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QoS-Aware Resource Allocation and Femtocell Selection for 5G Heterogeneous Networks

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Abstract

5G is not a simple cellular technology; it's a real revolution to improve the connection speed that assures Quality of Service (QoS) requirements and user satisfaction in a heterogeneous environment. 5G network is considered as a Heterogeneous Networks (HetNets) able to support a multitude of specific use cases (such as Smart Metering and Videoconferencing) and new services, where performance requirements will be extremely polarized. In this context, several key issues for 5G communications should be addressed to satisfy QoS provisioning. Radio resource allocation is considered as an important 5G key issue for Internet of Things (IoT) communications. In this paper, we propose a QoS-aware resource allocation and femtocell selection for 5G HetNets named QoS-RAS. Our proposed approach maximizes the total resource utilization of the network and it ensures a balanced load by selecting the suitable femtocell for each user and allocating the available resources with an adequate manner. Our work gives the best scenarios that aim to enhance system model performance in terms of resource utilization ratio, dropped request probability, total average throughput and fairness index.

Keywords: 5G, Resource Allocation, Femtocell Selection, Quality of service, Internet of things, M2M, H2H.

1. Introduction

Current mobile communication systems, such as the fourth generation (4G), are providing service regularly to the global world. Despite the great amount of data and services that are loaded in 4G, compared to the anterior cellular network, a considerable gap persists between the human's practical needs and technologies provided by the 4G. Therefore, the telecom industry, standards developing organization and academia have kicked off to achieve the fifth-generation mobile network (5G) landmark [1]. It is hard to define 5G features. Nevertheless, related to current cellular networks systems, it is forecasted that 5G must have a 10 to 100 times higher number of connected user and data rate, 10 times longer battery life for low power devices and 1000 times higher mobile data volume [2]. To do so, many standardization bodies and industries are competing and spending colossal resources and efforts on evolving 5G researches. Some of them, such as Huawei, aimed to make 5G able to support massive connectivity while implementing various sets of users, services, and applications with antithetical exigencies and requirements. Others, such as LTE, were devoted to some key technologies like cloud radio, software-defined air interface, massive Multiple-Input Multiple-Output (massive MIMO) [3], etc. Therefore, we believe that 5G has to be an intensive network that exhibits several key technologies such as IoT (Internet of Things) and M2M (Machine-to-Machine) communications, small cell deployment, mobility management, etc.

In the following, we present the features and functionalities of IoT communications in 5G networks. Then, we depict the benefits of the densification concept via small cell deployment.

1.1. *IoT and M2M in the era of 5G*

IoT communications are considered a real evolution made by the 5G network to make it real. These developments represent an important issue for several sectors of our society, particularly the economy. Organizations are present to ensure that operators meet standards for these technological developments. To

guarantee that these issues succeed and to keep pace with the growing evolution of connected objects on the market, networks are more moving towards virtualization. The 5G introduces new architectures [4] and new features at all levels. This goes from the object itself to the applications hosted in the cloud, going through the various network layers. The uses that we make of this technology are diverse and varied. For example, the enrichment of the connected home, the autonomous vehicle, immersive videos and the arrival of medicine 2.0 and industry 4.0. The IoT is used in a wide variety of fields. It can be classified into three categories: the low-speed IoT, the high-speed IoT and the critical IoT. Uses cases range from collecting information on objects in the home, to monitor critical infrastructure. The support for Machine-to-Machine communications (M2M) is treated as one of the major troublesome technologies of 5G because the new generation of cellular communications will have to cope with all the requirements of M2M while guaranteeing that all Human-to-Human communications (H2H) services are not threatened. Therefore, new emerging communications systems will need to handle with the coexistence of both types of traffic. The system of developed 5G takes into account the integration of indispensable enabling technologies for guaranteed QoS and ubiquitous connectivity to cope with to deal with the nature of particular M2M traffic. Providing connectivity to a huge number of M2M devices with their different requirements and characteristic is the main goal of 5G. Thus, significant improvements are forecasted in forthcoming 5G networks, which create integrated and compatible support for M2M communications.

1.2. Small cell Densification Concept

Given that, 5G networks will execute applications with high requirements for data rates, reinforce network densification via small cell deployment seems to be one of the solutions to satisfy these data rate demands. Thanks to their significant ability to increase density, coverage and network capacity, it is clear why there was broad and early industry agreement that small cells will be a decisive element in 5G wireless networks. The advantage of small cell network

compared to a macro-cellular network is quite reduce the number of users connected to each antenna, besides the low-cost capacity of deployment and the use of high-frequency specter bands and frequency reuse. In 5G, small cells will also deliver new services that are based on the presence information and location of the user and/or his proximity [5]. The small cells are microcells, picocells, and femtocells. These cells are classified according to the size of the geographical area that they cover. A microcell will be deployed on a neighborhood scale, while picocells will be deployed at the scale of a large building such as a factory or a shopping center. The femtocells are deployed at the scale of a house in an apartment or company. The simultaneous operation of macro-small cells is termed heterogeneous networks (HetNets) as depicted in Fig. 1. Het-Nets consists of various-type cells with different wireless coverage. In HetNet, base stations of small cells [6] (i.e, Small evolved Node B (SeNB)) are located in a macrocell, knowing that they assume the same capabilities of a standard evolved Node B (eNB). Table. 1 shows the difference between the various versions of small cells. They vary in their coverage radius, output power, number of users they can handle, etc. However, all cases incorporate 3G, 4G and Wi-Fi technologies carriers.

