TWO-STEP SCHEDULING ALGORITHM FOR IEEE802.16 WIRELESS NETWORKS

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ABSTRACT

This paper proposes a new scheduling algorithm for IEEE 802.16-2005 Broadband Wireless Metropolitan Area Networks in TDD mode. The proposed algorithm focuses on an efficient mechanism to serve high priority traffic in congested networks, without violating the right of lower-priority-traffic to be served in adequate manner. In this work, a detailed simulation study is carried out for the proposed scheduling algorithm as well as comparing its performance with some known algorithms such as Proportional Fairness (PF)[12], Round Robin (RR), and Strict-Priority. Analysis and evaluation of the performance of the scheduler to support the different QoS classes is given as well. The simulation is carried out via the OpNet modeler simulator [13]. The results show the proposed algorithm is capable to handle different users' requirements under congestion conditions.

Keywords : Scheduling, Algorithm, Wireless Networks, IEEE80 2.16

I. INTRODUCTION

Broadband wireless access (BWA) systems, [1], [2] are flexible and easily deployable high-speed communication systems. BWA systems complement existing last mile wired networks such as cable modem and xDSL. IEEE 802.16 group aims to unify BWA solutions [1]. A technical overview of IEEE 802.16 is provided in[1], [3]. The objective is to have an efficient use of radio resources while serving different types of data flows. These flows can have different constraints such as minimum traffic rate, maximum latency, and tolerated jitter.

The IEEE 802.16-2005 standard supports three different physical layers: 1) Single Carrier, 2) OFDM/TDMA and 3) OFDMA [1]. OFDMA physical layer is the most efficient and complex one[4]. In OFDMA each substation (SS) can receive some portions of the allocation for the combination of time and frequency so that the channel capacity is efficiently utilized. OFDMA outperforms the OFDM & SC[4]. This research focuses only on OFDMA.

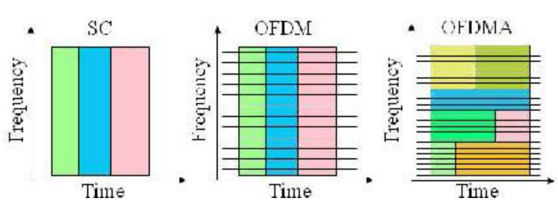

Figure 1: IEEE 802.16 PHYs: SC, OFDM and OFDMA

To support the different types of traffic with their various requirements IEEE 802.16-2005 defines five QoS service classes: Unsolicited Grant Scheme (UGS), Extended Real Time Polling Service (ertPS), Real Time Polling Service (rtPS), Non Real Time Polling Service (nrtPS) and Best Effort Service (BE). Each of these class is identified with a specific parameters like maximum sustained rate (MST), maximum latency or tolerated jitter (the maximum delay variation) that suites the type of traffic that it serves. A details overview of these classes characteristics as well as types of traffic assigned to each class is illustrated in[1].

In IEEE 802.16-2005, the process in MAC Layer responsible for allocating resources for SSs (Subscriber Stations) and active flows is called the scheduling process. Unlike other parts of IEEE 802.16, scheduling was left for research to specify it. The optimal scheduling algorithm is still in open research area [6], [7], [8]. In this research a new scheduling algorithm is proposed to provide a better allocation of resources to different SSs in case of congestion, based on their QoS parameters and priority

The remainder of this paper is organized as follows: Section II provides a review for relevant work and problem formulation. In section III, a detailed description of the proposed algorithm is given. Section IV describes the setup of the simulation environment Section V shows the results and output of simulation of the algorithm compared to other scheduling algorithms. Concluding remarks and directions for future work are given in section VI.

II. RELATED WORK AND PROBLEM FORMULATION

2.1 Related work

Scheduling techniques for WiMAX can be classified into two main categories: channel- unaware schedulers and channel-aware schedulers[4]. Channel-unaware schedulers use no information of the channel state condition in making the scheduling decision. The design of those schedulers varies based on the ultimate goal of the scheduler like, maximizing throughput or fair allocation of resources between different SSs. However, the main challenge facing researches is the distinctive characters of each of the QoS classes. No single queue algorithm can handle all QoS constrains simultaneously. For instance, no published researches show how to handle jitter over WiMAX, and most researches focuses on throughput rate or delay[4].

To overcome the obstacle above, many researches use Intra-class scheduling, where each class has a distinctive resource allocation mechanism that matches the requirements of the quality of service. Relation between inter classes is organized either on the bases of class-priority, where classes are served in the order UGS, ertPS, rtPS, nrtPS, BE, or on the bases of flow-priority, where highest priority flow is served first regardless of its class.

