iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 9 **Issue:** X **Month of publication:** October 2021

DOI: https://doi.org/10.22214/ijraset.2021.38642

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue X Oct 2021- Available at www.ijraset.com

An Improved Proportional Fair Scheduling Algorithm for Downlink LTE Cellular Network

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***Abstract:** Network providers of LTE networks can achieve maximum gain and Quality of Service (QoS) requirement of their users by employing a radio resource management technique that has the ability to allocate resource blocks to users in a fair manner without compromising the capacity of the network. This implies that for a better performing LTE network, a fair scheduling and balanced QoS delivery for various forms of traffic are needed. In this paper an improved proportional fair scheduling algorithm for downlink LTE cellular network has been developed. This algorithm was implemented using a MATLAB-based System Level simulator by Vienna University. The developed algorithm was compared to other scheduling algorithms such as the Proportional Fair (PF) algorithm, Best Channel Quality Indicator (CQI), and Round Robin (RR) scheduling methods. The system performance was also analyzed under different scenarios using different performance metrics. The achieved results showed that the developed algorithm had a better throughput performance than the Round Robin and Proportional fair scheduling. The developed algorithm shows improved cell edge throughputs of about 19.2% (as at 20 users) and 9.1% higher for cell edge users without and with mobility impact respectively. The Best CQI algorithm had higher peak throughput values but the fairness was highly compromised. The developed algorithm outperforms the Best CQI by 136.6% without the impact of mobility. Finally, in dense conditions, the developed algorithm still outperforms the other algorithms with a QoS metric of 4.6% increment when compared to the PF algorithm which was the closest competitor.*
***Keywords:** UE, eNodeB, Scheduling, Proportional Fair, LTE,*

I. INTRODUCTION

Multiple resource blocks can be scheduled in a transmission over the frequency and time by applying OFDMA in an LTE system which is its main challenge (Astély, Dahlman, Furuskär, Jading, Lindström and Parkval, 2009). LTE has three key components which are involved in the resource allocation and network optimization namely: resource block scheduling, power control, and client association. This work focuses on resource block scheduling in LTE system and proposed an improved proportional fair algorithm to allocate resource blocks. LTE communication is available in different frequency bands of different sizes. Communication can take place both in paired and unpaired bands. Paired frequency bands means that the uplink and downlink transmissions use separate frequency bands, while in unpaired frequency bands, downlink and uplink share the same frequency band (Sari et al, 1997).

In LTE downlink networks, transmissions are grouped in frames of length 10ms. One radio frame is made up of 10 sub-frames of 1ms duration. Each sub-frame is divided into two slots of 0.5 ms duration. Each slot counts 6 or 7 OFDM symbols for normal or extended cyclic prefix used. The spectrum is very flexible and allows LTE to use different bandwidths ranging from 1.4 MHz to 20 MHz. The larger the bandwidth, the higher the LTE data rates (Sudhir, Jyoti and Kharad, 2015). Orthogonal Frequency Division Multiplex (OFDM) is the core of LTE downlink transmission. A Resource Block (RB) has a duration of 0.5msec (one slot) and a bandwidth of 180 kHz (12 subcarriers). Each RB has 12x7 = 84 resource elements in the case of normal cyclic prefix and 12x6 = 72 resource elements in the case of extended cyclic prefix.

Scheduling is a process of distributing available resources among the users who need service in such a way that Quality of Service (QoS) is maintained. The basic idea is to schedule transmission for UEs that at current time and on a given frequency, good channel conditions based on selected metric would be experienced (Capozzi, Piro, Grieco, Boggia and Camarda, 2013). Its main goal is the allocation of resource blocks and transmission powers for each sub frame in such a way that a determined set of performance metrics is optimized, e.g. fairness, maximum/minimum/average throughput, maximum/minimum/average delay, total/per-user spectral efficiency or outage probability. With this information, the eNodeB scheduler optimizes the allocation of radio resources to the UEs, always within satisfactory latencies and meeting QoS requirements while being efficient from a spectral point of view.

II. REVIEWED WORKS

Several scheduling algorithms have been proposed in order to improve the resource allocation performance for LTE networks. Such as Round Robin (RR) which aims at allocating equal amount of time to all users regardless of other QoS requirements. RR scheduler is fair in terms of time but not in terms of throughput. While in the case of Best CQI scheduling, two users who have allocated an equal amount of time and one of them has bad channel conditions and the other has good channel conditions then the throughput of the later one is significantly higher than that of earlier one. Later on, Proportional Fairness (PF) was proposed to overcome such a problem (Hayuwidya, Ernawan and Iskandar, 2017).

Another approach namely Maximum Throughput (MT) was proposed by (Capozzi, Piro, Grieco, Boggia and Camarda, 2013) in order to improve the overall system throughput. The MT approach allocates the resources to the users with highest Signal to Noise Ratio (SNR) value. This improves the overall system throughput but starve to the users who are located at the cell edge where they have the lowest SNR value. To solve such a problem, Frame Level Scheduler (FLS) was proposed to give attention to the users with tightest delay (Piro, Grieco, Boggia, Fortuna and Camarda, 2011). FLS scheme is a two level scheduler which shows an acceptable performance for real time applications which are sensitive to delay.

(Gao, Bawa and Paranjape, 2020) focused on fairness to cell edge users to develop a fairer proportional fair (PF) scheduler using the control theory. The fairness of user data rate is dynamically adjusted by setting a threshold in the new scheduler. The authors added a proportional integral (PI) controller on the conventional PF scheduler to form a closed-loop feedback system. The results show that the scheduler can adjust the fairness and cell throughput properly according to the requirements. The drawback of this scheduler is that QoS requirements of the users were not considered by the authors and the parameters can only be monitored and adjusted manually. The controller's parameters for moving users should be automatically readjusted whenever users' radio conditions changes.

(Refaat, Islam, Shaalan, Nashaat and Zaki, 2020) proposed a scheduling algorithm that focused on reducing the consumption power transmitted from the eNodeB. They gave priority to users with larger delay and lower power consumption. This implies that users that consume lesser power and has larger delays will have the priority to get resources. In as much as the scheduler worked well from power consumption reduction point of view, it has a very bad performance from a fairness point of view.

(Huang and Zhang, 2020) worked on improving the utilization of spectrum resources and the problem of unscheduled users in the downlink transmission process in LTE system. They integrated cognitive radio (CR) technology into their proportional fair scheduling algorithm. The algorithm allows unscheduled users to perceive and use the idle spectrum (spectrum holes) that is not used by the primary user (PU) for data transmission. Also, two secondary users (SU) management schemes for continuing to wait and finding new subcarriers are given, and the delays under the two schemes are calculated. A new decision method is proposed to solve the problem of SU reconstruction. Numerical analysis shows that the new algorithm can ensure the fairness of users, effectively reduce system delay and improve system efficiency.

(Nasralla, 2020) proposed a hybrid QoS-aware downlink scheduling that aimed to address different traffic classes and balances the QoS delivery with improvements to the overall system performance. Nasralla classified the scheduling algorithms into four main classes: delay aware, queue aware, target bit-rate aware and hybrid aware. The author analyzed different downlink scheduling rules for their network-centric performance metrics. The results shows that the queue-aware and delay-aware scheduling rules deliver the best QoS performance for video traffic classes, whereas his proposed hybrid scheduling rules deliver balanced QoS for various types of traffic classes.

(Monikandan, Sivasubramanian, Babu, Venkatesan and Arunachalaperuma, 2019) proposed a new scheduler that he called "Channel Aware Optimized Proportional Fair (CAOPF)". The scheduler optimizes the channel behavior based on Channel Quality Indicator (CQI). While compared with other schedulers such as Round Robin (RR) and Proportional Fair (PF) performed well in terms of level of Quality of service (QoS) performance. The limitation is that the work does not support more number of UEs per TTI in a single cell with different arrival rates of traffic.

