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Adaptive Resource Allocation Scheme for IEEE802.16m Uplinks System: Comparison of Static Subscribers and Pedestrian Subscribers

Nurul Huda Mat Tahir[1], Kamarul Ariffin Noordin[2], Zairi Ismael Rizman[1], Norizan Mohamad[3], Nur Hafizah Rabi'ah Husin[4]

[1]Faculty of Electrical Engineering
[3]Faculty of Computer and Mathematical Sciences
[4]Academy of Language Studies
Universiti Teknologi MARA (UiTM) Terengganu, 23000 Dungun, Terengganu, Malaysia
[2]Faculty ofEngineering, University of Malaya (UM), 50603 Kuala Lumpur, Malaysia

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ABSTRACT

IEEE802.16m is a new standard for mobile Worldwide Interoperability for Microwave Access(WiMAX). It is expected to be the next 4G technology of wireless local area network(LAN)which offers high speed data rate and larger coverage area.The paper proposes a scheduler for uplink service that adaptsan additional service class called Adaptive Grant Polling Service (aGPS). Dealing with scheduling, Quality of Service (QoS) is still a scarce matter. To meet the QoS requirements, the scheduler uses a minimum group allocation where services ofQoS restriction will be in the group. Only the remaining bandwidth is distributed fairly using Enhanced Deficit Round Robin (EDRR). For an analytical purpose, the EDRR is compared against Deficit Round Robin (DRR). If the users are experiencing different channel conditions, the DRR seems to be the best way of distributing the resources. However, when the users have an identical channel condition, the method used by the DRR in distributing the same amount of quantum number to all users will result a greater packet drop for the users with larger queues. Therefore,the DRR needs to be modified by not just considering the physical condition, but also the state of bandwidth request. The results show the EDRR performs well than the DRR by reducing the amount of packet drop.
KEYWORDS: WiMAX,IEEE 802.16m.4,resource allocation,EDRR.

INTRODUCTION

Voice call, video streaming, online gaming or checking email are several services that support to the end user. Each service demands a different way of aggregation according to types of data supported. If the Quality of Service (QoS) does not fulfill the data, it will drop and retransmission is required. This does not just involve in losing of connection, but also initiates retransmission that would make the network congested with new incoming data along with dropped data.

Rapid development of Worldwide Interoperability for Microwave Access (WiMAX)shows many interests pour into technology to develop a better system. For the scheduling problem regarding to IEEE802.16m standard, itis not yetwidely discussed. Researchers like Chiu et al. [1], Yen et al. [2] and Reddy et al.[3] had made an effort to adapt the scheduling process into biological resolution like Genetic Algorithm (GA). The GA is used to compromise between the power consumption and modulation level. The algorithm will choose the most suitable data rate for each user with respect to their channel condition.

Round Robin (RR) performsa distribution of a set of task of circular action. It does not consider the priority of services involved. Therefore to overcome the situation, Wang et al. [4] combinedthe RR with Proportional Fair (PF) algorithm. The PF will act as a controller to provide balance between the throughput of the overall system and data rate served for each user. It is quite simple but can be implemented for both in real time and non-real time. The distribution in the RR fashion would not take the packet size into consideration. This createsan unfairness towards theservices such asNon-Real-Time Polling Service (nrtPS), Real Time Polling Service(rtPS) and Best Effort (BE) as they havea variable data rate.

Chowdry et al.[5] uses a different type of approach to separately solve real time and non-real time application. The method proposed determines the delay of real time service, while providing minimum sufficient data rate transmission for non-real time application. The algorithm developed is combined with Earliest Deadline First (EDF) algorithm and Deficit Fair Priority Queue (DFPQ). The EDF is for rtPS while DFPQ is for nrtPS and BE service. DFPQ is actually functioning just like ordinary Deficit Round Robin (DRR) method, except the quantum size will decide either the packet can be transferred on that time or need to wait untilnext Round Robin rounds. Quantum size will help in distributing bandwidth fairly among the variable size data packet. By using both methods, they find that a minimum bandwidth is needed to satisfy the QoS for each user. Then, the remaining bandwidth is aggregated according to the priorityUnsolicited Grant Polling Service(UGS)>rtPS>nrtPS>BE.

