Capacity Improvement of WiMAX Networks by Dynamic Allocation of Subframes

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ABSTRACT

A WiMAX TDD frame contains one downlink subframe and one uplink subframe, the capacity allocated to each subframe is a system parameter that should be determined based on the expected traffic conditions. Normally, the load in downlink is higher compared to uplink, hence the downlink subframe is expected to have a longer duration. The split between downlink and uplink subframes is usually decided once, based on average statistical traffic behavior, setting the system accordingly. Nevertheless, we show in this paper that it is also possible that through real-time monitoring, the system itself may adapt the uplink and downlink boundary dependent on the current traffic conditions. In other words the network resources are allocated dynamically via adaptive allocation of uplink and downlink subframes.

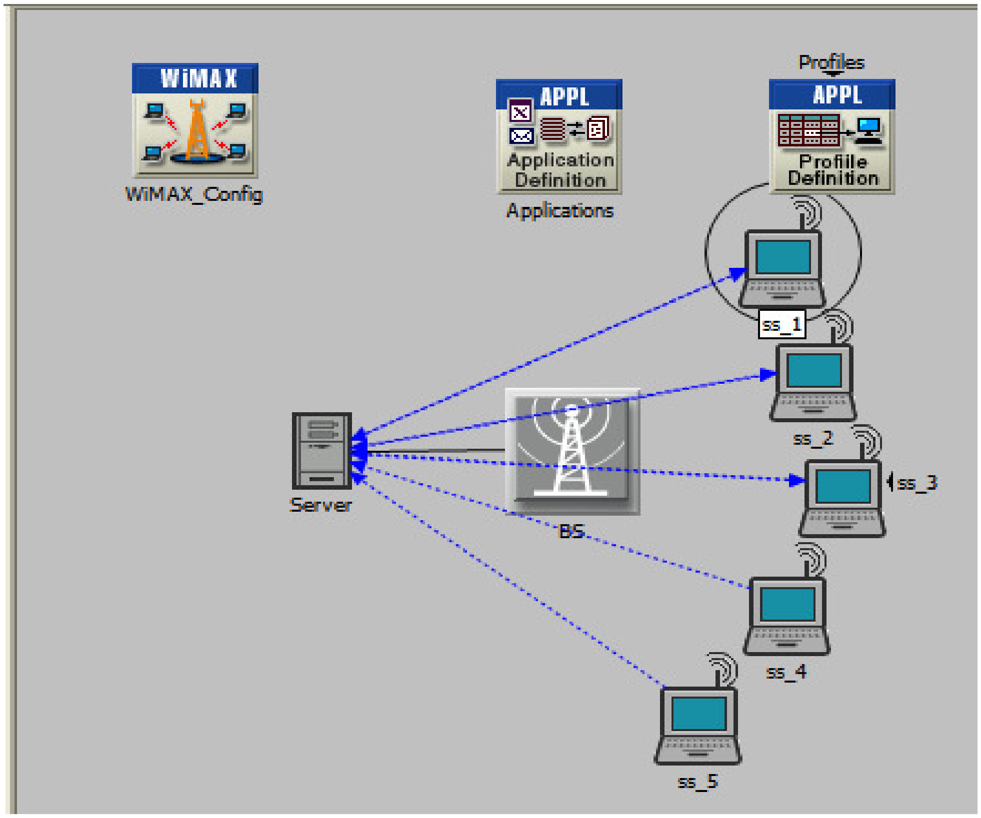
INTRODUCTION

There is on-going research studies on the assignment of WiMAX TDD subframes. In this regard Filin et al.[1] proposed adaptive subframe algorithm which is fast and efficient. Adhicandra [2] proposed simple subframe assignment algorithm. Pries et al.[3] studied different case studies of TDD frame split scenarios. We propose a simple yet efficient subframe assignment scheme which greatly improves the capacity of WiMAX networks.

The paper is organized as follows: In the first part we analyze the frame and application performance of a WiMAX network with static allocation of uplink and downlink subframes. In the second part we devise an alogorithm that dynamically changes the capacity allocated to UL and DL subframes. That algorithm is implemented on the WiMAX BS and the network is then simulated. Finally, the results are then compared with the static allocation of subframes. We use OPNET [4] for simulation.

