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Comparative Analysis of Scheduling Techniques in Downlink LTE Using MATLAB-Based LTE MAC-LAB Simulator

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***Abstract*—Traffic scheduling plays an important role in LTE technology by assigning the shared resources among users in the most efficient manner. This research compares the performance of three types of scheduling algorithms namely: Round Robin, best Channel Quality Indicator (CQI) and Proportional Fair (PF) schedulers representing the extreme cases in scheduling. The scheduling algorithms performances on the downlink were measured in terms of throughput and block error rate using a MATLAB-based system level simulation.**

***Keywords*—LTE, Scheduling, Throughput, 3GPP**

I. Introduction

Mobile and Data Communications have grown exponentially in the last few years and this is evident in the variety of social networking apps available, the range of newer smartphones and the constant influx of new software and technologies into the market. The demand for data connectivity and network availability is constantly increasing and research is on going to maximize and make the most efficient use of the limited spectrum via advanced techniques such carrier aggregation, relays stations and coordinated multipoint transmission and reception. Long Term Evolution (LTE), which is termed Release 8 by the Third generation partnership project (3GPP) is the bedrock of future air-interfaces and it is expected to have up to 560 million subscribers by 2016 [10].

The 3GPP has been saddled with meeting the ever-increasing performance requirements of mobile broadband [1]. Below are some LTE requirements as dictated in the 3GPP technical report 25.913 [3]:

- Increased uplink and downlink peak data rates.
- Scalable channel Bandwidths of 1.4, 3, 5, 10, 15, and 20 MHz in both the downlink and uplink.
- Spectral efficiency improvements over Release 6 high-speed packet access (HSPA) of three to four times in the downlink and two to three times in the uplink.

A key component of the LTE system that aids optimized throughput especially in fading channels is the dynamic packet scheduler, which is located in the evolved node B (eNodeB) and carries out the scheduling of radio resources to all the user equipment (UEs) under its coverage and also adjust the transmission parameters such as the modulation and coding scheme [6].

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Scheduling is the process by which decisions regarding allocation of radio resources, both time and frequency, in a mobile communications system amongst users is made. This decision is made at every transmission time interval (TTI) of 1 ms based on the radio conditions. Each TTI comprises two time slots of 0.5 ms, corresponding to 7 OFDM symbols; 10 consecutive TTIs form an LTE frame of 10 ms. in the frequency domain the entire bandwidth is broken down into 180-kHz sub channels [5]. The smallest radio resource in LTE is called Resource Block (RB), it spans one timeslot of 0.5 ms in time domain and one sub-channel in the frequency domain [8].

TABLE I. LTE RESOURCE BLOCK RELATION TO BANDWIDTH, FFT SIZE AND SUB-CARRIERS

Bandwidth (MHz)	1.4	3	5	10	15	20
No of Resource Blocks	6	15	25	50	75	100
No of occupied subcarriers	72	180	300	600	900	1200
IFFT/FFT Size	128	256	512	1024	1536	2048
Subcarrier Spacing (kHz)	15	15	15	15	15	15

The process for selecting the Modulation and Coding Scheme (MCS) is called Link Adaptation (LA), this adjusts the data rate using the adaptive modulation and coding (AMC). LA combined with scheduling maximizes cell capacity. AMC matches the transmissions from a HARQ process to the channel conditions. Basically this means in a good channel condition, lesser redundancy and a higher modulation format is chosen enabling transmissions at a higher data rate for the given bandwidth, conversely in weak signal conditions more redundancy bits and lower modulation format are employed to increase the probability of reception thereby lowering the user transmission data rate.

TABLE II. CQI MAPPING TO MODULATION CULLED FROM [7]

CQI Index	**Modulation**	**Coding Rate**	**Efficiency [b/s/Hz]**
0	OUT OF RANGE		
1	QPSK	78/1024	0.1523
2	QPSK	120/1024	0.2344
3	QPSK	193/1024	0.3770
4	QPSK	308/1024	0.6016
5	QPSK	449/1024	0.8770
6	QPSK	602/1024	1.1758
7	16 QAM	378/1024	1.4766
8	16 QAM	490/1024	1.9141
9	16 QAM	616/1024	2.4063
10	64 QAM	466/1024	2.7305

11	64 QAM	567/1024	3.3223
12	64 QAM	666/1024	3.9023
13	64 QAM	772/1024	4.5234
14	64 QAM	873/1024	5.1152
15	64 QAM	948/1024	5.5547

