QOS Downlink Schedulers in LTE towards 5G Network

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Abstract — **LTE is expected to be the dominant system used by operators in these years due to its promising solutions for achieving high capacity and data rate. However, LTE packet scheduling and distributing resources among users is still the main challenge due to unfairness and low performance which occur when allocating resources to users. In this paper, the above mentioned challenges are studied and analysed, focusing on three schedulers; they are Proportional Fair (PF), Maximum Throughput (MT) and Blind equal throughput (BET). These methods do not provide QoS to users that use different types of traffic flows. The proposed algorithm in this paper is to modify the PF scheduler in order to fulfil the QoS criteria maximizing throughput and minimizing the delay for real time service. VoIP and video have been selected as real time traffic and best effort as non-real time. LTE-Sim simulator is used to compare between the mentioned schedulers in terms of throughput, delay, packet loss ratio and spectrum efficiency.**

Keywords — PF, MT, BET, QoS

I. INTRODUCTION

LTE is the future of mobile broadband where 80% of all mobile broadband users are expected to be served by LTE in coming years [1]. Physical Resource Block (PRB) is the downlink physical resource in LTE that consists of multiple time-frequency resources (TR, FR) which are available for data transmission. PRB consists of a number of subcarriers and time slots. It also, represents the minimum quantity of data for scheduling process. A scheduler assigns the resources (time and frequency resources) to different users in the cell.

Maximum throughput scheduler maximizes the overall throughput by assigning resources to the user that can achieve the maximum throughput but there is no fairness of resource sharing to users with poor channel quality indicator (CQI). Blind equal throughput scheduler equalizes the throughput among users regardless of their channel conditions. Proportional fair scheduler is placed between MT and BET and it is the trade-off between throughput and fairness. In recent, PF was good enough for achieving the purpose but nowadays the requirements of LTE need to have some enhancement for PF in order to fulfil the QoS criteria. In this paper, a new solution for this problem is offered by having some modifications for the proportional fair scheduler to provide QoS service. The core enhancement behind the proportional fair is to differentiate between the real time flow (VoIP, Video) and non-real time flow (best effort, constant bit rate) by giving the real time traffic flow higher priority especially in case of video traffic regardless of the channel conditions.

This paper is organized into four sections which are described as follows. Section 2 provides a general overview of LTE downlink schedulers that are used in the simulation. The new proposed scheduler is described in section 3. Section 4 discussed the obtained simulation results. Finally, conclusions and recommendations are presented in section 5.

II. LTE DOWNLINK SCHEDULERS

Downlink scheduling is a way to allocate Resource Block (RBs) to users, in order to maximize a system throughput to all users that experience different channel conditions. For that reason many scheduling algorithms have been proposed for different purposes. In this section, a general overview is provided for schedulers that are used in the simulation.

A. Maximum Throughput algorithm

Maximum throughput scheduler is depended on the channel condition. The most advantage of this scheduler is to get very high throughput by assigning more resources. In uplink process, the scheduler starts to analyse the CQI reported form UE and based on that, it specify the required rate to each user. Based on the CQI mapping vs. Modulation and Coding Scheme (MCS), the selection of modulation scheme is done (QPSK, 16-QAM, 64-QAM) and there are abound 15 levels of CQI. The limitation of this algorithm is prioritization to users with good SNR over users with low SNR such as users located at cell edge [2] [3]. The metric can be calculated from the following

$$m_{i,k}^{MT} = d_k^i(t) \tag{1}$$

Where $d_k^i(t)$ is the expected data-rate for i-th user at time t on the k-th Resource block. It can be calculated by considering the Shannon expression for the channel capacity as:

$$d_k^i(t) = \log[1 + SNR_k^i(t)] \tag{2}$$

B. Blind Equal Throughput

The aim of the blind equal throughput scheduler is to provide fairness throughput among all users regardless to their channel condition, SNR and traffic flow. The metric (for the i-th user) is calculated as

$$m_{i,k}^{BET} = 1/\overline{R^i}(t-1) \qquad (3)$$

With

$$\overline{R^i}(t) = \beta\overline{R^i}(t-1) + (1-\beta)r^i(t) \qquad (4)$$

Where
$0 \leq \beta \leq 1$

$\overline{R^i}(t-1)$ is the average throughput of terminal i over windows in the past.

