WiMAX Downlink Burst Allocation Algorithm: Implementation and Improvement using Qualnet

Ahmed M Husein Shabani & M.T.Beg
Dept. of Electronics & Communication Engineering,
Jamia Millia Islamia New Delhi

Ajay Roy
Department of Instrumentation and Control Engineering
National Institute of Technology Jalandhar

Emaad Mohamed H. Zahugi
Department of Computer science & Engineering
Lingays University Faridabad

ABSTRACT

Worldwide Interoperability for Microwave Access (WiMAX) is a Broadband Wireless Access technology based on IEEE 802.16 standards. WiMAX use orthogonal frequency division multiple accesses (OFDMA) as one of its multiple access technique. Scheduling and burst allocation are major design factors of OFDMA resource allocation. QualNet is simulation software that using to simulate most recent wireless networks like, Long term evaluation (LTE) and WiMAX networks. In QualNet WiMAX library there are many scheduling algorithms are implemented but there is no specific burst allocation algorithm is implemented. In this paper we shows that the implemented burst allocation algorithm in Qualnet is not confirm the IEEE802.16 standard and we implement one of recent proposed burst allocation algorithm namely, eOCSA (enhanced One Column Striping with nonincreasing Area first mapping). In addition some improvement to eOCSA algorithm is proposed and both the eOCSA algorithm and its improvement are evaluated using Qualnet.

General Terms

WiMAX, Allocation algorithm, Implementation, Qualnet.

Keywords
WiMAX, OFDMA, Burst Mapping.

1. INTRODUCTION

WiMAX is a wireless broadband solution that offers a rich set of features with a lot of flexibility in terms of deployment options and potential service offerings [1]. IEEE802.16d, IEEE802.16e and IEEE802.16m are standards for Wireless Metropolitan Area Network (WMAN) [2, 3, 4]. In parallel, the WiMAX forum releases several technical specification profiles [5]. WiMAX is one of the most promising technologies for broadband wireless access solution, as well as a 4G candidate. The important futures of WiMAX are scalable OFDMA, multiple input multiple output (MIMO) antenna, beam forming and adaptive modulation and coding (AMC), support time division duplexing (TDD) and frequency division duplexing (FDD), space time coding, strong security and multiple QoS classes [6].

The frame structure in TDD WiMAX is divided into downlink sub frame followed by an uplink sub frame separated by a small gap as shown in Figure.1. Farther the downlink sub frame and uplink sup frame are divided into symbols in time domain and orthogonal subcarrier in frequency domain. The sub carriers are grouped into logical subchannel using distributed permutation mode such as partial use of subcarriers (PUSC) and full use of subcarriers (FUSC) or adjacent permutation mode like adaptive modulation and coding (AMC). The subchannels are modulated with several modulation schemes adaptively based on SNR Quality to improve overall channel efficiency. In a frame, minimum data allocation unit is a slot which consists of one subchannel over one or more symbol based on used permutation mode. DL-MAP & UL-MAP messages are used by BS to control access to the air frame. These messages contain the informational elements (IEs) that specify the burst profile.

In WiMAX system, base station (BS) controls the allocation of the resources in both uplink and downlink direction. The downlink resource allocation involves three main steps. First step is Call admission control where the BS decides whether to accept or reject new connections based on the available resource and QoS requirements. Second step is scheduling where the scheduler select data packet to be sent in the current frame for each subscriber station (SS) from the queued traffic flows. It also decides size of the selected data packets in slots based on the available slots and quality of services without any shape constrain. Third step is mapping or allocating the selected data packets (known as "burst") into downlink subframe and this is main focus of this paper. This paper discuses downlink burst allocation algorithm for IEEE 802.16e Mobile WiMAX networks and its implementation in Qualnet

