A Performance Analysis of Packet Scheduling Algorithms between Homogeneous Algorithm And Hybrid Algorithm in Point to Multipoint WiMAX Networks

Dadiek Pranindito[1]
Teknik Telekomunikasi
ST3 Telkom
Purwokerto, Jawa Tengah, Indonesia
dadiek@st3telkom.ac.id

Rendy Munadi[2]
Fakultas Teknik Telekomunikasi
Telkom University
Bandung, Jawa Barat, Indonesia
rendymunadi@telkomuniversity.ac.id

R. Rumani M.[3]
Fakultas Teknik Telekomunikasi
Telkom University
Bandung, Jawa Barat, Indonesia
rumani@telkomuniversity.ac.id

Abstract – WiMAX (Worldwide Interoperability for Microwave Access) is a wireless technology that provides long distance broadband connectivity. It has high speed access, wide coverage areas, and provides various types of services. Applying WiMAX has challenging problem when it has to provide quality assurance of service (QoS) for different types of services with diverse QoS needs.To meet the QoS requirements, a scheduling algorithm is needed. Scheduling algorithm is to regulate the transmission of data packets, such as regulating the sharing of resources (bandwidth) for each user.

This research implemented a WiMAX network simulation scheduling algorithm with homogeneous and hybrid algorithm methods. Representatives on the homogeneous algorithms method used Weighted Fair Queuing scheduling algorithm (WFQ) and Deficit Round Robin (DRR), whereas the hybrid algorithm method used a merge between DRR and WFQ scheduling algorithm. Testing the performance of the scheduling algorithm was performed by comparing the QoS class into 5 types, namely WiMAX UGS, RTPS, nRTPS, eRTPS and Best Effort. The parameters used to test the performance of a WiMAX network are throughput, packet loss, delay and jitter.

Keywords - QoS, homogeneous algorithm, hybrid algorithm.

I. INTRODUCTION

WiMAX (Worldwide Interoperability for Microwave Access) has been proposed to be one of the best wireless communication technologies on providing broadband access in Wireless Metropolitan Local Networks (WMLN) area. IEEE 802.16e is the standard used on WiMAX networks, and hopefully is able to be a Broadband Wireless Access technology which is capable of providing high speed access for users, up to 70Mbps on a radius of 50 Km [7]. IEEE 802.16e also has a set of specifications in the Physical (PHY) and Medium Access Control (MAC) layer [4]. The PHY layer is more concerned on the number of air interfaces, such as OFDMA (Orthogonal Frequency Division Multiplexing Access), while the MAC layer concentrates more on the scheduling process, which is the process of requesting and providing bandwidth to users according to the Quality of Service (QoS) [4][6].

Although IEEE provides QoS specifications, there is still no effective scheduling that can handle different QoS types [9]. There are 5 IEEE 802.16e standard specifications of QoS: 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) [9]. There are two main components on WiMAX architectures i.e. a Base Station (BS) and some Subscriber Stations (SS). There are two traffic data streams to link BS and SS, called uplink and downlink. Uplink is channel for data transmission from SS to BS, while downlink is channel for data transmission from BS to SS. This study, however, was only focusing on analyzing the downlink.

This research used 3 representatives of scheduling algorithm, they are Weighted Fair Queuing (WFQ), Deficit Round Robin (DRR) and Hybrid scheduling algorithm (WFQ-DRR). Based on the analysis of these algorithms it was shown that Hybrid scheduling algorithm (WFQ-DRR) gave the best result.

II. PROBLEM BACKGROUND

In facts, IEEE 802.16e 2005 technology has been established for wider bandwidth with larger coverage. However, there is still no efficient scheduling algorithm that can manage different applications compatible with QoS requirements yet [2][4][9][14]. Currently, there are 5 IEEE 802.16e standard specifications of QoS, these are: UGS, RTPS, eRTPS, nRTPS, and BE.

The growth of population and the development of wireless technologies boost the usage of internet. Fast internet access is needed to upload and download various multimedia applications, such as real-time audio, video streaming, multimedia conferencing, and interactive gaming [1]. To provide bandwidth from different applications, an efficient scheduling algorithm is required. This needs an algorithm that can fulfill user's QoS requirements, maximizing bandwidth, and ensuring balance among users needed.

The use of homogeneous optimal algorithm is only applicable to certain conditions. Based on this background, it is necessary to apply the hybrid algorithm that can complete each other to the advantage of any kind of scheduling algorithm in certain circumstances. The use of hybrid algorithm (DRR + WFQ) will be able to make improvements to maximize the performance of the algorithm with the available bandwidth and ensure fairness for each user.

