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# Dynamic Switching of Scheduling Algorithm for Uplink LTE System

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**Abstract:** Packet Scheduling (PS) is essential in Long Term Evolution (LTE) cellular system to handle huge traffic via allocating common resources among users. The main target of PS, in LTE systems, is the Radio Resource Management (RRM) by including strategies, algorithms, and schemes to control important parameters and factors such as transmit power, data rates, modulation scheme, and error coding scheme. The paper presents a performance comparison of two scheduling schemes for LTE uplink, Best Channel Quality Indicator BCQI, and Round Robin RR schedulers. Next, a new packet scheduler for uplink LTE networks, that adapts dynamically between the two mentioned packet scheduling algorithms is proposed, evaluated and compared with the performance of the two schedulers, BCQ and RR. The results of the performance, throughput, and fairness indicate that the proposed scheme gives compromise fairness between BCQI and RR in resource distributions in the LTE and maintains the system's capacity as high as possible. The same improvement has also been observed with delay-sensitive services traffic.

**Keywords:** Best CQI, Delay-CDF, Fairness, LTE, Resource Allocation, Round Robin, Packet Scheduling, Throughput.

## 1. Introduction

Vast demands on radio resources encourage researchers and network operators to compete towards higher system throughput, capacity, performance and efficient fairness networks. With the LTE systems, good performance and best throughput can be achieved by Packet Scheduling (PS) [1]. It is regarded as a Medium Access Control (MAC) layer scheme, which controls the distribution of the common resources among Users Equipment (UEs) at each Transmission Time Interval (TTI) which is equal to 1ms and involves information about the Channel Quality Indicator (CQI) to exploit frequency, time and space [1]. LTE systems utilize technologies which grant a very interesting multiuser motivation, several UEs distributed in the same geographic area, having different Signal to Noise Ratio (SNR) according to distances or multipath and require data rates in a limited available bandwidth [2]. The inspiration of scheduling the resource distribution is to improve system performance with low packet delay in order to achieve high spectral efficiency and improve the system performance, capacity, and fulfill the Quality of Service (QoS) requirements, which is one of the main objectives of the wireless network operators, and hence improves the fairness as it is taken into consideration. It is an important task to reach a method to achieve an operative trade-off between throughput and fairness. Several factors must be taken into consideration to develop an efficient scheduler to fulfill this trade-off. Those factors are packet delays, SNR, type of service, fairness and channel conditions [3].

Uplink LTE schedulers need to take into consideration as QoS, delay-CDF and objective bit error rate (BER) to improve the system's performance [4]. The LTE PS can, in general, be formulated as an optimization issue. The complexity of this problem depends on many aspects among which the useful function (accumulated throughput), the fairness requirements, and certain specific system characteristics [4].

Third Generation Partnership Project (3GPP) standard defined many scheduling algorithms and did not specify an inevitable scheduling scheme for both the downlink (DL) and the uplink (UL). Consequently, a number of scheduling proposals were used based on several tasks.

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For these targets, some researchers suggested scheduling algorithm to enhance system capacity, throughput, and improve the fairness [5]. In LTE systems, the LTE UL schedulers are located at the MAC layer of the eNB. The smallest resource in the LTE system is the Resource Element (RE). RE consists of one subcarrier through OFDM symbol. The REs are clustered into Resource Blocks (RB) that each RB comprises of 12 successive subcarriers in the frequency domain and one 0.5ms slot in the time domain [1].

Each 1ms TTI contains 2 slots, and each subframe is defined as 10 TTIs [1]. This puts the aim of the paper that is to evaluate and compare the Bit Error Rate (BER), throughput, fairness, and to evaluate delay-CDF of best CQI (BCQI) and Round Robin (RR) scheduling schemes and to propose an adaptive scheduling scheme in an attempt to improve the packet scheduling. The paper, also, investigates above schedulers to solve the problem of having different UEs moving with high speed and distributed in the cell with different SNR and hence to have higher throughput and better fairness within resources allocated. One major contribution of this paper is the enhancement of the LTE efficiency by increasing the throughput and improving the performance in high-speed user mobility by proposing scheduling scheme. This can be achieved through the investigation of the parameters that affect the performance of the system. The paper finds out that the main key part of LTE systems for achieving high spectral efficiency and throughput is through packet scheduling, which controls and manages the sharing of available common resources between UEs every TTI and requires information about the CQI to exploit time, space, frequency. Thus, the main trends of the paper are to investigate the above parameters that can improve the performance of the LTE systems and enhance the throughput of the channel and the user's throughput. A performances comparison of subcarrier scheduler evaluation in uplink will be done to investigate the scheduling schemes can be suggested with the real-time (RT) applications for UEs moving at high speed in terms of throughput, fairness and minimum delay.