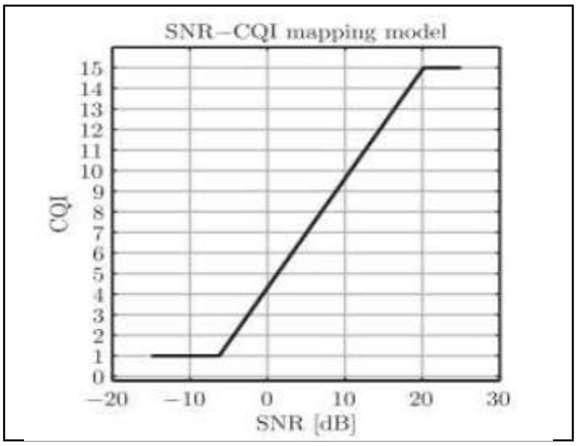


Figure 1. SNR-CQI Mapping culled from [4]

Three basic scheduling algorithms are simulated in this paper, namely:

- Round Robin
- Maximum SNIR
- Proportional Fair

A. *Round Robin*

This is the simplest scheduler in the radio resource management, which assigns resources blocks equally to all users. It does this by assigning resources to active users in turn without taking into consideration the channel conditions; it is based on the idea of fairness [11].

B. *Maximum SNIR*

This scheduling assigns radio resources to the user with the best channel quality. It is based on the channel quality indicator levels reported to the eNodeB; the user with the highest CQI is scheduled first [2]. This offers excellent cell throughput but it is not fair.

C. *Proportional Fair*

This strikes a balance between the Round Robin and Maximum SNIR scheduling, it considers both channel quality and fairness [9]. This algorithm assigns radio resources to users with best relative channel quality.

II. Design and Simulation

The simulations are based on the LTE MAC Lab, developed by IS-Wireless Poland, which is a system level simulator reflecting the behavior of a modeled radio access network. This is a tool that allows a user select and configure the LTE radio interface, choose appropriate channel and traffic models, define the network to be analyzed, choose the radio resource management functionalities and run the simulation.

TABLE III. SIMULATION PARAMETERS

Parameters	Value
Simulation time	150 TTI
Number of User Equipment	3
Bandwidth and Frequency	3 MHz and 1800 MHz
Environment Type	Urban
Number of Base Stations	1
User Equipment Speeds	Stationary, Medium & High
Multipath Model	3GPP Model
Antenna Type and UE power in dB	3 Sectors and 23 dB

Scenario with a different SNIR

The scenario uses the different SNIR for the 3-user equipment with a random directional model. UE 1 is stationary at [10, 120], UE 2 is moving at 45 km/hr. starting at [10, 11] and UE 3 is moving at 100 km/hr. starting at [240, 10]. The eNodeB is placed at [124, 124] while the cell size is [250, 250].

Figure 2. SNIR for the 3 UE

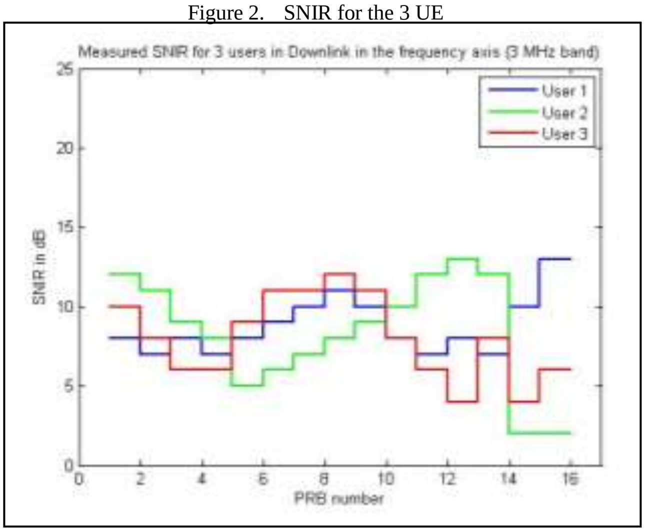
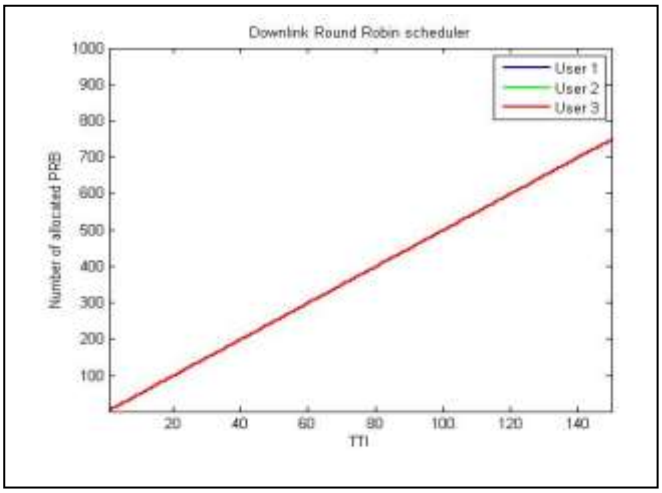


