Improved Link Level LTE Scheduler

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***Abstract*—Long Term Evolution (LTE) packet scheduler is a key mechanism in the LTE traffic handling. It is mainly in charge of allocating physical resource blocks for the attached UEs. The main problem in LTE scheduler is to maximize the throughput while maintaining the fairness. The performance of scheduler is very critical, especially when many UEs are located at the cell edge. The new proposed scheduler can give better cell throughput performance and at the same time maintain the fairness. The findings from the performance results show an increased up to 16 percent of cell throughput compared to proportional fair (PF) scheduler. The result also shows that the fairness level is almost the same as the PF scheduler.**

Keywords—LTE; scheduling; throughput; fairness; cell edge.

I. INTRODUCTION

The current trend in mobile applications demands high data rate, which led to the development of Long Term Evolution (LTE). LTE is the latest cellular technology that provides better broadband services in terms of high capacity, lower latency and efficient radio network. In order to sustain the efficiency of the radio resources and Quality of Service (QoS) for better network performance, in regard to the heavy packet data services, packet scheduling is profound [1].

As one of the main functionalities in radio resource management, packet scheduling plays a significant role in network performance optimization [1]. Study on packet scheduling has been tremendously in favor as it is the key mechanism in LTE traffic handling. A packet scheduling is designed to assign every User Equipment (UE) a portion of bandwidth [1]. In LTE system, the channel bandwidth is divided into a number of Resource Blocks (RBs), where each RB consists of 12 subcarriers [1, 8] and 7 OFDM symbols for normal Cyclic Prefix (CP).The RB is the elementary unit used for the data transmission [1, 8, 10-12]. Table I shows a relationship between the channel bandwidth and the number of resource blocks (RBs) [8].

TABLE I. NUMBER OF RBS PER CHANNEL BANDWIDTH

Channel Bandwidth (MHz)	*Number of Resource Block (RBs)*
1.4	6
3	15
5	25
10	50
15	75
20	100

Scheduling is a process of assigning RBs to the respective UEs fairly with some degree of performance guaranty [1]. The main purpose of scheduling is to improve performance of user application, such as file transfer and interactive video streaming [9]. There are many literatures on scheduling algorithms. Some of the most popular and well known scheduling algorithms are Round Robin (RR), Best CQI (BCQI) and Proportional Fair (PF). The performance evaluation of the LTE Packet Scheduling was measured based on the throughput and the fairness of the system [1,2].

The RR scheduler provides resources with equal opportunity to the users without deliberating the channel condition [1-3]. In this way; the UEs are scheduled only based on the available RBs without considering the Channel Quality Index (CQI) [1-3]. Therefore, the RR scheduler assured fairness for all users. On top of it, the RR scheduler is easy to implement. However, it degrades the system throughput performance which contradicts the main purpose of high system performance of LTE [1-6].

In contrast, the BCQI scheduler allocates RBs to the UE with the best channel condition [1-3]. The UEs which appear at the cell centre region are usually the best channel condition while those at the cell edges (far from the eNodeB) most of the time experiencing bad channel condition [4]. In LTE system, channel condition associated with each UE is represented by 16-level CQI value, where CQI value 0 denotes really bad channel condition, which deprives data transmission. On the other hand, CQI value of 15 represents very good channel condition, where the maximum throughput is achieved [1, 2]. In order to get the RBs allocation, each UE measures its Signal-to-Noise-and-Interference Ratio (SINR), which then converted to the corresponding CQI. Higher SINR means UEs appear near to the cell centre whereas lower SINR means UEs are at the cell edges. This CQI is later sent to the eNodeB [1] and become input the packet scheduler. Based on the received CQI, the UE with the best CQI value associated with an RB will be selected and assigned with that particular RB [1-3, 5]. Thus, this scheduling algorithm is very efficient and optimizes the system overall throughput [3, 4]. However, BCQI scheduler compromises the fairness, especially towards UEs at the cell edge, which are located far from the eNodeB [4-5, 13].