The rest of the paper can be summarized as follows; the literature review is explained in Section II. Section III presents a brief summary of the well-known LTE schedulers together with the proposed dynamic scheduling scheme. Section IV presents the simulation environment and evaluation together with the result analysis and assessment. Finally, section V sums up the finding and the conclusions.

## 2. Related Work

Many articles investigate, propose and evaluate different scheduling schemes and algorithms with LTE systems in terms of performance metrics such as fairness, capacity, and throughput [7-11]. The authors in [3] evaluated the effect of the high mobility of UEs impact on the performance of different data rate applications and services utilizing four scheduling schemes in the UL of LTE networks. They showed that, with UE mobility speed, less than 100 km/h, both BCQI and Proportional Fair (PF) schemes gave the best performance with low delay. While in [4], the authors modeled and proposed a new scheduling scheme for LTE systems in two phases, the RR in the first phase and the BCQI in the second phase. The scheme performance has been evaluated and compared with those evaluated for the BCQI and the RR schedulers in UL direction. Although they proposed a new scheme, they set the scheme only according to the method of the scheme switched from RR to BCQI and cannot back-off to RR scheduler again. In [5], the authors presented a performance evaluation for many scheduling schemes for uplink in LTE system and offered medium of comparison in order to highlight the individual characteristics of each proposals. In [6], the authors presented a comparative performance study of the priority queuing and class-based weighted fair queuing scheduling policies applied on a double-buffered, Multistage Interconnection Network (MIN) supports a 2-class priority mechanism was presented and analyzed using simulation experiments. In [7], the authors presented a new scheduling algorithm that depended on the application's priority in the allocation of available network resources. The algorithm attempts to achieve QoS through dynamic scheduling decision based on dynamic factors to fulfill the demands of low delay and high average throughput. In [8], the problem of scheduling the tasks which have mutual sensor formulated and a scheduling method to minimize the energy consumption by reducing the sensor utilization was proposed. The proposed method encouraged the UEs to share in multiple tasks at the same time. In [9] the authors investigated power-efficient scheduling for the UL of LTE systems. They formulated the scheduling process as a dynamic programming problem. They proposed two low complexity heuristic schedulers to reduce the transmitted power. Finally, [10], the authors analyzed the impact of resource scheduling algorithms on the in the microcellular 4G environment. They added a simple modification to each scheme to evaluate the average user throughput, average cell's capacity and the QoS. The constrains and limitations of the above-related works are used only single scheduling scheme and enhanced either the fairness or the throughput or the capacity while pay low attention to the others except [4] which used two schemes in two phases, the BCQI in the first phase, then the RR in the next (second) phase, and never back-off to first phase or state.

## 3. The Proposed Scheduling Algorithm

At each TTI, multiple RBs can be allocated to UEs with different classes. The packet scheduling (PS) in the LTE networks is concerned with the distribution of available common resources in radio channel between UEs. The PS assigned resources to UEs at downlink (DL) and uplink (UL). The scheduler algorithm in all LTE systems allocates a group of RBs to UEs [1]. A scheduler is considered efficient according to a QoS, desired performance in UE's throughput (data rate), network fairness resource distribution between UEs and packet delay. Generally, the issues of scheduling schemes are to offer efficient resource sharing and better performance. The BCQI scheduler was designed to allocate RBs to the UEs with the high CQIs (high SNR and best channel conditions) [4]. To perform scheduling, UE was created CQI and was fed it back to the eNB every TTI in a quantized method. Then, in the DL, the eNB sent the reference signal (RS) to the UEs to be utilized for CQI measurement.