(Mamman, 2020) proposed a new scheduling algorithm to improve the poor performance degradation that is experienced in Quality of Service Class Identifier (QCI) based scheduling algorithms. QCI based schedulers uses the QoS requirement and channel status to grant resource allocation users. The author introduced the idea of Genetic Algorithms (GA) before radio resources are allocated to users. GA is established on the imitation of natural biological development. GA examines a space of nominated solutions (chromosomes) considering the most fitting one. Results obtained show that the proposed algorithm performs considerably well when compared with other algorithm according to the measured metrics but it is limited to only QCI based scheduler.

(Yaqoob, 2020) studied the performance of existing schedulers in LTE network which include Proportional fair (PF), Modified largest weighted delay first (MLWDF), Exponential PF (EXP/PF), Logarithm rule (LOGRULE) and Exponential rule (EXPRULE) scheduler. The authors then enhanced the existing exponential rule scheduling whose limitations include high packet rate, low fairness and high delay. The enhancement separates each traffic metric computation based on the critical factors in each traffic flow. The proposed scheduler provides a significant performance improvement for video application without sacrificing the VoIP performance.

III. DEVELOPMENT OF THE IMPROVED PROPORTIONAL-FAIR (PF) ALGORITHM

The conventional PF is executed according to a predefined formula which uses the momentary and the past average throughput values of the UEs which are saved in a memory. The formula of the PF algorithm metric is given as (H. Kim, 2004):

$$k(t) = argmax_{i=1,\dots,N}(\frac{R_i(k,t)}{T_i(t)}) \quad (1)$$

Where $R_i(k,t)$ is the momentary data rate of the i^{th} user on k^{th} RB at time t, and $T_i(t)$ is the past average throughput of the i^{th} UE. The PF algorithm is realized in three stages. In the first stage, for each pair of unallotted n_{th} resource block and K_{th} UE, the system calculates the ratio as shown in equation (2) (H. Kim, 2004):

$$\frac{r_{k,n}}{(\propto -1)T_k + \sum_{n=1}^{N} \rho_{k,n} r_{k,n}} \quad (2)$$

Where $r_{k,n}$ is the momentary transmission rate of K_{th} UE on the n_{th} resource block, T_k is the average throughput of the same user, and $\rho_{k,n}$ is whether 1 or 0 meaning the RB is allotted to UE or not. During the second stage, the UE and RB pairs are picked using the formula (H. Kim, 2004):

$$(K^*, n^*) = argmax_{k,n}\left(\frac{r_{k,n}}{(\propto -1)T_k + \sum_{n=1}^{N} \rho_{k,n} r_{k,n}}\right) \quad (3)$$

At the last step, the system reiterates steps 1 and 2 until all RBs are paired with UEs and T_k is updated for each UE when the pairing process ends.

Although the PF algorithm provides very nice results both in terms of fairness and throughput, it lacks a mechanism to maintain a guaranteed rate of data transmission for different user applications.

The new scheduler algorithm is designed to allocate resources to users with both the best and poor channel quality in a single slot period. The Channel Quality Indicator (CQI) would be utilized as a key performance indicator in determining users with the best and poor channel quality. To ensure that good throughput and fairness are maintained in the network, a CQI threshold value was set. With this, the scheduler would be able to allocate resources to UEs with best and poor CQIs one after another during each slot period. CQI values in LTE ranges from 0 to 15.

Users with CQI value of 10 and above are users with good channel quality while users with CQI below 10 are users with poor channel quality. The scheduler estimates the terminals with high and poor CQI. Then using the set threshold, in the first time slot, the scheduler allocates resources to the terminals with the best and poor CQI respectively one after another until the first time slot elapses. In the same way, in the second time slot of the same sub carrier the scheduler continues to supply resource blocks one after another to users with best and poor channel.

At the end of each sub carrier, the process is repeated in the next sub carrier. Figure 1 represents the developed scheduling algorithm flowchart.

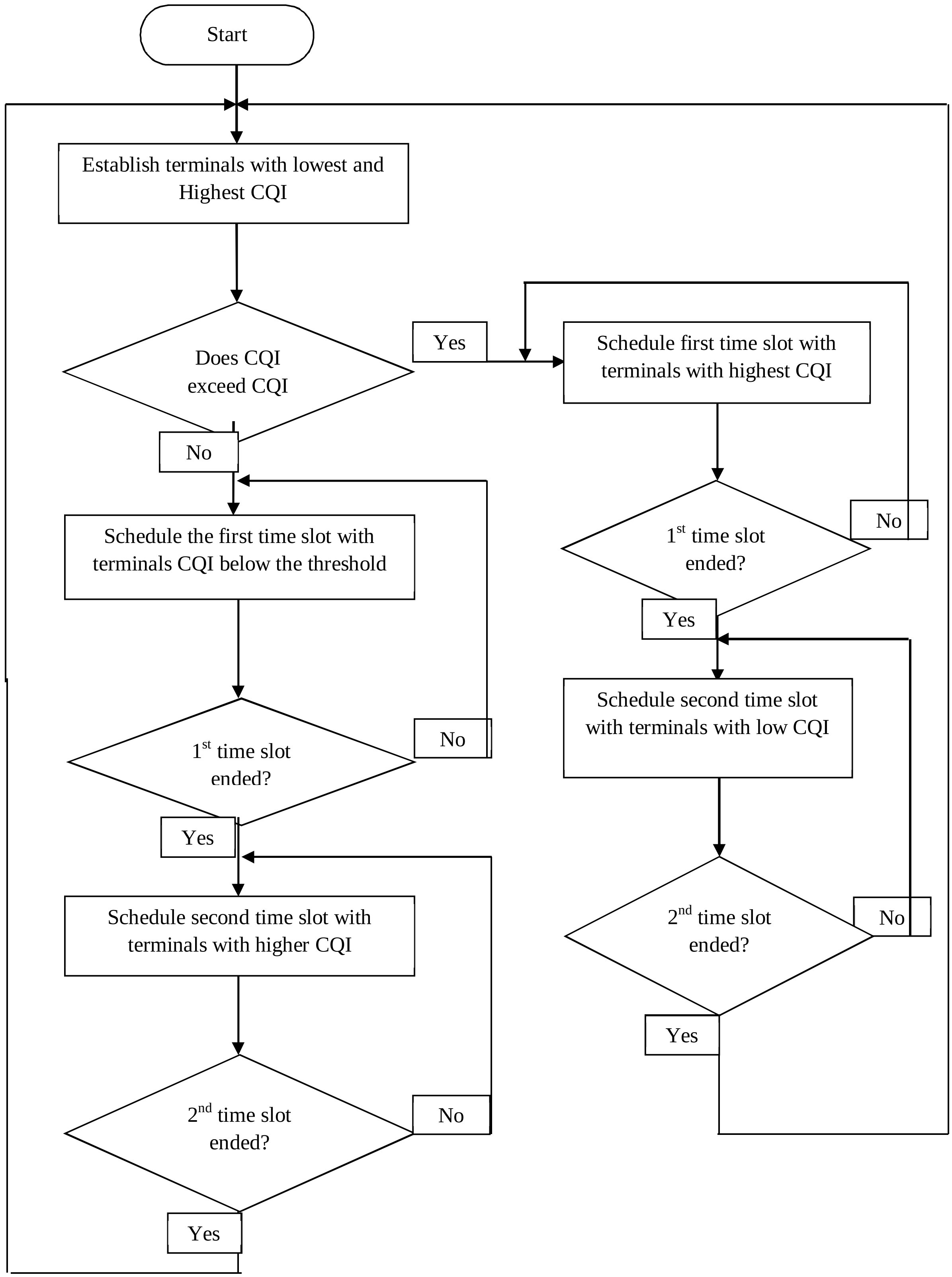

Fig 1: Flow chart of the developed scheduler

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue X Oct 2021- Available at www.ijraset.com

IV. RESULTS AND DISCUSSIONS

To execute the simulations, the Vienna LTE System Level Simulator was used. The Vienna LTE System Level Simulator was chosen because is free of charge for academic usage and its source codes are open. There are two main parts inside the structure of the simulator which are link measurement model and link-performance model. Link-measurement model is responsible for demonstrating link qualities coming from the UE evaluations, and it permits resource distribution and link adaptation. Link quality is evaluated for each subcarrier. The UEs calculate the necessary feedback such as CQI according to the SINR, and this feedback is used at the eNodeB side for accomplishing link adaptation. The link performance model pursues the link measurement model to anticipate BLER of the link according to the received SINR. Simulation parameters are given in Table 1

Table 1: Simulation parameters

Parameter	Value
Carrier Frequency	800, 1800, 2100 MHz
UE speeds	5, 50, 100km/h
Bandwidth	20MHz
Performance Metrics	Edge Throughput, Peak Throughput, Average Cell Throughput, QoS Fairness Metric, Effects of Mobility, and QoS Fairness Index Results with Mobility.
Scheduling Algorithms	Conventional Proportional Fair, Round Robin, and Best CQI.
Number of eNodeBs	3
Simulation duration	50TTI
Number of users per eNodeB	20 - 500

The results of the simulations are evaluated with regard to the performance metrics given in table 1. Figure 2 shows the approximate locations of the users in the cell area.

