Implementation and Evaluation of Scheduling Algorithms in Point-to-Multipoint Mode in Wimax Networks

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Abstract

The demand for high-speed broadband wireless systems is increasing rapidly and is fuelled by demand for bandwidth intensive applications like audio and video streaming. IEEE 802.16 based Wimax (Worldwide Interoperability for Microwave Access) is expected to emerge as major player as Broadband Wireless Access (BWA) technology providing voice, data and video services with different type of QoS (Quality of Service). Selection of proper Scheduling algorithm is crucial component in QoS provisioning over such broadband wireless access (BWA) network. The ideal scheduling algorithm is expected to have a multi-dimensional objective of satisfying QoS requirements of the users, maximizing system utilization and ensuring fairness among the users. From service provider point of view, the scheduling algorithms help in achieving efficient utilization of scarce radio resources.

In this work, a comprehensive performance study of scheduling algorithms in Point to Multipoint mode of Wimax network has been conducted. A detailed simulation has been carried out for the major scheduling algorithms such as FIFO, WFQ, Priority Queue, DWRR and MDRR and evaluating the performance of each scheduler to support the different QoS classes. The simulation results show that properly chosen scheduling algorithm can provide high service standards to support the QoS required for different type of traffics and users.

Keywords

IEEE 802.16, QoS, OPNET, Wimax Scheduling.

I. Introduction

During the last few years, the numbers of commercial and residential broadband wireless users have witnessed a rapid growth. The service scenario in this segment is going to be dominated by the multimedia applications, such as Voice over IP (VoIP), video conferencing, Video on Demand (VoD), massive online gaming and peer-to-peer applications. IEEE 802.16 standards [1, 2] based Wimax (Worldwide Interoperability for Microwave Access) is the technology aimed at providing broadband wireless data access over long distances for such applications. The huge increase in contemporary applications with varying QoS requirements has created a demand for a unified service and/or networking platform that can simultaneously support such applications. Broadband Wireless Access (BWA) has emerged as an ideal technology for Internet connection for delivering data, voice and video services. BWA is a fast and easy alternative to cable networks and Digital Subscriber Line (DSL) technologies. The IEEE 802.16 architecture is designed to achieve goals like easy deployment, high-speed data rate, large spanning area, and large frequency spectrum. The IEEE 802.16 standard is capable of providing QoS to all different kinds of application including real time traffic in the form of flow type associated with each application.

This paper has been organized into different sections as follow. In section II, the main characteristics of MAC Layer have been discussed. This section also includes overview of QoS and its five service flow classes. Scheduling algorithms have been discussed in section III followed by related work in section IV. Section V describes the simulation model and discussions of the obtained results. Section VI concludes the work.

II. IEEE 802.16 QoS

The IEEE 802.16 protocol stack supports two medium access control (MAC) modes namely Point-to-Multipoint (PMP) and Mesh mode. In the PMP mode, the nodes are organized into cellular-like structure, where the base station (BS) serves a number of subscriber stations (SSs) within the same antenna sector in a broadcast manner. However, the transmissions take place through independent Downlink (from BS to SS) and Uplink Channels (from SS to BS). The Uplink Channel is shared between all SSs while only the BS uses the Downlink Channel. In the mesh mode, the nodes are organized in an ad-hoc fashion and scheduling is distributed among them [3, 4]. The standard supports two type of duplex mode namely Time Division Duplex (TDD) and Frequency Division Duplex (FDD). The TDD frame consists of downlink and uplink sub-frames where the duration and the number of sub-frame slots are determined by the BS scheduler. The downlink sub-frame has downlink map (DL map) containing information about the duration of sub-frames. It also contains information about the time slot belonging to a particular SS in the downlink channel. The uplink map (UL map) consists of information element (IE), which includes transmission opportunities