The CQI bits contained the value of the SNR measured by the UE. LTE CQI includes Channel Quality Information CQI, Pre-coding Matrix Indicator (PMI), and Rank Indicator (RI) components. The requirement for each of these components depends on the transmission mode. The LTE UE use PMI information to signal preferred set of weights to be applied during the precoding process.

The eNB receives the CQI feedback that is in consistent calculated by the mapping method with the measured SNR as shown in Figure 1. This figure shows the measured SNR and the consistent CQI value at the DL for frequency selective channels modeled by ITU for Pedestrian- B (Ped-B) channels.

UE does this in order to maximize the downlink SNR. BCQI scheduling algorithm would increase the overall system throughput at the sacrificing the fairness. In BCQI scheme, UEs moving far from the eNB are probably having a lower probability to grant resources [4]. It is well known that the BCQI and RR cannot achieve high throughput and high fairness at the same time. Thus, the proposed UL LTE scheme tries to find a way through which the system can provide as high as possible throughput and a high fairness at the same time. This proposed system can be switched between BCQI and RR schedulers since it combines features of both schedulers in a dynamic way depending on the operating SNR. The proposed dynamic RR- BCQI scheduler scheme can be explained as follow: Having started the TTI cycle, the measured or received SNRs of all accessed UEs will be checked. If the SNRs are equal or more than a specific value, the algorithm picks the BCQI for high SNR and schedules the RBs with good throughput. However, if the SNRs received are less than the threshold, the system selects the RR with high fairness.

LTE, UEs have diverse applications, services, and facilities with QoS requirements and it is challenging to permit each UE to adapt the similar RBs for the equal probability. This challenge will drop the resource sharing effectiveness. For this reason, a block is added to assign user's service, whether the traffic is VoIP or game or video as indicated in Figure 2. A dynamic process is inserted to balance the main parameters, throughput, and fairness, by sensing the SNR, to switch between the two schemes and get the best assignment of RBs in the scheduling system. This can be better illustrated with the aid of the flowchart shown in (figure 2) and via the following steps;

Step 1: Insert UEs/packets into their queues.

Step 2: Find out for each UE CQI, PMI and RI.

Step 3: The scheduling starts at each TTI.

Step 4: Assign UE application (either VoIP, game or video).

Step 5: Measure the received SNR of each UE and compare it with a threshold of -10dB to achieve QoS requirements.

Step 6: If the SNR value is less than -10dB, the eNB schedules all UEs using the RR algorithm by the dynamic process, otherwise, the system scheduler switches to BCQI scheduler. In our proposed scheme, we choose the threshold level at -10 dB as the BCQI scheduler achieve accepted throughput at high SNR. For this reason, the scheme switches to RR when the SNR is lower than the threshold to achieve higher throughput.

Step 7: Determine the number of RBs to the number of UEs. If the result is an integer, then each UE will be assigned an equal number of RBs, otherwise, they will be assigned a minimum number of RBs to each UE. This decision function can be accomplished by the following relation;

$$(N\_RBr) \,/\, (N\_RBn) \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where N_RBr represents the number of remained RB, while N_RBn indicates the number of RB.

Step 8: Measure the occupancy of the RBs. If the occupancy is high, determine the $(N\_RBr)\,/\,(N\_RBn)$, otherwise check the remained RBs.

The proposed scheduling scheme checks the occupancy of the RB by the eNB in terms of the remaining RBs, as a matrix with the dimension of the numbers RBr x RBn $(N\_RBr)\,/\,(N\_RBn)$. This matrix corresponds to the comparison of the available RBs every TTI in terms of the remaining RBs. If the requested data rate for each UE is the same, the amount of the remaining RBs is high. The remained RBs are determined by utilizing the measured SNR from the detected signal using;