Alternatively, the PF scheduler tries to maintain the fairness while at the same time achieve the most out of the total throughput [2, 13-14]. PF scheduler ensures that every UE will be assigned RBs, and none are starving [1]. This scheduling method assigns RBs to the UE with the highest priority [1]. Highest priority means the best relative channel quality in

978-1-4673-7218-3/15/$31.00 ©2015 IEEE ICICS 2015

terms of CQI, and the level of fairness preferred [1].The eNodeB compares the CQI from different UEs and chooses a UE with the highest CQI. Then, it is cyclically scheduled for the other UEs. In this way, the PF scheduler provides a good balance between the throughput and the fairness [1, 2, 5]. However, a study showed that the PF scheduler had issued with improper incorporation of delay constraints, although it could balance the fairness and Quality of Service (QoS) [7].

Fig. 1 shows the division of a particular cell area. The Cell Edge refers to a region at the boundary of the cell, where UEs in this region are assumed to have relatively high path loss. The scheduler performance is vital, especially when many UEs located within this region. The Cell Mid refers to the region in between of the Cell Edge and Cell Centre. The Cell Centre is a region that is nearest to the eNodeB, where UEs in this region experience relatively low path loss, and can possibly have the best throughput performance.

In this paper, a new scheduling algorithm, which can improve the cell performance especially when many UEs are located at the Cell Edge, is presented. The proposed new scheduling algorithm will balance between throughput and fairness. This is vital in order to gain a better system performance. The performance is analyzed and compared with the RR, BCQI and PF scheduling algorithms, where the performance is evaluated by the aid of MATLAB simulations.

The rest of the paper is organized as follows: In Section II, the simulation architecture model is discussed focusing on the link level architecture. Then the proposed scheduler model and performance analysis are outlined in detail in Section III. Section IV is devoted to the simulation results for the throughput and fairness, and finally, section V will provide a brief conclusion from the findings.

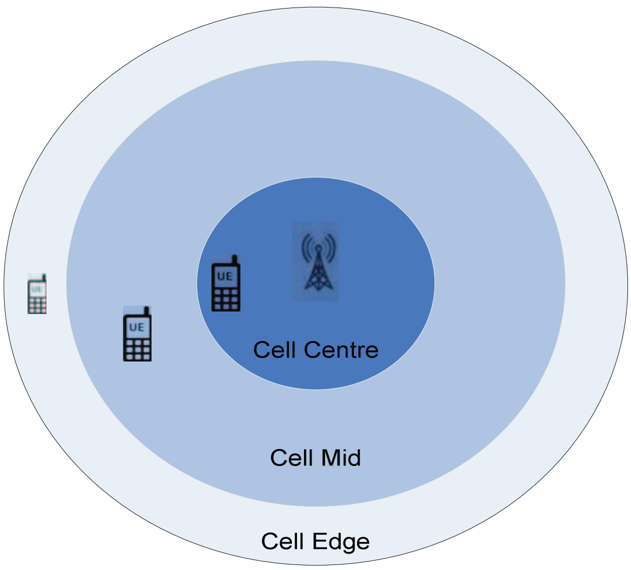

Figure 1. Cell classification

II. SIMULATION ARCHITECTURE MODEL

In order to evaluate the performance in the communication system, it is important to have a channel simulation, where the performance can be improved or optimized by changing the system parameters. In order to make the simulator useful, it is necessary to make the channel simulation realistic, having the ability to evaluate various methods and steps on how to implement the best approach for each method [15, 16]. For LTE, the simulation has to take into account all the phenomena introduced by the wireless communication.

There are several commercial and free LTE simulators exist to model wireless network system [15]. The Vienna LTE simulator, which is developed by Vienna University of Technology [15, 16] was used throughout our simulation work. The computation and simulation of this simulator are based on MATLAB known as LTE link level simulator and LTE system level simulator.

Performance evaluation for the scheduling scheme is performed using the LTE Downlink link level simulator. It consists of a transmitter (eNodeB), N receiver (UEs) and a channel model. In order to perform scheduling, the UEs will give feedback to the eNodeB by generating CQI. The CQI is used for choosing the appropriate Modulation and Coding Scheme (MCS) with modulation type ranging between QPSK, 16 or 64-QAM modulations.

