# PRIORITY BASED UPLINK SCHEDULER FOR IEEE 802.16 NETWORKS

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***Abstract*— IEEE 802.16, the standard for fixed, portable and mobile Broadband Wireless Access (BWA) systems, is promising to support different classes of traffic with Quality of Service (QoS). The Medium Access Control (MAC) protocol defines a wide variety of mechanisms for bandwidth allocation and QoS provision. However, the details of how to schedule traffic are left unspecified. In this paper, we propose a scheduling strategy for uplink traffic. Simulation results show that our scheme is capable to provide required QoS.**

***Keywords- 802.16 Networks, Quality of Service, MAC***

## I. INTRODUCTION

IEEE 802.16 is a set of telecommunications technology standards aimed at providing wireless access over long distances in a variety of ways - from point-to-point links to full mobile cellular type access [1]. It covers a metropolitan area of several kilometers and is also called WirelessMAN. The IEEE 802.16 advantages include variable and high data rate, last mile wireless access, point to multipoint communication, large frequency range and QoS for various types of applications. Despite of the above advantages, IEEE 802.16 WirelessMAN lacks in MAC scheduling architecture in uplink as well as downlink direction. Efficient scheduling design is left for the designers and thus providing QoS for IEEE 802.16 BWA system is a challenge for system developers. IEEE 802.16 standard [1] defines four types of service flows, each with different QoS requirements. Each connection between the SS and the BS is associated to separate service flow in both uplink and downlink direction.

The Un-solicited Grant Service (UGS) supports real-time service flows that have fixed size data packets on a periodic basis. The BS provides grants in unsolicited manner.

Real time polling Service (rtPS) supports real-time service flows that have variable size data packets on a periodic basis. The BS periodically provides unicast request opportunities in order to allow the SS to specify the desired bandwidth allocation.

The non-real-time Polling Service (nrtPS) is designed to support non real-time service flows that have variable size data packets on a periodic basis. The SS can use contention request opportunities to send a bandwidth request with contention. The SS can also be provided with unicast request opportunity.

BE is used for best effort traffic where no throughput or delay guarantees are provided. The SS can use unicast request opportunities as well as contention request opportunities.

A variation of the 802.16 standard, named 802.16e, was introduced to provide mobility to users. In the 802.16e standard a new service flow called extended real-time Polling Service (ertPS) was added. It is built on the efficiency of both UGS and rtPS. The BS provides unicast grants in an unsolicited manner like UGS. Whereas the UGS allocations are fixed in size, the ertPS allocations are dynamic. SS can change the size of grants by sending bandwidth change request.

IEEE 802.16 architecture in PMP mode consists of one Base Station (BS) and many Subscriber Stations (SSs). The only allowed communication is between SS and BS. SSs are allowed to send data only at scheduled time that is decided by the BS and communicated to all SS in the beginning of each frame in Uplink Map (UL-MAP)[1]. Scheduling has to be done in uplink as well as in downlink direction. Scheduling in downlink direction is relatively easy because BS has all the required information, but the scheduling in uplink direction is complex because of various parameters like number of clients, associated flows, delay bounds and required bandwidth of each flow.

To support QoS requirement of subscribers various scheduling approaches exists. Some of them are designed by modifying scheduling algorithms defined for wired networks but this approach does not give accurate results due to dynamic state of channel in wireless networks. Besides this, different scheduling algorithms work on a single approach to schedule different traffic classes [10]. Some of the algorithms supports the scheduling of one particular type of traffic like rtPS or BE [11].

In this paper we propose an uplink-scheduling scheme that may satisfy the QoS requirements of UGS, rtPS, ertPS, nrtPS and BE service flows and simulations results obtained using ns-2 are validated for QoS guarantees and allocation of fair bandwidth to SSs.

This paper is organized as follows. Section II presents the proposed uplink scheduler. Section III presents several simulation scenarios. Section IV discusses related work. Finally, Section V concludes the paper.

## II. SCHEDULING STRATEGY

MAC protocol of IEEE 802.16 is connection oriented to support multiple QoS classes to accommodate heterogeneous traffic. Each SS sends a request message containing its class and traffic specifications. BS accepts the connection when enough resources are available to accommodate it. The BS performs the bandwidth allocation according to an appropriate scheduling scheme. The SS can send or receive data through the allocated bandwidth [1].

To allow multiple QoS requirements, the proposed uplink scheduler keeps the data grants in three types of queues, Type1, Type2 and Type3. The scheduler allocates the resources by following strict priority from Type1 to Type3 queue. Type1 queue stores the periodic grants and unicast requests that must be scheduled in the next frame. Type2 queue stores the bandwidth requests of rtPS and nrtPS connections. These requests can migrate to Type1 queue to meet their QoS requirements based upon timeout value. The Type3 queue stores the bandwidth requests of BE connections.