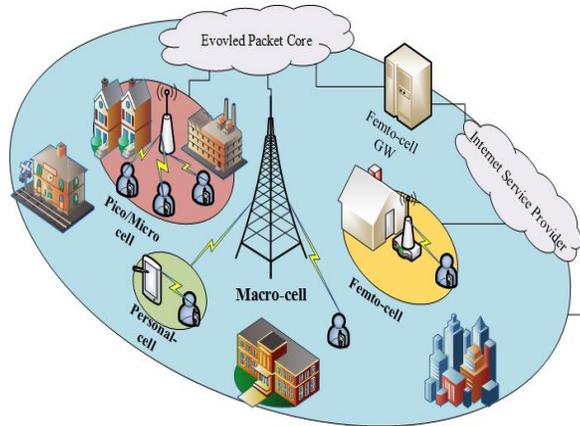


Figure 1: Heterogeneous Network Architecture.

Table 1: Comparison among different types of cells

	Macrocell	Microcell	Picocell	Femtocell
Cell radius	10 to 40 km	2 km	200 m	10 to 50 m
Indoor/Outdoor	Outdoor	Outdoor	Indoor or outdoor	Indoor
Output power	40 to 100 W	2 to 10 W	250 mW	20 to 100 mW
Bandwidth	60 to 75 MHz	20 to 40 MHz	20 MHz	10 MHz
Technology	3G/4G	3G/4G/Wi-Fi	3G/4G/Wi-Fi	3G/4G/Wi-Fi
Cost	60.000\$/year	30.000\$/year	10.000\$/year	200\$/year
Power Consumption	High	Moderate	Low	Low

1.3. Related Works

In the purpose to enhance 5G network functionalities and to guarantee QoS requirements for users, several contributions are proposed in the literature. We classify these related works into two categories including resource allocation and cell selection in 5G HetNets.

1.3.1. Related works of resource allocation in 5G HetNets

In [10], the authors proposed two schedulers for IoT communications based on QoS requirements of M2M and H2H flows by guaranteeing network performance and avoiding ineffective exploitation of available resources. The first one is a static scheduler that presents an allocation strategy of available resource blocks (in the eNB) between users at one TTI [11]. The second scheduler, named Dynamic Borrowing Scheduler (DBS), presents an extended version of the first scheduler using a borrowing policy for resource block allocation in the purpose to decrease the percentage of flow rejection and to maximize the bandwidth utilization rate [12]. In [13], the authors propose a resource allocation scheme and dynamic power control for the next generation cellular networks (5G). The objective is to mitigate the resource reuse interference in a multi-cell network between D2D user equipment's (DUEs) and cellular user equipment's (CUEs). In addition, the authors propose in [14] a resource allocation scheme for cooperative hybrid FSO/mmW 5G fronthaul network to optimize network

reliability, average transmitted power and average BER. The proposed scheme is considered as a discrete linear multi-objective optimization problem (ILP-MOP) achieving better performance at all weather conditions. In [15], a resource allocation scheme based on a genetic algorithm (GA) is proposed for 5G networks. In this scheme, a resource is allocated to those D2D pairs who create less interference. In [16], the authors propose a novel resource control algorithm based on long short-term memory for the 5G ultra-dense network. The proposed model makes localized prediction of future traffic characteristics such as future buffer occupancy status forecasting probable congestion.

1.3.2. Related works of cell selection in 5G HetNet

In [17], a cell selection and user association method are proposed for 5G heterogeneous networks using Bayesian game. The objective is to maximize the probability of proper association and to enhance the QoS performance in terms of achieved latency. Although this method could be efficient in achieving low latency objective the packet loss probability and its impact on the system performance are neglected in [17]. In [18], an optimal base station selection is proposed for smart factories based on two metrics the maximum SINR (Signal to Interference plus Noise Ratio) and the maximum receive power. Experimental results prove that the maximum receive power is an optimal technique for base station selection for smart factories. However, [18] neglects different classes of traffic supported by 5G network. Authors proposed, in [19], an optimal cell selection method when many higher frequencies are layered. Only the system throughput is well improved in a blocker deployment environment. In order to unload traffic to light load, D2D (Device-to-Device) serves as the edge computing center. A joint relay selection method is proposed in [20] based on this model to offload macro-cell users to small cell MEC (Mobile Edge Computing) application servers. Furthermore, dual connectivity is introduced to manage user mobility and network access in the small cells. Authors exploit dual connectivity in [21] for throughput maximization, multihop routing from small to the macro cell, and selection of a small cell eNB for user equipment (UE).

1.4. Motivations and objectives of this paper

From related works, the most contributions introduce separately resource allocation mechanism and cell selection for 5G HetNets. Moreover, the existing solutions need to be reviewed with the expansion of IoT communications in wireless systems to put good use of the technology. For these reasons, we propose a QoS-aware resource allocation and cell selection for 5G HetNets, named QoS-RAS. Our proposed approach introduces a joint solution for resource allocation and femtocell selection. The primary contributions are to perform a resource allocation and a femtocell selection with the objective to 1) maximize the total resource utilization, 2) ensure a balanced load by selecting the suitable femtocell for each user, 3) fairly allocate the available resources, and to 4) enhance the total average throughput for 5G specific use cases (such as Smart Metering and Videoconferencing).

The rest of this paper is organized as follows. In the next section, a description of the system model is provided. Proposed QoS-RAS scheme is detailed in section III. Then, performance analysis and comparison scenarios are presented in section IV. Finally, the conclusion and future works are drawn in Section V.

