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Improve Downlink Burst Allocation to Achieve High Frame Utilization of Mobile WiMAX (802.16e)

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Abstract

The burst allocation algorithm is responsible about calculating the appropriate dimensions and location of each user's data to construct the bursts in the downlink subframe in term of the number of slots for each user. Burst allocation is one of the performance parameter which influences the mobile WiMAX systems, due to resource wastage in the form of unused and unallocated slots per frame which affects the Base station performance. In this paper, a Sequential Burst Allocation (SBA) algorithm is proposed to overcome frame wastage. The SBA algorithm is based on the idea of sequential allocation of user slots. SBA limits the excessive unused slots, and burst fragmentation when necessary is forced to be used to eliminate unallocated slots between data bursts. Continuous allocation from one frame to the next has a significant impact on reducing resource wastage. It has been observed from the results that the percentage difference of the frame utilization between SBA and ST algorithms is 32.84 %, which achieve significant reduction of resource wastage per frame, leading to more exploit of the WiMAX frame.

Keyword – *Burst allocation, downlink subframe, overhead, Mobile WiMAX.*

1. Introduction

Worldwide Interoperability for Microwave Access (WiMAX) is the industry name given to the 802.16-2004 amendment by the vendor interoperability organization. IEEE 802.16 is mainly aimed at providing broadband wireless access (BWA) and is considered to be an attractive alternative solution to wired broadband technologies like digital subscriber line (DSL) and cable modem access. The mobile version of 802.16 is known as Mobile WiMAX or 802.16e. This amendment aims at maintaining mobile clients connected to a Metropolitan Area Networks (MAN) while moving around [1]. Mobile WiMAX works under Point-to-Multipoint (PMP) topology, where the traffic may take place only between a Base Station (BS) and its Mobile Stations (MSs) and where the BS is the centre of the system. Thus Mobile WiMAX systems performance is extremely dependent on BS efficiency.

The physical layer (PHY) of 802.16e uses Orthogonal Frequency Division Multiple Access (OFDMA) technology, which can be implemented using Time Division Duplex (TDD) or Frequency Division Duplex (FDD). TDD is the preferred technology for mobile WiMAX for many reasons which are not relevant to this paper. Mobile WiMAX frames that use TDD mode consist of two parts, the downlink subframe and the uplink subframe as shown in figure 1. The downward data is sent from the BS toward the MS through the DL subframe interval and the upward data is sent from the MS toward the BS through the UL subframe interval. The downlink-to-uplink-subframe ratio may vary from 3:1 to 1:1. Transmit-receive Transition Gap (TTG) and Receive-transmit Transition Gap (RTG) are guard time intervals between successive DL and UL subframes [2].

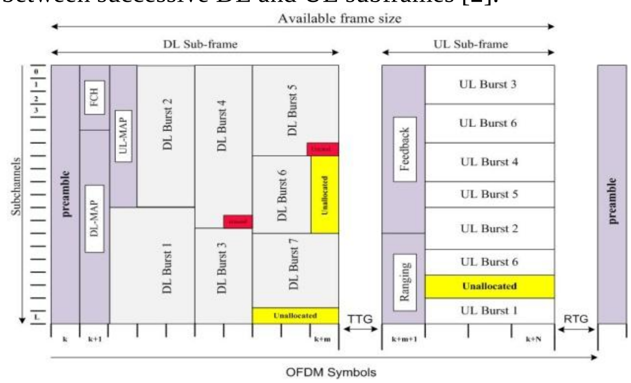

Fig. 1 TDD frame structure of mobile WiMAX.

Mobile WiMAX channel resources (frequency, time) are used to formulate frames which carry users' data in the form of data bursts. A burst is composed of 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, where each slot is one subchannel (frequency) by one to three OFDM symbols (time). The BS must assign the Burst Profile for each data burst to identify the combination of modulation, forward error correction (FEC) and code rate used for individual burst.

The frame has a limited size as defined in Mobile WiMAX standards (5ms) [3]. The frame should carry a maximum number of data bursts which are capable of being carried to satisfy high system performance. To achieve high frame utilization, a burst allocation algorithm (or burst mapping also called burst packing) faces a problem of filling up the frame with irregular downlink burst rectangles shapes, which impose the algorithm to waste resources in the form of unused and unallocated slots due to decision complexity of finding conformity between the rectangles shapes and the available area within the frame. Therefore, the efficient algorithms must be design to avoid the resource wastage in the form of unused and unallocated slots. The reason for unused slots within a burst is because the allocated burst to the user data in the DL subframe is bigger than the actual data size as shown in figure 1 (the red area). However the unallocated slots is the area that are unassigned to any burst inside the DL subframe due to a mismatch of rectangular shapes to that area within the DL subframe (the yellow area). Eventually, the unused and unallocated slots leave out vacant and transmitted as blank slots and will definitely decrease frame utility. Moreover, a part of the frame should be assigned to the overhead bursts, which is used to inform served users within a frame about their burst profiles and where/when to receive and send their data burst. The overhead is compulsory allocate at the beginning of each frame as shown in figure 1 and broadcasted to all users under BS coverage using the standard unified and mandatory predefined burst profile. Figure 1 shows the overhead bursts (preamble, Frame Control Header (FCH), downlink map (DL-MAP) and uplink map (UL-MAP)).

