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Comparative Study of Scheduling Algorithms in WiMAX

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Abstract— In recent years, telecommunication operators are constantly seeking more efficient wireless broadband service, while telecommunication technology is continuously upgrading its access network technologies to cope with the high demands for high-speed internet access and multimedia service by end-users. WiMAX seems to be the solution as it is able to provide easy deployment, high speed data rate and wide range coverage. Most importantly, WiMAX provides Quality of Service (QoS) that can support all kinds of real-time application in wireless networks that includes priority scheduling and queuing for bandwidth allocation that is based on traffic scheduling algorithms within wireless networks.

This paper aims to evaluate the implementation of the various types of scheduling algorithms of WiMAX wireless network technology namely: Diffserv-Enabled (Diffserv), Round Robin (RR), Self-Clocked-Fair (SCF), Strict-Priority (SP), Weighted-Fair Queuing (WFQ) and Weighted-Round Robin (WRR). A detailed simulation study via the QualNet 5.0 simulator evaluation version was carried out with the aim to analyze and evaluate the performance of each scheduler to support the different QoS classes. The results of the simulation showed that effective scheduling algorithm can provide high service standards to support the QoS requirements to meet the different types of demands by the various end-users.

Index Terms— Scheduling Algorithms, WiMAX, QoS, QualNet

1 Introduction

The demand for high speed broadband wireless systems, internet access and multimedia service has increased tremendously as these applications are used in all sectors; trade and commerce, education and research, communications, and even leisure and entertainment. Consequently, the need for broadband wireless access (BWA) has grown significantly due to the increase in the number and types of users. Due to their mobility and need for data access at all times, an efficient broadband connectivity is much sought after. Hence, WiMAX, (Worldwide Interoperability for Microwave Access) which is a trade name used to group a number of wireless technologies have emerged from IEEE (Institute of Electrical and Electronics Engineers) to meet the demands of the various end-users. It is deployed to serve all the end-users. Moreover WiMAX technology is based on a Standard that is IEEE 802.16 which is (BWA) that offers mobile broadband connectivity.

WiMAX provides Quality of Service (QoS) that supports five different categories of services namely: Unsolicited grant services (UGS), Real-time polling services (rtPS), Non- real-time polling service rate (nrtPS), Extended real-time polling service (ertPS) and Best-Effort services (BE). As such, scheduling class services must ensure there is efficiency and fairness in meeting the various QoS requirements.

The scheduling class services in wireless networks includes priority scheduling and queuing for bandwidth allocation based on traffic scheduling algorithms within wireless networks. Since the scheduling algorithm is still an undefined territory, designing an efficient scheduling algorithm that can provide high throughput with minimum delay is indeed a challenging task for system developers.

Although there are various studies on scheduling algorithms, there is a clear absence of a comprehensive performance study that provides a unified platform for comparing such algorithms. Therefore, this research paper is aimed to investigate and compare several scheduling algorithms in terms of performance and abilities to support multiple classes of service. Besides that, the paper intends to identify significant scheduling algorithms for the Uplink and Downlink channels that use QualNet-5.0. Finally it aims to measure the important metrics of the scheduling algorithms.

1.1 WiMAX Architecture

The basic IEEE 802.16 architecture consists of one Base Station (BS) and one or more Subscriber Station (SS). BS acts as a central entity to transfer all the data from SSs through two basic operational modes: mesh and point-to-multipoint (PMP). Meanwhile, transmissions take place through two independent channels: Downlink Channel (from BS to SS) and Uplink Channel (from SS to BS). The Uplink Channel is shared among all SSs, while the Downlink Channel is used only by BS [1].

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In the mesh mode, subscriber stations (SS) can communicate with each other as well as with the base station (BS). This means that traffic can be routed through other SSs. Also the traffic can occur directly among SSs. Therefore, within the mesh mode, uplink and downlink channels are defined as traffic in the direction to and from the BS, respectively.

