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A Dynamic Uplink Scheduling Scheme For WiMAX Networks

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ABSTRACT: There has been a rapid growth of new services such as online video games, video conferences and multimedia services to end users. WiMAX is an emerging technology for next generation wireless networks which supports a large number of users. To achieve Quality of Service (QoS) requirements, an efficient and reliable scheduling algorithm is needed. Among a large number of the proposed approaches in the literature, a Variably Weighted Round Robin scheduling algorithm (VWRR) has been proven to provide the best performance in an IP backbone network with no attempts on WiMAX networks. This paper proposes dynamic uplink scheduling algorithm for WiMAX networks based on VWRR to allocate the bandwidth to users to maximize the throughput and ensure the constraints of delay, jitter, and load. A comparative study between the proposed scheduling algorithm and the two most famous scheduling algorithms: Weighted Round Robin algorithm (WRR) and Modified Deficit Round Robin algorithm (MDRR) over WiMAX networks, is presented. Simulation results obtained using OPNET reveal that the proposed algorithm has a superior performance compared with WRR with respect to throughput, delay, jitter, and load. Additionally, the proposed scheduling algorithm is shown to provide an excellent level of reliability and scalability when increasing the number of served subscriber stations.

KEYWORDS— WiMAX; QoS; IEEE 802.16; VWRR; scheduling Algorithms

I.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. The standard does not define the scheduling algorithm which guarantees the QoS required by the multimedia applications. QoS is increasingly becoming one of the fundamental requirements for WiMAX to act as a key technology for the delivery of services for high-speed. To meet the QoS requirements of multimedia applications, a robust scheduling algorithm is needed to allocate the bandwidth to users to maximize the throughput and ensure the constraints of delay,jitter, and load.A critical survey on WiMAX scheduling algorithms is presented. The authors in [4] mentioned that the main responsibility of the scheduling algorithm is done by distributing the bandwidth and resources among subscriber stations (SSs). A comprehensive performance study of uplink scheduling algorithms using simulation analysis is introduced in [5]. The simulation analysis was carried out using average delay, average throughput, fairness, and frame utilization. A performance analysis of scheduling algorithms over WiMAX networks is found in [6, 7, 8, 9].The packets that cross the MAC layer are classified and associated with a service class. The IEEE 802.16 standards define five service classes: Unsolicited Grant Service (UGS), extended real-time Polling Service (ertPS), real-time Polling Service (rtPS), non real-time Polling Service (nrtPS) and Best Effort (BE). Each service class has different QoS requirements and must be treated differently by the Base Station.The scheduling algorithm must guarantee the QoS for both multimedia applications (real-time and non-real-time), whereas efficiently utilizing the available bandwidth. Some other recent approaches have relied on performance simulation studies of different scheduling schemes such as weighted fair queuing (WFQ), random early detection (RED),fair queuing (FQ), deficit round robin (DRR), round robin (RR), and weighted round robin (WRR)

[9, 10, 11, 12]. It has been proven that a weighted scheduling algorithm with a dynamic bandwidth allocation weight function gets the best performance for WiMAX networks [10]. This paper proposes a scheduling algorithm that is based on VWRR [13] scheduling scheme for WiMAX networks. A comparative study between the proposed algorithm and both MDRR [14] and WRR [5] for point-to-multipoint WiMAX networks is also presented. The reminder of this paper is organized as follows. In Section II, an overview of WiMAX networks is introduced. The most famous scheduling algorithms are introduced in Section III. The proposed approach is presented in Section IV. Finally, conclusions and future work are reported in Section V.