From the above equation it is clear that the BET scheduler prioritizes users with lower average throughput in the past. This implies that users with bad channel conditions are allocated more resources compared to the users with good channel conditions. Thus throughput fairness is achieved but at the cost of spectral efficiency [3].

C. Proportional Fair (PF) scheduler

Proportional Fair algorithm is commonly used for time-frequency scheduling. It has been used in past systems such as time domain scheduling (TDS) and later it was adapted to LTE to exploit the OFDMA capabilities FDS and TDS. The purposes are to achieve a good trade-off between overall system throughput and fairness among the users.

Fairness Allocation (FA) in proportional fair referred to the amount of resources allocated within a given time interval. Equation 5 expressed the allocation fairness in PF Scheduler.

$$FA(\Delta T) = \frac{\left(\sum_{m=1}^{M} Am(\Delta T)\right)^2}{(M.\sum_{m=1}^{M} Am(\Delta T)^2)} \qquad (5)$$

Where $0 < FA(\Delta T) \leq 1$ if $FA(\Delta T) = 1$ means all users received identical resources. m is number of considered users. m = 1,2,....,M user index. $Am(\Delta T)$ is the number of allocation units scheduled to the user m in time interval ΔT [4].

Proportional Fair (PF) scheme is used to trade-off between throughput and fairness. Its metric is a multiplication of MT and BET metrics; it can be shown by:

$$m_{i,k}^{PF} = m_{i,k}^{MT}.m_{i,k}^{BET} = d_k^i(t)/\overline{R^i}(t-1) \qquad (6)$$

III. THE NEW PROPOSED SCHEDULER ALGORITHM

In order to find a trade-off between throughput and fairness, we design a new scheduling algorithm that take the advantages of both MT scheduling and the BET scheduling to provide high priority to real time traffic. Several algorithms have been proposed as an improvement of PF that was only targeting the idea of maximizing throughput or optimizing for PF scheduler. However, the main objective of this new scheduler is to provide QoS service to PF downlink scheduler.

$$m_{i,j}^{PF} = \frac{\text{spectral efficiency} \times 180000}{\text{Average transmission Rate(i)}} \qquad (7)$$

It is well-known that, the metric of PF consists of BET and MT metrics. The former means fairness can be achieved

among all users in the system regardless the channel conditions. On the other hand, the latter depends on the CQI and channel conditions with no fairness.

The new proposed scheduler which is discussed in this paper aims to combine between the MT and PF scheduler. Based on the type of the traffic flow, we can say when the real time traffic initiated, the MT is applied because the real time traffic flow needs a very high data rate. Otherwise PF is applied to show fairness among other users. Therefore, the metric of this proposed schedulers is as the flowing:

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$$m_{i,j}^{NP} = \begin{cases} m_{i,j}^{MT} = d_j^i(t) & real\ time\ traffic \\ m_{i,j}^{PF} = d_j^i(t)/\overline{R^i}(t-1) & otherwise \end{cases} \qquad (8)$$

Where $m_{i,j}^{NP}$ is the metric of new proposed scheduler in this project.

Flowchart in Fig.1 shows the proposed scheduler algorithm. The differentiation between real time and non-real time comes at beginning of the scheduler before checking the channel conditions in order to deal with the real time traffic as special case. This way helps us to give a higher priority to real time traffic so the result appears in terms of maximum throughput and minimum delay. After that we can apply the MT scheduler to the real time for getting high throughput. On the other hand, PF is applied for non-real time to trade-off between throughput and fairness.

