

# A Performance Analysis of Different Scheduling Schemes in WiMAX

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**Abstract**—IEEE 802.16 (WiMAX) aims to present high speed wireless access to cover wide range coverage. The base station (BS) and the subscriber station (SS) are the main parts of WiMAX. WiMAX uses either Point-to-Multipoint (PMP) or mesh topologies. In the PMP mode, the SSs connect to the BS to gain access to the network. However, in the mesh mode, the SSs connect to each other to gain access to the BS.

The main components of QoS management in the 802.16 standard are the admission control, buffer management and packet scheduling. In this paper, we use QualNet 5.0.2 to study the performance of different scheduling schemes, such as WFQ, SCFQ, RR and SP when the numbers of SSs increase. We find that when the number of SSs increases, the average jitter and average end-to-end delay is increased and the throughput is reduced.

**Keywords**—WiMAX, Scheduling Scheme, QoS, QualNet.

## I. INTRODUCTION

THE number of people using the wireless networks to login the Internet has increased because it is more suitable and it supplies the mobility. This leads to large operation of the wireless networks, such as Wi-Fi or the IEEE 802.11 standard. Nevertheless, the 802.11 standard may have some weaknesses, such as the short transmission distances and the small transmission rates. Therefore, the IEEE 802.16 standard or the Worldwide Interoperability for Microwave Access (WiMAX) is proposed to solve the previous disadvantages [18]. The broadband wireless access (BWA) is supplied by the 802.16 standard [2]. Furthermore, some high-quality features, such as the high speed access to the Internet, sustaining Quality of Service (QoS), the low cost, the broad coverage range and the fast deployment are supplied for the organizing and the sustaining networks by the 802.16 standard. It can reach 75 Mbps as the data rate and it can achieve up to 50 Km as the extreme distance [15].

Generally, there are three essential components to handle the QoS in the 802.16 standard, which are the admission control, the packet scheduling and the buffer management.

The admission control is used to conclude whether the new connection request can be approved or not. This is based on the remaining complimentary bandwidth. Furthermore, the number of flows admitting into the network can be restricted by the admission control. Thus, several services overflow and the starvation may be controlled [4], [9].

The packet scheduling scheme is used to decide the priority to assure the QoS requirements. In other words, it is adopted

to decide the first packet to serve in the particular queue to assure the QoS requirements. The buffer management is used to organize the buffer size and to choose the deleted packets. In other words, the buffer size can be restricted by the buffer management which is used to determine the dropped packet [13].

There are several scheduling schemes using in WiMAX, such as Weighted Fair Queuing (WFQ), Round Robin (RR), Strict Priority (SP) and Self Clocked Fair Queuing (SCFQ). We will use the QualNet simulator to create our scenarios to study the performance of different scheduling schemes when the numbers of SSs increase. When the number of SSs increases, the average jitter and average end-to-end delay is increased and the throughput is reduced.

The remainder of this paper is organized as follows: Section II presents the background. Section III describes the scheduling schemes. Section IV presents our simulation model. Section V presents the simulation results and the performance analysis. Finally, Section VI gives some brief summary and the future work.

## II. BACKGROUND

There are two fixed stations in the basic architecture of WiMAX which are the base station (BS) and the subscriber station (SS). The BS is the essential tools set and it can offer connectively management and the control of some SSs located in different distances. However, the building prepared with the conservative wireless or wired Local Area Network (LAN) can be signified by the SS. The internetworking access to the buildings can be offered by the WiMAX throughout external antennas [10].

There are two different operation modes identified in the IEEE 802.16 standard which are the Point-to-Multipoint (PMP) and the mesh mode. In the PMP mode, multiple SSs can be associated by the controlling BS to different public networks. On the other hand, in the mesh mode, a direct communications between the SSs can be maintained without using the BS (Fig. 1) [7], [16], [17].

There are four different service classes maintained in the IEEE 802.16 standard which are Unsolicited Grant Service (UGS), Real-time Polling Service (rtPS), Non real-time Polling Service (nrtPS) and Best Effort (BE). The Extended Real-Time Polling Service (ertPS) service class is added in the IEEE 802.16e standard [1].