Corresponding Author: Kamarul Ariffin Noordin, Faculty of Engineering, University of Malaya (UM), Kuala Lumpur, Malaysia.Email: kamarul@um.edu.my

Instead of combining both methods, Rath et al. [6]usessingle approach to deal with both real time and non-real time communication services. They proposes an enhanced version of RR which is known as Opportunistic Deficit Round Robin (ODRR). The ODRR is responsible in distributing bandwidth of a set of eligible user. The algorithm starts by selecting a group of users to be transmitted at that particular time. They decide it by using polling interval (k) that represents the time chosen to give information about the data queue by the bandwidth polling done inBase Station (BS). The algorithm is unique since not many researchers concern about the polling interval in scheduling problem. Unfortunately, it only focuses on the delay requirement whichis suitable for a real time application.

Iyengar et al. [7], Peng et al. [8] and Lee et al. [9] only consider the real time traffic management. Iyengar et al. [7] proposesa resource allocation for UGS and rtPS. They assume that the channel condition is same throughout time interval (t) and UGS transfers a fixed amount of data. The main objectives are to find a maximum throughput of system while satisfying the QoS for each subscriber. To satisfy both objectives, they divided the user allocation on the subcarrier into two parts. First, they assigned user to subcarrier to satisfy the demand of each user. If the chosen subcarrier was able to satisfy the user needs, they tried to allocate the residual slot to obtain the highest possible throughput. The idea is to map the user and subscriber that would result on maximum data rate. Hence,the QoS is satisfied, and at the same time, the subcarrier is effectively utilized by a suitable user.

In theresearch,itis focussing on how to allocate bandwidth to users with different service requested involved in the uplink transmission. The method which has been developed is typically for IEEE802.16m standard. The proposed method is called Enhanced Deficit Round Robin (EDRR), which is an enhancement of DRR. The design scheduler emphasizes on aggregating bandwidth to meet the QoS requirement.The left over bandwidth will be distributed in EDRR manner. In such way,the scheduler will has less probability of packet drop, and will work efficiently in congested areas.

A simulation is performed in Matlab software where EDRR is compared against DRR. The rest of the paper will be organized as follows. Firstly, the proposed system model is elaborated. Then, the result which has been generatedusing Matlab is discussed. Finally, the last section will conclude the paper.

SYSTEM MODEL

The main task of the scheduler is to distribute bandwidth according to the QoS necessity in a fairly manner. Figure 1 illustrates the overall operation of scheduler. Initially, all the data buffers on each subscriber at time (t) will be examined and grouped into six types. The data will stay inside the queue, waiting to be served. At the same time, based on the status reported by Channel Quality Indicator (CQI), modulation level is determined for each user. The modulation level will affect the amount of bit that could be fitted in one Distributed Resource Unit (DRU). Then,the scheduler will calculate the bandwidth required for minimum allocation groups. If there is a remaining bandwidth available, EDRR will commence. Once the bandwidth is fully used, all data will be mapped into the Orthogonal Frequency Division Multiple Access (OFDMA) frame. In conclusion, the scheduler willguarantee the QoS requirement before improving the throughput via EDRR.