A. MAC-Layer Overview

The Wimax MAC layer provides an interface between the higher layers and the physical layer. It takes service data units (MSDUs) packets from the upper layer and organizes them into MAC protocol data units (MPDUs) for transmission and vice versa for reception [5]. The IEEE 802.16 MAC layer is divided in three parts; Privacy Sub-layer (lower), MAC Common Part Sub layer (middle) and Convergence Sub-layer (upper). The core of the MAC layer is Common Part Sub-layer (CPS). The MAC CPS is designed to support PMP and mesh network architecture. The MAC layer is connection oriented. Upon entering in the network, each SS creates one more connections, over which the data packets are transmitted to and from the BS. Each packet has to be associated with the connection at MAC level [6]. This provides a way for request for bandwidth, association of QoS and other traffic parameters and data transfer related actions. Each connection has a unique 16-bit connection identifier (CID) in downlink as well as in uplink direction. The MAC Packet Data Unit (MPDU) is the data unit used to transfer data between MAC layers of BS and SS. The standard defines two types of MAC header namely Generic MAC (GM) header and Bandwidth Request (BR) header. The generic header is used to transfer data or MAC messages while BR header is used to send bandwidth requests packets to BS. SSs send their bandwidth request in either bandwidth contention period or in allotted uni-cast uplink slots or piggybacked with data packets. The standard also defines a number of MAC management messages, which has to be transmitted between the SS and BS before actual data transfer take place. Any upcoming SS first synchronize itself with downlink channel to get Downlink Map (DL-MAP) and Uplink Map (UL-MAP) from the BS. DL-MAP and UL-MAP contains the information regarding downlink and uplink sub-frame, respectively. For connection setup, each SS has to perform ranging, capacity negotiation, authentication, registration process in-sequence. The IEEE 802.16 standard supports four different flow classes for QoS and the MAC supports a request-grant mechanism for data transmission in the uplink direction. These flows are associated with packets at MAC level. A unique flow type is associated with each connection. The IEEE 802.16 standard does not define any slot allocation criteria or scheduling algorithm for any type of service. A scheduling module is necessary to design ULMAP to provide QoS for each SS in the network and slot assignment for connections is done by BS and is included in the same UL-MAP [7, 8].

B. Quality of Service

The IEEE 802.16 standard includes the QoS mechanism in the Medium Access Control (MAC) layer (layer 2) architecture. It defines service flows which enables the end-to-end IP based QoS. The MAC layer is also responsible for scheduling of bandwidth for different users based on their requirements as well as the QoS profiles. The standard is designed to support a wide range of applications. These applications may require different levels of QoS. To accommodate these applications, the IEEE 802.16 standard has defined five service flow classes [9].

(i). Unsolicited Grant Service (UGS)

UGS is designed to support real-time data streams consisting of fixed-size data packets issued at periodic intervals. The BS provides fixed-size data grants at periodic intervals, like the case in E1and VOIP without silence suppression [10].

(ii). Real-Time Polling Service (rtPS)

rtPS is designed to support real-time data streams consisting of variable-sized data packets that are issued at periodic intervals. The BS provides periodic unicast (uplink) request opportunities, like the case in MPEG video transmission [10-12].

(iii). Extended Real-Time Polling Service (ertPS)

ertPS is suitable for variable rate real time applications that have data rate and delay requirements, like the case in VoIP without silence suppression. The IEEE 802.16e standard indicates that ertPS is built upon the efficiency of both UGS and rtPS. The BS provides unicast grants in an unsolicited manner like in UGS [10].

(iv). Non-Real-Time Polling Service (nrtPS)

nrtPS is designed to support delay tolerant data streams consisting of variable size data packets for which a minimum data rate is required, like the case in FTP traffic. The BS provides unicast uplink request polls on a regular basis, which guarantees that the service flow receives request opportunities even during network congestion [11].

(v). Best Effort (BE)

BE is designed to support data streams for which no minimum service guarantees are required, like the case in HTTP traffic. The BS does not have any uni-cast uplink request-polling obligation for BE SSs. Therefore, a long period can run without transmitting any BE packets [12].