2. System Model

2.1. Network Architecture

Our network architecture is brought out from a similar model adopted in past works [22], with appropriate modifications in order to be applied in different use cases. In this work, we consider the downlink (DL) data transmission of two-tiered cellular network, where one macrocell coverage is underlaid with femtocells as depicted in Fig. 2. The DL signaling is assumed to use Orthogonal Frequency Division Multiple Access (OFDMA). The Physical Resource Block (PRB) is the basic element in DL direction of 5G LTE. They are allocated to each user equipment (UE) according to its traffic type, demand and QoS requirements. The PRB is defined in both the time and frequency domain. On one hand, the time-domain consists of a single time slot (0.5 ms) including 7

symbols of OFDMA. On the other hand, the frequency domain involves 12 adjacent subcarriers of 15 kHz each resulting in a total PRB bandwidth of 180 kHz. The whole bandwidth of the network is presumed to be divided in orthogonal subchannels. Each one is assumed that can be allocated to one single user at the same time to avoid inter-channel interference between user groups. Besides, in order to minimize interference, contiguous stations are attributed to different channel groups. The range of area is entirely covering by a single macro base station (BS) eNB M located at the center of the cell $(0,0)$. In [22], femtocells were uniformly located in the cell. In the current environment, we have a set of femtocells i , with $i \in \{1, \dots, F\}$. We assume $F = 12$ is the total number of femtocells randomly and arbitrarily deployed in the macrocell coverage forming and overlay layer. The Home eNB (HeNB) are located at (x_i, y_i) . We note HeNB is the name of femtocell base station. Each BS (either the eNB or HeNB) handles a set of UEs $u \in \{1, \dots, U\}$ who are evenly distributed in the geographical area. Two types of user, H2H users and M2M users, are considered. We assume that UEs $n \in \{1, \dots, N\}$ with N is the total number of M2M users and a set of UEs $h \in \{1, \dots, H\}$ with H is the total number of H2H users at one Transmission Time Interval (TTI). Furthermore, the number of the accessing user follows the Poisson point process with a density of λ . The network is assumed that will work in an extremely backlogged system where all stations supply Continuous Bit Rate (CBR) applications to their associated UEs to fully use the allocated bandwidth. As well as, the network is assumed to be static when there are no departures of present demands or arrivals of new ones. Useful notations are listed in Table 2 for the best understanding of the proposed approach.

2.2. Problem Formulation

In this section, we give an optimization model to find the optimal solution of resource allocation and femtocell selection, with the available resources of each station (eNB or HeNB). These resources are shared by different existing traffic types. The problem formulation deals with both M2M and H2H users. Our intention is 1) to maximize the resource utilization ratio within the system

Table 2: Notations

Notations	Descriptions
α	value between 0.5 and 0.9
β	value between 0.5 and 0.9
N	The total number of M2M users
H	The total number of H2H users
F	The total number of femtocells deployed in the macrocell
$C_{n,i}$	The charge factor of a femtocell i for user n
$G_{n,i}$	The channel gain between a user n and a femtocell i
$W_{n,i}$	The utility function
$r_{n,i}$	The instantaneous end-to-end from femtocell F_i to user n
\bar{r}_n	The average of all end-to-end rates offered by neighboring HeNB
RS_M	Static resources of macrocell M
RD_M	Dynamic resources of macrocell M
RG_M	Global resources of macrocell M
RS_i	Static resources of femtocell i
RD_i	Dynamic resources of femtocell i
RG_i	Global resources of femtocell i
$RA_{i,x}$	Allocated resources of femtocell to user x i
$RA_{M,y}$	Allocated resources of Macrocell M to user y
X	Number of users served by HeNB
Y	Number of users served by eNB
x	index of users served by HeNB $x \in \{1, \dots, X\}$
y	index of users served by eNB $y \in \{1, \dots, Y\}$
i	index of femtocells $i \in \{1, \dots, F\}$

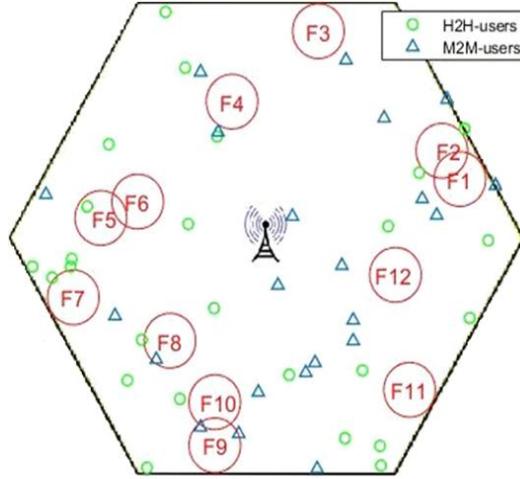


Figure 2: Network Model Scheme.

and 2) to select the suitable femtocell with the maximum value of $W_{n,i}$. Thus the model has two-objective optimization problem. The objective function is summarized in Equation 1 as follows:

$$Max \begin{cases} W_{n,i} = a.C_{n,i} + b.R_{n,i} + c.G_{n,i} \\ RU = \frac{1}{RG} \left(\sum_{i=1}^F \sum_{x=1}^X RA_{i,x} + \sum_{y=1}^Y RA_{My} \right) \end{cases} \quad (1)$$

Our purpose is to maximize two-objective function. The first objective intends to maximize the utility function $W_{n,i}$ and to select the appropriate femtocell for M2M users and the second aims to maximize the resource utilization function RU .

Firstly, the maximization of the utility function for femtocell selection is presented by equation 2:

$$Max \quad W_{n,i} = a.C_{n,i} + b.R_{n,i} + c.G_{n,i}, \quad (2)$$

subject to

$$C_{n,i} = \frac{RG_i - RA_i}{RG_i}, \quad (3)$$

$$RA_i = \sum_{x=1}^X RA_{i,x}; \forall x \in \{1, \dots, X\} \quad (4)$$

$$R_{n,i} = \frac{r_{n,i}}{\bar{r}_n}, \quad (5)$$

$$G_{n,i} = 10^{-PL_{n,i}/10}, \quad (6)$$

$$a + b + c = 1, \quad (7)$$

The utility function is a linear combination of three factors and it is calculated according to the following constraints. The constraint (3) ensures that the charge factor $C_{n,i}$ of femtocell i , is defined as the ratio of the number of available radio resources at the HeNB to its total capacity. These available resources at the HeNB are expressed by equation (4) as the total resources assigned to all served users in the femtocell i . Moreover, equation (5) ensures that the rate factor $R_{n,i}$ is the instantaneous rate factor offered by each femtocell i to user n divided by the mean data rate provided by the nearby i during one TTI. The channel gain $G_{n,i}$ between the user and the candidate femtocell i is also taken into consideration. It is expressed by equation (6) where $PL_{n,i}$ denotes the pathloss between the femtocell i and the user n (detailed in our previous work [22]). Finally, equation (7) ensures that the sum of the weights a , b and c is equal to 1.