Part I: Static Subframe Assignment

As shown in Fig. 1 the basic network consists of WiMAX base station with five subscriber stations (SS). All SS have UL load of 200 Kbps for a total UL load of 1 Mbps. At certain times server generates 400 Kbps of application traffic directed to ss_1, ss_2 and ss_3 for a total downlink load of 1.2 Mbps. The WiMAX network uses 5 MHz of bandwidth with 5 ms of frame size and 512 subcarriers. Modulation used is QPSK ½.



. Fig. 1

Users are allocated slots for data transfer and these slots represent the smallest possible data unit. A slot is defined by a time and subchannel dimension and it varies depending on the following operating modes:

■ For downlink FUSC, one slot is a single subchannel by one OFDMA symbol
■ For downlink PUSC, one slot is a single subchannel by two OFDMA symbols.
■ For uplink PUSC, one slot is a single subchannel by three OFDMA symbols.

A single packet of user data is distributed over multiple OFDMA symbols for the PUSC modes. Moreover In FUSC, there is one set of common pilot subcarriers; in PUSC, each subchannel contains its own set of pilot subcarriers[5].

Since we use QPSK ½, data rate comes out to be around 6.3 Mbps. If an FEC(Forward Error Correction Code) of 1/2 is applied, then the total effective data rate is 3.1 Mbps. In this scenario 34 symbols are used for DL subframe and 12 symbols for UL subframe. Hence DL capacity ~ 2.5 Mbps and hence UL capacity ~ 600 Kbps. List of simulation parameters is given below in Table 1:

Table 1 Simulation Parameters

WiMAX Base Station:	
Frame Duration	5 ms
Symbol Duration	100.8 µs
TTG	100.8 µs
RTG	302.4 µs
No. of subcarriers	512
Base Frequency	5.8 GHz
Bandwidth	5 MHz
Duplexing Technique	TDD(Time Division Duplex)
Frequency Division(DL Zone)	FFT-512 FUSC
Frequency Division(UL Zone)	FFT-512 PUSC
Maximum Transmission power	0.5 W
Number of initial ranging codes	8
Number of initial BW request codes	8
WiMAX Subscriber Station:	
Maximum Transmission power	0.5 W
Pathloss model	Free Space
BS MAC address	Distance based
Ranging power step	0.25 mW
Modulation and coding	QPSK ½
Piggyback BW request	Enabled
CQICH Period	3

The simulation is run and following results are obtained.

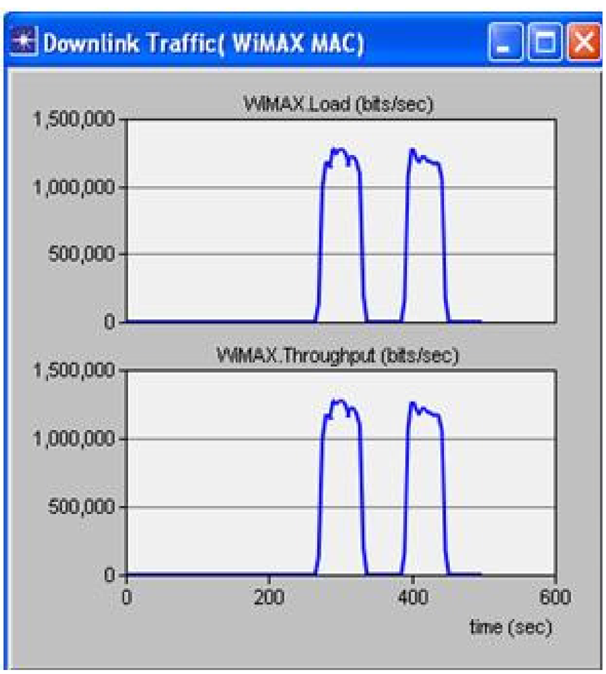
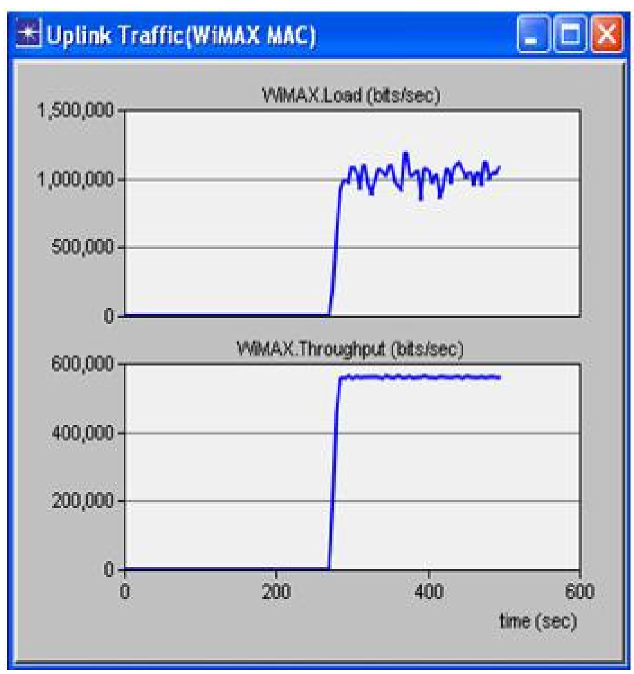