In the PMP mode, the SSs are only allowed to communicate through the BS. In this way, the provider can control the environment to ensure that the Quality of Service (QoS) meets the requirements of its customers. In the PMP mode, traffic only occurs between the Base Station (BS) and Subscriber Stations (SS).

1.2 WiMAX Quality of Services

WiMAX standard defines 5 service classes to support its wide range of applications as endorsed by IEEE 802.16.

1.2.1 Unsolicited grant services (UGS):

This class of service is designed to support fixed-sized data packets at a constant bit rate (CBR) such as E1/T1 lines that can sustain real-time data stream applications. This service provides guaranteed throughput, latency and jitter to the necessary levels as TDM services. UGS is used mainly to support Constant Bit Rate (CBR) services found in voice applications such as voice over IP [2,3,4,5,6].

1.2.2 Real-time Polling Services (rtPS):

This class of service is designed to support real-time service flow that generates variable-sized data packets on a periodic interval with a guaranteed minimum rate and guaranteed delay. The mandatory service flow parameters that define this service are inclusive of minimum reserved traffic rate, maximum sustained traffic rate, maximum latency and request/transmission policy. rtPS is used extensively in MPEG video conferencing and streaming [2,3,4,5,6].

1.2.3 Non-real-time Polling Service (nrtPS):

This class of service is designed for non-real-time traffic with no delay guaranteed. The delay tolerant data stream consists of variable-sized data packets. The applications provided by this service are time-insensitive and a minimum amount of bandwidth. This service is especially suitable for critical data application such as in File Transfer Protocol (FTP) [2,3,4,5,6].

1.2.4 Extended real-time Polling Service (ertPS):

This class of service provides real-time applications which generate variable-sized data packets periodically that require guaranteed data rate and delay with silence suppression. This service is only defined in IEEE 802.16e-2005. During the silent periods, no traffic is sent and no bandwidth is allocated. However, there is a need to have a BS poll during the MS to determine the end of the silent periods. ertPS is featured in VoIP with silence suppression [2,3,4,5,6,7].

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1.2.5 Best-Effort Services (BE):

This class of service provides support for data streams whereby no minimum service-level guarantee is required. The mandatory service flow parameters that define this service include maximum sustained traffic rate, traffic priority and request/transmission policy. BE supports data streams found in Hypertext Transport Protocol (HTTP) and electronic mail (e-mail) [2,3,4,5,6].

2 SHEDULING ALGORITHMS

The main focus of this research study is to examine the scheduling schemes in WiMAX network. In order to specify high network performance, an efficient scheduling algorithm is essential as it manages and controls the provision of an efficient level of QoS support.

Although many scheduling algorithms have been proposed in the literature for WiMAX network, the design of the algorithms are challenged by having to support different levels of services, fairness and implementation complexity. Many researchers have compared their proposal schemes on different scheduling schemes, but there is no common, simple and standardized packet scheduling to make their comparisons with.

In this study, six carefully selected scheduling algorithms in WiMAX wireless network are investigated. These algorithms which are considered the most dominant and popular include Diffserv-Enabled (Diffserv), Round-Robin (RR), Self-Clocked-Fair (SCF), Strict-Priority (SP), Weighted-Fair Queuing (WFQ) and Weighted Round Robin (WRR). Furthermore, these common packet scheduling schemes provides QoS support for real time applications in IEEE 802.16 system.

2.1 Diffserv-Enabled: Diffserv is a simple, scalable and measurable mechanism for classifying and managing network traffic. Besides, it provides low-latency with guaranteed service to critical network traffic as well as to non-critical services. It relies on the principle of traffic classification by involving the 6-bit Differentiated Services Code Point (DSCP) field in the header of IP packets to classify the packet and indicate the per-hop behavior (PHB). DSCP replaces the outdated IP precedence in classifying and prioritizing types of traffic. Every router on the Diffserv network is configured to differentiate traffic based on class so that each traffic class can be managed differently, ensuring preferential treatment for higher-priority traffic on the network [8].

