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Burst Fragmentation Model Based on Sequential Burst Allocation Algorithm for Mobile WiMAX

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Abstract— ***the downlink Bandwidth resources of WiMAX are allocated by the burst allocation algorithm. The algorithm is responsible for calculating the appropriate location of a number of the smallest unit of bandwidth which is called the slot for all users within the downlink subframe in the form of bursts. Resource wastage in the form of unused and unallocated slots is a real common problem accompanies resource management in the burst allocation algorithms. This paper investigates the Sequential Burst Allocation (SBA) that based on sequential slot allocation and burst fragmentation. An analytical model of frame utilization has been derived. Moreover, this paper presents criteria of burst fragmentation and investigates the effect of burst fragmentation to the allocation efficiency. It has been observed from the results that the SBA algorithm outperforms the Standard (ST) algorithm in term of number of users and resource wastage reduction per frame. The research results illustrates that burst fragmentation can enhance the proportion of frame utilization with minor effect to the overhead size. As well as, the results are useful to be a heuristic guide line for MAC layer scheduler to decide the best burst size that can be used.***

Index Terms— ***Burst allocation, Burst fragmentation, Downlink subframe, Overhead, Mobile WiMAX.***

I. INTRODUCTION

The air interface of the Mobile Worldwide Interoperability for Microwave Access (WiMAX) version (802.16e-2005) is a shared resource between all associated users with the Base Station (BS) and hence, a scheduler is needed to resolve the competition between users. The available frame resource is very limited and must be efficiently utilized. The efficient resource management increases the overall system capacity and enhances the Quality of Service (QoS) of the network [1], [2]. The resource allocation is usually formulated as a constrained optimization problem, either to minimize the total transmits power with a constraint on the user data rate (appropriate to satisfy operators' demands) or to maximize the total data rate with a constraint on total transmit power (appropriate to satisfy users' demands) [3]. This paper focuses on the operators' demands.

The downlink burst allocation is the process of assigning a number of subchannels in a frequency domain and a number of OFDMA symbols in the time domain to construct bursts within the downlink subframe, where a single subchannel versus single OFDMA symbol composes one slot. The collection of contiguous slots that dedicated to a single user is called data region. A burst of rectangular shape could contain one or more data region.

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The size of the emerging burst depends on the amount of data to be packed and the used modulation type, while the dimensions are based on the number of subchannels in the frequency domain and the number of OFDMA symbols in the time domain. Therefore burst allocation is an algorithm which is responsible about computing the appropriate dimensions and location of any burst within the downlink subframe.

An efficient burst allocation algorithm avoids wasting resources in the form of unused and unallocated slots within the downlink subframe to maximize frame capacity. Figure 1 shows Time Division Duplex (TDD) frame structure of Mobile WiMAX includes eight bursts. The figure depicts two distinguished areas; the unused and unallocated slots, these slots are vacant and will be lost because the BS is not able to serve additional downlink flows until the end of the subsequent uplink frame.

The reason of the unused slots within a burst is because the allocated burst into the user data in the downlink subframe is bigger than the actual data size as shown in figure 1 (blue lozenge area within bursts #4, #6 and #8). However the unallocated slots is the area that are unassigned to any burst inside the downlink subframe due to a mismatch of rectangular shapes to that area within the downlink subframe (striped in red). Eventually, the unused and unallocated slots leave out vacant and transmitted as blank slots. The transmissions of the frames with blank slots represent resources wastage which leads to degrade network performance.

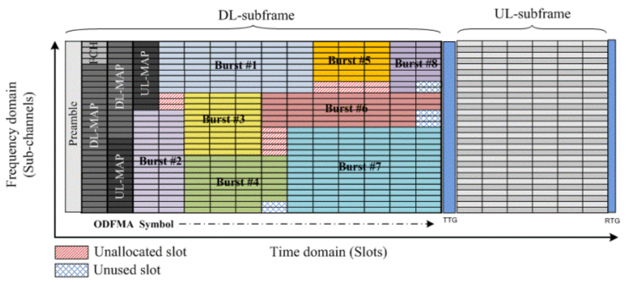

Fig.1 Frame structure of Mobile WiMAX.

