The 10th Conference for Informatics and Information Technology (CIIT 2013)

PERFORMANCE ANALYSIS OF THE REAL TIME SERVICE CLASSES IN MOBILE WIMAX

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ABSTRACT

In this paper we introduce a priority based uplink scheduling scheme for IEEE 802.16 standard that maximizes the QoS performances of the real time service classes, especially of the ertPS service class. Simulation experiments are done using the ns-2 simulator and wimax patch and they evaluate and compare the proposed uplink scheduling scheme changing the number of ertPS connections. Performance analysis of the real time services classes (ertPS, UGS and rtPS) in mobile WiMAX, was done measuring the average delay and average jitter. Given results prove that the proposed uplink scheduling scheme based on the priority of the service classes improves the average delay and average jitter results, especially in high loaded scenarios.

I. INTRODUCTION

WiMAX/802.16 is the broadband wireless acess (BWA) system designed for wireless metropolitan area networks. Nowadays it is already 4G wireless network technology, known as 802.16m mobile WiMAX standard. 802.16m is a follow-on to 802.16e standard, first standard from the WiMAX technology that fulfilled the requirement for wireless mobility and supported subscriber stations moving at vehicular speeds. Mobile WiMAX standards to provide different quality of service (QoS) for various demands of the users offer five classes of services. Unsolicited Grant Service (UGS), extended real-time Polling Service (ertPS) and real-time Polling Service (rtPS) are classified for real-time services. Non-real-time Polling Service (nrtPS) and best effort (BE) are for non-real-time services. Each of them has its own specific QoS parameters expressed in bandwidth requirement and delay. UGS periodically receives fixed size grants without requesting them. ertPS service class, the last included service class in mobile WiMAX, has similar grant mechanism as UGS service class. But, the difference between them is that in ertPS periodically allocated grants can be used for sending bandwidth requests to inform the required grant size. The third real time service class, rtPS, is providing to subscribers periodic unicast bandwidth request opportunities. They guarantee minimum traffic rate and latency bound. Non real time service class in mobile WiMAX, nrtPS service class offers periodic unicast bandwidth request opportunities with more spaced intervals than rtPS and minimum traffic rate guarantee. BE service class shares with the nrtPS contention bandwidth request opportunities.

Packet scheduling in mobile WiMAX in the uplink direction at the base station (BS) is more challenging than scheduling at the downlink direction. It takes into account all QoS parameters defined by the standard and it doesn't have direct access to the connections queues. The uplink scheduler is dependent on the bandwidth requests. They can suffer from delays that can be generated by the contention mechanism. This bandwidth requests may be also lost because of the channel noise causing outdated info.

In the literature there are a lot of solutions that are proposed for uplink scheduling algorithms. One of them, the uplink scheduler in [1] does not provide maximum latency guarantees. The uplink scheduler in [2] proposes a priority value computed by the subscriber stations (SSs) in order to provide latency and rate guarantees. Standard-compliant scheduling solution for the uplink traffic in IEEE 802.16 is proposed in [3]. This uplink scheduler uses three queues, low, intermediate and high priority queue and it can support minimum traffic rate, maximum sustained traffic rate, maximum traffic burst requirements, and maximum latency. A fair uplink scheduler is presented in [4]. It is based on the values of congestion window and TCP timeout and on the channel conditions. Authors in [5] proposed a scheduling mechanism that classifies packets in 4 classes in order to guarantee latency requirements for real time applications. Higher priority is given to the subscriber stations that have better channel conditions and this classification is based on the history of packets delays. But, authors in this paper do not provide minimum rate guarantees. In [6] authors propose an uplink scheduling algorithm that assigns priority values to the connections on the basis of the service class priority, the delay of the packets, the status of the queue and the quality of the channel.

In the work presented here we extend the uplink scheduler solution proposed in [3] and we introduce five levels of priority from 1 to 5 (1 is the highest and 5 is the lowest priority value). They are applied respectively to the five service classes ertPS, UGS, rtPS, nrtPS and BE. Our goal was to get better performances of the real time service classes in mobile WiMAX, especially for ertPS. Performance analysis of the results for real time service classes is done after implementing the level of priority for each service class according to our proposed uplink scheduling scheme.

