Performance Evaluation of Packet Scheduling with Channel Conditioning Aware Based On WiMAX Networks

Elmabruk Laias, Abdalla M. Hanashi, Mohammed Alnas

Abstract**—**Worldwide Interoperability for Microwave Access (WiMAX) became one of the most challenging issues, since it was responsible for distributing available resources of the network among all users this leaded to the demand of constructing and designing high efficient scheduling algorithms in order to improve the network utilization, to increase the network throughput, and to minimize the end-to-end delay. In this study, the proposed algorithm focuses on an efficient mechanism to serve non_real time traffic in congested networks by considering channel status.

Keywords**—**WiMAX, Quality of Services (QoS), OPNE, Diff-Serv (DS).

I. Introduction

WiMAX based on the standard IEEE 802.16, which consist of one Base Station (BS) and one or more Subscriber Stations (SSs), as shown in Fig. 1, the BS is responsible for data transmission from SSs through two operational modes: Mesh and Point-to-multipoint (PMP), this transmission can be done through two independent channels: the Downlink Channel (from BS to SS) which is used only by the BS, and the Uplink Channel (from SS to BS) which is shared between all SSs, in Mesh mode, SS can communicate by either the BS or other SSs, in this mechanism the traffic can be routed not only by the BS but also by other SSs in the network, this means that the uplink and downlink channels are defined as traffic in both directions; to and from the BS. In the PMP mode, SSs can only communicate through the BS, which makes the provider capable of monitor the network environment to guarantee the Quality of Service QoS to the customers [2], [11].

QoS parameters are the classes that the BS in a network should support to be able to support a wide variety of applications those parameters include:

- Unsolicited Grant Service (UGS): that supports constant Bit Rate (CBR) such as voice applications.
- Real-Time Polling Service (rtPS): support real-time data streams that contain variable size data packets, which are issued at periodic intervals such as MPEG video.
- Extended Real-Time Polling Service (ertPS): applicable with variable rate real-time applications that require data rate and delay guarantees like VoIP with silence suppression.
- Non-Real-Time Polling Service (nrtPS): support delay tolerant data streams that contains variable-size data packets that require a minimum data rate like FTP.
- Best Effort (BE): support data streams that do not need any QoS guarantees like HTTP.

Scheduling algorithms are responsible for Distributing resources among all users in the network, and provide them with a higher QoS. Users request different classes of service that may have different requirements (such as bandwidth and delay), so the main goal of any scheduling algorithm is to maximize the network utilization and achieve fairness among all users. In Strict Priority (SP) algorithm packets are represented by the scheduler depending on the QoS class and then they are assigned into different priority queues, these queues are served according to their priority from the highest to the lowest but this mechanism may causes some priority QoS classes to be starved.

Round Robin (RR), RR scheduler works in rounds by serving the first packet in each priority queue in sequence according to their precedence till all queues are served and then it restarts over to the second packet in each queue.

Weighted Round Robin (WRR), in WRR procedure, packets are categorized into different service classes and then assigned to a queue that can be assigned different percentage of bandwidth and served based on Round Robin order as shown in Fig. 4. This algorithm address the problem of starvation by guarantees that all service classes have the ability to access at least some configured amount of network bandwidth.

Weighted Fair Queuing (WFQ), each flow are assigned different weight to has different bandwidth percentage in a way ensures preventing monopolization of the bandwidth by some flows providing a fair scheduling for different flows supporting variable-length packets by approximating the theoretical approach of the generalized processor sharing (GPS) system that calculates and assigns a finish time to each packet.

Self-Clocked Fair (SCF) Queuing, SCF Scheduler generates virtual time as an index of the work progress; this time is computed internally as the packet comes to the head of the queue. The virtual time determines the order of which packets should be served next.

