Frequency Allocation Based on Angle-of-Arrival for Downlink User Selection in 5G MU-MIMO Heterogeneous Network

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Abstract—One of the most important issues in the efficient use of radio resource spectrum for multiuser multiple-input/multiple-output (MU-MIMO) systems is the selection of users to achieve the maximum system throughput. The optimal user device selection algorithm, which requires exhaustive search, is prohibitive due to its high computational complexity. Moreover, fairness among the users cannot generally be achieved with such a scheme. Therefore, we propose to use Jain's fairness index to assure that each user can achieve a required data rate, as in a system with quality of service guarantees. In this paper, we formulate an optimization problem for user selection based on angle-of-arrival (AoA), in a HetNET multi-user aiming to jointly maximize the total system throughput and the spectrum efficiency, notably, using a well-known beamforming technique to eliminate inter-users interference. Through computational complexity analysis, the proposed algorithms frequency allocation angular based with fairness FAABF-algorithm and frequency allocation angular based without fairness FAAB-algorithm, that are considered as the best solution for the formulated optimization problem, Indeed, they provide a low complexity. Simulation results validate that the proposed algorithm achieves almost the same system throughput than a capacity-based algorithm under a high SNR regime with a considerable reduction in complexity.

Index Terms—Multiuser multiple input multiple output (MU-MIMO), user selection, Jain's fairness, 5G heterogeneous network, beamforming, angle-of-arrival (AOA)

I. INTRODUCTION

Wireless technology is transforming society, indeed about seven billion individuals are communicating over radio cellular networks and over a billion using WiFi. In fact, only a small portion of the whole electromagnetic spectrum supports radio communication, making it crucial to use this precious resource as efficiently as possible. By using more efficient technology, the same amount of spectrum can deliver greater capacity, either by delivering more bits per second of capacity to each user or by servicing more users. Spectrum efficiency is a measure of how efficiently a limited frequency spectrum is utilized, on the other hand how readily spectrum can be reused across space. Various factors affect how efficiently spectrum is used, including the type of modulation, spectral efficiency, error-correction methods, reuse of frequencies across space, the number of users served, radio performance, and the percentage of time a service is active [3].

Recall [4], there are four new technologies that pop-up as a foundation of 5G. Millimeter waves (mmwaves), small cells, massive multi-input-multi-output MIMO, and beamforming. Combining all these technologies in one system have to be studied. As an advantage of the MIMO system, it may increase the throughput of today's networks by the factor Nt x Nr [1], where Nt and Nr are the number of transmitted and received antenna respectively.

Multi-user Multi-Input-Multi-Output (MU-MIMO) allows a base station to communicate with multiple devices simultaneously. This decreases the time each device has to wait for a signal and dramatically speeds up our network. In order to exploit the advantages of MU-MIMO, precisely, the spatial multiplexing and array gain offered, the allocation of the radio resource among the users needs to be designed carefully. In particular, a number of issues shall be taken into account: which users and how many shall be scheduled simultaneously, how the antenna angles (at the transmitter and receiver) shall be chosen.

Thanks for beamforming technique (sensor arrays for directional signal transmission or reception) and spatial multiplexing by using multiple antennas at the transmitter and receiver, we can simultaneously transmit parallel data stream for multi-users using one and only one resource unit (used as a notation for one radio resource unit RU) [5]. Accordingly, this could achieve multiplexing gain, reduce the bit error rate and improve the signal-to-noise ratio (SNR) at the receiver as well it suppress co-channel interference in a multi-user scenario [6]. In a dense network, users are tightly close to each other geographically and may experience high interference, which could affect the users that have a good channel quality and high channel gain, so instead of benefiting from these users to increase the total system throughput, users that have a low quality of the channel would be served. Moreover, it affects negatively the system quality of service (QoS). To solve such problem and to exploit the characteristics of multi-user MIMO system we have proposed to allocate the frequency by mean of an angular approach. Precisely, a model is proposed to formulate the problem. As a matter of fact, estimation of the angle-of-arrival (AoA), takes place by using the transmitted pilot sent from users, depending on these angles the angular