The Standard algorithm (ST) associated with drawbacks which affect the frame utilization. These drawbacks can be list as follows:

1- With the lack of knowledge about the incoming sizes of the data, the allocation algorithm facing a difficulty of area calculation and frequently re-dimension the incoming data to find a match between burst rectangles and available area.
2- The burst size has a major effect on the allocation procedure, which causes more resource wastage.
3- Consume more number of frames for a specific amount of data.
4- Increases user waiting time inside the Medium Access Control (MAC) layer queue, which contributes to an increase in data transmission time.
5- ST algorithm is an NP-complete problem [4], it is a class of decision complexity problems that uses a set of rules prescribes more than one action to be performed for a given situation, which lead to an increase in the computational load.

The objective of this paper is to design and model a burst allocation algorithm with low complexity and minimum resource wastage. The proposed algorithm is developed to achieve higher frame utilization within the downlink subframe through reducing the unused and unallocated slots without violating the agreed QoS guarantee.

The downlink burst allocation is the process of assigning a number of subchannels in a frequency domain and the number of OFDMA symbols in the time domain (slots) for each data burst and its overhead within a downlink subframe. Therefore burst allocation is an algorithm which is responsible about computing the appropriate dimensions and location of any burst within the downlink subframe.

The contribution of this paper is developing a new burst allocation algorithm based on sequential allocation of data slots in the form of columns using a new technique of organize burst fragmentation, to eliminate the unallocated slots between bursts and reduce the unused slots within a burst to be one slot per burst at the worst case. On the other hand, this technique is providing a numbered fragment that enable recipients to re-assemble their fragments in correct order. The proposed algorithm modifies the overhead contents for the additional fragments with reduction of unnecessary repeated fields.

The rest of this paper is organized as follows: Section 2 describes the related works, Section 3 describes mobile WiMAX Performance constraints, Section 4 describes the criteria of burst allocation, Section 5 demonstrates the proposed algorithm, Section 6 shows functional comparison of SBA and ST algorithms. Section 7 presents the results and discussion. Finally, Section 8 concludes the paper.

2. Related work

The burst allocation algorithm is crucial to the WiMAX systems performance; therefore it is a competitive subject to the manufacturers. The literature surveys can be divided into three main methods of designing the burst allocation algorithm, as follows:

The first method is the reshaping of burst rectangular to deal with height and width to find the suitable shape that can be inserted within DL subframe with minimum loss of slots, such as the literatures [5], [6] and [7]. In [5] the authors proposed an algorithm which uses a physical component called Bucket composed of a number of slots in the form of column allocated to each user which then combines Buckets with a similar profile to construct a single burst. The proposed burst construction scheme violates QoS when discard packets that not meet their transmission deadline and not match the available bursts space without an estimation of how many packets will be dropped. The proposed scheme could have well performance in burst construction at the expense of QoS.

Efficient Downlink Bandwidth Allocation (EDBA) has been proposed in [6], to calculate the sequence, shape, alleviation of unallocated slots and location of the bursts within downlink subframes. The author ignore the emerging overhead calculation within the frame, as well as the results shows an obvious unallocated wastage slots especially with lower number of users per frame. The proposed allocation scheme works in fourfold step which increases the computational load. The proposed algorithm in [7] named enhanced One Column Striping with non-increasing Area (eOCSA), in which the allocation based on the descending order of the burst sizes in the form of vertical columns taking into account minimum slots wastage and power consumption. The proposed scheme did not consider overhead size calculation in the algorithm, and just assign 2 OFDMA symbol, while the actual overhead size is exceed the reserved symbols especially for a large number of users and when four overhead repetitions is used. Therefore an efficient solution should include the effective factors in the algorithm design.

This method of burst allocation algorithm design is usually keep the overhead without changes, and deal with problem as rectangles arrangement within a container, which has the lower improvement to the system performance, because of rectangles dimensions limits the opportunities of reduction the resource wastage.

The second method is based on fragmentation the burst to get required shapes that can be fit within the available allocation spaces to achieve minimum wastage of the slots, such as the following publications. 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 and to a decrease in the available number of slots per downlink subframe. A linear complexity algorithm is proposed in [9], to enclose as a maximum as can of the unused and unallocated slots in single area to be used for fragments allocation. The procedure uses frequent reshaping and burst fragmentation to build the bursts, then shift the constructed busts to combines them in adjacent area. The author did not consider overhead size especially there is burst fragmentation which require additional overhead on the expense of data slots. An efficient burst arrangement called Burst fragment packing scheduling (BFPS) is proposed in [10], in which four schemes are used to implement burst pack allocation (allocation, fragmentation, packing and swapping) that leads to an increase the complexity and the computational load.