Fig. 2 shows the simulator structure for the downlink LTE link level simulator. The main matlab file that links the LTE_Tx.m, LTE_Rx.m and LTE_feedback.m files is calledLTE_sim_main.m.

Table II shows simulation parameters used in the LTE link level simulator. The bandwidth is set to 10 MHz with 10 UEs on a single antenna configuration.

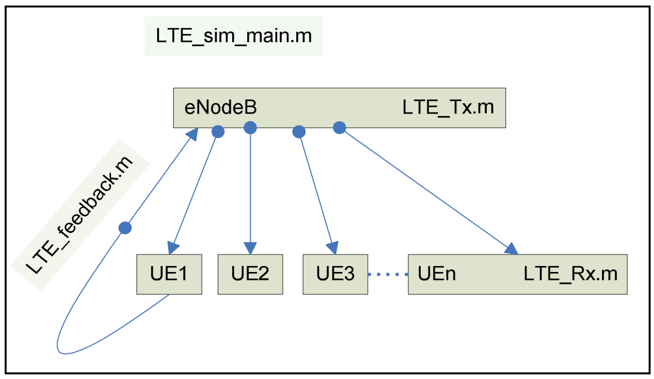

Figure 2. Structure of Downlink LTE Link Level Simulator.

TABLE II. SIMULATION PARAMETERS

Parameters	***Values***
System Bandwidth, MHz	10
Number of RBs per slot	50
Number of Subframe	100

Parameters	*Values*
Number of UEs	10
Number of eNodeB	1
Channel Model	PedB
Antenna Configuration	SISO

III. Proposed Scheduler Model

A. LTE Scheduler

A model on new scheduler (NS) was developed to test the performance of the system in low SNR environment. In this proposed model, the scheduler will schedule the UEs according its CQI value.

Fig. 3 explains the flowchart of the new scheduling algorithm. Initially, the CQI values are compared for each UEs. Next, the CQIs are sorted in descending order from the largest to the smallest value. Subsequently, the CQI have been set to Group (GCQI) valued from 0 to 3 based upon the modulation order: group 1 for QPSK (CQI = 1 to 6), group 2 for 16-QAM (CQI = 7 to 9) and finally group 3 for 64-QAM (CQI = 10 to 15). Moreover, no RB will be allocated to out of range scenario where CQI is equal to zero and will be categorized as group 0. In order to assign RBs to available UEs, the number of RB per UE per unit group, RB_UE_G is calculated based on the (1).

$$\mathrm{RB\_UE\_G} = \frac{\mathrm{nRB}}{\sum_{k=1}^{\mathrm{nUE}} \mathrm{GCQI}(k)} \tag{1}$$

where nRB is total number of RBs per subframes, nUE is the total number of UEs available and GCQI={0,1,2,3} is the group where the CQI belongs to.

Next, RB_UE_G is rounded to the lower integer value and then multiplied with each GCQI as shown in (2).

$$\mathrm{RB\_GCQI}(k) = \mathrm{RB\_UE\_G} \times \mathrm{GCQI}(k) \tag{2}$$

Therefore the RBs are distributed for each available UE based on the RB_GCQI (k) for k = 1: nUE. If the summation of RB_GCQI (k) is less than total number of RBs per subframes, then it will continue to distribute the RBs to available UEs cyclically until there is no more RBs available.