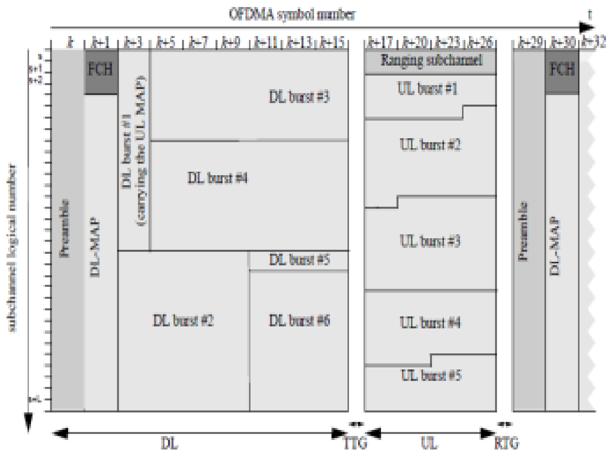

Fig 1: OFDMA TDD frame structure

1.1 Downlink Data Allocation Problem

The standard specifies that mapping data burst has to be in rectangular form into downlink sub frame. This constrain make the mapping as two-dimensional rectangle mapping problem. Shaping the selected data bursts in rectangles may require allocation of extra slots and fit those rectangles into big rectangle may leave some unutilized slots. Thus these unutilized slots affect the efficiency of mapping algorithm and WiMAX system performance. Also there are many consideration with two-dimensional rectangle burst mapping problem like: (i) minimize the number of burst time symbols to reduce SS active time and power consummation such as the work proposed in [7], (ii) minimize the number of burst subchannels to efficiently utilize the subchannel such as the work proposed in [8, 9] and (iii) reduce number of bursts to reduce DL-MAP overhead size such as the work proposed in [10]. The two-dimensional rectangle burst mapping problem is considered to be NP-complete problem [11]. The complexity of the solution grows exponentially with the number of objects [14]. Recently many heuristic algorithms have been proposed to solve this problem. But few of them are implemented and evaluated in system level simulation software like QualNet.

1.2 WiMAX Qualnet Simulation Software

QualNet is commercial simulation software implemented in C++ that simulates most recent wireless networks like, satellite, sensors, Long term evaluation (LTE) and WiMAX networks. It has a graphical user interface and sets of library function used to model, evaluate, implement and develop communication network protocols [xx]. In Qualnet wireless advance library most WiMAX system futures based on IEEE802.16 standard are implemented. For downlink scheduling there are many algorithms implemented and available in QualNet libraries like FRQ, WRQ, Stir, which allowing simulation and evolution of these algorithms such work proposed in [15,16]. But there is no specific downlink mapping algorithm is implanted in WiMAX library. And the implemented burst allocation algorithm is not confirming the standard. This motivate us to implement burst mapping algorithm namely, eOCSA (enhanced One Column Striping with nonincreasing Area first mapping) [14] using Qualnet. In addition some improvement to eOCSA algorithm has been proposed. Both the eOCSA algorithm and its improvement are evaluated using Qualnet.

The rest of the paper organized as follows, in section 2 description of downlink data allocation algorithm eOCSA and its improvement, in section 3 implementation of eOCSA and its improvement in Qualnet, in section 4 simulation result and finally conclusion in section 5.

2. DL-MAP OVERHEAD & ALOCTION ALGORITM

WiMAX assigns slots to users in downlink in a rectangular form called a burst where a burst contains data for a single or multiple CID that share the same physical parameters. Each user is informed about its burst allocation by broadcasting the DL_MAP massage with the most reliable MCS at the beginning of the DL subframe. The DL_MAP fields consist of two main groups. The first group which required 104 bits once per DL Subframe consists of Message Type, PHY Synchronization, DCD Count, BS ID and No Symbols. The second group consist of No CID, CID, Symbol Offset, Subchannel Offset, Boosting, No Subchannel, No Symbols, Repetition Coding Indication and DIUC [3]. This group requires (44+16 No CID) bits once per burst to define a two-dimensional allocation pattern of the burst and it's called Downlink MAP Information Element (DL_MAP_IE). Downlink data allocation algorithm return DL_MAP_IE information to broadcast at the beginning of each frame.