The data burst fragmentation is an effective approach in the burst allocation algorithm design that can reduce the resource wastage and mitigates the complexity of the allocation algorithm as concluded in [4]. The proposed Sequential Allocation Algorithm (SBA) in [5] based on sequentially allocation of data slots using new technique of numbered fragments. The objective of this paper is to investigate the burst fragmentation based on SBA algorithm to obtain the effect of fragmentation process on the resource allocation efficiency, overhead size, transmission time delay and number of users per frame.

The main contributions of this paper are: Derive an analytical model of burst allocation algorithm utilizing the standard rules of the two dimensional burst allocation algorithms.

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Secondly, developing an analytical model of burst allocation algorithm utilizing the sequential allocation algorithm that provides a new technique of slots wastage reduction. Moreover, the criteria of constructing fragments that meet the proper procedure of the burst fragmentation have been explained.

The rest of this paper is organized as follows; section II describes the related work, section III describes the downlink subframe resource analysis, section IV describes the proposed burst allocation algorithm, section V shows the analytical modeling, section VI describes the impact of frame wastage on Mobile WiMAX and section VII presents the results and discussion. Finally, section VIII concludes the paper.

II. RELATED WORK

The proposed algorithm in [6] named Mapping with Appropriate Truncation and Sort (MATS). The algorithm fill complete column and keep the remainder of the burst in a fragment queue to be packed later in a vacant space of the downlink sub-frame. Author states that the fragmented bursts must rephrase their Generic MAC header and Cyclic Redundancy Code (CRC), which is hard to implement since MAC Protocol Data Unit (PDU) passes the MAC layer and reaches the PHY layer. The overhead reduction depends on gathering the emerging fragments with a space of another burst to complete the columns. This method of fragments allocation leads to some of the data user scattered among multiple bursts causes high power consumption in MS side for the intended scattered burst. The simulation model used 40 symbols for the downlink sub-frame, which is incompatible for the 10MHz channel bandwidth as pointed out in the standard (WiMAX-Forum, 2010), consequently the achieved throughput seems high because it's out of the standard limits.

A Burst Overlapping and Scheduling Scheme (BOSS) proposed in [7] (Chiang & Shih, 2012). Four steps procedure conducted to allocates the data burst; Check and adjust the position of unused slots for each symbol, Shift bursts to fill the unused slots, fragment burst with unused slots and finally relocate fragmented bursts. The unallocated slots utilization did not reported fairly. The main concept of BOSS is to adjust the position of the unused slots of a burst and sharing them with unused slots of neighboring bursts to increase the bandwidth utilizations. The research does not address the direction of slots allocation and how to inform users about their slots allocation direction. Moreover, the overhead increment due to burst fragmentation of last two procedure steps are not provided in the results.

A burst fragmentation in [8] the author proposed filling complete columns and keeping the remainder of the burst in a fragment queue to be packed later in a vacant space of the downlink subframe, without limits to how many fragments would be generated, this would lead to an unexpected overhead increase that causes a decrease in the available number of slots per downlink subframe.

III. COMPREHENSION THE DRAWBACKS OF STANDARD BURST ALLOCATION

The burst allocation algorithm is responsible of computing the appropriate dimensions and location based on the number of slots for any burst within downlink subframe. The main common problem of the standard bust allocation is the resource wastage. To describe this problem clearly, a numerical example will be very helpful to explain and demonstrate this problem. Assume a data sequence queued in the term of slots for three users as follows: 22 slot for the first user, 8 slots for the second user and 6 slots for the third user. Suppose the available area for allocation is 6 subchannels in the frequency domain by 6 OFDMA symbol in the time domain. The total available number of slots is 36 per the supposed area. Figure 2 depicts all possible allocation probabilities. The standard allocation procedure shown in figure 2 demonstrates the existence of the wastage in the form of unused and unallocated slots. The standard allocation algorithm cannot prevent theses wastage even if the algorithm changes the queue sequence of the users' data. The minimum waste is in figure 2 (a) and (c), and all possibilities can construct just only two bursts (2 users) per the available area. The figure shows that there are two constraints affecting the procedure of the allocation to increase or decrease the wastage, which are the size of the burst and the sequence of the data arrival to the allocation algorithm. Consequently, the number of users and the amount of users' data per downlink subframe fluctuates up and down to follow the constraints variance.

