International Journal of Advanced Computational Engineering and Networking, ISSN: 2320-2106, Volume-3, Issue-7, July-2015

QOS-AWARE PROPORTIONAL FAIR (QAPF) DOWNLINK SCHEDULING ALGORITHM FOR LTE NETWORK

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Abstract- Long Term Evolution (LTE) supports several QoS (quality of services) classes and tries to guarantee their requirements. There are two main different QoS classes: Guaranteed Bit rate (GBR) such as VoIP and non-Guaranteed Bit Rate (non-GBR) such as FTP or HTTP. Having these different QoS requirements in packet domain introduces an additional challenge on the LTE MAC scheduler design. Therefore, the scheduler has to be aware of the different service requirements and satisfy them. In this paper, QoS aware proportional fair downlink scheduler (QAPF) is proposed. It can optimize the use of available resources while maintaining QoS requirements of different service classes. The result will show the performance evaluation of the proposed scheduler by comparing with others.

Keywords- LTE, QoS, GBR, nonGBR, QAPF

I. INTRODUCTION

Long Term Evolution (LTE) is an all-IP based future wireless communication network that is aiming to support a wide variety of applications and try to guarantee the requirements of the different services by defining the so-called “bearer” concept. A bearer is an IP packet flow between the user equipment and core network. In LTE system, wireless resources are available in both time domain (TD) and frequency-domain (FD) known as resource blocks RBs. As one of the core functionalities in radio resource management, packet scheduling (PS) plays an important role in optimizing the network performance and it has been under extensive research in recent years. Different PS algorithms have been deployed aiming at utilizing the scare radio resource efficiently.

In the paper, QAPF downlink scheduler first differentiates between different QoS classes mainly by defining several MAC bearer types such as Guaranteed (GBR) or non-Guaranteed (nonGBR) Bit Rate. Then, it generates the priority candidate lists for two bearer types in time domain (TD) scheduling. In the frequency domain (FD), physical resource blocks are assigned to each user according to the priority list. It aims at guaranteeing the QoS requirements of different service classes while maintaining the fairness and maximizing the system throughput. The paper is organized as follows: section II describes the works concerning the LTE packet scheduling scheme and section III presents the detail of proposed scheduling framework. Section V will give the result of the proposed scheduler. In section VI, conclusion and future plan are given.

II. RELATED WORKS

Some of the previous researches works that are related to the proposed system are described in this section.

Quality of Service (QoS), from as early as the IEEE 802.16 standard have been proposed, according to the needs of different users, providing different levels of service. In LTE, the established connection is divided into two categories, namely, Guaranteed Bit Rate (GBR), and Non-Guaranteed Bit Rate (non-GBR). GBR classes generally require lower latency (Delay) and constant bit rate, but will have a higher priority. Non-GBR classes are best effort services.

In O.S.Shin and K. Lee proposed Round Robin (RR) algorithm, which features provide the most complete fairness, each working in a unit of time have the same chance of being selected. In packet scheduling, it does not consider the quality of the user's channel condition. Although the benefit is provided between the users absolutely fair even when the user is in poor channel quality of service, it may lead to resources being wasted throughput.

In Toni Janevski told that Maximum C/I Scheduler (Max C/I) scheduler schedules the user with the best instantaneous channel quality. This scheduler is optimal in obtaining the maximum network throughput. However, it violates fairness because the users under the bad channel condition are unfavorable for the available services.

Proportional Fairness algorithm, which is implemented in High Data Rate (HDR) networks such as Universal Mobile Telecommunications System (UMTS), was introduced to compromise between a fair data rate for each user and the total data rate. It assigns the radio resources taking into account the instantaneous data rate and the past user experienced throughput. It can adjust the system throughput and fairness among users. However, it does not take into account the head of line (HOL) and packet delay which are importance for QoS of GBR service class. In, Gbolahan Aiyetoro et.al, made the performance analysis of Miximum Largest Weighted Dealy First

(M-LWDF) and Exponential Proportional Fair (Ex/PF) schedulers. These schedulers intend for GBR services by taking into not only channel condition but also head of line delay. However, they are not efficient for nonGBR services because they are delay based schedulers.