$$RN, R(t) = B/N \;\; Log \log_2(1 + SNR) \ldots\ldots (2)$$

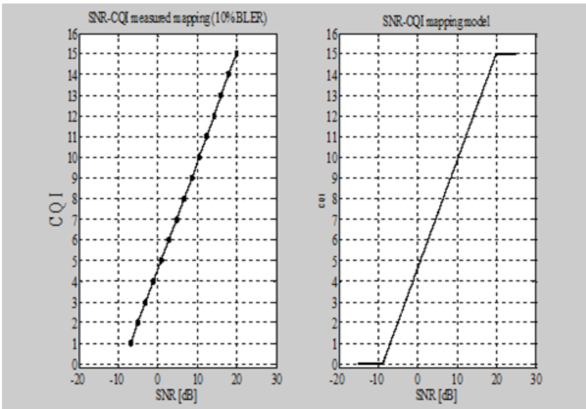


Figure1. The SNR-CQI Mapping

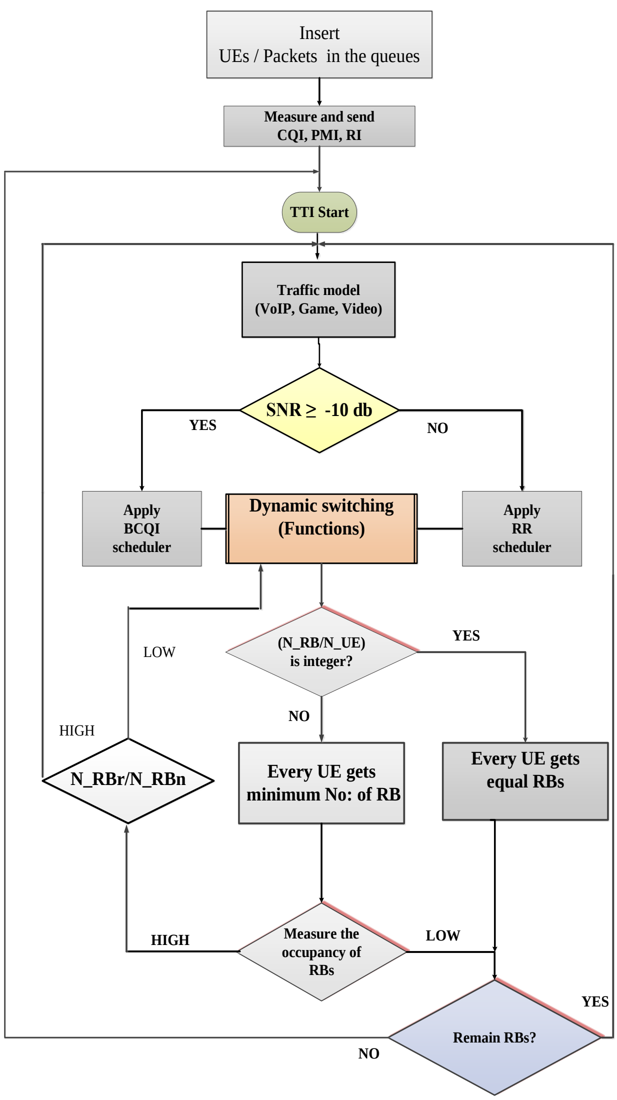


Figure 2. The proposed scheme Flowchart

## 4. System Modeling, Configuration and Simulation

In this proposed scheme, a rural environment of both pedestrian and Vehicular-A channel models is considered since both accounts of scenarios involve UEs with a wide range of mobility that started at a low velocity up to the vehicular movement at speeds 100km/h [1]. A network comprises an eNB that covers 3-sectors at which many UEs are located or moving around. To show the advantage of the proposed scheme, we evaluated the performance of the two scheduling algorithms mentioned earlier and evaluated the performance of the proposed scheme to examine the performances of the high UEs mobility using the UL that used Vienna link level UL-simulator [11]. The simulation setup is shown in Table I, assumes that for LTE system having a single cell with 25 users has a range of SNRs extending from -15 to 45 dB moving in the cell at a speed either 5 or 100 km/h in random directions as recommended for the QoS achievement. An inter-site range of 500 m is chosen in a rural environment with simulation parameters set up as shown in Table I.