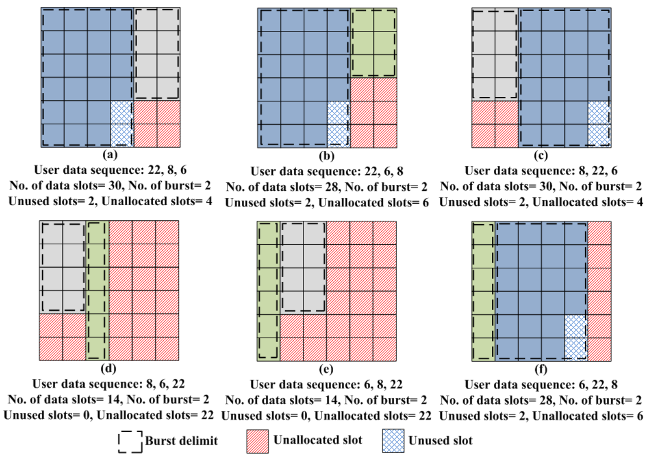

Fig.2 The standard allocation procedure

The main problem that the allocation algorithm faces is the burst size that should be a one unit of a rectangular shape to include user data. The standard algorithm can only manipulate the height and width of the rectangle to find multiple choices of dimensions that could be fit within the available area. Noting that the standard algorithm can adds vacant slots to the burst size in order to find the required dimensions.

IV. BURST FRAGMENTATION CRITERIA

The problem of unused and unallocated becomes clearer after figure out the wastage causes in the previous section, which are the burst size and burst arrival order. Therefore, the allocation algorithm that able to fragment the bursts when necessary can overcome the causes of the wastage.

The well design of the burst fragmentation procedure can achieves higher performance and reduces negative effects of burst fragmentation to the burst allocation algorithm .The burst allocation algorithm that adopts burst fragmentation approach should taking into account an important factors listed below in the design phase.

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1) A predefined procedure for re-assemble the fragmented bursts to take into account the ordering of fragments (first, second … etc.), because when a single burst fragmented into two or three parts, the recipient want to know which is the first, second and third part. The necessity of ordering comes from the fact that fragmentation may happen in the middle of PDU, which leads to the PDU being discarded in the two fragments, because the first part without CRC and the second part without PDU header.
2) Fragments of a burst should not scattered among different data bursts with different MCS, which lead to impose the intended MS to frequently changes the modulation mode with different subchannels conditions.
3) Fragments of a burst should not scattered along the time domain that leads to increase the power consumption at MS.
4) Overhead map should addresses the new emerging fragments within its fields as standalone burst, since each fragment has separate location within the downlink subframe and MS must knows these locations separately.

V. SEQUENTIAL BURST ALLOCATION ALGORITHM

The SBA [5] has been adopted to investigate the burst fragmentation effect to the bust allocation algorithm. Next section is a preface to the SBA algorithm to review the allocation mechanism and overhead modification.

A. SBA Algorithm Mechanism

The SBA algorithm in [5] divides the downlink subframe vertically into multiple columns. Each column consists of two contiguous slots in time domain and alonge all subchannels in the frequency domain. Inside the column each contiguous pair of slots in the time domain would be called Allocated Slots (AS) unit. The SBA uses AS unit to allocate users' data vertically in the form of consecutive vertical columns stating from right bottom corner of thr frame. Continuous allocation of burst fragments from frame to the next frameare support.

B. SBA Overhead Modification

The WiMAX standard pointed out that each data burst must be addressed in the frame overhead with separate IE [3]. Since each portion of a fragmented burst represents stand alone burst, and must be mapped with separate DL-MAP_ IE in the frame overhead. The proposed SBA overhead modification is based on the structure of the DL-MAP_ IE to separate the fragment mapping and include fragment sequence for the purpose of re-assembling the fragmented burst in the correct order at the recipient side. The new structure of IE was named (Frag.-IE). The Frag.-IE used separately for the second and third fragments only, (since SBA algorithm permits just two fragments per burst in the worst case). The first fragment holds the original structure of the IE to include all the standard information, while the modified Frag.-IE includes just the essential information pertaining to the position of the intended fragment within the downlink subframe. The proposed modification reduces 15 bit per Frag.-IE field in the overhead size.

