

## Performance Analysis of Delay Jitter in Mobile WiMAX Systems

D. M. Ali<sup>1,2</sup> and K. Dimiyati<sup>3</sup>

<sup>1</sup> Department of Electrical Engineering, Faculty of Engineering,  
University Malaya, 50603 Kuala Lumpur, Malaysia.

<sup>2</sup> Faculty of Electrical Engineering, Mara University of Technology (UiTM) Shah Alam,  
40450 Shah Alam, Malaysia

<sup>3</sup> Faculty of Engineering, National Defense University of Malaysia,  
Kem Sungai Besi, 57000 Kuala Lumpur, Malaysia

**Abstract.** Mobile WiMAX, based on IEEE 802.16e provides five different service classes: UGS, ertPS, rtPS, nrtPS and BE, to deliver the best quality experiences for mobile WiMAX users. Each service class is incorporated with several quality of service (QoS) mechanisms at the Media Access Control (MAC) layer to support the various applications. To ensure that the QoS of each class is provisioned, the uplink scheduler needs to allocate the available resources effectively to meet with the QoS parameters such as the delay, delay jitter and throughput requirements. In this paper, we propose a threshold-based priority algorithm to improve on the delay jitter of the UGS and rtPS classes. The proposed algorithm works by adjusting the threshold imposed on the nrtPS queue. The threshold value here represents the number of bandwidth request message in the nrtPS queue. Simulation results show that our proposed algorithm reduces the delay jitter for the UGS and rtPS when compared with other scheduling algorithms.

**Keywords:** Scheduling algorithm, uplink, Mobile WiMAX, delay jitter.

### 1. Introduction

WiMAX is a promising technology for a broadband wireless access which is based on wireless transmission methods defined by the standard IEEE 802.16. WiMAX is developed to substitute the broadband cable networks. It offers both fixed and mobile broadband wireless accesses, intended for the wireless metropolitan area networks. Theoretically, WiMAX can provide a broadband wireless access (BWA) up to 50 km for fixed stations and 5 - 15 km for mobile stations. It is an access technology that allows higher data rates over longer distances, more efficient use of bandwidth, avoids interference almost to a minimum with the issue of interference lessened. Initially, the standard allows the transmission in the range of 10 - 66 GHz. In 2004, the 802.16d was updated for lower frequencies in the range of 2 - 11 GHz, thus, resulting in less attenuation, an improved range and a better coverage within buildings. Then in 2005, the Mobile WiMAX 802.16e introduced the use of orthogonal frequency-division multiple access (OFDMA) as opposed to the orthogonal frequency-division multiplexing (OFDM) version with 256 subcarriers.

The Mobile WiMAX quality of service (QoS) depends heavily on the 802.16e physical (PHY) and medium access control layers (MAC), as these layers deal with the base-station (BS) and mobile station (MS) access. Since the 802.16 standard works for different applications, fixed or mobile terminals respectively, there have been found to be some significant differences between them, where the technology is concerned.

The MAC layer of Mobile WiMAX provides a medium-independent interface to the PHY layer. It is designed to support and manage different kinds of traffic and applications through five defined service classes: Unsolicited Grant Service (UGS); Extended Real Time Polling Service (ertPS); Real Time Polling Service (rtPS); Non Real Time Polling Service (nrtPS) and Best Effort (BE). The standard does provide the QoS requirements for the service classes, however it leaves the performing algorithm undefined. In such a heterogeneous traffic, the uplink scheduling algorithm serves as an important mechanism that affects the performance of the QoS. Thus, a number of scheduling algorithms have been proposed to deal with the above mentioned considerations. Among these, Yi-Neng Lin et al [1] propose Highest Urgency First (HUF)

which uses an urgency parameter of a maximum latency. For each service flow, bandwidth requests which deadlines are equal to one is serviced first and then to others until the minimum reserved rate is complemented. A combination of three algorithms; Strict Priority (SP), Weighted Round Robin (WRR) and Round Robin (RR) are evaluated in [2]. SP is applied to the scheduling classes in which the UGS gets the highest priority followed by the rtPS, nrtPS and BE. The UGS is allocated with a fixed bandwidth; the rtPS and nrtPS are served through WRR, while the BE with the RR discipline. In [3], a Red-based Deficit Fair Priority Queuing (Red-based DFPQ) is proposed which dynamically sets the quantum of the rtPS service class based on the current queue length. Zeynep Yurdakul et al [4] have modified the algorithm in [3] to include the intra-class scheduling which uses the signal to noise ratio to calculate the weights of each MS. However, they do not concern with the delay jitter of the UGS and ertPS as well as rtPS. Furthermore, delay jitter is the main QoS parameter for those service classes.