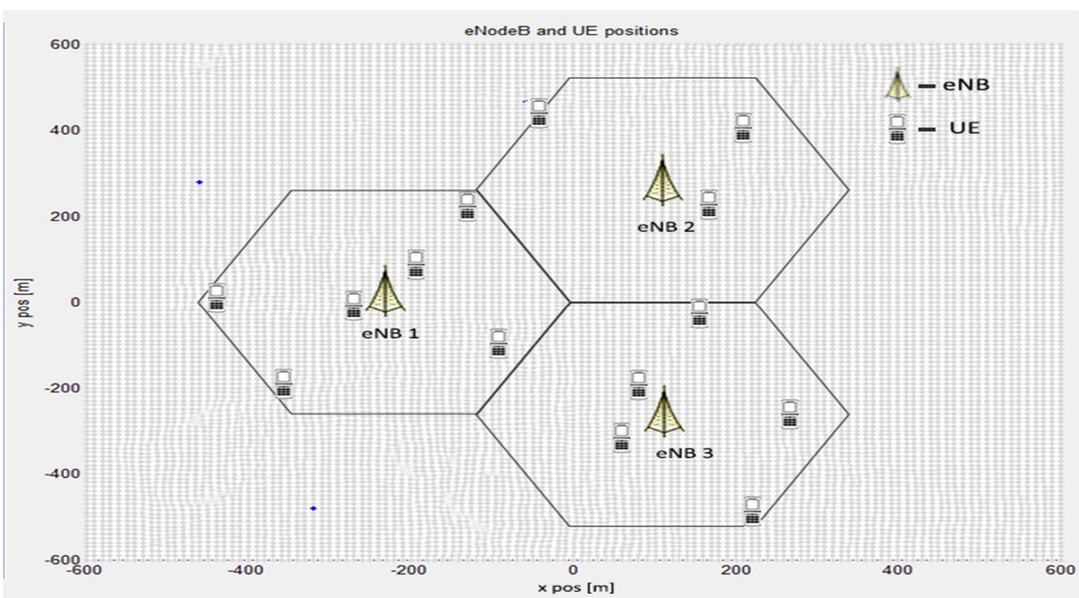

Figure 2: Positions of the UEs and the eNodeBs

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The system performance was analyzed under different scenarios and the following performance metrics were compared with other existing scheduling algorithms.

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1) *Scenario 1:* Cell edge performance

During the simulation, some UE's were placed at the cell edge as shown in figure 3. This simulation helps to present the system performance on resource allocation to users who are closer to the cell edges.

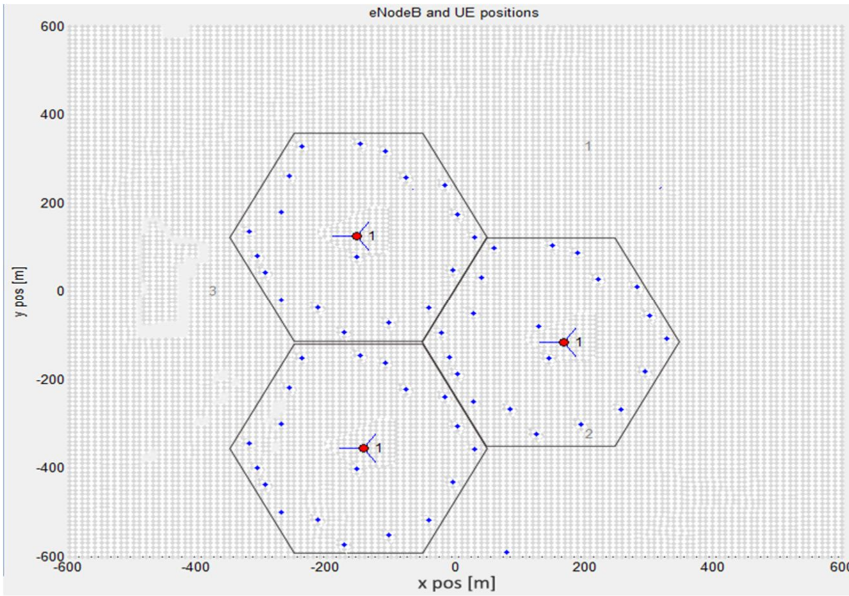

Figure 3: Simulation image of scenario 2

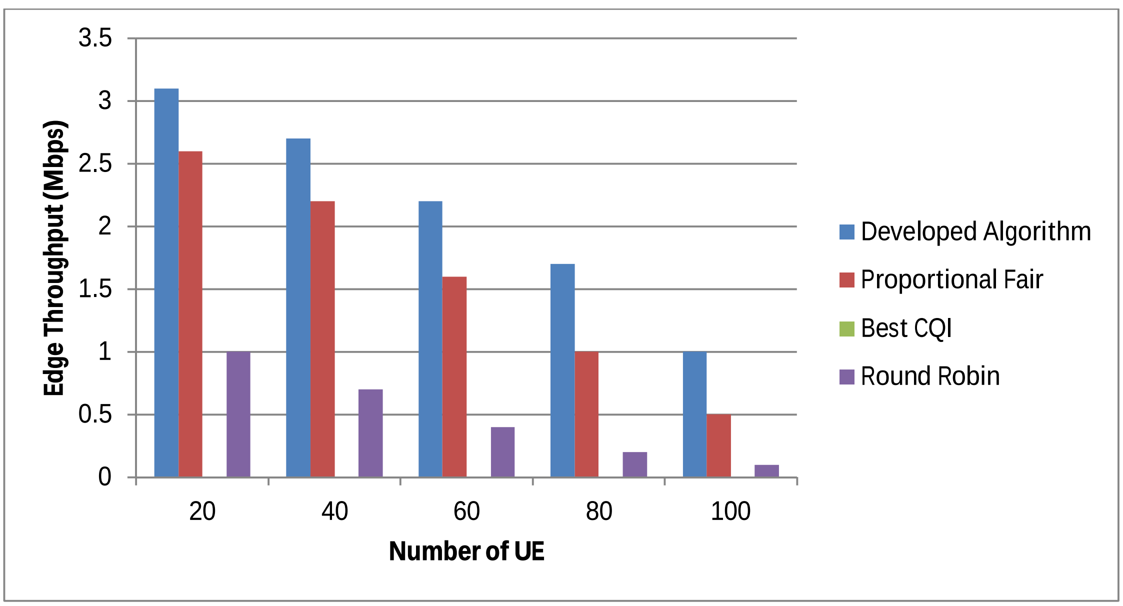

Figure 4: Comparison of Edge Throughput Performance

From figure 4, the average edge throughput kept decreasing in all the scheduling algorithms as the number of users increased. The reason for the decrease is attributed to scarcity of resources as an increased number of users compete for the limited resources. It can also be observed that the edge throughput for Best-CQI algorithm was always 0 Mbps since the algorithm was designed to only allocate resources to users with the best channel quality, in which case edge users cannot get any service as they have the worse channel quality because of fading channels problem in mobile networks. The algorithm developed in this work outperforms the conventional Proportional Fair algorithm by 19.2% when the number of users was 20. As at 100 users where the competition for available resources by the UE was intense, the developed algorithm outperformed both the conventional PF algorithm and Round Robin (RR) algorithms by 50% and 90% respectively.

