KIET IJCE KIET International Journal of Communications & Electronics
Volume. No. 1, Issue No. 1, Jan – Feb 2013.

Adaptive Column Strip Burst Mapping Algorithm for IEEE 802.16 WiMAX Networks

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Abstract: *Worldwide Interoperability for Microwave Access (WiMAX) is a Broadband Wireless Access technology based on IEEE 802.16 standard which utilize orthogonal frequency division multiple access (OFDMA) as its multiple access technique. OFDMA gives flexibility in resources allocation to accommodate maximum possible users supporting several services classes with quality of service (QoS). One of the most key performance factors of OFDMA resource allocation is downlink data mapping mechanism where the data is allocated to the users in rectangular regions, called burst. This paper proposes Adaptive Column Strip Burst Mapping Algorithm for IEEE802.16 WiMAX. The proposed algorithm is compared with eOCSA (enhanced One Column Striping with nonincreasing Area first mapping) algorithm and the result shows the proposed algorithm achieve higher efficiency.*

Keywords: *component; formatting; WiMAX; OFDMA; Burst Mapping.*

1. INTRODUCTION

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

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

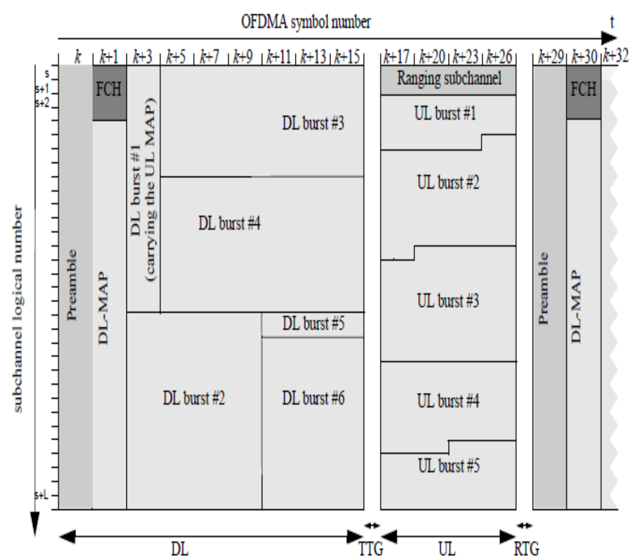


Fig. 1: OFDMA TDD frame structure

In WiMAX system, base station (BS) controls the allocation of the resources in both uplink and downlink direction. The downlink resource allocation involves three main steps. First step is Call admission control where the BS decides whether to accept or reject new connections based on the available resource and QoS requirements. Second step is scheduling where the scheduler select data packet to be sent in the current frame for each subscriber station (SS) from the queued traffic flows. It also decides size of the selected data packets in slots based on the available slots and quality of services without any shape constrain. Third step is mapping or allocating the selected data packets (known as "burst") into downlink subframe and this is main focus of this paper. Since, the standard specifies that mapping data burst has to be in rectangular form into downlink sub frame. This constrain make the mapping as two-dimensional rectangle mapping problem. Shaping the selected data bursts in rectangles may require allocation of extra slots and fit those rectangles into big rectangle may leave some unutilized slots. Thus these unutilized slots affect the efficiency of mapping algorithm and WiMAX system performance. Also there are many consideration with two-dimensional rectangle burst mapping problem like: (i) minimize the number of burst time symbols to reduce SS active time and power consummation such as the work proposed in [7], (ii) minimize the number of burst subchannels to efficiently utilize the subchannel such as the work proposed in [8, 9] and (iii) reduce number of bursts to reduce DL-MAP overhead size such as the work proposed in [10].

The two-dimensional rectangle burst mapping problem is considered to be NP-complete problem [11]. The complexity of the solution grows exponentially with the number of objects [14]. Recently many heuristic algorithms have been proposed to solve this problem and we will discuss some of proposed algorithms which are more related to our work in related work section.