VI. ANALYTICAL MODELING

This paper focuses on maximizing the frame utilization of the downlink subframe. All users assumed have the same channel quality over all subchannels (since PUSC permutation was used) and have the same MCS. Number of users is equal to the number of bursts per frame is assumed in [5].

A. Standard Burst Allocation Algorithm Modeling

The Mobile WiMAX downlink subframe composed of N subchannel (frequency domain) by Y symbols (time domain) [3], where N*Y is the total number of slots that can be allocated to the downward data flow within the downlink subframe.The downlink subframe mainly consists of two types of bursts; the overhead bursts and the data bursts. Let the total number of slots per the downlink subframe area denoted DFS, the total number of slots in the overhead area denoted OVS and the total number of slots in the data bursts area denoted DBS, then the overall number of slots in the downlink subframe area can be calculated as:

$$DFS = OVS + DBS \qquad (1)$$

The DBS area of the downlink subframe includes a number of users' bursts in the shape of rectangles allocated by the algorithm denoted B_m, where m is the individual user of the total users M, where m=1,2,3,…M. As well as the DBS area may include number of unallocated slots, the position of these unallocated is denoted by S_{n_i,y_j} of ith subchannel by jth OFDMA symbol within the downlink ubframe and the sum of all unallocated slots within the downlink area is denoted as W.

$$W = \sum_{n_i=1}^{N} \sum_{y_j=1}^{Y} S_{n_i,y_j} \qquad where\ , 0 \le S_{n_i,y_j} \le (N * Y)$$

The sum of all slots within the DB_S area defined as

$$DB_S = \sum_{m=1}^{M} B_m + \sum_{n_i=1}^{N} \sum_{y_j=1}^{Y} S_{n_i,y_j} \qquad (2)$$

Each user burst B_m has a number of contiguous subchannels n_{mH} and a number of contiguous OFDMA symbols y_{mL} and the sum of the allocated slots for user m defined by:

$$B_m = n_{mH} * y_{mL}$$

where, $0 < n_{mH} \le N$ and $0 < y_{mL} \le Y$. Let C denote the number of bits per slot (bit/slot) that's configured according to the MCS. Let R is the required number of slots for any user. And let (d =bit/user) the actual demand data size in term of bits for any user, then the required number of slots for user m is R_m defined by:

$$R_m = \frac{d_m}{C} = \frac{\frac{bit}{user}}{\frac{bit}{slot}} = \frac{slot}{user}$$

The burst B_m may include unused slots denoted by u_m. The number of unused slots within burst B_m is the allocated size minus actual size, which can be defined as:

$$u_m = B_m - R_m = (n_{mH} * y_{mL}) - R_m$$

If u_m equal to zero, then no wasted slots in the form of unused per the burst of user m , and if equal to a value, it represents the number of unused slots per B_m.

The sum of all useful slots excluding the unused slots which has been allocated to M users per the downlink subframe denoted as R_M and defined by:

$$R_M = \sum_{m=1}^{M} R_m = \sum_{m=1}^{M} [B_m - u_m]$$

The sum of all the unused slots u_M per the downlink data bursts area defined as:

$$u_M = \sum_{m=1}^{M} u_m$$

Let $DB_{ş\text{-Burst}}$ is the sum of all burst's slots that allocated to M users within the downlink area, which defined by:

$$DB_{ş-\text{Burst}} = \sum_{m=1}^{M} R_m + \sum_{m=1}^{M} u_m \qquad (3)$$

Eventually the total number of slots per the $DB_ş$ area can be calculated by:

$$DB_ş = \sum_{m=1}^{M} R_m + \sum_{m=1}^{M} u_m + \sum_{n_i=1}^{N} \sum_{y_j=1}^{Y} S_{n_i,y_j} \qquad (4)$$