Despite the numerous scheduling algorithms proposed for Wimax networks, there is no comprehensive study that provides a unified platform for comparing such algorithms. The aim of this work is to allow a thorough understanding of the relative performance of representative uplink scheduling schemes and subsequently utilize the results to address their scarcity in designing more efficient schemes. This work focuses on implementing representative algorithms for the uplink traffic using OPNET. Another major contribution of this work is evaluating the algorithms using traffic models specifically designed for Wimax to represent its diverse applications [12], incorporating the mandatory and some optional parameters of all the traffic classes as specified in the IEEE 802.16-2004 standard. The traffic model has also been implemented in OPNET simulator. This study indicates that none of the current algorithms is capable of providing efficient, fair, and robust scheduler to support all the Wimax classes. The analysis and conclusions from this study can be used in understanding the strengths and weaknesses of current scheduling algorithms and thus designing efficient scheduling algorithms that addresses some or all of these weaknesses.

III. Scheduling Algorithms In Wimax Networks

Packet scheduling is the process of resolving contention for bandwidth. A scheduling algorithm has to determine the allocation of bandwidth among the users and their transmission order. One of the most important objectives of a scheduling scheme is to satisfy the Quality of Service (QoS) requirements of its users while efficiently utilizing the available bandwidth [13]. In the survey, several scheduling algorithms are assessed with respect to the characteristics of the IEEE 802.16 MAC layer and Orthogonal Frequency Division Multiplexing (OFDM) physical layer [14,15]. The IEEE 802.16 standard does not specify the scheduling algorithm to be used. Vendors and operators have the choice among many existing scheduling techniques or they can develop their own scheduling algorithms. Some of the existing algorithms are:

A. First in First Out (FIFO)

FIFO is the simplest scheduling algorithm [16]. Packets coming from all the input links were en-queued into a FIFO memory stack, then they were de-queued one by one on to the output link. So it simply queues processes in the order in which they arrive in the ready queue. Since context switches only occur upon process termination, and no reorganization of the process queue is required, scheduling overhead is minimal. Throughput turnaround time, waiting time and response time can be low. No prioritization occurs, thus this system has trouble meeting process deadlines. The lack of prioritization does permit every process to eventually complete, hence no starvation.

B. Weighted Fair Queuing(WFQ)

WFQ is a data packet scheduling technique that is used for various size packets [17]. It is a generalization of fair queuing (FQ). It allows different scheduling priorities to statistically multiplexed data flows and provides the priority to traffic that automatically sorts among individual traffic streams without the requirement of an access list. If N data flows currently are active, with weights w_1, w_2..w_N, data flow number i then average data rate can be achieved as shown in equation [1].

$$\frac{Rw_i}{(w_1 + w_2 + \dots\dots\dots\dots\dots\dots + w_N)} \quad (1)$$

By regulating the WFQ weights dynamically, it can be utilized for controlling the quality of service, for example to achieve guaranteed data rate. WFQ gives each flow different weight to has different bandwidth percentage in a way that preventing monopolization of the bandwidth by some flows providing fair scheduling for the different flows [18].

C. Priority-Queue (PQ)

Strict-Priority packets are first classified by the scheduler according to the QoS class. Then these packets are placed into different priority queues. It services the highest priority queue until it is empty, and then moves to the next highest priority queue. This mechanism could cause bandwidth starvation for the low priority QoS classes [18].

D. Deficit Weighted Round Robin (DWRR)

Deficit round robin (DRR) also called DWRR [19]. M. Shreedhar and G.Varghese proposed DRR in 1995. It can handle packets of variable size without knowing their mean size. A maximum packet size number is subtracted from the packet length, and packets that exceed that number are held back until the next visit of the scheduler.

