

Resource Allocation by Pondering Parameters for Uplink System in LTE Networks

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Abstract—Long Term Evolution (LTE) Networks were proposed for serving a multitude of high-speed data-rate services. For such systems, the Quality of Service (QoS) at the wireless part needs to be guaranteed by using smart, fast and strong resource allocation mechanisms. In order to build such algorithms, several parameters such as channel conditions, packet delays, queue length sizes and flow bitrates should be used to compute a maximization metric. Most authors compute such metric by obtaining the product of the afore-mentioned parameters. We consider this fact as a huge mistake. In this paper, we analyse the relevance of each parameter and give them different pounds. We propose a new resource allocation algorithm that presents a low complexity level. It works in a heterogeneous service scenario real time (RT) and non-Real Time (NRT). In order to evaluate the performance of our algorithm, several QoS constraints such as throughput, Packet Loss Ratio (PLR) and Fairness Index (FI) are used.

Keywords—Wireless, QoS, LTE, SC-FDMA, uplink, scheduling.

I. INTRODUCTION

Resource allocation has become an important task in fourth-generation wireless networks such as LTE. LTE architecture is built to support high-speed data rates. LTE uses OFDMA (Orthogonal Frequency-Division Multiple Access) for downlink and SC-FDMA (Single Carrier Frequency Division Multiple Access) for uplink. SC-FDMA offers significant improvements in terms of throughput and spectral efficiency. It admits multi-user diversity and adaptive modulation and coding, hence it is qualified to exploit channel conditions for the resource allocation task.

In wireless systems such as LTE, the QoS that is guaranteed by the backhaul, could be seriously degraded by an inadequate resource allocation management. If the bandwidth is not wisely distributed, a minimal QoS level might not be assured. Thus, an optimal and robust resource allocation mechanism is required.

In order to perform the decision making process when scheduling, several parameters such as channel conditions, packet delays, queue length sizes and flow bitrates need to be taken into account. We deeply consider that those parameters do not possess the same characteristics, neither the same importance; therefore, they do not deserve to be treated as

equals when taking decisions. RT applications such as VoIP, online gaming, and video conferencing and NRT applications such as HTTP, FTP, P2P are examples of applications to be widely used in LTE.

In the resource allocation task, researches have started to propose schemes for uplink system. Several mechanisms based on opportunistic approaches have been introduced in [6]. Schedulers with Proportional Fairness (PF) based utility function such as First Maximum Expansion (FME), Recursive Maximum Expansion (RME), and Minimum Area Difference (MAD), Proportional Fair - Frequency Domain Packet Scheduler (PF-FDPS) are introduced and tested in [11][9]. In [2] the authors propose two algorithms: A Greedy Strategy Based Algorithm (GSBA) and a Local Ratio Technique Based Algorithm (LRTBA). A deep analysis including complexity, stability is presented, however, both algorithms are not able to differentiate between RT and NRT services.

In [12] a study related to delay-bounded combined with channel conditions and transmit power for packet scheduling is proposed. A different mechanism of delay-based algorithms is introduced in [13]. This algorithm computes the packet delays by estimation. The results show a good performance when using this technique.

Multiclass based algorithms take into account the flow classes to perform the scheduling decision-making granting efficient results for all classes [14][15][3]. These algorithms are built to prioritise RT flows without neglecting NRT ones. Those approaches are the most close to LTE requirements.

This paper is organised as follows. In Section II we present the uplink system model. In Section III we describe the method for pondering parameters and compute the metric for the decision-making performance. In Section IV we propose a resource allocation mechanism for scheduling. The simulation environment scenario and the traffic model are described in V. Numerical results are analysed and exposed. And finally Section VI concludes this paper.

II. CONSIDERED UPLINK SYSTEM MODEL

In LTE Networks, the eNodeB is the entity in charge of performing the resource allocation task. The Packet Scheduler (PS) is the controlling entity located in the MAC layer, and deals with allocating RBs to UEs at every Transmission Time Interval (TTI) of 1ms. In SC-FDMA, resources to be assigned to the same UE must be contiguous in the frequency domain.

This work is part of the SOAPS project, supported by: the French Ministry of Industry, the department of Essonne, and the department of Yvelines.

