HOCSA: AN EFFICIENT DOWNLINK BURST ALLOCATION ALGORITHM TO ACHIEVE HIGH FRAME UTILIZATION

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Abstract— **A Broadband Wireless Access technology known as Worldwide Interoperability for Microwave Access (WiMAX) is based on IEEE 802.16 standards. It uses orthogonal frequency division multiple accesses (OFDMA) as one of its multiple access technique. Major design factors of OFDMA resource allocation are scheduling and burst allocation. To calculate the appropriate dimensions and location of each user's data so as to construct the bursts in the downlink subframe, is the responsibility of burst allocation algorithm. Bursts are calculated in terms of number of slots for each user. Burst Allocation Algorithm is used to overcome the resource wastage in the form of unused and unallocated slots per frame. It affects the Base station performance in mobile WiMAX systems. In this Paper, HOCSA (Hybrid One Column Striping with Non Increasing Area) algorithm is proposed to overcome frame wastage. HOCSA is implemented by improving eOCSA algorithm and is evaluated using MATLAB. HOCSA achieves significant reduction of resource wastage per frame, leading to more exploitation of the WiMAX frame.**

Index Terms— **Burst allocation, downlink subframe, Mobile WiMAX, OFDMA, MATLAB.**

I. INTRODUCTION

The vendor interoperability organization gave the name Worldwide Interoperability for Microwave Access (WiMAX) to the 802.16-2004 amendment which is an industry name. Main aim of WiMAX is to provide broadband wireless access (BWA). WiMAX is an alternative solution to wired broadband technologies like cable modem access and digital subscriber line (DSL). Mobile WiMAX or 802.16e is known as the mobile version of 802.16. To maintain mobile clients connected to a Metropolitan Area Network (MAN) while moving around, this amendment is done[1]. Point-to-Multipoint (PMP) topology is used for Mobile WiMAX, where the traffic occurs between a Base Station (BS) and its Mobile Stations (MSs). Here, the BS is the centre of the system. Thus BS efficiency highly affects the performance of Mobile WiMAX systems performance.

Orthogonal Frequency Division Multiple Access (OFDMA) technology is used by the physical layer (PHY) of Mobile WiMAX. OFDMA can be implemented by Time Division Duplex (TDD) or Frequency Division Duplex (FDD). TDD is the preferred technology for mobile WiMAX. Mobile WiMAX frames uses TDD mode consists of two parts, the downlink subframe and the uplink subframe as shown in figure 1. The upward data is sent from the MS towards the BS through the UL subframe interval and the downward data is sent from the BS towards the MS through the DL subframe interval. The Ratio of downlink-to-uplink-subframe may vary from 3:1 to 1:1. Guard time intervals between successive DL and UL subframes are transmit-receive Transition Gap (TTG) and Receive transmit Transition Gap (RTG) [2].

Mobile WiMAX channel resources frequency and time are used to formulate frames. These frames carry users' data in the form of data bursts. The frame has a limited size as defined in Mobile WiMAX standards (5ms) [3]. The frame should carry a maximum number of data bursts to satisfy high system performance.

A data burst is formed by a number of slots in the form of irregular rectangles. A slot is the smallest resource portion that can be allocated to a single user in a frequency and a time domain. Each slot is defined by one subchannel (frequency) and one to three OFDM symbols (time). The Burst Profile for each data burst is assigned by BS. Burst

Fig. 1 TDD frame structure of mobile WiMAX.

Profile is used to identify the forward error correction (FEC), combination of modulation, and code rate for individual bursts.

A burst allocation algorithm or burst mapping faces a problem to fill up the frame with irregular downlink burst rectangle shapes. This often leads to wastage of resources in the form of unallocated and unused slots due to decision complexity of finding conformity between the rectangular shapes and that of the available area within the frame. This leads to design an efficient algorithm to avoid the resource wastage. When the allocation of bursts to the user data in the DL subframe is bigger than the actual data size it results in Unused slots as shown in figure 1 (the red area).