In the DRR scheme, stochastic fair queuing is used to assign flows to queues. For servicing the queues, Round robin servicing is used, with a quantum of service attached to each queue. It differs from the traditional Round-robin in that if a queue is unable to send a packet in the previous round because a packet was too large, the remainder from the previous quantum is added to the quantum for the next round. Queues that are not completely serviced in a round are compensated in the next round. However, once a flow is serviced, irrespective of its weight, it must wait for $N-1$ other flows to be serviced until it is serviced again. Also, during each round, a flow transmits its entire quantum at once. As a result, DRR has poor delay.

E. Modified Deficit Round Robin (MDRR)

MDRR scheduling is an extension of the previously mentioned DRR scheduling scheme [19].There may be different modifications of the DRR scheme and hence the name is MDRR. The algorithm depends upon the DRR scheduling fundaments to a great extent, however, in MDRR the quantum value given to the queues is based on the weight associated with them.

The MDRR scheduling scheme adds a PQ into consideration with DRR. A Priority Queuing scheme isolates high demanding flows from the rest of the other flows for the reason of better quality of service provisioning [20].

According to the mode of serving the Priority Queue, there are mainly two types of MDRR schemes.

(i). Alternate Mode

In this mode the high priority queue is serviced in between every other queue.

(ii). Strict Priority Mode

Here the high priority queue is served whenever there is backlog after completely transmitting all its packets then the other queues are served. However, as soon as packets are backlogged again in the high priority queue, the scheduler transmits the packet currently being served and moves back to the high priority queue.

IV. Related Work

In recent years, many researchers have shown active interest in IEEE 802.16 QoS research. The IEEE working group has designed a new standard based on BWA systems for last mile wireless access named IEEE 802.16 Wireless MAN. Literature view reveals.

J. Lin et al in [21] focuses on the analysis of QoS in Wimax networks. It includes the definition of various service flows and their applications defined by the IEEE 802.16 standard.

K. Wongthavarawat et al in [11,16] presents an approach based on a fully centralized scheduling scheme, where a global QoS agent collects all the necessary information on traffic flows, and takes decisions on traffic admission, scheduling, and resource allocation. Then based on the complete global knowledge of the system, the deterministic QoS levels can be guaranteed. In terms of the scheduling discipline used for the various classes WFQ and FIFO are used. The strict priority discipline allows the redistribution of bandwidth among its active connections to lowest priority.

L. Georgiadis et al in [12] describe that WFQ algorithm is a packet-based approximation of the Generalized Processor Sharing (GPS) algorithm which is an idealized algorithm. This algorithm assumes that a packet can be divided into bits and each bit can be scheduled separately. WFQ has the nice property of traffic protection and to out-perform WFQ in the end-to- end case is per node traffic shaping is exercised.

M.Shreedhar et al in [19] evaluate the performance of the DWRR scheduling algorithm for BWA networks.

V. Simulation Model and Analysis

A. Evaluation Methodology

The overall goal of this study is to analyze the performance of different existing scheduling algorithm in Wimax environment. The simulations have been performed using OPNET [22, 23]. There are three main methods to evaluate a Scheduling algorithm:

Deterministic Modeling: In this modeling there is a predetermined workload and different algorithms are tested against it. Then the performance results are compared.

Queuing Models: In this modeling the random backlogs are studied by analytically in a mathematical way.

Implementation/Simulation: The most versatile method of testing scheduling algorithms is to actually simulate the designed algorithm with real life data and conditions.

Although the commonly used software's like C, C++, Java, MATLAB and many other programming languages are strong and feature rich languages; however, these programming languages do not come with a model of a specific system. Thus for the sake of accuracy accompanied by an almost complete Wimax system model simulation OPNET Modeler has been researched to be one of the best candidates. [22- 24]. It is a Discrete Event Simulation (DES) program and events are handled in a chronological manner.