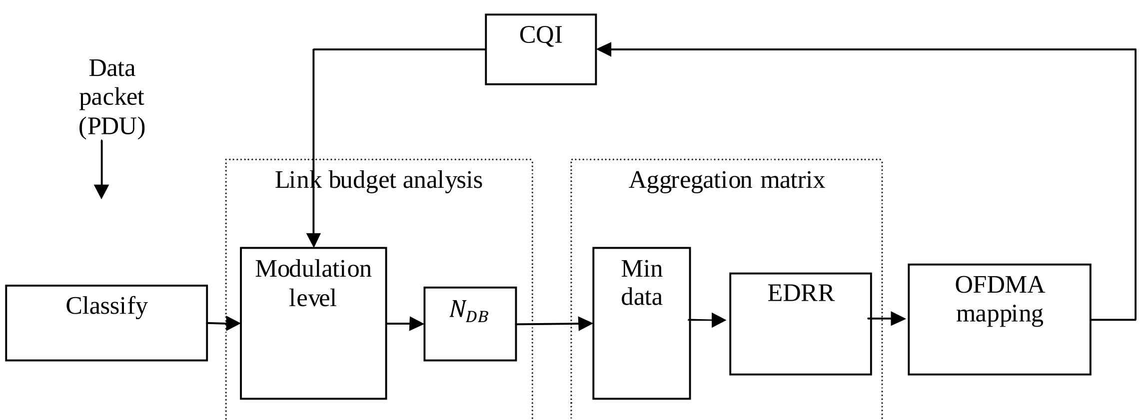

Figure 1: Proposed scheduler

Minimum Group Allocation

A minimum group allocation is a part in which to ensure the QoS restriction is strictly followed. It is known that UGS, ertPS and aGPS are very sensitive to the delay. Therefore, all data belong to this type ($\delta_k^{UGS}, \delta_k^{ertPS}, \delta_k^{aGPS}$) will be straightly granted. rtPS service is also delay sensitive, but it canstill tolerate than the other three services. Hence,the packets queue of rtPS

(δ_k^{rtPS}) for each user (k) is set to have a delay counter(D_k^c) which must be lower than the threshold delay (T_d) to prevent packet drop. The condition is shown in following equation.

$$D_k^c < T_d \quad (1)$$

and

$$D_k^c = nT_f \quad (2)$$

wheren is a number of frame elapse since last transmission and T_f is a duration to transmit the frame.

Unlike other services, nrtPS is sensitive on minimum data rate but not delay. For nrtPS, each Subscriber(SS) contains this type of data needs to send a minimum of $w_k$packets to meet the minimum throughput required during every frame transmission. Since BE services do not have any QoS requirement, it will not participate in the minimum allocation group. After all minimum data have been allocated, they will be scheduled on the frame based on the urgency level. The EDRR will start operating if there is remaining bandwidth left after serving the minimum allocation group. Since IEEE802.16m works for both static and mobile users, we focus to emphasize on the mobility effect. Therefore, the distance between Mobile Station (MS) and BS isassumed equal for all users to generate an identical path loss. Thus, the physical condition will be mostly affected by the subscriber speed (v).

Enhanced Deficit Round Robin (EDRR)

EDRR is an improvement over DRR method. It is designed to overcome the DRR impairment in determining the quantum number. The EDRR uses the same assignment concept as DRR,where the quantum number organizes the flow. The way in calculating the quantum number would be different. The quantum number indicates how much the data can be sent to each user. In other word, the quantum number is the weight of bandwidth grants in the scheduling process. The main idea of EDRR is the quantum number will not only depend on the user channel state, but also the amount of data queue. EDRR is firstly divided into four groups of users according to the speed of movement. According to ITU-R M.2134 [10], the following classes of mobility are defined.

$$\text{Group} = \begin{cases} \text{Static user: } v = \dfrac{0\text{km}}{\text{h}} \\ \text{Pedestrian user: } \dfrac{0\text{km}}{\text{h}} > v > \dfrac{10\text{km}}{\text{h}} \end{cases} \quad (3)$$

The quantum number would be differed according to the group type. Users who have the worst channel condition would obtain a lower quantum number. For instance, a static user will always receive lower bandwidth grants than a moving user due to the channel condition. The users of equal physical condition do not necessarily have the same amount of quantum number. It means that within the same group, if the user has a less bandwidth request, it will have a less allocation inside the frame. This will give a chance to the user with large data to send and able to loose up their queue.It also will have the space for incoming data packet. Therefore, there will be two filters in calculating the quantum number. First, the user is filtered into the respective group according to the outline ofInternational Telecommunication Union (ITU). Then, the amount of data queued which belongs to same type is analyzed. Thus two conditions are considered.