On the other hand the overhead area $OV_ş$ can be divided into two fields; the first field is the fixed size Fx, which is the preamble and FCH. The preamble takes one complete OFDM symbol as the standard mentioned [3], and is not included in the OFDMA symbol calculations, so it is omitted as a user resource allocation. The FCH also has a fixed size of 24 bits per frame. The second part is the variable size Vs of the downlink and uplink MAPs [9], [10], whereby according to the standard [9] the overhead variable size (DL-MAP and UL-MAP) can be calculated as:

$$DL_{MAP} = Ҡ + (\delta * No.of\ user/frame) \qquad (5)$$

$$UP_{MAP} = \beta + (\tau * No.of\ user/frame) \qquad (6)$$

Where, Ҡ and β represent the numbers of bits in the fields which precede the IEs in DL and UL respectively. Moreover, δ and τ are representing the numbers of bits in the IE fields.

$$OV_ş = Fx + Vs \qquad (7)$$

$$OV_ş = FCH + DL - MAP + UL - MAP$$

$$OV_ş = FCH + Ҡ + \beta + (\tau + \delta)M \qquad (8)$$

where, M represent the total number of users per frame. To convert the $OV_ş$ from bit to slot format.

$$OV_ş = \frac{FCH + Ҡ + \beta + (\tau + \delta)M}{C} \qquad (9)$$

The total number of slots per downlink subframe is $DF_ş = OV_ş + DB_ş$.

$$DF_ş = \frac{FCH + Ҡ + \beta + (\tau + \delta)M}{C} + \sum_{m=1}^{M} R_m + \sum_{m=1}^{M} u_m + \sum_{n_i=1}^{N} \sum_{y_j=1}^{Y} S_{n_i,y_j} \qquad (10)$$

Eq.10 of $DF_ş$ represents the downlink subframe utilization. The Eq. shows that the maximum utilization can be achieved when terms 1, 3 and 4 has the minimum value to allow 2nd term to be the maximum. Moreover it shows a direct proportional effect between the number of users M and overhead size. The number of users M is a critical factor in the Eq., because it is shared between 1st and 2nd terms, whenever the increasing number of users to achieve maximum utilization leads to overhead growth. The overhead is an essential term in Eq.10 that founded and designed by the standard. However 3rd and 4th terms are wasted resource depending on the efficiency of the allocation algorithm.

Number of bits per slot C is also an effective factor to the amount of data that can be packed in the downlink subframe, which depends on the modulation and the code rate scheme.

B. SBA Algorithm Modeling

The SBA algorithm mainly depends on the number of required subchannels n_{mH} for each burst, because in the time domain the algorithm fixes the number of y_{mL} to be the value of 2 through using AS column. In this scenario the number of the required subchannels n_{mH} that assigned to the user m can be calculated as:

$$n_{mH} = \frac{R_m}{2} + 0.5 * k_m$$

where k_m set to zero when an even number of slots for user m is provided to the algorithm, and set to 1 when an odd number of slots for user m is provided. For example if R_m=39, then n_{mH} =20, which is also equal to the required number of AS units. The algorithm fixes the unused slots to be one slot if and only if an odd number of user slots delivered. The SBA algorithm sets a flag k_m for each user to record whether k_m=0 or k_m=1 to calculate the unused slots of the SBA algorithm $u_{M_{SBA}}$ per downlink subframe.

$$u_{M_{SBA}} = \sum_{m=1}^{M} k_m$$

$$where \quad k_m \begin{cases} = 1\ if\ user\ m\ have\ odd\ number\ of\ slots \\ = 0\ if\ user\ m\ have\ even\ umber\ of\ slots \end{cases}$$

The rectangular area B_m of user m defined as:

$$B_m = n_{mH} * y_{mL}$$

$$B_m = 2n_{mH} = 2\left(\frac{R_m}{2} + 0.5\ k_m\right)$$

The sum of all burst's slots that allocated to M users within the downlink area will be:

$$DB_{ş-Burst\ SBA} = \sum_{m=1}^{M} 2n_{mH} = \sum_{m=1}^{M} R_m + \sum_{m=1}^{M} k_m$$

The SBA algorithm eliminates the unallocated wastage slots between data bursts unless there are two slots neglected by the algorithm at the top end of AS column, as explained in the SBA algorithm mechanism [5]. The SBA algorithm sets a counter q to calculate how many times repeated these two slots of wastage per subframe.

$$The\ two\ slots\ of\ wastage = 2 * q$$

There are still other unallocated slots positioned at S_{n_i,y_j} between data burst and overhead burst. This is because of the algorithm uses a safety area factor to prevent bursts overlap between data and overhead.