Fig. 2



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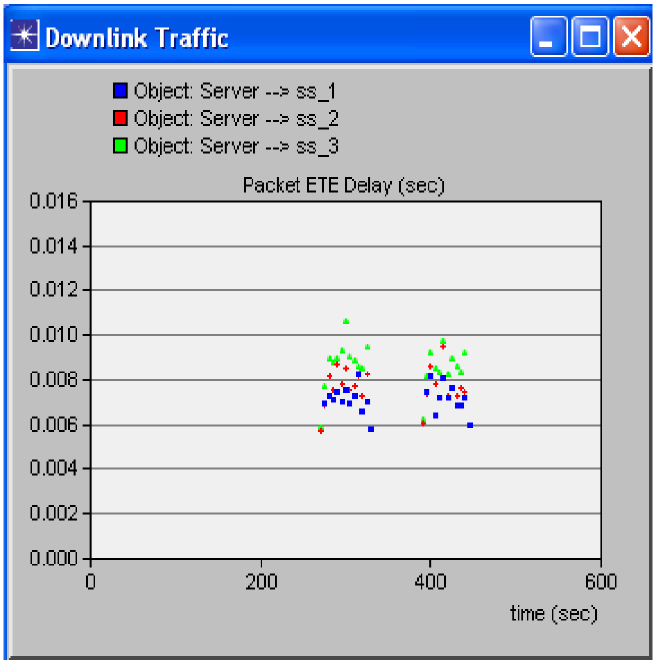