Figure 3. Resource Block Allocation using the Round Robin Scheduler



It is evident from Figure 3 that all UEs are allocated same number of resource blocks depicting the fairness of the round robin scheduler regardless of their SNIR.

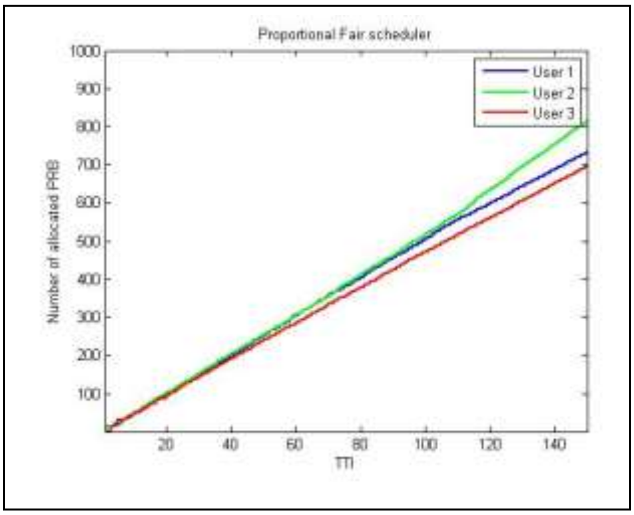


Figure 4. Allocation of Resource Blocks using Max SNIR Scheduler

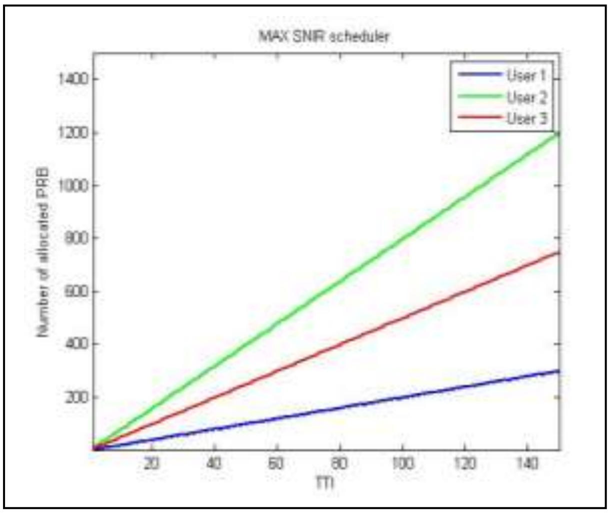


Figure 5. Allocation of Resource Blocks using Proportional Fair Scheduler

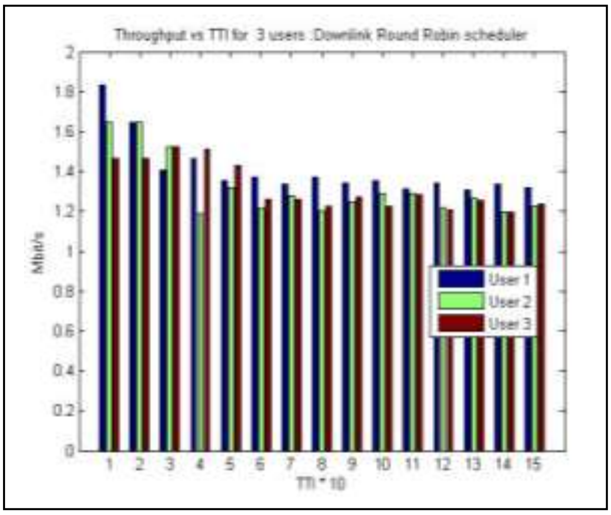


Figure 6. Round Robin Scheduler Throughput vs. TTI

In Figure 4, using the Max SNIR scheduler if it evident that User 2 is allocated more resource blocks because it has the highest average SNIR while User 1 receives the smallest number of resource blocks, despite its closeness to the eNodeB, because of its has the lowest SNIR suggesting poor channel conditions.