Most of the proposed mapping algorithms are non sequential where the scheduler select all the bursts to be packed in the current frame. Then mapping algorithm starts packing of those bursts. Also the first step of packing algorithm is sorting. This gives us information like, number of bursts to be packed, maximum burst size, smallest burst size and average burst size. This information may be utilized to increase Mapping efficiency. In this paper, we propose Adaptive Column Strips mapping algorithm for downlink IEEE802.16 WiMAX networks. In addition, we compare efficiency of our algorithm with eOCSA algorithm. The result shows our algorithm has higher packing efficiency. To best of our Knowledge this is not discussed elsewhere.

2. RELATED WORK

Recently several algorithms are proposed to address problem of two dimensional burst mapping for IEEE802.16 WiMAX. In this section we briefly discus some of proposed algorithms based on column striping. Ohseki et. al. In [12] propose an algorithm that first prepares a bucket of one time slot with more than one sub channel to construct data from different SSs with the same MCS in combined columns. It starts as one column, and if the buckets grow it expands by filling another column which may not be fully utilized.

One Column Striping with non-increasing Area first mapping (OCSA) proposed by So-In et. al. In [13] and it's enhancement in [14]. The algorithm can be described in three main steps. First step sort the bursts in decreasing order. Second step vertically allocate the large burst with minimum width and maximum height in one column. Third step allocate the left space in the allocated column horizontally. The algorithm minimizes the bursts time symbols which reduce SS active time. But when most bursts sizes are large the left space in third step cannot allocate to any burst this increases the unused space and degrade the algorithm efficiency. For example allocating set of bursts (96, 66, 42, 42, 40, 37, 32, and 5) using eOCSA will result more unused slot. Also the algorithm unable to allocate theses bursts (40 37 32) and the efficiency degrade to 69.72%.

Orientation-Based Burst Packing (OBBP) algorithm present by Eshanta et. al. In [15]. The algorithm is based on burst factorization and pre-arranging them using matrices. This simplifies finding optimal column or rows to minimize the unused slot and avoids padding. The algorithm shows good efficiency at heavy load. When the number of bursts is large and small in size the algorithm required more computation time for factorization and select optimal column. Where similar efficiency can achieved with less computation time using simple best fit without any factorization.

3. ADAPTIVE COLUNM STRIP MAPPING ALGORITHM

Columns strip mapping simplify the two dimension packing problem. The algorithm strips the two dimension area into columns then packs the burst in columns. In this way it is easy for the algorithm to deal with the leftover empty space in the columns and determine the next burst can be packed to minimize the leftover space. There are two main steps in designing of Column striping packing algorithm. The first step is selecting column strip width and the second step is selecting which burst and its dimensions to be packed first in the column.

In our design we consider PUSC with 10 MHz channel and According to WiMAX forum specification the dimensions of downlink frame data are rectangle in size (12 symbols width (w) × 30 subchannel high(sch)) with total area is 360 slots. The number and the sizes of the bursts to be packed in one frame depends on many factors like, either the burst contain the data for single user or it group the data for different users ,Scheduling mechanism and the allowed burst size. In our case, we assume that minimum burst size is 2 and maximum is 150 slots and the number of burst is vary from 5 to 40 bursts with constrain total data size is 360 slots.

A. Selecting column strip width

The rectangle data width is 12 symbols so that the possible stripping columns width are combinations sum of number 12 like, (10,2), (6,4,2), (5,4,3), (4,3,3,2), (3,3,2,2,1,1) and ….(1,1,1,1,1,1,1,1,1,1,1,1).We observe from packing algorithms proposed in [13, 14, 15] that when the bursts packed into DL-subframe, as the sizes of bursts become large i.e. it's number is small then the width of strip column becomes large. But when the sizes of bursts become small i.e. its number is large then the width of strip column becomes small. This gives indication that there is a relation between the number of bursts and the width of strip column. To select the width combination that gives higher packing efficiency based on the number of bursts to be packed, many simulation test for packing different bursts number and sizes with different strip width using the proposed algorithm have been conducted. The simulation result shows that one combination gives higher packing efficiency within specific bursts number range. Table (I) and figure (2) illustrated the mapping efficiency using some strips width combinations which gives higher mapping efficiency within some range. The algorithm will adaptively select these combination based on number of bursts to increase the overall packing efficiency.

