Quality of Service and Energy Efficient Aware (QEEA) Scheduling Algorithm for Long Term Evolution (LTE)

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Abstract**—The growing demands for wireless communication services pose new challenges in the coming generation of cellular networks design. In Third Generation Partnership Project (3GPP) Long Term Evolution (LTE) networks, ever-higher data rate and energy efficiency (EE) are required to meet the increasing demands in cellular traffic. High data rates can be achieved, however, it requires high level of energy consumption which needs to be controlled especially in this era of green communication trends. Hence, efficient solutions are necessary to optimize EE and at the same time achieve high data rates to meet green LTE requirements. This paper proposed an efficient algorithm, namely, the Quality of Service (QoS) and Energy Efficient Aware (QEEA) to improve EE and also maximize the throughput by using minimum power of 43 dBm (20 W) which is the lowest power setting according to the 3GPP LTE specifications. The QEAA algorithm is compared against other scheduling algorithms, namely, the Channel and QoS Aware (CQA), Priority Set Scheduler (PSS), Proportional Fair (PF), Maximum Throughput (MT) and Blind Average Throughput (BAT). The simulation process has been done using Network Simulator-3 (NS-3) and the performance of these packet scheduling algorithms were evaluated based on the performance metrics of throughput, delay, packet loss ratio (PLR), energy consumption rate (ECR), and EE for the voice over IP (VoIP), video and File Transfer Protocol (FTP) applications. The results showed that the QEAA algorithm outperformed the other algorithms as it could achieve up to 240% of maximum throughput, 61% reduction in ECR and 150% improvement in EE in terms of number of users in the cell. Thus, it can be concluded that QEAA algorithm is the most energy efficient and the best candidate for provisioning the QoS for the real time (RT) and non-real time (NRT) applications.**

Index Terms**—Energy Efficiency; LTE; QEEA; Scheduling Algorithm.**

I. Introduction

Mobile communication plays an important role in the current day of age. The cellular network sector has developed rapidly over the past few years. This rapid growth is due to the increase in the numbers of mobile subscribers, multimedia applications, and data rates [1]. The availability of data and information has become a global necessity. With time, new mobile generations are being introduced and they must fulfill the increasing requirements from the users, as they demand better and improved Quality of Service (QoS). However, there is no denying that these technological advancements also come in parallel with immense challenges that need to be addressed such as high energy consumptions and adverse impacts to the environment. The Information and Communication Technology (ICT) sector is playing its part to overcome the energy crisis as well as reducing impact to the environment.

In [2], it is stated that, by 2020, smartphones will represent 81% of the total mobile data traffic, compared to 76% in 2015 and fourth generation (4G) connections will encompass 40.5% of total mobile connections and will account for almost 72 % of mobile data traffic. Furthermore, by 2020, 75% of the world's mobile data traffic will be video, up from 55% in 2015. Therefore, the consequent networks evaluation will oblige communication operators to manage the EE of their networks, in order to keep low operational costs and to maintain margins while guaranteeing the QoS for customers. Energy consumption by radio access network is particularly the main contributor of the total consumption of the network. Energy consumption by cellular networks is expected to increase rapidly in the future if no measures are taken to alter this trend [3].

In Third Generation Partnership Project (3GPP) Long Term Evolution (LTE) system architecture, there exist a LTE BS which is called evolved nodeB (eNodeB) where the packet scheduling process is performed along with other Radio Resource Management (RRM) tasks. The scheduler is an important aspect in the medium access control (MAC) layer for system performance. The scheduler in the MAC layer is the main factor that affects the system performance and the resource reusability [4]. The scheduling decision is made based on various parameters such as channel conditions, Head-of-Line (HOL) packets delay, traffic types and buffer size. In general, designing a scheduler for wireless networks is more challenging than wired networks because of restrictions on radio resources and variations in channel conditions. The scheduler in LTE aims to maximize system performance. Furthermore, scheduling algorithms are responsible for selecting which user equipment (UEs) that have the access to the system resources and with which configuration [5][6][7].

Many methods were proposed by researchers to improve the energy efficiency (EE) in LTE system. One of the methods introduced is radio resource allocation algorithm that is meant to balance EE and throughput maximization. Furthermore, cell sleeping of small cell networks, power efficient link adaptation (LA), and a low complexity algorithm are some of the alternatives being proposed by the researchers. Therefore, in this paper, a new scheduling algorithm was proposed to improve the EE of the LTE system without sacrificing the QoS. The scheduling algorithm is evaluated within the LTE downlink transmission using a simulator which is called the Network Simulator-3 (NS-3).