In this paper, we propose a threshold-based priority algorithm to study the delay jitter of the real-time traffic applications (which are represented by UGS, ertPS and rtPS) in the uplink scheduler of Mobile WiMAX.

## 2. System Model

A point-to-multipoint (PMP) network with a single cell that operates on an OFDMA system is considered in this paper. The BS communicates with several MS within a cell. Connections between the BS and an MS are structured in frames and identified by a connection identifier (CID). A CID can represent an individual or even a group of applications. The transmission of data from MS to BS is called the uplink (UL) whereas the downlink (DL) is from BS to MS. The duplexing technique supported is the Time Division Duplex (TDD). A TDD frame has a fixed duration and is further partitioned into DL and UL sub-frames. For a mobile WiMAX (OFDMA) system profiles, 5 ms frame duration [5] and 10MHz of bandwidth are employed. The 5ms frame gives low-latency jitter to delay-sensitive applications while keeping the framing overhead low [6].

The MS will send a DSA-REQ message to request for an uplink request opportunity after the initialization process takes place. DSA-REQ contains the service flow parameter for the request connection and MAC address. The BS that receives the message will call the admission control (CAC) to decide whether to accept or reject the request based on the available capacity [7]. Assume that each MS carries a single service flow (SF) which eliminates the effect of packet scheduling at MSs. Each SF is fixed to a maximum sustained traffic rate (MSTR) for UGS and ertPS. As for rtPS and nrtPS, it is set to a minimum reserved traffic rate (MRTR) and BE is given the available capacity after all the service classes are considered. If there are several SF arriving simultaneously, the SF is handled according to the priority of each class. Then the available bandwidth is updated accordingly, following the acceptance of the SF. The available bandwidth can be calculated as:

$$C_{avail} = C_{total} - \sum_{i=0}^I \sum_{j=0}^{J_i} SF \quad (1)$$

where  $C_{total}$  represents the total bandwidth.  $I$  represents the total number of SF or connections and  $J_i$  is the total number of service classes of the  $i_{th}$  connection. A DSA-RESP will be sent from BS to inform the acceptance of the connection and a unique connection identifier (CID) will be assigned to the MS.

Please note that for an uplink transmission, packets are queued at the MSs and the uplink scheduler works on a request-grant basis. Each MS will send a bandwidth request message to the BS. Several bandwidth requests' mechanisms are available such as the unicast polls, broadcast and multicast polls, contention and piggybacking. Subsequently, after receiving the bandwidth request messages, the messages are grouped according to the respective service class and QoS parameter. Information element (IE) is created in the UL-MAP to indicate the control region and new resource assignments that MSs should transmit. The UL-MAP placed at the beginning of the DL's sub-frame is then broadcast to the MSs. Each MS listens to the broadcast MAP message for their CID, decodes the IE and sends the packets according to the slots granted.

## 3. Mobile WiMAX Uplink Scheduler

The tasks of the Mobile WiMAX uplink scheduler are of complexity. The scheduler must be able to support different types of applications [8] as well as deliver the available bandwidth to accompany different service classes [9] while satisfying the QoS requirements. The uplink scheduler has no information on the packets and the queue status information of each flow. Thus, most of the proposed algorithms assume an estimate of the delay information which is less accurate and timely [10].

The standard IEEE 802.16e enables the optimization of each MSs data rate by allowing the BS to set the MCS according to the channel condition. Thus, to account for the adaptive MCS, each service flow is translated into the coding rate and bits per symbol carried for each modulation. Table 1 summarises the coding rate and bits per symbol supported in the Opnet software. Fragmentation is supported in order to achieve full frame utilization and allow packets to be partitioned in case there are some left-over spaces in the MAP.