First condition: For all users who have a different physical condition (different group). The users who belong to different group will have a different amount of quantum number.

$$Q_i = \frac{\text{Numberof bit DRU per SSi}}{\text{Numberof bit of FEC block}} \quad (4)$$

Second condition: For the users who belong in the same group. If the users have been in the same group but the request bandwidth is not equal, the EDRR will give wider bandwidth to heavy loaded users.

$$Q_i = \frac{\text{Bandwidth request by SSi}}{\text{Maximum number of queue in group}} \times \frac{\text{Numberof bit DRU per SSi}}{\text{Numberof bit of FEC block}} \quad (5)$$

SIMULATION MODEL

The proposed method is developed using Matlab software. It is assumed that the available bandwidth is fully utilized. The aim is to focus on the influence of the speed towards the channel condition. Therefore, the distance from BS to all SS have been kept identical to generate equal path loss. Other additional parameters that are used for the link level simulatator are shown in Table1. The values are solely to provide a consistent evaluation of the user.

Table 1: Simulation parameters

Parameter	Value
System bandwidth	10MHz
Number of iterations (number of frames)	10
Subcarrier frequency spacing	10940Hz
Duration of one superframe	20ms
Duration of one frame	5ms
Duration one frame elapse	10ms
Number of subframe	8 (type 1)
Number of Logical Resource Unit (LRU) per subframe	24
Receive noise level	-174dBm
Maximum delay for rtPS before packet drop	20ms
Minimum throughput (nrtPS)	192kbps
Maximum delay for UGS and ertPS before packet drop	5ms
RequiredBit Error Rate (BER)	10^{-5}
Transmit power (P_T)	23dBm

The IEEE802.16m network consists of one BS which covers four active subscribers. The simulation scenariofocuses on network comprises of two static users (user 1 and 2) and two pedestrian users (user 3 and 4).

Apart from the physical condition, the bandwidth requests from the subscribers are also important. Therefore, the data rate for each service for the corresponding user is known to analyze the pattern. A bulk data transfer is generated to simulate the congested area. It shows the effect of scheduler in optimizing the utilization of the limited bandwidth. Besides,it investigates on what would be the result if the static users are in the same cell with the moving users. Specifically,it focuses on how it would influence the throughput, packet drop and which services would be affected mostly. The value of bandwidth polling as listed in Table 2.

Table 2: Simulation of loads in each user corresponding to type of service

	UGS (Mbps)	ertPS (Mbps)	aGPS (Mbps)	rtPS (Mbps)	nrtPS (Mbps)	BE (Mbps)
SS1	0.240	0.280	0.280	0.432	0.432	0.384
SS2	0.280	0.312	0.312	0.576	0.624	0.432
SS3	0.240	0.280	0.280	0.432	0.432	0.384
SS4	0.280	0.312	0.312	0.576	0.624	0.432

From Table 2, the second and the fourth users are configured to have the identical bandwidth request,which is higher than the first and the third users. Even though there are two users posses the same speed as first user and second user, the data inside the buffer are different. The user 1 and 2 will definitely have identical Signal to Inteference and Noise Ratio (SINR)due to belonging to the same group. The user 2 haslarge data in queue than user 1.