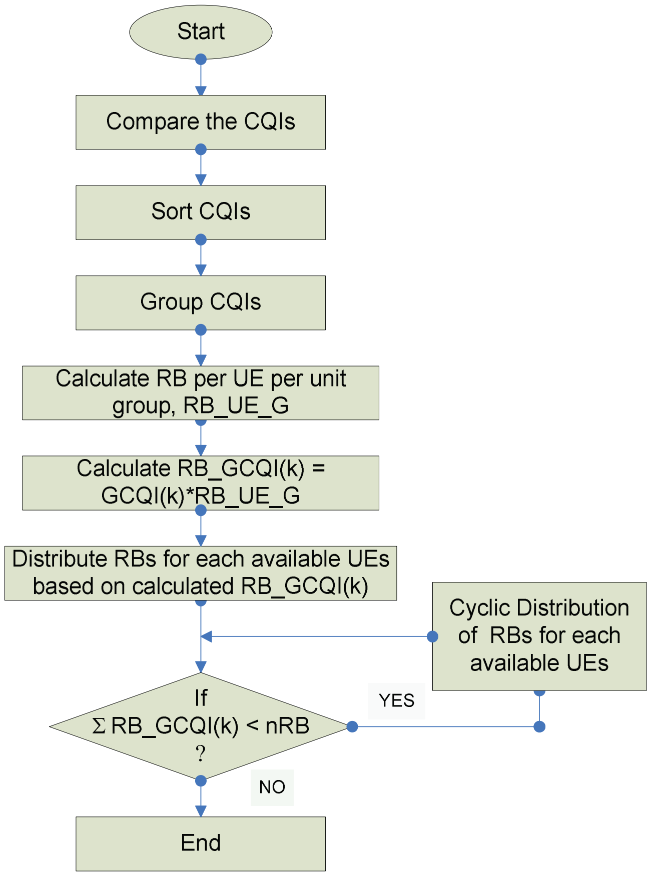

Figure 3. Flowchart of new scheduling algorithm.

B. Performance Measures

The performance evaluation of the simulation is based on two main parameters; throughput and fairness [1-4]. Throughput is the total number of bits, B successfully transmitted from UE to eNodeB over the total simulation time, tsim as shown in Equation (3). The more number of bits transmitted denotes a better throughput in the system.

$$\mathrm{Throughput} = \frac{B}{t_{sim}} \tag{3}$$

Fairness is a measurement of the equal distribution of the system resources among the UEs. The measurement of the fairness is taken as follows:

$$f(R_1, R_2, \ldots, R_K) = \frac{\left[\sum_{k=1}^{K} R_k\right]^2}{K\sum_{k=1}^{K} (R_k)^2} \tag{4}$$

Where K is the total number of users, and Rk is the time average throughput of user k [1]. Fairness of 1 denotes the highest fairness when all users have the same throughput [1].

IV. Simulation Results

The simulation setup for this simulation is based on the CQI versus SNR graph which shows in Fig. 4. From the graph, the range of SNR can be determined by the values of CQIs. It can be observed that the Cell Edge lies in between SNR -5 to 5 dB and the Cell Mid lies in between SNR 6 to 15 dB. Whilst, the Cell Centre scenario is located at SNR above 15dB.

The simulation of the scheduler performance is done under different SNR condition for different UE. Table III shows the group of location UEs in the cell. This setting are used to generate the SNR value for each UEs in the cell. The **n** represent the number of experimental conditions.

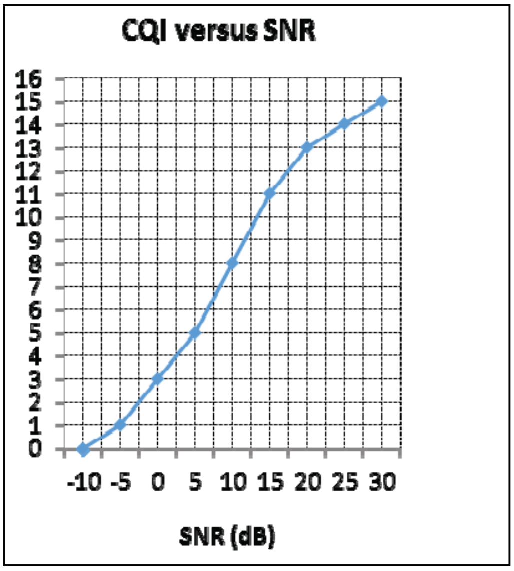

Figure 4. CQI versus SNR

TABLE III. UEs Location In the Cell

n	Location (%)		
	edge	*mid*	*centre*
1	100	0	0
2	80	10	10
3	60	30	10
4	40	20	40
5	20	30	50
6	0	60	40