Very few researchers are focusing on the packet scheduling strategies that can improve the EE. For evaluation of EE, the power consumption model of wireless access is necessary to compare the performance of different scheduling schemes. As explained in [8] there are four ways to trade off for green communication. Firstly, deployment efficiency (DE) can be traded off with EE which is to balance the deployment cost, throughput, and energy consumption in the network as a whole. Secondly is the spectrum efficiency (SE) trade-off with EE. SE is among the key feature of LTE. SE-EE trade-off is studied in [9], [10]. For instance, in [9] EE is achieved by increasing user's required bandwidth for given data rate under non-full load conditions. Thirdly is the bandwidth-power trade-off where expanding the signal bandwidth is used to reduce the transmit power thus providing EE. Finally is the Delay-Power trade-off. Delay is one of the QoS metrics which has to be analyzed in detail.

The performance of Max C/I, RR and PF algorithms in multi cell scenario are compared in the perspective of EE [11], which proved that the spectrum efficiency and energy efficiency of Max C/I algorithm is the best. However, Max C/I is not QoS aware scheduler. The authors in [12] showed that the resource scheduling algorithms can be adopted to improve the system gain by exploiting multiuser diversity gain, which can be translated into energy saving. The authors in [13] and [14] proposed an energy-efficient scheduling strategies under low load conditions for LTE downlink. In [13], the authors discussed on the relationship between MCS levels and energy-saving, which indicates the feasibility of spectrum in exchange for power under non-full load conditions, and it presents the energy-efficient strategy in which the users' modulation levels are lowered step by step. In [14], the paper presented a Bandwidth Expansion Mode (BEM) techniques that allocates more RBs with lower transmit power to users under low load conditions in order to reduce the energy consumption. It should be noted that the BEM techniques fails to produce energy savings under high load conditions.

Currently, there are limited researches focusing on energy efficient schedulers for LTE. The main issue of the algorithm is to find a solution that maximizes energy saving without compromising the throughput, delay and PLR. Hence, in this paper, QoS and Energy Efficient Aware (QEEA) scheduling algorithm is proposed. This algorithm is introduced to reduce the power requirements of eNodeB, while maintaining the QoS.

II. Quality Of Service And Energy Efficient Aware (QEEA) Scheduling Algorithm

The Quality of Service and Energy Efficient Aware (QEEA) is the scheduling algorithm that is being proposed for this paper. This algorithm considers the HOL delay, achievable throughput, past average throughput and transmitted power. The goal of QEEA is to achieve maximum throughput and improve the EE by using low transmitted power. The algorithm works for real-time (RT) and non-real-time (NRT) applications. Thus, different classes of traffic such as voice over IP (VoIP), video, and File Transfer Protocol (FTP) are considered in this paper.

Basically, the QEEA scheduler is based on the Time Domain (TD) and Frequency Domain (FD) scheduling where it is dependent on the QoS requirements to allocate resources. This approach is more efficient than only TD or FD scheduling respectively [15] and also allows the attainability of a higher amount of spectral efficiency while satisfying the traffic delay requirements.

In the TD scheduler, at each TTI, the grouping metric $m_{td}^{j}(t)$ for user $j = 1, \ldots\ldots, N$ is calculated as follows:

$$m_{td}^{j}(t) = \left\lceil \frac{d_{HOL}^{j}(t)}{g} \right\rceil \qquad (1)$$

In the TD (at each TTI) the QEEA scheduler group users according to priority. The purpose of grouping is to enforce the FD scheduler to consider first the flows with the highest HOL delay. $d_{HOL}^{j}(t)$ is the current value of HOL delay of flow j, and g is a grouping parameter that determines granularity of the groups which is the number of flows that will be considered in the FD scheduling iteration. The grouping is used to select the most urgent flows which has the highest value of HOL delay, and to enforce the scheduling mechanism to consider those flows in the following FD scheduling iteration.