The rest of this paper is organized as follows. Section 2 describes the real time service classes and uplink scheduling principles in mobile WiMAX. Section 3 depicts the simulation environment and shows the results of the performance analysis of the real time service classes using priority based uplink scheduling scheme. Section 4 concludes the paper.

II. MOBILE WIMAX REAL TIME SERVICE CLASSES

In the Mobile WiMAX technology that utilizes point-to-multipoint mode the base station (BS) communicates with several subscriber stations (SS) in the WiMAX cell. When the

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transmission is from the BS to the SSs, it is called downlink transmission (DL). Uplink transmission (UL) is when the transmission of the traffic is from the SSs to the BS. The admission of the new connection by the BS is performed on the basis of the current situation with the available resources. If the QoS requirement of the requested bandwidth is supported the BS will generate CID (Connection Identifier) and Service Flow Identifier and will notify the SS. The admission control algorithm will accept a new connection if only this condition is fulfilled:

$$C_{reserved} + TR_i^{service} \le C \tag{1}$$

where $TR_i^{service}$ is the traffic rate of the new connection i of one of the WiMAX service types denoted with *service*. In (1) the already reserved capacity is denoted with $C_{reserved}$.

C in (1) denotes the whole capacity that is available for the uplink scheduler. It is the amount of the uplink bandwidth that can be allocated by the uplink scheduler for transmission and unicast polling.

The scheduling schemes in the MAC layer in Mobile WiMAX are designed to deliver successfully different service classes to the users over the wireless channel. The set of QoS parameters of the three real time scheduling types at MAC layer (UGS, rtPS, ertPS) are presented in Table 1.

The UL-BS scheduling process in mobile WiMAX is the most complicated because when the base station makes scheduling decisions it has no updated information about the current queue status at the SSs. As a consequence of this, the base station on the basis of the bandwidth requests received from the SSs estimates the current queue status. In the case of the DL-BS scheduling process things are much easier. In this case the base station has the current information about the queue status of all downlink connections.

Packets are queued at the SSs during the uplink transmission of the data. The uplink scheduler operates on a request-grant basis. Each subscriber station sends a message with a bandwidth request to the base station. Our proposed uplink scheduler is based on the class priority level with respect to other service classes. The highest priority is given to ertPS, then to UGS, and as a third for priority, rtPS service class. Although UGS and ertPS are in the same high priority queue according [3], adding our proposed uplink scheduling priority scheme, when they are active in the same period, ertPS service class will have higher priority compared to UGS. Real time service, rtPS, that is in intermediate queue according [3] has the third priority value according our priority based uplink scheduling scheme.

ertPS, the newest class of the WiMAX standard combines the efficiency of the UGS and rtPS classes. The allocation of slots is similar to the rtPS class:

$$N_i^{\min} = N_i^{\max} = \begin{cases} 1, & R_i = 0, \\ \left\lceil \dfrac{T_i}{S_i FPS} \right\rceil, & R_i > 0, \end{cases} \tag{2}$$

$$\forall i \mid C_i = ertPS$$

where T_i stands for bandwidth requirement of the *i*th connection, N_i stands for the number of slots within each frame, S_i stands for the slot size, R_i is the request size, C_i stands for the *i*th connection class, and *FPS* stands for the number of frames the WiMAX BS sends per one second, i.e. the number of bytes a connection can send in one slot.

Table 1: Mobile WiMAX real time service classes and QoS.

