# RESOURCE ALLOCATION FRAMEWORK FOR DOWNLINK SUBFRAME OF MOBILE WiMAX



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# RESOURCE ALLOCATION FRAMEWORK FOR DOWNLINK SUBFRAME OF MOBILE WiMAX

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**Zaid Ghanim Ali AL-Aqeedi**

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| | |
|---|---|
| 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 Dultiplexing |
| 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 |
| $Fx$ | 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 |
| $\mathcal{K}$ | Number of bits in DL- MAP fields precedes Information Element |
| $\delta$ | Number of bits in DL- MAP Information Element |
| λ | Number of bits in the fragment Information Element field |
| $\beta$ | Number of bits in UL- MAP fields precedes Information Element |
| $\tau$ | 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* |

| | |
|---|---|
| ɣ | 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 |
| $DB_{s\text{-}Bursts}$ | 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 |
| $u_{M_{SBA}}$ | 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 overhed 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