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Diff-Serv(DS) Enabled, Diff-Serv Uses the 6-bit Differentiated Services Code Point (DSCP) field in the header of IP packets that used to classify packets, by replacing the out dated IP precedence with a 3-bit field in the Type of Service byte of the IP header originally used to classify and prioritize types of The IEEE 802.16 standard defines several scheduling classes at Media Access Control (MAC) layer for preferential treatment of service flows depending on Quality of Service (QoS) requirements specific to a service flow. In this Chapter, a new framework has been proposed to solve and address QoS issues for fixed Point to Multi Point (PMP) 802.16 systems. The proposed framework consists of a Uplink scheduler, Call Admission Control (CAC) module and a simple yet frame allocation scheme. The proposed CAC module interacts with the uplink scheduler status and makes its decision based on the scheduler's queues status. Extensive OPNET simulation demonstrates the effectiveness of the proposed framework.

II. Related work

In [4], Mohammed Sabri Arhaif evaluated the implementation of various types of scheduling algorithms in WiMAX network, such as Diffserv-Enabled (Diffserv), Round Robin (RR), Self-Clocked-Fair (SCF), Strict-Priority (SP), Weighted-Fair Queuing (WFQ) and Weighted-Round Robin (WRR). In this study QualNet 5.0 simulator evaluation version are used to evaluate these algorithms and to determine the most efficient one among them.

In [5], Ashish Jain and Anil K. Verma descried three scheduling algorithms Proportionate Fair (PF) Scheduling [6], Cross-Layer Scheduling Algorithm [7] and TCP-Aware Uplink Scheduling Algorithm for IEEE 802.16 [7]. And it was proposed to provide a comparative study of these algorithms to define the pros and cons for each technique. In other hand, Cross-Layer algorithm guaranteed the QoS parameters, and the channel quality was considered in the scheduling, but it had a complex implementation and all slots per frame were allocated to the highest priority connection. In [9], Ahmed Rashwan, Hesham ElBadawy, and Hazem Ali performed a detailed simulation study, in addition to analyzing and evaluating the performance of some scheduling algorithms, which were WFQ, Round Robin, WRR and Strict-Priority. The simulation results showed that the UGS, ertPS and rtps traffic had the largest throughput value. However the BE and nrtPS traffic almost had no traffic because the Strict-Priority scheduler caused bandwidth to be starved for low priority traffic types, the higher priority traffic had a higher throughput and the lowest priority traffic had low throughput, meanwhile WRR distributed the bandwidth according to the assigned weights to all traffic types, WFQ and WRR were very similar despite that they were different in distributing the bandwidth among the traffic types, In [10], Jani Lakkakorpi, Alexander Sayenko and Jani Moilanen presented a detailed performance comparison of some scheduling algorithms such as Deficit Round-Robin, Proportional Fair and Weighted Deficit Round-Robin, taking into account in their comparison the radio channel conditions and the throughput improvement was considerable. The simulation experiments were obtained on a modified version of ns-2 simulator, The simulation resulted in the fact that both PF and WDRR algorithms performed better than DRR in terms of MAC throughput and TCP good-put, the WDRR had a good performance in time this scheme was easier to implement and less computationally complex than PF. finally the results showed that when the Active Queue Management AQM at the BS was used, it causes the queuing delay to be reduced without affecting the good-put.

III. Proposed Scheme

The Customized Deficit Round Robin Uplink Scheduler (CDRR) with Strict Priority algorithm [1], is based on a single queue for both UGS and unicast polling, and one queue for a BE. Moreover, a list of queues for both rtPS and nrtPS is provided. We should note that grouping multiple rtPSs connections into a single queue under EDF algorithm fails to guarantee the minimum reserved traffic rate of individual rtPS connection; for such, this might lead to an unbalanced sharing of the available bandwidth since one rtPS connection with tight delay budget and extra amount of traffic may consume the entire bandwidth and starve all the other rtPS connections in the same queue. In the proposed scheme each queue in the list represents a single. This list is updated for every frame by adding new queues and removing empty queues from the list.

Bandwidth requirement can be measured by the maximum sustained traffic rate (r_{max}) and the minimum reserved traffic rate (r_{min}) depending on the service flow scheduling type. Each queue in the list is attached with a deficit counter variable to determine the number of requests to be served in the round and this is incremented in every round by a fixed value (*quantum*) and the quantum is computed as follows:

$$Quantum = MTU + (w - 1) \times \Delta \tag{1}$$

where MTU is a Maximum Transmission Unite on the link and Δ is a fixed increment (512 bytes) and the queue weight: $w_i = \frac{r_{min}[i]}{\sum_{i=0}^{i=N} r_{min}[i]}$, where $r_{min}[i]$ is the minimum rate for the connection *i* and *N* is the number of all connections .