WiMAX service class	**Applications**	**QoS Specification**
UGS Unsolicited Grant Service	VoIP	Maximum Sustained Rate Maximum Latency Tolerance Jitter Tolerance
rtPS Real-Time Polling Service	Streaming Audio or Video	Minimum Reserved Rate Maximum Sustained Rate Maximum Latency Tolerance Traffic Priority
ertPS Extended Real-Time Polling Service	Voice with Activity Detection (VoIP)	Minimum Reserved Rate Maximum Sustained Rate Maximum Latency Tolerance Traffic Priority

The maximum amount of time that each SS is allowed to transmit using the ertPS service class is given by:

$$T_{ertPS,\max} = \frac{T_{MAC\_UP} - T_{overhead}}{N_S} \tag{3}$$

where T_{MAC_UP} is the duration of one MAC frame in uplink, $T_{overhead}$ is initial ranging period duration, N_s is the number of connections associated to SSs - subscriber stations i, $i=1,2,\ldots N_s$.

When using the ertPS service class in mobile WiMAX, packet transmission performance strongly depends on the MAC frame size. When we have a short MAC frame duration, we achieve using the ertPS service approximately as good packet transmission performance as using the UGS service. The packet transmission performance using the ertPS service degrades as the frame size increases.

III. SIMULATION SCENARIO AND RESULTS

Several modules were proposed in the literature for the simulations of IEEE 802.16-based networks. One of them is implemented by the National Institute of Standards and Technology (NIST). But it fails to implements MAC QoS support. The simulation module for IEEE 802.16 presented in [7] provides packet fragmentation and packing, but we cannot configure QoS requirements with it. Another 802.16-based simulator exists for the OPNET tool, but it is a private domain simulator. Researching the mobile WiMAX simulators we have concluded that the most adequate simulator for WiMAX real time service classes is the one developed by the University of Campinas [8]. This module is focused on the MAC layer and its mechanisms for bandwidth allocation and QoS support.

The topology of the simulation scenarios that we created for the performance analysis consists of a BS located at the center of a 250 X 250 meter area. Subscriber stations - SSs are uniformly distributed around the BS. Random motion is enabled to the SSs by setting the random-motion to 1, which means that random destinations are assigned to the nodes. Each SS has one uplink flow and one downlink flow, which are mapped to the same service type. In order to eliminate the impact of the packet scheduling at the SSs on uplink scheduling, each of the SSs has only one service flow.

We used as a voice model for UGS service class an exponential model with mean duration of 1.2 seconds of the “on period” and 1.8 seconds of the “off period”, respectively. For UGS service class according this model packets of 66 bytes are generated every 20 milliseconds. For simulating ertPS service class we used in the simulator EVRC – Enhanced Variable Rate Codec as a model of voice with silence suppression [9]. In our scenarios rtPS service class was simulated using real MPEG traces. nrtPS service class in the simulator that we use is generated with FTP traffic using an exponential distribution with a mean of 512 KBytes. BE service class is simulated with WEB traffic that is modeled in the simulator by a hybrid Lognormal/Pareto distribution with the body of the distribution modeled by a Lognormal distribution with a mean of 7247 bytes and the tail modeled by a Pareto Distribution with mean of 10558 bytes.

UGS and ertPS service classes have unsolicited grant interval of 20 milliseconds. rtPS has unsolicited polling interval of 20 ms and nrtPS of 1 second. BE service class doesn’t have any QoS requirement. In all simulated scenarios the number of UGS, rtPS, nrtPS and BE connections is equal to 10. We only change the number of ertPS connections from 5 to 30 in order to test the performances under different ertPS traffic load. The duration of each simulation scenario is 100 seconds. Each simulation scenario is processed ten times with different seeds. In the figures we show the mean values and the 95% confidence intervals.

Because in the reality, the received power at some distance is a random variable due to multipath propagation effects, known as fading effects we don’t use in the simulations the free space model and the two-ray model. All of the simulated scenarios in our work are done using the Shadowing propagation model. This model consists of two parts. The first part is the path loss model. It predicts the mean received power at some distance *d*, denoted by $\overline{P_r(d)}$. Close-in distance d_0 is used as a reference. $\overline{P_r(d)}$ is computed relative to $P_r(d_0)$ as follows:

$$\left[\frac{\overline{P_r(d)}}{P_r(d_0)}\right]_{dB} = -10\beta\log\left(\frac{d}{d_0}\right) + X_{dB} \tag{4}$$

β in (4) is denoted as path loss exponent which is usually determined empirically by measurements on the field, X_{dB} is a Gaussian random variable with zero mean at standard deviation denoted with δ_{dB}, sometimes called the shadowing deviation. This value is also obtained empirically by measurements. In our simulations this value was set to 4.

