access as an alternative to the fixed broadband technologies such as Cable and Digital Subscriber Line (DSL). Also it's a competitive mobile broadband technology to the wireless communication of high-speed data for mobile phones and data terminals known as Long Term Evolution (LTE).

The two key players in the development of WiMAX are; the Institute of Electrical Electronics Engineers (IEEE) 802 Standards Committee and WiMAX Forum (Asif, 2010). IEEE 802.16 Working Group is a part of IEEE. The IEEE 802.16 standardization work started in the late 1990s and was completed the first standard of air interface version called IEEE 802.16-2004 (Fixed WiMAX) in October 2004 (IEEE-Std, 2004). Fixed WiMAX systems operate in 10-60 GHz frequencies. IEEE 802.16-2004 modification adds portability and mobilization aspects. The modified version is called IEEE 802.16e-2005 (Mobile WiMAX); it was published in December 2005 (IEEE-Std, 2005). The 802.16e air interface specification supports Non-Line of Sight (NLOS) for systems below 11 GHz. Mobile WiMAX mainly available in 2.3, 2.5, and 3.5 GHz (Yang, 2010). In May 2009, the IEEE Standards approved the IEEE 802.16-2009 air interface standard (IEEE-Std, 2009). This standard is a revision of IEEE 802.16-2004, and consolidates material from IEEE 802.16e-2005. The IEEE standard only defines Physical layer (PHY) and Media Access Control layer (MAC) specifications.

WiMAX Forum is a non-profit organization; its members consist of hundreds of major network operators as well as vendors for components and equipments of communications systems. It was termed to define guidelines known as profiles. The profiles include frequency bands of operation, the physical layer to be used, and minimum performance levels. It has also been tasked to certify compatibility and interoperability of broadband wireless products from different suppliers.

Mobile WiMAX standard supports point-to-multipoint (PMP) operating topology. In PMP mode, multiple Mobile Stations (MSs) are connected to one Base Station (BS) where the access channel from the BS to the MS is called the downlink channel, and the one from the MS to the BS is called the uplink channel. The downlink and uplink channels share the same frequency band at different durations of time when Time Division Duplexing (TDD) is employed, while at Frequency Division Duplexing (FDD) each of the downlink and uplink have separate frequency band. This thesis focused on TDD operating mode.

Mobile WiMAX BS fully responsible for allocating bandwidth to all MSs in both downlink and uplink, depending on the particular Quality of Service (QoS) which defines traffic parameters associated with a service (Yang, 2010). A fundamental part of the Mobile WiMAX MAC layer design is to support strong QoS, which is achieved by using connection-oriented MAC architecture, where all downlink and uplink connections are identified by a temporary address for data transmission associated to a unidirectional set of QoS parameters (Tang, Muller, & Sharif, 2010).

Mobile WiMAX MAC layer is built to support a variety of PHY layer specifications to address the needs of bursty data traffic, low-latency VoIP, and streaming video content. The PHY layer is based on the principles of Orthogonal Frequency Division Multiplexing (OFDM) in their transmission technique; it supports multiple users to access the air interface simultaneously, where an OFDM signal can be made from many user signals, giving the Orthogonal Frequency Division Multiple Access (OFDMA) based physical layer (Asif, 2010). OFDMA allows a wide range of flexibility in addressing the need for wide variation in spectrum allocation and user/operator demands, because of OFDMA can provide sophisticated frame structure which enables dynamic allocation of resources both in frequency (subcarriers) and time (OFDM symbols). MSs identify their resources within a frame through control (also called MAP) messages at the beginning of each frame to define resource allocation changes on a frame-by-frame basis. This flexibility provides the ability to manage the resource allocation in different policies to satisfy various user/operator preferences.

Mobile WiMAX systems provide wide range of services (such as real time audio and video streaming, VOIP, multimedia conferencing, and interactive gaming) for fixed and mobile stations (such as mobile smart-phones, Personal Digital Assistants (PDAs), notebook and laptop/desktop computers) in their deployment target. The increasing in the information exchange volumes with the increasing number of devices and users requires an efficient resource management to accommodate such volumes of data to ensure the better the services.

1.2 Research Scope

Part of Mobile WiMAX resource management is downlink resource allocation. It is the process of allocating scarce shared resources among downlink users. Downlink resource allocation is a plan for using available downlink resources, which is performed every frame of 5ms time duration.

One of the main distinguishing factors among Mobile WiMAX network operators is the efficient management of the shared downlink bandwidth resources of a BS, which affects network performance. BS allots for every downlink user specific resources represented by a fraction of channel frequency to be accessed by the user in a specific time within time duration of downlink channel.

Allocation management and the distribution of shared downlink resources of Mobile WiMAX BS are performed by burst allocation algorithm. Design of burst allocation algorithm needs to take advantage of PHY layer's specification and considers MAC layer requirements to satisfy the desired design objectives.

1.3 Problem Statement

Allocation of downlink resources to the users is the problem of allocating two dimensions of resources (time and frequency), where the smallest unit of resource called *slot*. Users' resources (group of contiguous slots for each user) are allocated and formulated in the form of irregular rectangles shapes called *bursts*. The complexity of arranging irregular rectangles of users' resources within downlink channel causes

resource wastage. The complexity of this problem has increased for many reasons which must take into consideration while allocating resources to the users, such as conserve users' priorities to meet the required fairness and QoS, rationalize power consumption at MSs, nature of system deployment, frequency interference between neighboring BSs and others. Downlink resource wastage takes place in two forms; *unused slots* which are allocated within user's burst as vacant slots for reasons formation rectangular shape, and the *unallocated slots* which exist inside downlink channel and undesignated to any user due to the difficulty of contiguously arranging of irregular rectangles within downlink channel. Both of unused and unallocated slots are transmitted in the downlink channel as blank resources. Therefore, inefficient use of downlink resources has double negative impacts; to the network operators and end users, since it affects data transmission speed, BS capacity and users' satisfaction.

1.4 Research Objectives

The objectives of this work are as follows:

1. Design and model a new burst allocation algorithm that satisfies the following requirements:
 - A. To minimize resources slots wastage to increase data transmission for the BSs leading to increase of operator revenues.
 - B. Low complexity algorithm to ensure low execution time in order to promptness delivering the services and complies with the limited time duration of the downlink channel.