II. Overview Of WiMAX Networks

WiMAX networks [1, 2, 4] consist of two main layers:

Physical layer (PHY) and the medium access control layer (MAC). The PHY layer is defined on IEEE802.16 standard using many physical layer types such as: wireless MANOFDM (orthogonal frequency division multiplexing), wireless MAN-SC (single carrier), wireless MAN-SCa, and wireless MAN-OFDMA. WiMAX can use two types of duplexing: frequency division duplexing (FDD) and time division duplexing (TDD) in frame structure to send data. The frame structure consists of two sub-frames: downlink sub-frame an uplink sub-frame. The downlink sub-frame implies data from the base station (BS) to subscriber stations (SSs) and some control information such as: preamble, downlink and uplink maps. The uplink sub-frame delivers information from SSs to BS such as channel quality information and uplink bursts. Downlink and uplink sub-frames are separated by a Transmit receive Transition Gap (TTG) and Receive-transmit Transition Gap (RTG). The reported results in this paper are deduced based on TDD.The main feature of WiMAX is the QoS support [3,4]. WiMAX is designed to manage dissimilar applications, including voice, video, and data by defining five different service classes for constant and variable bit rate applications. There are five service classes outlined as follows. Unsolicited grant service (UGS) which is used to support constant data rate real-time applications such as VoIP without silence suppression. Real-time polling service (rtPS), which is defined to support real-time applications with variable data rate such as a MPEG compressed video. Extended realtime polling service (ertPS), which is used to support real-time applications with variable data rate such as VoIP with silence suppression. Nonreal- time polling service (nrtPS), which is defined for variable bit rate non-real-time applications. Finally, the best effort (BE) service class defines non-real-time applications with no need of any special requirements. There are two types of operation modes in WiMAX networks [4, 5]: point-to-multipoint (PMP) mode and the mesh mode. In PMP mode, the communications between all SSs are organized and passed through the BS. But in mesh mode, the communications can be achieved directly between SSs. To manage the bandwidth allocation in WiMAX networks efficiently and reliably, we need a scheduling algorithm.

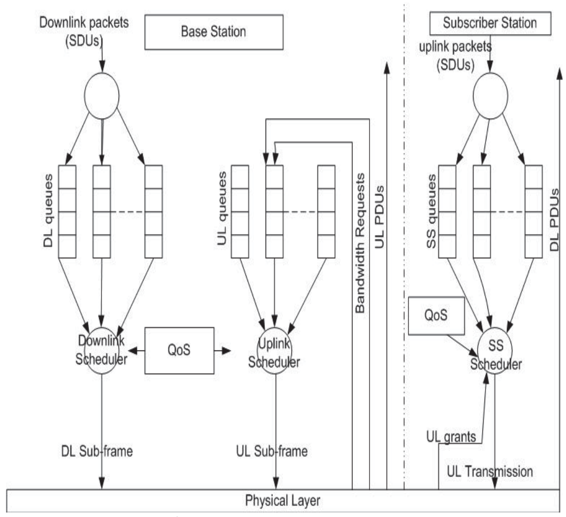


Figure 1: Overview of WiMAX Networks

III. Scheduling Algorithm

The design of scheduling algorithms in WiMAX networks is highly challenging because the wireless communication channel is constantly varying (Pantelidou & Ephremides, 2009). The key issue to meet the QoS requirements in the WiMAX system is to allocate the resources among the users in a fair and efficient way, especially for video and voice transmission. However, the amount of allocated resources depends on the Modulation and Coding Schemes (MCSs) used in the physical layer. The aim of the MCSs is to maximize the data rate by adjusting transmission modes to channel variations. The WiMAX supports a variety of MCSs and allows for the scheme to change on a burst-by-burst basis per link, depending on channel conditions.

A powerful scheduling algorithm is essential in WiMAX networks to satisfy the growth of end user requirements for different applications. There is no specific scheduling algorithm stated in IEEE802.16 standard to use. The selection of the algorithm is left for service providers to pick a suitable one, which is suitable for network application requirements. Scheduling algorithms can be classified into two categories: channel-aware and channel-unaware algorithms. Channelaware algorithms take the channel information into account in the bandwidth allocation decision. But, channel-unaware algorithms do not use any channel information in the bandwidth allocation decision.