Fig. 4

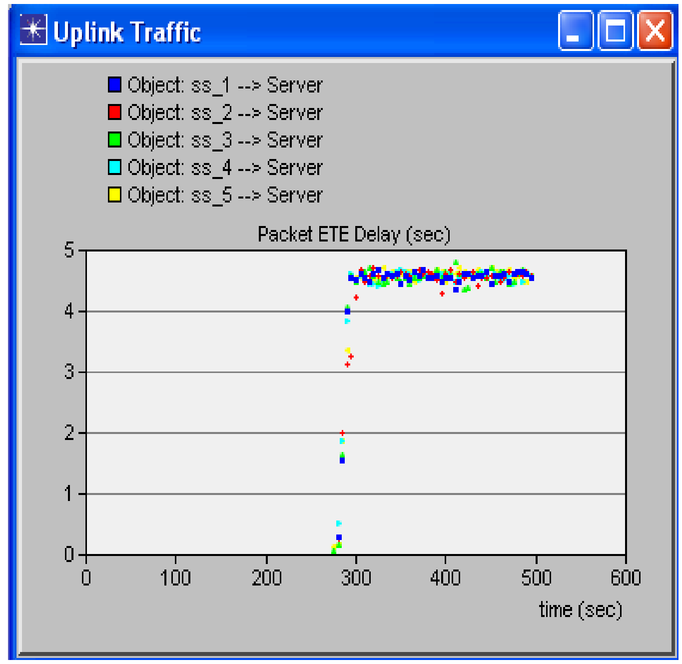

Fig. 5

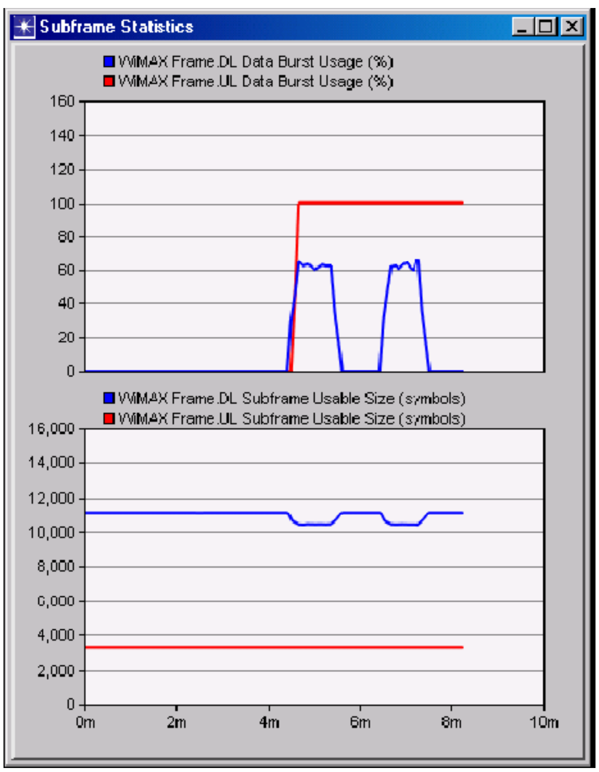

Fig 6.

As it is evident that Downlink has enough capacity to support 1.2 Mbps but for uplink the load is 1 Mbps but the UL capacity is only around 600 Kbps, so throughput is low and delays are high.

Part II: Dynamic Subframe Assignment

In part 1 we observed that DL subframe had enough resources to spare for UL subframe which was starving and its subframe utilization was reaching 100%. Hence in part II we propose an algorithm which dynamically assigns symbols to DL and UL subframes. If the uplink subframe utilization exceeds 90% threshold and at that moment downlink subframe utilization is less than 60% then uplink subframe size is increased. On the other hand if the DL subframe utilization starts increasing 70% threshold then the frame is reset to the initial settings. Algorithm is given below

Start

If DL subframe already reduced & DL subframe utilization > 70%

  Reset frame partitions

    end

else If UL subframe utilization > 90%

  If DL subframe utlilization < 60%

   If DL subframe length N.L.E.Q to min. subframe length

    Increase UL subframe

    end

 else

 end

Part III: Results

Since WiMAX BS controls the framing and we use OPNET for simulation so this algorithm is implemented on WiMAX_BS_Control which is a child process of WiMAX_BS_MAC. After compiling WiMAX_BS_Control, we run the simulation again and get following results.