The value of safety area factor depends on the last user data size and number of generating fragments per downlink subframe.

The unallocated wastage slots W_{SBA} of the SBA algorithm are the sum of the entire unallocated slot and can be defined as:

$$W_{SBA} = \sum_{n_i=1}^{N} \sum_{y_j=1}^{Y} S_{n_i,y_j} + (2 * q)$$

From Eq. 4, the total number of slots per the $DB_ş$ area can be calculated

$$DB_ş = DB_{ş-Burst\ SBA} + W_{SBA}$$

$$DB_ş = \sum_{m=1}^{M} R_m + \sum_{m=1}^{M} k_m + \sum_{n_i=1}^{N} \sum_{y_j=1}^{Y} S_{n_i,y_j} + (2 * q) \quad (11)$$

Recall Eq.5, the SBA algorithm calculates overhead according to the overhead modification. The downlink subframe includes a number of fragments denoted (Frag.-Burst) with associated Frag.-IE denoted Fr_{IE}, since each fragment requires separate Frag.-IE. The modified DL-MAP of the SBA becomes:

$$DL_{MAP_{SBA}} = \text{Ҟ} + (\delta * No.of user/frame) + (\lambda * Fr_{IE}) \quad (12)$$

where, λ represents the number of bits in the Frag.-IE fields. If a burst is fragmented into three parts, then the IE of the first fragment included in the second term of Eq.12, and the Frag.-IE of the second and third fragments included in the third term of the Eq. The SBA algorithm is able to count the numbers of the emerging Frag.-IE to be included in Eq. 12. The overhead of Eq. 9 become as:

$$OV_ş = \frac{FCH + \text{Ҟ} + \beta + (\tau + \delta)M + (\lambda * Fr_{IE})}{C} \quad (13)$$

The downlink subframe utilization can be defined as:

$$DF_ş = \frac{FCH + \text{Ҟ} + \beta + (\tau + \delta)M + (\lambda * Fr_{IE})}{C} + \sum_{m=1}^{M} R_m + \sum_{m=1}^{M} k_m + \sum_{n_i=1}^{N} \sum_{y_j=1}^{Y} S_{n_i,y_j} + 2 * q \quad (14)$$

Eq.14 enforces high frame utilization using a fixed parameters that can control the wastages. The first term of the overhead includes the additional value of the fragmentation mapping ($\lambda * Fr_{IE}$) which is depend on how many fragments constructed within the downlink subframe and doesn't depend on *M*. As well as the first term shows that burst fragmentation not necessary will enlarge the overhead too much, but it depends on how many bursts that faces a critical location then need to be partitioned.

The third term adds one slot in case of m has an odd number of slots provide to the algorithm to balance the rectangular shape. The fourth term depends on the safety area factor as explained previously. The fifth term depends on the opportunities of the two slots left at the top end of AS column occurrence, which is an unlikely possibility to frequently occur.

VII. RESULTS AND DISCUSSION

The SBA algorithm has been modeled based on the IP packet level traffic model that recommended by WiMAX Forum for the resource allocation [11]. A Scilab-5.3.3 simulation tool is used to evaluate and analyze the effect of burst fragmentation to the SBA algorithm. The standard allocation (ST) algorithm has been adopted for the comparison purpose. Table 1 shows the parameters setup.

Table 1. Parameters setup

Parameters	Value
Frame type and duration	TDD (5ms)
Channel bandwidth	10 MHz
Symbol duration	102.9µs
FFT size	1024
Subcarrier Permutation	PUSC
DL to UL Ratio	29/18
No. of subchannels	30
Preamble size	One OFDM symbol
Overhead repetition	4
Modulation	QPSK
Code rate	½
MAC PDU size (payload size)	20 – 2048 bytes
FCH	24 bits
DL-MAP and UL-MAP size	Dynamically calculated by algorithm
Simulation time	1 – 50 Sec.

Firstly the fragmentation effect to the allocation efficiency of SBA algorithm in term of number of fragments and overhead increment are discussed in figures 3 and 4. The rest of the results show SBA algorithm overcomes the ST algorithm, although overhead size increased due fragmentation process, still SBA can achieve higher proportion of data packing within a frame.