UEs ask for resources from the eNodeB depending on their queue status. Let us consider a cellular network whose uplink system bandwidth is divided into m RBs, each single base eNodeB n active UEs. The eNodeB can allocate m RBs to a set of n UEs. At each time slot, multiple RBs (with the contiguity constraint) can be assigned to a single UE. The eNodeB monitors the channel conditions of each UE over the entire bandwidth. Each UE sends its Channel State Information (CSI) to the eNodeB. This information is composed by the quality of channel and its Buffer Status Report (BSR), information that is related to the amount of buffered data to be transmitted and their priority.

An important parameter is the packets delay (the time that a packet waits in the queue before being served). It limits the time that packets can wait in the queue. Packets exceeding this time threshold are classified as expired and removed from the queue. This causes packet losses and retransmissions. On the other hand, when using the channel conditions as the main metric for the decision making process, it is highly likely to experience resource waste. Thus, the quantity of RBs granted to users by the scheduler must be limited to the users needs even if they possess the "perfect" channel conditions.

III. PARAMETERS PONDERING

A. Multi-Criteria Decision Making (MCDM)

We model our resource allocation scenario as a decision-making problem where: there is only an entity in charge of the decision making performance, and this decision is based on several parameters. This brings us to a Multi-Criteria Decision Making (MCDM) problem. MCDM is the most well known branch of decision-making. MCDM deals with decision situations where there are several conflicting objectives. We model our resource allocation problem by MCDM as follows: The eNodeB is the decision maker M that aims to reach several objectives such as reducing the delays, increasing the throughput gain and reducing the PLR when transmitting data to users U and vice versa. This objective must be reached by using n multiple criteria $C_1, C_2, C_3, \dots, C_n$ such as channel conditions, delays, queue lengths, etc. In order to choose the user who possesses the best metric, the classic maximization function is computed as follows:

$$U = \max(C_1 \cdot C_2 \cdot C_3 \cdot C_n) \quad (1)$$

We consider Formula (1) as a mistake, because the parameters used to perform the decision making are heterogeneous, therefore they cannot be treated as equals. Assigning weights to each criteria is a method to differentiate criteria importance. We modified Formula (1) by adding weights $w_1, w_2, w_3, \dots, w_n$ to criteria.

$$U = \max(C_1(w_1) \cdot C_2(w_2) \cdot C_3(w_3) \cdot C_n(w_n)) \quad (2)$$

where: $w_1 + w_2 + w_3 + \dots + w_n = 1; w_n \in \mathbb{R}; 0 < w < 1$

In Formula (2) weights must be assigned. This point is open for decision makers in MCDM models. The decision maker should create the hierarchical weighting to build Formula (2).

Nevertheless, this decision/judgement has to be wisely taken based on any mathematical method to represent this weights as scalar relative values. Let us take our scenario as an example.

Table I: Decision making parameters

Parameters	Values	Importance (weights)
Channel Conditions	C_{ch}	w_{ch}
Type of Service GBR/NonGBR	C_{gbr}	w_{gbr}
Packet queue lengths	C_{pql}	w_{pql}
Service Bit-rate	C_{sb}	w_{sb}

Table I shows four potential parameters to be used in up-link scheduling decision making. There exist several possible combinations for granting an estimated hierarchy importance among those parameters. Let us randomly take one of 2^n possible combination.

$$C_{ch} > C_{gbr} = C_{pql} > C_{sb} \quad (3)$$

In Formula (3) we assume that "Channel conditions" are more important than the "type of service" and "Packet queue lengths" which are in the same importance level. Finally, the "Service Bit-Rate" is the less important. This assumptions must be justified by any validation method. Since there is no mathematical process to validate it, we use simulations. In the next step, this importance levels (weights) must be expressed with scalar relative values by following the conditions presented in Equation 2.

B. The Centroid Method (CM) for estimating weights

The centroid Method was introduced by Solymosi and Dombi in [7]. Weight values are obtained by averaging extreme points, as an estimate of the true set of weights. For n factors, the weight of each factor will be for factor $K = 1$ to n ,

$$\frac{\left(\sum_{i=k}^n \left(\frac{1}{i}\right)\right)}{n} \quad (4)$$

Based on Table I and Equation 4, let us build the following process: $w_{ch} > w_{gbr} = w_{pql} > w_{sb}$

Table II: Computing weights

w_{ch}	w_{gbr}	w_{pql}	w_{sb}
1	0	0	0
0.5	0.25	0.25	0
0.25	0.25	0.25	0.25
0.58	0.17	0.17	0.08

Thus, having the weight values $w_{ch}=0.58$, $w_{gbr}=0.17$, $w_{pql}=0.17$ and $w_{sb}=0.08$ the Equation 2 is complete.