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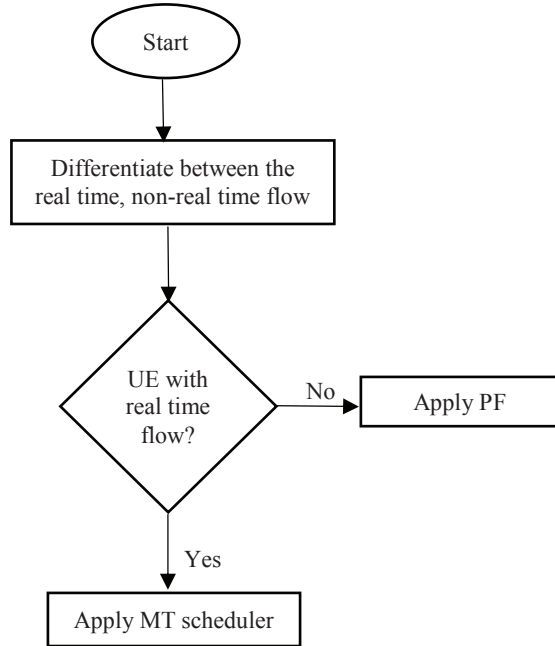

Fig. 1.   New Proposed scheduler

IV.   SIMULATIONS RESULT AND DISCUSSION

The scenario used in this project is known as "*Single Cell with Interference*" as shown in Fig. 2. It is considered more realistic and closer to the real life of LTE communication environment. This scenario is not complicated, besides it considers nearly all the possible effects that can be generated from neighboring cells as well as the interference.

The scenario in hand was designed to assign three traffic flows to each user, which means each user in the system had VoIP, video and best effort traffic flows. Although some modifications were added to the scenario for the purpose of QoS comparison among targeted users so each one is indicated by a type of traffic flow instead of three. Those users are 15 divided into three groups of 5 users for VoIP flow, video flow and best effort flow, respectively. Table 1 gives the parameters that used in our simulation

The simulation runs and transmits the three types of traffic (VoIP, video, BE) from eNB to all 15 users. The video application simulates 242 kbps video stream which is produced by the H.264 coder. The VoIP application is generated on G.729 code with an ON-OFF pattern.

With ON period, the source data rate is 8 kbps while the rate is equal to zero with OFF period. The packet size of the VoIP is fixed on 20 bytes plus 12 bytes of RTP header. The

non-real time traffic (Best effort) corresponds to the ideal greedy source that always has packets to send [6].

Table 1: SIMULATION PARAMETER

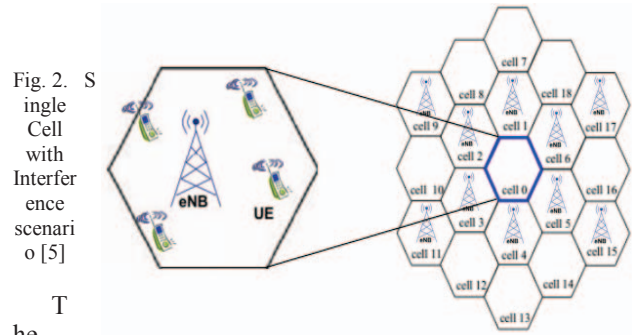| Number of users	10
Bandwidth	10 MHz
Frame Structure	FDD
Types of traffic flow	Video with bit rate = 242 kbps
	VoIP with bit rate = 8.4 kbps
	Infinite buffer or Best effort
User speed	3 km/h
Cell radius	1 km
Flow Duration	40s
Number of RB	50

Fig. 2. Single Cell with Interference scenario [5]

The PF, MT, BET and the new proposed downlink scheduler are compared and their performance is measured based on the following:

A. Goodput

There is slight difference in definition between throughput and goodput. Throughput is the number of bits that deliver from eNB to UE whereas goodput does not consider the control bits of the header (receipted packet at destination - headers). Also error packets (packets that failed to arrive in transmission time) are not counted in both goodput and throughput.

Fig.3 shows the goodput as we declared before that users 1-5 have only VoIP traffic flow, users 6-10 with video traffic and 11-15 with best effort (infinite buffer). The newly proposed scheduler shows the best result among others where higher priority is given to the real time traffic flow (VoIP, video). By comparing video and best effort users, the video users (6-10) got higher goodput than best effort ones (11-15). Besides, fairness is shown among video users (6-10) since their goodput looks nearly straight line and it is above 100kbps. For VoIP users, the goodput is low for all schedulers but it is not equal to zero due to low rate is needed for VoIP that is around 8 kbps whereas video and best effort traffics need very high data rate. The MT scheduler shows good throughput performance but with zero fairness as it is clear at user 12; the goodput is too high due to high SNR at that user. Whereas the CQI is low at user 7 (video user) so that it has lower value of goodput. On other words MT depends on channel condition only. PF scheduler shows moderate fairness among users but goodput is still low in video users. In addition, the performance of PF is high at BE users due to restriction applied on VoIP and video