2.2 Round-Robin (RR): It is designed for a time-sharing system whereby the scheduler assigns time slots to each queue in equal portions without priority. It starts with the highest priority queue with packets, services a single packet, then visits the next lower priority queue with packets, and continues servicing every single packet from each queue. This is carried on until each queue with packets has been serviced once. Every queue is allocated with the same portion of system resources regardless of the channel condition, ultimately utilizing the same resources. However, the RR scheduler has the same bandwidth efficiency as a random scheduler, so it cannot guarantee different QoS requirements for each queue [9, 14].

2.3 Self-Clocked-Fair (SCF): It is an efficient queuing scheme which satisfies the quality of services (QoSs) in broadband implementation. The algorithm is based on the concept of virtual time that adopts the concept of an internally generated virtual time as the index of work in progress. It links virtual time to the work progress in the fluid-flow fair queuing (FFQ). As virtual time function is involved in determining the order of which packet should be served next, the virtual time that is produced depends very much on the progress of work in the actual packet-based queuing system. This scheme is efficient for the internal generation of virtual time as it involves negligible overhead. This is because virtual time is easily computed from the packet situated at the head of the queue. In addition, the SCFQ algorithm can accomplish easier implementation and it can maintain the fairness attribute in virtual time function. [10, 11,15].

2.4 Strict-Priority (SP): In Strict-Priority algorithm, the selection order is based on the priority of weight order. The packets are first categorized by the scheduler depending on the quality of service (QoS) classes and then allocated into different priority queues. The algorithm services the highest priority queue until it is empty, after which, it moves to the next highest priority queue. Thus, strict-priority algorithm may not be suitable in WiMAX network. This is because there is no compensation for inadequate bandwidth. Also this technique is only appropriate for low-bandwidth serial lines that currently uses static configuration which does not automatically adapt to changing network requirements. Finally, this process may result in bandwidth starvation for the low priority QoS classes whereby the packets may not even get forwarded and no guarantee is offered to one flow [6].

2.5 Weighted-Fair-Queuing (WFQ): This algorithm is employed for uplink traffic in WiMAX with different size packets. As it caters to different size packets, it emphasizes on providing fair scheduling for the different flows by assigning finish times to the packets. The finish times are based on the size and weight of the packets. In general, the WFQ algorithm outperforms the WRR due to variable size packets. However, the weaknesses of WFQ algorithm are, the start time of a packet is not taken into consideration, and it can lower the scheduler system if many packets occur in the priority region [12, 13].

2.6 Weighted Round Robin (WRR): It is a scheduling algorithm implemented for resource sharing in a computer or network. In fact, WRR is an extension of the Round Robin (RR) algorithm. In a network, WRR serves a number of packets that are computed by normalizing weight of data divided by the average of packet size from non-empty connection queue. It begins by classifying packets into a variety of service classes followed by assigning a queue that is determined by the different percentage of bandwidth. Finally, it is serviced in round robin order. Since the bandwidth is assigned according to the weights, the algorithm will not provide good performance in the presence of variable size packets. However, WRR method makes certain that all service classes have access to at least some configured amount of network band width to avoid bandwidth starvation [2,6,7].

3 Simulation Model

The purpose of this simulation study is to investigate and evaluate different types of scheduling techniques in order to determine the one that is most efficient in WiMAX network. The simulations are performed using QualNet simulation. This simulation provides an intuitive model set up capability that includes core components such as animator, packet tracer analyzer, protocol designer and protocol stack.