III. RELATED WORK

WiMAX (Worldwide Interoperability Microwave Access) is based on IEEE 802.16 standard that provide wireless technology for nomadic and mobile data access. Wireless system is covering geographic area without cost for cable infrastructure for every single access point services. WiMAX offers effective cost and gives alternative connection just like what fiber optic, coaxial, digital subscriber line, or T1 network do. In particular, the current Mobile WiMAX technology is mainly based on the IEEE 802.16e amendment (IEEE, 2006a), approved by the IEEE in December 2005 [8][15].

3.1. QoS Types

A service class is identified by a unique set of QoS requirements. Connections within a certain class can have individually different QoS requirements [8][15]. Service grouping flows into different services scheduling, uniquely determine the mechanism by which traffic is allocated to each flow. QoS requirements on 802.16 MAC can be grouped onto: UGS, RTPS, eRTPS, nRTPS, and BE [3] with the explanation below:

Table 2.1. Provision of QoS service for IEEE 802.16e [19][20]

Class of Service	Parameters	Possible Applications
UGS	Maximum Sustained Traffic Rate Maximum Latency Tolerated Jitter Request/Transmission Policy Minimum Reserved Traffic Rate	TDM Voice;
RTPS	Minimum Reserved Traffic Rate Maximum Sustained Traffic rate Maximum Reserved Traffic Rate	Video Telephony, VoD, AoD, Internet Shoping
eRTPS	Maximum Sustained Rate Traffic Priority Minimum Reserved Traffic Rate Maximum Latency Jitter Tolerance	VoIP with Silence Suppression
nRTPS	Minimum Reserved Traffic Rate Maximum Sustained Traffic rate Traffic Priority Request/Transmission Policy	High-speed File Transfer
BE	Maximum Sustained Traffic rate Traffic Priority Request/Transmission Policy	Web-browsing, P2P File Sharing

3.2. WIMAX Scheduling Algorithms

IEEE Std. 802.16 does not establish scheduling algorithm on WiMAX, so everyone can improve scheduling algorithm that can minimize bandwidth and controls the service quality. Algorithms that will be discussed in this research are Weighted Fair Queue (WFQ), Deficit Round Robin and Hybrid scheduling algorithm (WFQ-DRR).

3.2.1. Weight Fair Queuing (WFQ)

WFQ is a scheduling algorithm example on WiMAX. WFQ is used to determine the total number of data packages that are being processed at a certain time and also managing the channel capacity while allocating the lowest finish time. Determining the amount of weight depends on the type of service and its size. When a data package arrives, it will be classified by the classifier before it is sent to one of the gates. On the classifier, the data packages are classified based on the type of service, size, source, and destination. Each gate has different weight composed of various applications based on the QoS needed.

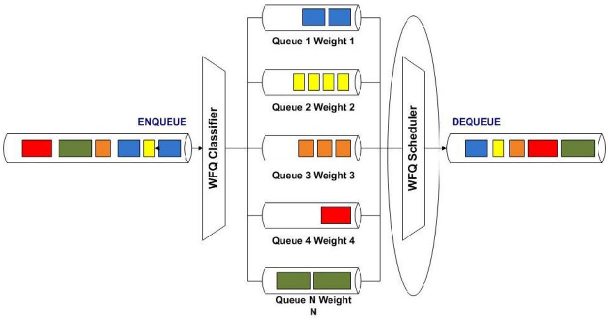


Figure 2.1. Weight Fair Queuing

3.2.2. Deficit Round Robin (DRR)

Earliest Deadline First scheduling algorithm is one of the most widely used for real time applications. In the algorithm DRR (Deficit Round Robin) become the order of priority of its deficit counter, if the package size is smaller than the deficit counter, the package is sent and when the package size is greater than the deficit counter, the package will not be sent [4] [11].

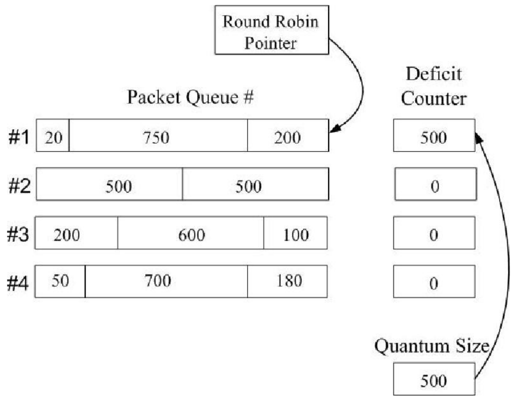


Figure 2.2. Deficit Round Robin (1)