traffic for fairness purposes besides of BE is considered greedy source. BET scheduler is considered the worst case of goodput for all users (VoIP, video, best effort).
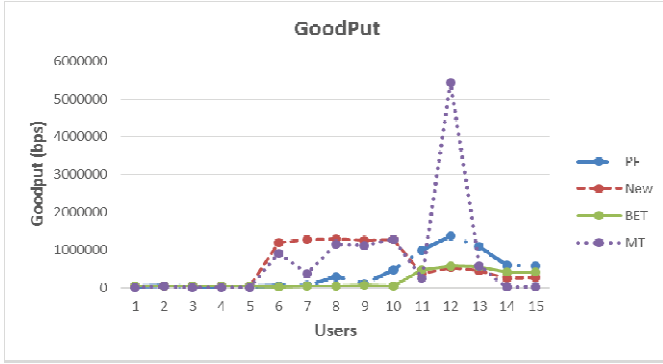

Fig. 3.   Goodput comparison between MT, BET, PF and new scheduler

B. Packet Loss Ratio (PLR)

PLR represents the difference between the number of sent and received packets. PLR can be calculated from this equation:

$$PLR = \frac{P_{sent} - P_{received}}{P_{sent}} \qquad (9)$$

Where,

$\boldsymbol{P_{sent}}$ = Number of packet sent from eNB.

$\boldsymbol{P_{received}}$ = Number of packet received by UEs.

When PLR is low, the scheduling algorithm is considered good.

The PLR is shown in Fig.4. The proposed scheduler shows almost zero PLR if it is compared to the other three schedulers and the highest value of PLR occurs in user 6 which is about 5.8 %. For the MT, the PLR has fluctuation values for real time users from 1 to 10. If we refer to Fig.5, we can notice that user 1, 3, 4, 5, 7 have not only high PLR but also have high delay whereas user 2, 6 have lower PLR and delay. This is because of whenever scheduler experiences high delay that exceed the threshold (maximum delay), the packet or the frame will be discarded. For PF and BET, the PLR occurs on video users only because of no enough resources to share among users due to fairness that lead to drop packets. The best effort users has smallest values of PLR among other schedulers. This is because of their characteristics where no much consideration to time factor not as real time flows that cause packet to drop.

C. Delay (in seconds)

The amount of time for the packets to be transmitted from the eNB to UEs which is called propagation delay in some other books. Only the successful packets that arrive destination are counted.

The delay is shown in Fig. 5. The proposed scheduler has the lowest delay among all other downlink schedulers which is below 0.02s. The maximum delay of this proposed scheme occurs at user 6 and it is equal to 0.02s. This is considered a reasonable delay for adequate video quality. MT and PF schedulers experience high delay in real time users and their delay occurs between (0.02-5) s. According to [6] the video streaming may have some re-buffering events during play-out, if the packet delay above 0.2s. Therefore, MT and PF schedulers cannot provide adequate video quality to the supported UEs since there average delay above 0.2s.
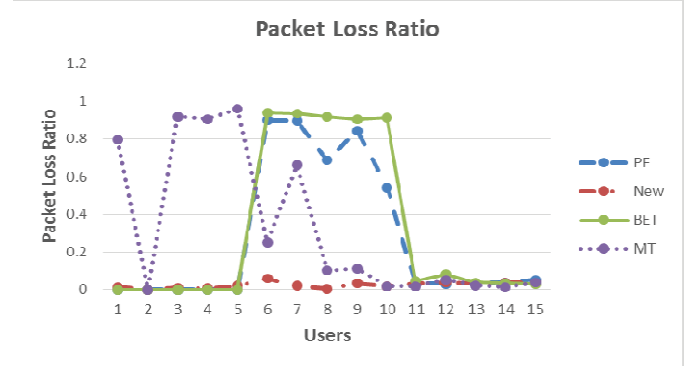

