Review: Scheduling Mechanism for WiMAX Scheduling Strategies

Dushyant H.Bodkhey

SIOM, Pune,Pune University, India

Abstract
WiMAX provides QOS that can support all kinds real time application in wireless network that includes priority scheduling and queuing for bandwidth allocation that is based on traffic scheduling algorithms within wireless network. That's why interest in broadband wireless access (BWA) has been growing due to increased user mobility and the need for data access at all times. Scheduling algorithms for WiMAX is not well defined till now and left open for vendors to implement as per needs. The goal of scheduling are to achieve the optimal usage of resource of ,to assure the quality of Service guarantees ,to maximize good-put and to minimize power consumption while ensuring feasible algorithm complexity and system scalability.

Keywords:
WiMAX, QOS, Scheduling Algorithm

1. INTRODUCTION

The WiMAX technology, based on the IEEE 802.16 standards is a solution for fixed and mobile broadband wireless access networks, aiming at providing support to a wide variety of multimedia applications, including real-time and non-real-time applications. As a broadband wireless technology, WiMAX has been developed with advantages such as high transmission rate and predefined Quality of Service (QoS) framework, enabling efficient and scalable networks for data, video, and voice. However, the standard does not define the scheduling algorithm which guarantees the QoS required by the multimedia applications. The scheduling is the main component of the MAC layer that helps assure QoS to various applications. The radio resources have to be scheduled according to the QoS parameters of the applications. Therefore, the choice of the scheduling algorithm for the WiMAX systems is very important. There are several scheduling algorithms for WiMAX in the literature; however, studies show that an efficient, fair and robust scheduling algorithm for WiMAX systems is still an open research area[1].

WiMAX provides Quality of Service (QoS) that supports five different categories of services namely: Unsolicited grant services (UGS), Real-time polling services (rtPS), Non- real-time polling service rate (nrtPS), extended real-time polling service (ertPS) and Best-Effort services (BE). As such, scheduling class services must ensure there is efficiency and fairness in meeting the various QoS requirements.

The scheduling class services in wireless networks includes priority scheduling and queuing for bandwidth allocation based on traffic scheduling algorithms within wireless networks. Since the scheduling algorithm is still an undefined territory, designing an efficient scheduling algorithm that can provide high throughput with minimum delay is indeed a challenging task for system developers. Although there are various studies on scheduling algorithms, there is a clear absence of a comprehensive performance study that provides a unified platform for comparing

Such algorithms. Therefore, this research paper is aimed to investigate and compare several scheduling algorithms in terms of performance and abilities to support multiple classes of service. Besides that, the paper intends to identify significant scheduling algorithms for the Uplink and Downlink channels that use QualNet-5.0. Finally it aims to measure the important metrics of the scheduling algorithm.[2]

2. OVERVIEW OF WIMAX SCHEDULING

IEEE 802.16 standard specifies five scheduling types: UGS, rtPS, ertPS, nrtPS, and BE. UGS is designed for constant bitrate (CBR) or CBR-like flows such as VoIP, which require constant bandwidth allocation, and the BS allocates a fixed number of slots on a periodic basis. The rtPS service is designed for variable bit-rate (VBR) flows such as MPEG video, which have specific bandwidth requirements as well as the maximum latency. The BS provides periodic unicast request opportunities for contention-free Bandwidth Request (BR). However, the scheduling method of the BS on how to allocate slots for the data transmission is not defined in the IEEE 802.16 standard. The ertPS builds on the efficiency of both UGS and rtPS and is designed to support real-time service flows that generate variable-size data packets on a periodic basis, such as Voice over IP services with silence suppression. As the names suggest, the nrtPS and BE are for VBR nonrealtime applications (e.g. bandwidth intensive file transfer) and best-effort applications (e.g. HTTP), respectively.