The group of flows selected in the TD iteration are forwarded to the FD scheduling starting from the flows with the highest value of the $m_{td}^{j}(t)$ metric until all RBGs are assigned in the corresponding TTI. In the FD, for each RBG $k = 1, \ldots.K$, the QEEA scheduler assigns the current RBG to the user j that has the maximum value of the FD metric which is express as:

$$m_{fd}^{(k,j)}(t) = d_{HOL}^{j}(t) \cdot GBR^{j}.\,\overline{R^{j}}(t)\,.\,1/Ptx \qquad (2)$$

where $d_{HOL}^{j}(t)$ is the current value of HOL delay of flow j, GBR^{j} is the bit rate specified in Evolved Packet System (EPS) bearer of the flow$j$ and $\overline{R^{j}}(t)$ is the past averaged throughput performance that is calculated with a moving average perceived by user j.

Ptx is the power transmitted in the eNodeB which is set to 43 dBm or equal to 20 W. 43 dBm is the lowest power setting being specified by the 3GPP LTE [16]. The main reason of the Ptx was set as $1/Ptx$ in equation (2) is when the power transmitted was set to the lowest, then the value of $m_{fd}^{(k,j)}(t)$ increases. When the metric is high, there is higher chance or possibilities that the flow will be selected. On the other hand, when the power transmitted was set to the highest which is 48 W, the value of $m_{fd}^{(k,j)}(t)$ decreases. Table 1 shows the total BS transmit power for LTE [16].

Table 1
BS power model for LTE [16]

Parameters	Value
Total BS Transmit Power	43 dBm for UTRA FDD 46 dBm for 10 MHz LTE, 49 dBm for 40 MHz LTE-A

III. Simulation Parameters

In this research, the simulation runs for a single cell with the eNodeB location at the center of the cell where the users are uniformly distributed among the cell and modeled according to a constant velocity mobility model. The users' mobility imitates the pedestrian [17] with constant speed of 3 km/h while the path loss is the Cost 231 model [18]. Each user receives one video flow, one VoIP flow and one FTP flow at the same time. VoIP and video bit rates are 64 kbps and 242 kbps respectively. The system bandwidth is 10 MHz and made up of 50 RBs [19]. The carrier frequency is equivalent to 2110 MHz. Since the carrier frequency is 2110 MHz, the maximum radius can be set up to 1000 m is shown in Figure 1 [20]. Thus, the radius in this paper was set 600 m. Furthermore, the LTE module implements an adaptive modulation and coding (AMC) model that is a modified version of the PiroEW2010 [21] which is based on analytical bit error rate (BER). The QEEA scheduling algorithm is compared to other algorithms namely the Channel and QoS Aware (CQA), Priority Set Scheduler (PSS), Proportional Fair (PF), Maximum Throughput (MT) and Blind Average Throughput (BAT). The simulation parameters are described in Table 2.

Table 2
Simulation Parameters

Parameter	Value
Simulator	NS-3
Simulation Duration	20s
ENodeB	1 eNodeB with one cell
Transmission Power For ENodeB	43 dBm
Frame Structure	FDD
Number Of RBs	50
Bandwidth	10MHz
Number Of Subcarriers	600
Number Of Subcarriers Per RB	12
Subcarrier Spacing	15kHz
Number Of OFDM Symbols per slot	7
Packet Interval	10ms
Carrier Frequency	2.11 GHz
User Speed	Constant velocity (3km/h)
Scheduling Time (TTI Duration)	1 ms
Slot Duration	0.5 ms
QoS Services	1)GBR Conversational video 2)GBR Conversational VoIP 3)Non-GBR FTP
VoIP Codec	G.711
VoIP Guaranteed Bit Rate	64 kbps
Video File	st_highway_cif (MPEG-4)
Video Guaranteed Bit Rate	242 kbps
FTP Send Size	1024
Pathloss Model	Cost231
Fading Model	Pedestrian EPA model 3km/h
Adaptive Modulation And Coding Scheme	PiroEW2010
Scheduling Algorithm	a) QEEA b) CQA c) PSS d) PF e) MT f) BAT

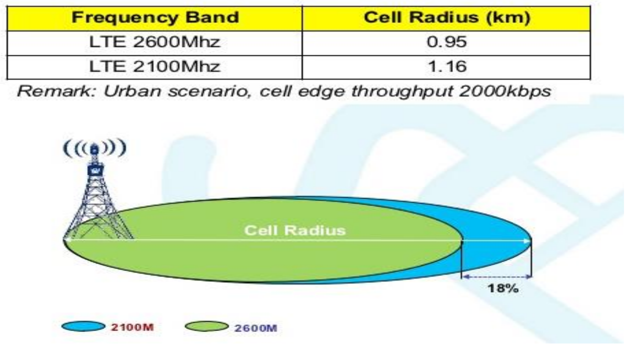

Figure 1: Carrier frequency and cell radius in LTE [20]