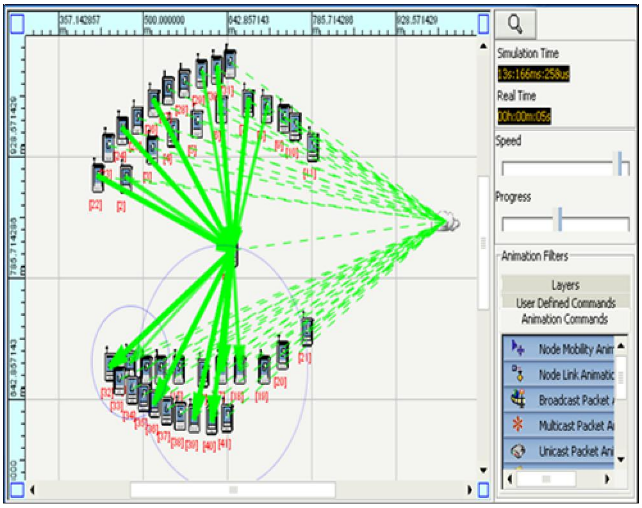

Fig.1.System Model Implementation by QualNet

The system parameter used in this simulation study consists of a single cell with a BS, and a number of MS that

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varies from 10 to 50 MS. Table 1 summaries the simulation parameters used in the experiments with 20MS.

TABLE 1.SIMULATION PARAMETERS

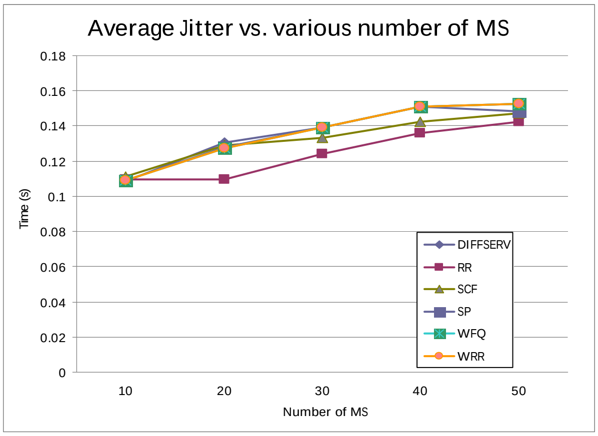
Parameter	Value
BS range radius (m)	1000
MS range radius (m)	500
Frequency band (GHz)	2.4
Channel bandwidth (MHz)	20
Frame duration (ms)	20
FFT size	2048
Number of MS	10-50
Number of BS	1
BS transmit power P_t $dBm/height$ (m)	20 / 5
MS transmit power P_t $dBm/height$ (m)	15 / 1.5
Services types (QoS)	BE, nrtPS, rtPS, ertPS, UGS
Simulation time (s)	30

4 SIMULATION RESULTS

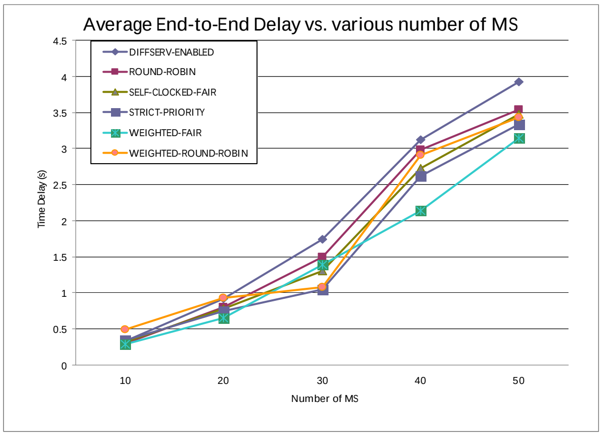
Six experiments with varying simulation parameters were carried out and the findings show varying results.
The results of experiment 1 are shown in Figure 4.1 that SP, WRR, and WF are the best scheduling techniques in WiMAX network with respect to the end-to-end time delay.