In order to analyze the performances of the real time service classes in mobile WiMAX (ertPS, UGS and rtPS), especially the ertPS service, we varied the number of ertPS connections from 5 to 30 with a step of 5 connections. So, we made 6 scenarios where each of the other 4 service classes had 10 connections, while the number of ertPS connections was 5, 10, 15, 20, 25 and 30. The results are shown in average jitter and average delay only for the real time service classes, because they are sensitive to delay and jitter.

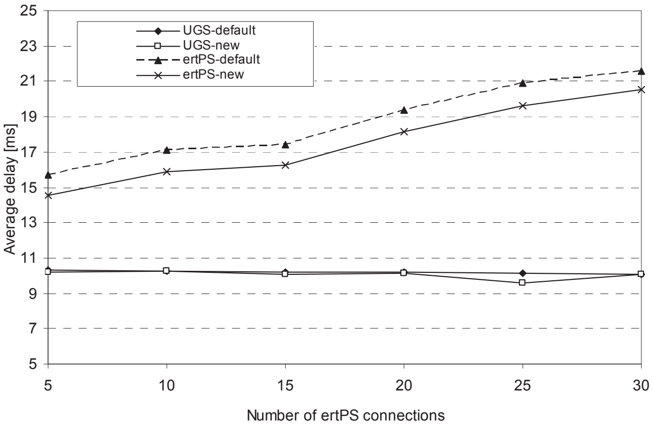

Figure 1: Average delay of 10 UGS connections changing the nubmer of ertPS connections.

Fig. 1 presents the average delay of variable number of ertPS connections from 5 to 30 with a step of 5 and average delay of 10 UGS connections. All other service classes have also 10 connections. In Fig. 1, UGS-default and ertPS-default present the results obtained using the scheduling mechanism in [3]. UGS-new and ertPS-new present the results obtained with our modified scheduling scheme.

We can conclude analyzing Fig. 1 that after applying our priority based scheme results for ertPS connections are better. In the same time average delay of the UGS connections is not degraded. It is obvious from the graph analyzing the UGS curve before and after the implementation of the proposed scheduling scheme. It can be also noticed from Fig. 1 that the increase of the ertPS traffic connections has no influence on the average delay of UGS connections. This situation can be explained by the fact that ertPS and UGS service class are in the queues with high priority.

Increase of the ertPS traffic load in Fig. 2 impacts on the average delay of the rtPS service class, because rtPS service class is in the queue with intermediate priority. Modification of the scheduling mechanism in [3] with our added strict priority for all five service classes where we give the highest priority to ertPS service class doesn’t have a negative effect on the average delay results for rtPS service class. Contrary, in the simulations that we have done, we have even better results in some of the scenarios (when number of ertPS connections are 5, 15, 20, 25). We verified in Fig. 3 that the average delay of 10 rtPS connections hasn't violated the maximum latency requirement of 100 ms.

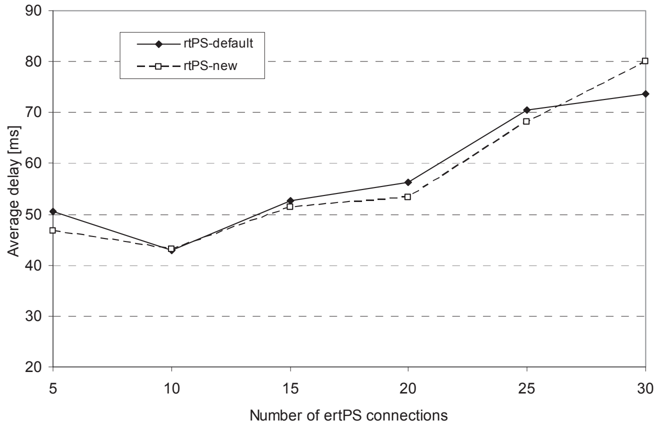

Figure 2: Average delay of 10 rtPS connections changing the number of ertPS connections.