Manuscript received January 5, 2026
Manuscript revised January 20, 2026
https://doi.org/10.22937/IJCSNS.2026.26.1.16

In WiMAX, QoS is maintained at the granularity of connection which is identified by a unique Connection ID (CID). Before an SS can start to send or receive data, it must register with the BS, negotiating the initial QoS requirements with the BS. Then a new connection can be established on demand with its specific QoS requirement. Since each connection is associated with a single scheduling service, there can be multiple separate connections between the BS and SS. The IEEE 802.16 supports two types of uplink bandwidth allocation modes: grant per connection (GPC) and grant per SS (GPSS). In the case of GPC, the bandwidth is granted to each connection individually. In contrast, for GPSS, the bandwidth is granted to each SS and it is the SS that decides how to allocate the bandwidth among its active connections. Since GPSS mode is more scalable and efficient than GPS, GPSS is considered in this paper. In order to track resource demands, the BS maintains separate queues for the downlink connections, and keeps so-called virtual queues individually for the uplink connections. The downlink queue is updated whenever a packet has been transmitted or comes from the upper layer. And the uplink virtual queue is based on the bandwidth request from the relevant SS, which corresponds to the uplink resource demand of the SS. The uplink virtual queue is updated whenever the BS receives a bandwidth request or an uplink packet from the connection.

Based on the QoS parameters and the resource demands, the BS can make a scheduling decision for the uplink and downlink sub-frames. The BS scheduler should allocate bandwidth to connections by the order of the QoS requirements and has to assign slots based on the features of the connection's scheduling service. Having analyzed the service classes, it is possible to arrive at a conclusion that the bandwidth allocation should follow strict priority, from highest to lowest: UGS, ertPS, rtPS, nrtPS and BE. In addition, a specific scheduling algorithm should be used within certain scheduling type. For example, the UGS class does not send Bandwidth Request and cannot participate in the contention resolution, and the BS always allocates fixed resource based on the bandwidth requirement. On the other hand, the BE service has no minimum rate requirement, and the bandwidth is allocated to this service after the QoS requirements are satisfied for other services.[3]

3. LITERATURE REVIEW: SCHEDULING ALGORITHMS EVALUATION

Several researchers analysed and evaluated different scheduling algorithms: In 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.

The system parameters in the simulation consists of a single BS and a number of Mobile Stations (MSs), varies from 10 to 50 MSs, the BS radius range is 1000 meters, MS radius range is 500 meters, the frequency band is 2.4 GHz, the channel bandwidth is 20 MHz, frame duration of 20 ms, the Fast Fourier Transform (FFT) size is 2048, the BS transmission power is 20/5 P_t dBm/height (m), the MS transmission power is 15/1.5 P_t dBm/height (m), and a simulation time of 30 seconds, the QoS parameters that the simulation covers are BE, nrtPS, rtPS, ertPS, and UGS.[2]

Six experiments with different parameters were carried out; the results showed that the SP, WRR and WFQ are more efficient in terms of end-to-end time delay, the behaviour of algorithms were widely different when the number of MS was small (10 MS), RR dominated other algorithms when the number of MSs became more than 50, SCF performed better than Diffserv, WRR, SP, and WFQ when the number of MS became more than 40, RR algorithm achieved the highest value of throughput when the number of MS was more than 30, WFQ showed the best performance as the average end-to-end time delay had the lowest reading. Another observation that the RR algorithm was the most efficient in terms of overall throughput 125Kbps, SP and WRR had the shortest amount of end-to-end delay time for all classes of QoS, RR algorithm achieved the best percentage of fairness index. And as a conclusion of this evaluation, the best scheduling algorithms were: WF, in terms of the amount of end-to-end delay. RR algorithm was the best in terms of packet latency (Jitter). Finally WRR outperformed the rest scheduling algorithms by producing the highest rate of throughput of data packet in the network.