The results of experiment 2 are shown in Figure 4.3 indicate that there is much difference between all algorithms when the number of mobile stations (MS) is small (10MS). This happens as MS produces the shortest amount of time for packet latency. Another result obtained is RR outperforms the other techniques when the number of MS becomes more (20-50MS). The results also indicate that SCF performs better than Diffserv, WRR, SP, and WFQ when the number of mobile stations (MSs) is increased (30-40MS).

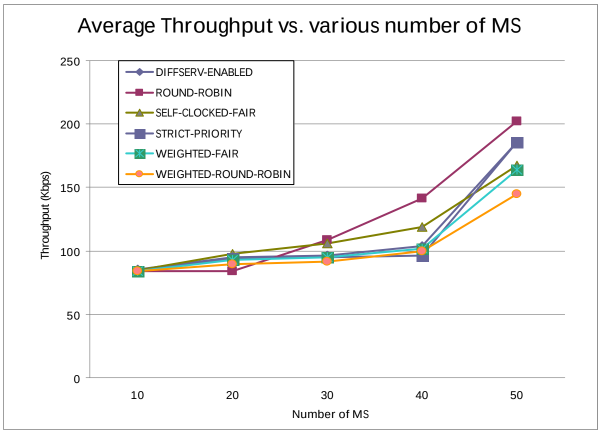
The result of experiment 3 are shown in Figure 4.5 clearly shows that RR technique has achieved the highest value of throughput for different numbers of MS (20-50) compared to the other five techniques. However, RR technique shows the same amount of throughputs as the others when the number of MS ranges between 10-20. Furthermore, most of the algorithms have the same performance when the numbers of MS are fewer than 30.



EXPERIMENT 1: FIGURE 4.1: THE AMOUNT OF END-TO-END DELAY



EXPERIMENT 2: FIGURE 4.3: THE PACKET LATENCY (JITTER)



EXPERIMENT 3: FIGURE 4.5: THE THROUGHPUT OF NETWORK

Meanwhile the results tabulated in Figure 4.2 shows that Diffserv has the lowest performance in producing the highest amount of end-to-end delay time. On the other hand, WF shows the best performance as the average end-to-end time delay has the lowest reading. Finally, it can be concluded that there is much difference in terms of the average end-to-end delay time among RR, SCF and WRR.

From the figure 4.4, it is noted that RR technique shows the most favourable results as the average jitter has low reading (0.124s), while Diffserv shows the most unfavourable result as the average jitter has higher reading (0.137s). The results also show that WF and WRR produce almost the same amount of average jitter (0.136s). However, there is no big gap between the two algorithms, WF and WRR, in terms of overall average jitter and SP.

From the figure 4.6, it is noted that RR algorithm outperforms the other five algorithms in terms of the overall throughput 125Kbps. The results of the experiment shows that WRR is a poor scheduling technique as it produces the lowest amount of average throughput 100Kbps. Diffserv, SCF, and SP produce almost the same amount of overall average for the throughput 110Kbps, while WF is ranked after these algorithms as the average throughput is 103Kbps.