Table .I Mapping efficiency using some strips width combinations

No	Width Combination	Best burst number range	Maximum efficiency
1	(5,4,3)	(5 to12)	95%
2	(4,3,3,2)	(12 to 18)	95.72%
3	(3,3,2,2,1,1)	(18 to 24)	96.6%
4	(2,2,2,2,1,1,1,1)	(24 to 30)	97.7%
5	(1,1,1,1,1,1,1,1,1,1,1,1)	(30 to 40)	100%

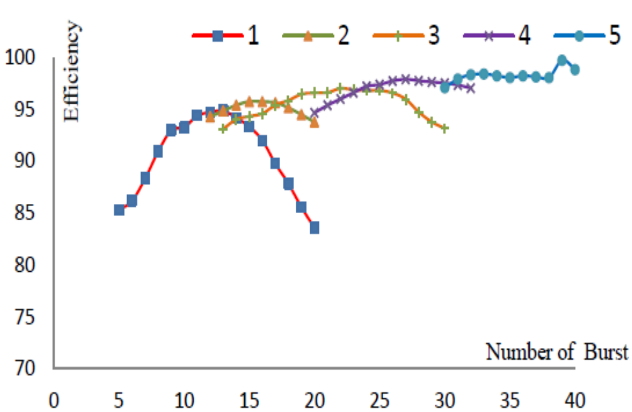


Fig . 2:Mapping efficiency using some strips width combinations

A. Selecting the burst and its dimensions to be packed

After selecting the strips width (W1, W2… Wn) based on the number of bursts. The steps of packing burst as follows:

Step1

Sorting the bursts in decreasing order (B1, B2,.....Bi)

Step2

Divide all bursts by (W1) and return hi as [h1 = int+ (B1/W1), h2 = int+ (B2/W1),……and hi=int+(Bi/W1)] Select Oh such that [(h1+ (Oh)) - sch] is minimum. Where Oh (Optimal height) is summation any of (h2, h3,…hi) and (int+) is closes higher integer . Assume that Oh = (h3+h5) then the bursts that correspond to selected height are (B1, B3, B5).

Step3

Allocate the selected bursts in current column as [(B1→ (W1×h1)), (B3→ (W1×h3)), (B5→ (W1×h5))

Step4

For remaining bursts (B2, B4, Bi) repeat step 2 with divider factor W2. And same steps for the remaining till last Wn or no data burst.

The algorithm select optimal bursts height to minimize the left space also we can minimize both the left space and the extra slot where the extra allocated slots ei = (Wn×hi - Bi) but the complexity may increase. Fig 3 describe Adaptive Column Strip mapping algorithm steps

```
If #burst  = X then select ( w1, w2 ,wn)      //step1
Sort burst =(B1,B2,…..Bi)                     //step2
FOR W= w1, w2,  wn                            // step3
Divide each burst in sorted list by W and return hi= int+ Bi/W
Select[ (h1+any of (h2,h3..,hi)) – sch] is minimum
Allocate the selected bursts  as
 (B1→ (w×h1), B3→ 1( w×h3) ,.. Bj→ ( w×hj)
Remove the allocated burst from sorted list
END FOR
END
```

Fig 3: Adaptive Column Strips mapping algorithm steps

A. Numerical exampe

In this section, we provide an example that helps explain our algorithm. Once again, the DL subframe is assumed to be 12×30 resulting in 360 slots. The set of bursts to be packed are (84, 42, 63, 14, 50, 70, 34, 3 slots) total data size is 360. The number of bursts are 8 the algorithm will select strips width (5, 4, 3) as in table (I). The packing steps are:-

