Performance Analysis of a Scheduler for Multiple Traffics of LTE Network

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Abstract

Long Term Evolution(LTE)can support multimedia services.To guarantee the different requirements of the different services, packet scheduler plays an important role in LTE. Especially, the additional challenges are exposed to the design of scheduler when real time traffics such as VoIP (voice over IP) are transmitted over the LTE network.In this paper, a new scheduler is proposed for satisfying the different QoS requirements. This scheme distinguishes whether this connection is real time or not and give the high priority to real time traffics which are closing to time out. After scheduling allreal time traffics, delay tolerant traffics are scheduled.The performance of the proposed scheduling schemeis evaluated in terms of throughput, average delay and fairness. The result will be proofed by comparing with another LTE downlink schedulers.

1.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 [1]. In LTE system, there are two main bearer types [2]: Guranteed Bit Rate (GBR) which is real time traffic such asVoIP and non-Guaranteed Bit Rate (nonGBR)which is streaming such as data flow. 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 low-to-average power ratio over OFDMA for uplink. The smallestunit defined within the LTE 3GPP specification that the scheduler can allocate over the radioiscalledPhysical Resource Block (PRB). It consistsof 12 subcarriersin the frequency domain andtwoslotsin the time domain (i.e. 14 OFDMA symbols).

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

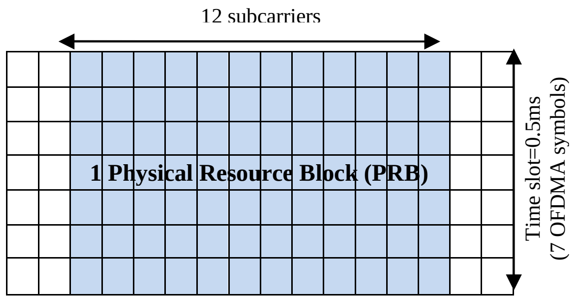

Figure 1: Downlink Resource Grid

Table 1: Number of PRBs per different spectrum

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

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, the 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, itgenerates the priority candidate lists fortwobearer types in time domain (TD) scheduling.In the frequency domain (FD),physical resource blocks are assigned to each user according tothepriority list. It aims at guaranteeing the QoS requirements of different service classes.

The paper is organized as follows: section 2 describes the works concerning the LTE packet scheduling scheme. The detail of proposed scheduling framework will be described in section 3. Section 4 will give the result of the proposed scheduler. In section 5, conclusion and future plan are given.

2. Related Works

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

Quality of Service (QoS), from as early as the IEEE 802.16 standard [3] 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 [4] O.S.Shin and K. Leeproposed 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 [5] Toni Janevski told that Maximum C/I Scheduler (Max C/I) scheduler schedules the user with the best instantaneous channel quality. Thisscheduler 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 (PF) algorithm[6], which is implemented in High Data Rate (HDR)networks such as Universal Mobile Telecommunications System (UMTS), was introducedto 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. Being $r_j(t)$ is the maximum expected throughput for user j at time t and $\overline{r_j}(t)$ is the average past throughput for user j until time t, the priority matrix for PF is given by

$$P_j(t) = \frac{r_i(t)}{\overline{r_j}(t)} \quad (1)$$

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 [7], GbolahanAiyetoro et.al, made 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.

In [8],Pedro Junior Ashidani et.al, proposed a scheduler based on deadlines for LTE network. This scheduler adds deadline consideration to proportional fair for prioritizing the users who are close to deadline. The deadline of user $j, (DL_j)$ is calculated in terms of maximum delay threshold for each traffic class i, D_i, and head of line delay for user j of class $i, HoL_{i,j}$as follows:

$$DL_j = D_i - HoL_{i,j} \quad (2)$$

The priority matrix for this scheduler modifies to PF scheduler with delay consideration as follows:

$$P_j(t) = \frac{r_i}{\overline{r_i} * DL_j} \quad (3)$$

However, the situation in which delay is exceeding the maximum delay budget is out of scope although deadline is considered for avoiding delay violation. The resource allocation for this scheduler focuses just on real time traffic.

