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To cite this version:

Aicha Ben Salem, Seifeddine Bouallegue, Kaouthar Sethom. A QoS based Resource Allocation in Femtocell Networks. The 12th IEEE International Conference on Embedded and Ubiquitous Computing (EUC 2014), Aug 2014, Milan, Italy. pp.299-303, 10.1109/EUC.2014.51 . hal-01202356

HAL Id: hal-01202356

https://hal.science/hal-01202356v1

Submitted on 7 Apr 2016

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A QoS based Resource Allocation in Femtocell Networks

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***Abstract*- LTE has been identified as a new wireless standard by the 3rd Generation Partnership Project (3GPP) which is using the VoIP to transmit the voice services and packet the data for all services. Traffic scheduling plays an important role in LTE technology by assigning the shared resources among users in the most efficient manner.**
The main objective of this paper aims to design an efficient scheduling algorithm for LTE standard. It can not only obtain the high system performance but also maintain the proportional fairness. Each user is allocated the requested resource according to the predefined QoS parameters. The scheduling algorithms performances on the downlink were measured using a MATLAB based system level simulation.

***Keywords: Wireless networks, long-term evolution, resource allocation*.**

I .INTRODUCTION

A solution to maintain this LTE performance in user dense areas or areas with bad reception is the deployment of so-called femtocells. Femtocells are small base stations that are deployed indoors and share the RF spectrum with the whole mobile network. The idea is that femtocells will increase mobile operators network coverage and capacity while it at the same time increase users data throughput.

The QoS provisioning has been an important issue in the mobility management of wireless femtocell networks [1-5]. To provide QoS in wireless networks, the Radio resource management (RRM) plays a crucial role in managing the limited radio resources effectively [6]. The Packet Scheduler is an entity of RRM in LTE that resides in the MAC layer of eNodeB [7-8]. It is responsible for the allocation of shared radio resources among the mobile User Equipments (UEs). The scheduler assigns resources to users with the granularity of resource blocks (RBs) every TTI, based on the channel condition feedback received from UEs in the form of Channel Quality Indicator (CQI).

Due to the importance of the scheduling process at the MAC layer in LTE, various packet scheduling algorithms have been developed to support RT and NRT services, comprising the most commonly used Proportional Fair (PF), M-LWDF and Exponential Proportional Fair (EXP-PF) schedulers [1-4]. With regard to the previously mentioned schedulers, each flow is assigned a metric value depending on specific measurements. Therefore, the bearer which carries the flow with the highest metric value will be scheduled first at the correspondent, Transmission Time Interval (TTI).

The QoS guarantees become more feasible when radio resources are allocated according to the well-defined demands of traffic types rather than by estimation. In this paper, we focus on how to perform scheduling at the eNobeB while providing QoS to users according to their needs and network access priority.

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II. PROBLEM STATEMENT

Traditionally, macrocellular networks require complex and expensive manual planning and configuration. Currently, 3GPP LTE-Advanced and IEEE 802.16m are standardizing the Self Organizing Network (SON) concept for IMT-Advanced networks. The main functionalities of SON for integrated femtocell/macrocell networks are self-configuration, self-optimization, and self-healing [9]. The self-configuration function includes intelligent frequency and bandwidth allocation among neighboring F-BSs; self-optimization attribute includes optimization of transmission power among neighboring F-BSs, maintenance of neighbor cell list, coverage control, and robust mobility management; and self-healing feature includes automatic detection and resolution of most failures. Fig1. shows the basic features and framework of the proposed SON-capable integrated femtocell/macrocell network architecture.
Network operators may need to deploy the hierarchical femtocell network architecture based on centralized or distributed manner. The centralized architecture is necessary for cooperative hotspot coverage, but the distributed and flat way is required for individual, ad-hoc, and random femtocell coverage.
In this paper, we propose a decentralized resource management with open access mode in Femtocell networks.

III. Proposed Resource Allocation

Our solution consists of two steps:

A. *Distribution of the total bandwidth among traffic classes*

To resolve this resource allocation problem [8] proposed to use game theory. Game theory is a mathematical tool for analyzing the interaction of two or more decision makers. A (strategic) game consists of three components: a set of players, the strategy set for each player and a utility (payoff) function for each player measuring the degree of "happiness" of the player. The users interaction in a wireless network can be modeled as a game in which the users terminals are the players in the game competing for network resources (example bandwidth). Any action taken by a user affects the performance of other users in the network. Game theory is the natural tool for studying this interaction.