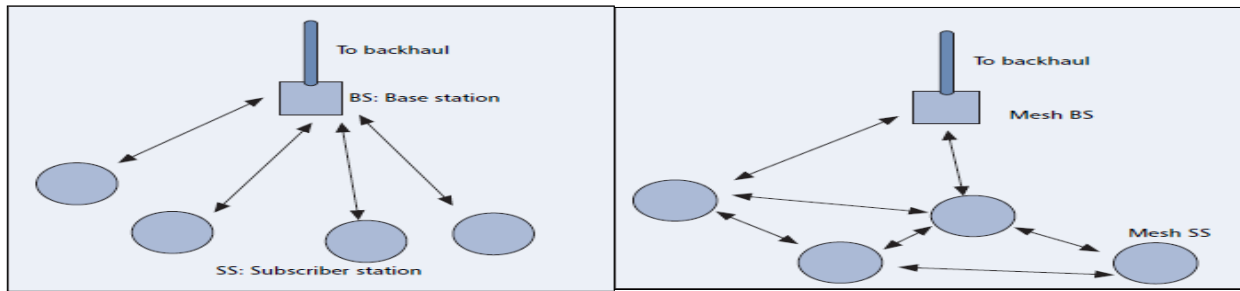


Fig. 1 PMP Mode &amp; Mesh Mode

TABLE I  
OBLIGATORY QoS PARAMETERS OF THE SCHEDULING SERVICE CLASSES

Scheduling Types	MSTR	MRTR	Maximum Latency	Traffic Priority	Request/Transmission Policy	Tolerated Jitter
UGS	✓	Can be present	✓		✓	✓
rtPS	✓	✓	✓		✓	
nrtPS	✓	✓		✓	✓	
BE	✓			✓	✓	

#### A. Unsolicited Grant Service (UGS)

The UGS service class is proposed to maintain the real-time data streams contained the data packets with the fixed-size concerned at the periodic intervals, such as Voice over IP (VoIP) with no silence suppression and T1/E1. The Maximum Sustained Traffic Rate, the Tolerated Jitter, the Maximum Latency and the Request / Transmission Policy are the compulsory QoS service flow factors for the UGS scheduling service. The Minimum Reserved Traffic Rate factor is equal to the Maximum Sustained Traffic Rate factor when it is present.

#### B. Real-Time Polling Service (rtPS)

The rtPS service class is proposed to maintain the real-time data streams contained the data packets with the variable-size concerned at the periodic intervals, such as the Moving Picture Experts Group Video (MPEG). The Maximum Sustained Traffic Rate, the Minimum Reserved Traffic Rate, the Maximum Latency and the Request / Transmission Policy are the compulsory QoS service flow factors for the rtPS scheduling service.

#### C. Non Real-Time Polling Service (nrtPS)

The nrtPS service class is proposed to maintain the delay-tolerant data streams contained the data packets with the variable-size when the minimum data rate is involved, such as the File Transfer Protocol (FTP). The Maximum Sustained Traffic Rate, the Minimum Reserved Traffic Rate, the Traffic Priority and the Request / Transmission Policy are the compulsory QoS service flow factors for the nrtPS scheduling service [5].

#### D. Best Effort (BE)

The BE service class is proposed to maintain the data streams when there is no minimum service level involved, such as the HTTP. Hence, it can be held on the space-variable basic. The Maximum Sustained Traffic Rate, the Traffic Priority and the Request / Transmission Policy are the

compulsory QoS service flow factors for the BE scheduling service.

#### E. Extended Real-Time Polling Service (ertPS)

The ertPS is inserted by the IEEE 802.16e standard. It is a scheduling scheme built on the competence of the UGS and rtPS service classes. The bandwidth request latency may be saved in the ertPS service class because the unicast grants in the unsolicited approach are offered by the BS in this scheduling service class as in the UGS. While the allocations of ertPS are dynamic, the allocations of UGS are fixed in the size. The ertPS service class is proposed to maintain the real-time data streams with the delay and data rate requirements contained the data packets with the variable-size concerned at the periodic intervals, such as the VoIP with no silence suppression [1].