MCS	QPSK		16-QAM		64-QAM		
Code rate	1/2	3/4	1/2	3/4	1/2	2/3	3/4
Bits per symbol	2		4		6		

Table 1 Coding rate and bits per symbol for different MCS

#### 4. The Proposed Uplink Scheduling Algorithm

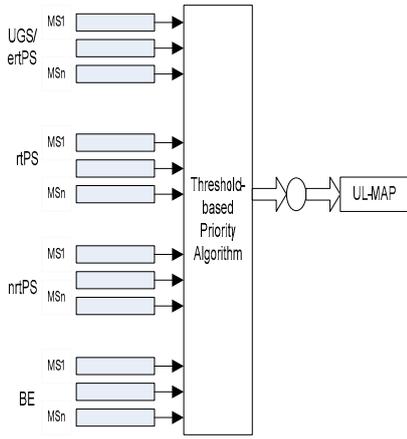
We propose a threshold-based priority algorithm to improve the throughput of the lower priority class as well as to ensure that the delay and jitter properties of the real-time traffics (UGS, ertPS and rtPS) is provisioned. The approach aims at adjusting the threshold value which represents the number of bandwidth request message in the nrtPS service class. The scheduling scheme starts with the scheduler visits to UGS/ertPS. The UGS/ertPS is service until no more slots available. Then, rtPS is served next and once the queue is empty, the scheduler will check on the amount of bandwidth request available in the nrtPS queue. If the amount of bandwidth request exceeds the threshold assigned, then the scheduler will carry out the service to nrtPS and subsequently BE. On the other hand, the scheduler will return to service UGS/ertPS if the amount of the bandwidth request is less than the threshold assigned. Fig. 1 shows the architecture of scheduler.

In order to ensure that the bandwidth requirement of each scheduling service complies with the QoS specification, an exhaustive service approach is used. This is because each queue in the buffer represents a service flow which carries the required QoS parameters of the MS. Thus, each MS, regardless of its service class is serviced until the buffer is completely empty which basically satisfies the MSTR or MRTR. The idea of imposing a threshold on the nrtPS service class, which is based on the amount of backlog (bandwidth request message) is to ensure that the nrtPS and BE service classes are given the opportunity of being serviced.

### 5. Simulation Environment and Performance Analysis

#### 5.1. Simulation Environment

The performance of the algorithms as explained in section IV is evaluated using the Opnet simulator. UGS, rtPS and nrtPS are involved in the evaluation. UGS and ertPS are built based on the VoIP traffic, thus choosing one of them to represent the traffic should suffice. The uplink scheduler in this work performs its operation, based of the amount of bandwidth request messages of the nrtPS service class. Therefore, we choose the nrtPS instead of BE since both differ merely in the priority. The traffic parameters and simulation parameters are summarized in Table 2 and 3 respectively. To select the suitable value for the threshold, we have performed the simulation rigorously, varying the threshold. Through this, we observed the optimal value of the threshold to be equal to 10 and the smallest to be 1. If there is a high load demand of the real-time traffic, the threshold value can be set high to guarantee the delay and jitter properties of the real-time traffic. However, this will cause low throughput of the BE service class. Thus, it is important to select the best value of the threshold that can guarantee the QoS of each service class. Selecting the ideal value of the threshold will be our future direction.



Application	Parameters <sup>⊕</sup>
Voice	G711 Encoder <sup>⊕</sup> - $T_{\text{enc}} = 0.352^{\text{⊕}}$ - $T_{\text{off}} = 0.65^{\text{⊕}}$ - Size = 10 ms <sup>⊕</sup> - Coding rate = 64 kbps <sup>⊕</sup>
Video Conference [1,11]	Frame size: <sup>⊕</sup> - Lognormal distribution <sup>⊕</sup> - Average : 4.9 bytes <sup>⊕</sup> - $\sigma^2$ : 0.73 bytes <sup>⊕</sup> - Inter-arrival time: <sup>⊕</sup> - Normal distribution <sup>⊕</sup> - Mean : 33 msec <sup>⊕</sup> - $\sigma^2$ : 10 msec <sup>⊕</sup>
FTP	Interrequest time : <sup>⊕</sup> - constant distribution <sup>⊕</sup> - 30 seconds <sup>⊕</sup> File size : <sup>⊕</sup> - constant distribution <sup>⊕</sup> - 10000 bytes <sup>⊕</sup>

