Performance Analysis of EXP-BET Algorithm

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***Abstract*—Most of the mobile devices today support multimedia services as well as legacy mobile services such as voice, short message service (SMS) and multimedia messaging service (MMS). Real-time services like video streaming and multimedia gaming are given higher priority to be scheduled as compared to the non-real-time services like web browsing and sending email. However, both real-time and non-real-time services have equal demand and the urgency for the services to be scheduled cannot be neglected. This paper investigates the effect of tuning the parameter beta (β) in the Exponential Blind Equal Throughput (EXP-BET) algorithm. Different values of beta used were between 0.1 and 0.9. The simulations have been done using the LTE-Sim simulator and the performance of the proposed algorithm was observed in terms of fairness and throughput for video and best effort flows. From here, it can be concluded that when β = 0.1, the algorithm delivers best performance of fairness for both real-time and non-real-time services.**

***Index Terms*—LTE; Packet Scheduler; Scheduling; Multiple Services; LTE-Sim.**

I. INTRODUCTION

The newer multimedia applications require high data rate and power to provide better Quality of Service (QoS) to a user. However, due to low transmission rate and high service costs, Third Generation (3G) technology has been unsuccessful in delivering high-speed mobile broadband [1].Long Term Evolution (LTE) network has been developed to respond to this challenge where one of its ability is to improve the QoS [2]. In order to provide better QoS to customers, the resources must be fully utilized like resource scheduling which is one of the important functions for remanufacturing or upgrading system performance.

Third Generation Partnership Project (3GPP) has introduced LTE based on the packet-optimized system. The aims of the LTE are to reduce latency, increased data rates, improved system capacity and coverage, better battery lifetime and reduced cost for the operator. LTE offers greatly improved data rates, 100 Mbps for downlink and 50 Mbps for uplink and operates in different bandwidths ranging from 1.25 MHz up to 20 MHz [3].

The multiple access technique of Orthogonal Frequency Division Multiple Access (OFDMA) has been implemented in the physical layer of the 3GPP LTE system for the downlink transmission to transmit data from the LTE network base station, Evolved Node B (eNodeB) to user equipment (UE). OFDMA is able to improve the spectrum efficiency, flexible resource allocation, immunity to frequency selective fading and it can overcome the problem of inter-symbol interference (ISI) [4]. On the other hand, the uplink transmission employed the Single Carrier Frequency Division Multiple Access (SC-FDMA) to increase the UE's battery life[5]and reduce the Peak-to-Average Power Ratio (PAPR) [6].

The author in [7] used an approach by varying the value of beta to modify the past achieved throughput in the current metric of the Proportional Fairness (PF) algorithm. The main purpose of their approach is to create an unfair overall performance of the PF algorithm. If β is set at less than 1, the past achieved throughput is decreased and has less fair metric of the PF algorithm. The study shows that there is a trade-off between fairness and throughput. By having a larger value of parameter beta, fairness among users is improved but at the expense of reducing throughput.

Mobile operators are required to provide fairness and high throughput to users since users pay equal amount of money for the services. This paper investigates the effect of tuning the parameter beta in EXP-BET algorithm towards fairness and throughput performance.

Two types of traffic have been considered. A video flow is representing the real-time services while best effort flows represent the non-real-time services. The effect of varying the beta was also observed when there are increasing numbers of users in a cell.

An event driven LTE-Sim network simulator[8]was used as the simulation tool. LTE-Sim has been chosen because it is an open source network simulator and supports several packet scheduling algorithms.

The rest of this paper is organized as follows. The background and basic principles on scheduling is presented in Section 2. Section 3 describes the proposed algorithm; Section 4 discusses the simulation environment and parameters used while Section 5illustrates the simulation results. Finally, Section 6 concludes the paper.

II. SCHEDULING PROCESS

Scheduling is one of the main features in the LTE system which is performed in the Medium Access Control (MAC) layer. In the LTE network architecture, the packet scheduler is located at eNodeB. The packet scheduler is responsible for distributing resources among users in a fair and efficient way to maximize the system throughput, fairness and spectral efficiency. Thus, the effect of the bad channel quality can be reduced or would almost be negligible.

