Comparative Assessments for Different WiMAX Scheduling Algorithms

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Abstract— **WiMAX (Worldwide Interoperability for Microwave Access) is expected to arise as the main Broadband Wireless Access (BWA)technology providing voice, data and video services with different type of QoS (Quality of Service).Although different type of QoS classes had been defined by the IEEE 802.16 standard, the scheduling architecture is left to be vendor specific. Designing an efficient scheduling algorithm provide high throughput and minimum delay is challenging for system developers.**

In this work, a detailed simulation study was carried out for some scheduling algorithms such as WFQ, Round Robin, WRR and Strict-Priority, analyzing and evaluating the performance of each scheduler to support the different QoS classes. The simulation is carried out via the QualNet 4.5 simulator evaluation version and the results show that effective scheduling algorithm can provide high service standards to support the QoS required by different type of traffic as well as different type of user.

Index Terms—**QoS, QualNet, Scheduling Algorithms, WiMAX**

I. INTRODUCTION

WiMAX the IEEE 802.16 standard for broadband wireless metropolitan area network (WMAN) is becoming popular mainly due to its open standard and support to quality of service (QoS) for different categories of services. Voice over IP, home entertainment video, triple play and the high evolution of Internet usage have created an excessive demand of broadband technologies such as E1/T1 and DSL. On the other hand, it is very expensive to create new infrastructures with either fiber optic or copper wires. IEEE 802.16 can offer a great advantage to SPs to provide low cost connections and extensive mobility.

The IEEE 802.16 Medium Access Control (MAC) specifies five types of QoS classes: Unsolicited Grant Service (UGS); real-time Polling Service (rtPS); extended real-time Polling Service (ertPS); non real-time Polling Service (nrtPS) and Best Effort (BE) QoS classes.

This paper focuses on comparing some of the scheduling algorithms that can be used to serve these QoS types and the remaining of this paper is organizing as follow; Section II gives a short description of IEEE 802.16 standard and the need of IP in wireless networks, the mechanism of supporting different QoS and some scheduling algorithms are discussed in section III. Section IV describes the simulation model. Section V presents the results and the analysis. Finally, concluding remarks are presented and further future work is proposed in Section VI.

II. IEEE 802.16 QoS

A basic WiMAX network consists of a base station (BS) and multiple subscriber stations (SSs). The BS schedules the traffic flow, communication between BS and SSs are bidirectional, downlink channel (BS to SS) is in broadcast mode and uplink channel (SS to BS) is shared by various SSs.

The standard supports two type of duplex mode, Time Division Duplex (TDD) and Frequency Division Duplex (FDD).The TDD frame consists of downlink and uplink subframes, the duration and the number of subframe slots are determined by the BS scheduler. The downlink subframe has downlink map (DL map) contains information about the duration of subframes and which time slot belongs to a particular SS as the downlink channel and uplink map (UL map) consists of information element (IE) which includes transmission opportunities[5].

A. MAC-Layer Overview

The WiMAX MAC layer provides an interface between the higher transport 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 sent transmission and vice versa for received transmission.

Its design includes a convergence sublayer (CS) that can interface with a variety of higher-layer protocols, such as ATM, TDM, Ethernet, IP, and any future protocol. In addition to providing mapping to and from higher layers, the CS supports MSDU header suppression to reduce the higher layer overheads. [4]

B. Quality of Service

Supporting QoS is a fundamental part of the WiMAX MAC-layer design. WiMAX borrows some of the basic ideas behind its QoS design from the Data Over Cable Service Interface Specification (DOCSIS) cable modem standard.

In a MAC connection oriented architecture, data in between BSs and SSs is transmitted in the context of connection. Each connection is identified in the (MPDU) by a connection identifier (CID) which also provides a mapping to a service

flow identifier (SFID).SFID is an important concept in the MAC layer in the standard, which provides a mapping, to the QoS parameters for a particular data entity. [1]

To support a wide variety of applications, WiMAX defines five QoS classes that should be supported by the BS:

Unsolicited Grant Service (UGS)

Which 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[3].

Real-Time Polling Service (rtPS)

Which 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[3].

Extended Real-Time Polling Service (ertPS)

Which 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[3].

Non-Real-Time Polling Service (nrtPS)

Which 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[3].