The area which is not assigned to any burst in the DL subframe due to a mismatch of rectangular shapes to the available area within the DL subframe is known as Unallocated slots (the yellow area). Eventually, the frame's utility will definitely be decreased by the unused and unallocated slots left out vacant and transmitted as blank slots. A part of the frame is assigned to the overhead bursts, which informs the served users

about their burst profiles. At the beginning of each frame the overhead is compulsory to be allocated and broadcasted to all users under BS coverage. The overhead bursts include: preamble, downlink map (DL-MAP) and uplink map (UL-MAP), Frame Control Header (FCH) as shown in figure 1.

Drawbacks which affect the frame utilization of the standard allocation algorithm can be listed as follows:
(1) The allocation algorithm faces problem in area calculation and frequently re-dimensioning the incoming data to find a match between burst rectangles and available area due to lack of knowledge about the incoming data sizes. (2) Burst size affects the allocation procedure, which results in more resource wastage. (3) User waiting time inside the Medium Access Control (MAC) layer queue increases, which results in increase in data transmission time. (4) ST algorithm is an NP-complete problem [4]. NP-complete problem is a class of decision complexity problems. It uses a set of rules that prescribes more than one action to be performed for a given situation, which leads to an increase in the computational load.

A. Downlink Data Allocation Problem

The IEEE 802.16e standard specifies some constraints while mapping the user data bursts into downlink sub frame these are described below:-
1. Downlink subframe has a limited size as defined by Mobile WiMAX standards. This subframe should carry a maximum number of user data bursts in order to achieve high system performance.
2. The overhead is compulsory to be added at the beginning of each subframe, which informs the served users within a subframe about their burst profiles and significantly effects the system performance.
3. Mapping of the data bursts into downlink subframe has to be in rectangular form. This constrain results in two-dimensional rectangular burst mapping problem which is a NP complete problem. To shape the selected data bursts in rectangular form may require extra allocation of slots, moreover to fit those rectangles into subframe may leave some slots as unutilized. These unutilized slots and unallocated slots left out vacant decreases frame utility and the efficiency of mapping algorithm.
4. There are many considerations along with two-dimensional rectangular burst mapping problem like: (i) to reduce power consumption and SS active time minimize the number of burst time symbols [7], (ii) to efficiently utilize the subchannel minimize the number of burst subchannels [8, 9] and (iii) to reduce DL-MAP overhead size reduce the number of bursts [10].

B. DL-MAP Overhead & Allocation Algorithm

Users are assigned slots in the rectangular form called a burst. A burst contains data for a single or multiple CID that share same physical parameters. DL_MAP massage is broadcasted with the most reliable MCS at the beginning of the DL subframe which informs each user about its burst allocation. The DL_MAP field consists of two main groups. The first group needs 104 bits once per DL Subframe. It consists of Message Type, DCD Count, BS ID, PHY Synchronization, and No Symbols. The second group needs (44+16 No CID) bits once per burst. It consists of No CID, CID, Boosting, No Subchannel, No Symbols, Symbol Offset, Subchannel Offset, DIUC and Repetition Coding Indication [3]. This group is used to define a two-dimensional allocation criteria

of the burst and is known as Downlink MAP Information Element (DL_MAP_IE).

The contribution of this paper is to design and develop a burst allocation algorithm with low complexity and minimum resource wastage. The developed algorithm is based on allocation of data slots in the form of columns. The algorithm is developed to achieve higher frame utilization, by reducing the unused and unallocated slots without violating the agreed QoS guarantee within the downlink subframe.

The rest of this paper is organized as follows: Section 2 describes the related works, section 3 describes the proposed work, section 4 presents the results and discussion and finally in section 5 conclusion and future work.