In Figure 5, it can be seen that the there is a go-between fairness and CQI depicted in the SNIR. UE 2 still receives slightly more resource blocks than any other UE, whilst UE 1 follows closely showing that the scheduler considers the closeness thereby scheduling UE slightly more than UE 3, which is farthest from the eNodeB.

It is evident from Figure 6 that all UEs are allocated same number of resource blocks depicting the fairness of the round robin scheduler regardless of their SNIR, it is evident that throughput fluctuates even in the UE 2 which has the highest SNIR, while UE 1 has the highest throughput since it is stationary and closest to the eNodeB.

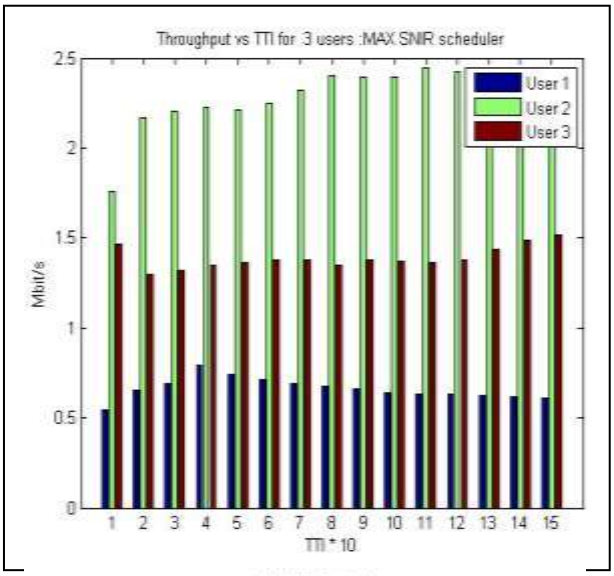


Figure 7. MAX SNIR Scheduler Throughput vs TTI

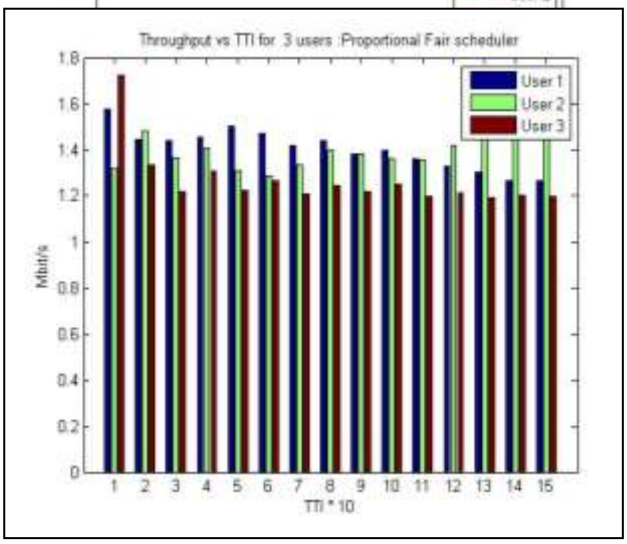


Figure 8. Proportional Fair Scheduler Throughput vs TTI

In figure 7, using the Max SNIR scheduler it is evident that User 2 is allocated more resource blocks because it has the highest average SNIR therefore it has the highest throughput, while User 1 receives the smallest number of resource blocks and has the lowest throughput, despite its closeness to the eNodeB, because of its has the lowest SNIR suggesting poor channel conditions.

In Figure 8, it can be seen that the there is a go-between fairness and CQI depicted in the SNIR. UE 2 has a slightly higher throughput than any other UE, whilst UE 1 follows closely showing that the scheduler considers the closeness thereby scheduling UE slightly more than UE 3, which is farthest from the eNodeB.

III. Evaluations and Conclusion

In this Simulation work, Scheduling in downlink LTE was examined using IS-Wireless Matlab-based LTE MAC Lab. Three basic scheduling algorithms, namely round robin, max SNIR and proportional fair, were compared using different SNIR. It was observed that using round robin fairness was ensured thereby limiting the throughput, whilst the Max SNIR ensured that the UE with the highest SNIR had more resource blocks and hence much higher throughput and the proportional fair scheduler found a middle ground between ensuring fairness and maximizing throughput.

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