This method of the burst allocation algorithm design usually need an overhead manipulation to address the additional fragments in the overhead field, as well as it is required a procedure to re-assemble the fragmented bursts to take into account the ordering of fragments (first, second…etc). which is very important because when a single burst fragments into two or three parts, the recipient want know which is the first, second or third part. The necessity of ordering comes from the fact that fragmentation may happen in the middle of MAC PDU, which leads to the MAC PDU being discarded in the two fragments, because the first part without CRC and the second part without the MAC PDU header, will lead to an increase in the error bit ratio. To the best knowledge of the author there is no publication take care about the fragment order.

The third method is the cross layer design between MAC and PHY layers to utilize the QoS information to satisfy differentiation between service types in order to allocate the bursts according to their constrains and priorities considering the wastage slots reduction. In [11] the authors propose two algorithms for slot allocation depending on the differentiation between service flow types through QoS priority or dynamically assigning a different percentage weight for each service flow type to achieve QoS requirements for different types of service flows. It is clear that the main effort is directed to QoS satisfaction and burst allocation take secondary attention. A cross layer design is used in [12] to achieve real time and non-real time scheduling in addition to burst allocation. The authors proposed a two tier framework. The first for priority scheduling and the second for burst allocation. The proposed burst allocation is designed to divide the downlink subframe horizontally into several slices, each called a bucket. The allocation procedure neglects the calculation of the unused slots within bucket, and overhead reduction depend on how many buckets that can be aggregated, which follow the channel conditions of each user link.

This method usually dedicated to enhance the system QoS through utilizing burst allocation features such as the ability of manipulating subchannels, aggregates similar users conditions in a single burst, the ability of choosing the location within the frame, distributes the computational load between QoS scheduler and burst allocation algorithm and so on. While burst allocation algorithm takes the minor attention in term of reduction the wastage slots within the frame.

3. Performance constraints

The BS of mobile WiMAX should be able to serve hundreds of users simultaneously, and the number of users per BS is depend on many factors, such as system bandwidth, the call admission control policy used in the system, the type of services presented, frequency-reuse, cell radius, antenna patterns and so on. On the other hand, frame capacity depends on the scheduling algorithms and subcarrier permutation used to fill the frame with the largest possible number of users (or user data). System capacity therefore depends on frame capacity. This is the idea of focusing on the downlink burst allocation algorithm.

The performance and capacity of the mobile WiMAX BS is affected by two important parameters, firstly the selection of data to be packed in the downlink data bursts with certain priority and secondly, the allocation of these bursts in the downlink subframe with minimum wastage. These two parameters represent the QoS scheduler and the downlink burst allocation algorithm respectively, which are tightly combined to guarantee the required QoS and maximize radio resource usage.

One of the keys of the robustness of the WiMAX system is the subcarrier permutation; it is a technique that defines number of subcarriers and their distribution within a single subchannel vs. the number of OFDM symbols within a single slot. The subcarrier permutation technique can be implemented in two ways. Whereby distributed and adjacent subcarriers permutation to provide the following types of permutation for downlink and uplink connections. The Downlink Partial Usage of Sub-Carriers (DL-PUSC) is the mostly used and mandatory for frame overhead, Downlink Full Usage of Sub-Carriers (DL-FUSC), Uplink Partial Usage of Sub-Carriers (UL-PUSC), Tile Usage of Subcarriers (TUSC), Band Adaptive Modulation and Coding (Band AMC) [13].

4. Burst allocation criteria

The MAC layer receives the Service Data Unit (SDU) from a higher layer to segment or concatenate them into MAC Protocol Data Unit (PDU), which is the basic payload unit handled by the MAC and PHY layer. Each PDU is provided with all necessary requirements to enable them to reach their destinations, such as a connection identifier (CID), service flow conditions, QoS requirements, priority, burst profile, security etc. then schedule them over the PHY layer [14].

The downlink burst allocation input is provided by the MAC scheduler after the Forward Error Correction (FEC) stage in the PHY layer. MAC PDU is scheduled according to service flow constraints and QoS requirements to form a queue of data users corresponding to their priority. The MAC PDU is expressed in term of the number of bytes per user, and then the downlink burst allocation algorithm receives MAC PDU to include in PHY layer frame as a burst in term of slots, taking in consideration the burst profiles for each user. It should be mentioned that burst allocation algorithms should never pass over or bypass the priority queue or drop users, because the priority queue is formed and organized in the MAC layer to satisfy service flow conditions and QoS requirements.

The specifications of the burst should be identified clearly:

1) The emerging bursts are shaped in irregular two-dimensional rectangles, depending on the allocation policy that specifies the number of OFDMA symbols vs. the number of sub-channels.
2) The commonly defined rectangles of the bursts to be formed and allocated from top to bottom in the frequency domain and from left to right in the time domain.
3) All data packed within an individual burst must be transmitted using the same burst profile.
4) The base station responsible for calculating the burst profile for each user depending on the user channel quality, to concatenate a similar burst profile within a single data burst.
5) Burst overlap or interference is prohibited.
6) Burst profiles of overhead bursts (control messages) are pre-defined by standards and are mandatory to use [3].
7) A burst can be assigned to one or more users if and only if they have the same burst profile, then each user has a dedicated data region within the burst.
8) More than one burst can be assigned to a single user.
9) The burst fragment into parts must be kept in a scientific way to enable recipients to reassemble the fragments and retrieve their bursts or data regions.
10) Each burst or user data region within a burst should be defined and mapped in the frame overhead bursts.