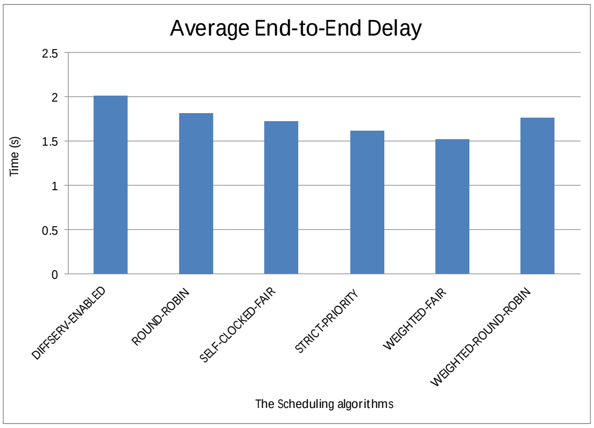


FIGURE 4.2: THE TOTAL AVERAGE OF END-TO-END DELAY TIME

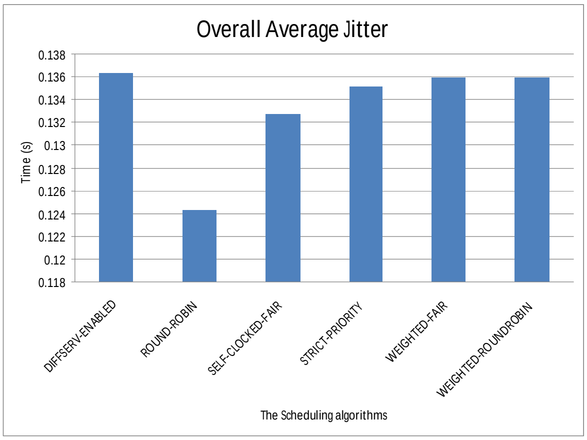


FIGURE4.4: THE AVERAGE OF PACKET LATENCY (JITTER)

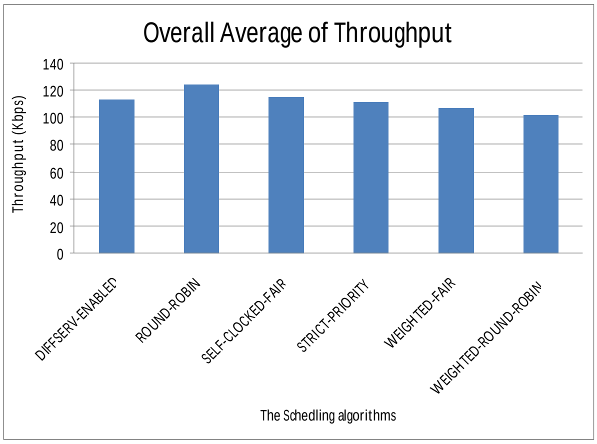
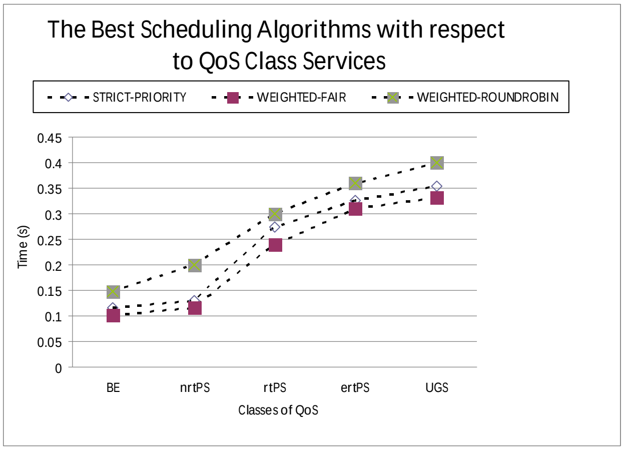


FIGURE 4.6: THE OVERALL AVERAGE OF THROUGHPUT

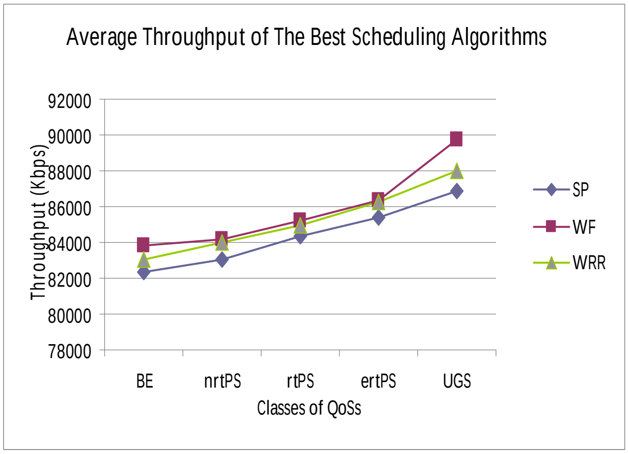
The results of experiment 4 are shown in Figure 4.7 that WF outperforms SP and WRR as it achieves the shortest amount of end-to-end delay time for all the classes of QoS. However, WF achieves the same amount of end-to-end delay time for the class BE and nrtPS. It is also noted that BE achieves the shortest amount of end-to-end delay time for the three algorithms, while UGS produces the longest amount of end-to-end delay time for all the three algorithms.