In the beginning of the scheduling process, the user determines the Channel Quality Indicator (CQI) index by estimating the instantaneous channel condition and sends a feedback to the eNodeB. Subsequently, this CQI index is used by the eNodeB to select the user with the most suitable modulation and coding scheme (MCS) for spectral efficiency maximization at the physical layer. Larger CQI index represents higher level of MCS which means more efficient usage of resources and fewer resource blocks being occupied for transmission. Certain information such as channel quality, resource allocation history, status of transmission queues, buffer state and QoS requirements may be considered by the packet scheduler when making the scheduling decision.

The traffics are classified according to its category as specified in the 3GPP specification based on the standardized QoS Class Identifier (QCI) characteristics[9]and stored in the logical buffer for each user according to the traffic classes. Figure 1 shows the architecture of the scheduling.

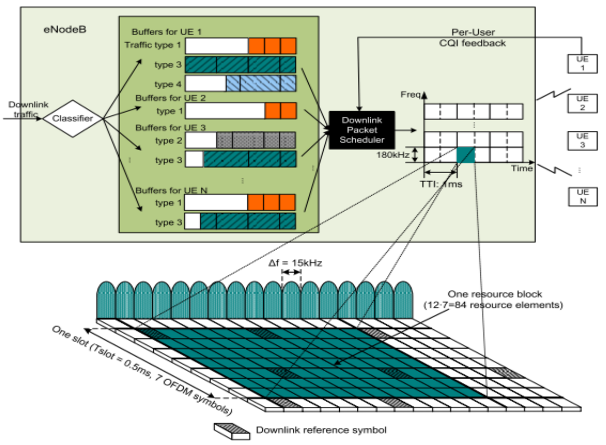


Figure 1: LTE downlink packet scheduling

The packet scheduler can apply any packet scheduling algorithms in the eNodeB in accordance to the design objectives. Examples of the packet scheduling algorithms include Proportional Fairness (PF), Blind Equal Throughput (BET), Modified Largest Weighted Delay First (M-LWDF), Exponential Rule (EXP Rule) and Frame Level Scheduler (FLS).

III. PROPOSED ALGORITHM

The proposed algorithm namely Exponential Blind Equal Throughput (EXP-BET) algorithm is created to support both the real-time and non-real-time services. It is a combination of the EXP Rule and BET algorithms. The EXP Rule algorithm is used to schedule the real-time services by giving higher priority to the user with the highest transmission delay or user that has more packets in its buffer while the BET algorithm takes care of the non-real-time services by giving higher priority user with the least average throughput in the past. Then, the EXP-BET algorithm will select the user with the highest metric for the assignment of physical resource blocks (PRB). The flowchart of the EXP-BET algorithm is depicted in Figure 2.

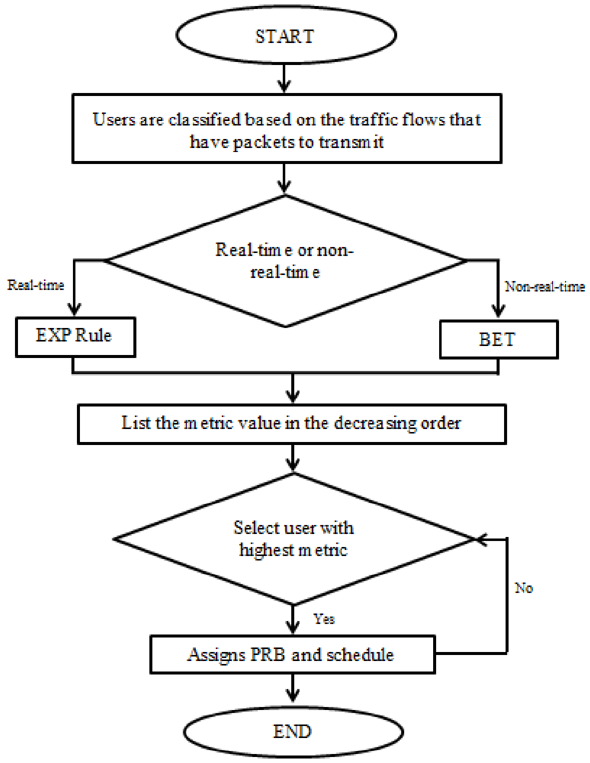


Figure 2: The flow chart of EXP-BET algorithm

A. Blind Equal Throughput (BET) Algorithm

The BET algorithm works on the principle of the past average throughput achieved by each user. It tries to reach fair throughput for all users regardless of their radio channel quality. The BET algorithm is calculated as:

$$m_{i,k}^{BET} = \frac{1}{R_i(t)} \tag{1}$$

$R_i(t)$is the past average throughput achieved by user *i*-th until time *t*-th.