Secondly, our target is to maximize the resource utilization function RU defined by equation 8:

$$\text{Max } RU = \frac{1}{RG} \left(\sum_{i=1}^F \sum_{x=1}^X RA_{i,x} + \sum_{y=1}^Y RA_{My} \right) \quad (8)$$

subject to

$$RG = \sum_{i=1}^F (RG_i) + RG_M; \forall i \in \{1, \dots, F\} \quad (9)$$

$$RG_i = \alpha RS_i + (1 - \alpha) RD_i \quad (10)$$

$$RG_M = \beta RS_M + (1 - \beta) RD_M \quad (11)$$

$$\sum_{x=1}^X RA_{i,x} \leq RG_i; \forall x \in \{1, \dots, X\} \quad (12)$$

$$\sum_{y=1}^Y RA_{M,y} \leq RG_M; \forall y \in \{1, \dots, Y\} \quad (13)$$

As it is mentioned above, the function RU is the resource utilization ratio that computes the rate of the allocated resources to the global ones at one TTI. RG denotes the global resources in the system, however, $RA_{i,x}$, (respectively $RA_{M,y}$) represents the allocated resources for user x in femtocell i , (respectively macrocell M). X is the total number of served users by the HeNB of femtocells and Y is the total number of served users by the macrocell M . So as to solve the objective function stated by eq (1), a set of constraints are needed. The constraint (9) ensures that RG is the sum of the global resources of all femtocells RG_i (expressed in the constraint (10)), plus the global resources of the macrocell RG_M (expressed in the constraint (11)). As we explained above, the global resource of each station i , (respectively M) is the sum of static resources RS_i , (respectively RS_M) and dynamic resources RD_i , (respectively RD_M). The division is done randomly with respect to the random variables α and β , where $0.5 \leq \alpha, \beta \leq 0.9$. Besides, in the constraints (12) and (13), we consider that the upper limit of allocated resource in each cell is equal to the global one.

3. Proposed femtocell selection and QoS-aware resource allocation Scheme

In order to solve the problem (1) detailed previously, we propose a joint QoS-aware resource allocation and a femtocell selection scheme named QoS-RAS. In fact, with the limited available resources of the system, it is necessary to manage an efficient resource allocation method that intends to maximize the resource utilization within the system and to ensure a balanced load by selecting the adequate femtocell for users. Accordingly, a description of the proposed approach with its two stages is given and illustrated in Fig.3. The

first stage presents a selection of the suitable femtocell with a maximum value of the utility function. Jointly, the second stage gives a QoS-aware resource allocation in order to serve M2M and H2H requests. Our QoS-RAS ensures the selection of the relevant femtocell i by computing the utility function in the first stage. It provides also a resource allocation strategy between H2H and M2M users.

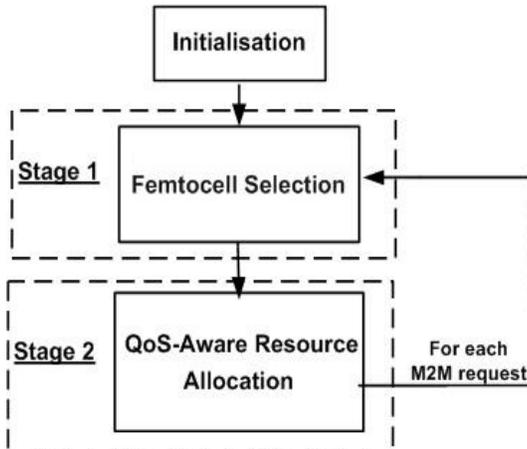


Figure 3: Proposed Resource Allocation Scheme.

After the initialisation step, the utility function process is launched in order to select the suitable femtocell for each M2M request. This function is calculated for each user n from the appropriate HeNB according to equation 2. Starting from the fact that such station will be selected only if it acquires enough resources to serve either M2M or H2H demands, the utility function is introduced to select the best femtocell and to satisfy M2M user demands. This utility function denoted by $W_{n,i}$, provides the suitable femtocell i for each user n and it takes into consideration three parameters: the charge factor $C_{n,i}$ defined by equation 3, the rate factor $R_{n,i}$ given by equation 5 and the channel gain $G_{n,i}$ between a user n and the femtocell i defined previously by equation 6. The flowchart illustrated in figure 4 gives a description of the utility function.

The next stage has to do with the QoS-aware resource allocation model.