A. Channel-unaware algorithm

This type of algorithms do not use the channel information such as power level, loss rate, and channel error in the bandwidth allocation decision. There are many types of channel-unaware schedulers such as weighted family and fairness family [4, 5]. The weighted family in particular includes five schedulers. The round robin (RR) algorithm [4] is a simple algorithm and fair in assigning one allocation for each connection in each serving cycle. Weighted round robin (WRR) [4, 5, 6] assign a weight to each connection then the connections served according to their weights. The main problem of WRR is that when the traffic has

a variable packet size, WRR provides incorrect percentage of bandwidth allocation. Deficit Round Robin (DRR) [11, 12] solves this problem of WRR. DRR defines two variables for each queue, deficit counter (DC) and quantum (Q). Q is set to

constant value equal to the maximum traffic packet of the queue, and DC is initialized by a zero value when the queue created. When the queue is visited to serve, the value of Q is added to DC and the queue is still served until the head packet size is greater than DC. For each packet served, the value of DC decreases by the value of packet size. When the queue is empty, DC retunes to zero. Deficit weighted round robin (DWRR) [14] is the same as DRR but adds a weight variable for each queue and the Q value depends on the weight value. Another modification on DRR named modified deficit round robin (MDRR) [14] works in the same way as DRR but a priority parameter is added for each queue to contribute to queue selection, it is a queue priority. The VWRR is proposed [13] to overcome the problems of WRR, but only for bandwidth allocation of IP backbone networks.

B. CHANNEL AWARE ALGORITHM

This type of schedulers takes into account the information about the channel such as signal strength, signal-to-noise ratio, and received signal power. There are many channel-aware schedulers, for example, modified largest weighted delay first (M-LWDF) [15] and link Adaptive largest weighted throughput (LWT) [16].

*1)*WEIGHTED ROUND ROBIN (WRR) SCHEDULING

The WRR scheduling is an extension of RR scheduling. This algorithm has been implemented and evaluated. The algorithm is executed at the beginning of every frame at the BS. At this moment, the WRR algorithm determines the allocation of bandwidth among the SSs based on their weights. So, the authors assign weight to each SS with respect to its Minimum Reserved Traffic Rate (MRTR) as follows:

$$Wi = MRTRi / \sum\_(k=0)^n MRTRj$$

where Wi is the weight of SSi and n the number of SSs. The average waiting timeW1 grows most rapidly in the direction of the growth of average packet sizeE(X1) and concurrently to the direction of decrease of the size of portionBR1. The smaller the size of the portion BR1 is, the steeper will be the increase of the average waiting time W1, which depends on the increasing average packet size E(X1). The bigger the average packet size E(X1) is, the steeper will be the increase of the average waiting time W1 that depends on the decrease of the proportion BR1.

The relation for the average waiting time can be generalized using mathematical induction. For the average waiting time of packets of ith queue Wi, it is valid that

$$Wi = \frac{[(BR - BRi).E(Xi)]}{[BRi.2(1 - pis).BR]}$$

The maximum queue length N1 max can be expressed using the required value of maximum delay of i = 1 packets The maximum value of waiting time W1 max reached by packet i = 1 will be in the case of entering the system just in the moment when the service of its queue has been finished. Concurrently, just N1 max − 1 packets are located before it, so the considered packet is placed in the last position in the queue. For the maximum waiting time W1 max of packet belonging to the first queue according to Figure 4, it is valid that