The design of downlink allocation algorithm should take into account the above mentioned specifications in addition to the parameters that make the algorithm more realistic in term of its application in a real life situation, such as simplicity which reduces the computational load so that it can continue to work under the deadline time of the frame duration (5ms), Another important factor is overhead growth, which is closely associated with the number of users per frame. The algorithm should focus also on a single task to get better results, rather than a designer trying to collect many tasks in a single design attempt, leading to a loss of robustness and less efficiency.

5. The Proposed burst allocation algorithm

The proposed algorithm has been designed and modeled and is called the Sequential Burst Allocation (SBA) algorithm.

Some preconditions will be defined to clarify the flow sequence of the algorithm.

1) A new factor, called Allocated Slots (AS) will be used, to denote two contiguous slots in a time domain and in one row of frequency domain, as shown in figure 2.
2) The subcarrier permutation used is PUSC, in which each slot consists of one subchannel with two OFDM symbols.
3) All users have the some channel conditions.
4) Each burst contain a single MAC PDU (i.e. single user)

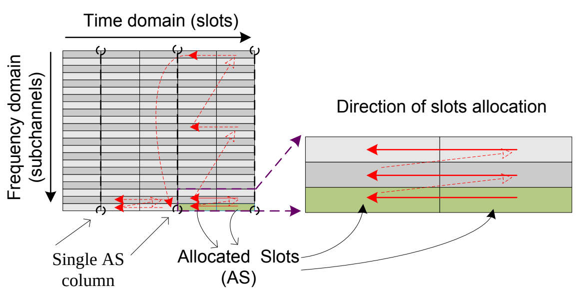

Fig. 2 Resource allocation procedure.

5.1 procedure policy of the SBA algorithm

The proposed SBA algorithm follows the procedure listed below to construct and allocate data bursts with its overhead.

1- The SBA algorithm will use AS to construct a burst, start from the bottom right to allocate one AS, then upward to allocate the next AS and so on, until the whole column is complete or the slots of data fulfill, as shown in figure 2.
2- If the user data slots do not end in a single AS column, then it is necessary to start with another contiguous AS column. Figure 3 shows the blue area with two fragments (Burst #2) and (Frag.1-Burst #2).
3- In case the user data slots ending, while the AS column not yet (just two slots remains) as in figure 3 Burst #5, the SBA algorithm will neglect these two slots, because it costs more overhead when it is used, It is therefore better to neglect it rather than use it as a fragment.
4- At the end of the frame, it could be the remaining area that does not fit precisely with the last user slots. At this point the SBA algorithm will fragment the burst according to the available space, and allocate the first fragment in the current frame and save the second fragment in the fragment buffer to become the first data fragment in the next frame.
5- SBA will calculate and allocate required overhead burst for each data burst constructed.

The above steps show frame resources (frequency, time) allocation for each user taking into consideration burst fragmentation. The SBA algorithm does not need extra calculations to evaluate burst shape or re-size in advance, as it works directly to allocate the incoming numbers of slots to the frame sequentially using the AS column concept. More precisely SBA algorithm is low complexity class of decision problem that uses a set of rules prescribed at most one action to be performed for a given situation.

The AS concept is used to divide the number of slots by 2 in order to alleviate the numbers of subchannels in the frequency domain, and to gain three advantages. The first is to reduce unused slots per burst, which will become one slot if and only if there is an odd number of slots provided to the algorithm, otherwise there is no unused wastage. Figure 3 (Burst #3) shows one unused slot in a dark violet color. The second advantage is to minimize the burst transmission time, as it is allocated in vertical stripes instead of horizontal or irregular ones, which lead to a reduction in power consumption in the MS (i.e. MS needs working time equal to the period of its related burst).The third advantage is that it minimizes burst fragmentation probability. Figure 4 show six bursts, whereby burst #2 is fragmented into two parts, and burst #4 is fragmented into three parts. These fragments require extra mapping in the overhead, which will be discussed in detail in the overhead section.

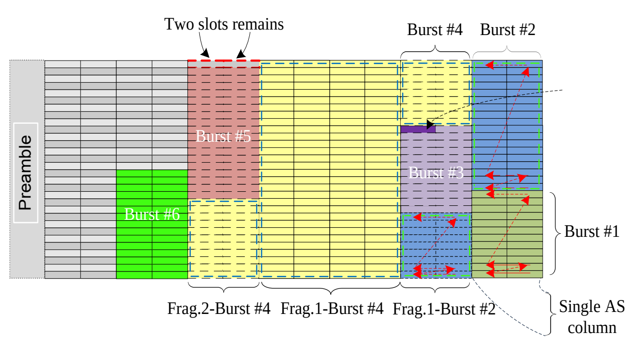

Fig. 3 Mobile WiMAX TDD downlink subframe depicts resource allocation using proposed SBA allocation algorithm.