In every transmission time interval (TTI), BET algorithm allocates the resources to flow that have been served with low average throughput in the past. Under this allocation policy, user experiencing the lowest throughput will be served as long as the user does not reach the same throughput of other users in the cell. In this way, users with bad channel conditions are more often allocated as compared to others.

B. Exponential Rule (EXP Rule) Algorithm

The EXP Rule can be considered as an enhancement of the Exponential Proportional Fairness (EXP-PF) algorithm. It gives higher priority to the user with the highest transmission delay or user that has more packets in its buffer. The EXP Rule is a channel-aware scheduling algorithm which considers the CQI metric in the scheduling decision [10] and is proven to be the most promising approach for delay sensitive real-time applications such as video and VoIP. The EXP Rule algorithm is expressed as in Eq. (2).

$$m_{i,k}^{EXP\,Rule} = \exp\left[\frac{\alpha_1 D_{HoL}}{1+\sqrt{\theta}}\right] * \frac{D_i(t)}{R_i(t)} \tag{2}$$

$\theta = \frac{1}{N_{RT}} \sum_{i=1}^{N_{RT}} D_{HoL}$with N_{RT} is the number of active real-time flows and D_{HoL} is Head of Line (HoL) delay. According to [10], the optimal parameter α_i is define as $\alpha_i \in \left[\frac{5}{0.99\tau}, \frac{10}{0.99\tau}\right]$ where τ is the maximum allowable delay.

Both the BET and EXP Rule algorithms consider the varying value of beta since it is located in the past average throughput equation which is calculated as:

$$R_i(t) = \beta R_i(t-1) + (1-\beta) r_i(t) \quad (3)$$

$R_i(t-1)$ is the past average throughput of user i-th at t-1, β ($0 \le \beta \le 1$) is the weight factor for moving average and $r_i(t)$ is the achievable data rate of user *i*-th at time *t*-th.

IV. Simulation Environment and Parameters

A single cell with interference delivering the best effort and video flows were simulated. The best effort application model is based on the ideal greedy source that always has packets to send. For video, the application sends packets based on the realistic video trace files, which can be seen in [11]. The selected video flow was encoded at the rate of 242kbps using the H.264 encoder. The simulation parameters are summarized as in Table 1.

Table 1
LTE downlink simulation parameters

Parameter	Value
Frame structure	FDD
Bandwidth	10MHz
Number of RB	50
Radius	1km
Maximum delay	0.1s
User speed	3km/h
Video bit rate	242 kbps
VoIP bit rate	8.4 kbps
Number of user	From 10 to 60
Beta value	0.1, 0.3, 0.5, 0.7, 0.9

LTE-Sim simulator [8]was used to perform the study. The simulator supports single and multi-cell environments, QoS management, multi-users environment, user mobility, handover procedures and frequency reuse techniques.

In this simulation, the propagation loss model which is composed of path-loss, shadow fading, multipath fading and the penetration loss is considered too. The summarization of the propagation loss model is tabulated in Table 2.

Table 2
Propagation loss model

Parameters	Value
Path loss	128.1 + 37.6 $\log_{10}(d)$ where *d* is the distance between the user and eNodeB in km
Shadow fading	Log-normal distribution with 0 mean and 8 dB of standard deviation
Multipath fading	Jakes model
Penetration loss	10 dB

The EXP-BET algorithm has been tested with different values of beta ranging from 0.1 to 0.9 to define the suitable value of beta to be used in order to provide better fairness and throughput performance towards the EXP-BET algorithm.

The value of beta of 0 and 1 was excluded from the analysis. This is because when β is set to 0, the past average throughput is equal to the last instantaneous data rate. On the other hand, when β is approaching 1, the last achieved rate would never be included into the past throughput calculation and the time window would theoretically become infinite [12].