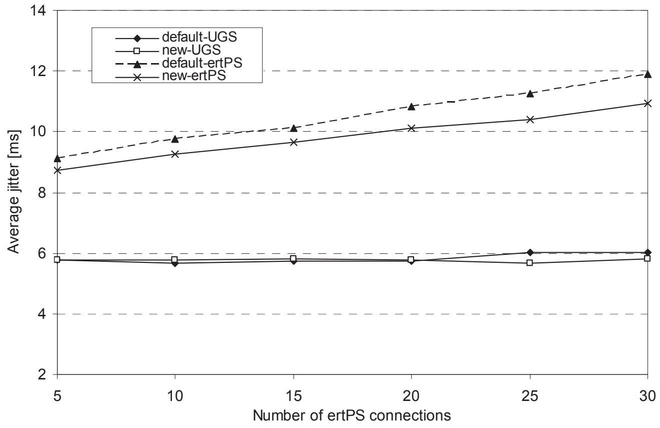

Figure 3: Average jitter of 10 UGS connections and average jitter of 5-30 ertPS connections.

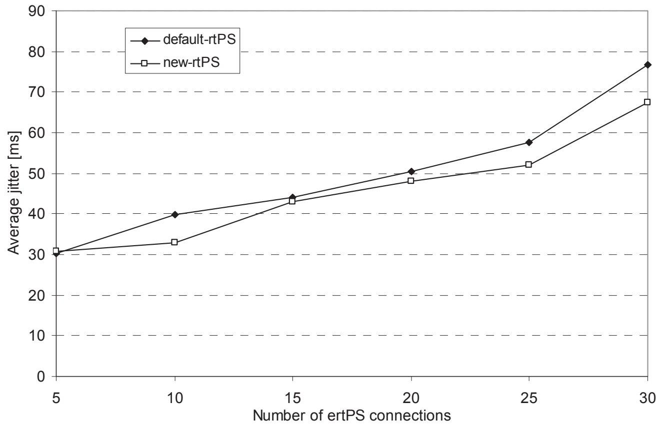

Figure 4: Average jitter of 10 rtPS connections and 5-30 ertPS connections.

Fig. 3 presents the average jitter results for UGS and ertPS connections. Similarly to average delay results, average jitter results for ertPS service class are better using the proposed scheduling scheme compared to the scheduling mechanism in [3]. Average jitter results for UGS service class are in both cases not affected by the increase of the ertPS connections. Their values are under or around 6 ms in all of the simulated scenarios in both cases.

Fig. 4 illustrates the average jitter results for 10 rtPS connections changing the number of ertPS connections comparing the uplink scheduling mechanism in [3] with our proposed scheduling scheme. Compared results show that our proposed scheduling scheme gives even a little better results for this service class.

IV. CONCLUSION

In this paper we obtained a performance analysis of the real time service classes in mobile WiMAX with our proposed priority based uplink scheduling scheme. We used the wimax simulator that was developed in [8] and implemented there our proposed uplink scheduling scheme. Results that are obtained in Section 3 prove that the proposed priority based scheduling scheme gives better results in average delay and jitter for the real time service classes, especially for ertPS, compared with the uplink scheduling mechanism in [3].

Results are obtained using scenarios where all 4 service classes have 10 connections and only ertPS service class has variable connections from 5 to 30. Using the proposed scheduling scheme we obtained better results in average delay and jitter for ertPS service class. This gain hasn't decreased the performances in average delay and jitter of UGS and rtPS service classes. Contrary, in many cases we have even better results in the measured average delay and jitter of UGS and rtPS service classes.

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