III. LTE RADIO INTERFACE

The LTE radio interface is the interface between eNodeB (eNB) and user equipment (UE). For downlink, LTE uses (orthogonal frequency division multiple access) OFDMA air interface as opposed to the CDMA (code division multiple access) and TDMA (time division multiple access) air interfaces, which means that the spectrum is divided into multiple subcarriers in the frequency domain and several OFDMA symbols in the time domain. SC-FDMA (Single carrier-OFDMA) is better for uplink because it has a better peak-to-average power ratio over OFDMA for uplink. The smallest unit defined within the LTE 3GPP specification that the scheduler can allocate over the radio is called Physical Resource Block (PRB). It consists of 12 subcarriers in the frequency domain and two slots in the time domain (i.e. 14 OFDMA symbols).

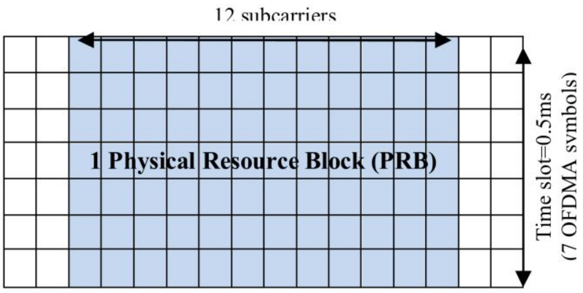

Figure 1. Downlink Resource Grid

Figure 1 shows the LTE downlink resource grid in over both time and frequency domains. Each subcarrier has 15 kHz bandwidth resulting in a PRB resolution of 180 KHz. This means that the LTE spectrum is divided into a number of PRBs. Table 1 shows the number of PRBs per each of the LTE transmission bandwidth. This number is not exactly the division of the spectrum by the 180 kHz since some of the subcarriers are reserved for signaling purposes.

Table 1: Number of PRBs per differ spectrum

LTE Spectrum (MHz)	1.4	3	5	10	15	20
Number of PRBs	6	15	25	50	75	100

IV. PROPOSED SCHEDULING FRAMEWORK

Figure 2 shows the general framework of the proposed scheduling scheme. The QAPF scheduler is divided into three main stages: QCI classification, TD and FD scheduling. The TD scheduler normally deals with addressing the issues related to the QoS requirements, whereas the FD scheduler deals with issues related to spectrum allocation and exploiting the users' in different channel conditions.

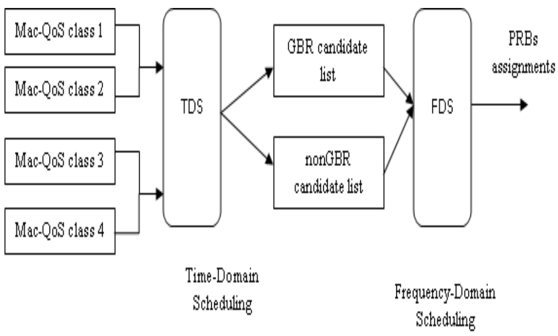

Figure 2. QAPF General Scheduler Framework

A. QCI Classification

The QAPF scheduler defines 4 different MAC-QoS-Classes: voice over IP (VoIP), live video streaming, video streaming from buffer and background traffic which represents the best effort (BE) class of traffic and don't have any QoS requirements. The first two are used for the GBR bearers, whereas the others are used for the nonGBR bearers. The scheduler maps the incoming IP packets into different MAC QoS classes which are shown in Table 2 of 3GPP TS 23.203(V11.3.0).

Table 2. CQI to MAC-QoS-Class mapping

Bear Type	Traffic Type	Priority	Packet Delay Budget	Mac-QoS Class
GBR	VoIP	2	100ms	Mac-QoS class1
	Live Video Streaming	4	150ms	Mac-QoS class2
nonGBR	Video Streaming	7	300ms	Mac-QoS class3
	Background (Email/SMS)	8	300ms	Mac-QoS class4

B. Time Domain Scheduling

The TD scheduler is responsible for prioritizing the bearers based on their QoS requirements. The TD scheduler separates the bearer's prioritization into two categories: GBR bearer's prioritization and nonGBR bearer's prioritization. The prioritization matrix for GBR list is mainly based on head of line delay (HoL). Before generating the prioritization matrix, the bearers

which have HoL delay exceeding the maximum delay budget are discarded such that:
If maximum delay budget, D_b,> HoL, then drop that bearer This can lead to avoiding the bandwidth wasting. For the prioritization matrix, emergency bearers which have delay closing to the maximum delay are first extracted such that If maximum delay budget,D_b, - HoL delay > minimum delay threshold, insert that bearer to the emergency list Then, these extracted emergency bearers are sorted in descending order according to their HoL delay. After prioritizing all emergency bearers, bearers whose delay below the minimum threshold are prioritized by using their HoL delay value. By giving the high priority to the bearers that can close to expiration, system spectrum efficiency can be good.