B. System Modeling

To study the performance of various scheduling algorithms a scenario consisting of 8 mobile stations and 1 base station in Wimax Network has been created in circular mode using OPNET 14.0 as shown in fig. 1. The parameters for the mobile nodes, base station and Wimax Node have been configured and the detail of configuration is shown in fig. 2, fig. 3, and fig. 4 respectively. The Wimax configuration node has been used to store profiles of PHY and service class, which can be referenced by all Wimax nodes in the network. QoS attribute configuration node defines the attribute configuration details for protocols supported at the IP layer. The individual nodes can reference these specifications.

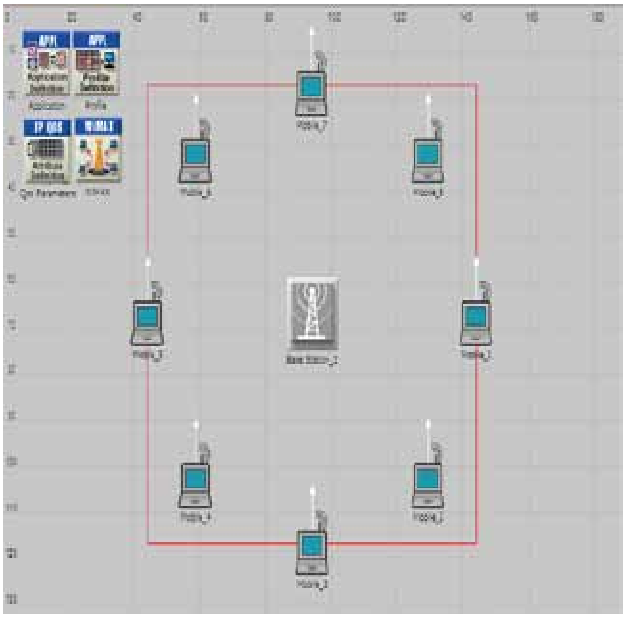

Fig. 1: Circular mode configuration

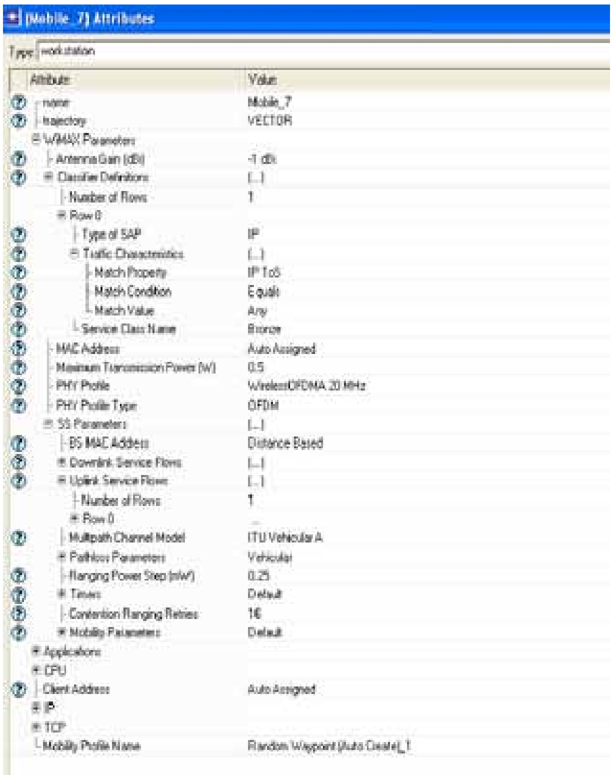

Fig. 2: WiMAX mobile station parameters

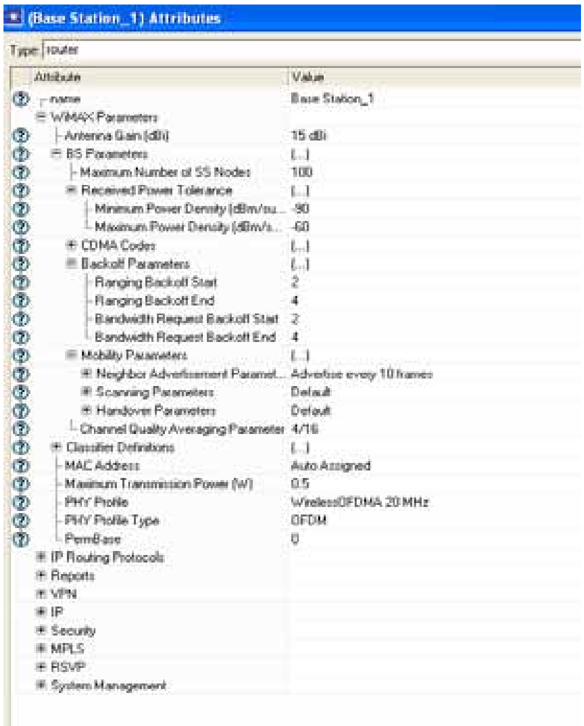

Fig. 3: WiMAX base station parameters

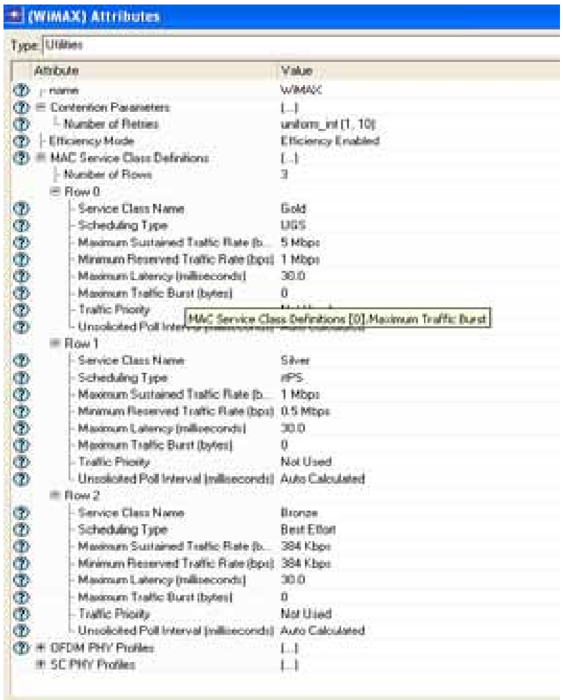

Fig. 4: WiMAX configuration node parameters

The PHY and MAC layers have been configured for the same scenario and their important parameters have been summarized in Table 1. A 20 MHz bandwidth with 5 GHz base frequency is configured to study the effect of heavy traffic on each QoS class with different scheduling algorithms.

Table 1: Simulation parameters

Base Station Parameters	Antenna-Gain = 15 dBi Antenna-Type = Omni PHY Profile=Wireless OFDMA 20MHz PHY Profile type=OFDM
Transmission Parameters	Duplex Mode=TDD CH-Bandwidth=20MHz CH-Frequency=5GHz Max Transmission Power(w)=0.5 Frame Duration (milliseconds) =5 Bandwidth Grant=GPSS mode Area(square meters) =5000.00 Buffer Capacity=1000

C. Simulated Scenario

The simulation is executed on created scenario for transfer of data, voice and video service in Wimax network using different uplink scheduling algorithm such as FIFO, WFQ, Priority Queue, DWRR, and MDRR. The simulation gives the results for average jitter, packet delay variation, packet end-to-end delay, throughput and traffic received for voice and video conferencing.

