Modeling and Performance Evaluation of Scheduling Algorithms For Downlink LTE cellular Network

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Abstract— **Long Term Evolution is standardized by the 3rd Generation Partnership Project to have wider channels up to 20MHz, with low latency and packet optimized radio access technology. The peak data rate envisaged for LTE is 100 Mbps in downlink and 50 Mbps in the uplink. The 3GPP has chosen the OFDMA as the radio access technology due to his simple implementation in receiver and spectral efficiency. To enhance system's data rate and ensure quality of service, the Radio Resource Management Scheduling Mechanisms plays a very crucial components to guarantee the Quality of Service performance for different services. In this paper we modeled and evaluated the performance of Round Robin, Proportional Fairness and Max Rate scheduling algorithms. The performances are compared in term in throughput and fairness index for this scheduler.**

Keywords- Scheduling; Fairness; Max Rate; Ressource Block.

I. INTRODUCTION

The Long Term Evolution (LTE) is standardized by the 3GPP in Release 8, as the successor of the Universal Mobile Telecommunication System (UMTS), in order to ensure a high speed data transmission with mobility for mobile communication. The radio access technology chosen for LTE system is the Orthogonal Frequency Division Multiple Access (OFDMA), in both Time Division Duplexing (TDD) and Frequency Division Duplexing (FDD), because of the high degree of flexibility in the allocation of radio resources to the Users Equipments (UEs) and his robustness to the selectivity of multipath channels [1][2]. LTE is capable of supporting different transmission band of spectrum allocation (Multiple Channel Bandwidth), ranging from 1.4 Mhz to 20 Mhz, for both paired and unpaired bands. The high peak transmission rate reaches the LTE system is 100 Mbps in downlink (DL) and 50 Mbps in uplink (UL). To achieve the performance objectives, LTE employs the several enabling technologies which include Hybrid Automatic Repeat Request (HARQ) technical and different MIMO transmission methods are deployed [3] [4].

LTE technology presents a very challenging multiuser problem: Several User Equipments (UEs) in the same geographic area require high data rates in a finite bandwidth with low latency. Multiple access techniques allow UEs to share the available bandwidth by allocating to each UE a fraction of the total system resources. The strong motivation beyond the resource allocation algorithms for scheduling is the improvement of system performance by increasing the spectral efficiency at the wireless interface and consequently enhancing the system capacity. Other constraints such as fairness must also be improved. Hence, it is important to find away to performance effective trade-off between efficiency and fairness. To develop an efficient scheduler to reach this trade-off, several factors must be taken into account such as: Signal-to-Interference-plus-Noise Ratio (SINR), packet delays, buffer status (queues length and packet delays), and type of service, fairness, channel conditions and complexity (time and computing).

In this paper, we study and compare the different scheduling algorithms for downlink LTE system and we discuss the factors which mentioned earlier for several proposed resources allocation schemes. This paper is organized as follow: in Section II, we describe the LTE downlink scheduling mechanism and in Section III, we evaluate and compare the algorithms performance.

II. LTE DOWNLINK SCHEDULING

The air interface of LTE technology is based on OFDMA and SC-FDMA in the downlink and Uplink respectively to deliver the flexibility and increase data rate without additional bandwidth or increase transmit power. The base station (eNodeB) is the entity responsible for controlling the air interface between the network and user equipments. The data transmission in LTE system is organized as physical resources which are represented by a time-frequency resource grid consisting of Resources Blocks (RBs) which has a duration of 0.5 ms and a bandwidth of 180 KHz (12 subcarriers spaced with 15 KHz). It is a straight forward to see that 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.

The scheduler entity have a role to assigns resources blocks every TTI, based on the channel condition feedback received from User Equipment in the form of Channel Quality Indicator (CQI) send by the UEs to the eNodeB, to indicate the data rate supported by the downlink channel. Every value of CQI, index in the range 1 to 15, corresponds to the highest Modulation and Coding Scheme (MCS) and the amount of redundancy included [12]. The corresponding bit rate per bandwidth is standardized by 3GPP and is shown in TABLE I.