Table I summarizes the obligatory QoS parameters using in different scheduling service classes.

### III. SCHEDULING SCHEME

Scheduling is used to decide the priority to assure the QoS requirements. In other words, it is adopted to decide the first packet to serve in the particular queue to assure the QoS requirements. The scheduling scheme that has higher throughput and lower delay is required to have better network environment. It is an important research topic since it is not specified in the IEEE 802.16 standard. Furthermore, there are several researches proposed to create an efficient packet scheduling scheme. Thus, we will compare different scheduling scheme by using QualNet simulator. These different scheduling schemes are explained in the following subsection.

#### A. Weighted Fair Queuing (WFQ)

WFQ scheme, which derives from the General Processor Sharing (GPS), grants each flow different weights in order to have different bandwidth percentage. In this scheme, the

packet is selected and outputted at the time among the active sessions. When each packet arrives, it is given a virtual start time  $S(i,j)$  and a virtual finish time  $F(i,j)$ . The queue that has the smallest finish time is served first in the WFQ scheduler. Equation (1) uses to calculate the  $S(i,j)$  and  $F(i,j)$  of the  $i$  packet in the  $j$  session [8], [12].

$$\begin{aligned} S(i,j) &= \max(F(i-1,j), V(a(i,j))) \\ F(i,j) &= S(i,j) + L(i,j) / r(j) \end{aligned} \quad (1)$$

where:  $a(i,j)$  = the packet arrival time;  $L(i,j)$  = the packet length;  $V(t)$  = the virtual time function representing the virtual time process in the simulated GPS model.

#### B. Round Robin (RR)

The RR scheduling scheme is one of the most widely scheduling scheme used in the networking. It is simple and easy to implement. It start serve each queue without any priority in the circular order (Fig. 2). In other words, it serves the first node and then move to serve the next node in circular order [14].

#### C. Strict Priority (SP)

In the SP scheduling scheme, firstly the packets are classified into different QoS classes with different priority queues by the scheduler. The packets with the highest priority queues are served first until it becomes empty. Then, the scheduler moves in order to serve the packets with the second highest priority queues (Fig. 3). As a result, it may lead to bandwidth starvation for the lower priority QoS classes, such as nrtPS and BE [11].

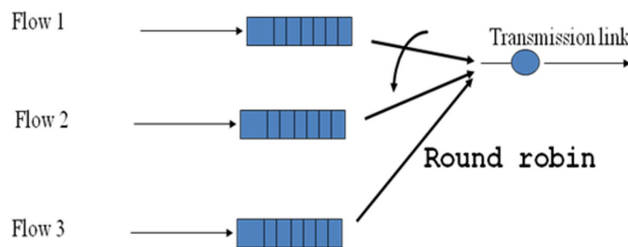


Fig. 2 Round Robin (RR) Scheme

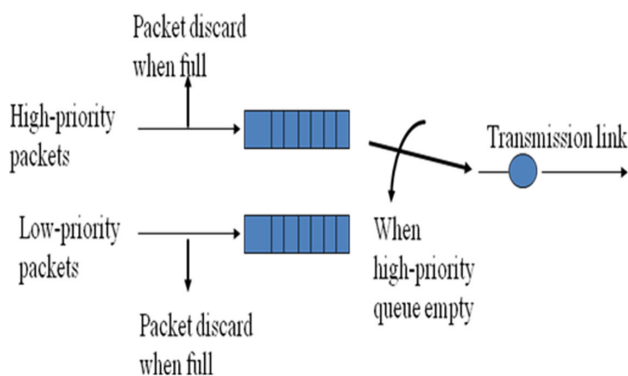


Fig. 3 Strict Priority (SP) Scheme

#### D. Self Clocked Fair Queuing (SCFQ)

In the SCFQ scheduling scheme, a specific bandwidth rate can be assigned for each flows depended on their priorities. When the scheduler receives the packet for a certain flow, the packet finish time ( $FT(i,j)$ ) is calculated by (2). The queue that has the smallest finish time is served first in the SCFQ scheduler [6].