2.1 (eOCSA) Downlink Data Allocation Algorithm

One Column Striping with non-increasing Area first mapping (OCSA) proposed by So-In et. al. In [13] and it's enhancement in [14]. The algorithm can be described in three main steps. First step sort the bursts in decreasing order. Second step vertically allocate the largest burst (Bi) with dimensions (Wi,Hi)

Where $W_i = \lceil B_i/H \rceil$, $H_i = \lceil B_i/W_i \rceil$ where H is maximum height and $\lceil\ \rceil$ is ceiling function. Third step allocate the left space in the allocated column horizontally. Figure 2 illustrates the algorithm steps.

```
1st step
Sorted_allocations = Sort(resource_allocations)
FOR each unmapped element in sorted_allocations

2nd step
Vertical_Mapping (&start_strip_i, &end_strip_i, &heigh_i)
FOR each unmapped element in sorted_allocations

3rd step
Horizoontal_Mapping (start_strip_i, end_strip_i, height_i,
 &sub_height_i)
END FOR
END FOR
```

Fig 2: eOCSA algorithm steps [14]

The algorithm minimizes the bursts time symbols which reduce SS active time. But when most bursts sizes are large the left space in third step cannot allocate to any burst this increases the unused space and degrade the algorithm efficiency. Figure (3. a) illustrates example of allocating set of (84, 42, 63, 14, 50, 70, 34, 3 slots) using eOCSA algorithm and it result, total left space = (3+3+27+10+30)= 73 , total extra slots = (1+2)= 3 ,packing efficiency =360-(73+3)/360 = 78.89 % and the burst (34,42) are failed to allocate . This example shows degrading in packing efficiency we try to overcome this problem in next sections.

2.2 Improve eOCSA Algorithm (IOCSA)

The vertical mapping step in eOCSA algorithm maps the requests based on maximum height (H). This minimizes the burst width (time symbols). But when most the burst are large the left space cannot fit any burst in horizontal mapping step. Our idea is to increase slightly the burst width in vertical mapping step to fit more burst in horizontal mapping step. This minimizes the left space and increases the efficiency and it can be done simply by reduce the height in vertical mapping step. The improvement algorithm is same as eOCSA algorithm with miner change in the vertical mapping. Instead of map based on maximum height we use 3/2 of maximum height. Figure (3. b) illustrates example of allocating same as previous set of (84, 42, 63, 14, 50, 70, 34, 3 slots) using improvement eOCSA algorithm and it result total left space = (0+0+3)=3 , total extra slots = (2+1+2+2+1+1+2)=11

,packing efficiency =360-(3+11)/360 = 96.111 and the burst (14) is failed to allocate. This example shows improvement in packing efficiency as compare with previous example.