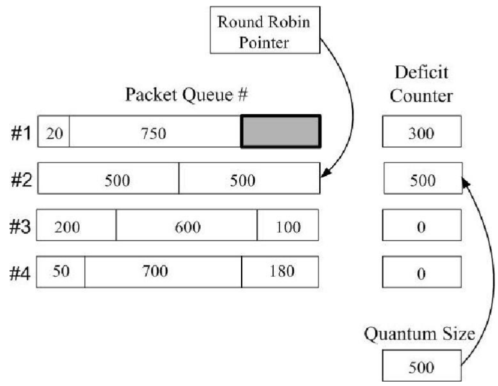


Figure 2.3. Deficit Round Robin (2)

Figure 2.2 shows the current packet from the queue # 1 will be served, the value of the deficit counter queue # 1 is filled with a quantum of time. Due to the size of the first packet of the queue # 1 which is less than the deficit counter, then the packet is sent. Figure 2.3 shows the condition when the first packet of the queue # 1 has been sent. The pointer of the queue will be moved to the queue # 2 and the deficit counter queue # 1 will be reduced by the amount of packets that have been sent. DRR algorithm is effective to apply to the datagram network with the number of packages that are very diverse.

IV. Performance Parameter

4.1. Throughput

Throughput value is determined by [5][10]:

$$\text{Throughput} = \frac{\text{number of data bytes received}}{\text{bytes} - \text{time delivery}} \text{ Bps} \quad (1)$$

Throughput system is the comparison between number of data bytes received and byte-time delivery. Byte-time delivery is the time used to send a packet, from the beginning of the transmission until the packet is received by the receiver.

4.2. Packet loss

Packet loss is defined as transmission failure. A relative measure of the number of packets that were not received compared to the total number of packets transmitted. Packet loss percentage should not be more than 10%. The best percentage for audio is not more than 1%, for video not more than 5%, and for data, packet loss should be 0% [12].

$$\text{Packet loss} = \frac{\text{transmitted packets} - \text{received packets}}{\text{delivery packets}} x\ 100\% \quad (2)$$

4.3. Delay

Delay is the time span between the time when the packet arrives on queue and packet discharged from queue, and the time when it is ready to be transmitted. One-way delay should not be more than 150ms. But the best delay is less than 30ms for video and audio service, while for data service is below 400ms [12]. The formula is as below [5][10]:

$$\text{delay(n)} = T_{out}(n) = \text{serving time} + T_{in}(n) \quad (3)$$

Where :

$T_{out}(n) =$ timing of n data discharge from queue and ready to be transmitted.

$T_{in}(n) =$ timing of n data arrives on queue.

4.4. Jitter

Jitter is the inter-packet delay variation that occurs in the IP network. The amount of jitter will be strongly influenced by variations in the traffic load and the amount of collisions between packets (congestion) that exist in the IP network.

V. MODELLING SYSTEM

5.1. Hybrid algorithm modeling in NS-2

Hybrid Algorithm in this study is a combination of algorithms WFQ and DRR algorithm. WFQ algorithm is very suitable to execute non-real-time applications (nrtPS, and BE), while DRR algorithm gives very good results for the applications of real-time (UGS, rtPS and ertPS).

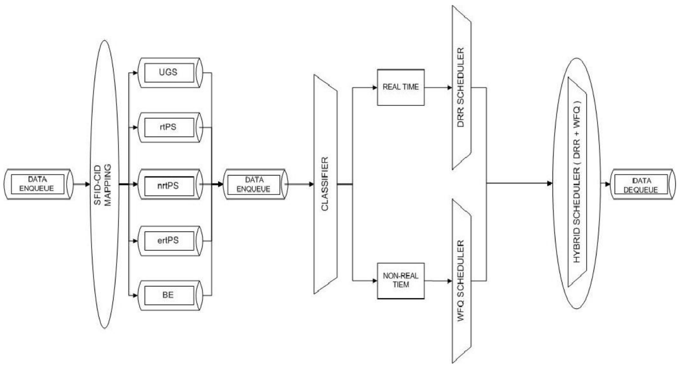


Figure 5.1. Hybrid Algorithm

From figure 5.1 the data queue will be processed into two processes at the same scheduling algorithm. In the early stages queue the data to be classified based on the application, including the application of real-time or non-real-time. Applications of real-time QoS prioritise to delay, whereas the non-real-time applications over QoS emphasis on throughput and packet loss. Therefore, real-time applications will be executed in advance by the DRR scheduler. The next record will be forwarded to the WFQ scheduler. It is expected that the hybrid method algorithm can improve the performance of systems with improved delay in real-time applications, and improved throughput and packet loss on the applications of non-real-time.