IV. RESULT AND DISCUSSION

The simulation consists of a cell with a radius of 600 m in which the UEs were distributed uniformly. The number of UEs was varied from 50 to 200. Then, the performance of the QEEA algorithm is compared to the CQA, PSS, PF, MT and BAT to gauge the efficiency of the algorithm. The performance metrics of throughput, delay, PLR, ECR and EE were analyzed and illustrated in Figure 2 to Figure 12 respectively.

Figure 2, Figure 3 and Figure 4 show the throughput analysis of VoIP, video and FTP flows respectively. For the VoIP flow, as shown in Figure 2, the throughput for all schedulers increased exponentially for low number of UEs that is from 50 to 100 while the performance of the MT scheduler deteriorates. Furthermore, when the number of UEs exceeds 100, the throughput achieved by the UEs using the PF and BAT schedulers is low as compared to the QEEA and CQA schedulers. There is no variation in throughput for the QEEA, CQA and PSS when the number of UEs increases up to 100 and remain constant at 2.75Mbps. This is mainly due to the fact that some VoIP packets were being dropped as the number of UEs being increase, this resulted in less utilization of assigned physical resource blocks (PRBs). It is clear that the MT has the lowest throughput than other schedulers. This is because, only those UEs that were close to the eNodeB can get access to resource blocks (RBs). The QEEA shows significant improvement of throughput even when the network is loaded with 200 UEs. Although throughput is similar to the CQA scheduler, QEEA still has the highest throughput which is 0.40% higher than the CQA algorithm.

Figure 3 shows the throughput of video flows. The throughput drops as the number of UEs in the cell increases for all scheduling algorithms and increase rapidly after 150 UEs. When the UEs number in the cell exceeds 50, throughput for MT, PF and BAT were subjected to a sharp decrease, whereas the throughput of QEEA, CQA and PSS are almost the similar. The QEEA, CQA and PSS show the same trending of the video throughput from low to high load. However, it is noticed that when there were 50, 150 and 200 users in the cell QEEA has the highest throughput which is 0.18%, 0.74% and 1.22% respectively as compared to the CQA. This is because the proposed scheduler is taking the maximum achievable throughput and past average throughput, thus, enabling full utilization of the network throughput. As shown in Figure 3, the throughput of the PF algorithm is the lowest of all schemes. The reason for this is that many packets are loss during video transmission, which in turn, assigns the resources to the FTP flows. Furthermore, PF allocates PRBs solely based on weights.

From Figure 4, it is noticed that the throughput decreases for FTP flow when the number of UEs increases. This means that the QoS of most of the users is affected as more users are added and the effective throughput decreases due to the limited amount of resources available, which results in more deadline violations. The PF, BAT and MT schemes show the worst performance among the six schemes being considered. This is due to the fact that the NRT services are pushed to the back with the increase of multimedia traffic. Therefore it is observed that the throughput decreases gradually with the increasing number of UEs. The proposed QEEA scheduler achieves significant gain in the terms of throughput. The QEEA throughput is 26.90% and 70.87% higher than the CQA and PSS schedulers respectively. This is mainly due to the non-stringent delay requirement of the NRT traffic. As a result, the resource allocation prioritizes the RT traffic instead of the NRT traffic. The QEEA is still able to allocate the resources to the FTP traffic. From this figures, it is obvious that the QEEA algorithm can support up to 200 UEs as compared to the other algorithms.