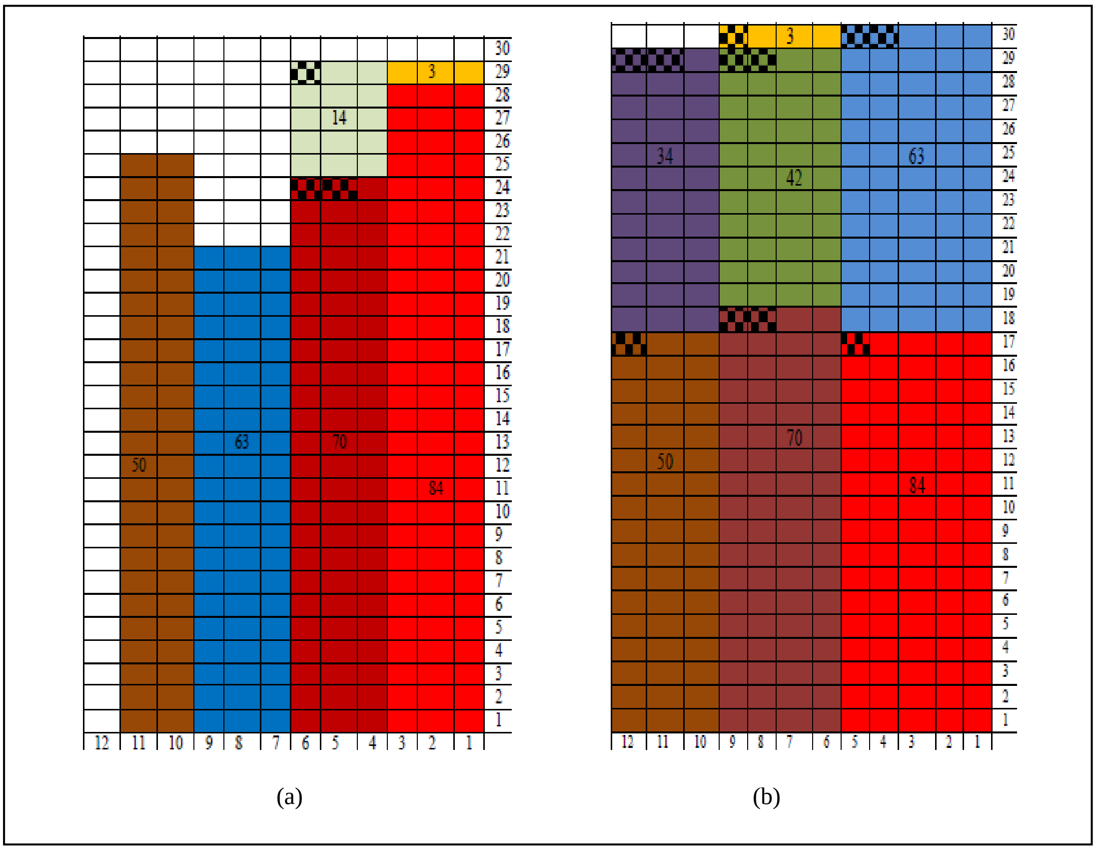

Fig 3: Allocating set of data (a) using eOCSA algorithm (b) using IOCSA algorithm

3. IMPLEMENTATION OF MAPPING ALGORITHM IN QUALNET

The Qualnet implement most WiMAX features based on IEEE802.16 standard in advance wireless library. This library contains many cpp files. Mac_dot16_sch.cpp is one of these files which contain the scheduling and mapping related functions. BS will call MacDot16ScheduleDlSubframe function to schedule PDUs to be transmitted in the downlink subframe in slots without any shape constrains. And it use by default weighted fair scheduling for user data and Strict-Priority scheduling for management messages. The MacDot16SchAllocDlBurst is called to map the scheduled PDUs in rectangular bursts. But there is no any specific allocation algorithm is implemented in Qualnet. The implemented allocation function is not conforming to the standard. This is why we implement one of allocation algorithm that confirm with the standard namely, eOCSA allocation algorithm.

3.1 Current Implementation of Downlink Data Allocation in Qualnet

The implemented data allocation function in Qualnet is MacDot16SchAllocDlBurst and its main steps are:-

Step1

Define frame parameters like, (number of subchannel (rows), number of time symbols (columns), PS size (1 subchannel X 2 time symbols) , symbol (0) for preamble, Symbol 1 and symbol 2 on subchannel 0 and 1 are for FCH, Burst 0 for(FCH +DL-MAP), Burst 1for UL-MAP)

Step2

Get the scheduled request from MacDot16SchAllocDlBurst and convert it into PS as per physical parameter (MCS).

Step 3

For each request do

If (request size > number of subchannels) means it need to allocate more than one columns

{

numColNeeded = ┌(sizeInPs / numSubchannels)┐

numSubchannels = numSubchannels

numsymbols = numColNeeded * num symbols per PS

Mark these symbols are used on all subchannels

}

If (request size ≤ number of subchannels) means it need to allocate in one column

}

Check if any of previous allocated can fit this request

eles allocate it in new columns as

numSubchannels = sizeInPs

numsymbols = num symbols per PS

}

Step 4

return allocated burst info (burstIndex, modu encoding type, subchannelOffset, numSubchannels, symbolOffset, numSymbols)

END

Figure (4. a) illustrates the details of bursts allocations information that resulting from running WiMAX scenarios in Qualnet. The result shows there is allocation overlapping. Burst allocation plot in figure (4. b) shows that burst N# 4 overlap with burst N# 6. This is not confirming with IEEE802.16 standard. Next section describes implementation of data allocation algorithm that confirm with standard.