V. Result and discussion

This section analyses the simulation results. The results consist of the fairness and throughput for real-time and non-real-time services which are represented by the best effort and video flows respectively. The value of beta was tuned between 0.1 and 0.9 where the QoS metric of fairness and throughput were observed.

The analysis on fairness and throughput was further observed for fixed number of users of 30 and 60 when varying value of beta was applied. The 30 users represent the low loads condition while 60 users represent high loads situations.

The fairness index indicates that every user in the system receives a fair share of the resources. Fairness among users is implemented using the Jain's Fairness Index and the best value is 1 while throughput is define as the rate of successful message delivery by a system over a given interval of time.

A. Best Effort Flows

Fairness index and throughput performance for best effort flows is illustrated in Figures 3(a) and 3(b) respectively. It can be seen in Figure 3(a) that as the number of user increases, the fairness index decreases. When β = 0.1, the fairness index maintains higher than the other values of beta. On the other hand, varying the value of beta did not significantly affect the throughput performance for the best effort flows as in Figure 3(b).

When the beta value is set lower; the past average throughput will be low. Thus, the metric ofm_(i,k)^BET becomes higher. This is in accordance to the BET algorithm principle which is to schedule the user with the least average throughput in the past.

i. Fairness

Figures 4(a) and 4(b) show the fairness index performance for best effort flow when the number of users is fixed to 30 and 60 respectively. It can be observed here that as the value of beta is set lower; the fairness value is higher for both 30 and 60 users. This also shows that as the number of user increases, the fairness is highest at a lower value of beta.

ii. Throughput

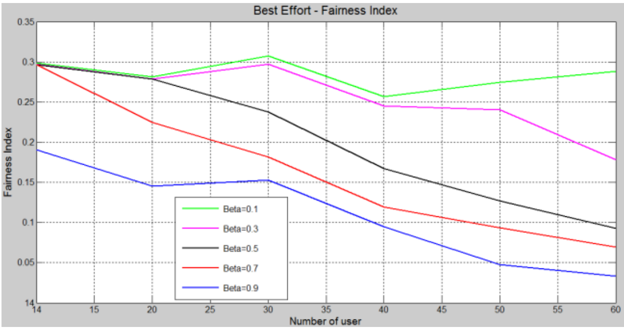
The best effort flow's throughput for 30 and 60 users is showed in Figures 5(a) and 5(b) respectively. It can be noted here that the throughput of best effort flow does not depend on the value of beta in order to result in a higher or lower throughput. This also might be due to some losses considers during simulation.

B. Video Flows

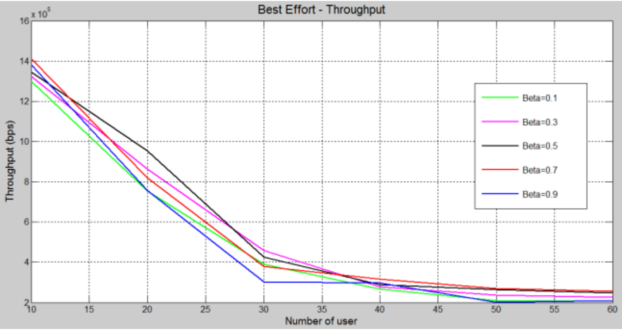
Figures 6(a) and 6(b) show the fairness index and throughput performance for video flow. The fairness index for video flow is quite similar when up to 30 users. It starts to decrease as the number of user increases. The best fairness index performance is observed when β is set to 0.1while β = 0.9 gives the lowest fairness.

For the throughput performance for video flow in Figure 6(b), the lower value of beta gives higher throughput. The throughput of video flow increases as the number of user increases.

Based on Equation (2), the small value of parameter beta will give the highest value of metric, $m_{i,k}^{EXP\ Rule}$ while large value of parameter beta gives a lower value of metric. In the EXP-BET algorithm, real-time flows will be scheduled according to this metric value where the highest metric value will be scheduled first.