The scheduler type and the speed of UEs are the main parameters used to evaluate the impact of the mobility on the performance, throughput, delay, and fairness at each run. The cell performances (BER versus SNR) for 25 UEs moving at 5 and 100 km/h are shown in Figures 3 and 4, respectively. For clarity, the results are presented only for the interesting region of SNR between 25-40 dB. From Figure 3, at 0.001 BER, the proposed scheme gains 0.68 dB over BCQI scheme and 1.0 dB over RR. While from Figure 4, at 0.001 BER, the proposed scheme gains 0.12 dB over BCQI scheme and 0.62 dB over RR. Those gains enhance the QoS requirement for guaranteed bit rate (GBR), used for real-time (RT) services, such as conversational voice and video. The system throughputs for 25 UEs moving at 5 km/h are depicted in Figure 5 for the RR, BCQI and the proposed scheduling algorithm whereas Figure 6 shows the system throughputs for the UEs moving at 100 km/h in the cell. The evaluation shows (figures 5 and 6) that the throughput decreases as the user velocity increase. This is due to the degradation in the channel severity at high mobility [2]. The results presented in Figures 5 and 6 show the consistency in systems performance for both speeds and the proposed system is improving at SNR above 31dB.

To achieve a precise assessment of the results, the scale of SNR was presented in the range above 30 dB, since that range is required in most applications and quality. In the evaluation assessment, the results from Figures 3 and 4 and Figures 5 and 6 gives an indication that the proposed scheme is better in system throughput than both BCQI and RR schemes.

TABLE I. PARAMETERS USED IN THE SIMULATIONS

| ***Parameters*** | ***Settings*** |
|---|---|
| Carrier frequency | 2GHz |
| System BW. | 1.4 MHz |
| No; of subcarriers | 72 |
| Available RBs/ subcarrier | 6 |
| Tx and Rx mode | SISO |
| Inter site distance to eNB | 500 m |
| No; UEs/cell sector | (25) UEs |
| User speed | (5 or 100) km/h |
| Channel model types | PedB, Veh-A |
| Schedulers type | BCQI, RR |
| Traffic model | VoIP, Game, and Video |
| Uplink feedback delay | 3 TTI |
| Simulation time | 5000 TTI |