The resource allocation problem is where a finite divisible bandwidth capacity B must be divided among a set N of flow users. For each class A_n, each group of k_i flows claim a bandwidth share$b_i \in R_+$. The vector of class resources claim is denoted as $g \equiv (g_i)_{i \square N}$, with g_i is the product of *ki* and b_i , $g_i = k_i\, b_i$.
Each player is represented by a class. The benefit of this division is the total resources at each TTI. A coalition is defined when several classes share an amount of resource, and the benefits should be distributed between all of the members of the coalition.

We consider a dynamic allocation process, and the number of users in each class is variable. In a bandwidth allocation problem, the classes of users represent the players who benefits from capacity B. We define 3 users classes as players in our scenario N= {UsP1, UsP2, USP3 }while taking into account their priority level in the femtocell system:

- UsP1 : Users with priority P1
- UsP2 : Users with priority P2
- UsP3 : Users with priority P3.

To resolve this resource allocation problem we propose to use the simple equation (1):

(1)

$$B_{Pk} = \min\left(B - \sum_{i=0,k-1} b_{pi} \; ; \; \sum_{i=0,2} n_i(P_k) \times b_{pk} \right)$$

Where
- B_{Pk}: is the bandwidth allocated to the priority class Pk.
- $n_i(P_k)$: the number of flow of type i in the class Pk

Following equation (1), we can see that users with higher priority are satisfied before the others. At each TTI, a new redistribution of resources is performed. When a new flow joins the network and claims for resources, the arbitrator must start to re-divide the bandwidth, this is executed in the next TTI. Each class has its corresponding bandwidth chunk and must divide the resource among their flows.
Our solution is less complex than [8] where at each TTI, a new heavy redistribution of resources is performed through game theory (CPU and time consuming). When a new class of users joins the game and claims for resources, the femtocell must start a new game to re-divide the bandwidth, this is executed in the next TTI.

In our case, each class has its corresponding bandwidth chunk and must divide the resource among their users.

Total Bandwidth [T]	32000
	Value b
A) Video (kbps)	242
B) Voip (kbps)	8,4
C) CBR (kbps)	2

	Application	Numbers of flows(k)	total g (g=b*k)	
	Video	100	24200	
Class_users_P1	Voip	30	252	
	CBR	40	80	
			Bandwidth_P1	24532
			Rest	7468
	Video	30	7260	
Class_users_P2	Voip	10	84	
	CBR	40	80	
			Bandwidth_P2	7424
			Rest	44
	Video	30	7260	
Class_users_P3	Voip	10	84	
	CBR	40	80	
			Bandwidth_P3	44
			Rest	0

Fig.1 Bandwidth allocation

An example is shown in Figure 1. The femtocell total bandwidth is 32Mb. It must be shared between (100 video, 30VoIP,40 CBR) users from UsP1 and (30 video, 10VoIP,40 CBR) from UsP2 and (30 video, 10VoIP,40 CBR) from UsP3.
As we can see the execution of the algorithm satisfies P1 users first then P2 one, the remaining bandwidth is for P3 clients.

B. *Step 2: Packet scheduling*

Due to the voluminous and equal growth of multimedia services and NRT services, it is worth thinking of tailoring a downlink packet scheduling scheme that copes with both service classes simultaneously, delivers balanced QoS and utilizes the system radio resources efficiently.

Resource allocation for each UE is usually based on the comparison of per-RB metrics: the *k*-th RB is allocated to the *j*-th user if its metric *mj;k* is the biggest one. QoS differentiation is handled by associating a set of QoS parameters to each flow. Knowing the values of such parameters, the scheduler can treat data to guarantee some minimum required performances, either in terms of guaranteed data rates or of delivery delays.

Almost all QoS aware schedulers is somehow inspired by the classical proportional fair (PF) scheduler [1]. We note that the PROP-FAIR rule does not account for delays of packets and can result in poor delay performance. M-LWDF algorithm thus incorporates HOL packet delay together with PF properties (e.g. the ratio of achievable data rate to the average data rate) when determining users' priority. M-LWDF prioritizes the user with higher HOL packet delay and better channel conditions relative to its average levels [2]. A very promising strategy was presented in [5]. It adopts the consideration of the queue size and the packets delay parameters in the VT-M-LWDF and M-LWDF rules respectively.