Performance Evaluation

To evaluate the robustness and the reliability of the proposed scheduler, the EDRR is compared against the ordinary DRR. There will be five figures collected and presented, namely:

i. Distribution of quantum number.

ii. Throughput in each user (in Media Access Control (MAC) layerwhich not at the receiver). The throughput is calculated at the transmitter side.

$$T_i = \frac{\text{Number of packet sent in kth iteration x Number of bit per packet}}{\text{Time for one frame elapse}} \quad (6)$$

iii. Percentage of packet drop in each user

$$PD_i = \frac{\text{Number of packet drop in kth iteration}}{\text{Number of packet sent in kth iteration}} \text{x100} \quad (7)$$

iv. Total packet drop in each service

$$TD_i = \frac{\text{Number of packet drop in kth iteration x Number of bit per packet}}{\text{Time for one frame elapse}} \quad (8)$$

v. Comparison of EDRR and DRR performance in term of total number of packet drop.

RESULTS AND DISCUSSION

The simulation records the performance of both schedulers in dealing with static users and pedestrian users. The graph of quantum number is generated, as shown in Figure 2. The pattern in Figure 2(a) clearly implies that the DRR gives almost equal quantum number to the users, which belong to the same group. The user 1 and 2 have nearly equal quantum number, while the user 3 has almost equal quantum number with user 4. Figure 2(b) indicates the EDRR has tolerated between the physical layer condition and the amount of bandwidth request. Even though, the user 1 and 2 are in the same group, they have significant differences in the amount of the quantum number. It is proven that the EDRR allocatesa greater quantum number for user 2 than user 1, whereuser 2 has higher data request. Therefore, a larger quantum number makes the user 2 has a higher chance to transmit the data. This process is same for user 3 and 4. The user 4 with a larger data inside the queue has a possibilityto be placed inside the OFDMA frame. The effect of distribution of quantum number will be shown where the evaluation in term of throughput and packet drop was done.

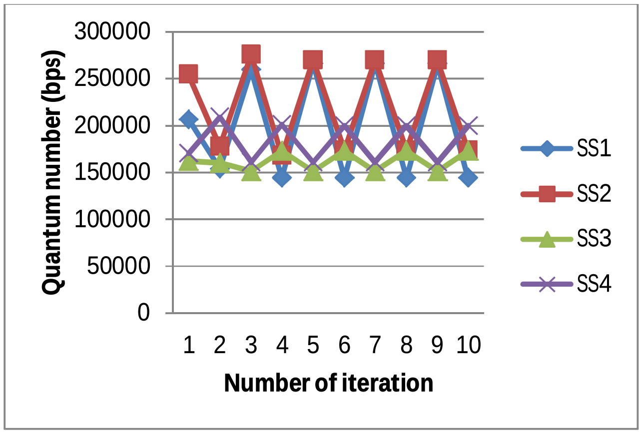

Figure 2(a): Distribution of quantum number using DRR

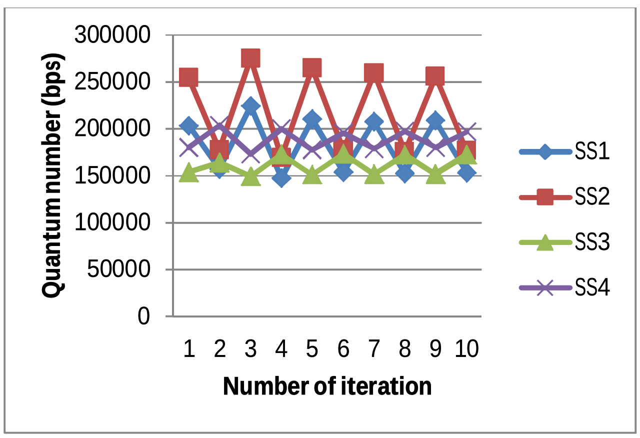

Figure 2(b): Distribution of quantum number using EDRR

Figure 3 examines the throughput for each service provided in the system. The data are recorded in each time when the frame elapses in 10 ms. Figure 3(a) depicts the DRR behavior while Figure 3(b) represents the EDRR. Figure 3(a) clearly shows the characteristics of DRR, which only considers the physical condition for the bandwidth aggregation. As shown in Figure 3(a), the DRR gives almost equal amount of quantum number to the user who belongs in the same group. Thus, the user 1 and 2 are having nearly equal throughput. This is also applied for the user 3 and 4. However, the throughput for user 3 and 4 are lower than user 1 and 2. This is due to the user who belongs to the static group that experiences wide bandwidth grants than the pedestrian user. The user 3 and 4 have a lower bandwidth allocation when it faces a turbulence from the environment factor, which then leads to a lower SINR performance. A poor SINR performance further initiates a lower quantum number which contributes to smaller bandwidth grants.