$$FT(i,j) = \text{Max} (CT, FT(i, j-1) + (PS(i,j) / Bi)) \quad (2)$$

where:  $FT(i,j)$  = The virtual Finish Time of the  $i$  packet in the  $j$  session;  $CT$  = Current Virtual Time;  $PS(i,j)$  = Packet Size in the certain flow;  $Bi$  = The flow required bandwidth.

### IV. SIMULATION MODULE

The overall goal of this simulation study are to analysis the performance of different scheduling schemes, such as WFQ, RR, SP and SCFQ when the number of SSs increase in the WiMAX environment. QualNet version 5.0.2 is used to perform this simulation [3].

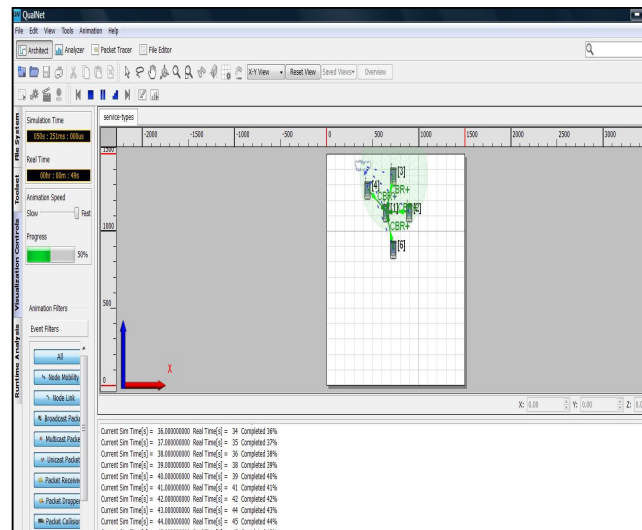


Fig. 4 Simulation Environment in QualNet

TABLE II  
PHY & MAC LAYER PARAMETERS

System Parameter	Value
Transmission Power	30 dBm
Channel Bandwidth	20 MHz
FFT Size	2048
Cyclic Prefix Factor	8
ARQ & H-ARQ	Disabled
Path Loss Model	Two-Ray

TABLE III  
PRECEDENCE VALUES FOR EACH SERVICE CLASS

Service classes	Precedence Values
UGS	7
rtPS	3
nrtPS	1
BE	0

Fig. 4 shows our simulation environment. We simulate 1 channel with a number of SSs 4, 8, 16 and 32 respectively. The important parameters using to configure the PHY and MAC layers summarizes in Table II. We use 20MHz as channel bandwidth and 2048 as FFT size. We only use CBR application for different service classes with different precedence values. There are eight queues configured to avoid queuing packets from different service types into one queue. Table III shows the precedence values for each service classes.

## V. RESULTS & PERFORMANCES ANALYSIS

We evaluate the performance of different scheduling schemes when the numbers of SSs in the IEEE 802.16 standard increase. This paper is focused in the most important factors for the QoS which are average Jitter, average end-to-end delay and throughput.

### A. Average Jitter

Fig. 5 shows that when the number of SSs increases, the average jitter is increased. The SP scheduling scheme has the lowest average jitter because it classifies the data into high priority queues and low priority queues and then the high priority queues are served first. However, if we study the performance of different service classes, the low priority service classes, such as nrtPS and BE service classes will have a higher average jitter. Therefore, the SP scheduling scheme is not recommended when the network in the high load and there are high numbers of high priority queues. However, the WFQ scheduling scheme has the highest average jitter especially when the number of SSs in the network is high because the bandwidth is shared between all different service classes equally.