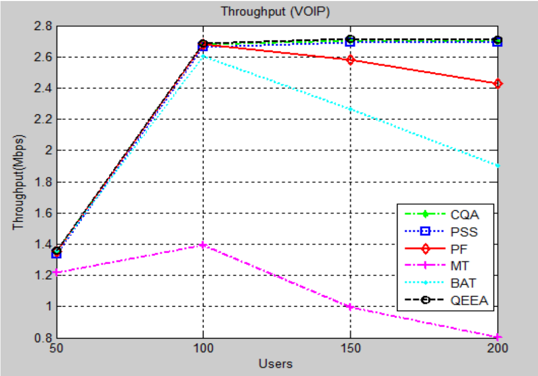

Figure 2: VoIP Throughput vs Users

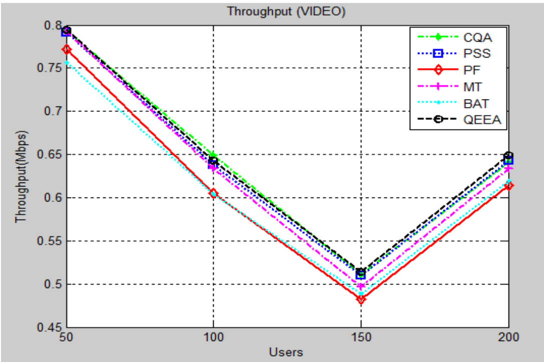

Figure 3: Video Throughput vs Users

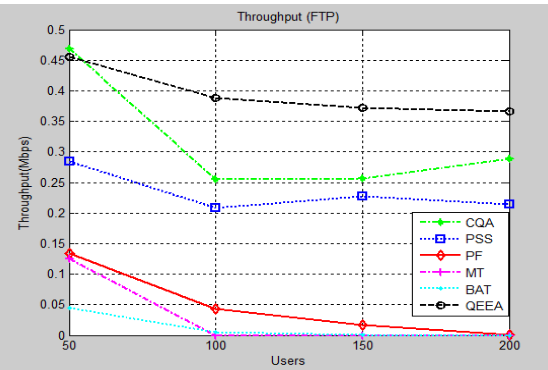

Figure 4: FTP Throughput vs Users

Figure 5 shows that the VoIP users suffer longer delay when using the BAT and PF scheduling algorithms. When there were more than 50 UEs, the packet delay for VoIP flows show a surge of increase in delay achieved of up to 110 µs when using BAT than that of the other five scheduling algorithms. The BAT algorithm is designed to provide equal throughput to all UEs under eNodeB thus neglecting the packet delay. The MT scheduler shows the highest delay when the number of UEs was 50 since MT allocates the available resources to the users with highest channel quality indicator (CQI) value regardless of the users with delay requirements. In other words, it distributes the resources to the users who are close to the eNodeB since they have the highest signal to noise ratio (SNR) value. PF scheme does not consider the delay requirement since the highest delay is 50 µs when there were 200 UEs. The PF allocates the resources to users who had the lowest throughput in the previous TTI. Meanwhile, the proposed scheduler QEEA has the lowest delay than the remaining schedulers. The QEEA is 91.19% lowest than the BAT scheduler when there were 200 UEs. On the other hand, QEEA is able to maintain the delay even when the number of UE increases which is from 100 to 200. The CQA and PSS have similar trending with QEEA where QEEA is 14.26% and 46% lower than CQA and PSS respectively as QEEA algorithm considered the HOL packet delay and delay threshold of active flows while allocating radio resources to the users. Thus, it is observed that QEEA is giving the lowest delay among the five schemes and plays an important role in improving the QoS of VoIP.

Figure 6 demonstrates that video flows have a longer delay when there are more UEs in the cell. QEEA has the lowest delay of around 0.4 to 0.7 µs even when the number of UE was incremented as compared to the PF and BAT algorithms which delivered higher delay is around 1.1 to 1.9 µs. Initially, the delay of PF is lesser than the BAT, but it increases when the number of UEs increases which is 28% than the BAT when there were 150 UEs. The PF yields the highest delay because it uses weight to determine which of the packet flows to transmit. Therefore it can be concluded that the PF and BAT schedulers cannot provide adequate video quality to the supported UEs. When the number of video user is more than 50, the QEEA scheduler is having better performance than the MT and other schedulers. This show that the QEEA algorithm can handle traffic with delay constrain better than other algorithms. It also shows that by monitoring the guaranteed bit rate (GBR) and HOL delay, QEEA could optimize the resource allocation and allocate the resource block efficiently.