Thus, a queue with the lowest weight (equal to 1) is allowed to send an MTU on each round.

In this scheme, an extra queue has been introduced to store a set of requests whose deadline is due to expire in the next frame. Every time the scheduler starts the scheduling cycle, this queue will be filled by all rtPS requests which are expected to miss their deadline in the next frame. An rtPS request is said to be subject to deadline when the request connection is engaged but will probably fail to meet the expected deadline. In other words, we define a request packet as due to deadline in a certain frame if its deadline expires before the next frame is totally served and at the same time, the remaining capacity of the current frame will not be enough to service this packet after the service flow currently being serviced or about to be serviced uses up its Quantum.

More formally, an rtPS data grant G is said to be it is transmit time due to deadline if (2) and (3) are satisfied:

$$deadlineG < (frame_n + 1)\, Xframe_{duration} \quad (2)$$

$$sizeG > frame_{aval} - DC_i \quad (3)$$

where $frame_n$ is the current frame number, $frame_{aval}$ is the available capacity in the current frame, *sizeG* is the size of the current packet G and DCi is the deficit counter of the i_{th} service flow belonging to the rtPS queue which will be about to be serviced. In the proposed scheme, it is assumed that the deadline of a request should be equal to the sum of the arrival time of the last request sent by the connection and its maximum delay requirement.

In the next scheduling cycle, the scheduler will first check if any request has been added to this extra queue. If the extra queue is not empty, the scheduler will serve this queue after the UGS and polling queue. Once the extra queue becomes empty and there are available BW in the UL_MAP, the scheduler will continuing serving the polling services (PS) list, using DRR with quantum as expressed in (1). Note that, it is well known that lower priority PS queues can actually be starved when extra queue has packets to be served. Therefore, PS queues cannot be guaranteed a minimum service rate or a maximum latency, unless constraints on the extra queue traffic are enforced. In this paper, it is assumed that when the connection get polling opportunity, more requests are expected to be sent in the next uplink frame so the scheduler will share the polling interval time and the sum of deficient left as a result of moving a due to deadline requests from rtPS connections, in adding extra value to the deficient counter for the such connections to increase the number of requests to be served in this round under the following conditions:

a) The connection has been just polled in this frame.
b) The queue size of this connection is exceeding its maximum threshold :

$$queu\_\max\ \_threshold \;= r_{min} \text{ x (frame\_duration)} \quad (4)$$

Although PF is simple and efficient, it cannot guarantee any QoS requirements, such as delay and jitter, due to the fact that it was originally designed for saturated queues with non-real-time data services, so we use this algorithm for Nrtps and BE services. For time t, and user k, the Channel Quality Indicator (CQI) denoted as CQI(t). This is directly proportional with the signal which the SS receives and determines the maximal transmission rate. CQI(t) is calculated based on modulation, coding and repeat times. For time t, and user n, the last rate is Lr(t). The user's priority is calculated by the following formula:

$$priority_k(t) = \frac{CQI_k(t)}{1 + Lr_k(t)} \quad (5)$$

The user with the highest priority will be scheduled with the highest probability. The Adaptive Proportional Fairness (APF) scheduling scheme aims at extending PF [3] scheduling to real time services application and provides various QoS requirements. The scheduling scheme is based on the Grant Per Type-of Service (GPTS) principle, which aims at differentiating the delay performance of each queue. A novel priority function is devised for all the QoS guarantees, including rtPS and ertPS, for allocating time slots on the queues with the highest priority value.