TABLE I. CQI TABLE

CQI Index	Modulation	Code rate X1024	Efficiency
0	No transmission		
1	QPSK	78	0.1523
2	QPSK	120	0.2344
3	QPSK	193	0.3770
4	QPSK	308	0.6016
5	QPSK	449	0.8770
6	QPSK	602	1.1758
7	16QAM	378	1.4766
8	16QAM	490	1.9141
9	16QAM	616	2.4063
10	64QAM	466	2.7305
11	64QAM	567	3.3223
12	64QAM	666	3.9023
13	64QAM	772	4.5234
14	64QAM	873	5.1152
15	64QAM	948	5.5547

In LTE system, the resource allocation is done in time and frequency domain. In time domain, the downlink channel is divided into frame of 10ms each consists of 10 subframes of 1 ms each referred to as Transmission Time Interval (TTI). In frequency domain, the available system bandwidth is divided into sub-channels of 180 KHz, comprising of 12 consecutive equally spaced OFDM sub-carriers of 15 KHz each. A time-frequency radio resource spanning over 0.5 ms slots in the time domain and over 180 KHz sub-channel in the frequency domain is called Resource Block (RB) [5]. The number of resource blocks in the available bandwidth is called Resource grid. Resource Element (RE) represents one OFDM subcarrier during one OFDM symbol interval. The number of RBs in a resource grid depends on the size of the bandwidth. The LTE operates in the bandwidth of 1.4 MHz up to 20 MHz, with number of RBs ranging from 6 to 100 respectively [5] [6].

A. LTE scheduling Mechanisms

In wireless communications, specifically in LTE system, each user return a value of CQI to eNodeB every TTI corresponding to the channel state of the user i and the mean data rate supported by the channel at the time slit t. The scheduler is responsible for assigning the RBs in time and frequency domain resources to the different UEs under the CQI-received as a feedback from the UE by the BS. Every 1ms the assignment of resources could change depending upon various factors including CQI for each user. In order to perform channel-aware packet scheduling, each eNodeB need to have the knowledge of Channel State Information (CSI) for each user, for all the RBs in the available bandwidth. The CSIs are derived based on channel gain, interference conditions and SINR estimation errors. In this paper, we discuss the major scheduling algorithms that are used by the LTE downlink schedulers, they are, Round Robin (RR), Proportional Fairness (PFS) and Max-Rate algorithms. These scheduling algorithms are described in the next section [7]. The Figure 1 describes the packet scheduling strategies.

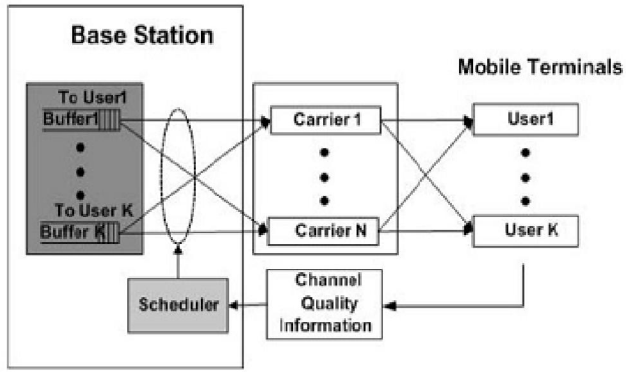

Figure 1. LTE Scheduling Scenario.

The LTE downlink scheduler is designed to ensure high Quality of service (QOS), maximization of system capacity, reducing complexity and ensures fairness between all active users. Then, scheduling algorithms should be capable to exploit the channel variation condition with maintaining fairness between the users flows.