The scheduling rule is given by:

(3)

if $i \in RT/NRT$

$$m_j(t) = max_i \left\{ a_i(t) \times \mathrm{d}_{Hol,i}(t) \times Q_i(t) \times \frac{\mu_{i,j}(t)}{\overline{\mu_i}} \right.$$

Where

- $\mu_i(t)$ denotes the data rate corresponding to the channel j state of the user i at time slot t,
- $\overline{\mu_i}$ is the mean data rate supported by the channel j.
- $\mathrm{d}_{HOL,i}(t)$ is the HOL packet delay
- $a_i(t)$> 0, i = 1, ...,N, are weights, which define the required level of QoS.
- Q*i*(t) is the token queue length (a counter value at time t)

Because of users' priorities P*n*, for each class of users' priority, we attribute different maximum target delay that users can tolerate: T_{in}

(4)

$$a_{i,n} = \frac{-\log(\sigma_i)}{T_{i,n}}$$

σ_i Represents the maximum probability for HOL packet delay to exceed the delay threshold of user *i* and $T_i$defines Target Delayfor the ith user.

The scheduling rule becomes:

(6)

For i $\in RT/NRT$

$$m_{j,n}(t) = max_i \left\{ a_{i,n}(t) \times \mathrm{d}_{Hol,i}(t) \times Q_i(t) \times \frac{\mu_{i,j}(t)}{\overline{\mu_i}} \right.$$

VI. PERFORMANCE RESULTS

MATLAB and LTE-Sim simulator [6] are used to perform our tests. We use a single cell scenario where users are moving at speed of 3 km/h in random directions (random walk). LTE-Sim simulator is used to perform tests.

As it can be seen in Figure 2, two classes P1 an P3 are competing for the bandwidth resources. Our bandwidth algorithm treats in priority P1 traffic, even if no more resources are available for the rest of classes. In fact after serving P1 users the rest of bandwidth is equal to 40Kbps; the total RBs for the class P3 is zero because 40Kbps doesn't satisfied one Video stream.

To better understand the obtained results in figure 3, the following notations are used: "EXP" represents the exp rule

scheduler; “ML” for M-LWDF algorithm,“S” represents our solution.

With respect to these measures (Figure 3), we found that our new algorithm performs the best among the classical scheduler because it treats differently any type of flows RT and NRT.
Our results show that our mechanism used in conjunction with an intelligent scheduling algorithm can improve the efficiency of this algorithm for multimedia services.