Parameters	Value
PHY Profile	OFDMA
Bandwidth	10 MHz
Base Frequency	2.5 GHz
OFDMA symbol duration	100.8 $\mu$ s
Frame preamble	1 symbol
FFT size	1024
Frame duration	5 ms
Subframe ratio (DL/UL)	1:1
MSTR UGS	96000 b/s
MRTR rtPS	20000 b/s
MRTR nrtPS	80000 b/s
Polling time (rtPS)	2 msec
Polling time (nrtPS)	10 msec

Fig. 1 The architecture of the uplink scheduler

Table 2 Traffic parameters

Table 3 Simulation parameters

## 5.2. Performance Analysis

We compare the performance of the proposed algorithm with reference to [2] and [3] for the rtPS service class. We have chosen the work in [2] and [3], provided that our proposed algorithm falls into the category of priority-based algorithm. DFPQ is also a priority-based algorithm in which the highest priority class is fixed with a larger quantum value than the lower priority class. For UGS, we evaluate the performance of the fixed bandwidth implementation as specified by the standard IEEE 802.16e.

Fig. 2 shows the average delay jitter for the proposed algorithm with the threshold of one and ten which is compared against the fixed bandwidth implementation. Delay jitter is defined as the amount of variance in the arrival of packet to the destination. We observe that the average delay jitter value increases when the MS approaches 40. This is because when the queue that holds the UGS packets is full, most of the incoming packets will be discarded due to the overflow. As a result, the delay jitter is very small in a low-loading condition because most packets are immediately served without dropping. However, the delay jitter increases steeply when the queue is about to be full. The threshold of 10 of the proposed algorithm has reduced the delay jitter further. This is because higher amount of slots (for the UGS, the BS allocates periodic slots to the MS with the UGS connection) are given to the MS, thus, reducing the jitter.

Fig. 3 compares the delay jitter of the rtPS service class which is configured with a video conferencing application. The comparison shows that our proposed algorithm delivers the lowest delay jitter of all the algorithms and the WRR has reported to be the highest. In the WRR, each MS is allowed to be allocated with the amount of slots which is equal to the weight assigned for each connection. In this case, the weight is fixed to the MRTR of the rtPS service class. The quantum of the Red-based DFPQ is also fixed to the MRTR, however, the rtPS is given higher transmission opportunities when the number of bandwidth request messages increases. Thus, the delay jitter for the Red-based DFPQ is lower than the WRR. However, as the MS approaches 40, the performance of the Red-based DFPQ is about comparable to WRR. This shows that the weight and quantum of WRR and the Red-based DFPQ respectively should be set higher to reduce the delay jitter. Furthermore, the BS is only capable of estimating the uplink traffic [11] through the bandwidth request messages sent from the MS and the MRTR assigned for each service class. The actual packets reside in the MS, in which there is no mechanism of sending the information of the individual packet sizes to the BS.

From fig. 4, we can observe that the average delay jitter for rtPS of the threshold ten is slightly lower than the threshold of one. Since the proposed algorithm is in the category of priority algorithm, the scheduler needs to satisfy the UGS class before the rtPS is serviced. Therefore, the difference in jitter with different threshold value is not significant.

## 6. Conclusion

In this paper, a threshold-based priority algorithm has been presented and validated in the context of the delay jitter of the real-time traffic application. The proposed algorithm takes the information of the number

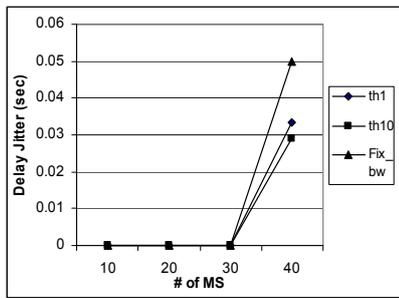


Fig. 2 Delay jitter for the UGS service class.

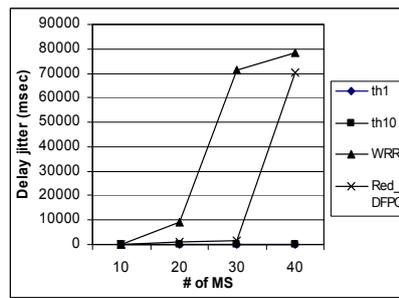


Fig. 3 Delay jitter for the rtPS service class.