Best Effort (BE)

Which 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 unicast uplink request polling obligation for BE SSs. Therefore, a long period can run without transmitting any BE packets [3].

III. QoS Mechanisms and Scheduling Algorithms

Providing end-to-end QoS is done by negotiating and agreeing upon the required QoS specification, and enforcing the agreed-upon QoS requirements by controlling the network resources. For each connection QoS mechanisms are required in both the control plane and the data plane

A. Control Plane Mechanism

It includes QoS policy management, signaling, and admission control, defining and provisioning the various levels and types of QoS services, as well as managing which user and application gets what QoS[1].

B. Data Plane Mechanism

These methods enforce the agreed-on QoS by classifying the incoming packets and allocating appropriate resources into several queues. Classification is done by inspecting the packets headers; resource allocation is done by using appropriate scheduling algorithms and buffer-management techniques for storing and forwarding packets in each queue, two different approaches to how these queues are defined:

Per-flow Handling the first approach which is to have a separate queue for each individual session or flow which becomes very difficult or impractical with a large number of flows. The IntServ methods use per-flow handling of IP packets

The second approach is Aggregate Handling which is to classify packets into a few different generic classes putting each class in a different queue that is more scalable and reduces the maintenance and processing. DiffServ and 802.1p use aggregate traffic-handling mechanisms for IP and Ethernet[1].

C. Scheduling Algorithms

Better QoS guarantees can be provided by higher complexity in both control plane and data plane, to obtain higher QoS for reducing unnecessary complexity network developer need to do their best in the aim of delivering a meaningful QoS.

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 these algorithms are:

Strict -Priority

Strict-Priority packets are first classified by the scheduler according to the QoS class and then 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 [8].

Round-Robin

It serves each priority queue, starting with the highest priority queue that contains packets, services a single packet, and moves to the next lower priority queue that contains packets, servicing a single packet from each, until each queue with packets has been serviced once. It then starts the cycle over with the highest priority queue containing packets [8].

Weighted Round Robin (WRR)

Packets are first classified into various service classes and then assigned a queue that can be assigned a different percentage of bandwidth and is serviced in round robin order.

WRR ensures that all service classes have access to at least some configured amount of network band width to avoid bandwidth starvation. In order to provide the correct percentage of bandwidth to each class if only all of the packets in tall queues are the same size or when the mean packet size is known in advance [10].

Weighted Fair Queuing (WFQ)

WFQ gives each flow different weight to has different

bandwidth percentage in a way that preventing monopolization of the band width by some flows providing fair scheduling for the different flows supporting variable-length packets by approximating the theoretical approach of the generalized processor sharing (GPS) system by calculating and assigning a finish time to each packet [6].

IV. SIMULATION MODEL

The overall goal of this simulation study is to analyze the performance of different existing scheduling algorithm in Mobile WiMAX environment. The simulations have been performed using QualNet version 4.5 evaluation version [7]

Fig. 1. System Model implementation by QualNet

The important parameters used to configure the PHY and MAC layers are summarized in (table I). A five MHz bandwidth with 512 FTT size is configured to simulate bandwidth congestion to study the effect of heavy traffic on each QoS class with different scheduling algorithm.

TABLE I
SIMULATION PARAMETERS

PHY 802.16	FREQUENCY = 2.4 GHz
	PATHLOSS = TWO-RAY
	FADING = RAYLEIGH
Transmission parameter	TX-POWER = 15 dBm
	CH.-BANDWIDTH = 5MHz
	FFT-SIZE = 512
	CYCLIC-PREFIX = 8
	FRAME-DURATION = 20MS
	DUPLEX MODE=TDD
Base Station parameter	ANTENNA-TYPE = OMNI
	ANTENNA-GAIN = 15 dB
	ANTENNA-HEIGHT = 25 m

Eight queues have been configured to avoid queuing packets of different service types into one queue. Even if the application sets a high precedence for its packets, they may be blocked by lower precedence packets in network queues. The precedence values corresponding for each queue are shown in (table II)

TABLE II
TRAFFIC CLASS VS PRECEDENCE

MAC Layer Services	Precedence/Queue
BE	0
nrtPS	2
rtPS	3
ertPS	4
UGS	7

To evaluate the performance of scheduling algorithm, both qualitative and quantitative metrics are needed. This paper focuses on the QoS most important metrics which are throughput and the average end-to-end delay. The five QoS classes have been compared in four different scheduling algorithms at different speed.