The priority matrix for nonGBR list is out of the delay consideration because of its best effort nature. The requirements of nonGBR service are mainly based on channel condition. Therefore, it is based on the instantaneous data rate. For the fairness consideration, it also takes into account of average channel throughput and for differentiating priorities among the nonGBR class of services, it considers weight factor according to the priority list in Table 2 of CQI standardized, i.e; video streaming of the nonGBR bearer is given higher weight value because it has higher priority than Background service (Email/SMS). The priority for bearer j at time t, $nonGBR\_P_j(t)$ is

$$nonGBR\_P_j(t) = \arg\max[w_j * \frac{r_j}{\overline{r_j}}] \quad (1)$$

Where, w_j is weight factor of bearer j, r_j is the instantaneous throughput and $\overline{r_j}$ is average throughput for bearer j.The time average throughput of user k is updated by the moving average as below as:

$$\overline{r_j}(t) = (1-\alpha)\overline{r_j}(t-1) + \alpha r_j(t) \quad (2)$$

where, $\alpha = \frac{2}{1+N}$ is scaling factor of N time period.

C. Frequency Domain Scheduling

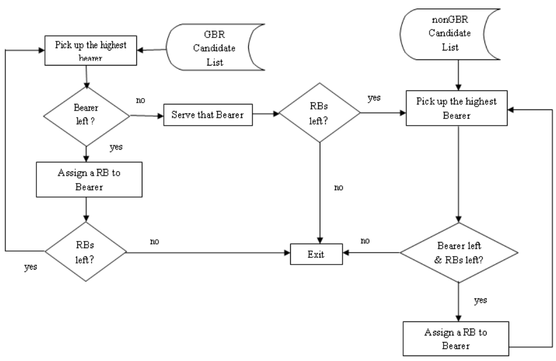

Figure 3: Frequency Domain Scheduling Scheme of Proposed Scheduler

The FD scheduler is responsible for distributing the radio interface resources (PRBs) among the different bearers. It uses the candidate list given by the TD scheduler as a basis for choosing which bearer should be served within next TTI.

As described earlier, two different candidate lists are used by the TD scheduler, a GBR and a nonGBR candidate lists. The FD scheduler starts assigning resources with the GBR list, the assignment of PRBs is done by giving each bearer one at a time, starting from the highest priority bearer to the lowest priority one at the end of the list. After all GBR bearers have finished, FD scheduler will continue to schedule the subset of nonGBR bearers and not the whole one as in the GBR case. The subset nonGBR list is chosen by picking the highest *N* nonGBR bearers from the top of the nonGBR candidate list. The reason for this is that the remaining PRBs may not enough to serve them all since the scheduler has already served all GBR bearers. Therefore, only the *N* highest priority nonGBR bearers are served within each TTI.

V. ANALYTICAL RESULT

In this section, the performance of proposed scheduler is compared with the proportional fair (PF), maximum largest weighted delay first (MLWDF) and exponential proportional fair (EXPPF). For this performance evaluation, LTE-Sim open source simulator for LTE network, is used. Table 2 shows the simulation parameters.

Table 2: Simulation Parameters

Parameters	Value
Simulation Duration	46 Sec
Number of users	5,10,15,20,25,30
Cell radius	1 Km
User speed	3 Km/h
Frame Structure	FDD
Bandwidth	10 MHz
Transmission time interval	1ms
Maximum Delay	0.1ms
Minimum Delay	0.05ms

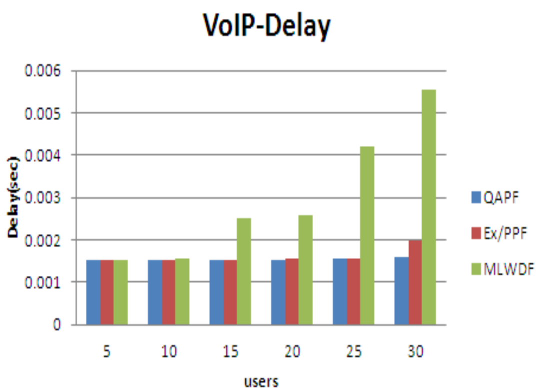

Figure 4: Average VoIP Delay Vs number of users

As shown in figure 4, QAPF has similar performance in delay with the comparison of MLWDF and Ex/PF. When the number of users is increased, it has higher performance in delay.