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2) *Scenario 2:* System performance for users close to eNB

The system performance was also analyzed for instances where the users are located close to the eNB's. The Peak throughput performance indicates the value calculated for those users who are closest to the cell centers, and it mainly affects the overall cell throughput. The simulation scenario is as shown in Figure 5, while the system performance under this scenario is as shown in figure 6

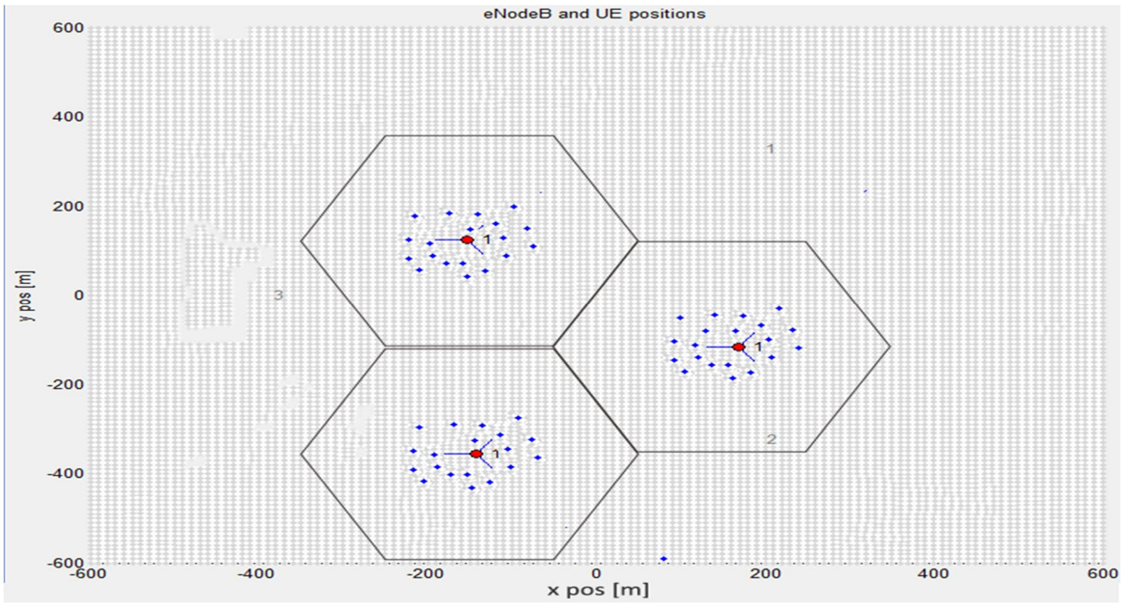

Figure 5: Simulation image of scenario 2

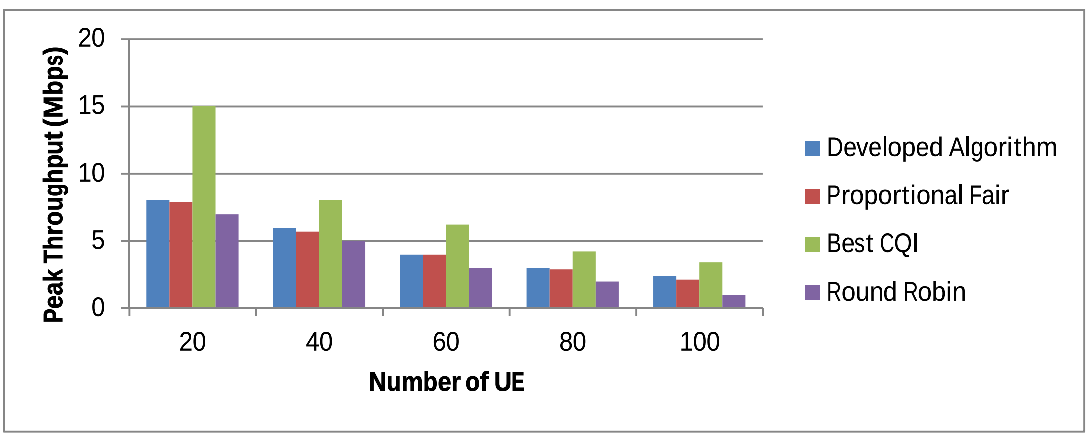

Figure 6: System performance of scenario 2

From figure 6, it can be seen that the users who are closest to the cell center suffer least from fading channels problem, and they have the best channel quality when compared to other users. This leads to a better communication between central users and the eNodeB, and hence, they can get the maximum throughput from the eNodeB. It can be observed from figure 6 that the Best-CQI algorithm performs best as it allocates the resources to the users with best channel qualities. Good channel quality means having high throughput result; this is why the Best-CQI algorithm has a higher throughput value when compared to the other scheduling algorithms. The drawback to this is that the system fairness result is poor. Users with good channel qualities are allocated resource blocks by Best-CQI algorithm while edge users are never allocated resource blocks. On the other hand, Improved Proportional Fair algorithm developed provides very similar results when compared to Proportional Fair algorithm with reference to throughput and it outperforms Proportional Fair algorithm when the number of users in the cell increases. Round Robin results were also outperformed by Best-CQI algorithm.

3) *Scenario 3:* Average Cell Throughput Performance

The Average cell throughput is the sum of average throughput of all the UE in the network and it is one of the most important criteria in resource scheduling of LTE systems. The higher the throughput, the better the services rendered to the users. The network has to serve all of its users without ignoring service requests of any user. The average cell throughput of each system is analyzed in this section.

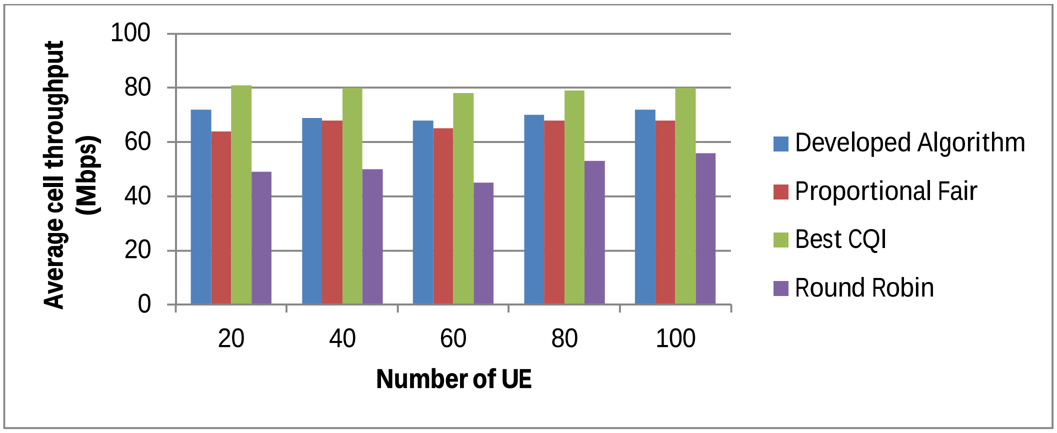

Figure 7: Average Cell Throughput Performance of the Schedulers when the users are mostly located at the center

From figure 7, the average cell throughput deviated a little in all the scheduling algorithms as the number of users increased. It can be observed that the Best-CQI algorithm performs best as it allocates the resources to the users with best channel qualities, though at the detriment of cell edge users with poor channel conditions. The algorithm developed in this work outperforms the conventional Proportional Fair algorithm by 12.5% when the number of users was 20. As at 100 users, the developed algorithm outperformed both the conventional PF algorithm and Round Robin (RR) algorithms by 5.8% and 28.6% respectively. Although Best-CQI algorithm provides high results about peak and cell throughput, but it is not fair. For edge users, the result is presented in figure 8. The result shows that the Best CQI under performed in all the instances as the UE kept increasing. This underperformance is due to poor channel condition experienced by the edge users. The developed algorithm and the PF algorithms showed the best performance among the others. When there was just 20 UE, the conventional PF algorithm outperformed the developed algorithm by 9.7%, but as the number of UE increased to 60, the developed algorithm had a 4.6% improvement over the conventional PF algorithm. The RR algorithm also performed fairly better than the Best CQI, but since it is channel blind, it sometimes allots UEs who are on fading channels and this causes decrease in the throughput as a result of bad channel condition. Although RR seems like a fair algorithm, the fairness it provides is in terms of the number of RBs assigned to each UE rather than throughput manner.