Fig. 4.   PLR comparison between MT, BET, PF and new scheduler

The same case happen for VoIP users, the maximum delay recommended by the [7] for voice service is 0.15s and this value should not be exceeded. BET scheduler is the worst case among these schedulers, video delay is too high between 8-14s and the effect of that, packets are discarded if the delay above the threshold. For BE users, the delay is not equal to zero but most of these values are 0.001s which are considered low delay and this due to the characteristic of BE traffic. Best-effort delivery does not provide any guarantees of data delivered or in other words, BE is not sensitive to QoS services (jitter, packet loss, delay) and it is supported by UDP protocols.
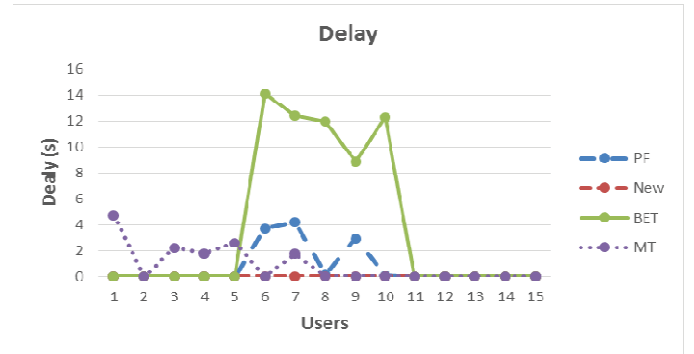

Fig. 5.   Delay comparison between MT, BET, PF and new scheduler

D. Spectral Efficiency

The spectral efficiency is defined as the information rate that can be transmitted over a given bandwidth and its unit is bits/second/Hz. It can be calculated from the following:

$$Spectral\ Efficiency = \frac{UE\ goodput}{Bw} \qquad (10)$$

The spectral efficiency represented in bits/s/Hz. Fig.6 shows the spectral efficiency for the 15 users. The proposed

algorithm has the best spectral efficiency among other downlink schedulers. The second best one is MT, its performance is higher than BET and PF especially at video users except at user 7. For PF and BET, spectral performance is low but not equal to zero especially at real time users. PF shows good utilization of the bandwidth at BE users because they are greedy source.
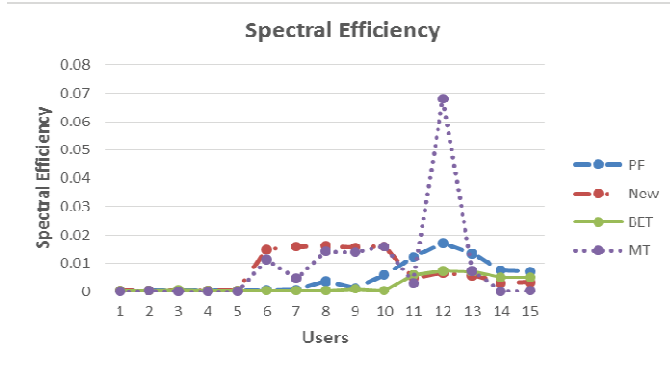

Fig. 6. Spectral efficiency comparison between MT, BET, PF and new scheduler

V. CONCLUSION & 5G FUTURE WORK

This new scheduler is considered as QoS scheduler that supports real and non-real time service in LTE networks. The main key for this scheduler is to maximize the throughput and to ensure the fairness among users with higher priority for real time.

In 5G networks, the trend goes to provide extreme high capacity and extreme low latency. However, QoS service is also required in 5G technology since a huge number of devices will be connected together with diverse traffic flows. One of the proposed QoS paradigm in 5G is the development of network function virtualization (NFV) including the radio access and cloud core networks. According to [8], the concept of NFV will lead the quality management function to introduce two functions which are Cloud QoS management (CQMF) and Cloud QoS control function (CQCF). The CQCF function provides control on real-time traffic flows based on the QoS level established during the connection. Whereas, CQMF function is responsible for providing QoS in 5G networks in accordance with SLA service contracts, also providing maintenance, monitoring and review of QoS.

The other direction of QoS paradigm is development of algorithms based on the traffic classification such as video, VoIP, BE as well as M2M traffic. Also, the SNR and the changes of application should be considered as well and higher priority will be given for video and M2M traffic flows.

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