B. LTE scheduling Algorithms

In LTE system, the scheduling algorithms assume that the eNodeB would receive the CQI feedback, every TTI, as a matrix with dimensions Number_UEs x RB_grid_size. The value of each field in the matrix is the CQI feedback of each user for each RB [6]. The different scheduling algorithms are describes as follow:

- ***Round Robin (RR)*** is the simplest scheduling algorithm which assigns time interval to each mobile station in equal portion and in order with the same priority. This algorithm is very simple and easy to implement [14].
- ***Proportional Fairness Algorithm (PFS)*** work as follow. The CQI feedback of user k in time TTI i is in term of a requested data rate $R_{k,n}(t)$, which design the k^{th} user's sub-carrier can currently supported. The PFS algorithm keep track of the average throughput $T_{k,n}(t)$ of each user on every sub-carrier in a past window of length t_c. The t_c parameters means the trade-off between fairness and throughput. The larger value of t_c is $t_c = \infty$, in this situation the allocation resources according to PFS algorithm is decided solely by instantaneous SNR, leading to maximum system throughput and poor fairness characteristics. On the other hand, the lower value of t_c parameter is $t_c = 1$ in this situation scheduling becomes fair [8] [9]. In the time slot t, the PFS algorithm transmits at each sub-carrier to the user K with the largest value of J calculated as follow:

$$j = \frac{R_{k,n}(t)}{T_{k,n}(t)} \quad (1)$$

The average throughput $T_{k,n}(t)$ can be updated using an exponentially weighted low-pass filter [13] :

$$T_{k,n}(t+1) = \begin{cases} (1-\frac{1}{t_c})T_{k,n}(t) + \frac{1}{t_c}R_{k,n}(t) & k = k^*(t) \\ (1-\frac{1}{t_c})T_{k,n}(t) & k \neq k^*(t) \end{cases} \quad (2)$$

- ***Max-Rate*** scheduler transmit, every TTI, to the user having the largest SNR, so users that have the fading peak are likely to be scheduled all the time, while other that experience deep fades are not scheduler at all. Max Rate scheduler has to maximize system throughput but it totally ignores fairness. The received SNR of the n^{th} RB signal of the k^{th} user at the t^{th}TTI can be expressed by[8]:

$$SNR_{k,n}(t) = \frac{S_{k,n}(t)\ H_{k,n}(t)}{N_0\, B/N} \quad (3)$$

Where $S_{k,n}(t)$, $H_{k,n}(t)$ are the allocated transmission power and channel gain on n^{th} sub-carrier at t^{th} TTI respectively, N_0 is the power spectral density of AWGN, B is the bandwidth and N is the number of sub-carriers.

The instant data rate of each user is determined and the BS serves each user at this rate. The instant service rate on the n^{th} sub-carrier at t^{th} TTI is got by:

$$R_{k,n}(t) = B/N\ Log_2(1 + SNR) \quad (4)$$

Where, $R_{k,n}(t)$ is the k^{th} user transmission rate at t^{th} time slot, B is the total bandwidth and N is the number of sub-carriers [10] [11].

PFS algorithm transmits for each user when its channel is good and at the same time the scheduling algorithm is perfectly fair on the long term. We plot in Fig. 2 the frequency response of three users. Thus, the PFS algorithm schedules a user when its instantaneous channel quality is high relative to its own average channel condition over the time scale t_c.

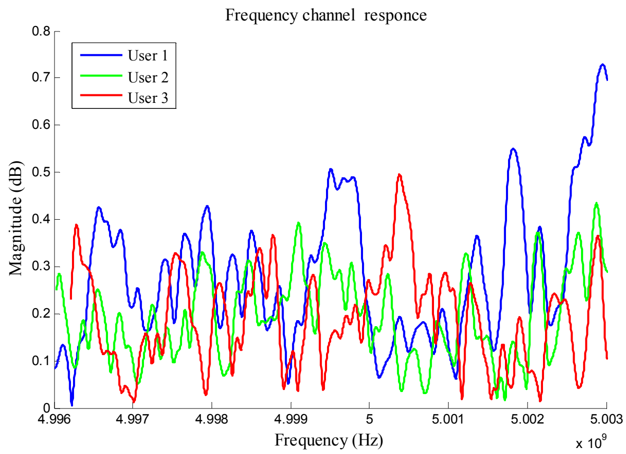

Figure 2. Frequency Channel Response for Three users.