5.2. Network Configuration

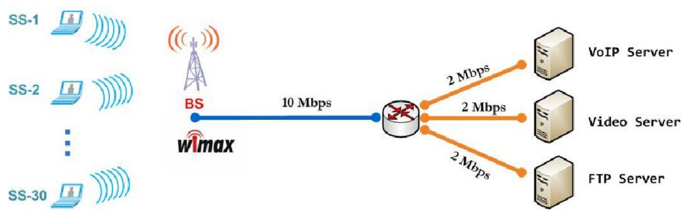


Figure 5.2 Simulation Topology

Wimax network consists of two main components, namely a Subscriber Station (SS) and the Base Station (BS). SS is WiMAX devices that exist on the customer side. When a connection request is approved, a service with specific QoS parameters will be made. Service scheduling is the data handling mechanisms to support the MAC scheduler for a transport of data connection. Scheduler will calculate throughput. DL broadcast and burst scheduler fills each frame based on the QoS parameters on the queue. UL scheduling scheme is more complex since it requires coordination between the BS and SS individuals. In this study, the total number of subscriber station (SS) used was 30 SS.

VI. INTREPETATION OF DATA

Scenario testing was done by collecting data on mobile user using the random seed. Random seed aimed at generating a random number during the simulation, which was used for determining the location of mobile nodes (rounded up). Each random seed would generate the same random number row, although used in different simulations. Here is a picture of simulation testing on random seed 13.

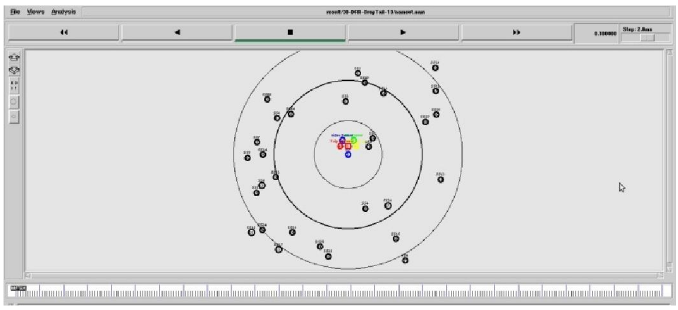
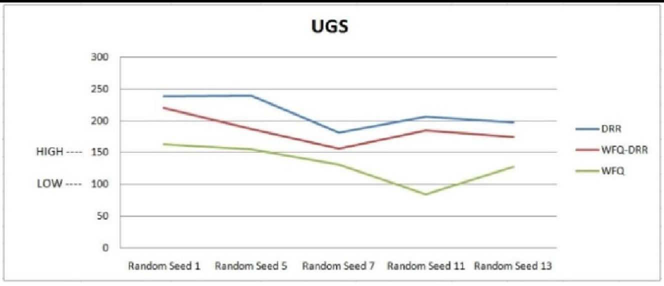


Figure 6.1. Testing Scenario on Random Seed 13

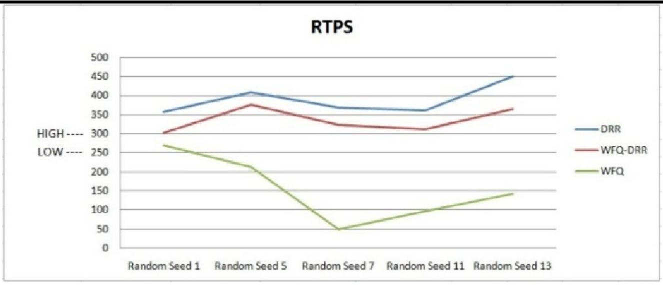
As noted above, there are 5 types of traffic on the IEEE 806.16e which are UGS, rtPS, eRTPS, nRTPS, and BE. Testing was done by dividing the number of mobile nodes in the ratio of mobile nodes for UGS QoS class; rtPS; eRTPS; nRTPS; BE is 6; 6; 6; 6; 6 user SS. The total number of subscriber station (SS) used was 30 SS. Parameters to be tested were the delay, throughput, packet loss, and jitter.

6.1. Throughput

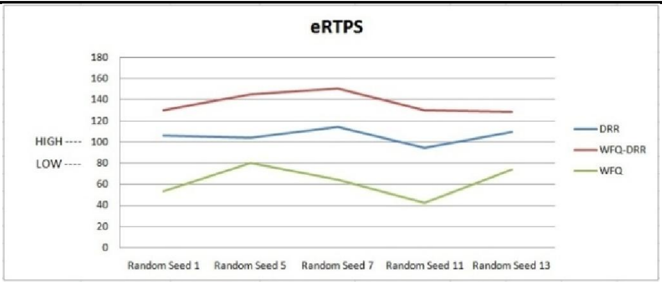
Picture below is the throughput for the five types of QoS classes, namely UGS, rtPS, nRTPS, eRTPS, and BE. The result of throughput values for each QoS class would be a comparison between the homogeneous algorithm (WFQ and DRR) with Hybrid algorithm (WFQ + DRR). Data collection was carried out on every scheduling algorithms in mobile conditions. Scenarios where network traffic for mobile conditions randomized seed which was divided into five types: random seed 1, random seed 5, random seed 7, random seed 11, and random seed 13.