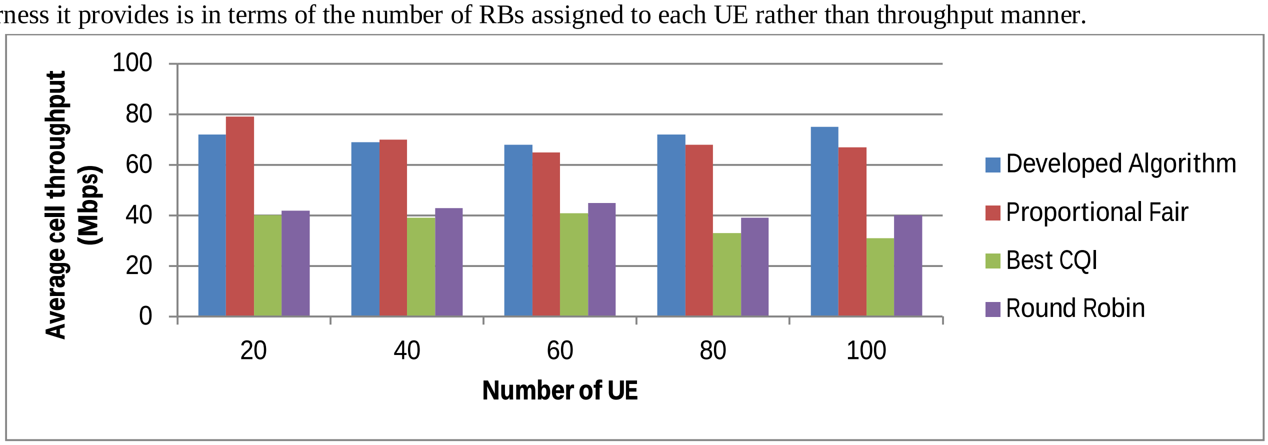

Figure 8: Average Cell Throughput Performance of the Schedulers when the users are mostly located at the cell edge

To estimate the fairness value for each system, the Jain's Fairness metric is employed. The Jain's fairness value is given as (R. Jain, 1999):

$$J(x_1, x_2, \dots x_n) = \frac{(\sum_{i=1}^{n} x_i)^2}{n \sum_{i=1}^{n} x_i{}^2} \quad (4)$$

Where, $J(x_1, x_2, \dots x_n)$ estimates the throughput value for n users and x_i is the throughput value gained on the i^{th} channel. The Jain's fairness metric was computed for each of the scheduling system, and the result is as presented in figure 9.

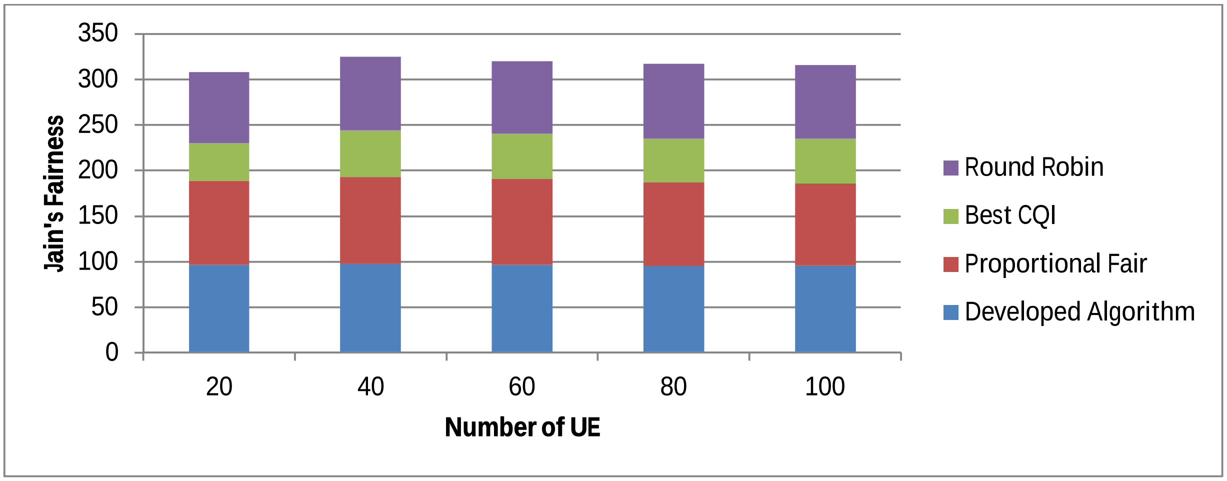

Figure 9: Jain's Fairness Index of the Schedulers

As shown by figure 9, the developed algorithm outperformed all the other scheduling algorithms. When there was 20 UE, the developed algorithm outperformed the conventional PF algorithm by 5.4%, and also outperformed the Best CQI and Round Robin algorithms by 136.6% and 24.3% respectively. The developed algorithm showed better fairness than all the other algorithms, unlike the Best CQI which had a higher cell throughput but at the detriment of the fairness of the system. The Best CQI algorithm under performed at all point as the UE kept on increasing during the simulation. The Round Robin and conventional PF algorithms also showed a better fairness performance than the Best CQI. When the cell was loaded to a high capacity of 100 UE, the developed algorithm still maintained a high Jain's fairness value of about 96, while the conventional PF algorithm was about 90, and Round Robin and Best CQI was 81 and 41 respectively. The developed algorithm performed better than others in the Jain's fairness index beacause while trying to fulfill QoS requirements of all the users inside a cell, the algorithm allocates more resources to edge users and shares the resources out more equally among the users. Although the conventional PF algorithm and Round Robin also tries to do the same, the difference with the developed algorithm is that beyond distributing the resources fairly, the algorithm also ensures that good throughput levels for each user is also factored in.

4) Scenario 4: Quality of Service (QoS) Fairness Metric Performance

This metric is introduced to examine how diverse scheduling algorithms handle users' service requests and network experiences under a dense condition as shown in figure 10.