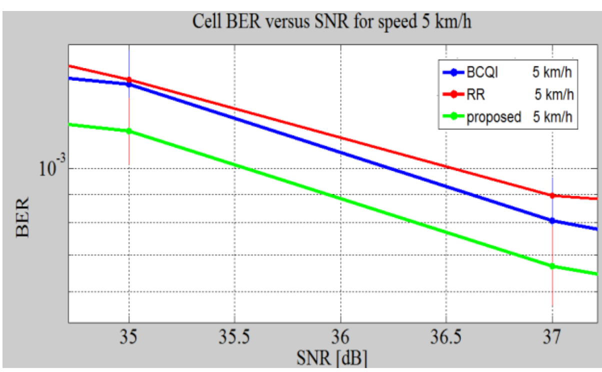


Figure 3. The BER versus SNR, at speed 5 km/h

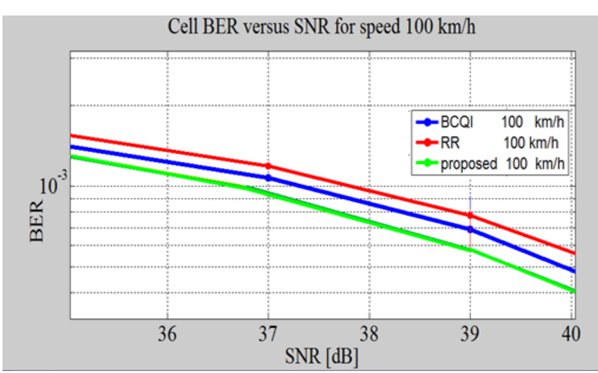


Figure 4. The BER versus SNR, at speed 100 km/h

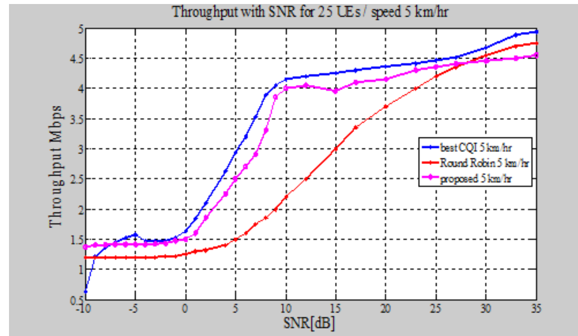


Figure 5. System throughput versus SNR, at speed 5 km/h

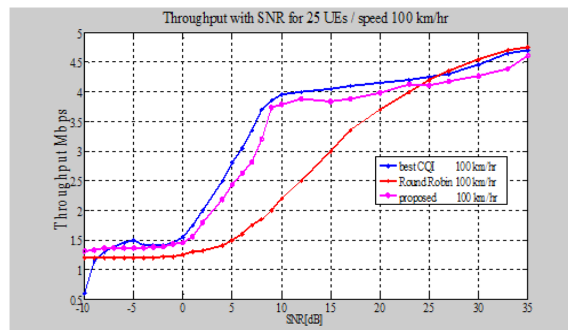


Figure 6. System throughput versus SNR, at speed 100 km/h

An extra assessment was achieved with the average throughput computation for eNB sector are shown in Figures 7 and 8 for the BCQI, RR and the proposed scheme with speed 5 and 100 km/h, respectively. It is clear that the proposed scheme achieves higher average throughput than BCQI and the RR for both speeds. Also, the average throughputs achieved for eNB sectors for a user moving in the cell at low speed higher than that achieved for the throughput sectors having users moving at high speed. This is due to channel condition degradation caused by high speed.

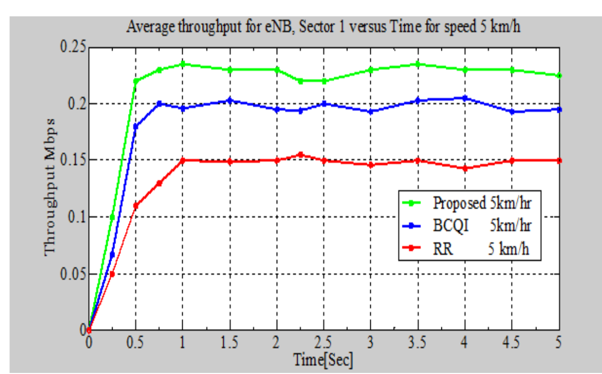


Figure 7. Average throughputs at speed 5 km/h

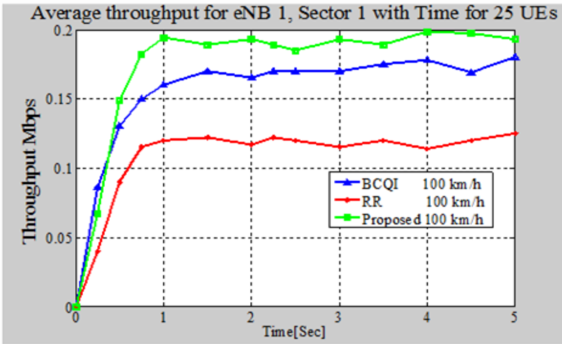


Figure 8. Average throughputs at speed 100 km/h

Next assessment shows system Fairness for 25 UEs moving at 5 km/h and 100 km/h. The results of such assessment are depicted in Figure 9 for the RR, BCQI and proposed scheduling algorithms. From the fairness statistics, it is obvious that the proposed scheme achieves good fairness than BCQI but worse than that of RR scheduler. Therefore, a compromise needs to be used in choice and compare between the schemes to balance between the throughput and the Fairness.

Finally, the delay-CDF of the packets are evaluated for the three types of delay-sensitive services, namely VoIP, real-time gaming and video streaming (multimedia applications) using the BCQI, RR and the proposed schemes.