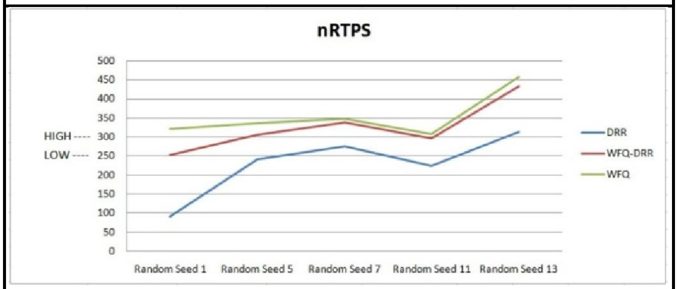
Curve A. Throughput comparison DRR, WFQ-DRR, and WFQ for UGS



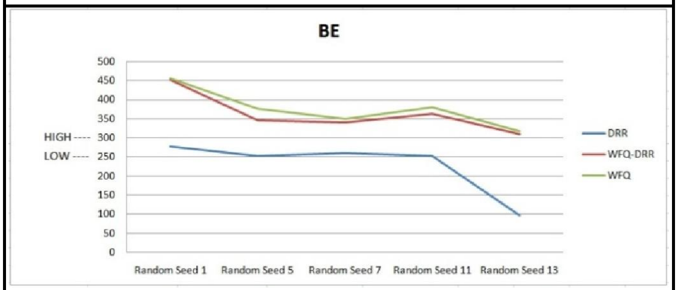
Curve B. Throughput comparison DRR, WFQ-DRR, and WFQ for RTPS



Curve C. Throughput comparison DRR, WFQ-DRR, and WFQ for eRTPS



Curve D. Throughput comparison DRR, WFQ-DRR, and WFQ for nRTPS



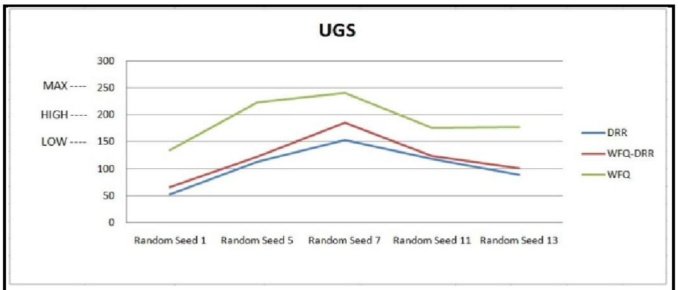
Curve E. Throughput comparison DRR, WFQ-DRR, and WFQ for BE

Figure 6.2 Throughput Comparison

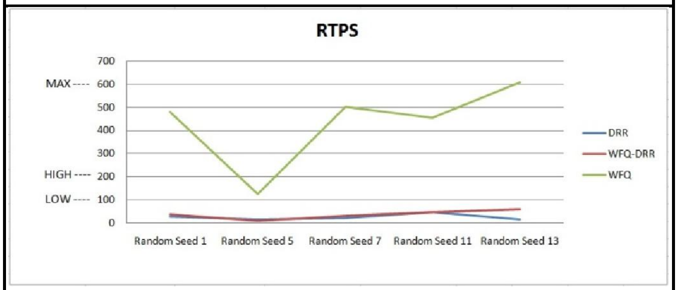
In Figure 6.2, section curve A and curve B show that the UGS and rtPS QoS class, DRR scheduling algorithm scored high throughput, which reached 250 KBps for UGS QoS class and up to 500 Kbps for rtPS QoS class. Good results were also characterized by high curves. But classes that were real-time QoS were not going well when using WFQ scheduling algorithm. WFQ scheduling algorithm decreased throughput at the real-time data packet, which is characterized by the low value of the curve as shown in Figure 6.2 section curve A and curve B. On the other hand, for non-real-time data packets (nRTPS and BE), WFQ scheduling algorithm could produce a high throughput rate, reaching 500 KBps. This is also shown by the increase in throughput in Figure 6.2 section curve D and curve E. As for the hybrid algorithm always showed relatively good throughput and stable at the fifth grade of QoS. As seen in Figure 6.2, the hybrid algorithm produced an average high value on all packets of data, both real time and non-real time. Given this assessment, it can be concluded that the hybrid algorithm can result good throughput when run on a system with diverse traffic data, i.e real time and non-real time data packets.