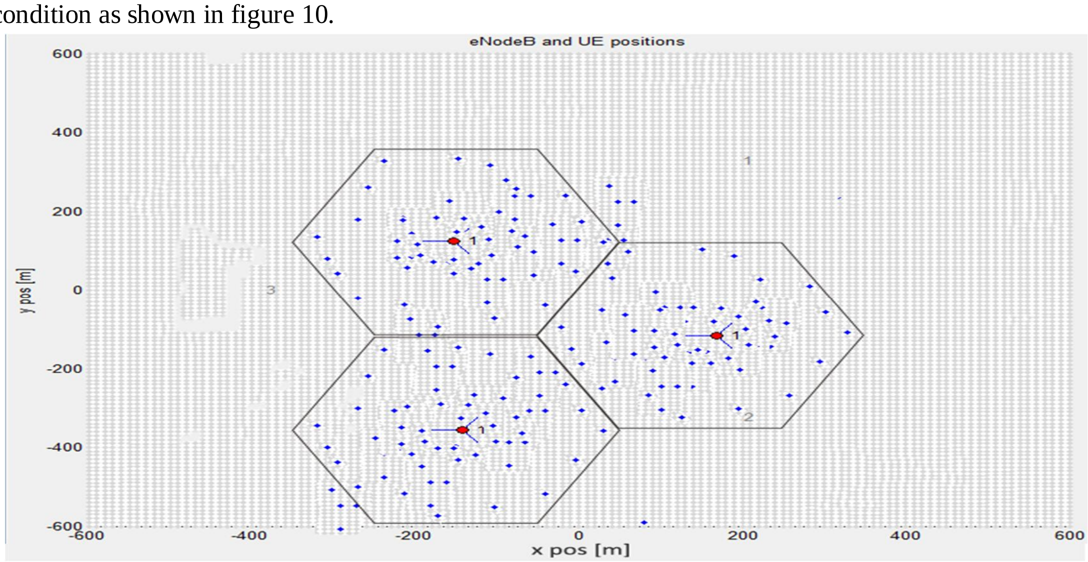

Figure 10: Simulation image of scenario 4

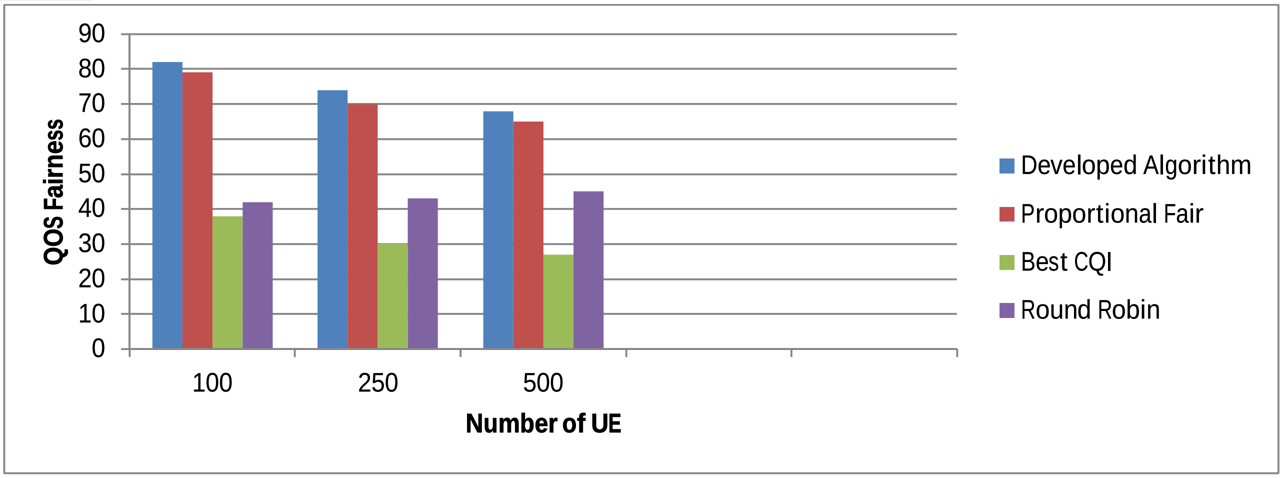

Figure 11: QoS Fairness Index of the Schedulers

As the number of UE's and variation of mobile applications increases, the QoS service demands of the users increase simultaneously. This tends to impact the scheduling algorithms and affects their performance badly. As it can be seen from figure 11, the QoS fairness index decreases as the number of users increases. A maximum of 500 UE was used for the simulation, and from the obtained result, the developed algorithm provides the highest results and outperforms the conventional PF algorithm, Best-CQI, and Round Robin. As at 500 users, the developed algorithm produced about 4.6% higher results than the conventional Proportional Fair algorithm. The Best CQI is the worst performer, as its performance decreased by 40.7% by the time the number of UE was 500.

A. Mobility Impact on Performance

The effects of user mobility on system performance were also considered, as it plays a vital role in UE activity. During the simulations, three levels of user speeds were considered which are: 5km/h as average human walking speed, 50km/h as maximum urban driving speed and 100km/h as highway driving speed. The mobility impact for cell edge users as described in scenario 1 was considered and the result is as shown in figure 12.

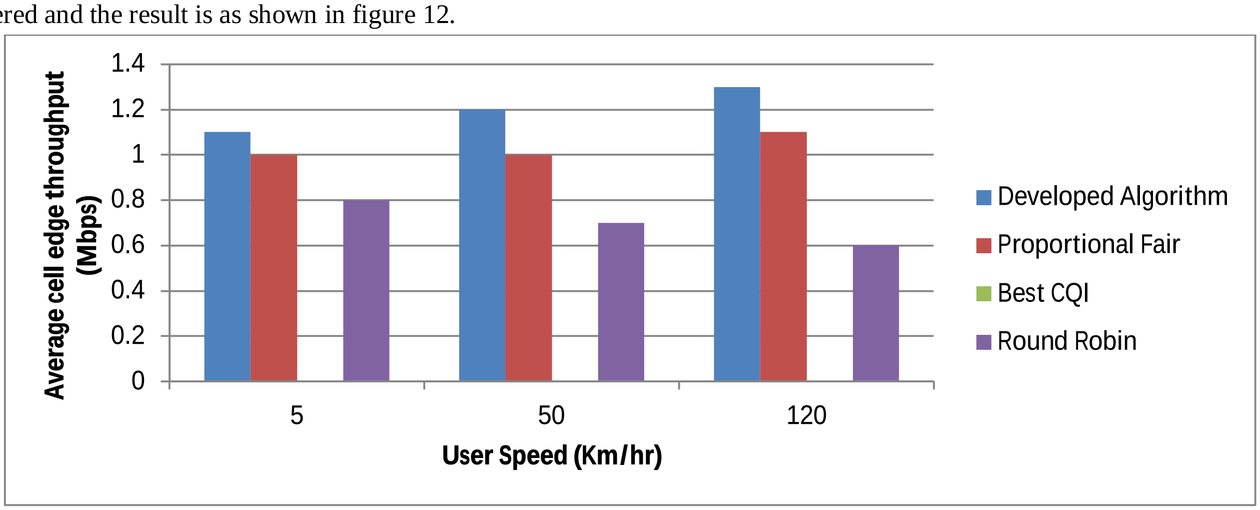

Figure 12: Average cell edge Throughput with Mobility for scenario 1

As seen from figure 12, the Best-CQI algorithm does not provide any throughput for edge users just as in the normal scenario. The developed algorithm and the conventional PF algorithm outperformed the other algorithms when edge throughput is considered. The developed algorithm provides the best results about edge throughput which is about 9.1% higher than the conventional Proportional Fair algorithm and 27.3% higher than the RR when the UE was at 5Km/hr. As the UE speed increased to 120km/hr, the developed algorithm also outperformed all the conventional PF scheduling algorithms and RR algorithm by 15.4% and 53.8% respectively.

It is also important to note that the average edge throughput supplied by each scheduler tends to increase as the speed of the users increase. This is also a natural result of mobility, because as the speed of a user increases, the harder is it to maintain good channel quality between the user and the eNodeB. This means there are going to be more users behaving as edge users as the user speed increases.

The mobility impact on the user activity described by scenario 2 was considered and the results is as shown in figure 13.