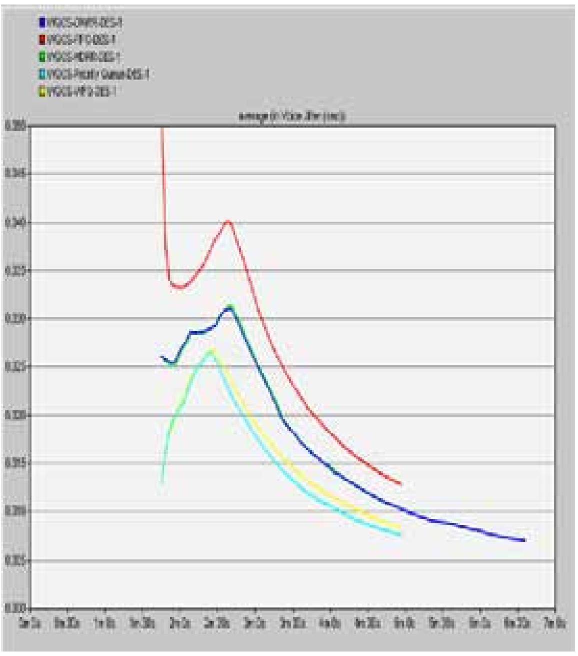

Fig. 5: Average jitter- Voice (rtps)

Fig. 5 shows that the Priority Queue and WFQ have minimum jitter value due to the strict priority where as FIFO scheduling algorithm has the highest jitter value. MDRR and DWRR have average jitter values, which is in between the FIFO and Priority Queue.

In fig. 6 and fig. 7, results for packet delay variation and end-to-end packet delay (sec) graph for rtps has been presented. The results indicate that the Priority Queuing has the minimum delay where as the FIFO algorithm has maximum delay value. The WFQ, DWRR and MDRR scheduling algorithm have average end-to-end delay and packet delay variation.

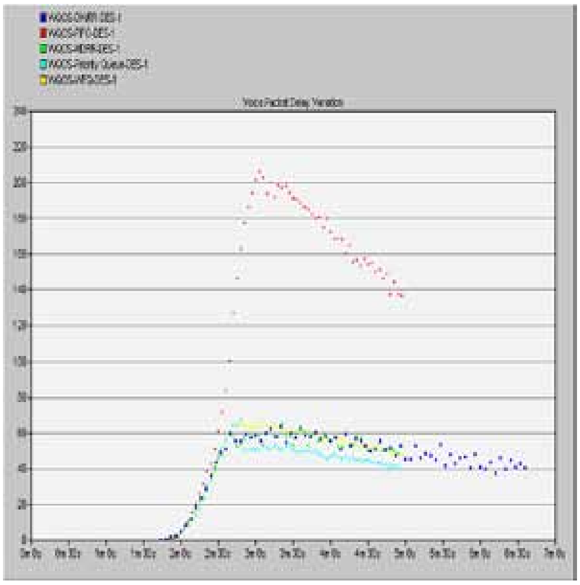

Fig. 6: Packet delay variation

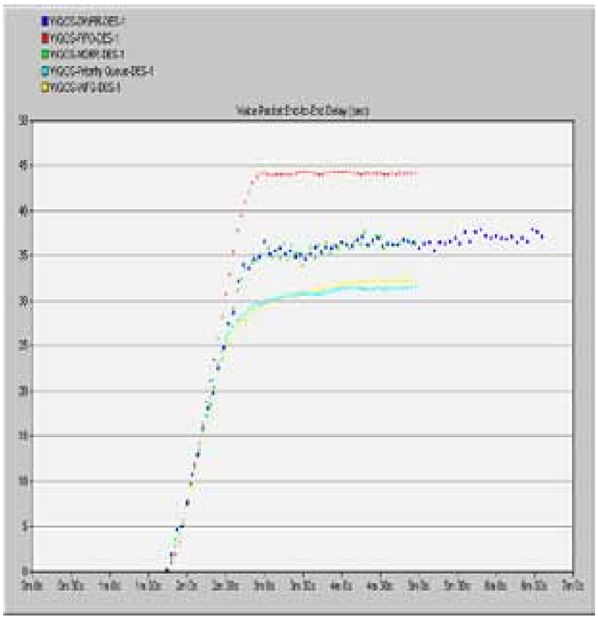

Fig. 7: Packet End-to End Delay (sec)

Results for as presented in fig. 8 reveals that Priority Queue scheduling algorithm has the highest throughput value where as the FIFO has lowest throughput value. However, WFQ and DWRR have the similar throughput values and MDRR has the average throughput value.