6.2. Delay

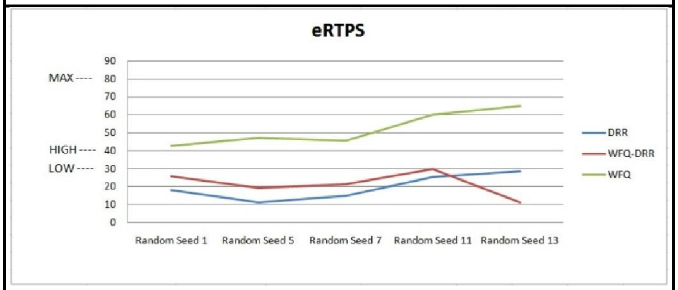
Delay is the interval between the arrival time of packets in the queue and the release of the packet from the queue and ready to be transmitted. As the throughput of data retrieval, data retrieval on Delay were done on 5 of WiMAX QoS classes, namely UGS, rtPS, nRTPS, eRTPS, and BE. Scenario traffic on Delay measurement was equal to the current traffic scenario testing of throughput, i.e the mobile condition and using different random seeds.



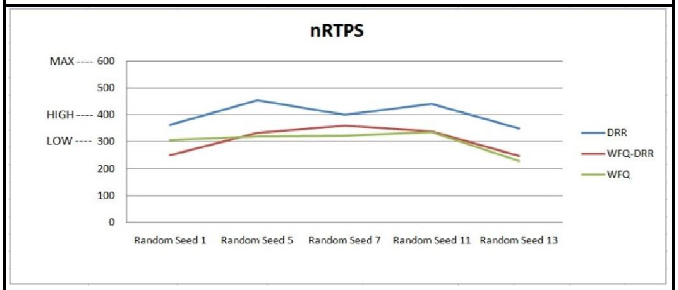
Curve A. Delay comparison DRR, WFQ-DRR, and WFQ for UGS



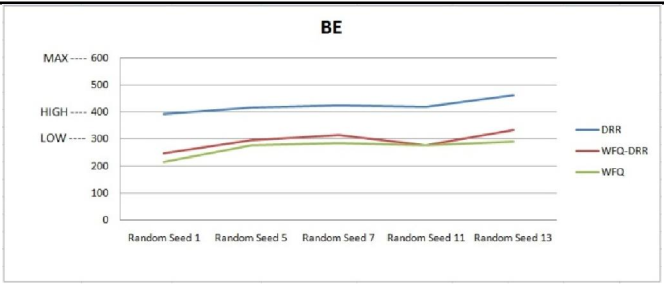
Curve B. Delay comparison DRR, WFQ-DRR, and WFQ for RTPS



Curve C. Delay comparison DRR, WFQ-DRR, and WFQ for eRTPS



Curve D. Delay comparison DRR, WFQ-DRR, and WFQ for nRTPS



Curve E. Delay comparison DRR, WFQ-DRR, and WFQ for BE

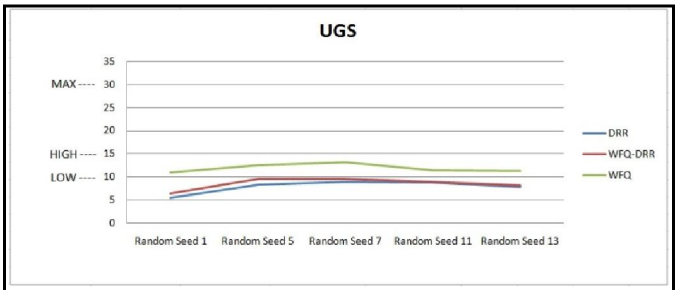
Figure 6.3 Delay Comparison

Minimum delay request for UGS QoS class is <250 ms, rtPS QoS class <600 ms, eRTPS QoS class <80 ms, nRTPS QoS class <600 ms, and BE QoS classes <600 ms. If the delay results obtained met the minimum value it indicates that the system is running well. UGS, rtPS, and eRTPS QoS classes are real time data packets that are prone to delay. So, we need a scheduling algorithm that can provide the minimum delay for packets of the real time data. DRR algorithm and hybrid algorithm could meet the demand, which could serve real time data packets to produce a low delay value. As seen in figure 6.3 section curve A, curve B and curve C, DRR algorithm and hybrid algorithm produced an average low values of delay, i.e <120ms for UGS QoS class, <240ms for rtPS QoS class, and <30ms for eRTPS QoS class. While the results of delay for data packets generated by the non-real time WFQ and hybrid algorithms were good. Values that have appeared on the curve for the comparison of the two algorithms were relatively low. Results of the delay value were <450ms for both nRTPS QoS class and BE QoS class. This showed that for non-rela time data packets, WFQ and hybrid algorithms could result in delay value slightly better than the DRR algorithm could. So it can be deduced, the hybrid algorithm can yield the minimum delay for real time and non-real time data packets.