IV. PROPOSED SOLUTION:

PONDERING PARAMETERS SCHEDULING (POPAS)

The parameters used in our method to perform the decision making process are channel conditions, packet queue size, and Modulation and Coding Scheme (MCS) values.

In order to introduce our method, let us define the following sets where A represents a set of n users and B represents the channel conditions of each user of the set A . Having the channel conditions, it is possible to compute the MCS values which is represented by C . And finally, D represents the total quantity of resource blocks to be distributed among n users. $A = \{u_1, u_2, u_3, \dots, u_n\}$, $B = \{c_{u1}, c_{u2}, c_{u3}, \dots, c_{un}\}$, $C = \{p_{u1}, p_{u2}, p_{u3}, \dots, p_{un}\}$, $D = \{rb_1, rb_2, rb_3, \dots, rb_m\}$, $D \subseteq \mathbb{Z}\{1, m\}$. Let us define δ as the metric to be used to compute the chunk of resource blocks for each user.

$$\delta = \frac{\sum_i^m rb_i}{\sum_i^n p_{ui}} \quad (5)$$

In order to compute the chunk of resource blocks γ belonging to each user, δ should be multiplied by each MCS value of each user.

$$\gamma = \delta \cdot p_{ui} \quad (6)$$

Set $E = \{\delta p_{u1}, \delta p_{u2}, \delta p_{u3}, \dots, \delta p_{un}\}$ contains the portion of RBs for each user. Considering that $E \subseteq \mathbb{Z}\{1, m\}$, it is not possible to allocate $RB's < 1$, therefore, only chunks greater than 1 will be taken into account. So, let us consider $E' \subset E$, $E' \subseteq \mathbb{Z}\{> 1\}$.

V. PERFORMANCE ANALYSIS

A. Simulation Environment

The simulation scenario is set with a single cell with no neighbouring interference that transmits 40% video, 40% VoIP and the remaining 20% NRT flows. Users are randomly distributed among cells and constantly moving at a speed of 3 *kmph* in random directions. LTE-Sim simulator is used to perform this process [4].

Table III: LTE downlink simulation parameters

Parameters	Values
Simulation duration	100 s
Frame structure	FDD
eNodeB Radius	1 km
Bandwidth	10 MHz
Slot duration	0.5 ms
Scheduling time (TTI)	1 ms
Number of RBs per eNodeB	50
Max-delay	0.1 s
Video bitrate	128 kbps
Voip bitrate	8.4 kbps
NRT bitrate	20 kbps
Number of Cells	1
Confidence Interval	95%
Mobility model	Random Walk
Multipath	Jakes model
PenetrationLoss	10 dB
Shadowing	log-normal distribution (mean = 0dB, S. = 8dB)

B. Traffic Model

A video service with 128 *kbps* source video data rate is used in the simulation. This traffic is a trace based application that sends packets based on realistic video [5]. The voice flow is modeled with an ON/OFF model. During the ON period, the source sends 20 byte sized packets every 20 *ms* (i.e., the

source data rate is 8.4 *kbps*), in the OFF period the rate is zero, the presence of a Voice Activity Detector is assumed. Since modeling NRT services (i.e. HTTP, SMS, P2P) is hard, we use CBR traffic as a parasite flow which sends packets all the time. The propagation loss model is composed by 4 different models which are taken from the 3GPP specifications [4].