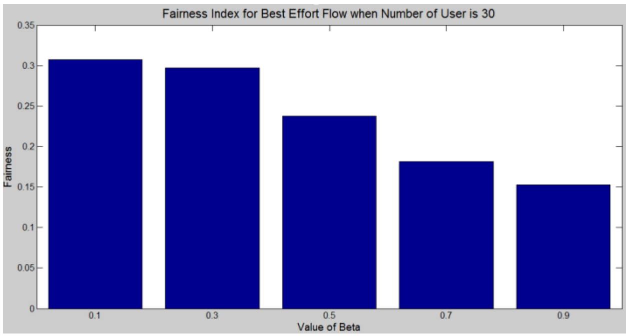


(a)

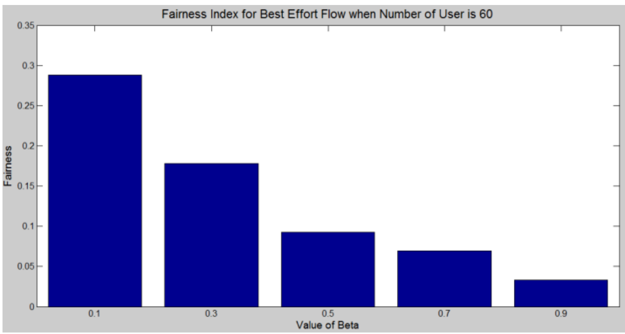


(b)

Figure 3: Best effort flows performance in terms of (a) fairness index and (b) throughput

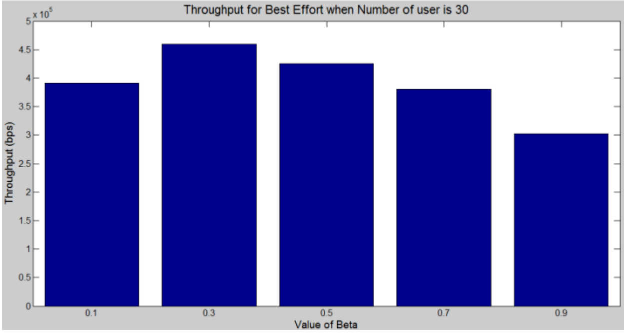


(a)

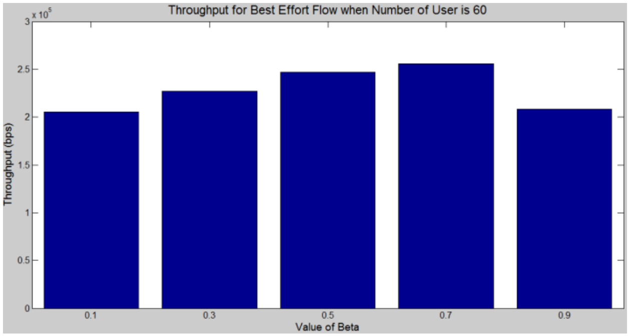


(b)

Figure 4: Fairness index for best effort flow when number of user is (a) 30 and (b) 60

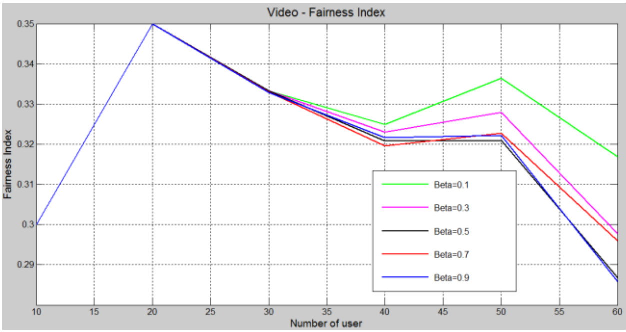


(a)

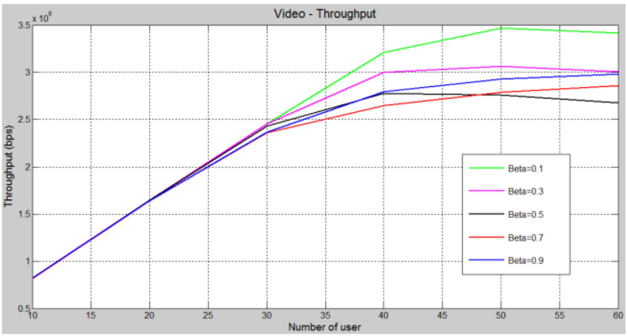


(b)

Figure 5: Throughput for best effort flow when number of user is (a) 30 and (b) 60



(a)