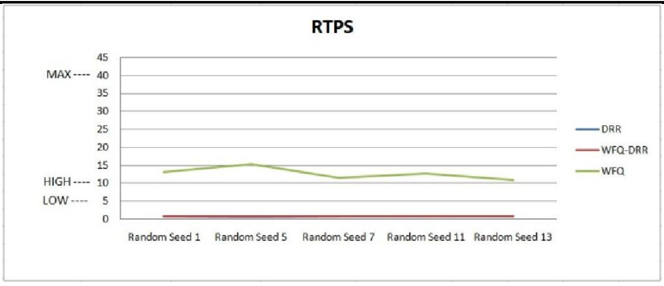
6.3. Jitter

Jitter is the inter-packet delay variation, i.e the difference between the packet arrival intervals at the destination terminal. Large jitter values are affected by large variations in traffic load and packet collisions (congestion) in the IP network. The greater the traffic load in the network, the greater the chances of congestion thus its jitter value will increase.

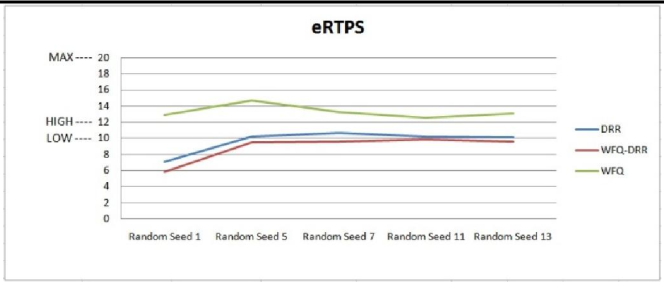
Jitter values produced by the DRR algorithm and hybrid algorithm were good, especially for real-time data packets (UGS, rtPS, eRTPS). This is shown in Figure 6.4 section curve A and curve B, that the two algorithms obtained low values for UGS and RTPS QoS class. While Figure 6.4 curve section C indicates that the etPS QoS class was dominated by very low values.



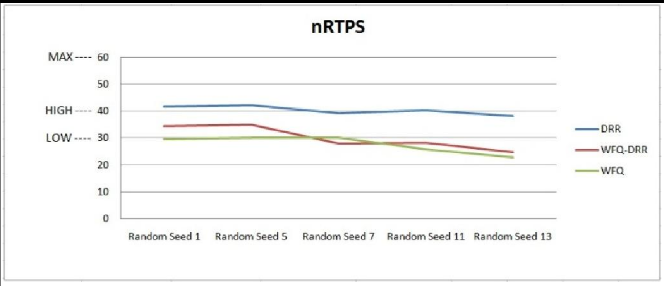
Curve A. Jitter comparison DRR, WFQ-DRR, and WFQ for UGS



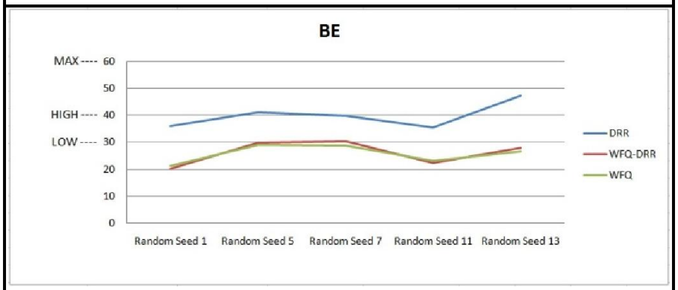
Curve B. Jitter comparison DRR, WFQ-DRR, and WFQ for RTPS



Curve C. Jitter comparison DRR, WFQ-DRR, and WFQ for eRTPS



Curve D. Jitter comparison DRR, WFQ-DRR, and WFQ for nRTPS



Curve E. Jitter comparison DRR, WFQ-DRR, and WFQ for BE

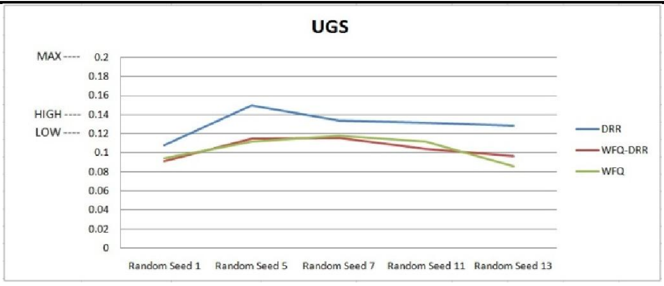
Figure 6.4 Jitter Comparison

Both algorithms in Figure 6.4, the value of jitter for UGS and eRTPS data packet was less than 12ms, while the value of jitter for nRTPS QoS class was less than 10ms. Whereas, the WFQ algorithm produced worse results when it was run on real-time data packets. Jitter values that appeared in the algorithm was relatively high for UGS and rtPS QoS classes, while for eRTPS QoS class it was dominated by high-value curves. However, for non-real time data packets, WFQ algorithm and hybrid algorithm produced slightly better jitter values when compared to the DRR algorithm.