V. RESULTS AND ANALYSIS

A. Comparative Results with Previous study

In Proceedings of Quality in Research Conference (QIR) 2007, Sari R. F., Gde D I, Mukhayaroh N, Laksmiati D [9], made a performance evaluation of Weighted Round Robin which showed that the WRR based scheduler Implementation in WiMAX has supported WiMAX QoS by suppressing packet loss and providing each QoS classes throughput value as they should be.
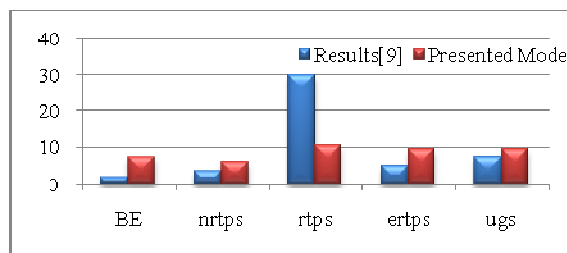

Fig.2 comparison Throughput in WRR scheduler

In Fig.2, it is shown that, the represented model is has the same throughput [9], from which the average of throughputs for the five trials was obtained for comparison with the same number of nodes. A higher performance in this paper's study was obtained especially in the UGS and rtPS traffic. However the in case of rtPS it has lower throughput because CBR traffic is used oppose the VBR in [9].

B. Throughput Analysis

From the throughput graphs, it can be seen that the scheduling algorithm affects the throughput for QoS class.

In Fig. 3. The UGS, ertPS and rtps traffic has the largest throughput value. However the BE and nrtPS traffic almost have no traffic because the Strict-Priority scheduler causes bandwidth starvation for low priority traffic types.
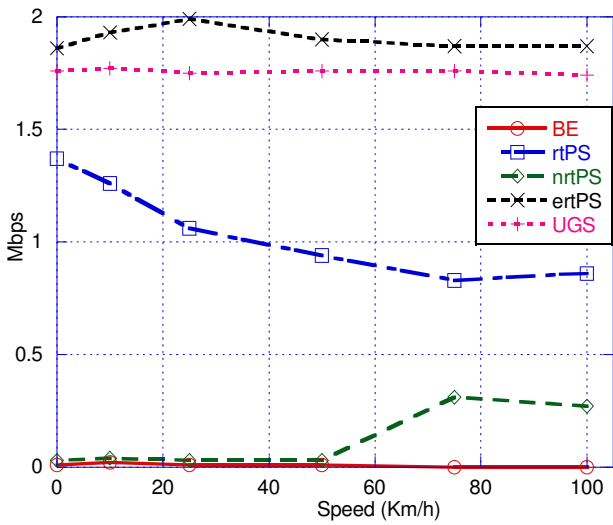
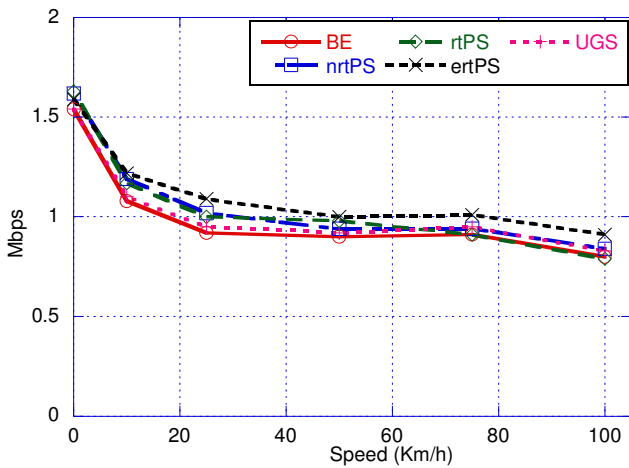Fig. 3. Throughput in Strict Priority Scheduler