5.2 SBA algorithm steps

#1: generate a new empty frame.
#2: check if there are any saved user slots in the fragment buffer, go to (#5) if yes.
#3: pull user from the queue in term of MAC PDU sized as number of bytes.
#4: calculate number of slots required to pack the data of the pulled user.
#5: calculate the available space in the frame.
#6: if the available space is equal to or bigger than the number of slots, then start allocation sequentially slot by slot.
#7: allocate required overhead slots and go to (#2).
#8: else if the available space is less than the number of slots, fragment the user slots according to the available space.
#9: allocate the first fragment in the current frame and save the second fragment in the fragment buffer.
#10: allocate required overhead slots, then end the allocation process and the frame is ready to send, go to (#1).

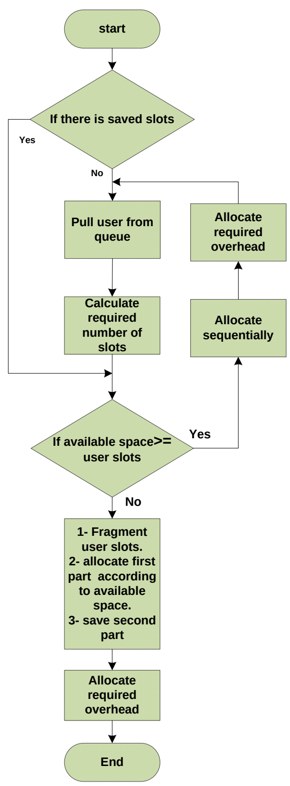

Fig.4 The SBA algorithm flowchart.

5.3 Overhead consideration and modification:

As there is a close relationship between overhead and burst allocation, any modification or new policy related to burst allocation should take into account overhead manipulation, due to the fact that the overhead must always reflect these modifications or policies to the recipients. As a result, research that does not consider overhead gives it ostensible enhancement.

As aforementioned, frame overhead consists of three fields, preamble, FCH and MAPs. MAPs includes DL-MAP and UL-MAP, both include multiples of IEs. This paper focuses on the downlink bursts and related DL-MAP, while the UL-MAP will remain as it is. The numbers of DL-MAP_ IE are equal to the number of bursts per frame (each burst contains one user as assumed). Whenever a burst fragments it is necessary to construct a new DL-MAP_IE for each fragment.

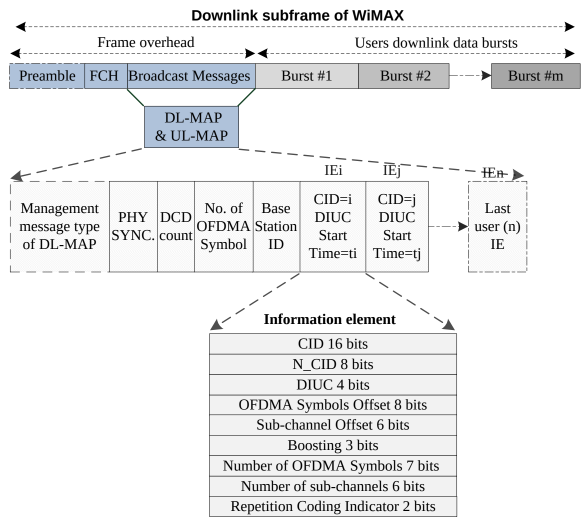

Fig.5 Overhead details of Mobile WiMAX TDD frame.

Prior to the proposed overhead modification, an overview to the original structure and contents of the DL-MAP_IE is explained. The information element shown in figure 5 includes the following fields; the Connection Identifier (CID) that uniquely determines a connection between a BS and a MS. The N_CID is the number of CIDs in the corresponding burst (each burst can contain more than one CID), Downlink Interval Usage Code (DIUC) indicates the burst profile (i.e. modulation and coding schemes used). The OFDMA Symbol offset, is the offset for the symbol at which the burst starts (measured in symbols), the subchannel offset used for carrying the burst starting from subchannel 0. The boosting field indicates whether the sub-carriers for this allocation are power boosted. The number of OFDMA symbols is the number of symbols that are used to carry the burst. Similarly, the number of sub-channels is the number of subchannels that are used to carry the burst. The repetition coding indicates how many times the code is repeated [15].

The proposed modification based on fragment sequences for the purpose of re-assembling in the correct order, a reduced structure of IE is proposed and symbolized as

(Frag.-IE) as in figure 6. Whenever a burst fragments, the first fragment will assign the original structure of IE and the second fragment will assign Frag.-IE, which has an implicit fragment number. For further clarification Burst #4 in figure 3 is fragmented into three parts, the first part is denoted by burst #4 and assigned IE4, the second fragment is denoted by Frag.1-Burst #4 and is assigned Frag.1-IE4 and the third fragment is denoted by Frag.2-Burst #4 and is assigned Frag.2-IE4. Each Frag.-IE includes the essential information required to find the position of related Frag.-Burst within the downlink subframe, while the original IE will include all the standard information. The idea behind the modification is that the same recipient will collect all the fragments, so it is not necessary to repeat all the information fields each time, just renewal the location information fields of the new emerging fragments is needed and omit the repeated fields.