In [4], Ashish Jain and Anil K. Verma descried three scheduling algorithms which were: Proportionate Fair (PF) Scheduling [5], Cross-Layer Scheduling Algorithm [6] 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. First for PF algorithm which had the advantage of fairness in scheduling priority based, and a simple implementation multi-user diversity gain, but in this algorithm no QoS parameters were guaranteed. 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. And finally the TCP-aware uplink algorithm which was efficient in utilizing the resources among BE connections, but this was not enough to treat with only one class of QoS, and it has a complex implementation. In [8], Ahmed Rashwan, Hesham ElBadawy, and Hazem Ali performed a detailed simulation study, in addition to analysing and evaluating the performance of some scheduling algorithms, which were WFQ, Round Robin, WRR and Strict-Priority. The simulation experiments were performed using QualNet version 4.5 evaluation version. The system parameters in their simulation consisted of five MHz bandwidth with 512, the Fast Fourier Transform (FTT) size was configured to simulate bandwidth congestion in order to study the effect of the heavy traffic on each QoS class with different scheduling algorithms, a transmission parameter with TX-power of 15 dBm were used, channel bandwidth of 5 MHz, FFT size of 512, cycle prefix of 8, frame duration of 20ms and TDD duplex mode, and the parameters for the BS were: OMNI antenna type, 15 dB antenna gain, and 25ms antenna height, eight queues were configured to avoid queuing packets of different service types into one queue. And the precedence for each class of QoS is: BE of 0, nrtPS of 2, rtPS of 3, ertPS of 4 and UGS of 7. 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, Strict-Priority scheduler produced the highest UGS, rtPS traffic against the speed since it serves the highest priority traffic queues, RR was fair algorithm but this make it degrade the UGS, rtPS throughput to approximately half of the Strict-Priority, at the same time it increased the BE, nrtPS to be double more, RR scheduler had equal average end-to-end delay for all traffic types except for the BE it had a higher value. RR scheduler had also better performance for low QoS classes on the expense of the high QoS classes. Both WFQ and WRR can control the performance of each class by assigning different weight to each queue.

In [9], 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 [10], conducting several numbers of simulations for each case of the study to assure 95% confidence interval and a simulation time of 200 seconds. One-way core network delay was set to 31 ms.

The traffic mix was simulated, having 5 VoIP connections, 5 video streaming connections (DL only); 10, 14, 18, 22, 26 or 30 web browsing connections and 5, 7, 9, 11, 13 or 15 file downloading connections per BS. All user traffic was given BE treatment except for VoIP traffic that was given rtPS treatment.

The network parameters used in the simulations: PHY is OFDMa, and the duplexing mode was TDD, a frame length of 5 ms, the bandwidth used was 10 MHz, FTT size of 1024, cyclic prefix length was 1/8, the Transmit-receive Transition Gap was 296 PS, the Receive-transmit Transition Gap was 168 PS, the DL/UL permutation zone was FUSC/PUSC with ratio 35/12, the DL-MAP/UL-MAP fixed overhead was 13 bytes/ 8 bytes, and one opportunity as a number of ranging, ranging back-off start/end was 0/15, three opportunities as a number of requests, request back-off start/end was 3/15, the CDMA codes for ranging and BW requests of 64/192,the maximum size for MAC PDU was 100 bytes, the fragmentation and packing were taken into account, all connections but VoIP with ARQ (Automatic Repeat reQuest) [11], and all the connections were with ARQ feedback types, the ARQ block size of 16 bytes, and the window size of 1024, and there was no ARQ block arrangement.

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, meanwhile the PF scheduler can leave a connection without any resources for a long time period that if it was large enough make a problem if ARQ times were set to expire in short time, in other hand, the differences of round-trip time RTT may lead to retransmissions of TCP, that make it possible to the TCP good-put to be degraded, WDRR scheduler performed better than

PF when the traffic load was small, since the PF algorithm needs to have enough connections to achieve throughput gain, and by increasing the number of connections the PF algorithm picked the connections with a good MCS, however when the time reserved for connections without resources was large in the PF scheduler to had a better TCP good-put cause increasing in delay, 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.

4. RELATED WORKS

Scheduling is one of the most important topics in WIMAX development. Currently in the literature, many scheduling algorithms are introduced. They could be classified into two main categories: channel-unaware and channel-aware schedulers. Basically, the channel-unaware schedulers use no information of the channel state condition in making the scheduling decision. The channel-aware schedulers take into account channel state and the channel quality variation between the subscriber station and the base station. Channel-unaware schedulers generally assume error-free channel since it makes it easier to prove assurance of QoS. However, in wireless environment where there is a high variability of radio link such as signal attenuation, fading, interference and noise, the channel-awareness is important. Ideally, scheduler designers should take into account the channel condition in order to optimally and efficiently make the allocation decision [12].