II. RELATED WORK

WiMAX systems performance depends on the burst allocation algorithm; therefore it is a very crucial matter for the manufactures. This paper identifies key factors and tradeoff issues associated with the downlink burst packing algorithm through a competitive survey of algorithms.
Literature surveys can be divided into many methods of designing the Burst Allocation Algorithm, as follows:

A. The first method is to reshape the rectangular burst to get the appropriate shape that can be inserted into the DL subframe with minimum wastage of slots, as given in the following literatures :-

In [19] authors introduced an algorithm which used a physical component called Bucket. A Bucket consisted of a number of slots allotted to each user in the form of columns. Then the Buckets with similar profile were combined to construct a single burst. This scheme violated QoS, when the packets that did not match the available burst space and did not meet their transmission deadline were to be discarded because there was no estimate of how many packets to be dropped.

In [10] Hung-Chang Chen et.al. authors presented Efficient Downlink Bandwidth Allocation (EDBA) algorithm. It calculated the shape, alleviation of unallocated slots, sequence and location of the bursts within downlink subframes. In this algorithm overhead calculation was ignored within the frame as well as the results showed that there was much wastage of slots with lower number of users per frame. This algorithm increased the computational load.

Chakchai SO-IN et al. developed OCSA algorithm in which all the user data to be mapped was sorted in the descending order [7]. The resource allocations were mapped from bottom to top and from right to left in the DL subframe. According to the burst area, there were many possible combinations of height and width out of which we chose the pair which was smallest in width. Small width lead to save energy as the receiving MS shut down its electronic circuit for the remaining of the DL subframe.

Chakchai SO-IN et al. presented eOCSA (enhanced One Column Striping with non increasing Area first mapping) algorithm [8]. It was a two-dimensional burst mapping algorithm. Its goal was to minimize the unused slots and the energy consumption as in [11]. It allowed the MAP to grow dynamically. In this algorithm, allocations were sorted in the decreasing order, and mapped from right to left and bottom to top. It consisted of two phases. In the first phase, vertical mapping took place in which the largest allocation was mapped with the least width or least height. After this the left space above this allocation was used for the horizontal mapping phase, where

eOCSA tries to assign the largest allocation that can be fitted in that space. Also, in this scheme some slots were left unused, some were over allocated.

Zhu et. al. introduced an algorithm in which the bursts were allocated in the columns of identical width .Then these allocated bursts were shuffled to combine the left scattered unused space in the frame. This formed a large space which could accomodate more bursts [10]. .

Ahmed M Husein Shabani et al. presented Improved eOCSA Algorithm (IOCSA) [3]. The improvement algorithm is same as eOCSA algorithm with a little difference in the vertical mapping step. In eOCSA algorithm the requests were mapped based on maximum height (H) which minimized the burst width. In case most of the bursts were large sized, the unused space left above the allocated burst cannot accommodate any burst in the horizontal mapping step. In IOCSA, the vertical mapping step included slight increment in the burst width so as to fit more bursts in the horizontal mapping step. Instead of maximum height we used 3/2 of the maximum height. This efficiently utilized the left space.

B. The second method is to fragment the burst to get the required shape that can fit the available allocation space in the DL subframe, such as in the following papers:-

Jincao Zhu et al. presented a linear complexity algorithm [13]. It included frequent reshaping and fragmentation of the bursts. The constructed bursts were shifted and combined in the adjacent area. Overhead size was not considered especially when there was burst fragmentation which required additional overhead on the expense of the data slots.

Zaid G. Ali introduced a low complexity algorithm called Sequential Burst Allocation (SBA) [25]. SBA was based on sequential allocation of data slots in the form of columns. It reduced the unused slots within a burst to be one slot per burst at the worst case and eliminated the unallocated slots between the bursts. It numbered the fragments to be re-assembled in the correct order by the recipients.

C. The third method consists of the cross layer design between PHY and MAC layers to satisfy the differentiation between service types and utilize the QoS information to allocate the bursts according to the priorities and constrains to reduce the slots wastage.