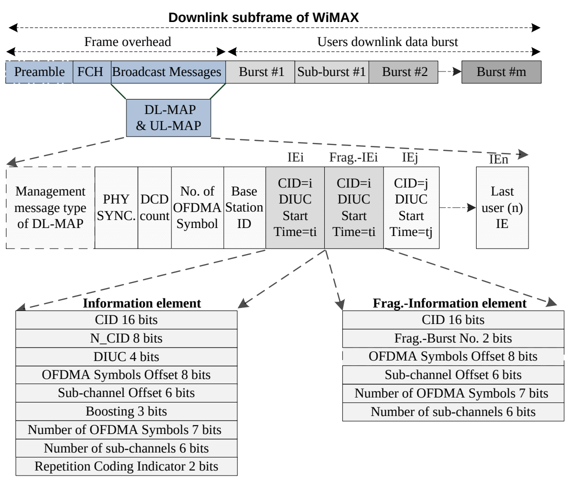

Fig.6 Modify overhead of Mobile WiMAX TDD frame.

Frag.-IE contain six fields as shown in figure 6, the first field is the CID, which will be kept with no change in any fragment to guide the recipient to collect all the fragments which have the same CID (i.e. whenever a recipient finds his CID is repeated, it means that is a fragmentation of a single burst and must be collected). The second field is used for the fragment number, (Frag.-Burst no.) and is composed of 2 bits to refer to the fragment order (the worst case is 3 fragments, so 2 bits is adequate). The remaining fields are updated with a new location in the frame.

The overall size of the overhead can be divided into two parts; the first part is fixed size, which is the preamble and FCH. The preamble takes one complete OFDM symbol as a standard mentioned 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 of the DL and UL MAPs, whereby according to the standard the overhead variable size (DL-MAP and UL-MAP) can be calculated as [3, 14]:

$$\text{DL-MAP} = \mathcal{K} + (\delta * \text{No. of user/frame}) \quad \dots 1$$
$$\text{UP-MAP} = \beta + (\tau * \text{No. of user/frame}) \quad \dots 2$$

Where, $\mathcal{K}$ 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. Figure 6 shows the overhead fields.

The SBA algorithm calculates overhead according to the overhead modification. The downlink subframe includes Frag.-Burst and Frag.-IE, neither are additional fields but modified type of IE fields. The DL-MAP becomes:

$$\text{DL-MAP} = \mathcal{K} + (\delta * \text{No. of user/frame}) + (\lambda * \text{No. of Frag.-IE}) \quad \dots 3$$

where, λ represents the number of bits in the Frag.-IE fields. In other words any burst has been fragmented will follow equation 3 in overhead calculation. First fragment will included in the second term of equation 3, the second and third fragments will included in the third term of equation 3. It is worth mentioned that the overhead modification enhance the fragments mapping Frag.-IE by a 15 bits reduction over the standard IE as shown in Figure 6.

6. Functional comparison of SBA and ST algorithms

To illustrate the operational procedure for both algorithms, a practical example can help to explain the reason of high slots wastage in a frame when using the ST algorithm. Assuming MAC PDU sequence in the MAC priority queue expressed in number of slots per user ordered as (56, 30, 43, 55, 6, 53, and 47) and the available area in the frame is 300 slots (Y-axis is 30 subchannels, and X-axis is 10 OFDMA symbols as shown in Figures 7 and 8). And as assumed in section 5, each burst represent one user, thereby the queue represent seven data bursts.

The allocation procedure used by ST algorithm is performed according to the available space within the frame as shown in Figure 7. it starts with the first user (56 slots) at the top left, then check the available space to allocate the second user (30 slots) and so on until the available space area does not fit the incoming user slots dimensions. The remains space area within the frame cannot enclosure the last user (47 slots) because of the remaining area spread in different positions within the frame, thus the frame should be send and a new empty frame will generate. The last user (47 slots) in the queue will be assign to the next new frame. Eventually the wastage slots will be (55 un-allocated + 2 unused=57 slots).

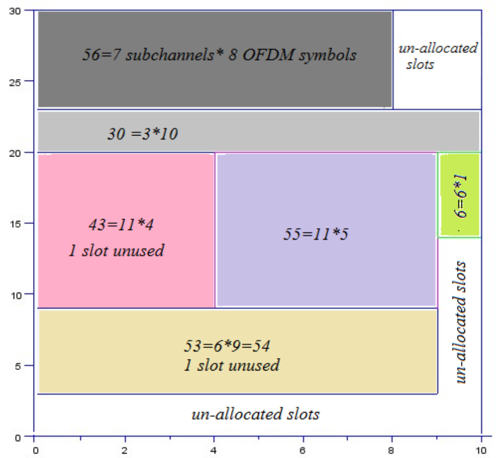

Fig.7 ST Algorithm allocation procedure.

The SBA algorithm allocates users slots sequentially as shows in Figure 8. The allocation starts with the first user (56 slots) at the bottom right to follow the procedure explained in section 5.1, and using same queue order, SBA able to include the last user (47 slots) in the frame. The wastage slots will be (6 un-allocated+4 unused= 10 slots).