Several research works have been conducted in order to provide QoS in IEEE 802.16 networks [13-22]: In [13], a channel-unaware scheduling architecture for the IEEE 802.16 was presented. Different scheduling algorithm was implemented for the service flows, the UGS traffics are scheduled with First In First Out (FIFO), the rtPs traffics are scheduled with Earliest Deadline First (EDF), the nrtPs traffics are scheduled with Weighted fair queuing (WFQ) and Best Effort traffics are scheduled with Round Robin (RR). However, implementing different scheduling algorithm may increase the complexity and decrease the consistency of the system.

Ting et al. Proposed Random Early Detection (RED) based Deficit Fair Priority Queuing scheduler [14] for bandwidth allocation among the service classes of WiMAX networks. It uses dynamics Deficit Counters (DCs). First it transmits the rtPS packets and then the nrtPS packets will be transmitted. If there is no rtPS or nrtPS packet left, scheduler transmits BE packets. This algorithm ignores the channel quality and the low priority traffic will be suffered from starvation.

In [15], a channel-unaware scheduling algorithm was presented. It based on Round Robin but the channel quality was ignored. However, the main weakness of the study is treatment of time sensitive service flow and time insensitive service flow with the same manner.

New ideas were proposed in [16-17], it based on Deficit Round Robin (DRR) and Weighted Round Robin (WRR). The proposed algorithm used for the downlink and uplink schedulers, respectively. These algorithms are suitable for non real-time data services because they focus on the throughput guarantee of data flows and ignore the channel quality.

A Customized Deficit Round Robin (CDRR) was proposed in [18]. This scheduling algorithm is based on Modified Deficit Round Robin (MDRR) [19] with High Priority Queue (HPQ) and new Call Admission Control (CAC) framework, but it ignores the channel quality.

Wail and Mai proposed a Modified WRR Scheduling Algorithm for WiMAX Networks [20]. They integrate both WRR and Strict Priority (SP). The author ignores the channel quality which affects the overall performance. Ali and Dimyati proposed new scheduling algorithms for Mobile WiMAX Systems called the Threshold based Cyclic Polling (TbCP) [21]. TbCP is a Priority Queue combine with threshold, but the channel quality was ignored.

Belghith and Nuaymi [22] discussed the maximum Signal to Interference Ratio (mSIR) which sorts the SSs bandwidth requests in descending order according to the received Signal to Noise Ratio (SNR) values and the BS serve the SSs in this order. Therefore, the mSIR has the heights throughput, but it does not guarantee fairness for small SNR to increase the capacity of the WiMAX system and it does not take into account the quality of service parameter like maximum latency. In addition, they proposed a new scheduling algorithm, namely, modified maximum Signal to Interference Ratio (mmSIR) which sorts the SSs in descending order according to the received signal to noise ratio (SNR) values and If the next SS to be served had a unicast opportunity in the next frame, the BS does not serve this SS. Otherwise, the BS serves the SSs having the highest SNR. The main drawback of mmSIR does not take into account the QoS parameters like maximum latency. So it serves real-time application and delay insensitive application with the same priority.

5. Conclusion

In this paper, various WiMAX scheduling algorithms strategy such as Strict Priority algorithm (SP), Round-Robin (RR), Weighted Round Robin (WRR), Weighted Fair Queuing (WFQ) and Self- Clocked Fair (SCF) have been reviewed and the working of their respective schedulers have been studied in case of data communication. It has been analyzed that the Strict Priority (SP) scheduling algorithm does not perform well as compared to other scheduling algorithms due to the reason of its bandwidth starvation.

References

[1] Marcio Andrey Teixeira and Paulo Roberto Guardieiro , **Quality of Service and Resource Allocation in WiMAX** ,Federal Institute of Education, Science and Technology of São Paulo,Faculty of Electrical Engineering, Federal University of Uberlândia,Brazil, **Publisher** InTech, February 2012.

[2] Mohammed Sabri Arhaif,"Comparative Study of scheduling Algorithms in WiMAX ", (IJSER) International Journal of Scientific & Engineering Research ,Vol. 2,No.2,Februrary – 2011.

[3]yanquen Le,Yi Wu & Dongmei Zhang,"An Improved Scheduling Algoritham for rtPS Service in IEEE 802.16 ", IEEE,2009.

[4] Comparative Study of Scheduling Algorithms for WiMAX. Ashish Jain, Anil K. Verma. Chennai, India : Proceedings of the National Conference on Mobile and Pervasive Computing,2008. pp. 10-13.