Authors proposed a cross layer design [14] to achieve the non-real time and real time scheduling in addition to the burst allocation. It consisted of a two tier framework, the first was for the priority scheduling and the second was for the burst allocation. The burst allocation divided the downlink subframe into several slices horizontally, each called a bucket. The allocation process ignored the calculation of the unused slots within a bucket. The overhead reduction depended on the number of buckets that can be aggregated. This method enhanced the system QoS by manipulating the subchannels, distributing the computational load between burst allocation algorithm and the QoS scheduler, aggregates similar users conditions in a single burst.

Jia-Ming et. al. combined the problem of burst allocation and scheduling in the cross-layer manner. The proposed allocation algorithm scheduled the non real time and real time data traffic

as multiples of buckets which are fixed sized can be easily packed into the DL subframe [11].

III. PROPOSED DOWNLINK BURST ALLOCATION ALGORITHM

The contribution of this work is to develop a new burst allocation algorithm, a Hybrid One Column Striping with non-increasing Area first mapping (HOCSA) algorithm with low complexity to overcome frame wastage. HOCSA is implemented using MATLAB software.

A. HOCSA (Hybrid OCSA Algorithm)

Hybrid OCSA is obtained by improving One Column Striping with non-increasing Area first mapping (OCSA) proposed by So-In et.al. in [13] and it's enhancement in [14]. HOCSA uses Genetic Algorithm to optimize the allocated space so as to have better frame utilization.

The algorithm can be described in three main steps.
1. Sort all the data bursts in decreasing order.
2. Vertically allocate the largest burst (Bi) with dimensions (Wi,Hi).
   (Here mapping is done if the allocated slots are less than unallocated slots. And mapping will take place if user data burst is equal to the fitness function. 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.)
3. Allocate the left space in the allocated column horizontally.

After this we further optimize the frame utilization by merging the adjacent unallocated columns and map the remaining appropriate bursts that best fits in it. There by utilizing the left space to the maximum. For this step, if the column value is less than the fitness function then merge this column with the adjacent column to allocate the remaining appropriate bursts, and continue this process till all the columns are covered.

Figure 4.1 illustrates the algorithm steps.
1st step
Sorted_allocations = Sort (resource_allocations)
FOR each unmapped element in sorted_allocations
2nd step
Vertical_Mapping(&start_strip_GA_i,&end_strip_GA_i,
&height_GA_i)
FOR each unmapped element in sorted_allocations
If allocated.slot<unallocated.slot
Allocate.slot.initialize.coulumn
If sorted.structure==fitness.function
Allocation.column=true
Else
Allocation.column=false
end
3rd step
Horizontal_Mapping(start_strip_GA_i,end_strip_GA_i,
height_GA_i, &sub_height_GA_i)
For i=1:column.count
If column.value<fitness.value
Column.e=column.e+column.e+1
end
END FOR
END FOR

1) Genetic Algorithm used in HOCSA

Genetic algorithm is a method for solving both constrained and unconstrained optimization problems based on a natural selection process. The algorithm repeatedly modifies a population of individual solutions. At each step, the genetic algorithm randomly selects individuals from the current population and uses them as parents to produce the children for the next generation. Over successive generations, the population "evolves" toward an optimal solution. As proposed in HOCSA, Genetic Algorithm optimizes eOCSA Algorithm to have better frame utilization. Genetic Algorithm uses fitness function. Inputs to the Genetic Algorithm are provided slots and used slots. Genetic algorithm further optimizes the used slots by comparing the value of used slots with that of fitness value. Fitness value is calculated using Fitness Function. If the value of used slots is equal to the Fitness value then allocation is mapped otherwise it is ignored.

Fitness function that the GA uses:- $f = (1-e)*((1-F_s)/F_t)$

F_s = each slot, F_t = total number of slots, e is the classification error rate

The following outline summarizes the genetic algorithm:-

1. The algorithm begins by creating a random initial population.
2. The algorithm then creates a sequence of new populations. At each step, the algorithm uses the individuals in the current generation to create the next population.