Step1

Sorting the bursts in decreasing order as (84, 70, 63, 50, 42, 34, 14, 3)

Step2

Divide bursts by (W1=5) as below

Bi/w 1	84/ 5= 16	70/ 5= 14	63/ 5= 12	50/ 5= 10	42/ 5= 8.4	34 /5 =6	14/ 5= 2.8	3/5 = 0.6
Int+(	17	14	13	10	9	7	3	1
ei	2	0	2	0	3	1	1	2

Select Oh such that [(h1+ (Oh)) – sch] is minimum where h1=17, Sch=30 then Oh= 13 the corresponding bursts are (84, 63) and its dimension are (5×17), (5×13) without any left space and 3 extra allocated slots

Step3

Repeat step2 with remaining burst (70, 50, 42, 34, 14, 3) using w2= 4

Bi/w 2	70/4= 17.5	50/4= 12.5	42/4= 10.5	34/4= 8.5	14/4= 3.5	3/4= 0.75
Int+(hi)	18	13	11	9	4	1
ei	2	2	2	2	2	1

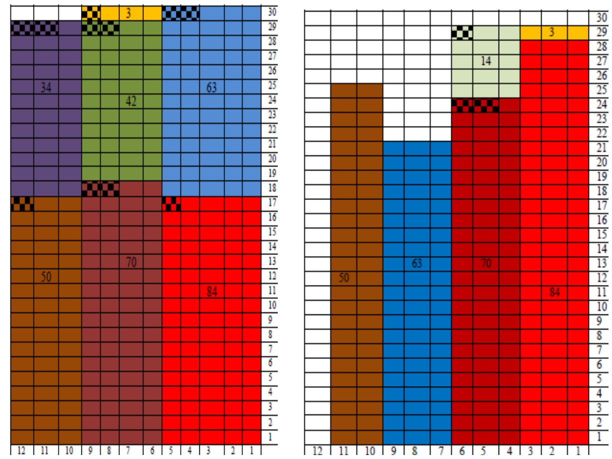
In this step h1= 18, Oh = (11+1) then the corresponding burst are (70, 42, 3) and its dimension are (4×18, 4×11, 4×1) no unused slot and extra slot is 5

Step4

Repeat step2 with remaining burst (50, 34, 14) using W3= 3

Bi/w3	50/3= 16.6	34/3= 11.3	14/3=4.6
Int+(hi)	17	12	5
ei	1	2	1

In this step h1=17, Oh = (12) then the corresponding burst are (50, 34) and its dimension are (3×17, 3×12,) left space = 3 slots and extra slot is 3.



(a) (b)

Fig. 4.: Example of burst mapping using (a) the proposed algorithm and (b) eOCSA algorithm.

The final results obtained from this example are: - total left space = (0+0+3)=3 , total extra slots = (2+1+2+2+1+1+2)=11 ,packing efficiency =360-(3+11)/360 = 96.111 and the burst (14) is failed to allocate . Figure .4 illustrates Example of burst mapping using (a) Adaptive Column Strip mapping algorithm and (b) eOCSA algorithm.

4. PERFORMANCE EVALUATION

In this section, we compare the performance of the proposed algorithms with eOCSA. TABLE-II shows the parameters used in the simulation are as per suggestions of WiMAX forum. The data bursts sizes are generated randomly with the constraint that sum of all bursts is (12×30=360) slots. The number of bursts is chosen from 5 to 40.

TABLE II. :System Simulation Parameters

Parameter	Value
Frame length	5 ms
Channel BW	10 MHz
Permutation scheme	PUSC
Number of subchannels	30
DL subframe	12 slot columns
Total number of slots per DL	30×12 slots
Simulation time	500 frames

Figure. 3 illustrate the average unused slots per DL subframe and the result shows that the average of unused slots for the proposed algorithms is smaller than that for eOCSA. That is because eOCSA left more unused space that cannot accommodate any burst.