DL burst for 82 bytes (16 PS): burstIndex = 0 modu encoding type = 0 subchannelOffset = 0 numSubchannels = 16 symbolOffset = 1 numSymbols = 2 DL burst for 25 bytes (5 PS): burstIndex = 1 modu encoding type = 0 subchannelOffset = 0 numSubchannels = 5 symbolOffset = 3 numSymbols = 2 DL burst for 1062 bytes (89 PS): burstIndex = 2 modu encoding type = 2 subchannelOffset = 0 numSubchannels = 30 symbolOffset = 5 numSymbols = 6 DL burst for 102 bytes (4 PS): burstIndex = 3 modu encoding type = 6 subchannelOffset = 5 numSubchannels = 4 symbolOffset = 3 numSymbols = 2	DL burst for 978 bytes (163 PS): burstIndex = 4 modu encoding type = 0 subchannelOffset = 0 numSubchannels = 30 symbolOffset = 11 numSymbols = 12 DL burst for 288 bytes (16 PS): burstIndex = 5 modu encoding type = 3 subchannelOffset = 9 numSubchannels = 16 symbolOffset = 3 numSymbols = 2 DL burst for 166 bytes (14 PS): burstIndex = 6 modu encoding type = 2 subchannelOffset = 13 numSubchannels = 14 symbolOffset = 21 numSymbols = 2 DL burst for 550 bytes (62 PS): burstIndex = 7 modu encoding type = 1 subchannelOffset = 0 numSubchannels = 30 symbolOffset = 23 numSymbols = 6

Fig 4(a): WiMAX Burst allocations info in existing Qualnet

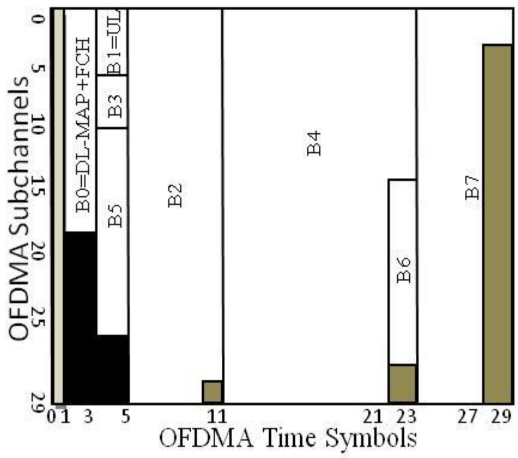

Fig 4(b): Burst allocations plot

3.2. Implementation of eOCSA algorithm in Qualnet

The algorithm steps are explained in the previous section and we will describe its implementation in Qualnet in this section. The algorithm implemented in MacDot16SchAllocDlBurst C++ function and its main steps are:-

Step1

Define frame parameters like, (number of subchannel (rows), number of time symbols (columns), PS size (1 subchannel X 2 time symbols) , symbol (0) for preamble, Symbol 1 and symbol 2 on subchannel 0 and 1 are for FCH, Burst 0 for(FCH +DL-MAP), Burst 1for UL-MAP)

Step2

Allocate B0 (DL-MAP) &B1 (UL-MAP) as previous allocations.

Step3

Sort the scheduled data based in PS required as set by scheduler. Merge Sorting is used here.

Step 4

Start allocate from the head of sorted list do

Vertical mapping

Calculate number of columns needed and number of rows needed inside the frame as per the equation:

numColNeeded = ┌(sizeInPs / numSubchannels)┐
numSubchannels = ┌(sizeInPs / numColNeeded) ┐
numsymbols = numColNeeded * num symbols per PS
Mark these symbols are used on all subchannels

Horizontal mapping

Calculate Empty slots available in Current allocation and Check largest request can fit and Calculate number of columns needed and number of rows needed inside the frame as per the equation

numColNeeded = same previous numColNeeded
numSubchannels = ┌ (sizeInPs / numColNeeded)┐
numsymbols = numColNeeded * num symbols per PS
Mark these symbols are used on all subchannels

Step 5

return allocated burst info (burstIndex, modu encoding type, subchannelOffset, numSubchannels, symbolOffset, numSymbols)

END

Figure (5. a) and (5. b) illustrates the implemented bursts allocations and its plot. The result shows there is no overlapping between the Bursts. This is confirming with IEEE802.16 standard.