III. SIMULATION RESULTS AND DISCUSS

A. Simulation Parameters

In this section, we will simulate and discuss the performance of the three scheduling algorithms, such as RR, PFS and Max-Rate, over LTE system. The simulations are carried out for frequency-selective channels modeled by ITU for Pedestrian-B (Ped-B) channels. Our simulations are performed for users ranging from 5 to 25, choosing the bandwidth of 5MHz containing 25 RBs and 300 occupied sub-carriers. The simulations parameters used are listed in the TABLE II.

TABLE II. SIMULATION PARAMETERS

Parameters	Value
Channel type	ITU-Pedestrian B
Number of Base station	1
Number of users	5, 10, 20, 30, 40
Scheduling Algorithms	Round Robin Max-Rate Proportional Fairness
Bandwidth (MHz)	5
Transmission mode	SISO
Numbers of subframes	140
Tc parameter	1

B. Simulation Results and Discuss

In this section, we present the simulation evaluation of scheduling algorithms. In order to evaluate and find the scheduler disciplines, the performance is measured in term of overall system capacity and fairness index using the three scheduling algorithms. First, we plot the number of allocated RBs for every user over time using each scheduling algorithm.

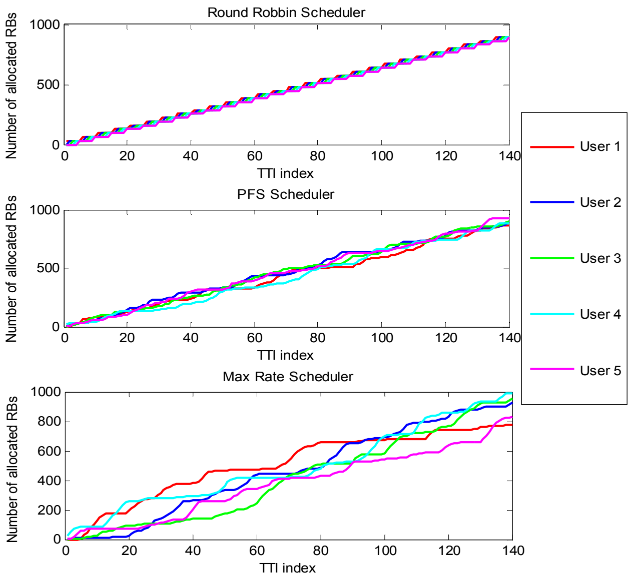

Figure 3. Number of allocated RBs for each user vs. TTI index using RR, PFS and Max Rate schedulers.

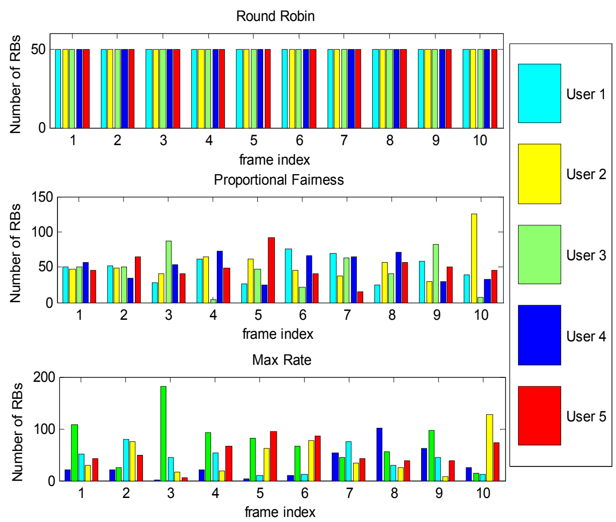

Figure 4. Means allocated RBs per frame for each user using RR, PFS and Max Rate schedulers.

Figures 3 and 4 show the evolution of allocated RBs versus time and means number of RBs per frame, respectively, allocated for each user using RR, PFS and Max-Rate algorithms. From the simulation results, we can see that the RR scheduler delivers fairness for all users with allocates the same number of RBs for each user which have 50 Resources Block each frame. But, Max-Rate scheduler allocates a different number for each user derived from channel quality SNR to maximize average system throughput. The PFS scheduler tries to strike a balance between fairness and achieving the Maximum throughput by allocation almost equal means RBs for each user every TTI.