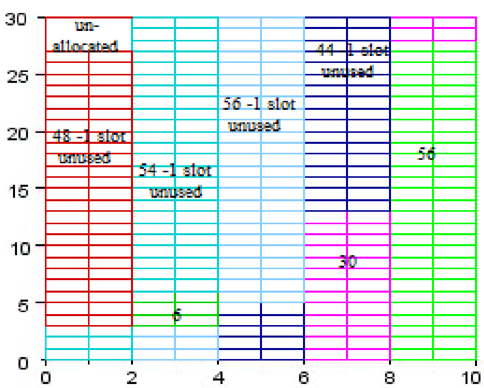

Fig. 8 SBA algorithm allocation procedure

The overhead related to each algorithm has different size. The ST overhead can be calculated as in equation 1, and the SBA overhead follows equation 3.
Figures 7 and 8 show the power consumption of MS is less when using SBA algorithm. For example the first user (56 slots) occupy 2 OFDMA symbols as a working time to receive the related data, while the same user occupy 8 OFDMA symbols as a working time to receive the same data. More specifically the SBA algorithm outperforms the ST algorithm in term of power consumption at recipient side.

6.1 Performance metrics

The metrics that are selected to evaluate the SBA algorithm performance are:

- Frame utilization – represent the usage of the frame, as well as it is the maximum downlink rate per PHY layer frame.
- Unallocated slots – represent the unassigned slots to any data burst within a frame.
- Unused slots – represent the vacant slots within data burst.
- Packed data – represent the amount of users' data carried within the frame in term of slots, moreover it is reflect the data rate per frame.
- Overhead size – represent number of slots reserved to overhead, also it reflects number of users per frame.

The most effect factor to the metrics is the MAC PDU size, which is used in this paper as a reference to gauge the metrics performance. The allocation algorithm converts MAC PDUs bytes into a number of slots for each data burst.

7. Results and Discussion

Scilab-5.3.3 is used to model the SBA algorithm. The designed model with an extensive set of parameters is performed to evaluate and analyze the performance of the SBA algorithm with respect to the ST algorithm. Table 1, shows the parameters setup.

Table -1- Simulation parameters.

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

Figure 9 shows the frame utilization versus different MAC PDU sizes. There are two curves, each corresponding to an individual allocation algorithm SBA and ST. The figure shows that the SBA outperforms ST and the percentage difference between them is 32.84%, since the frame utilization when using SBA is higher than the utilization as compared to ST, moreover the figure depicts that the utilization at using the SBA is not affected by the MAC PDU size, while the utilization of the ST algorithm decline with increasing the MAC PDU size. This is because, when using SBA algorithm, the allocation is sequential and this procedure of allocation reduces the unallocated slots. While at using ST algorithm, the size of MAC PDU in the form of rectangles limits the opportunities of fitting more users in the frame which leads to an increase in slot wastage.

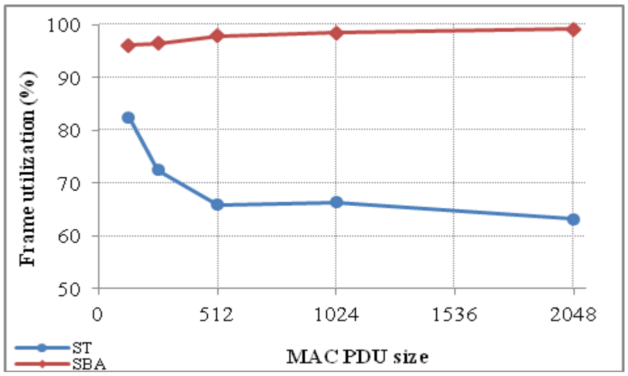

Fig.9 Frame utilization vs. MAC PDU size.

Figure 10 shows the unallocated slots versus different MAC PDU sizes. There are two curves, each corresponding to an individual allocation algorithm SBA and ST. The SBA algorithm able to fragment the MAC PDU and the continuity allocation from frame to the next frame has a major effect of reducing the unallocated slots per frame. On the other hand the ST algorithm curve able to allocate 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 ST curve behavior explains the effect of MAC PDU size to the increment of the unallocated slots.

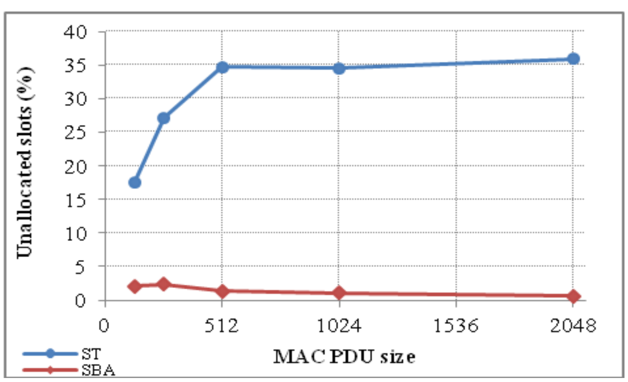

Fig.10 Unallocated slots vs. MAC PDU size.