Figure 3(b) generated by the EDRR shows a quite distinct difference between the throughput of user who belongs to the same class. Both user 1 and 2 are static users, but the throughput is not identical. The user 3 and 4 also deal with the same situation where the user 4 has a greater throughput than the user 3. Recall that the user 2 and 4 have a wider bandwidth request than the user 1 and 3. The EDRR is different from DRR in which apart from SINR consideration. It allocates a wider bandwidth to the user who hasa greater data queue. The user 1 and 2 belong to the same group. Since the user 2 has a greater data in the buffer, the scheduler will give a bigger quantum number for the user 2, as stated in Figure 2(b). This also occurs to the user 3 and 4. However, the EDRR does not violate the right of obtainingwider bandwidth allocation for the users with good channel circumstances. It shows the static users always have a higher throughput. Only the user within the same group will experience the difference.

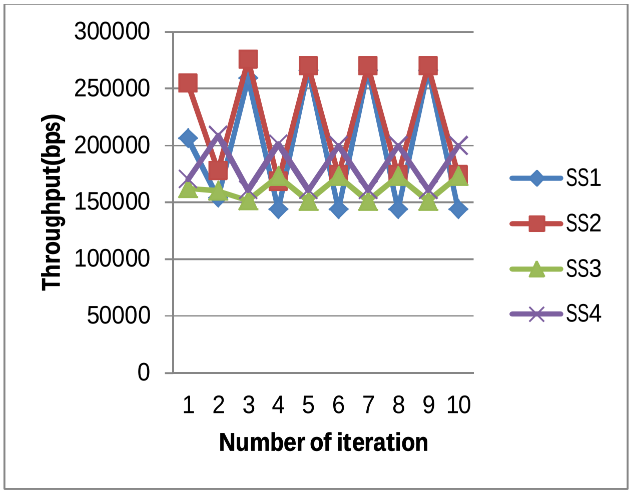

Figure 3(a): Throughput in each user using DRR

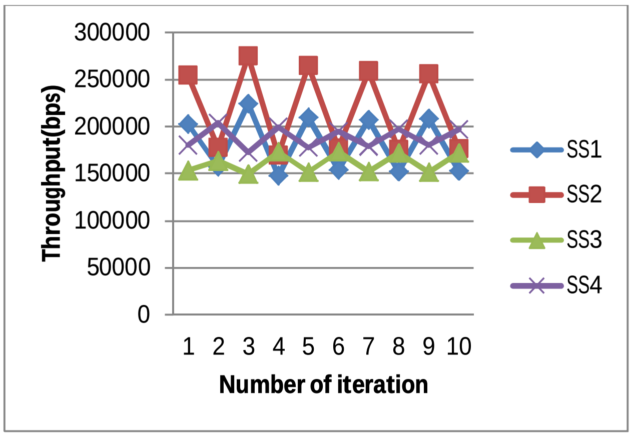

Figure 3(b): Throughput in each user using EDRR

Figure 4 examines the packet drop for each type of service to indicate the scheduler is maintainedto the QoS requirements. As shown in Figure 4(a) for DRR, all delayed sensitive data are transmitted before the deadline. Since the bandwidth is already full, the nrtPS missed the chance to participate inside the OFDMA frame which causes the packet drop. The BE service does not experience packet drop since it does not havea QoS restriction. For the EDRR in Figure 4(b), it is clearly seen the EDRRfaces the same circumstances in the nrtPS packet drop as the DRR, but the amount is lower. This is due to the control of the bandwidth access according to the physical conditions and bandwidth request. The user with a wider bandwidth request can afford to loose up its queue to give opportunity for the new incoming data on the next iteration.