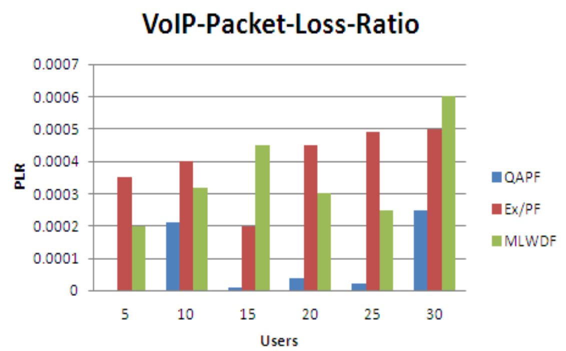

Figure 5: Average Packet Loss Rate (PLR) for VoIP users

Figure 5 shows that packet loss rate for QAPF is lower than MLWDF and EXPPF.

As shown in figure 6, throughput performance for VoIP users is similar to others.

According to figure 7, overall system spectrum efficiency for three schedulers is high when the number of users is low. When the traffic load is high, system spectrum efficiency falls. Among them, QAPF can cause lower system throughput than others because users with low channel condition, but more waiting time are scheduled to guarantee the QoS requirements of GBR services.

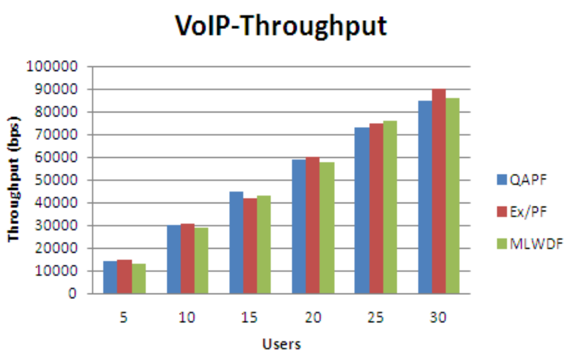

Figure 6: Average Throughput for VoIP users

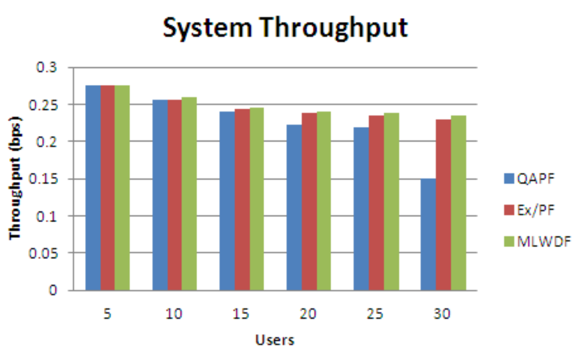

Figure 7: Overall System Spectrum Efficiency

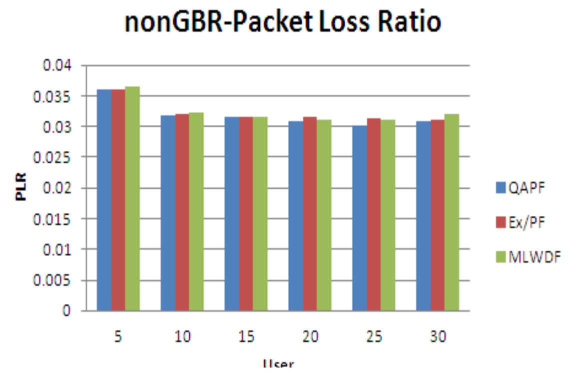

Figure 8: Packet Loss Ration for nonGBR services Vs number of users

Figure 8 shows the average packet loss ratio of nonGBR services (Video streaming or Background traffic).When the users are increased, QAPF has slightly higher performance in packet loss rate than other schedulers.

CONCLUSION

In this paper, QoS aware proportional fair (QAPF) downlink scheduler for LTE network is proposed. It can satisfy the QoS requirements of both GBR and nonGBR. Packet loss rate for GBR class is low because of giving highest priority to bearers which are close to deadline. Under the comparison of other schedulers, lower packet loss rate can be maintained for nonGBR bearers while GBR bearers are getting high performance in delay and packet loss rate. Indeed, fairness analysis of the proposed scheduler is working as our future work. Our proposed algorithm will be compared other delay based schedulers also in future.

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