Figure 11 demonstrates the unused slots versus different MAC PDU sizes. There are two curves, each corresponding to an individual allocation algorithm SBA and ST. The SBA algorithm curve behavior depends on how many users that have odd number of slots. Therefore in small MAC PDU sizes; the frame can tolerate more users within single frame which increases the probability of odd number occurrence of user data slots to increase the unused slots per frame. In the large MAC PDU size the frame has less number of users that reduces probability of odd number to decrease unused slots per frame. While ST algorithm depend on re-dimension the burst size that require adding vacant slots to get match between available area and MAC PDU sizes.

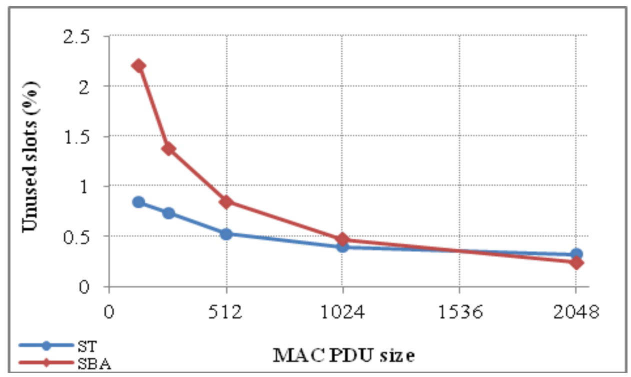

Fig.11 Unused slots vs. MAC PDU size.

Figure 12 shows the amount of users' data that can be packed per frame versus different MAC PDU sizes. There are two curves; each corresponding to an individual allocation algorithm SBA and ST. Figure 12 shows the SBA algorithm overcomes the ST algorithm and the percentage difference between them 31.34%. As well as the figure demonstrates that SBA algorithm has the ability to utilize more slots allocated to users' data, which leads to increasing the number of users per frame. However, the ST algorithm shows less utilization, due to the MAC PDU size restrict the algorithm to manage unassigned remaining area, which decreases the number of users per frame. Both curves grow up when MAC PDU size become larger, which means less number of users per frame and thus less overhead required. Consequently, increase the available slots to pack large MAC PDU.

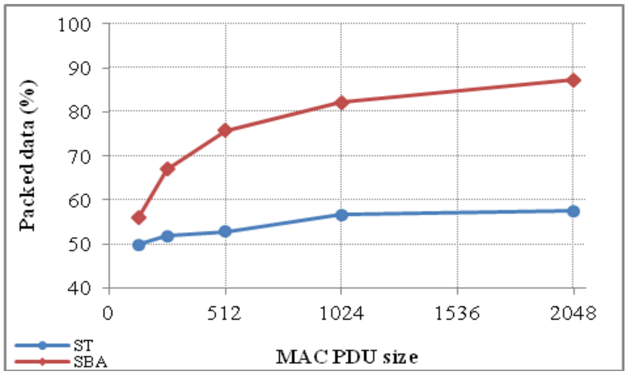

Fig.12 Packed data vs. MAC PDU size.

Figure 13 shows the allocated overhead slots versus different MAC PDU sizes. There are two curves; each corresponding to an individual allocation algorithm SBA and ST. The overhead is directly proportional to the number of users within the frame. The SBA curve shows more slots allocated which explain the effect of burst fragmentation (when force to be used) and the new users included within the frame, which requires to add additional overhead slots to guide recipients collecting their data. The ST curve shows less overhead to indicate less number of users. Both curves decline when the MAC PDU size increases, since an increase MAC PDU size decreases the number of users per frame.

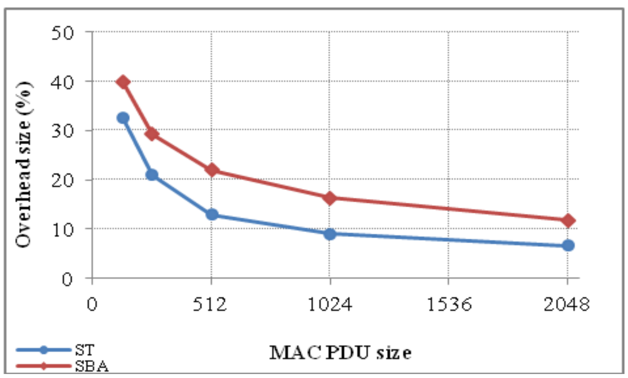

Fig.13 Overhead vs. MAC PDU size.

8. Conclusion

Worldwide Interoperability for Microwave Access (WiMAX) is a promising broadband wireless access (BWA) technology to provide high speed and high bandwidth efficiency. The flaw that needs improvement is that the standard allocation algorithm that assign and control WiMAX frame resources does not provide optimum effective frame utilization, which based the allocation on the available space area within the frame causes unexpected wastage affected by burst size.

This paper presents a new low complexity algorithm of burst allocation decisions which has been called the Sequential Burst Allocation (SBA). The SBA algorithm based on burst fragmentation and sequentially allocation of user data in the form of consecutive vertical columns.

The evaluation results shows that the SBA algorithm improve the frame utilization by 39.29%, increases the amount of packed data by 37.16% and decreases the wasted slots in the form of unused and unallocated by 92% as compared to ST algorithm. 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. It has been concluded from the observed results that the SBA algorithm has a significant reduction of the resource wastage which leads to improve the network capacity.

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