Due to the voluminous and equal growth of multimedia services and NRT services, it is worth thinking of tailoring a downlink packet scheduling scheme that copes with both service classes simultaneously, delivers balanced QoS and utilizes the system radio resources efficiently. In other words, the users nowadays request not only video and VoIP services but also CBR, Internet browsing and best-effort services simultaneously.
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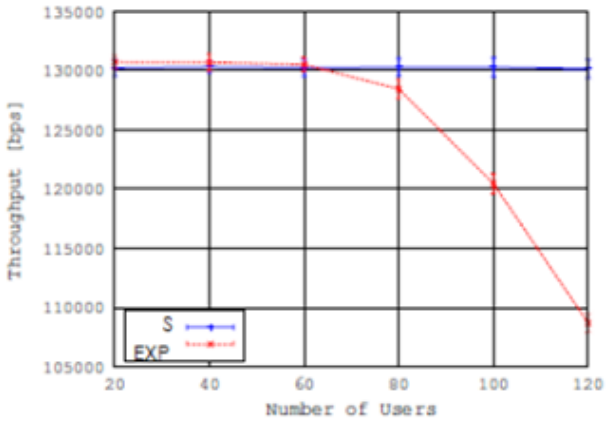
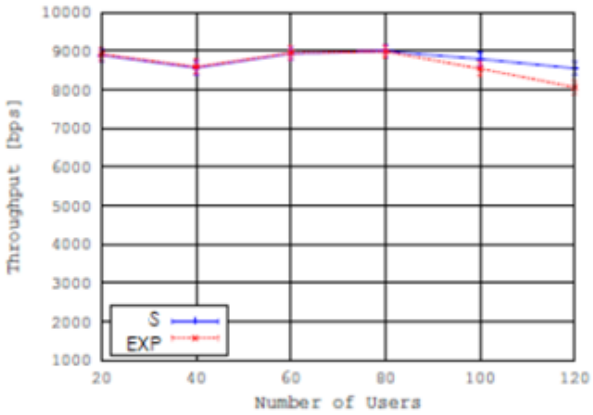
Total Bandwidth [T]	44										
	Value b			Numbers of flows (k)	total g (g=b*k)						
A) Video (kbps)	242			20	4840						
B) Voip (kbps)	8,4			40	336						
C) CBR (kbps)	2			10	20						
VIDEO C1	Coalitions	s	n	(s-1) !	(n-s) !	n!	((s-1)!(n-s)!)/n !	v(S)	v(s-{i})	v(S)-v(S-{i})	total pesos
	A	1	3	1	2	6	0,3333333333	-312	0	-312	-104
	AB	2	3	1	1	6	0,1666666667	24	-4816	4840	807
	AC	2	3	1	1	6	0,1666666667	-292	-5132	4840	807
	ABC	3	3	2	1	6	0,3333333333	44	-4796	4840	1613
									TOTAL bandwidth [kbps]		3122,7
									TOTAL ressources Block		4,879
VOIP C1	Coalitions	s	n	(s-1) !	(n-s) !	n!	((s-1)!(n-s)!)/n !	v(S)	v(s-{i})	v(S)-v(S-{i})	total
	B	1	3	1	2	6	0,3333333333	-4816	0	-4816	-1605
	AB	2	3	1	1	6	0,1666666667	24	-312	336	56
	BC	2	3	1	1	6	0,1666666667	-4796	-5132	336	56
	ABC	3	3	2	1	6	0,3333333333	44	-292	336	112
									TOTAL bandwidth [kbps]		-1381,3
									TOTAL ressources Block		-2,16
CBR C2	Coalitions	s	n	(s-1) !	(n-s) !	n!	((s-1)!(n-s)!)/n !	v(S)	v(s-{i})	v(S)-v(S-{i})	total
	C	1	3	1	2	6	0,3333333333	-5132	0	-5132	-1711
	AC	2	3	1	1	6	0,1666666667	-292	-312	20	3
	BC	2	3	1	1	6	0,1666666667	-4796	-4816	20	3
	ABC	3	3	2	1	6	0,3333333333	44	24	20	7
									TOTAL bandwidth [kbps]		-1697,3
b= desired bitrate per flow of each class									TOTAL ressources Block		-2,65
k= number of users in each class									Total Bandwidth		44,0
									Total RB's		0,06875

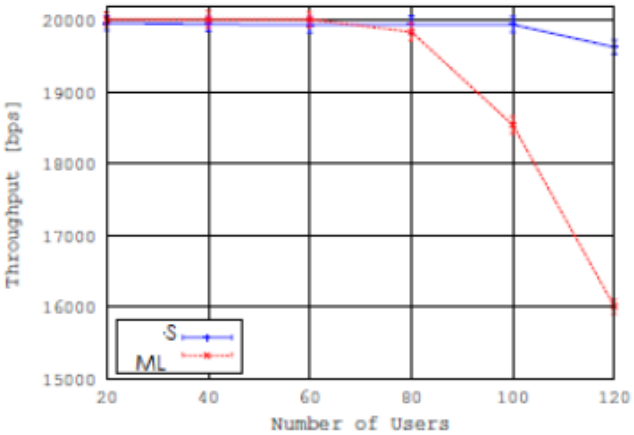
Fig.2: Example of scheduling between P1 and P2 classes



(a) Video Flows



(b) VoIP Flows



(c) NRT Flows

Fig.3 Throughput simulation results

VI. CONCLUSION

This paper mainly focused on the performance of a modified EXP-rule and M-LWDF packet scheduling algorithms in downlink LTE femtocell system. Our proposed solution combine the two scheduling algorithms in order to create an intelligent scheduler which insure a throughput optimal according to the number of users per femtocell and their access priority. Simulation results argue in favor of our solution

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