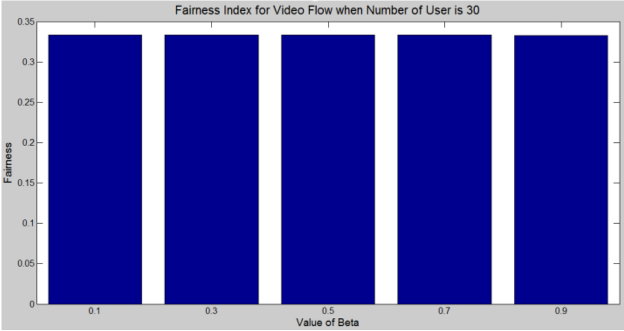


(b)

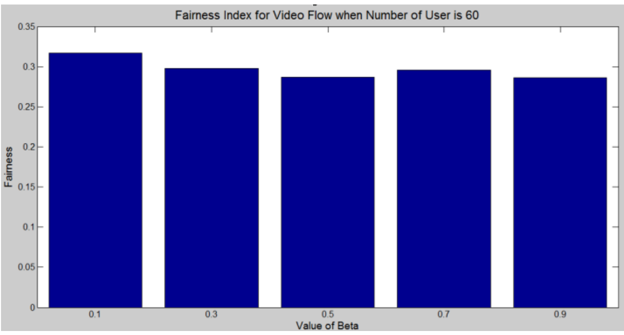
Figure 6: Video flows performance in terms of (a) fairness index and (b) throughput

i. Fairness

The fairness index for video flow when the number of user is at 30 and 60 is depicted in Figures 7(a) and 7(b)respectively. At a lower number of users, the fairness is deemed to have the same value of fairness regardless of the value of beta value used. However, at high number of users, the fairness is highest when beta is 0.1.



(a)

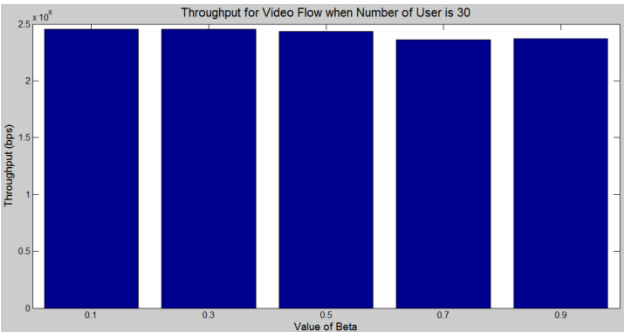


(b)

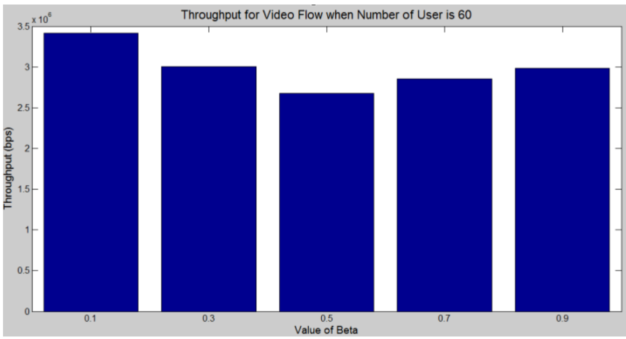
Figure 7: Fairness index for video flow when number of user is (a) 30 and (b) 60

ii. Throughput

Figures 8(a) and 8(b) illustrate the video flow's throughput for 30 and 60 users respectively. Both at low loads and high loads show that when β=0.1 is used, the throughput is keep highest among others.



(a)



(b)

Figure 8: Throughput for video flow when number of user is (a) 30 and (b) 60

VI. CONCLUSION

This study analyses the impact of different values of beta used in the EXP-BET algorithm. The performance of fairness and throughput of the EXP-BET algorithm was observed where the value of beta varied from 0.1 to 0.9. It was observed that a different value of beta has significant effect towards fairness and throughput performance.

For real-time services, both fairness and throughput performance was the best when β = 0.1 especially when there are high loads. Furthermore, the best effort flows also shows a higher fairness value when beta is 0.1.

This approach is interesting especially to operators in providing better fairness and throughput to users. Besides that, the cost to build a system that considers low and high loads could be reduced by the operator.

As a future recommendation, the performance of the EXP-BET algorithm in terms of QoS metrics of packet loss rate, fairness, throughput and delay and compare it with other algorithms will be investigated.

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