Fig. 4. Throughput in Round-Robin Scheduler

In Fig.4, the graph shows that all traffic types have the same throughput value but it is much lower than Strict-Priority scheduler.
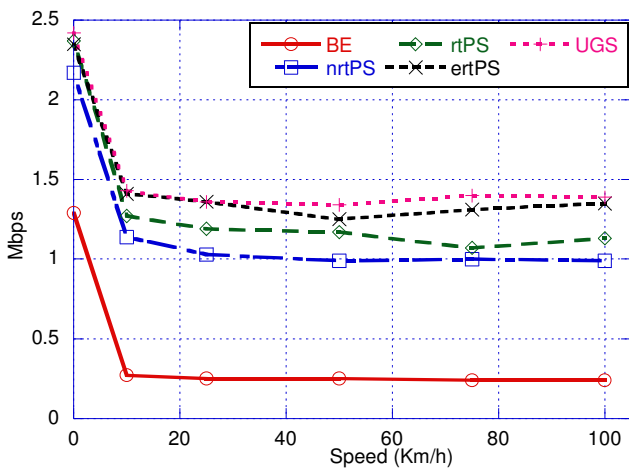

Fig. 5. Throughput in WRR Scheduler

In Fig.5, it can be seen that the high priority traffic has high throughput, in the same time the lower priority traffic has low throughput. WRR distributes the band width to all traffic types according there weights.
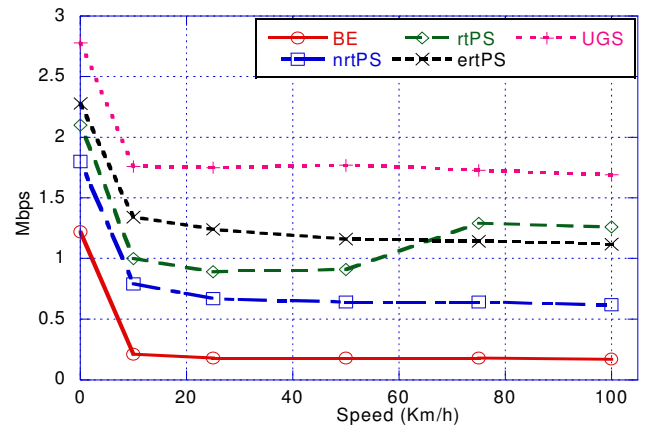

Fig.6. Throughput in WFQ Scheduler

In Fig.6, it can be seen that the WFQ scheduler acts very similar to the WRR but it has more variation in distributing the bandwidth among the traffic types.

From Fig.3 to Fig.6 it can be noticed that the Strict-Priority scheduler is giving the highest UGS, rtPS traffic against the speed. This is because it serves the highest priority traffic queues at first and then it tries to serve the other traffic queues.

The RR is a fair algorithm, so it has no distinguished performance between different QoS traffic types and so it will degrade the UGS, rtPS throughput to be approximately to the half of the Strict-Priority and then it had increases the BE, nrtPS to the double or more.

The WFQ, WRR show fair resource distribution algorithms, so a suitable throughput can be offered according to each class