In Fig. 3 the Y-axis represent the average number of users and fragments per frame versus all possible burst sizes (slots) per frame. The Fig. shows the average number of fragments never exceed 5.4 fragments per frame at the worst case. Each fragment cost the overhead 45 bits (i.e. 32 bytes for 5.4 fragments per frame according to SBA design). The Fig. depicts that the proposed fragmentation procedure of the SBA algorithm would not generate extensive number of fragments. The typical number of user per frame is (8-10) as mentioned in [12], and the fragmentation procedure is more efficient at that range of users per frame as depicted in the Fig

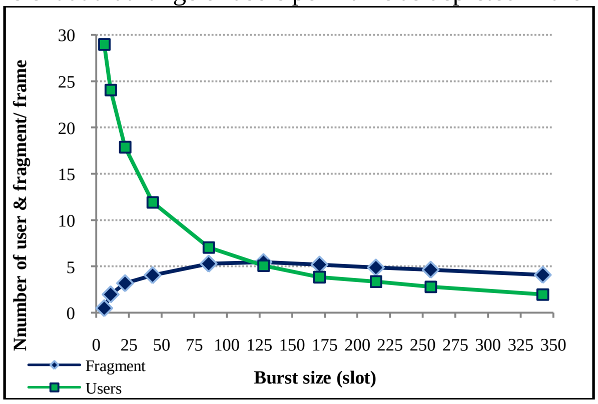

Fig.3 Number of users and fragments per frame vs. burst sizes.

Figure 4 shows the average overhead size versus different burst sizes. The red area represents the additional size added to the overhead due to the new emerging fragments. The presented overhead columns represent the four repetition of the overhead, and if the two repetitions were used, hence the overhead size would become half size and permit more users to be packed.

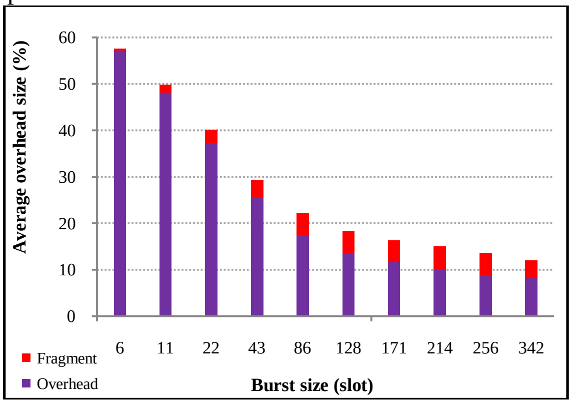

Fig.4 Overhead and fragments map size per frame vs. burst sizes

Figure 5 shows the average number of users per frame versus different sizes of MAC PDU. The figure shows that the SBA outperforms the ST in terms of number of users per frame and the average difference between them is 23.14%. This is because the SBA has the ability to conduct burst fragmentation and continuous allocations from a frame to the next frame. While at using ST algorithm, the allocation scheme is based on the available area, which causes resource wastage whenever there is a mismatch between the MAC PDU size and the available area in the subframe. For different MAC PDU sizes, the average number of users which can be packed within the frame when using SBA is 8.58 users, while it is equal to 6.8 users when using ST algorithm. The design of the SBA algorithm provides the ability of partial allocation of user's slots, whilst the ST algorithm cannot conduct the partial allocation of user slots.

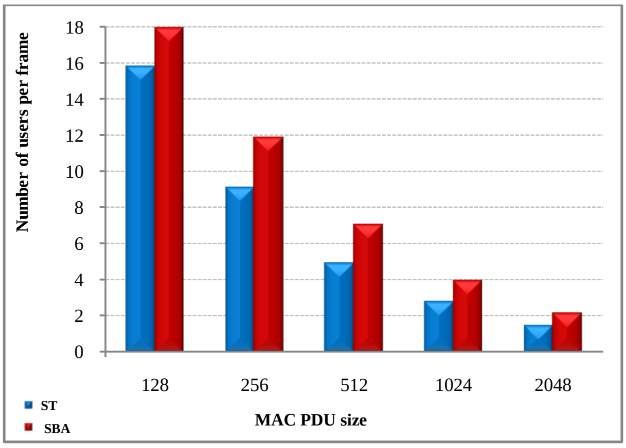

Fig.5 Number of users per frame vs. different MAC PDU size.