2) Implementation of HOCSA algorithm in MATLAB

The algorithm implementation's main steps are:-

Step1

Define frame parameters (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 allocation 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 = $\lceil$(sizeInPs / numSubchannels)$\rceil$

numSubchannels = $\lceil$(sizeInPs / numColNeeded)$\rceil$

numsymbols = numColNeeded * num symbols per PS

If allocated.slot<unallocated.slot

Allocate.slot.initialize.coulumn

If sorted.structure==fitness.function

Allocation.column=true

Else

Allocation.column=false

end

Mark these symbols are used on all subchannels

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

numColNeeded = same previous numColNeeded

numSubchannels = $\lceil$ (sizeInPs / numColNeeded)$\rceil$

numsymbols = numColNeeded * num symbols per PS

For i=1:column.count

If column.value<fitness.value

Column.e=column.e+column.e+1;

end

Mark these symbols are used on all subchannels

Step 5 return allocated burst info (burstIndex, moduencoding type, subchannelOffset, numSubchannels, symbolOffset, numSymbols)

IV. SIMULATION RESULTS AND DISCUSSIONS

Results are the most important part of any research work, they are used to justify the work. To analyze Downlink Burst allocation algorithm in a WiMAX network, MATLAB is chosen as the simulation tool to reflect the actual deployment of the WiMAX network.

A. Simulation Parameters

Table 5.1 shows the parameters that are used to perform the evaluation experiments. The data traffic is generated with different packet sizes and different time intervals to produce different burst sizes. The number of users(SS) are changed from 10 to 50.

Table.5.1 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	50
FFT	1024
Simulation time	100 ms

B. Results (Performance evaluation)

Here different simulation scenarios are used for performance evaluation and the results are obtained from them. In this section, we compare the performance of the Hybrid eOCSA with eOCSA and IOCSA algorithms using MATLAB simulation software.

Average unused slots- Unused slots are calculated for every allocated frame then divided by number of allocated frames to get the average unused slots.

Figure 5.6 illustrates the average unused slots per DL subframe and the results show that the average of unused slots for the HOCSA algorithm is smaller than that of eOCSA and IOCSA. This is because eOCSA and IOCSA left more unused space that cannot accommodate any burst. But the HOCSA Algorithm uses Genetic Algorithm to optimize the frame space and merges the unused columns to allocate the data bursts that best fits into that space. Results also show that the unused slots continuously decrease as the number of users or the load increases in the given subframe.

of rectangles limits the opportunities of fitting more users in the frame which leads to an increase in slot wastage.
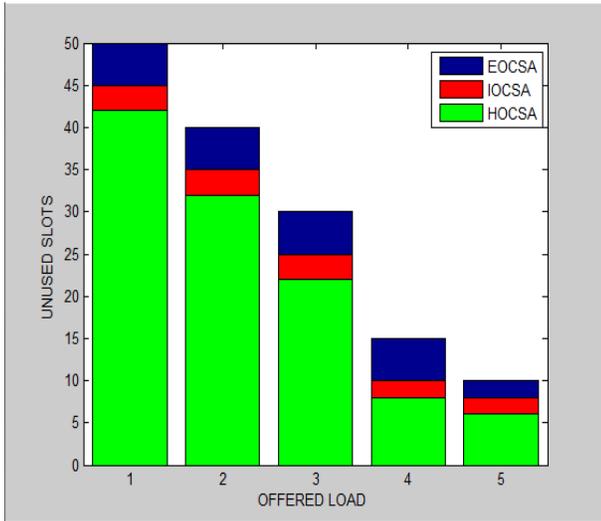