However, even within the same class, there are many constrains that can't be handled through one scheduler[4]. For instance, rtPS class is defined, by maximum sustained rate, minimum reserved rate, maximum latency and priority. Most existing scheduling algorithms give precedence to flows based on one or two of those parameters and neglect the remaining. For instance, RR, and all its variations WRR, WDRR[11], focuses only on the distribution of resource over all queues regardless of flow priority nor its minimum rate requirements. Other technique, like Max-Min Fair Allocation, focuses on giving priority to lowest data rate flow regardless of its priority or delay constrains. On the other hand, strict priority algorithms put more emphasis on high priority traffic, but causes other lower priority flows to starve.

To sum up, since the primary goal of a WiMAX scheduler is to assure the QoS requirements, the scheduler needs to support at least the five basic classes of services with QoS assurance. Since it is very difficult for any scheduler to handle all the parameters in one step, a new technique is proposed here to switch between different scheduling criteria's so the scheduler can consider many parameters simultaneously. For the time being, the design of the new algorithm is considering handling three types of quening,:1) priority queuing, 2) Proportional Fairness, and 3) Minimum traffic Maximization.

2.2 Problem formulation,

This research aims to design a scheduling algorithm which is capable of maximizing throughput of priority traffic in congested domains, where bandwidth needs of SSs exceeds system capacity. Meanwhile, the algorithm considers serving less priority traffic in a fair manner. Fairness here is defined for less priority traffic as its ability to fulfill the class constrains, including Minimum Reserved Rate (mRR) and maximum latency without bandwidth reservation. The research focuses on handling rtPS & nrtPS classes, UGS and ertPS classes are very sensitive for delay/bandwidth variation and will be handled via strict priority, where their needs are served before any other class. On the other hand BE class of service is not considered, since the standard doesn't specify any minimum requirements for its QoS parameters therefore BE classes will use the residual bandwidth.

III. PROPOSED ALGORITHM

As indicated above, most scheduling algorithms focus on one criterion to allocate resources (For example. Fairness, starving avoidance, Priority, etc..). This behavior creates imbalance distribution of resources between flows, which appears either in the form of starving of some flows, or ignorance of right of some flows to get the right bandwidth share that proportional to its priority.

To overcome this drawback, this research considers using a mixture of queuing methods simultaneously, for example priority queue, Fair queue, etc. Since two queuing methods can't be applied instantaneously, the algorithm initially chooses one queuing method then switches to other one based on the changes of system needs. The following subsection illustrates the details of the algorithm.

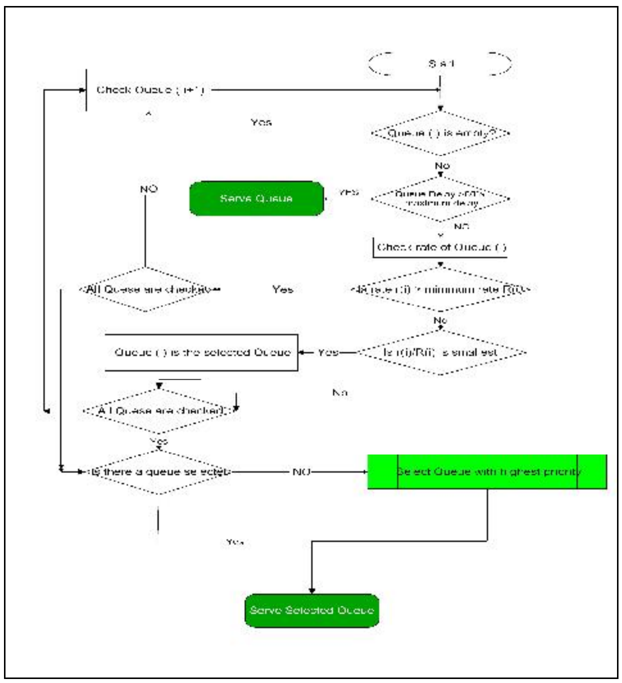

Figure 2: Flow Chart of the algorithm

To consider the various requirements of the flows, the algorithm defines two layers of priority, First layer, with higher precedence and always in the first place, priority is given to the flow that needs to be served to meet class of service minimum requirements. (For example to achieve minimum bandwidth requirements of the class or not to violate packets maximum latency). The second layer, which only considered(served) where there are no flows or queues match the first layer criteria, is a layer that gives precedence to priority traffic that needs to more bandwidth to meet its MST.

The following sequence is followed to choose which flow will be served

1- Ignore empty flows
2- Check packets latency (waiting for service time) in each flow queue.
3- If any packet latency is more than 80% of its flow maximum delay, serve it at once.
4- If no packet needs to be served according to the above criteria, check the transmission rate of each flow.
5- Serve queue that didn't reach its minimum Reserved Rate(mRR), giving priority to queue that has smallest (current rate/mRR).
6- If there in flows needed to be served according to previous criteria, switch to second layer of priority and serve flows according their priority, considering using fair queuing between queues with the same priority.