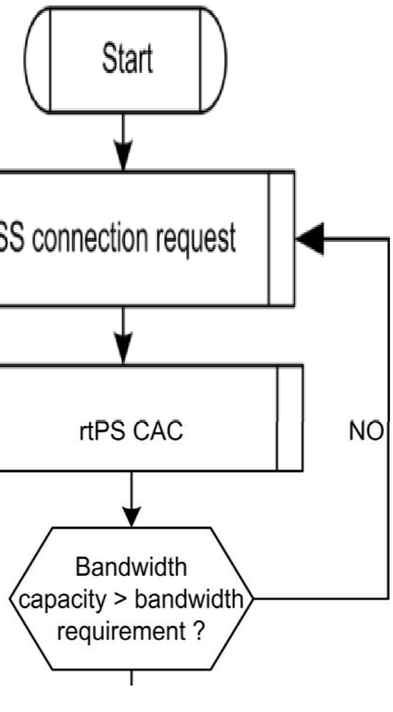
$$W1\ max = (n+1) \cdot \Delta 2 + (N1\ max - 1) \cdot E(T1)$$

After deduction for maximum queue length N1 max, we get

$$N1max = \frac{[W1\ max + (E(X1)/BR) \cdot (1 + BR2/(2BR1))](BR - BRi).E(Xi)]}{[BRi.2(1 - pis).BR](E(X1)/BR) \cdot (1 + BR2/BR1)}$$

*2)*DEFICIT ROUND ROBIN (DRR) SCHEDULER

This algorithm is a variation of RR. A fixed quantum (*Q*) of service is assigned to each SS flow (*i*). When an SS is not able to send a packet, the remainder quantum is stored in a deficit counter (*DC_i*). The value of the deficit counter is added to the quantum in the following round. When the length of the packet (*L_i*) waiting to be sent is less than the deficit counter *DC_i* the head of the queue (*Q_i*) is dequeued and the value of the (*DC_i*) is decremented by *L_i*. The algorithm is flexible enough as it allows provision of quantum of different sizes depending on the QoS requirements of the SSs. However, the DRR algorithm requires accurate knowledge of packet size (*L_i*), very complex in its implementation.



If Yes BS Schedules rtps services based on EDF.

IV. The Proposed Approach

In WiMAX networks, the BS is responsible for the scheduling of service classes for uplink and downlink directions. The scheduling algorithm works on the bases of the bandwidth requests of SSs in the uplink direction. The proposed approach is considered as an uplink scheduling algorithm in the MAC layer of BS. This approach is a type of weighted scheduling algorithms with a dynamic weight equation defined in terms of the two parameters: minimum reserved traffic rate and average packet size. The bandwidth is allocated among n queues based on the (fractional) weight function Wi(t) which is evaluated using equation :

Wi(t)=max(Pjavg(t))/piavg(t) *wi for

1≤j≤n (1) where Piavg(t) is the time-varying average packet size of the queue i, max (Pjavg(t)) is the maximum average packet size at time t among n queues. Note that

$$\sum_{}(k=0)^{n} Wi(t) = 1 \quad (2)$$

In equation 1, wi is the weight computed in WRR by equation 3

Wi=MRTRi/$\sum_{}(k=1)^{n}$ MRTRj

Where MRTRi is the minimum reserved traffic rate of queue i.

The Approaches are:

1.The packet is classified into queues according to the flow.

2.For each queue the time varying of each packet is calculated.

3.The weight of each queue is calculated.

4.The Bandwidth of the uplink subframe is Distributed among n queues based on the relationship: BWi=Wi*ULBW

Where BWi is the bandwidth reserved for queue I and ULBW is the total bandwidth of the uplink sub-frame.

6.The value of the bandwidth of each queue is sent to SS.

7.The service for the queue is continued until the bandwidth is completed when the head packet size value is greater than the remained queue bandwidth.

8.Using round robin algorithm the service is moved between the queues.

The dynamic weight Wi(t) performs a major role in the scheduling algorithm.

V. Simulation And Discussion

In order to validate the proposed algorithm, extensive simulations have been performed using OPNET [17]. The proposed network used consists of four WiMAX service classes: ertPS, rtPS, nrtPS, and BE. The applications adopted are VoIP, video conference, FTP, and HTTP. The traffic parameters for each service class are taken from [5] and are given in table1.