Throughout the time interval t, the priority function for queue i is defined below in (6), $r_{min}(t)$ is the real-time service minimum rate requirement, $NC_i(t)$ is the number of connections at the ith queue,and ChCondk(t) is the channel quality at time t. Channel quality time determines the transmission capacity. We calculate the APF priority as follows:

$$priority_k(t) = \frac{CQI_k(t)}{1 + r_{(i)min} + Lr_k(t)/Nc_i(t)} \quad (6)$$

Each queue corresponds to one QoS requirement class. We schedule the user according to its priority. For the fairness of my algorithm, we can calculate priority in (5) and (6); both equations schedule an SS in a given round with a given throughput. In the next round, it will be less probable to schedule the same SS. The scheduling should work along these lines, for a given channel condition, the higher the throughput, the lower the priority. Similarly, for a given throughput, the higher the channel condition, the higher the priority.

IV. Simulation Model

The overall objective of the simulation model is to analyze the behavior and performance of the proposed algorithm in a congested uplink domain. The simulations have been performed using Opnet Modeler, version 14.5 [12].

In this section, the output of simulation is shown and analyzed: we compared the proposed Enhanced Customized Deficit Round Robin Uplink Scheduler (ECDRR) scheduling with the APF [7] and MDRR [8].

WiMAX supports a variety of modulation and coding schemes and allows for the scheme to change on a burst-by-burst basis per link, depending on channel conditions. Using the channel quality feedback indicator, the SS can provide the base station with feedback on the downlink channel quality. For the uplink, the base station can estimate the channel quality, based on the received signal quality.

Following Table I is a list of the various modulation and coding schemes supported by WiMAX.

TABLE I
Modulation and Coding Schemes Supported by WiMAX

	Downlink	Uplink
Mandatory	BPSK, QPSK, 16 QAM; 64 QAM; BPSK optional for OFDMA-PHY	BPSK, QPSK; 16 QAM; 64 QAM optional
Coding	**Mandatory**: convolution codes at rate 1/2, 2/3, 3/4, 5/6. **Optional**: convolution rate colts at 1/2, 2/3, 3/4; 5/6; repetition coda at rate 1/2, 2/3, 3/4, 5/6, LDPC, RS-Coles for OFDM-PHY.	**Mandatory**: convolution codes at rate 1/2, 2/3, 3/4, 5/6. **Optional**: convolution rate colts at 1/2, 2/3, 3/4; 5/6; repetition coda at rate 1/2, 2/3, 3/4, 5/6, LDPC.

Figs. 1 and 2 compare the deference in rate for subscribers using different modulation with the same MDRR, APF and ECDRR. The average occupancy rate of queues parameter has been observed in order to better understand the performance of the proposed algorithm. In fact, the ECDRR algorithm is based on modulation. Since ECDRR takes into consideration this parameter, the user will have a more important priority that allows a better control the queues and thus minimize saturation. In Fig. 1 for SSs with nrtps connections, the ECDRR algorithm increases the proportion of instant processing of packets based on channel conditions and modulation. Furthermore ECDRR algorithm limits the excessive accumulation of packets in the nrtps queues and it remains always more efficient than APF as it accommodates the unprocessed packets and enforce rate to remain below rmax values. In the other hand the MDRR scheduler, increase of the traffic load (around 600 kb/s) leads to the accumulation of unprocessed packets, thus to the saturation of the queues.