In this algorithm, delay checking step is considered the most significant step to guarantee the success of the algorithm. Ignoring this step could lead to a high jitter and delay for different flows even if they have high priority. Without this step a burst of traffic in an idle flow, might lead to big latency in remaining flows till this flow achieve its mRR.

Figure 3 System Model Implementation in Opnet

To reduce jitter problems, the algorithm uses an extra procedure, which is optimizing the burst window of each flow so that each flow will only be allowed to send part of its MST, in this window instead of sending its whole need of packets sequentially causing high jitter to other flows. Typically,20 window are used, each window length is around 50MS, and the flow is not permitted to send no more than 5~10% of its MST(according to packets size) in this period. Considering that for rest measures of the algorithm is still using the 1 second period to calculate, flows' current rate, mRR and MST.

Following are the simulation environment, and output results of the algorithm.

IV. SIMULATION MODEL

The over all goal of the simulation model is to analyze the behavior and performance of the proposed algorithm in a congested domain The simulations have been performed using Opnet Modeler version 15.0 [13].The important parameters used to configure the PHY and MAC layers are summarized in table (1)

The simulation assumes error-free channel since it makes it easier to prove assurance of QoS. Maximum theoretical capacity of the upload system is estimated as follows:

Upload Data rate = *number of uncoded bits per data symbol * total number of upload symbols*

.In this model : *number of uncoded bits per data symbol,= 560 * 6 *3/4 = 2520 bit*, where 560 is total number of data sub carrier for upload PUSC usage mode.

Data rate *=2520*12 symbol per frame *200 Frame= 6.048Mbps*

The simulation environment consists of one BS and (20~26) SSs operating in IEEE 802.16 PMP mode. There will be one service flow between each SS and the BS. Traffic flows classes and their configuration is indicated in Table(2).

Since the simulated rtPS and nrtPS SSs are using polling service, which uses BPSK modulation at1/2 coding rate, it can be assumed that the idle average throughput of upload bandwidth is 5.5Mbps. *So,* the congestion criteria in this model is achieved via increasing the total maximum sustained rate requirements of all substations to exceed 5.5Mbps

The congestion condition in the system is conducted via increasing throughput load on the BS by increasing number of flows of a specific type (for example video priority traffic).

Model	Point to Multipoint
WIMAX channel bandwidth	= 10 MHz
Frame duration	5ms
Symbol Duration	102.86 Micro second
N	28/25
Delta_f	10.94khz
Number of sub carriers	1024
Frame structure	
Preamble symbols	1 symbol
Dublexing technique	TDD
Base Frequency	2.5GHZ
TTG	106 micro second
RTG	60 micros second
UL/DL Boundary	Fixed
UL sub frame size	= 12 slot
DL sub frame size	= 32 slot
Initial ranging	= 2 slot * 6 sub channel
Contention slot	= 1slot * 6 sub channel
Initial coding rate	¾
Initial modulation	64QAM

Table 1: MAIN PARAMETERS OF THE SIMULATION MODEL

Class	Max. rate Kbps	Min. Rate kbps	Pri	Traffic Type	No of SS
UGS	100	100	N/A	Video	2
RTP	384 ~600	200	20	Video	2~8
RTP	384	200s	10	Video	2
nRTP	384	200	20	FTP	1
nRTP	384	200	10	FTP	2
nRTP	200	100s	10	FTP	2
RTP	200	100	20	Video Conf.	2
RTP	200	100	10	Video Conf.	2
RTP	60	40	20	VOIP	3
BE	384	N/A	N/A	HTTP	2

Table2: Service flows

V. RESULTS

In this section, the output of simulation is shown and analyzed

Figure (4)&(5) compare the average throughput & real time throughput of low-priority station with same MST and mRR, (where MST equals to 400Kbps, mRR equals to 200kbps), while flow maximum delay varies from 50ms up to 300ms. It is shown from figure(4) that all the SS successfully meets the minimum class constrains, which is the mRR, despite of congestion, which is 120% , in the shown case. The effect of the maximum allowed delay value on the behavior of the throughput of the SS is shown in figure (5). It is shown that for very small delay allowance, 50 ms, the system send packets at almost a constant rate. Variance in packet delivering rate increases as maximum delay allowance increase. This result confirms the importance of choosing maximum delay as the first criteria in the algorithm to serve packets. Without maximum delay criteria, jitter of time sensitive traffic, as voice or video, can be affected severely.Note that rtPS class allows SS to be polled at fixed intervals, but doesn't guarantee bandwidth to the request.