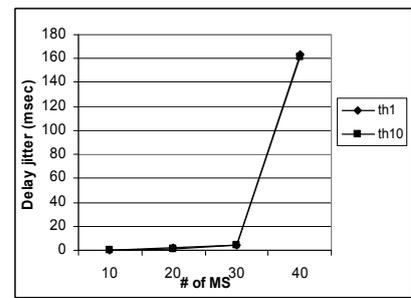


Fig. 4 Delay jitter for the proposed algorithm with different threshold value for the rtPS service class

of bandwidth request message in the nrtPS queue as the threshold value. It combines the priority algorithm among the different service classes with an exhaustive service strategy for each connection.

The simulation results show that the proposed algorithm with the threshold of ten outperforms the fixed bandwidth implementation for the UGS by lowering the delay jitter by 42%. Furthermore, the proposed algorithm delivers the lowest delay jitter among the algorithms for the rtPS class. Finally, the advantage of exploiting the threshold value is highlighted. The threshold value of ten has reduced the delay jitter for classes, also the UGS and rtPS respectively.

## 7. References

- [1] Yi-Neng Lin, Ying-Dar Lin, Yuan-Cheng Lai, Che-Wen Wu. Highest Urgency First (HUF): A Latency and Modulation Aware Bandwidth Allocation Algorithm for WiMAX Base Stations. *Computer Communications*. 2008, 32: 332-342.
- [2] M. Settembre MP, S.Garritano, P.Testa, R. Albanese M. Mancini, V. Lo Curto. : Performance Analysis of an Efficient Packet-Based IEEE 802.16 MAC Supporting Adaptive Modulation and Coding. *Proc. Of International Symposium on Computer Networks*. Turkey:Istanbul. 2006, pp. 11-16.
- [3] Po-Chun Ting C-YY, Naveen Chilamkurti, Wang Tung-Hsien, Ce-Kuen Shieh.: A Proposed RED-Based Scheduling Scheme for QoS in WiMAX Networks. International Symposium on Wireless Pervasive Computing. Australia:Melbourne. 2009, pp. 1-5.
- [4] Zeynep Yurdakul and SO. A Hierarchical Channel-Aware Uplink Scheduler for WiMAX Base Stations. Sixth Advanced International Conference on Telecommunications (AICT'10). Spain:Barcelona. 2010. p. 398-403.
- [5] Nuaymi, Loutfi. WiMAX Technology for Broadband Wireless Access. Wiley, 2007.
- [6] Raj Jain, Chakchai So-In and Abdel-Karim Al Tamimi. System-Level Modeling of IEEE 802.16e Mobile WiMAX Networks: Key Issues. *IEEE Wireless Communications*. 2008, 15(5): 73-79.
- [7] Jani Lakkakorpi, Alexander Sayenko, Jani Moilanen. Comparison of Different Scheduling Algorithms for WiMAX Base Station. *Proc. of Wireless Communications and Networking Conference*. USA:Las Vegas. 2008, pp. 1991-1996.
- [8] Aymen Belghith and Loutfi Nuaymi. Comparison of WiMAX Scheduling Algorithms and Proposals for the rtPS QoS Class. *Proceedings of European Wireless Conference*. Czech Republic:Prague. 2008, pp.1-6.
- [9] Chakchai So-In, Raj Jain, Abdel-Karim Tamimi. Scheduling in IEEE 802.16e Mobile WiMAX Networks : Key Issues and a Survey. *IEEE Journal On Selected Areas In Communication*. 2009, 27(2):156-171.
- [10] Y. Ahmet Sekercioglu, Milosh Ivanovich, Alper Yegin. A Survey of MAC Based QoS Implementation for WiMAX Networks. *Computer Communications*. 2009, 32(14): 2517-2536.
- [11] Hua Wang and Lars Dittman. Adaptive Radio Resource Allocation in Hierarchical QoS Scheduling for IEEE 802.16 Systems. *Proceedings of IEEE Global Telecommunications Conference*. USA: Washington DC.2007, pp. 4769-4774.