Since the delay of the FTP for MT and BAT algorithms are very poor (no value starting from 50 UEs), only the delay performance of the QEEA, CQA, PSS and PF algorithms are shown in Figure 7. The PF scheme does not consider the delay requirements since it allocates the resources to users who had the lowest throughput in the previous TTI. Furthermore, this figure shows that QEEA, CQA and PSS have merely constant delay which is lower than 10 µs. It can be seen that the packet delay of QEEA is decrease until 86% as compared to other algorithms. This is because the priority increases significantly when the delay of UE approaches to the delay threshold. However, when there were 150 UEs, the QEEA delay increase slightly because as queue size increases, more packets will start to experience delay since QEEA allocates resources to GBR and non-GBR in each time slot. However, the delay is still the lowest than the rest.

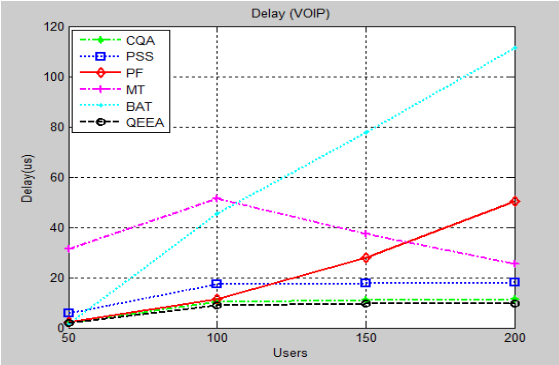

Figure 5: VoIP Delay vs Users

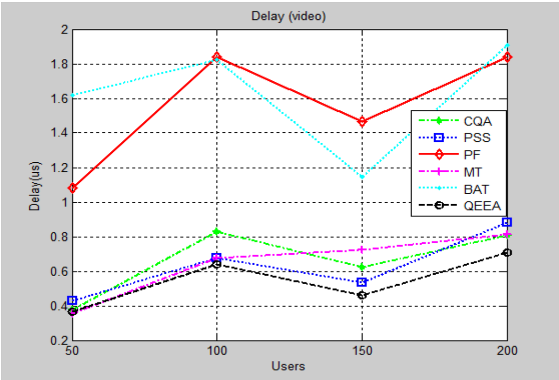

Figure 6: Video Delay vs Users

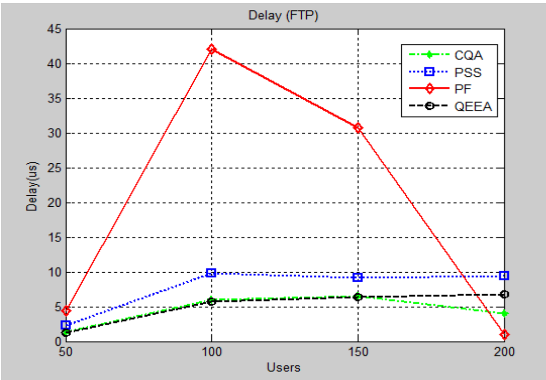

Figure 7: FTP Delay vs Users

The PLR for VoIP, video and FTP flows are depicted in Figure 8, Figure 9 and Figure 10 respectively. All the traffics show that the PLR increases with the increasing number of users because of increased network loads. The reason is that, as the network load increases, the possibility to discard packet for deadline expiration increases. As expected, with increasing average system delay as shown in Figure 5 to Figure 7, there will be more packets being discarded since there are insufficient RBs to transmit all the packets whose HOL packet delays are approaching the delay threshold as shown in Figure 8 to Figure 10. Nevertheless, the QEEA still gives the lowest PLR among all other schemes for all traffics.

There is no considerable difference of PLR for VoIP flows for all the scheduling schemes when the cell is charged with less than 100 UEs except for MT algorithm as shown in Figure 8. The PLR shows a sharp increase when using MT when increasing number of UEs, which is up to 50% since this algorithm neither HOL delay nor PLR information into account in the scheduling decision. On the other hand, the BAT and PF schedulers performs better at 38% and 76% respectively lower than MT at 200 UEs. Meanwhile, the QEEA, CQA and PSS performed better and keep the PLR value less than 3% even when there are 200 UEs in the cell. Although the proposed scheduler, QEEA has the approximately similar value of PLR when compared to the CQA and PSS schedulers the proposed scheduler is still has the lowest PLR value that is 17% and 26% in comparison to the CQA and PSS schedulers respectively. The PLR value decreases considerably up to 96% at 200 UEs as compared to the MT scheduler. Furthermore, the PLR value of the proposed scheduler is stable and maintained at below than 2% even when the number of UE increases. The QEEA algorithm always selects UE with delay approaching deadline expiration and good channel condition to transmit as many packets as possible.