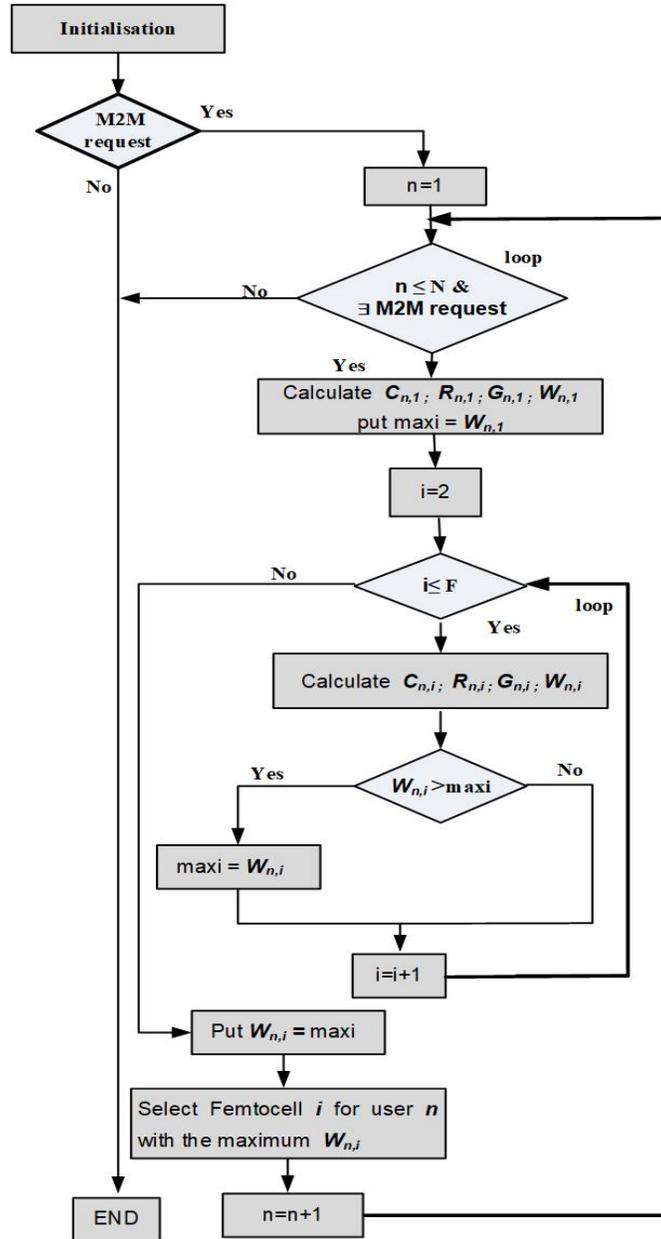


Figure 4: Utility Function Flowchart.

As it mentioned in the previous section, we propose a dynamic model where the resources of each station (either eNB or HeNB) are divided into static and

dynamic resources. If there are enough available resources to supply service to users, the static resources will be used preferably. Whereas, when it is about large system traffic, the dynamic resources will be allocated according to the type of the users. We take into consideration the QoS requirements of users in the resource allocation strategy in order to support two specific use cases: smart metering and videoconferencing, which are detailed below.

3.1. Smart Metering Scenario

In order to guarantee QoS requirements for smart metering applications, we prioritize M2M requests over H2H ones. The corresponding resource allocation scenario is illustrated in Fig.5. After the execution of the utility function process, M2M request has the ability to be accepted :

- Case 1: if there are enough static resources RS_i in the selected femtocell i ,
- Case 2: If case 1 is not satisfied, we check the availability of the dynamic resources RD_i of the appropriate femtocell.
- Case 3: If case 2 is not satisfied, the system makes use of the static resources RS_M of the macrocell M .
- Case 4: If case 3 is not satisfied, the M2M request will be served from the dynamic resources RD_M of the macrocell M .

Therefore, the system will abort the M2M request when resources are fully allocated.

According to the H2H request, we check the availability of static resources RS_M of the macrocell M firstly. If there are not enough resources to satisfy H2H request, the system verifies the availability of the dynamic resource RD_M of the macrocell. If not, the system makes use of the dynamic resources of the selected femtocell RD_i with a maximum value of the SINR. Otherwise, the H2H request will be rejected. In this scenario, the M2M requests can be served through several cases and so they have more chance to be accepted than H2H

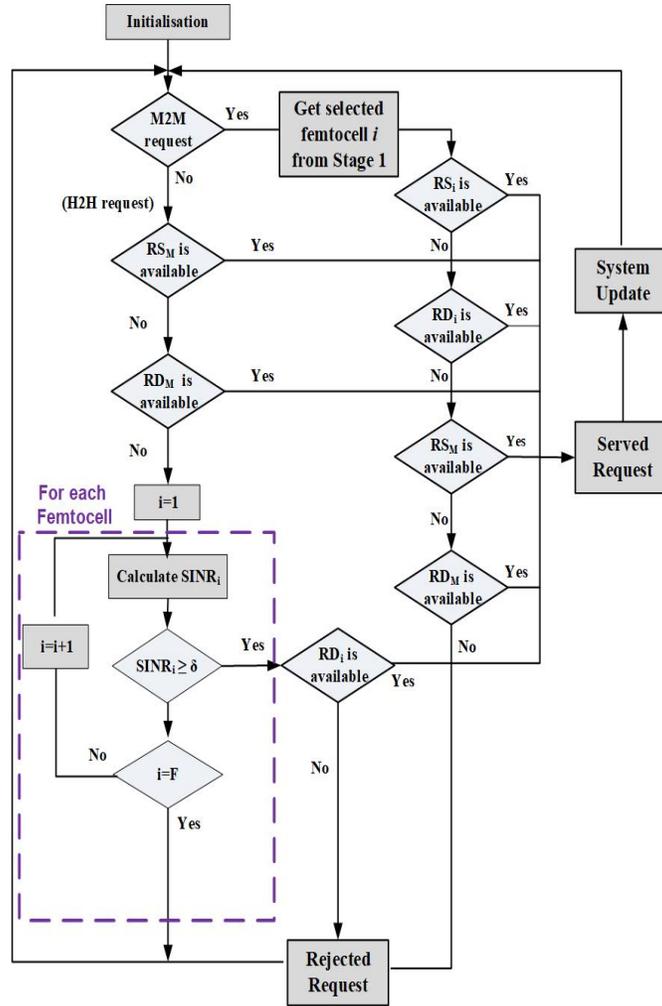


Figure 5: Resource Allocation Flowchart for Smart Metering Scenario.

demands. Furthermore, our model gives QoS satisfaction to the smart metering application as it enhances the acceptance probability of M2M users.