Figure 5.6: Comparision of unused slots of eOCSA, HOCSA, IOCSA

Average allocation efficiency- Allocation efficiency is calculated for every allocated frame and then divided by the number of allocated frames to get average allocation efficiency. Figure 5.7 illustrates the average allocation efficiency of HOCSA, eOCSA and IOCSA. Here we increase the load upto 30%, the results show that the HOCSA algorithm achieves higher efficiency than eOCSA and IOCSA when the most burst sizes are large and close in size. HOCSA Algorithm uses Genetic Algorithm to optimize the frame space by mapping more number of user data bursts, thus efficiently packs the downlink sub frame further merges the unused columns to allocate the data bursts that best fits into that merged space.
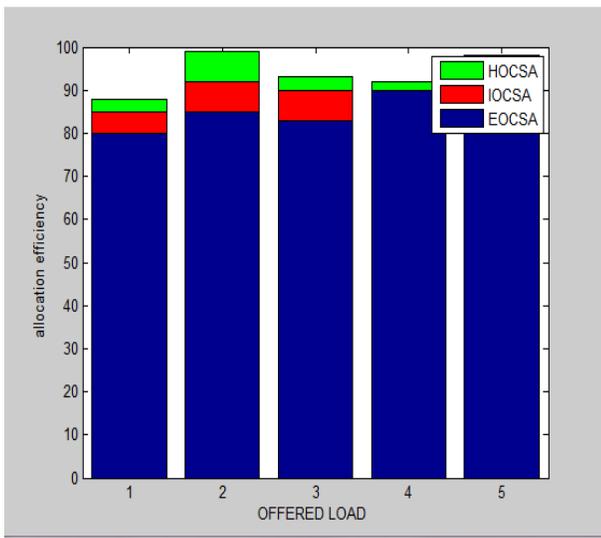

Figure 5.7: Comparision of allocation efficiency of eOCSA,HOCSA,IOCSA

Figure 5.8 shows the frame utilization versus different MAC PDU sizes. There are two curves, each corresponding to an individual allocation algorithm HOCSA and eOCSA. The figure shows that the algorithm HOCSA outperforms the eOCSA and the percentage difference between them is 22.84%. Moreover the figure depicts that the utilization of the eOCSA algorithm declines comparatively to the HOCSA while increasing the MAC PDU size because in eOCSA, the size of MAC PDU in the form
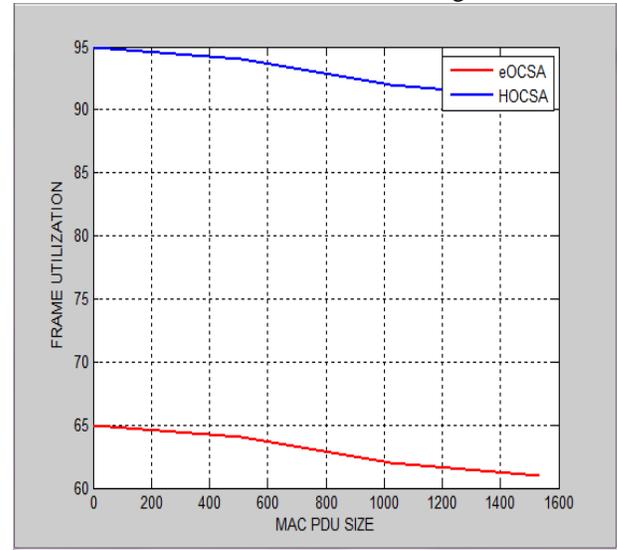