Figure. 4 illustrates the average extra allocated slots per DL frame and the result shows that the average extra allocated slots are higher in our algorithm because of height approximation. But our algorithm has total wastage slots smaller than eOCSA.

Figure. 5 illustrate the average packing efficiency and the result shows that the proposed algorithms achieve higher efficiency than eOCSA.

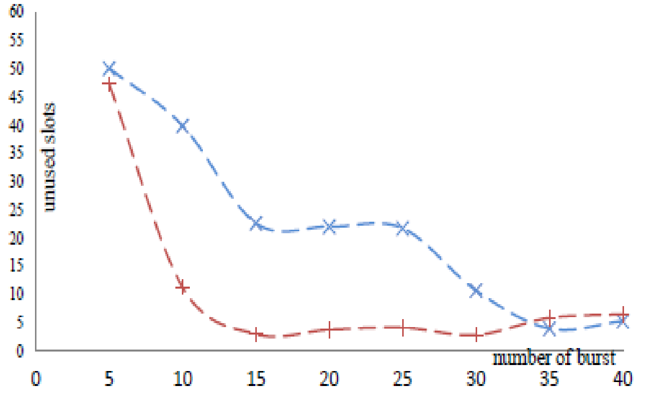


Fig.. 3: average unused slots

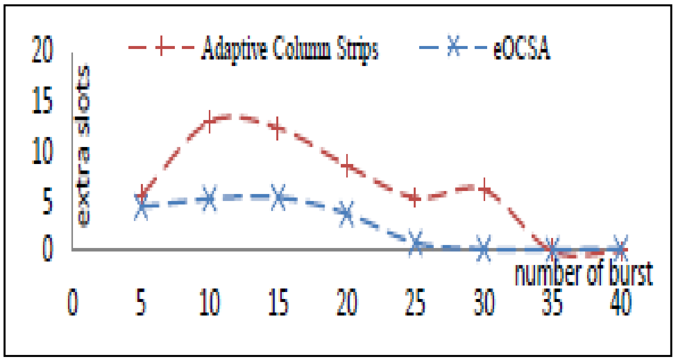


Fig.4: average extra allocated slots

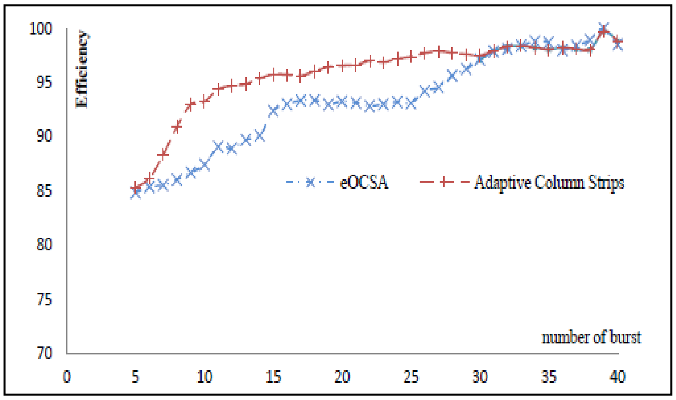


Fig.5: average packing efficiency

5. CONCLUSION

This paper presented adaptive downlink burst allocation algorithm for IEEE 802.16e Mobile WiMAX networks. The proposed algorithm meets the rectangle shape allocation constraint and achieves high throughput by considering mapping for the larger burst first. The algorithm based on column strips and its basic idea is to select the strip columns width adaptively based on number and sizes of the bursts to be packed. Then select the bursts that minimize the left space in the column. The performance of the proposed algorithm is compared with eOCSA. Simulation results show that the proposed algorithm can achieve higher packing efficiency.

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