3.2. Videoconferencing Scenario

In the videoconferencing scenario, illustrated in Fig.6, H2H demands are more prioritized than M2M requests. H2H users can be served according these cases:

- Case 1: there are enough static resources RS_M in the macrocell M .
- Case 2: the dynamic resources RD_M of the macrocell M are available to satisfy the request.
- Case 3: the system makes use of the dynamic resources of the selected RD_i femtocell with a maximum value of the SINR.

Otherwise, the H2H demand will be rejected when all resources are fully allocated. According to the M2M requests, the system verifies the static resources RS_i of the selected femtocell i (from the result of the utility function $W_{n,i}$) firstly. Elseways, the M2M demands can be served from the available dynamic resources RD_M in the macrocell. Correspondingly, the system offers more flexibility for H2H communications to be accepted and so to enhance QoS of the videoconferencing applications.

3.3. Performance Metrics

Then, we define several important metrics for evaluations and comparisons, including packet dropping probability, system throughput, SINR (Signal to Interference plus Noise Ratio), and Fairness index. Meanwhile the impact factors considered in this work include various numbers of UEs. First of performance metric is Request Dropped Probability (RDP) in the whole system, defined by:

$$RDP = \frac{\sum_{u=1}^U R_u^{dropped}}{\sum_{u=1}^U R_u^{total}}, \quad (14)$$

where $R_u^{dropped}$ represents a dropped request of a user u and R_u^{total} denotes the total number of traffic of a user u . Lower the RDP is corresponding to a higher performance.

Second of performance metric is throughput. The practical capacity of user u can served by either the eNB or HeNB is defined as:

$$C_{M/i,u} = \Delta f \times \log_2(1 + \alpha SINR_{M/i,u}), \quad (15)$$

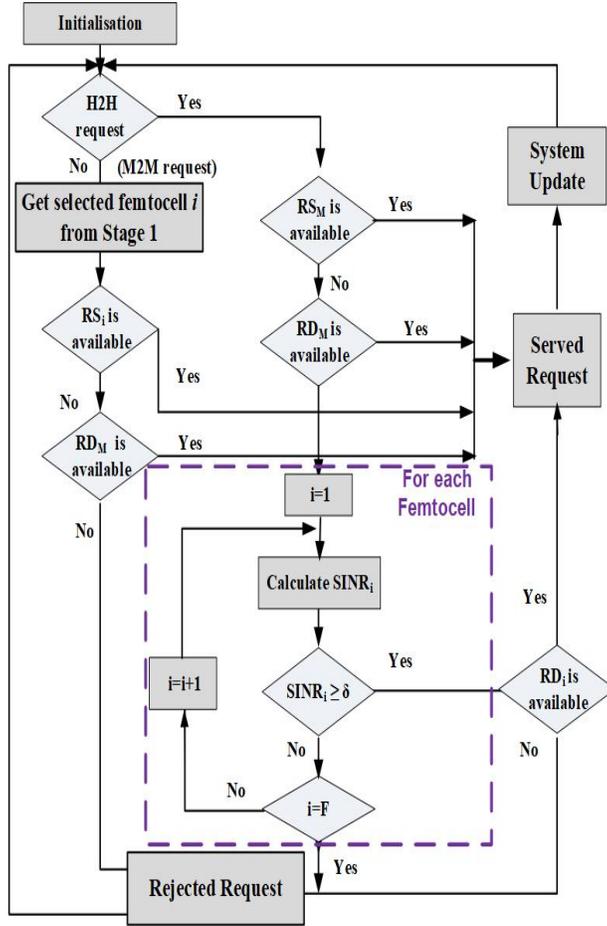


Figure 6: Resource allocation Flowchart for Videoconferencing Scenario.

where, Δf is the subcarrier spacing and α is a constant for target Bit Error Rate (BER), which defined by $\alpha = -1.5/\ln(5BER)$. $SINR_{(M/i,u)}$ is the estimation of the received $SINR$ of user u , when the user is interfered from adjacent macro-cells and all the contiguous femtocells. In our analysis, the $SINR$ calculation is expressed by the equation (16)

$$SINR_{M/i,u} = \frac{P_{M/i,u} G_{M/i,u}}{N_0 \Delta f + \sum_{M' \neq M} P_{M',u} G_{M',u} + \sum_{i' \neq i} P_{i',u} G_{i',u}}, \quad (16)$$

where $P_{M/i,u}$ is the transmitted power of serving eNB M or HeNB i . $G_{M/i,u}$ represents the channel gain of UE u receiving power transmitted by eNB M or HeNB i . $P_{M',u}$ and $P_{i',u}$ are the transmitted power of neighbouring eNB M' and HeNB i' , respectively. Similarly, $G_{M',u}$ (respectively $G_{i',u}$) denotes the channel gain between a UE u and neighbouring eNB M' (respectively HeNB i'). N_0 represents the white noise spectral density.

Finally, the overall throughput of serving can be expressed as follows:

$$Th_{M/i,u} = \sum_{M/i} \sum_u \beta_{M/i,u} C_{M/i,u}, \quad (17)$$

where, $\beta_{M/i,u}$ represents the subcarrier assignment for macrocell (respectively femtocell) users u . When the subcarrier is assigned to user, $\beta_{M/i,u} = 1$. Otherwise, $\beta_{M/i,u} = 0$.

The last one is the Jain's fairness index. It measures the level of satisfaction of the different users in the system. In fact, we focus on the performance of the proposed model with regards to the throughput.

$$FI = \frac{(\sum_u Th_{M/i,u})^2}{U \sum_u Th_{M/i,u}^2} \quad (18)$$

4. Performance analysis and comparison

We focus in this section on the performance evaluation of our proposed method QoS-RAS provision in 5G heterogeneous network. In order to validate our proposal, our study is carried out and the simulations are performed using MATLAB. We give the main parameters of the simulation model in Table 3.