For the video flows shown in the Figure 9, the PLR curves increases as the number of UE increases up to 50 UEs and then drops rapidly after 100 UEs for all schedulers. When the number of UE exceeds 50, the PLR of MT, PF, and BAT show a rapid increase whereas QEEA, CQA and PSS have relatively low delay which is below than 0.08 µs when the cell is charged with 200 UEs. The BAT shows a dramatic increase of PLR by increasing the number of UE whereas the CQA and PSS algorithms show almost the same fluctuations. Although the proposed scheduler QEEA does not have a good PLR when the number of video users are less than 100, but overall, QEEA is still having the lowest PLR. The PLR value of QEEA starts to decrease when the number of UE is 100 and has the lowest PLR when the number of UE increases to 200. Therefore, it can be said that the proposed scheduler provides an excellent PLR performance of video flow when the load is high because the PRBs have been utilized adequately.

Since the PLR analysis for FTP flows of the MT and BAT algorithms are very poor, only the PLR performance of the QEEA, CQA, PSS and PF algorithms are shown in Figure 10. The PLR for all schedulers is increasing when the number of UEs is increasing. Figure 10 has shown that the PF has the largest PLR since this algorithm usually does not consider PLR and packet delay. The PLR for QEEA is the lowest from 50 to 200 users which is 49% lower than the CQA, PSS and PF schedulers. Thus, the QEEA algorithm outperforms the other schemes and is suitable for all environment either in RT traffics or NRT traffics.

Figure 11 and Figure 12 show the ECR and EE for VoIP, video and FTP flows. The ECR value for QEEA, CQA, PSS, PF and BAT schedulers decreases as the number of users increases in the cell as shown Figure 11. Thus, ECR will decrease in high load. However, it can be seen that when the system at low number of users, the energy consumption of MT scheduler is more than the other schedulers and this energy is increased rapidly until 200 UEs. It is because the MT algorithm is not suitable at high load. When the number of UE is beyond 50 , all packets of the FTP traffics in MT algorithm have been discarded because the MT algorithm could not cope with the RT traffics such as VoIP and video in high load condition. Thus, the throughput MT was low since not a lot of traffics have been worked at each UE then the ECR will be increase. Furthermore, in the proposed scheme, QEEA scheduler achieved up to 32.36% reduction of energy consumption as compared to other schedulers. This shows that the QEEA can reduce the consumption of energy when the traffic load is high in the network. The main reason is that the QEEA scheduler transmits the highest amount of data at the same power level as the other schedulers thus achieving the lowest ECR. Therefore, the lower the ECR value, the higher the power efficiency achieved as the radius increases. This can be justified by the results shown in Figure 12. It is observed that when the number of UE increases, higher EE value can be achieved of the five algorithms. This is because when the number of users increases, eNodeB have more opportunities to serve UEs with better channel condition which results in higher energy efficiency. The proposed scheme QEEA can provide improvement of up to 48% energy efficiency gain as compared to the remaining schedulers.