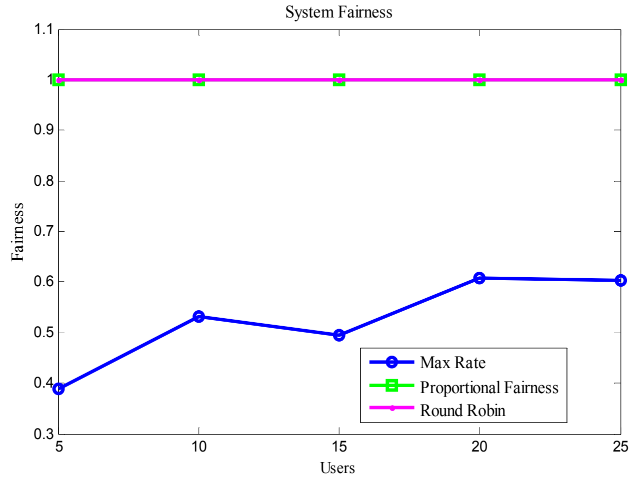

Figure 5. Number of allocated RBs for each user vs. TTI index using RR, PFS and Max Rate schedulers.

The system fairness for scheduling algorithms versus users ranging from 5 to 25 is investigated in Fig. 5. It is also observed that Max rate is the unfairness algorithm and the index fairness not exceed 0.6. This is because the Max rate algorithm allocates the system resources to users who have a strongest channel and serve the users who are demanding service in system. But as we can see, the PFS scheduler has a constant fairness index almost equal to 1 because as we saw in section II, with a low t_c parameter this algorithm maintenance index fairness without involving system throughput.

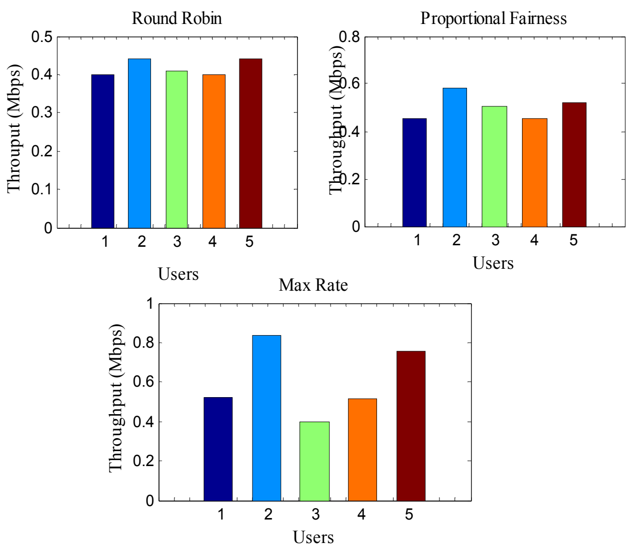

Figure 6. Total Throughput for each user using RR, PFS and Max rate scheduler, 5 Users