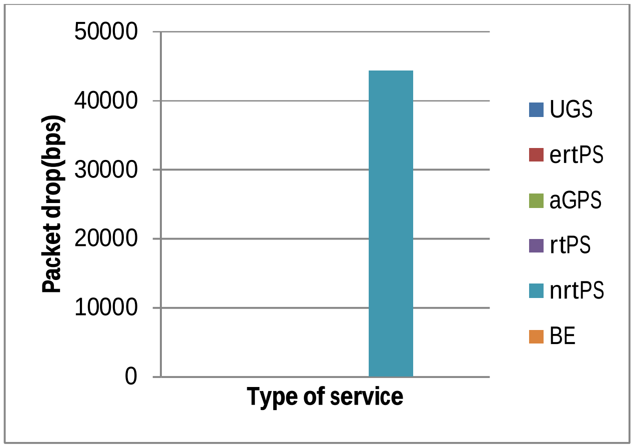

Figure 4(a): Percentage of packet drop in each service using DRR

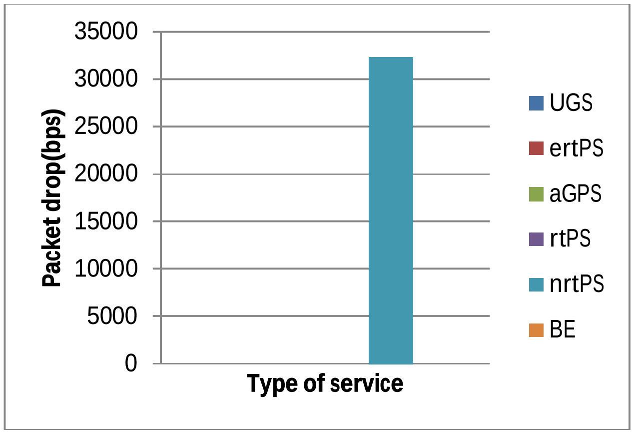

Figure 4(b): Percentage of packet drop in each service using EDRR

Figure 5 illustrates the total amount of packet drop throughout the simulation. Figure 5(a) shows the user 4 in DRR does experience unsatisfied QoS requirement in the fourth, sixth, eighth and tenth iteration. This is due to lower bandwidth grants, since it has the worst channel condition than the user 1 and 2. Even though,the user 3 has the same physical condition with the user 4, it has a lowest amount of data inside the queue.The user 3 manages to at least fulfill the QoS restriction, saving it from any data loss.

Figure 5(b) shows the EDRR is able to lower the amount of packet drop in each iteration. The ability of EDRR to distribute the resources carefully among the same group of users according to the bandwidth request gives a great benefit to the situation. The EDRR tolerates with the amount of bandwidth grants from the user 3 and 4. The scheduler gives the user 4 a higher amount of bandwidth access than the user 3, so it could support the larger request. Therefore, the amount of packet drop is lower.