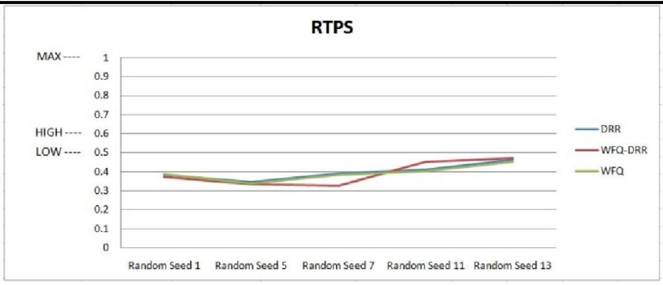
6.4. Packet Loss

Packet Loss indicates the number of lost packets. Packet loss occurs when one or more data packets through a network fail to achieve its objectives. Lost or dropped packets can degrade performance. However, it is important to note that packet loss does not necessarily indicate a problem in the network. If the amount of lost packets can still be accepted by the destination, the packet loss is not a problem. In this research, the discussion of the analysis of packet loss is only for the real time data packets. This is because the real-time data packets are vulnerable to the presence of lost packets.

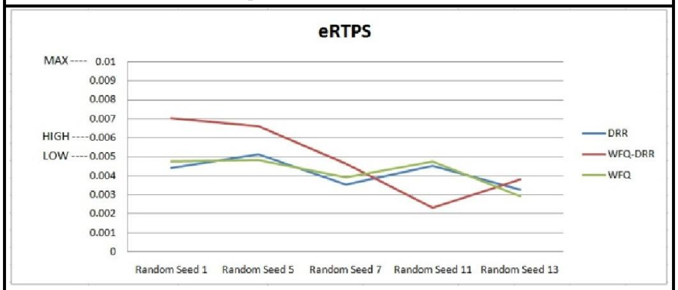
Network system run well when the packet delivery success rate reaches a value of more than 99%.



Curve A. Packet loss comparison DRR, WFQ-DRR, and WFQ for UGS



Curve B. Packet loss comparison DRR, WFQ-DRR, and WFQ for RTPS



Curve C. Packet loss comparison DRR, WFQ-DRR, and WFQ for eRTPS

Figure 6.5 Packet Loss Comparisons

The three algorithms that were simulated (DRR, WFQ, and hybrid) could meet the minimum standards required by packet loss requirements, i.e <0.2% for UGS QoS class, <1% for rtPS QoS class, and <0.01% for eRTPS QoS class. Value of packet loss for the third data packet (UGS, rtPS, and eRTPS) was still superior when using WFQ algorithm than using DRR and hybrid algorithms. Figure 6.5 shows that WFQ algorithm had average low values, while DRR and hybrid algorithms had average high scores. However, in the figure it is also seen that the hybrid algorithm gave less maximum results for eRTPS QoS class. This was because the eRTPS QoS class traffic had varied the size of the packages, so that data loss could occur when sharing a data packet service between real time and non-real time. Therefore, the use of the hybrid algorithm had greater potential to the loss of data packets.

VII. Conclusion And Future Works

7.1. Conclusion

The following are the conclusions of this research:

1. Hybrid algorithm discussed in this research is an integration of WFQ and DRR algorithms. Hybrid algorithm (WFQ + DRR) is suitable to be applied to networks where traffic conditions have various types of data packet, namely the real time and non-real time ones simultaneously. The hybrid algorithm separates the data queue, the DRR handles the real time data packets and the WFQ handles the non-real time ones.
2. The results of the algorithms assessed by means of testing frameworks shows that:
   a. Real time data packets
   DRR and hybrid algorithms result in good throughput, delay values, and value of jitter.
   b. Non-real time data packets
   WFQ and hybrid algorithms result in good throughput, delay value, and value of jitter.
   c. Packet Loss
   The results of data packet loss of the three scheduling algorithms are relatively good, the success rate of data packet delivery is more than 99%, in other words, only <1% of the data lost.

7.2. Recommendations

To improve and to obtain better results, several similar studies need to be carried by considering these following points:

1. To have a comprehensive analysis, the experiments can be carried out using the combination of other types of scheduling algorithm (hybrid algorithm), such as EDF, PI, WRR, and so on.
2. There are two metrics to measure the quality of a scheduling algorithm that are not implemented in this research. These are the frame utilization and the fairness index. The implementation of both metrics can be conducted by modifying the structure of the simulation results of the trace file. By implementing these two metrics, the assessment of the quality of the scheduling algorithm can be more comprehensive.

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