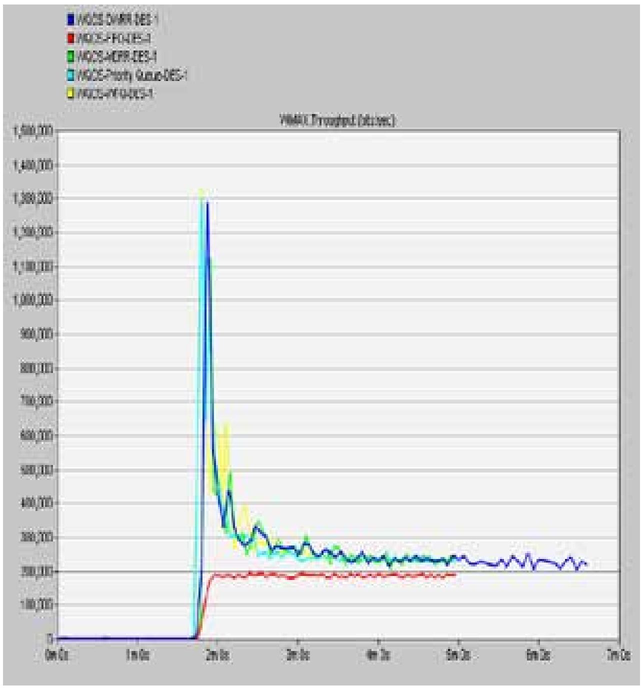

Fig. 8: WiMAX throughput (bits/sec)

Fig. 9 represent the Video Conferencing traffic received (bytes/sec) for different scheduling algorithms. Here the maximum traffic can be received and handled by Priority Queue due to strict priority and DWRR has been found to handle lesser traffic. WFQ and MDRR have been found to have similar traffic handling capability in Wimax network.

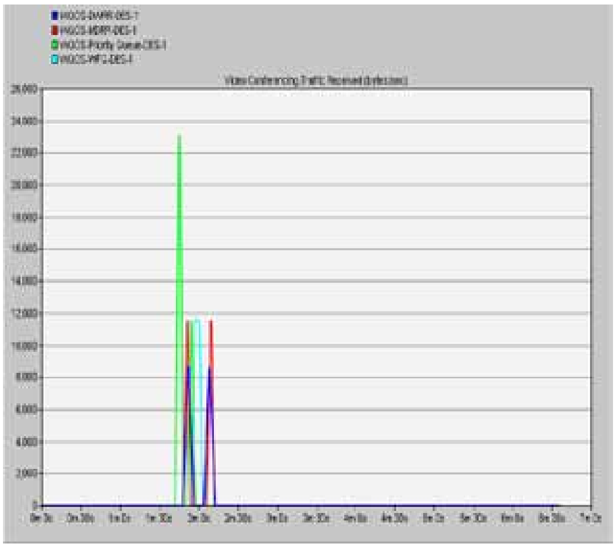

Fig. 9: Video conferencing traffic received (bytes/sec)

VI. Conclusion & Future Work

This paper presents a comprehensive performance evaluation of representative algorithms for the uplink traffic in Wimax networks. The behavior of the FIFO, WFQ, Priority Queue, DWRR, and MDRR scheduling algorithms in Wimax has been investigated here. A simulation study has been used to compare the performance of each scheduler on the different QoS classes. The simulations results verified that the Priority Queue scheduling algorithm has the highest throughput value and minimum jitter and packet delay variation for high QoS classes. The average end-to-end packet delay in the Strict-Priority has lesser value for the rtPS traffic.
For future work, context and traffic aware scheduling algorithms need to be developed for improving throughput and reduce delay.

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