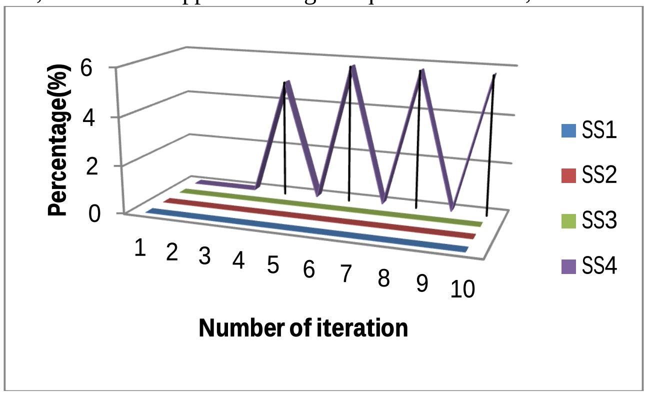

Figure 5(a): Percentage of packet drop in each user using DRR

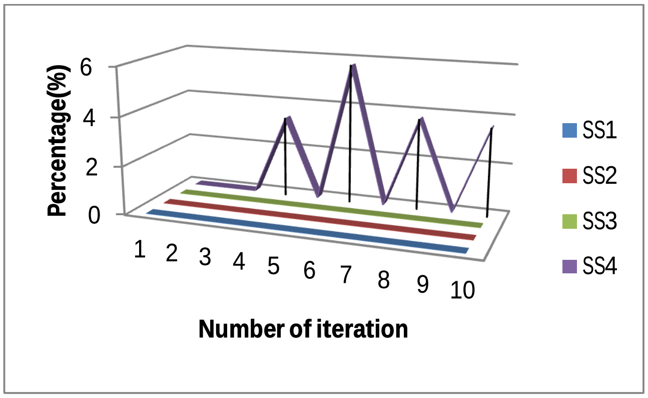

Figure 5(b): Percentage of packet drop in each user using EDRR

Figure 6 shows the comparison of EDRR and DRR in terms of the total packet drop in bits per second. It proves that the EDRR posses a better performance than the DRR by reducing the data loss to 27.08%. The percentage is gained from the following calculation.

$$\text{Loss} = \frac{\text{Total packet loss in DRR} - \text{Total packet loss in EDRR}}{\text{Total packet loss in DRR}} \times 100 \quad (8)$$

$$\text{Loss} = \frac{44266.67 - 32281.37}{44266.67} \times 100 = 27.08\%$$

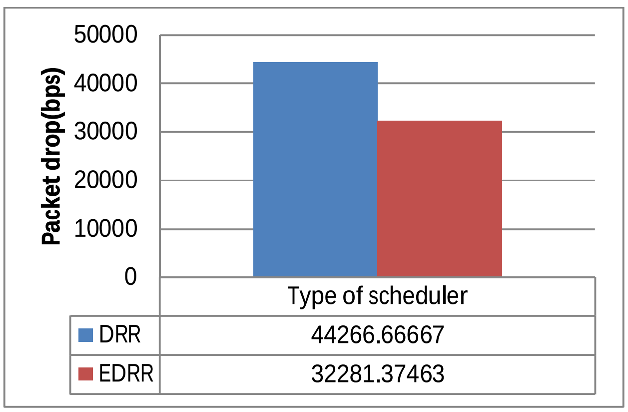

Figure 6: Total number of packet drop in each scheduler

CONCLUSION

In the paper, a scheduler for IEEE802.16m is proposed. The scheduler is mainly divided into 2 parts, which are minimum allocation group and EDRR. The minimum allocation group emphasizes that the important service will remain as top interest in data aggregation. Consequently, the minimum packet which satisfies the QoS requirement is prior placed on the OFDMA frame. After that, the left over bandwidth is managed by EDRR.

The results show that the EDRR outperformesthe DRR by decrementing the amount of packet drop. This is due to the users who have a wider bandwidth which requestsa higher chance to be placed in the OFDMA frame. It is done by granting a larger quantum number for user with higher demand initiating in higher transmission of data. Thus, it looses up the data queue for the sophisticated user. Since less data accumulated inside the queue, the emptied space is ready for the next incoming bulk data which minimizes the packet drop.It leads to less retransmission which only makes the traffic much busier in the next iteration. As a result, the EDRR would not just benefit in current iteration, but also in the next round. The overall system performance is further boostby increasing the throughput of the users. The user that has a good channel quality will still get the privilege to obtaina wider bandwidth allocation. It evidently shows that only the user 4 has a packet drop, even though the user 2 and 4 have same amount of data inside the queue.

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