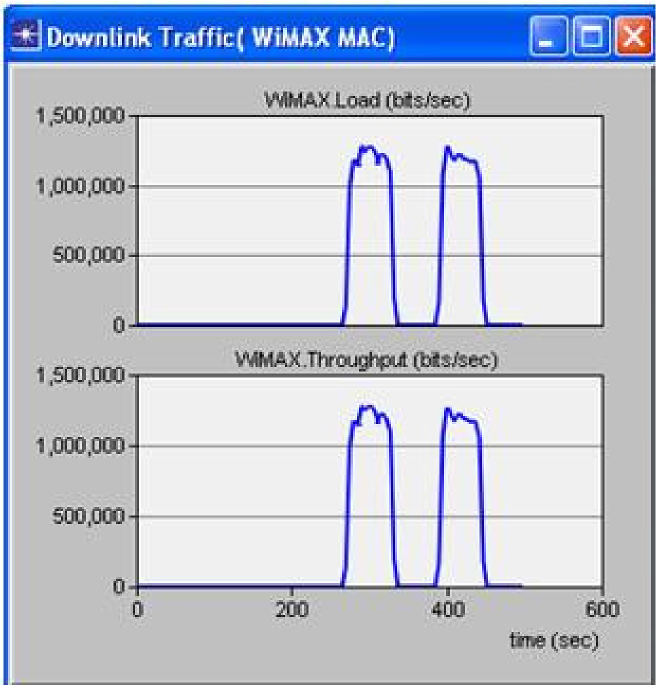

Fig. 7

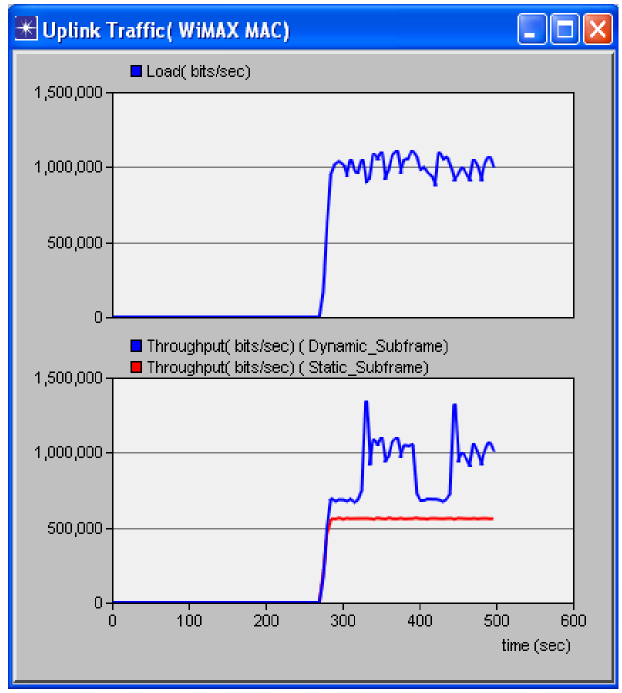

Fig. 8

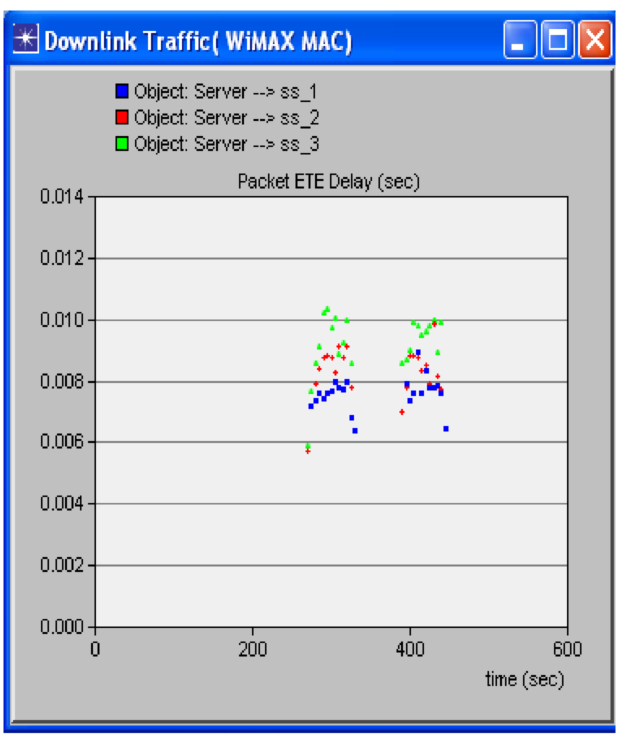

Fig. 9

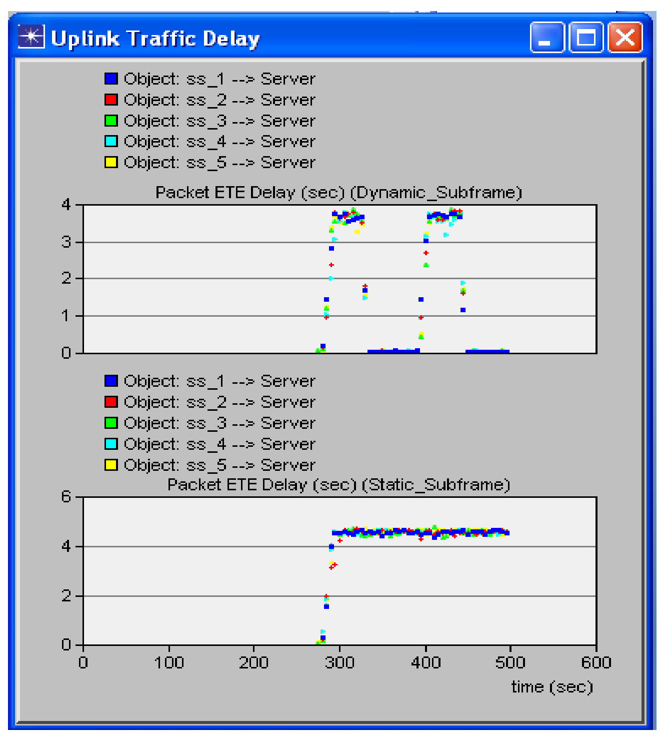

Fig. 10

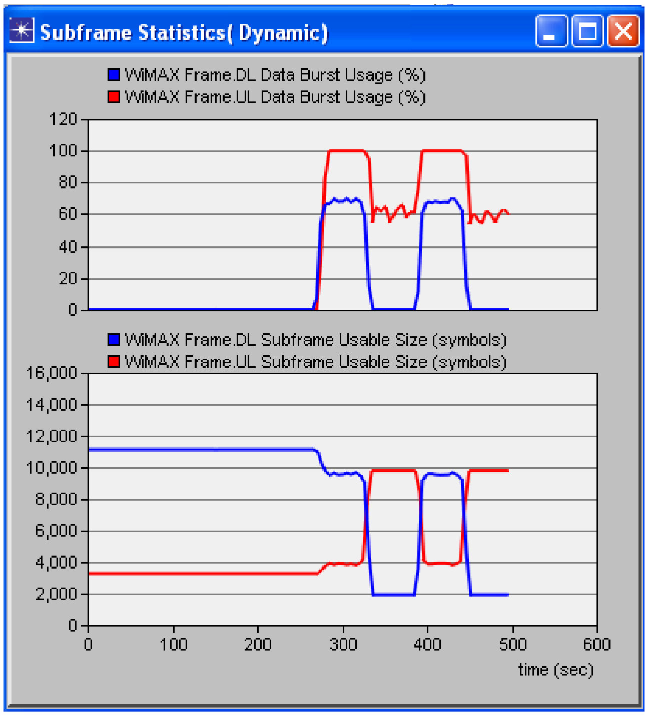

Fig. 11

From the graphs we have the following observations:

Downlink Traffic:

It is obvious that the results are same for downlink traffic ~ 1.2 Mbps with around 8 ms delay when dynamic subframe assignment is used as compared to static subframe downlink traffic.

Uplink Traffic:

When dynamic subframe assignment is used, uplink throughput is aournd 700 Kbps with 3 ms delay when there is downlink traffic. However as the downlink traffic decreases, the uplink throughput is increased to around 1 Mbps with 50 ms delay.

When static subframe was used, uplink traffic throughput was around 560 Kbps with 3.7 ms delay. Hence there is a big improvement in performance when we use dynamic subframe assignment.

The above graph shows the utilization of both downlink and uplink subframes. The main advantage is when download utilization reaches zero and uplink can borrow all resources it requires. But since our algorithm evaluates instantaneous subframe utilization values, then even if the downlink subframe utilization exceeds 60%, the uplink subframe would borrow resources from any downlink subframe whose utilization falls below 60%.

Conclusion:

Subframe partition size is the main system configuration parameters that directly determines the capacity balance of the cell between uplink and downlink sections. Our proposed mechanism successfully improves the performance of the uplink while taking advantage of the underutilized downlink subframe, allowing uplink subframe to take temporarily the unused resources. On the other hand it also kept the performance of the downlink traffic unaffected by monitoring the downlink utlilization in real time and returning DL resources as needed.

References:

[1] S. A. Filin, S. N. Moiseev, M. S. Kondakov, "Fast and Efficient QoS Guaranteed Adaptive Transmission Algorithm in the Mobile WiMAX System", IEEE Trans. on Vehicular Technology, Vol. 57, No. 6, 2008.

[2] Iwan Adhicandra, "Adaptive Subframe Allocation in WiMAX Networks", 33rd International Conference on Telecommunications and Signal Processing- TSP 2010

[3] R. Pries, D. Staehle, D. Marsico, "IEEE 802.16 Capacity Enhancement Using an Adaptive TDD Split", VTC 2008.

[4] www.opnet.com

[5] www.wimaxforum.org