To ensure the bandwidth to UGS connections, data grants are periodically inserted into the Type1 queue. SS sets the period for grants at the time of connection establishment. The unicast request grants are also inserted into the Type1 queue to give bandwidth request opportunities to the rtPS connections. The BS defines intervals between the request opportunities to rtPS and nrtPS connections. BS computes the timeout value for each rtPS request in Type2 queue. For computing the timeout value BS must know the arrival time of packets at the SSs queue, but BS has no access to this information. The timeout of the request is equal to the sum of the arrival time of last request sent by the connection and its maximum tolerable delay. Scheduler will migrate the requests whose timeout is going to expire in the next frame to Type1 queue.

To guarantee the minimum bandwidth requirement of rtPS and nrtPS connections over a window of duration T, scheduler calculates a priority value on the basis of minimum bandwidth requirement, amount of backlogged requests (in bytes) and amount of bandwidth received in the current window for all the requests in the Type2 queue. The priority assigned to a request is inversely proportional to the amount of bandwidth received by the connection to which it belongs. Low priority values are assigned to those requests sent by the connections, which has already received the minimum required bandwidth in the current window. Type2 queue is sorted on the basis of priority values and request with high priority value are migrated to Type1 queue. The requests in the Type3 will be taken up for the bandwidth allocation after satisfying the needs of type1 and type2 queues.

## III. SIMULATION RESULTS

To evaluate the effectiveness of the proposed scheduler, we carried out discrete event simulation experiments using ns2-module for IEEE 802.16 networks. The topology of the simulated network consists of a BS wire-attached to a fixed node through a 100 Mbps link with 2 ms delay. The BS was located at the center of a 250x250 meter area, and the SSs were uniformly distributed around it.

### *A. Experiment 1*

The aim of this experiment is to analyze the effect of increasing the frame size on the delay as the rtPS load is varied in the system. For this purpose, the simulated scenario includes one BS and 26 SSs. In the experiment, there are 3 UGS connections, 2 nrtPS connections, 2 BE connections, and the number of active rtPS connections varies from 5 to 20.

Figure 1 shows the delay of the rtPS connections with variations in the frame size. The delay for low load is not affected much by the frame size. However as the load increases the delay decreases with increasing frame size. This is expected as more number of requests are processed by the scheduler per frame, so queue size decreases as frame size is increased. This leads to a decrease in the delay.

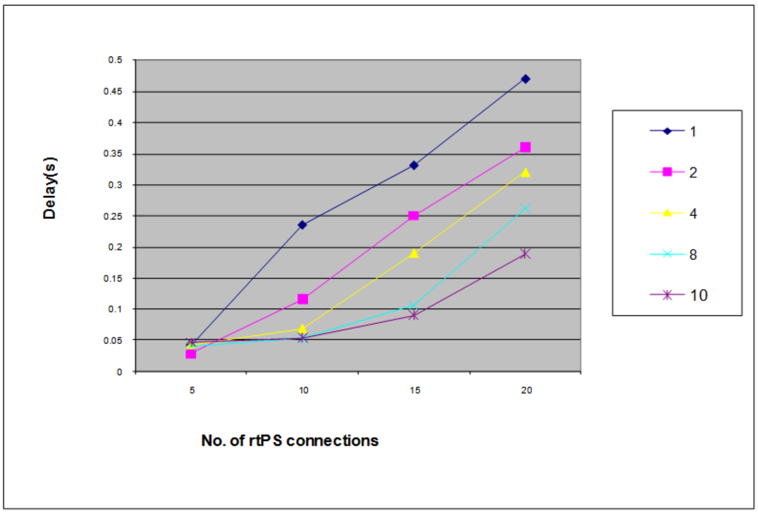


Fig. 1 Delay of rtPS connections with frame size variations

## B. *Experiment 2*

This experiment verifies the impact of variation in number of contention slots on the throughput of nrtPS connections. The scenario for this experiment consists of one BS and 60 SSs. There are 3 UGS connections, 3 rtPS connections, 2 BE connections and the number of active nrtPS connections varies from 5 to 25.

Fig 2 shows the throughput of the nrtPS connections with varying number of contention slots. The throughput for low load increases with increase in the number of contention slots. This is expected due to reduction in the collision probability with increasing number of contention slots. But as the load increases throughput start decreasing after a particular value of the contention slots. This is occurring because with the increase in the number of contention slots the available capacity dedicated to data transmission also decreases.