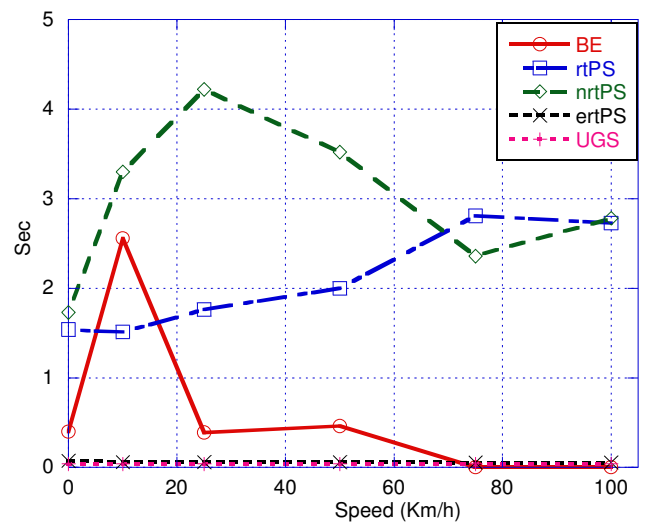*C.   Average end-to-end Delay*

Fig. 7. Delay in Strict-Priority Scheduler

In Fig.7, it can be seen that the UGS,ertps traffic has no delay at all speed; the BE traffic has large delay at low speed and has no delay at high speed (80-100) km/h; this because the throughput at high speed is tends to zero. The rtPS and nrtPS traffic have some delay at all speed.
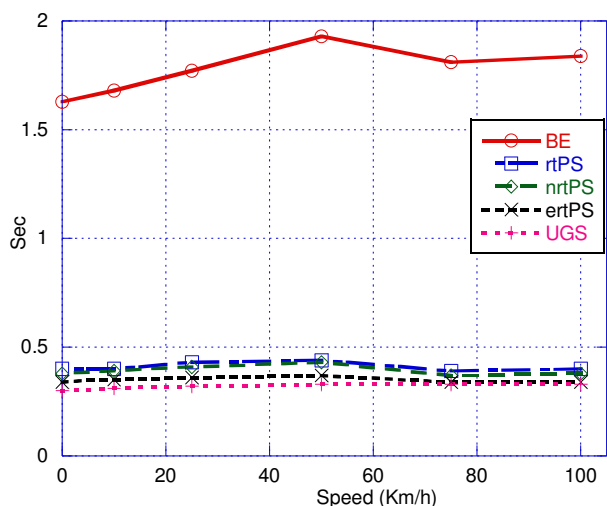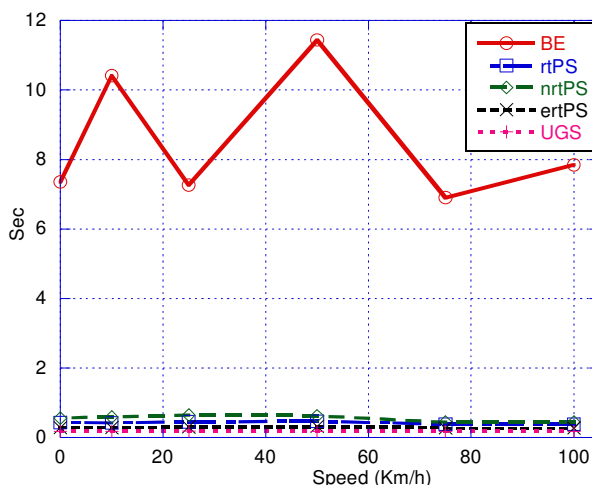
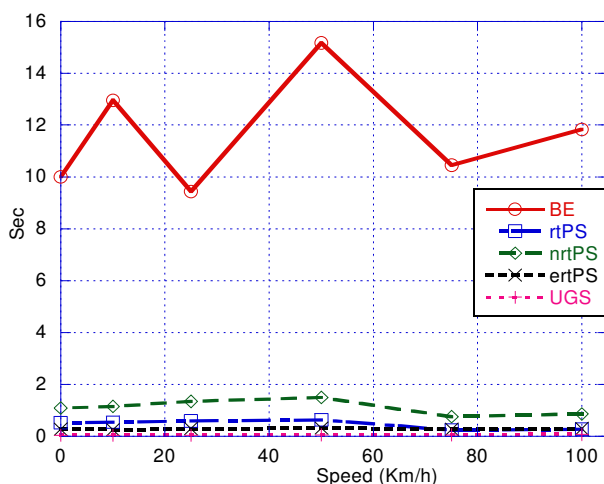g. 8. Delay in Round-Robin Scheduler

Fig. 9. Delay in WRR Scheduler

Fig. 10. Delay in WFQ Scheduler

Fig 8. shows that the Round-Robin scheduler has equal average end-to-end delay for all traffic types except for the BE it has a higher value.

Fig.9 and Fig.10 show that both WRR and WFQ has different delay value according to the traffic priority higher priority has very low delay value but the BE has more delay.

VI. CONCLUSION AND FUTURE WORK

In conclusion, the behavior of the Strict-Priority, Round Robin, Weighted Round Robin and Weighted Fair Queuing scheduling algorithms in WiMAX has been investigated in this paper. A simulation study was used to compare the performance of each scheduler on the different QoS classes. The simulations verified that the Strict-Priority scheduler has the highest throughput and minimum delay for high QoS classes. However it caused bandwidth starvation for the BE and the nrtPS classes. The average end-to-end delay in the Strict-Priority has large value for the rtPS traffic.

The RR scheduler has 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.

For future work, the full version of QualNet simulator should be used, to be able to control/modify scheduling algorithms parameters to improve throughput and reduce delay.

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