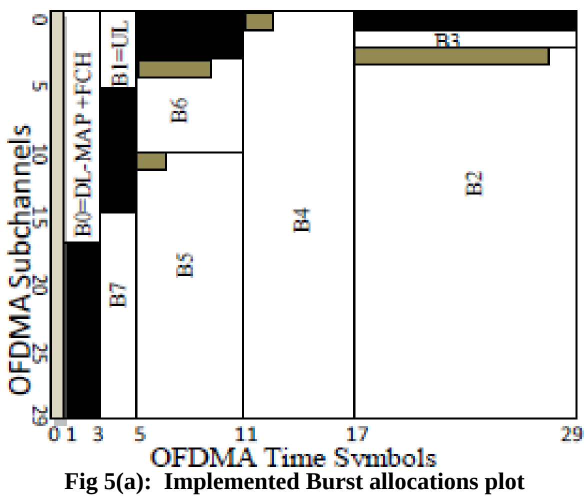

Fig 5(a): Implemented Burst allocations plot

DL burst for 82 bytes (16 PS):
burstIndex = 0
modu encoding type = 0
subchannelOffset = 0
numSubchannels = 16
symbolOffset = 1
numSymbols = 2
DL burst for 25 bytes (5 PS):
burstIndex = 1
modu encoding type = 0
subchannelOffset = 0
numSubchannels = 5
symbolOffset = 3
numSymbols = 2
DL burst for 978 bytes (163 PS):
burstIndex = 2
modu encoding type = 0
subchannelOffset = 2
numSubchannels = 28
symbolOffset = 17
numSymbols = 12
DL burst for 102 bytes (4 PS):
burstIndex = 3
modu encoding type = 6
subchannelOffset = 1
numSubchannels = 1
symbolOffset = 17
numSymbols = 12

DL burst for 1062 bytes (89 PS):
burstIndex = 4
modu encoding type = 2
subchannelOffset = 0
numSubchannels = 30
symbolOffset = 11
numSymbols = 6
DL burst for 550 bytes (62 PS):
burstIndex = 5
modu encoding type = 1
subchannelOffset = 9
numSubchannels = 21
symbolOffset = 5
numSymbols = 6
DL burst for 288 bytes (16 PS):
burstIndex = 6
modu encoding type = 3
subchannelOffset = 3
numSubchannels = 6
symbolOffset = 5
numSymbols = 6
DL burst for 166 bytes (14 PS):
burstIndex = 7
modu encoding type = 2
subchannelOffset = 16
numSubchannels = 14
symbolOffset = 3
numSymbols = 2

Fig 5(b): Implemented Burst allocations info in Qualnet

4. PERFORMANCE EVALUATION

In this section, we compare the performance of the improvement eOCSA with eOCSA algorithms using Qualnet simulation software. Table.1 and figure 6 shows the parameters and simulation scenario that used to perform the evaluation experiments. The data traffic is generated using CBR with different packet sizes and different time interval to produce different burst sizes. The number of user (SS) is changed from 5 to 40.

Table1. WiMAX System Simulation Parameters.

Parameter	Value
Frame length	5 ms
Channel BW	10 MHz
Duplexing	TDD
Multiple Access	OFDMA
Permutation scheme	PUSC
Number of subchannels	30
FFT	1024
Traffic	CBR
Simulation time	10 second

Allocation efficiency and unused slots are calculated every allocated frame then divided by number of allocated frames to get average Allocation efficiency and average unused slots. Figure 7 illustrate the average unused slots per DL subframe and the result shows that the average of unused slots for the IOCSA algorithms is smaller than that for eOCSA. That is because eOCSA left more unused space that cannot accommodate any burst.

Figure 8 illustrate the average packing efficiency and the result shows that the IOCSA algorithm achieves higher efficiency than eOCSA when the most burst sizes are large and close in size.