4.1. Smart Metering Scenario Simulation

Performance evaluation of smart metering scenario is given by Fig.7, Fig.8 and Fig.9. In Fig.7, we compute the dropped request probability vs. the number of users (H2H and M2M). Through this figure, we prove that the dropped request probability for *macrocell-only* scenario is almost 60% higher than the dropped

Table 3: Simulation Parameters

Parameters	Values
Macrocell radius (m)	250
Femtocell radius (m)	20
Frequency (GHz)	2
eNB power (dBm)	46
HeNB power (dBm)	20
Outdoor walls loss low (dB)	20
Indoor walls loss low (dB)	5
Channel bandwidth (MHz)	10
Modulation scheme	16 QAM
Sub-carrier spacing (KHz)	15
White noise (dBm/Hz)	-174

request probability for M2M users and 25% than the ones of H2H dropped request probability. The fact that M2M users are more prioritized than H2H ones is highlighted in this figure for the different values of α and β . Indeed, the M2M minimal dropped request probability is achieved when $\alpha= 0.9$ and $\beta = 0.9$ since H2H demands are denied to be served by the static resources of femtocells. Fig.8 illustrates the improvement of fairness among users after the deployment of the femtocells, mainly if $\alpha= 0.5$. In addition, the fairness index exceeds 90% which confirms that the utility function satisfies all users in the system. Fig.9 illustrates the CDF of the total user throughput which is affected by the total number of users in the system. As it is shown in this figure, the CDF of the total user throughput increases as the user throughput increases.

4.2. Videoconferencing Scenario Simulation

The videoconferencing scenario is evaluated in terms of dropped probability of request (Fig.10), fairness index (Fig.11) and resource utilization rate (Fig.12). In Fig.10, we compute the dropped request probability vs. the number of total users (H2H and M2M). Since we give more priority to H2H requests to ensure QoS requirement for videoconferencing application, M2M demands are denied to be served by femtocells resources. This graph proves that the minimal dropped request probability for H2H requests is achieved when $\alpha= 0.9$ and $\beta = 0.9$.

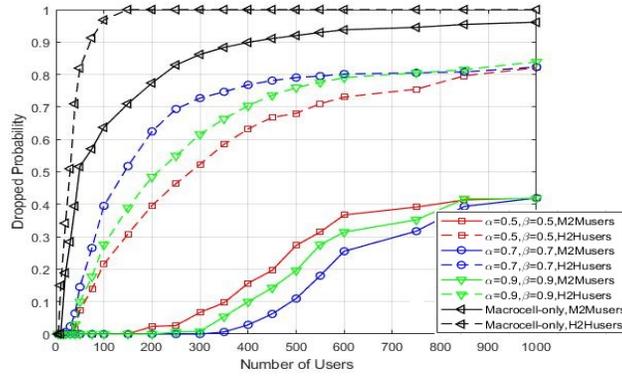


Figure 7: Dropped Probability with different values of α and β .

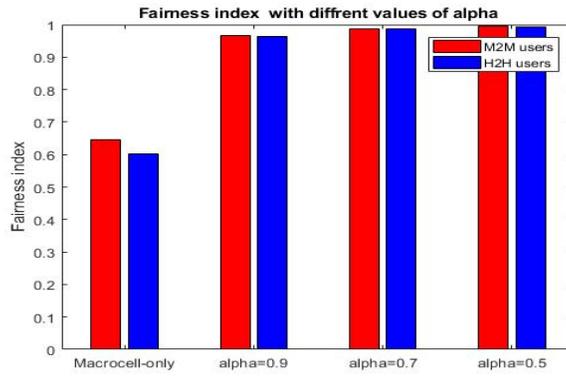


Figure 8: Fairness index per type of request with different values of α

We notice that the best scenario for H2H users is achieved when $\alpha = 0.5$ since they shared half of the resources of the femtocells. According to *macrocell-only* scenario, the dropped request probability for M2M requests is higher than the dropped request probability for H2H users. Through Fig.11, the fairness index is depicted for different types of users for both *macrocell-only* scenario and for different values of α . We notice the enhancement of this index with the deployment of femtocells in our proposed QoS-RAS and mainly for H2H users. Moreover, we observe that the fairness index among users reaches its maximum and surpasses 90% when $\alpha= 0.5$. In Fig.12, we compute the rate

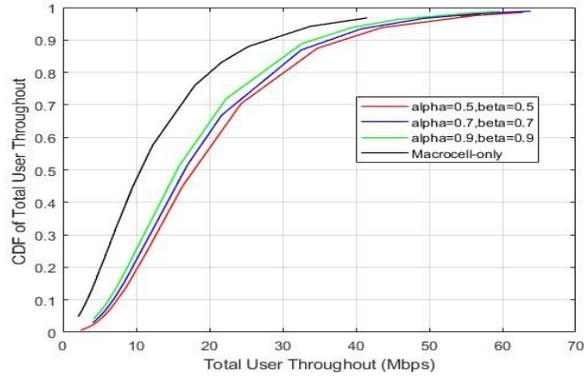


Figure 9: CDF of the total user throughput

of the resource utilization in the system as the number of total users. In the scenario of *macrocell-only*, the resources are almost fully allocated from 170 users. According to the rest of the scenarios, the resources are totally allocated from 1000 users. Even on the side of HeNB, the resources can be shared between both traffic types and so there is not any waste of resources.