Fig 5.8 Frame utilization vs MAC PDU size

Figure 5.9 shows the unallocated slots versus different MAC PDU sizes. In HOCSA the allocation is optimized as the result of Genetic algorithm, further merges the unallocated columns to map appropriate burst into it. Thus has a major effect of reducing the unallocated slots per frame. On the other hand the eOCSA algorithm curve allocates more users when MAC PDU is small size which reduce the unallocated slots, while when MAC PDU become large size the opportunity of allocating more users decreases which increase the unallocated slots per frame. The HOCSA algorithm behavior explains the effect of MAC PDU size to the increment of the unallocated slots.
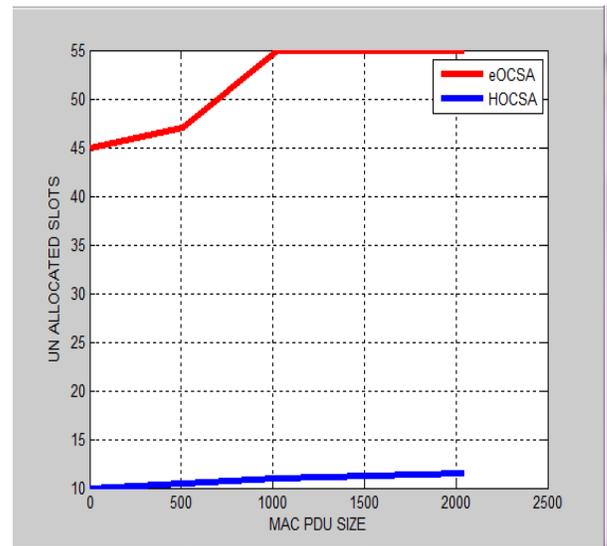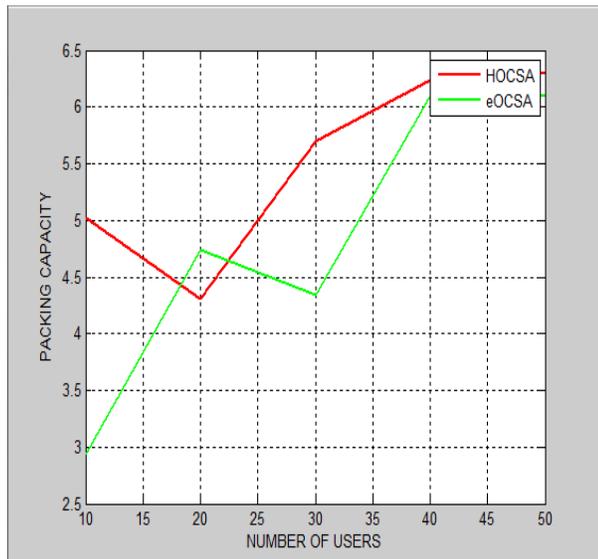

Fig 5.9: Unallocated slots vs MAC PDU size

The graph in Fig. 5.10 below shows the average packing capacity of the number of users in HOCSA and eOCSA. Average packing capacity of HOCSA is more than that of eOCSA. As the size of MAC PDU increases average packing capacity of both increases.

Fig. 5.10: Packing Capacity vs No of users in HOCSA and eOCSA

V. CONCLUSION AND FUTURE WORK

A. Conclusion

In this paper, an efficient burst allocation algorithm for mobile WiMAX network has been presented. This work discussed the downlink burst allocation algorithm for IEEE 802.16e Mobile WiMAX networks and its implementation in MATLAB, namely HOCSA. Our work shows that the implemented burst allocation algorithm (HOCSA) in MATLAB is obtained by modifying eOCSA (enhanced One Column Striping with non-increasing Area first mapping). HOCSA is a burst allocation algorithm with low complexity and minimum resource wastage. It has been observed from the simulation results, obtained by MATLAB simulation model that the HOCSA exhibit 15% improvement in efficiency as compared to the eOCSA. The proposed algorithm achieves higher frame utilization within the downlink subframe, by reducing the unused and unallocated slots and without violating the agreed QoS guarantee.

B. Future Work

Future work may be done to optimize the frame utilization and reduce the unused and unallocated slots in the DL_Subframe without violating the agreed QOS. Here, the proposed downlink burst allocation algorithm known as HOCSA reduces the wastage of slots by using genetic algorithm and further by merging the adjacent vacant columns to allocate the remaining bursts that best fits into it.

Future work may include various design factors and optimization techniques to achieve significant reduction of resource wastage per frame, leading to more exploitation of the WiMAX frame. Furthermore, the proposed algorithm may be taken forward and BFO optimization algorithm may be used on it to achieve higher frame utilization.

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