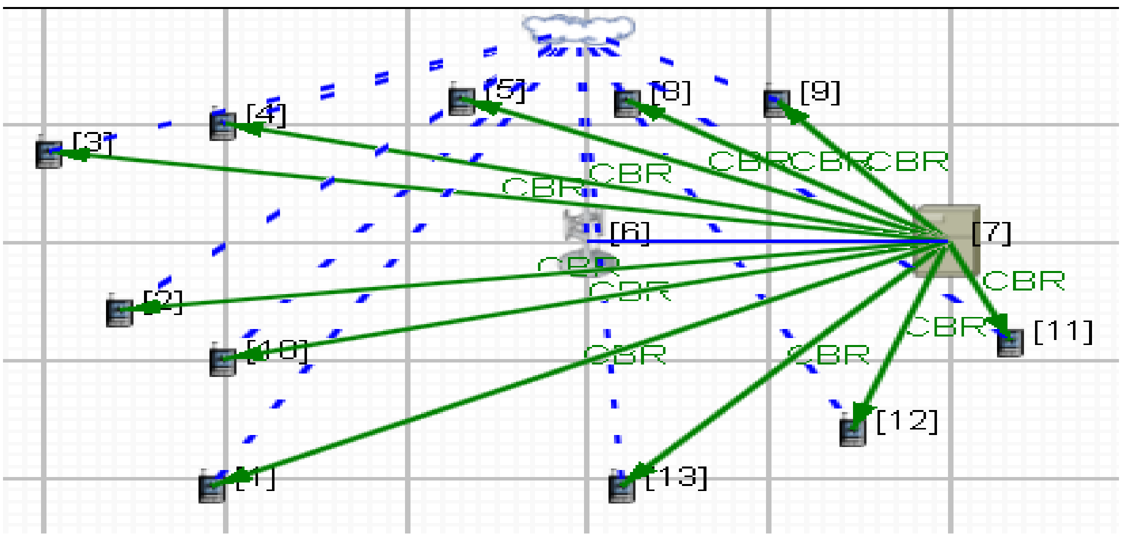

Fig 6: GUI QualNet simulation scenario

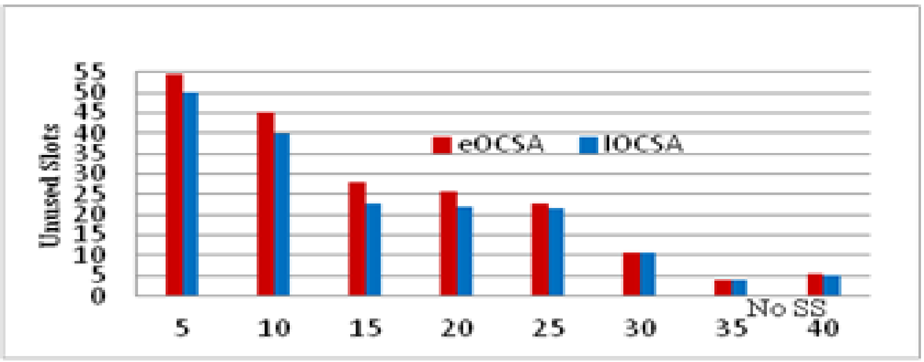

Fig 7: Average unused slots

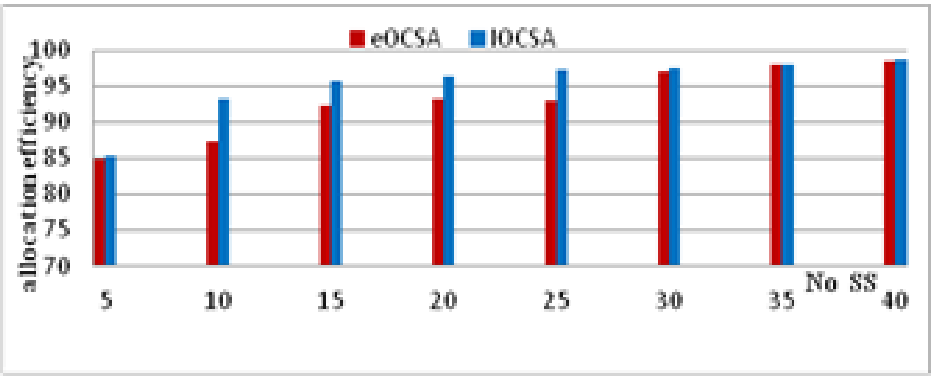

Fig 8: Average allocation efficiency

5. CONCLUSION

This paper discussed downlink burst allocation algorithm for IEEE 802.16e Mobile WiMAX networks and its implementation in Qualnet. our work shows that the implemented burst allocation algorithm in Qualnet is not confirm the standard and implement one of recent proposed burst allocation algorithm that confirm with standard namely, eOCSA (enhanced One Column Striping with nonincreasing Area first mapping). In addition some improvement to eOCSA algorithm is proposed and both the eOCSA algorithm and IOCSA algorithm are evaluated using Qualnet. Simulation results show that the IOCSA algorithm can achieve higher packing efficiency than eOCSA

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