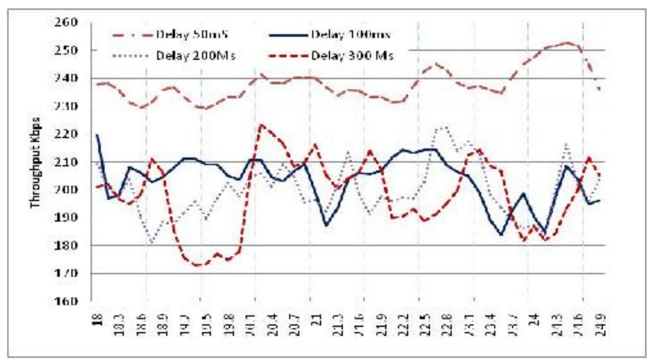

Figure 4: Average throughput of low priority traffic with different minimum delay

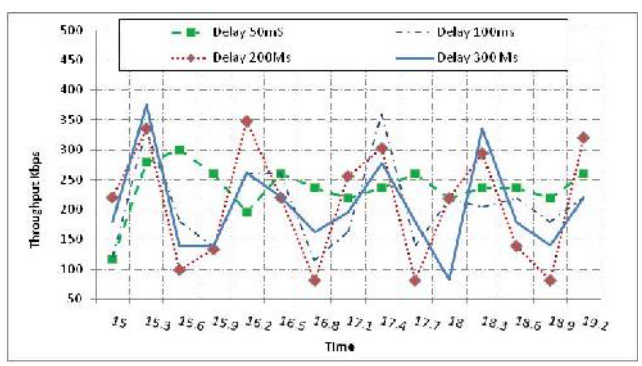

Figure 5: Throughput of low-priority traffic in real time.

Figure(6) shows the throughput of low priority traffic under different scheduling algorithms. It is shown that the proposed Two-step algorithm adopts its behavior to slow declining in throughput and keeps it at 50%, which in the proposed case equals to 200kbps, which is the MRR. The performance of throughput is less than RR and Fair Queue algorithms, however, this is due to dedicating more bandwidth to higher-priority traffic as shown in Figure(7) Figure (s) Shows how the algorithm has higher throughput, for higher priority traffic, Compared to RR & FQ.

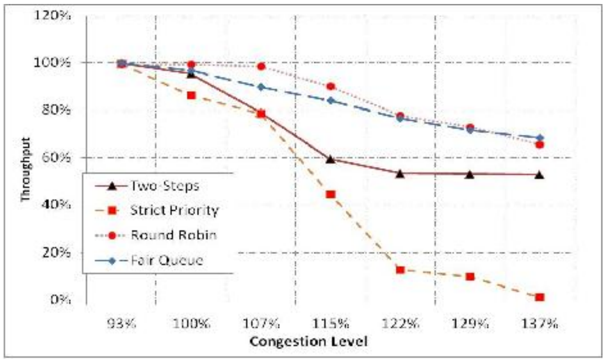

Figure 6: Throughput of low-priority traffic under different scheduling algorithms

Figure (7) shows that the proposed two-steps algorithm has lower performance, for high priority traffic, compared to Strict Priority algorithm. Whoever, the, algorithm avoids the main drawback of SP, which is the starvation of low priority traffic as shown in Figure (6), where the two-steps algorithm meets the minimum flow requirements , mRR & delay of the flow to survive.

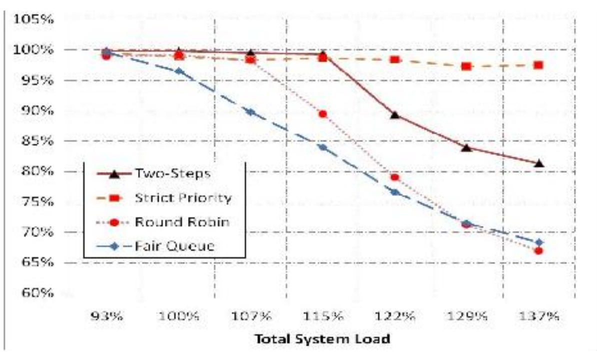

Figure 7: Throughput of High-priority traffic

VI. CONCLUSIONS

In this paper, a new scheduling algorithm for IEEE 802.16 Wireless MAN in PMP mode is given. The algorithm proposes a mechanism to show how the BS can balance between serving high and low priority traffic simultaneously. The algorithm gives precedence to high priority traffic, to reach its MST, but only when lower priority traffic is capable to achieve its MRR. The algorithm also monitors all traffic flows to guarantee that no flow, whether high or low priority will violate maximum delay limitation of the flow.

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