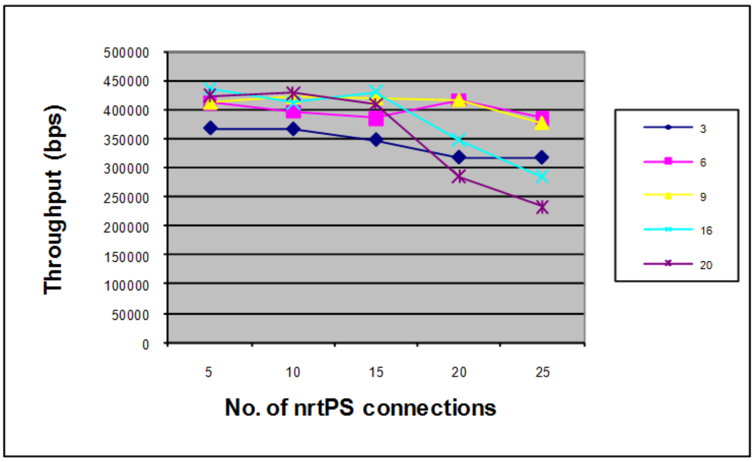


Fig 2 Throughput of nrtPS connections with variation in number of contention slots

## C. *Experiment 3*

The aim of this experiment is to analyze the effect of increasing the UGS traffic on the QoS level of services with other traffic classes. For this purpose, the simulated scenario includes one BS and 55 SSs. In the experiment, there are 5 rtPS connections, 10 nrtPS connections, 10 BE connections, and the number of active UGS connections varies from 10 to 30.

Fig. 3 shows the delay of UGS and rtPS connections. The delay of the UGS connections was not affected by the load increase, which shows that the scheduler is able to provide data grants at fixed intervals as required by this service. The delay of the rtPS connections varies from .027s to .032s as the number of UGS connections increased. Moreover, the delay values were considerable lower than the required one.

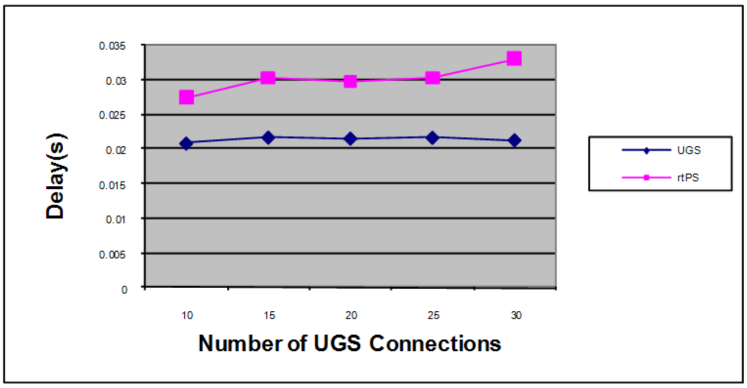


Fig. 3 Delay of UGS and rtPS connections

## IV. RELATED WORK

There are several papers on the WiMAX QoS scheduling that have presented architectures and scheduling disciplines to guarantee QoS. In [9,2] authors have focused mainly on the scheduling issues and components of the QoS architecture without presenting any exact method with the extensive simulation results.

The Deficient Fair Priority Queue (DFPQ) [5], which uses the maximum sustained rate as the deficit counter to specify the transmission quantum, dynamically adjusts the uplink and downlink proportion. Nonetheless, this method is suitable only for GPC rather than GPSS.

Uplink Packet Scheduling (UPS) introduced in [8] for the service differentiation. It applies the Strict Priority to the selection among service classes, in which the UL and DL have same capacity, and each service class adopts a certain scheduling algorithm for queues within it. However, this scheme deals with only uplink channel so the overall bandwidth utilization suffers.

Some of the previous works also include classical/standard scheduling algorithms like N Liu et al used Earliest Deadline First (EDF) [3], M. Shreedhar et al used Deficit Round Robin (DRR) [4], A.K Parekh et al used Weighted Fair Queuing (WFQ) [6] and J.C.R Bennett et al used Worst-case Weighted Fair Queuing [7]. Scheduling schemes based on these algorithms introduces overheads in scheduling. Moreover use of different type of scheduling algorithm for each traffic class is a challenging task, as QoS requirements of each connection should be translated to scheduler configuration. Furthermore, it is not enough to calculate the scheduler configuration only at SS entry and exit. As SSs send data, their request sizes changes with time resulting in re-calculation of scheduler configuration, which causes overheads in scheduling at BS.

## V. CONCLUSIONS

In this paper, an uplink scheduling mechanism for IEEE 802.16 networks was introduced. The proposed solution supports all the service flows specified by the standard and considers their QoS requirements for scheduling. Simulation experiments show the affect of frame size and number of contention slots on the rtPS and nrtPS traffic classes respectively. Results show that the strategy proposed is quite promising.

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