TRAFFIC PARAMETERS

Service Class	**Minimum reserved traffic rate in bps**	**Maximum sustained traffic rate in bps**	**Maximum latency in msec**	**Maximum jitter in msec**
ertPS	25000	64000	20	150
rtPS	64000	500000	30	160
nrtPS	45000	500000	100	300
BE	1000	64000	N/A	N/A

The simulation results are obtained using several scenarios by varying the number of SSs. Each scenario builds from a network of one BS serving a number of SSs in PMP mode of operation. The frame duration is 5 msec, with 50% for each uplink and downlink sub-frame. A random topology in 1000 x 1000 m square space is used. The number of SSs changes from 10 to 60 with ratio 2:3:3:2 SSs for ertPS:rtPS:nrtPS:BE, respectively. The prop algorithm is compared with WRR [6, 7, 10] The throughput, delay, jitter and load of the W are considered as performance metrics. The 10 minutes. The simulation results are shown and 5. It is seen in figure 2 that the proposed higher throughput than WRR and MDRR increases.

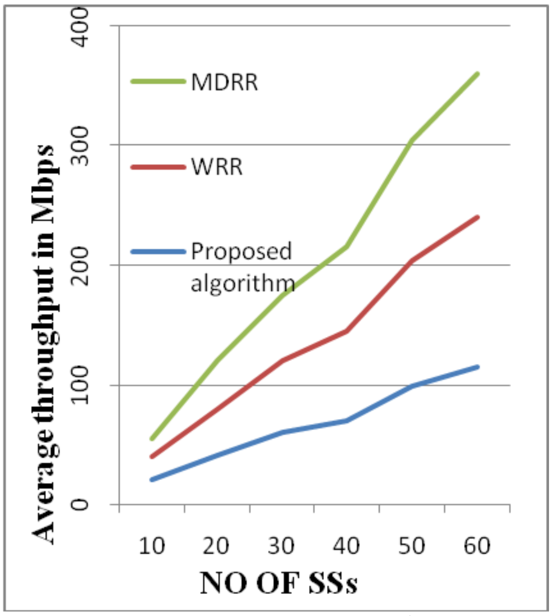


Figure 2: average throughput *vs.* number of proposed algorithm together with WRR.

More interesting is the detailed compara approach with WRR and MDRR with respect as shown in figure 3. It is clear that the average proposed algorithm has a lower time delay MDRR especially for large number of SSs.

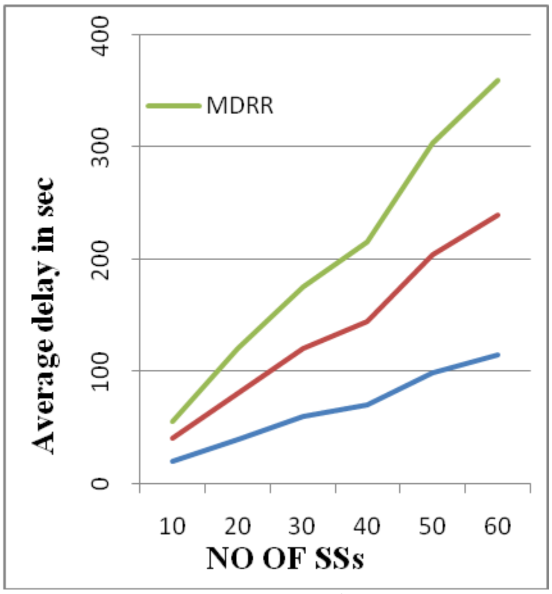


Figure 3: average delay *vs.* number of SSs algorithm together with WRR and MDRR.

Beside throughput and time delay, the pre proposed algorithm is compared with the with respect to jitter and average load. summarize the results of this comparison. That the average jitter and load for the three algorithms approximately the same at low values of SSs(less than 30) but the difference gets greater than(our algorithm gets better) higher numbers of SSs.