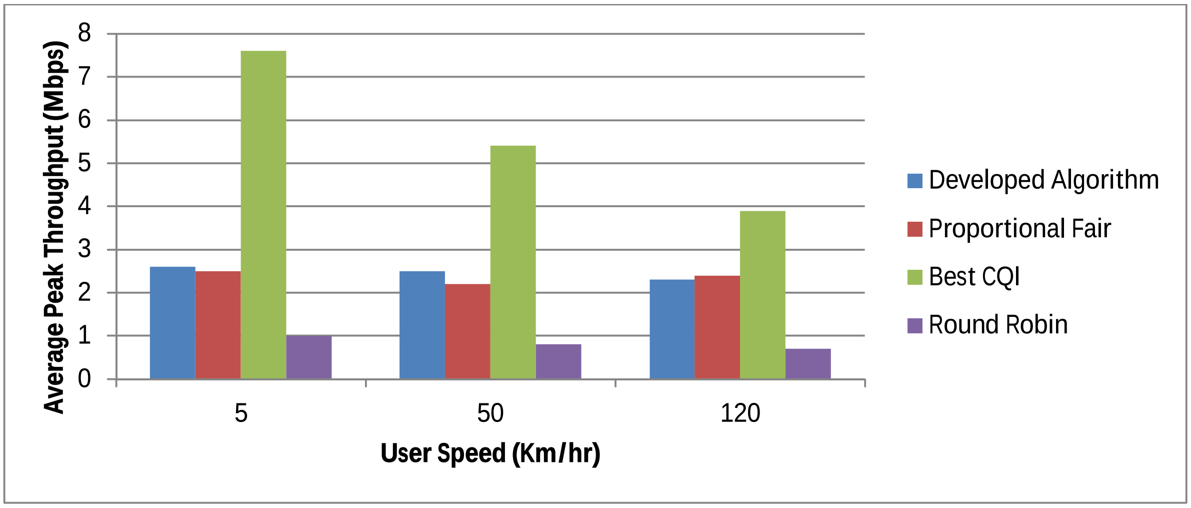

Figure 13: Average Peak Throughput with Mobility for scenario 2

It can be observed from Figure 13 that, the average peak throughput supplied by each scheduler decreases as the speed of the users increase. This is an expected result of mobility, because the more the speed of a user increases, the harder is it to maintain a good channel quality between the user and the eNB. On the other hand, it can be seen that while Best-CQI algorithm provides best peak throughput results, its performance decreases rapidly as the UE speed increases. The other algorithms including the developed algorithm were affected by the UE mobility, though they were more robust as their fluctuations were pegged at a maximum of about 8% deviation, while the Best CQI deviations got up to 28.9%.

The developed algorithm and Proportional Fair produce similar results; as at 5Km/hr, the developed algorithm was 3.8% better than the Proportional Fair, but the Proportional Fair provides 4.1% better results when the UE speed was 120Km/hr.

Average cell throughput results are another important measure to show the effects of mobility of the users on scheduling algorithms. Figure 14 depicts the average cell throughput results for the three speed levels.

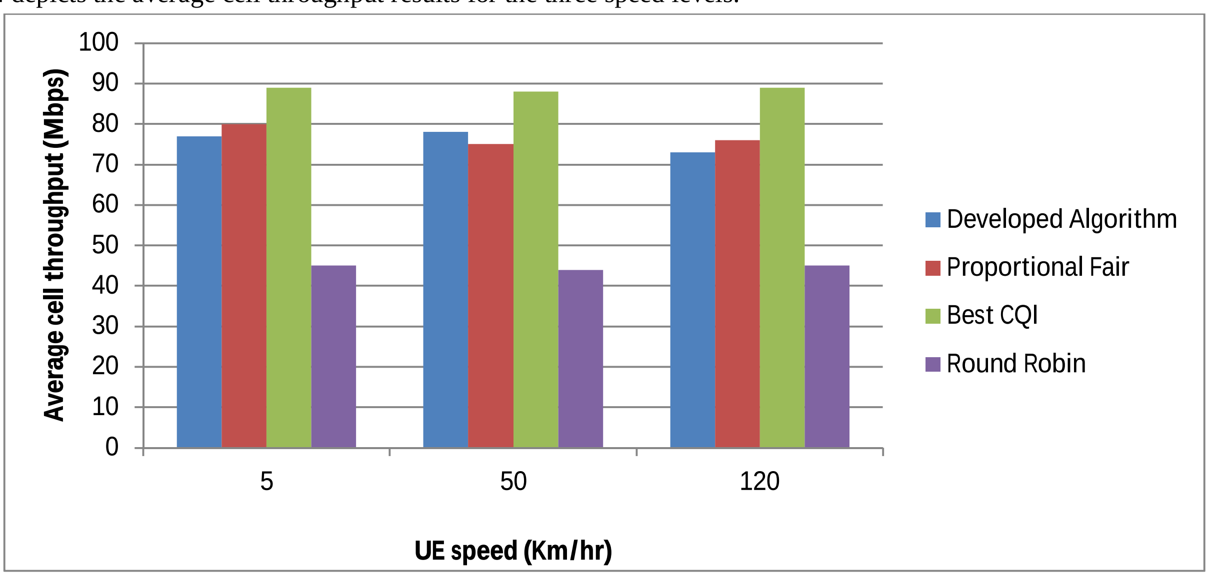

Figure 14: Average cell Throughput with Mobility for scenario 3

From figure 14, the Best-CQI algorithm provides the highest peak throughput rates across all the UE speeds. This is because the Best-CQI at all point in time always allocated resources to the users with best channel qualities only. The developed algorithm performed moderately better when compared to the Proportional Fair algorithm. At about 5Km/hr, the PF algorithm had a throughput of about 80Mbps, while the developed algorithm and RR algorithm had throughputs of 77Mbps and 45Mbps respectively. Conversely, at UE speed of 50Km/hr, the developed algorithm had about 3.8% improvement when compared to the conventional PF which was about 75Mbps.

Consideration was made of the impact of mobility on the Jain's fairness metric. This metric shows the fairness level of each of the scheduling algorithms as the UE speed increases during the simulation. The result of this performance is as shown in Figure 15.

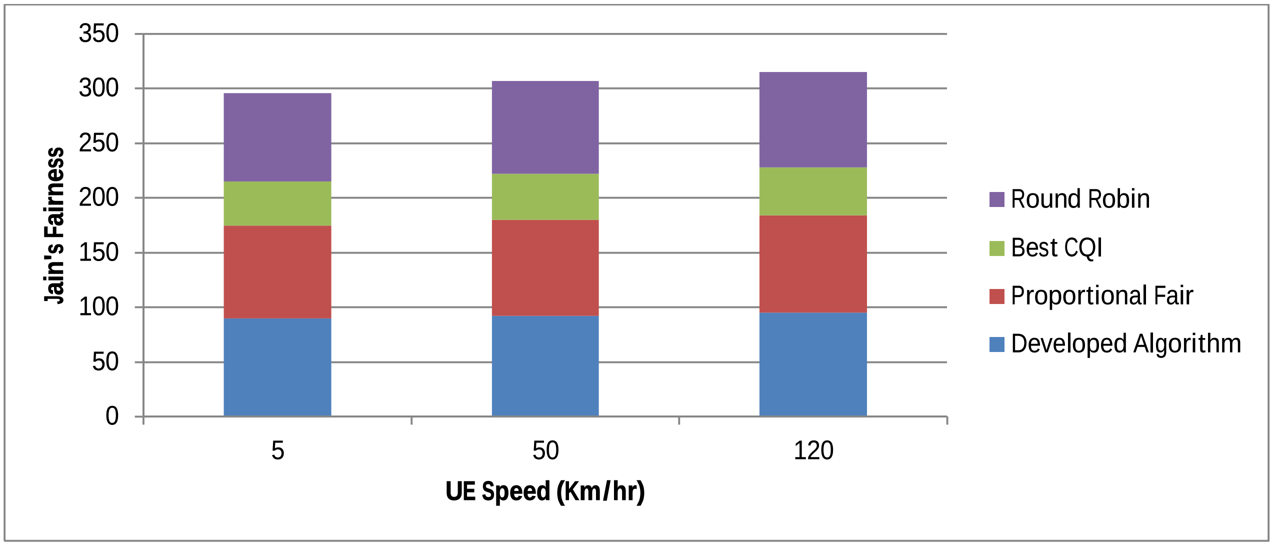

Figure 15: Jain's Fairness Index Results with Mobility

From the results in figure 15, the Jain's fairness index results showed that the Best-CQI produced the lowest fairness result, which was outperformed by all the other algorithms. Even with increasing UE speed, the developed algorithm still had a Jain's fairness level of 92 when the speed was 50Km/hr, and 95 when the speed was 120Km/hr. This goes a long way to establish and validate the improved fairness claim made by this work. The only other algorithm whose performance tried to rival this is the conventional PF algorithm. The developed algorithm outperformed the PF algorithm by 5.5%, 4.3%,and 6.3% when the UE speed was 5Km/hr, 50Km/hr and 120Km/hr respectively.

It is important to also note from figure 15 that the fairness level for all the algorithms increased with increasing UE speeds. This is because as the UE speed increases, the channel conditions became worst, thus more UE would start acting as edge users. Allocating more resources to edge users allows the fairness index to increase.