3. Proposed Scheduling Framework

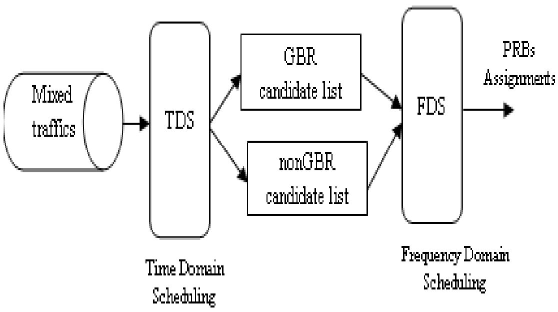

Figure 2: General Framework of Proposed Scheduler

Figure 2 shows the general framework of proposed scheduler. The scheduler is divided into three parts: (1) traffic differentiation (GBR or nonGBR) ,(2) Time Domain (TD) scheduling, and (3) Frequency Domain (FD) scheduling.

3.1. Traffic Classification

In the framework, the scheduler classifies the mixed traffic into GBR or nonGBR . It maps the IP packets of the traffics to the corresponding bearer type as shown in table 2 of 3GPP TS 23.203(V11.3.0) [9].

Table 2: Standardized QoS Class Identifiers (QCIs)

Bearer Type	Traffic Type	Priority	Packet Delay Budget
GBR	VoIP	2	100ms
	Live Video Streaming	4	150ms
	Real Time Gaming	3	50
	Video (Buffer Streaming)	5	300
nonGBR	IMS Signaling	1	100
	Interactive Gaming	7	100m
	Application with TCP: browsing, email, file download, etc	6	300ms
		8	300
		9	300

3.2. 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 considersweight factor according to the priority list in Table 2 of CQI standardized, i.e; interactive gaming 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

$$nonGBR_{P_i}(t) = argmax\left[w_j * \frac{r_j}{\bar{r}_j}\right] \qquad (4)$$

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:

$$\bar{r}_j(t) = (1-\alpha)\bar{r}_j(t-1) + \alpha r_j(t) \qquad (5)$$

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

3.3. Frequency Domain Scheduling

The frequency domain (FD) scheduler is responsible for distributing the physical resource blocks (PRBs) among the different bearers.It uses the candidate list given bythe TD scheduler as a basis for choosing which bearer should be served within next TTI.

FD schedulingscheme of the proposed scheduler is shown in figure 3. As described earlier, two different candidate lists are generated by the TD scheduler: a GBR and a nonGBRcandidate lists, are used. 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.

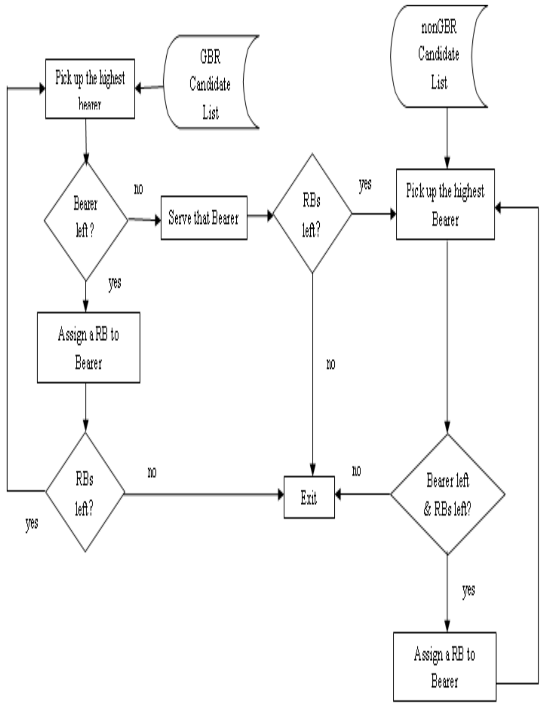

Figure 3: Frequency Domain Scheduling Scheme of Proposed Scheduler

4. Analytical Result

In this section, the performance of proposed scheduler for GBR service is compared with another scheduler based on deadlines [8].LTE-Sim [10],open source simulator for LTE network, is used for evaluation. Table 3 shows the simulation parameters. In the analysis, VoIP is considered asthe representative of GBR services. Bufferdata is tested as data flow of nonGBR services.The measurements which are used in the experiments are as follows:

Average delay : time from the arrival toqueue until the departure from queue

Average throughput: total data received by all users over the simulation time

Fairness : determination of whether users are receiving a fair share of system resources. In [10], Jain's fairness index is used to measure among users as given below:

$$F = \frac{(\sum_{i=1}^{n} x_i)^2}{n * \sum_{i=1}^{n} x_i{}^2} \qquad (6)$$

Where, there are n users in the system and x_i is the number of PRBs to user i.When all UEs have the same throughput, the value of fairness index is 1 andthis indicates the highest fairness.

Table 3: 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

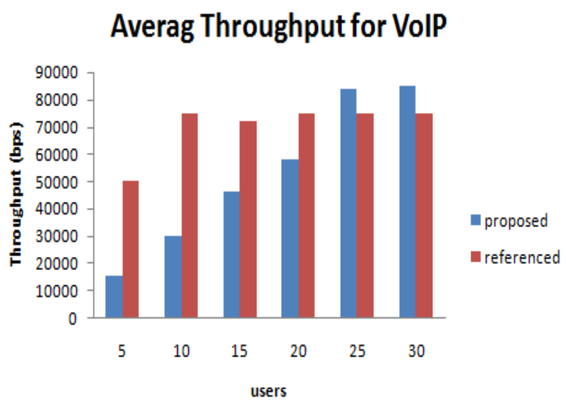

Figure 4. Average Throughput of VoIP Vs users

According to Figure 4, although referenced scheduler has good performance in throughput under the low traffic, the proposed scheduler has higher performance when the number of users is increased.

As shown in Figure 5, the proposed scheduler has good performance in delay for VoIP users.

For fairness, proposed scheduler is compared with Proportional Fair (PF) [6] which is guaranteed for fairness of nonGBR. Figure 6 shows that my scheduler can give higher fairness than PF until 25 users.

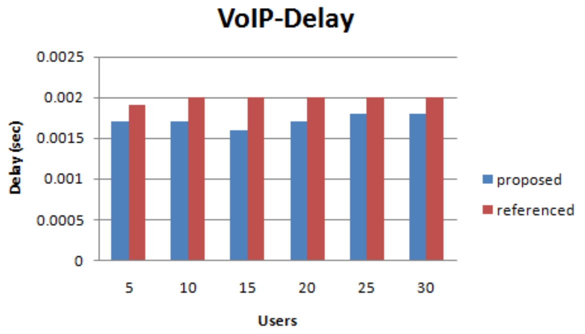

Figure 5. Average Delay for VoIP Vs Users

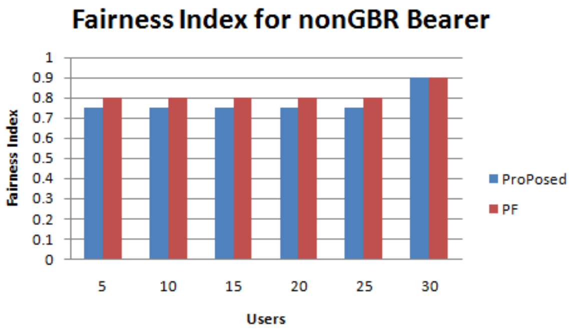

Figure 6. Fairness Index of nonGBR Bearer

5. Conclusion

In this paper, a new scheduler for multiple traffics of LTE network is proposed.This scheme first distinguishes that traffics areGBR services or nonGBR services. It gives the high priority to GBR services which are closing to dead line. Moreover, the traffics which are over the maximum delay budget are dropped for the purpose of avoiding bandwidth wasting. The performance of the proposed scheduling scheme is evaluated in terms of throughput and average delay and fairness. According to experiments, it can satisfy the QoS requirements of GBR traffics while maintaining the certain degree of fairness among nonGBRservices.

Indeed, this scheduler is part of my research. This scheduler will be tested under more traffic load.

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