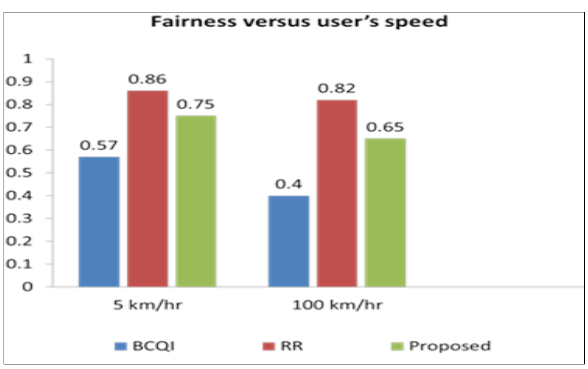


Figure 9. Average throughputs at speed 100 km/h

The delay is the time of that certain packet has already been waiting in queue to be scheduled. An example of delays-CDF evaluation is illustrated in Figure 10 for 25 UEs and VoIP case at speed of 5km/h. The CDF curve shown in Figure 10 is determined in such a manner that all the UEs with the same delay are added up i.e. 0.4 for with a delay time of 40ms. This means that 40% of the packets were successfully transmitted for a time less or equal to 40ms. It is clear from Figure. 10 that BCQI achieves the lowest delay compared to RR and the proposed schemes and the proposed scheme achieve lower delay compared to RR scheme. The computation of the fraction of transmitted packets (FTP) for each scheduler for the given case in Figure 10 is computed through the projection of the red line at the 40 TTI delay. This will give 0.86, 0.275 and 0.025 fractions of transmitted packets (FTP) for each scheduler as tabulated in the last column of Table II. In the same manner, the other cases can be computed for other speed and other forms of multimedia. The results in Table II reveals that the BCQI and the proposed schemes provide have fractional transmitted packets for 40 TTI delay than the RR scheduler. Other values for delays were computed using uplink Vienna institute LTE simulator by just selecting the traffic types with speed [11].

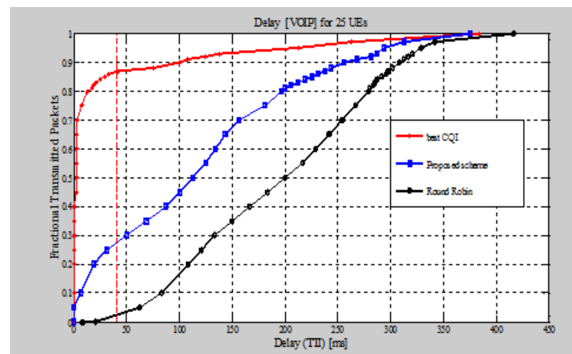


Fig. 10. VoIP Delay-CDF of the packets for BCQI, RR, and the proposed schemes.

TABLE II: THE DELAY-CDF COMPARISON RESULTS BETWEEN RR BCQ AND PROPOSED SCHEMES

| Media / Scheduler | Voice (ms) | Game (ms) | Video (ms) | Fractional transmitted packet 40 TTI |
|---|---|---|---|---|
| BCQI | 375 | 315 | 400 | 0.86 |
| RR | 497 | 500 | 482 | 0.025 |
| Proposed | 400 | 500 | 450 | 0.275 |

From table II, the results reveal that the BCQI and the proposed schemes achieved better performance than RR in terms of throughput. The tabulated results showed that the BCQI scheduler achieved the highest fractional transmitted packets for 40 TTI delay among the schedulers considered

## CONCLUSION

To conclude a scheduling scheme in the uplink of LTE systems has been proposed and evaluated under high-speed users' mobility. The proposed scheme was based on the BCQI and RR and it is dynamic in the scene that it achieves the good performance, throughput, fairness and CDF-Delay depending on the SNR. The proposed scheduler together with BCQI and RR were simulated using Vienna system level and uplink-simulators and the performances for scheduling in the

UL were evaluated and compared in terms of BER, throughput, fairness, and packet delay for UEs moving at high mobility. The simulation consequences reveal that the proposed scheme is better in fairness compared to the BCQI and better than both BCQI and Round Robin schedulers in throughput. Furthermore, the results show that there is an improvement in fairness along the SNR values. Regarding the Fairness, the proposed scheme achieves better fairness than BCQI although it is still less than the RR scheduler, but achieves better throughput when a compromise is found to magistrate between the schemes and to balance between the throughput and the Fairness. From the perspective of performance and Fairness, the proposed scheme achieves better in throughput and BER, although it is still lower fairness than RR. Finally, for the delay- CDF evaluated for VoIP, video and game traffic, the results reveal that the BCQI and the proposed schemes achieved better performance than RR in terms of throughput. The tabulated results showed that the BCQI scheduler achieved the highest fractional transmitted packets for 40 TTI delay among the schedulers considered.

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