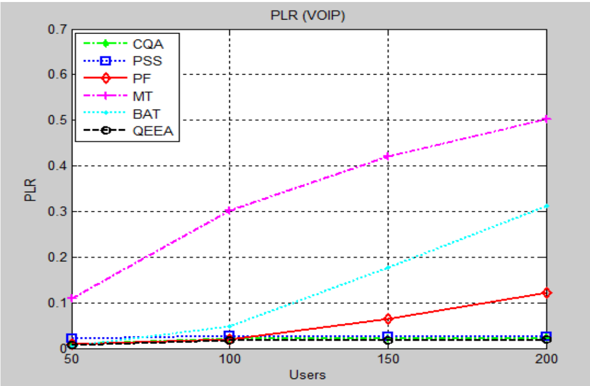

Figure 8: VoIP PLR vs Users

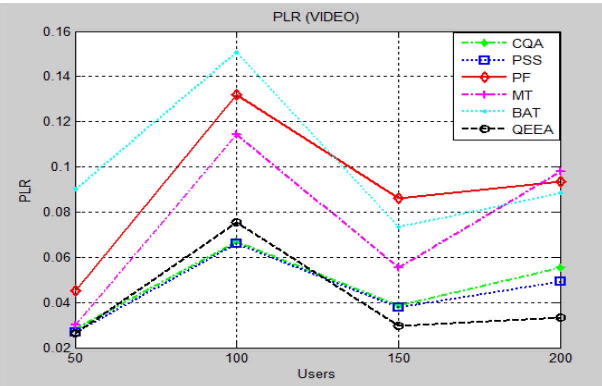

Figure 9: Video PLR vs Users

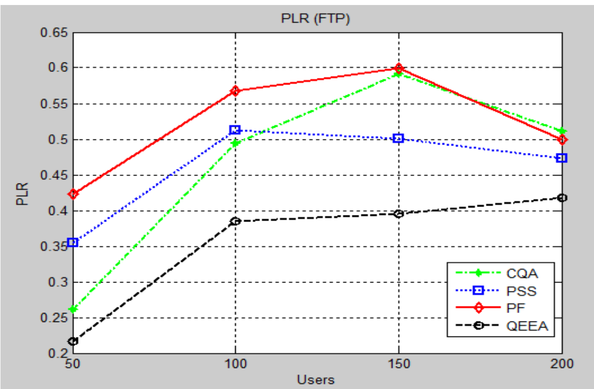

Figure 10: FTP PLR vs Users

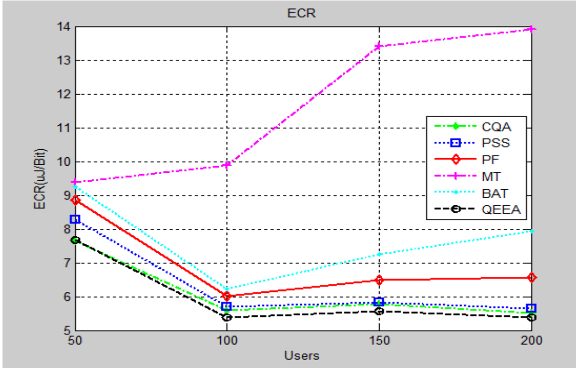

Figure 11: ECR vs Users

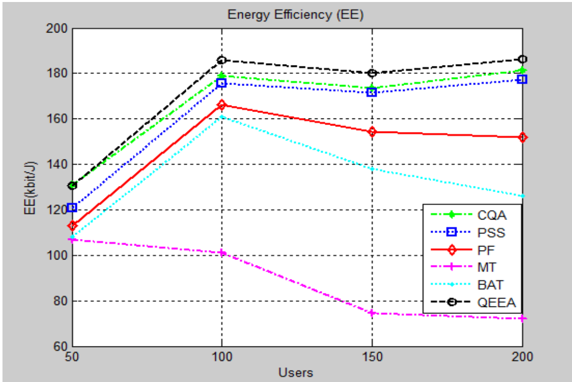

Figure 12: EE vs users

V. CONCLUSION

From the simulation performed, it can be concluded that QEEA is the most suitable algorithm to manage the VoIP, video and FTP in LTE network. Overall QEEA algorithm shows the best result in terms of higher throughput, maintaining lower delay and PLR. In order to make wireless technologies competitive in terms of EE, this result shows that it is interesting to investigate how the power consumption of the eNodeB of the wireless technologies can be reduced. This proposed algorithm is suitable for development of green communication which is the lowest ECR is achieved for all traffics and improves EE as compared with other schemes. According to the aforementioned results, significant energy saving and superior performance during high traffic situation can be achieved by implementing of the proposed scheme which is introducing the relevant energy efficient scheduler. The QEEA algorithm also would be suitable for both RT and NRT multimedia services and enable the higher number of UEs is served with satisfactory quality. Moreover, QEEA is an energy efficient scheduling to overcome energy consumption while improving the throughput performances of LTE cellular networks. In a commercial LTE network, where the balancing of operator-customer equation is of utmost importance there is no doubt that the QEEA scheduler will come in handy. There awaits a world with data hungry users and this new algorithm is proven to serve of them.

Future research will focus the uplink scheduling algorithm in LTE with difference scenarios. This scheme also can be further modified with new QoS parameter so that, it can perform much better for RT services such as throughputs and delay for VoIP and video and also it could be modified in such a way that it can work well for any kind of traffic either it is RT or NRT service. In future more work can be done to efficiently allocate resources with determining the complexity and fairness of proposed scheduling algorithm. Moreover, in this simulation, frequency division duplex (FDD) is used for duplexing. Behavior of next proposed scheme can be studied for time division duplex (TDD) case.

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