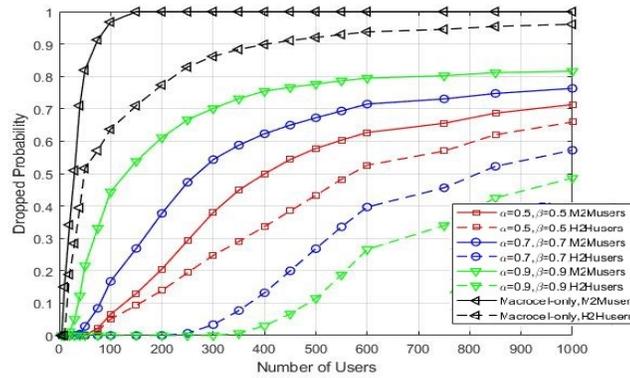


Figure 10: Dropped request H2H priority

4.3. Comparison

As it mentioned before, authors has proposed in [10], a Dynamic Borrowing Scheduler (DBS) for M2M and H2H flows based on QoS requirements. DBS

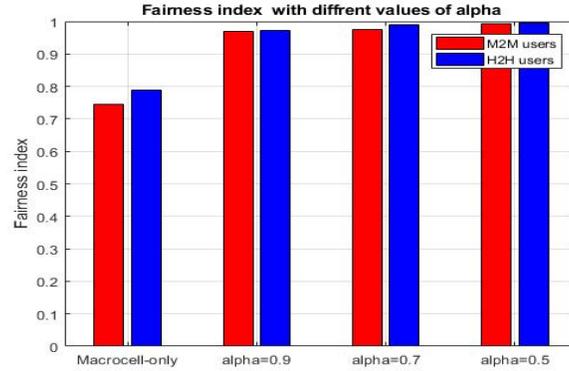


Figure 11: Fairness index

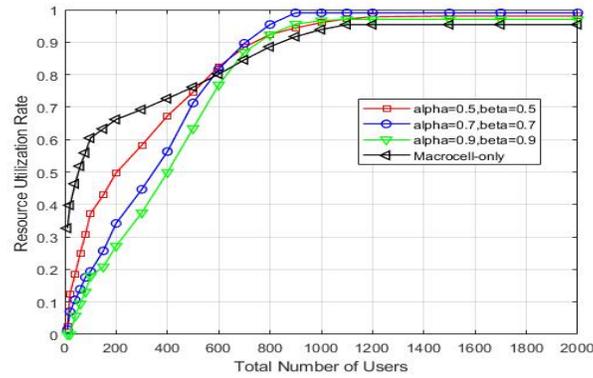


Figure 12: Resource utilization rate H2H priority

uses a borrowing policy for resource blocks allocation in order to decrease the dropping probability of flows and to maximize the bandwidth utilization rate. Since our proposed algorithm QoS-RAS has the same objectives, a comparison between those two approaches is done in this section. This comparison is represented by Fig.13 and Fig.14 in the term of dropped request probability. First, Fig.13 compares the probability of dropped request for M2M users of DBS algorithm by QoS-RAS one for smart metering use case scenario under different number of UEs. The probabilities of compared schemes increase as the number of UEs increases. QoS-RAS leads to the least dropped probability request, but

DBS yields the highest one. The reason is that QoS-RAS is not only a HetNet network model deploying 12 femtocells, but also it proposes an adaptive QoS-based M2M priority as shown in stage 2 for smart metering scenario (Fig. 5). Thus notably minimizes the dropped probability of M2M requests. Nevertheless, the other compared approach, even it also prioritizes the M2M users, it steels a *macrocell-only* system model. Second, Fig.14 evaluates the same metric for H2H users. To do so, we consider the videoconferencing scenario which prioritizes H2H traffic. We notice that the performance of our proposed scheme is better either in low or high user numbers.

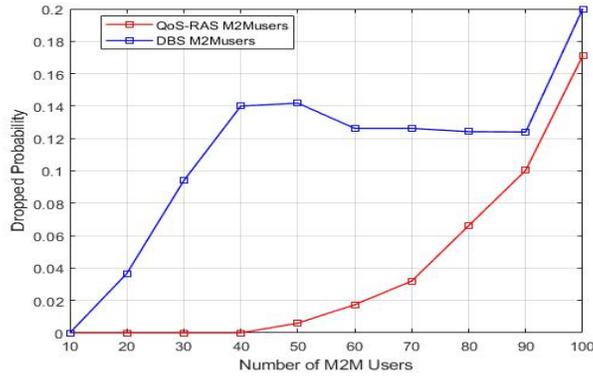


Figure 13: Comparison of the dropped probability of M2M requests

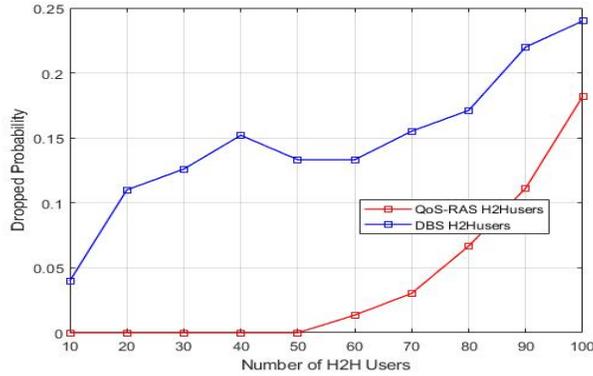


Figure 14: Comparison of the dropped probability of H2H requests

5. Conclusion

We proposed a QoS-aware resource allocation and femtocell selection for 5G HetNet. Our QoS-RAS scheme aims to enhance system model performances in terms of guaranteeing QoS satisfaction for 5G specific use cases related to smart metering and videoconferencing scenarios. The objective of our system is to maximize the total resource utilization of the network and to ensure a balanced load by selecting the adequate femtocell for each type of user. Our QoS-RAS ensures the selection of the relevant femtocell by executing the utility function in the first stage. It provides also an adaptive QoS-based priority resource allocation between H2H and M2M users in the second stage. Since our proposed scheme focuses only on the M2M and H2H users, we aim to extend our research considering V2X users and further use cases and application for 5G HetNets.

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