[5] Data throughput of CDMA-HDR a high efficiency-high data rate personal communication wireless system. Jalali, A., Padovani, R. and Pankaj, R. Tokyo, Japan : Proc. IEEEE VTC pp.1854–1858, 2000.

[6] A Cross-layer scheduling Algorithm with QoS support in wireless. Liu, Q., Zhou, S. and Giannakis, G.B. 3, s.l. : IEEE Transactions on vehicular Technology, 3, May, 2006, Vol. 55.

[7] TCP-aware Uplink scheduling for IEEE 802.16. Kim, Seungwoon and Yeom, Ikjun. s.l. : IEEE Communication Letter, Feb., 2007.

[8] Comparative Assessments for Different WiMAX Scheduling Algorithms. Ahmed H. Rashwan, Hesham M.ElBadawy, Hazem H. Ali. San Francisco, USA : World Congress on Engineering and Computer Science, 2009, Vol. 1. ISBN:978-988-17012-6-8.

[9] Comparison of Different Scheduling Algorithms for WiMAX Base Station. Jani Lakkakorpi, Alexander Sayenko, Jani Moilanen. Las Vegas, Nevada : IEEE Wireless Communications and Networking Conference WCNC, 2008, Vol. 08. 1525-3511.

[10] UCB/LBNL/VINT, "Network Simulator – ns (version 2)", 2011. http://www.isi.edu/nsnam/ns/index.html

[11] A. Sayenko, V. Tykhomyrov, H. Martikainen and O. Alanen, "Performance Analysis of the 802.16 ARQ Mechanism," Proceedings of IEEE/ACM MSWiM 2007, Chania, Greece, Oct. 2007.

[12] E.Laias,I.Awan ,and P.M.L.Chan , "Fair and Latency Aware Uplink Scheduler in IEEE 802.16 Using Customized Deficit Round Robin ," Advanced Information Networking and Applications Workshops , pp.pp.425-432 ,May 2009.

[13] K. Wongthavarawat and A. Ganz, "Packet Scheduling for QoS Support in IEEE 802.16 Broadband Wireless Access Systems", International Journal of Communication Systems, Vol. 16, 2003, pp81-96.

[14] Po-Chun Ting, Chia-Yu Yu, and Naveen Chilamkurti, "A Proposed RED-based Scheduling Scheme for QoS in WiMAX Networks," IEEE International Symposium on Wireless Pervasive Computing (ISWPC), February 2009.

[15] C. F. Ball, F. Treml, K. Ivanov, and E. Humburg, "Performance evaluation of IEEE 802.16 WIMAX with fixed and mobile subscribers in tight reuse," European Transactions on Telecommunications, Vol. 17, pp.203–21., March 2006.

[16] C. Cicconetti, et al., "Quality of service support in IEEE 802.16 networks," IEEE Network Magazine, Vol. 20, Issue 2, pp. 50–55, 2006.

[17] C. Cicconetti, L. Lenzini, and E. Mingozzi, "Performance evaluation of the IEEE 802.16 MAC for QoS support," IEEE Transactions on Mobile Computing, Vol. 6, no. 1, pp. 26–38, January 2007.

[18] E. Laias, I. Awan, and P. M. L. Chan, "Fair and Latency Aware Uplink Scheduler in IEEE 802.16 Using Customized Deficit Round Robin," Advanced Information Networking and Applications Workshops, pp. pp.425-432, May 2009.

[19] Cisco Systems, "Understanding and Configuring MDRR/WRED on the Cisco 12000 Series Internet Router", (http://www.cisco.com/warp /public/63/mdrr_wred_overview.html).

[20] W. Mardini, M.A. Alfool, "Modified WRR Scheduling Algorithm for WiMAX Networks," Network Protocols and Algorithms journal, Vol. 3, No.2, 2011.

[21] D. M. Ali and K. Dimyati, "Threshold based Cyclic Polling (TbCP): An Uplink Scheduling Algorithm for Mobile WiMAX Systems," International Journal of Information and Electronics Engineering, Vol. 1, No. 1, July 2011.

[22] A. Belghith and L. Nuaymi, "Comparison of WiMAX scheduling algorithms and proposals for the rtPS QoS class," 14th European Wireless Conference, 22-25 June, 2008.