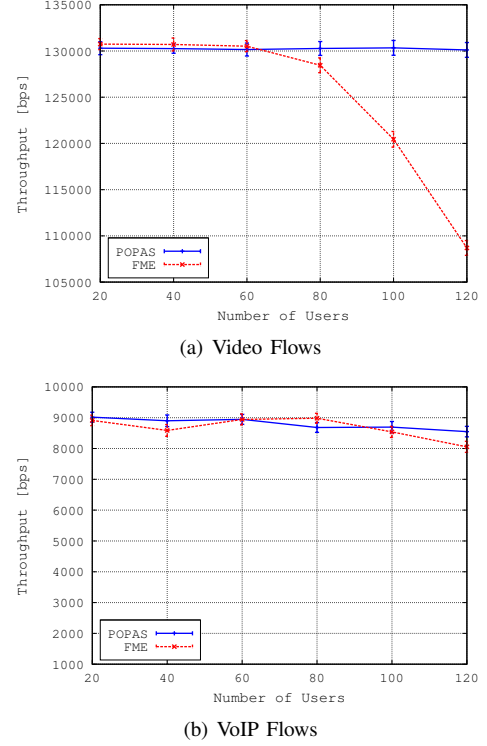
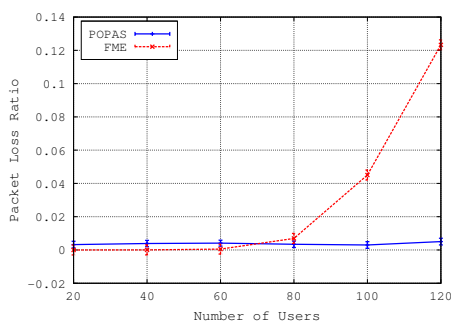


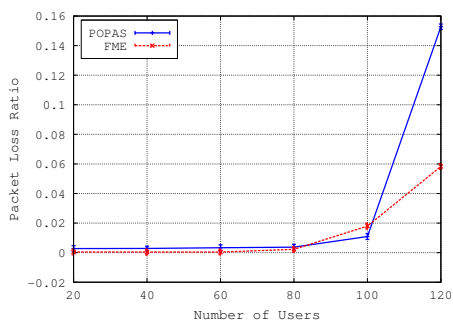
Figure 1: Average throughput per user

C. Results Analysis

In order to depict the behaviour of our proposed solution named POPAS, we compare it to FME Algorithm. Since POPAS uses packet queues length as a parameter to compute the decision-making metric, video flows get priority for allocation. This can be easily explained by the fact that high data-rate flows possess the longest packet queues. Since packet queues length is not the most important parameter for the decision making, VoIP and flows get also a desired allocation. POPAS shows a higher fairness index compared to FME for all classes of flows as shown in Figures 3(a) and 3(b). The Jain's Fairness Index method is used [10]. A fundamental factor to achieve such a good result can be explained by the fact that POPAS does not serve only the user who possesses the best channel conditions, but the group of users that possess the best channel conditions. When increasing the number of users being served by the eNodeB, the packet delays in the queues are shorter, therefore packet losses caused by expired packet delays in queues decrease. This means that PLR also decreases accordingly and throughput decrease is partially mitigated.

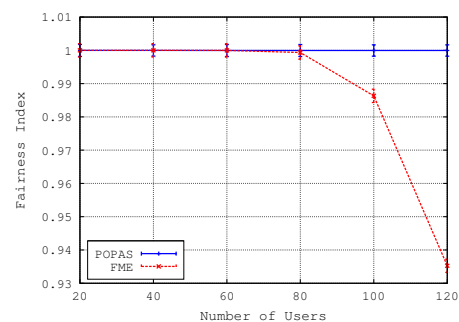


(a) Video Flows

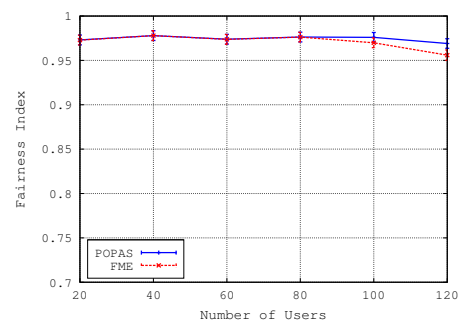


(b) VoIP Flows

Figure 2: Packet Loss Ratio



(a) Video Flows



(b) VoIP Flows

Figure 3: Fairness Index

VI. CONCLUSIONS

In this paper we introduced a new scheduler for uplink system named POPAS. This study focused on the performance of RT and NRT services. Our scheme performs a resource allocation task based on user needs, queue status and channel conditions and pondering parameters. This paper has provided convincing evidence of the importance of assigning weights to parameters when computing the scheduling metric. Unless our approach seems to be a potential mechanism for optimizing the scheduling task, a wise judgement about the importance of each parameter made by the decision maker is needed. Future works shall focus on testing the robustness of our approach under multi-cell scenarios taking into account the users transmit power level and interferences models.

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