TABLE IV. SNR values set for each UE

UEs	n					
	1	*2*	*3*	*4*	*5*	*6*
1	5	21	12	25	29	29
2	3	12	27	20	21	13
3	2	0	2	26	18	20
4	0	-5	15	13	10	10
5	-5	-10	5	18	17	11
6	1	-10	0	15	11	25
7	-1	0	12	4	14	15
8	-2	-5	5	2	22	8
9	0	3	4	5	5	13
10	-5	0	3	5	1	30

Table IV shows the SNR setting for each UE. These SNR values are set based on the location of the UE in the cell.

The scenario of the LTE scheduler simulation were designed to observe the performance of the system in terms of total throughput and fairness achieved at different SNRs for four schedulers. Fig. 5 shows the graph of cell throughput for different types of scheduler. Whilst, the results of fairness of the schedulers are as in Table V below;

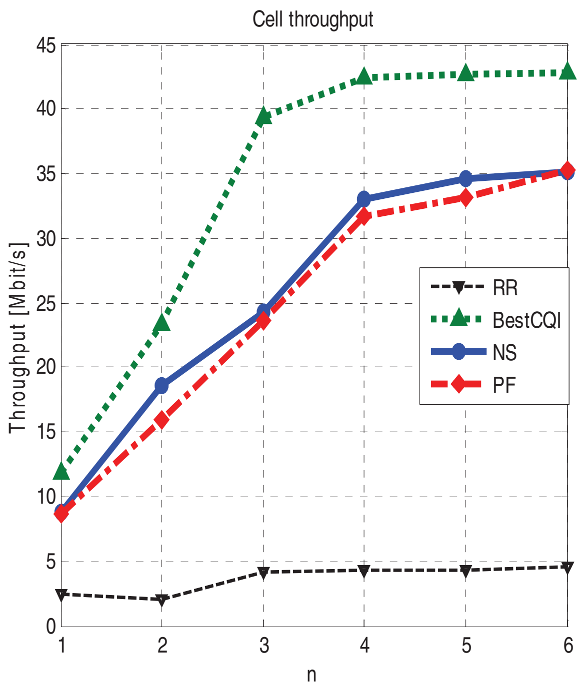

Figure 5. Cell throughput for different types of scheduler.

TABLE V. FAIRNESS FOR EACH OF THE SCHEDULER

Schedulers	n					
	1	*2*	*3*	*4*	*5*	*6*
Round Robin, RR	0.7	0.6	1.0	1.0	1.0	1.0
Best CQI, BestCQI	0.4	0.1	0.1	0.3	0.3	0.4
Proportional Fair, PF	0.8	0.3	0.6	0.7	0.8	0.8
Proposed new Scheduler, NS	0.7	0.3	0.6	0.7	0.8	0.9

Based on the presented graph and table, it shows that Best CQI has the best throughput but with lowest fairness. In contrast, RR scheduler's throughput does not improve much but it has the best fairness. This explains the fact that RR aims at maximizing fairness without guaranteed equal resource allocation to the UEs. PF is an optimum scheduler with a good tradeoff between throughput and fairness. Therefore a new proposed New Scheduler, NS is designed to improve the performance of the cell throughput. From the graph, it can be observed that the throughput performance of the NS always better than that of the PF scheduler, where the performance improvement compared to the PF scheduler is up to 16 %.

V. CONCLUSION

The purpose of this paper is to propose a new scheduling algorithm that can improve the cell performance. Three schedulers, RR, BCQI and PF were selected and examined in the studies to design a new scheduler. MATLAB simulation has been used as an option to evaluate the performance and compared in terms of cell throughput and fairness. A scenario with varying the SNR value was implemented to observe the performance. The result shows that the new proposed scheduler, NS increased the performance of the cell throughput while maintaining the fairness compared to the PF. The maximum of throughput performance was increased up to 16 percent compared to PF when there are many UEs located at the cell edge. This scheduler improved the throughput by grouping the CQI level in order to distribute the RBs to respective UEs efficiently.

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