The results of experiment 5 are shown in Figure 4.8 the observations of the average throughput for the best three scheduling algorithms; SP, WF, WRR with respect to the classes of the quality of services (QoSs). In Figure 4.7, it is clear that WF is the best algorithm as produces BE, nrtPS, rtPS, ertPS, and UGS class. However, the performance of SP is not favorable compared to the performance of WRR and WF. These three algorithms are selected due to the fact that they achieve the best performance with respect to different scenarios and various numbers of factors in the simulation experiments.

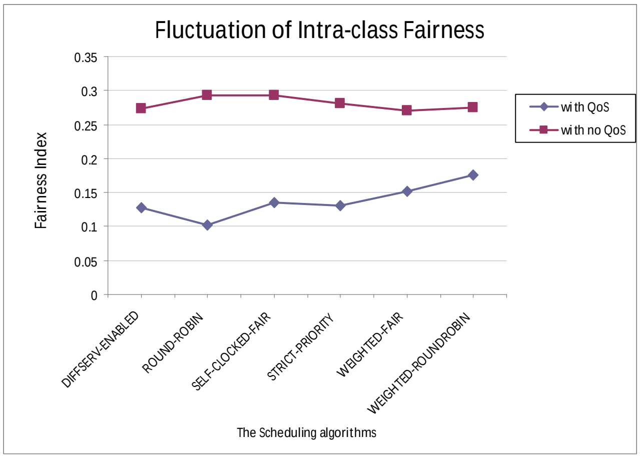
The results of experiment 6 are shown in Figure 4.9 reveal that the classes of the QoSs positively influence the percentage of the fairness index for each scheduling technique. It is also noted that RR scheduling technique with QoS achieves the best percentage of fairness index, while WRR with QoS shows the highest percentage of fairness index. However, RR technique with no QoS achieves higher percentage of fairness index, while WRR with no QoS shows the lowest percentage of fairness index. Finally, from Figure 4.8, it can be concluded that the QoS class services have a high impact on the percentage of the fairness index.



EXPERIMENT 4: FIGURE 4.7: THE AMOUNT OF DELAY TIME FOR THE BEST SCHEDULING ALGORITHMS



EXPERIMENT 5: FIGURE 4.8: THE AVERAGE OF THROUGHPUT FOR THE BEST SCHEDULING ALGORITHMS



EXPERIMENT 6: 4.9: THE FLUCTUATION OF INTRA-CLASS FAIRNESS

6 CONCLUSIONS AND FUTURE WORK

In conclusion, the investigation of the behaviors of several wireless scheduling algorithms namely Diffserv, RR, SCF, SP, WFQ, WRR has shown the strengths of some of the scheduling algorithms that were under study. One of the best scheduling algorithms is WF, in terms of the amount of end-to-end delay. The other is RR, in terms of packet latency (Jitter). Finally WRR outperforms the rest by producing the highest rate of throughput of data packet in the network. As to the best scheduling algorithms in terms of the amount of delay time with respect to QoSs classes are WF, SP, and WRR respectively. Finally, it is clear that there is not a single scheduling scheme that provides superior performance with respect to all the QoS requirements and characteristics of the IEEE 802.16 MAC layer. This is because issues such as the amount of information required by the grant scheduler at the BS and the allocation of time-slots and sub-channels to different SSs require attention.

As the scheduling in WiMAX wireless network is a challenging topic, future works should include further investigation on scheduling algorithms under different bandwidth request mechanisms and CAC schemes.

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