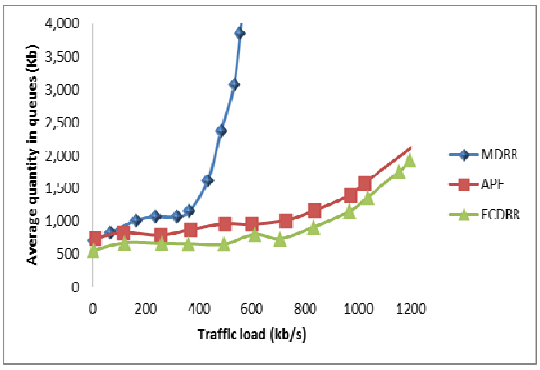

Fig. 1 Average quantity in queues (kb/s) of SSs

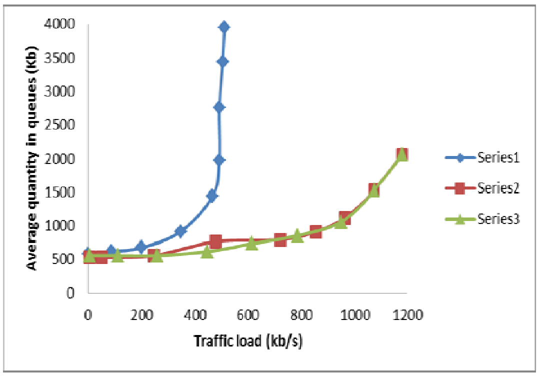

Fig. 2 Average quantity in nrtps queues (Kb/s) of SSs with high channel quality

Fig. 1 shows the occupancy of queues for SS's which have better channel quality. Queues with MDRR algorithm become saturated as soon as we increase the traffic load. We note that the occupation of queues with APF and ECDRR algorithms is almost the same for the mobiles connected with good channel quality. Thus, the priority functions of both algorithms ECDRR and APF become closer than those of SSs with bad channel condition.

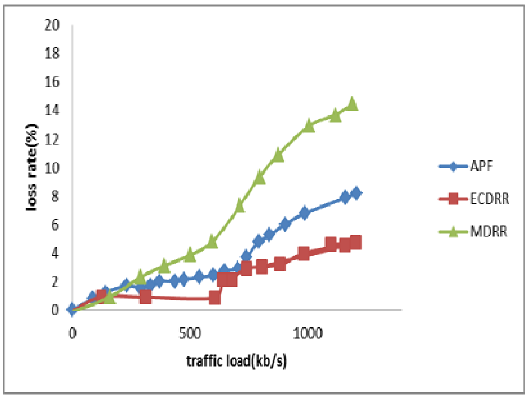

Fig. 3 The rate of packets loss

The packet loss rate shown in Fig. 3: the green line represents the MDRR scheduler, the blue line is for the APF and eventually the red curve represents the result of the proposed solution.

We notice that the packets loss caused by our solution, that is to say ECDRR, is less than those given by MDRR and APF.

To sum up, the ECDRR algorithm offers the opportunity to decrease the queue size compared to the other schedulers. Therefore, it decreases the probability of packet refuse. The loss rate increases when we apply the MDRR algorithm: we notice that when the traffic load is equal to 600 kbit /s, the rate of loss exceeds the rmax. This is caused by the saturation of queues represented by Fig. 4. Thus, with the AFP scheduler, the packet rate is relatively high and as soon as the payload exceeds the maximum rate to keep the connection undisturbed, therefore the ECDRR algorithm offers the opportunity to minimize the data waiting time, reduces the size of queues and especially decreases the loss rate of packets. These results are quite important and beneficial. For each rtPS connection, the BS must allocate a throughput higher than or equal to the reserved minimum throughput. Thus, the notion of throughput for this class is very interesting especially for video stream transfer applications. Fig. 4 shows the throughput of rtPS-type connections according to the traffic load. According to the simulation results, we notice that the proposed algorithm ensures a through put of rtPS connections that reaches 9.5 Mbit/s and always remains more efficient than the APF and MDRR algorithm.

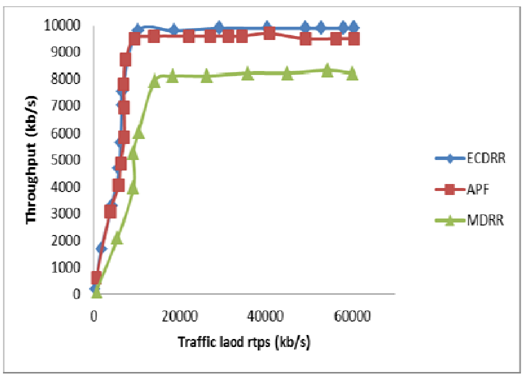

Fig. 4 rtPS throughput as a function of traffic load

V. CONCLUSION

In this paper, a new scheduling algorithm for IEEE 802.16 wireless MAN in PMP is proposed called "Enhanced Adaptive Proportional Fairness". This algorithm proposes a mechanism to enable the BS scheduler to balance between serving high and low priority traffic simultaneously.

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