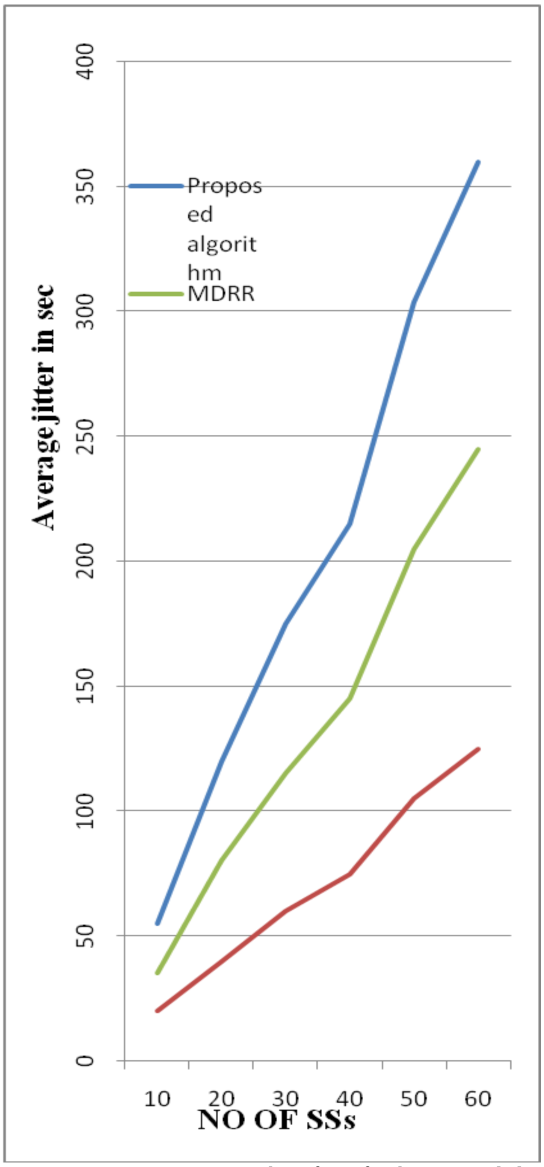


Figure 4: average jitter *vs.* number of SSs for the proposed algorithm together with WRR and MDRR

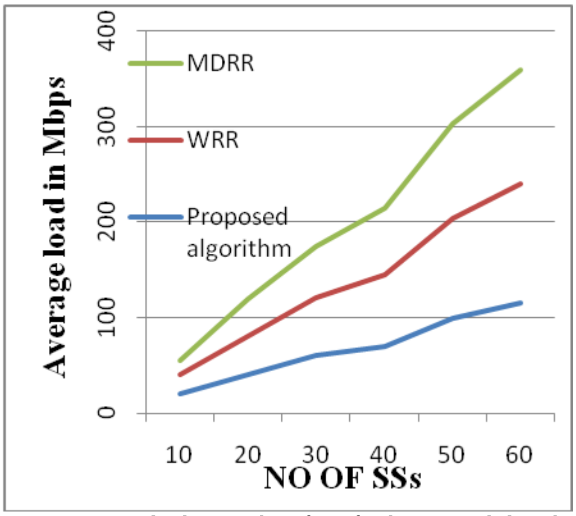


Figure 5:average load *vs.* number of SSs for the proposed algorithm together with WRR and MDRR

VI. CONCLUSIONS AND FUTURE WORK

In this paper, an uplink dynamic weighted scheduling approach has been proposed for WiMAX networks. A performance study of the proposed algorithm compared with WRR and MDRR is presented. The introduced algorithm compared with WRR and simulated using OPNET simulator. The results demonstrate that the proposed algorithm outperforms the other algorithms with respect to throughput, delay, jitter and load as functions of the number of subscriber stations. Converting VWRR and WRRs to channel- aware algorithms and studying their performance in WiMAX networks and Long-term evolution (LTE) networks[18] will be considered as future work.

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