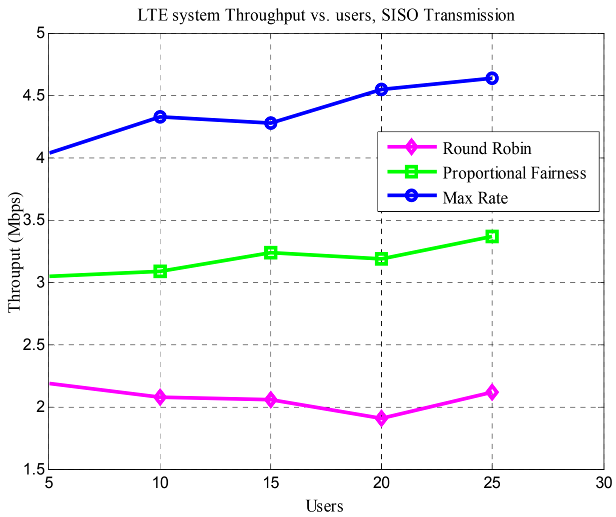

Figure 7. System Throughput versus user using RR, PFS and Max Rate schedulers

In order to compare the different scheduling algorithms, we simulate and plot the average throughput for each user and system throughput versus users ranging from 5 to 25. We can see that the system throughput achieved by RR algorithm reaches the lowest value because this algorithm allocates all sub-carriers to one user at each time slot independently of users' channel response and rate requirements. But Max Rate algorithm, according to system throughput, reaches the best result because this algorithm allocates system resources to users with the strongest channel and it maximizes the system throughput. PFS algorithm exploits the propagation channel condition in order to maximize system capacity without comprising fairness. As we can see in Figs. 6 and 7, PFS algorithm has a good behavior because it reaches a good level of system throughput.

IV. CONCLUSION

In this paper, we present the performances of three scheduling algorithms such as Round Robin, Proportional Fairness and Max Throughput in term of fairness and system capacity. We can see that the RR scheduler promotes priority to fairness between all users regardless of system throughput. On the other hand, Max throughput is used to maximize the system capacity without considering the fairness among users. But, from the results obtained, it is also observed that the proportional fairness algorithm performs a compromise between system fairness and throughput. From this result, we can use a mixed between PFS and Max Throughput scheduler to maximize system throughput with guaranteed fairness between users.

REFERENCES

[1] 3GPP TS 36.212 Version 10.0.0 Release 10, Evolved Universal Terrestrial Radio Access (E-UTRA): Multiplexing and channel coding, March, 2009.

[2] C. Mehlführer, M. Wrulich, J. Colom Ikuno, D. Bosanska, and M. Rup, "Simulating the Long Term Evolution Physical Layer," in Proc. EUSIPCO 2009, March 2009, pp.1471 – 1478.

[3] M. AMMAR, B. NSIRI, W. HAKIMI and M. ELJAMAI, "A comprehensive study of Open-loop Spatial Multiplexing and Transmit Diversity for Downlink LTE", International Journal of Computer Sciences and Telecommunication (IJCST), volume 5 Issue 2, January 2014, pp. 1-7.

[4] Technical White paper: "Long Term Evolution (LTE): A Technical Overview," by Motorola.

[5] S. M. Chadchan, "A Fair Downlink Scheduling Algorithm for 3GPP LTE Networks", I. J. Computer Network and Information Security, 6, pp 34-41, 2013.

[6] D. Talevski and Li. Gavrilovska, "Novel Scheduling Algorithms for LTE Downlink Transmission", Telfor Journal, Vol. 4, No. 1, February 2012, pp. 45-56.

[7] Dinesh Mannani, "Modeling and Simulation of Scheduling Algorithms in LTE Networks", Bachelor of Science Thesis report, Warsaw, January 2012.

[8] Al. Bahillo Martinez, "Evaluation of multiuser scheduling algorithm in OFDM for different services", Master of Science in Electronics report, June 2006.

[9] P. Viswanath, D. Tse, and R. Laroia, "Opportunistic Beamforming Using Dumb Antennas" IEEE transactions on information theory, vol. 48, no. 6, June 2002.

[10] H. Seo and B. Gi Lee, "A Proportional Fair Power Allocation for Fair and Efficient Multiuser OFDM Systems", School of Electrical Engineering, Seoul National University, April 2004.

[11] E. L. Hahne, "Round-Robin Scheduling and Window Flow Control for Max-Min Fairness in Data Networks" IEEE, technical report, November 1987.

[12] Raymond H. Y. Louie, "Open-Loop Spatial Multiplexing and Diversity Communications in Ad Hoc Networks", Revised version. Submitted to IEEE Tr. Info Theory, 17 september 2010.

[13] Institute of Telecommunications Vienna University of Technology, Austria Gusshausstrasse 25/389, A-1040 Vienna, Austria, "Vienna LTE Simulators System Level Simulator Documentation, v1.7r1119".

[14] C. Mehlführer, J. Colom Ikuno, M. Šimko, S. Schwarz, M. Wrulich and M. Rupp, "The Vienna LTE simulators – Enabling reproducibility in wireless communications research", EURASIP Journal on Advances in Signal Processing 2011, pp 1-14.