The last scenario involving the QoS metric for a dense cell was also analyzed to see the impact of mobility. The result from this scenario is as shown in figure 16.

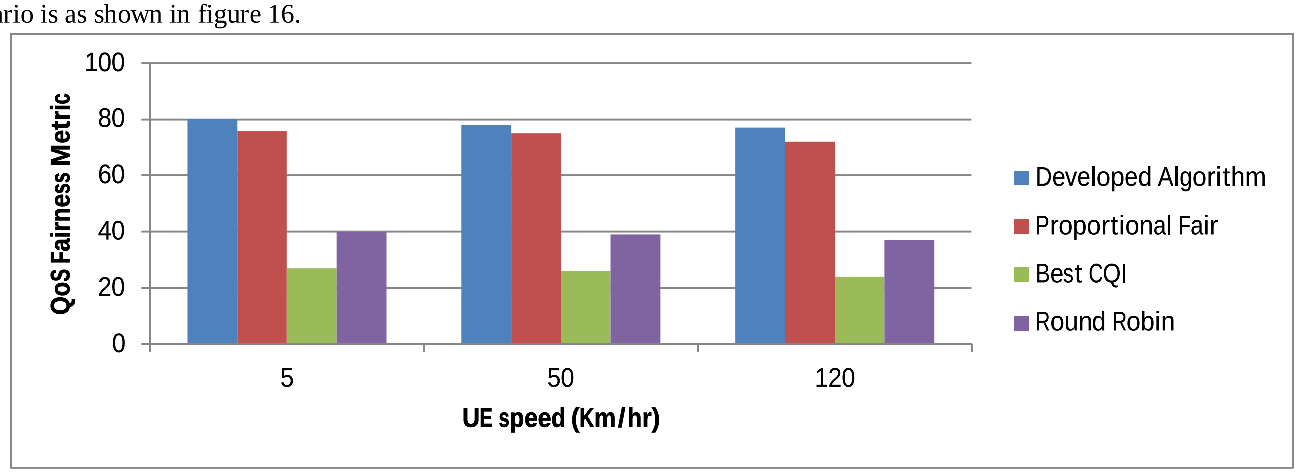

Figure 16: QoS Fairness Index Results with Mobility

The results of the QoS fairness index with mobility is as depicted in figure 16. From the results, it can be seen that the developed algorithm outperforms all the other scheduling algorithms. As the UE speed increases, the QoS fairness index decreased. As at 120Km/hr, the developed algorithm produced about 6.5% higher results than the conventional Proportional Fair algorithm, and about 51.9% higher performance than the RR algorithm. The Best CQI is the worst performer, as its performance decreased by 7.5% by the time the UE speed was 120Km/hr.

V. CONCLUSION

The ever-growing number of mobile devices sharing the limited radio resources leads to higher cost and difficulty of information acquisition and computations in the resource scheduling process. To meet the QoS requirements for LTE-A based heterogeneous networks, scheduling and resource allocation has been employed. Scheduling and resource allocation is one of the important tasks of the radio resource management layer in long-term evolution (LTE) and LTE-Advanced wireless systems. In this thesis an improved proportional fair resource allocation algorithm for downlink LTE cellular network has been developed. This algorithm was implemented in a MATLAB-based System Level simulator by Vienna University. A comparative analysis of the developed algorithm and other scheduling algorithms such as the conventional PF algorithm, Best CQI, and Round robin was carried out. The system performance was analyzed under different scenarios using different performance metrics. Simulation results showed that the developed algorithm had a better throughput performance than the Round Robin and Proportional fair scheduling. With the algorithm showing improved cell edge throughputs of about 19.2% (as at 20 users) and 9.1% higher for cell edge users without and with mobility impact respectively. While the Best CQI algorithm had higher peak throughput values, the fairness was highly compromised, with the developed algorithm outperforming it by 136.6% without the impact of mobility. Even in dense conditions, the developed system still outperformed the other algorithms with a QoS metric of 4.6% increment when compared to the conventional PF algorithm which was the closest competitor. The utilization of higher order modulation techniques like 64QAM which enhances system throughput to a greater extent is recommended for future research, so as to investigate the extent to which the developed algorithm would improve in terms of average peak throughput values.

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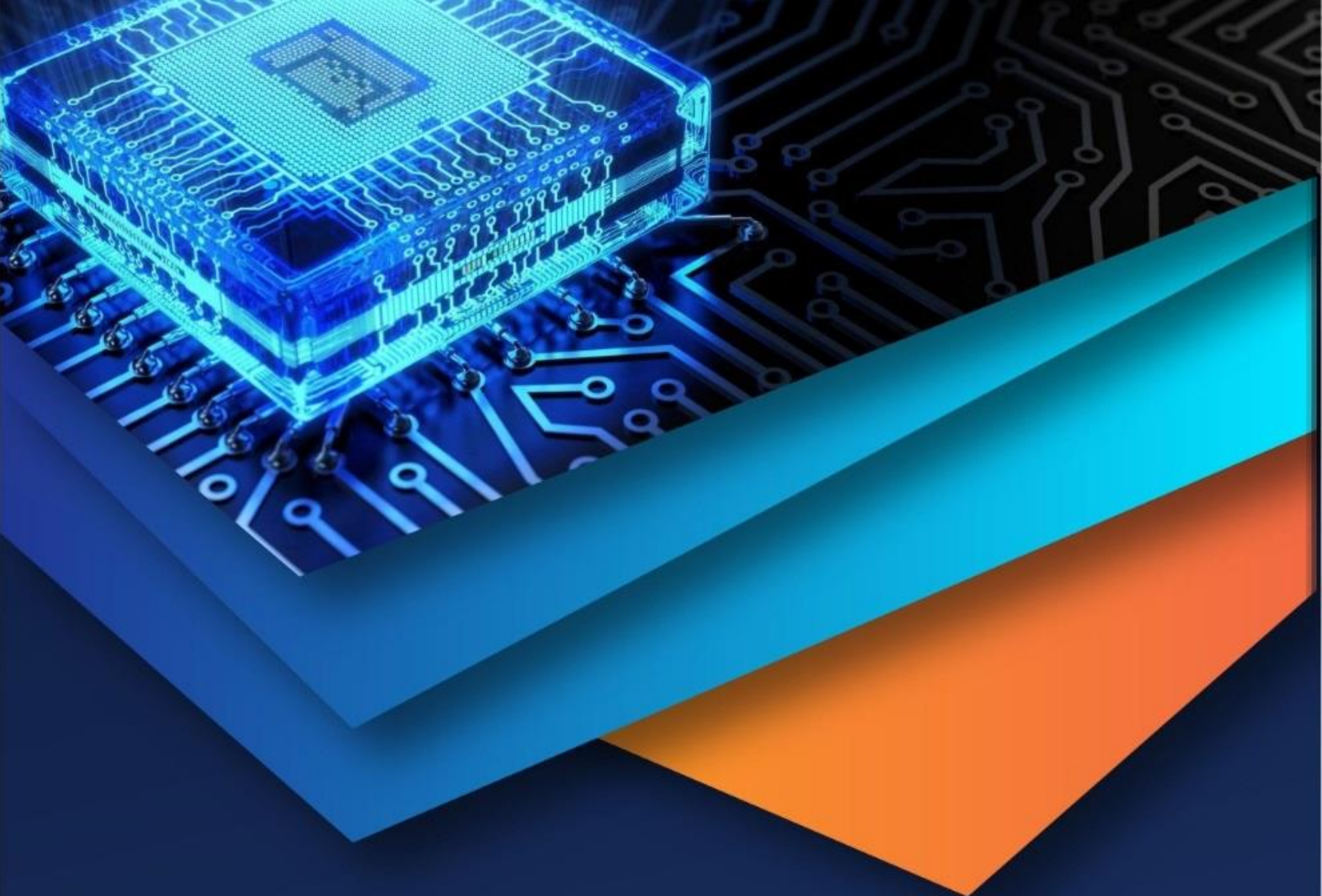

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