### Average Jitter (ms)

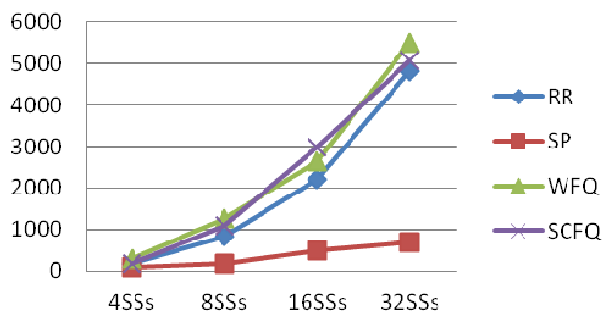


Fig. 5 Average Jitter for Different Scheduling Schemes

### B. Average End-to-End Delay

Fig. 6 shows that when the number of SSs increases, the average end-to-end delay is increased. The SP scheduling scheme has the lowest average end-to-end delay because it classifies the data into high priority queues and low priority queues and then the high priority queues are served first. However, if we study the performance of different service classes, the low priority service classes, such as nrtPS and BE service classes will have a higher average end-to-end delay. Therefore, the SP scheduling scheme is not recommended

when the network in the high load and there are high numbers of high priority queues. However, the WFQ scheduling scheme has the highest average end-to-end delay especially when the number of SSs in the network is high because the bandwidth is shared between all different service classes equally and it is based on the finish time. In addition, the average end-to-end delay in the RR scheduling scheme is increased regularly. For example, the average end-to-end delay when there are 8SSs in the network is doubled the average end-to-end delay when there are 4SSs in the network. Moreover, the average end-to-end delay when there are 32SSs in the network is doubled the average end-to-end delay when there are 16SSs in the network.

### Average End-to-End Delay (sec)

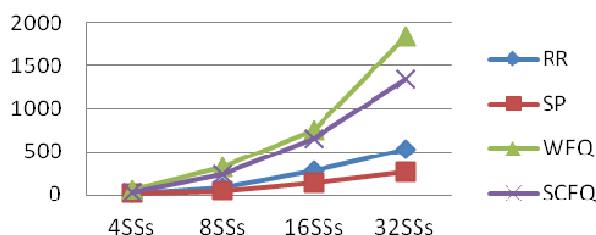


Fig. 6 Average end-to-end Delay for Different Scheduling Schemes

### C. Throughput

Fig. 7 shows that when the number of SSs increases, the throughput is reduced. The RR scheduling scheme has the lowest throughput. However, the WFQ scheduling scheme has the highest throughput. The throughput in the SP scheduling scheme is almost the same as the throughput in the SCFQ scheduling scheme. However, the low priority traffic classes, such as nrtPS and BE may have low throughput by using the SP scheduling scheme because of the bandwidth starvation for the low priority traffic classes. According to Figs. 6 and 7, if the node has higher delay, it has lower throughput. In other words, if it has lower delay, it has higher throughput.

### Thuroughput (KB/sec)

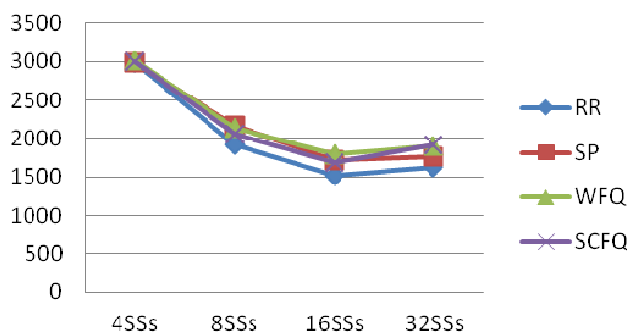


Fig. 7 Throughput for Different Scheduling Schemes

## VI. CONCLUSION

There are different scheduling schemes, such as WFQ, SP, RR and SCFQ used in the WiMAX networks. QualNet 5.0.2 is used in this paper to study the performance of different scheduling schemes when the numbers of SSs increase. The average jitter and average end-to-end delay is increased and the throughput is reduced when the number of SSs increases.

Designing an efficient scheduling scheme is one idea can be done as a future work. In addition, a new admission control can be created.

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