Figure 6 shows the effective data rate per frame versus different MAC PDU sizes. The figure shows that the SBA provide higher effective data rate per frame than the ST due to the efficient exploit of the downlink subframe. For different MAC PDU sizes, using QPSK with ½ code rate, the average data rate per frame that has been achieved by the SBA is 2.97 Mbps, while it is 2.14 Mbps when using ST algorithm. The average data rate achieved per user when using SBA algorithm is 346 Kbps and for the ST algorithm is 314.97 Kbps. Consequently, the SBA algorithm increases the average user data rate by 31.03 Kbps.

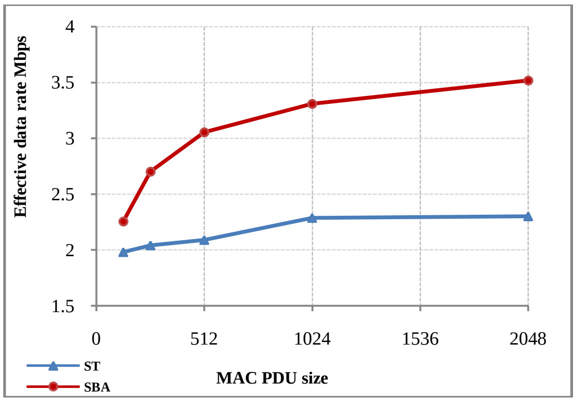

Fig.6 Effective data rate per frame vs. different MAC PDU sizes.

To illustrates the effect of the burst allocation algorithm performance on the transmission time. A fixed amount of data simulation was conducted to calculate the required time for allocation and framing over the air of the same data in each algorithm.

Figure 7 shows the time required for data allocation within the downlink subframe and framing over the air versus different MAC PDU sizes. The figure depicts that SBA reduces the required time for sending the same amount of data, and the average time for different MAC PDU sizes when using SBA algorithm is 0.348333 sec, while it is 0.467667 sec at using the ST algorithm. The SBA algorithm contributes in reduction the transmission time, and the achieved reduction is 119.334 msec.

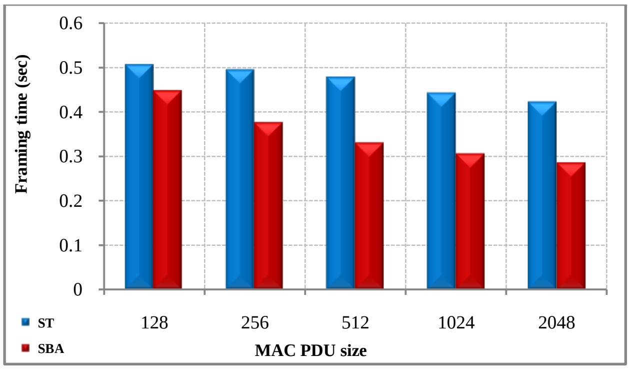

Fig.7 Data allocation and framing time vs. Different MAC PDU sizes.

VIII. CONCLUSION

This paper presents two analytical models for the downlink subframe utilization of Mobile WiMAX system. The first one is based on standard allocation algorithm and the second is based on Sequential Burst Allocation. The burst fragmentation criteria have been clarified.

It has been concluded from experimental results evaluation that burst fragmentation approach of SBA algorithm can achieve higher performance. Superiority is in term of number of users and resource wastage reduction, as the analytical models endorsed these results.

As well as it has been noted that burst fragmentation approach of SBA is powerful for bursts sizes below 125 slots, because it generates less number of fragments and regulates the downlink subframe to include more data and more users. The performance metrics were strengthened as follows: the number of users increased by 26.26%, the effective data rate per frame increased by 38.69%, the wastage slots reduced by 91.98%. However, the overhead increment has minor effect comparable to the enhancement of the frame utilization. Moreover the SBA eliminates the influence of burst size on the allocation procedure, and to contribute in the reduction of the transmission time delay.

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