resolution $\Delta\theta(v_i, v_{i+1})$ (difference between the AoA of two consecutive UEs) could be calculated. Afterward it will be compared with the beam width B_m which has a standard size for all the study [7]. Therefore base stations (BS) that are the decision maker, will allocate the frequencies between the users under the following conditions: i) If $\Delta\theta(v_i, v_{i+1})$ greater than B_m, then the selected users will be served simultaneously by having the same frequency, this because there is no risk to have too much interference, as the range of the beam will not intersect together. ii) If $\Delta\theta(v_i, v_{i+1})$ less than or equal B_m, then the selected users will be served simultaneously by having two different frequencies to avoid interference. In this way we could achieve high throughput jointly with fairness, as well we increase the spectrum efficiency. Fairness is something relative from one scenario to another and from one researcher to another. In our case, the highest throughput could be achieved easily without having any limitation for the maximum number of frequencies allocated to a user at once. But, explicitly we are looking for an optimal set of users that could provide maximum total system throughput, guarantee fairness between the users and maximize the spectrum efficiency.

In the literature, [10] introduces a low complexity angular based beamforming and power allocation framework, that requires the knowledge of the main contributive Directions of Arrival/Departure (DoAs/DoDs) of the propagation channel. In contrast, we focus on the frequency allocation knowing only the AoAs, using a well-known beamforming technique which is ZF zero-forcing technique to suppress inter-user interference. The authors in [8] have proposed an algorithm for user selection using the angle between subspaces for downlink MU-MIMO systems. They propose an iterative user selection algorithms with low complexity, where the product of eigenvalues of effective channels is utilized as a selection metric by applying the concept of principal angles between subspaces. Nevertheless, they apply proportional fair (PF) scheduling which is not the same type of fairness (it can't measure how unfair the system is, and no weighted strategies are considered originally) we applied in our proposed algorithm. In [2], the impact of elevation angle on MIMO capacity have been investigated, where they manage the resource allocation under the estimation of the elevation angle, but they only address the physical layer.

We address the issue of user selection in 5G heterogeneous network MU-MIMO, where we propose an algorithm for a multi-user scenario to get the best solution for the formulated optimization problem. In order to meet the overwhelming demands of network throughput for a practically important case wherein the number of users, N_u is larger than the number of transmit antennas N_t. Our aim is fivefold: i) Formulate an optimization problem for a user selection based on angle-of-arrival (AoA) while using ZF zero-forcing as digital beamforming, in a heterogeneous cellular network based on two different radio access technologies (4G) and (5G), for the purpose of jointly maximizing the system throughput, spectrum efficiency and guarantees fairness between selected
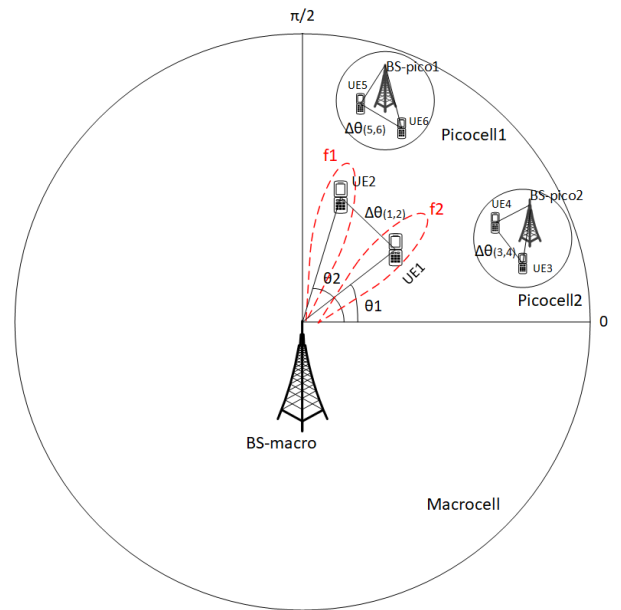

Figure 1. Heterogeneous network with MIMO base stations (BS).

users [9]; ii) Generate a frequency allocation angular based with fairness algorithm (FAABF) to find the best solution taking into account our objective and constraints; iii) Compute the exhaustive search (ES) algorithm that gives the maximum throughput and will be considered as a maximum threshold for all other solutions; iv) Propose a sub-optimal solution, frequency allocation angular based without fairness algorithm (FAAB) to reduce the complexity and approach to the optimal one, in a way to achieve our goals; v) Assess the performance of FAABF-algorithm, FAAB-algorithm and compare them with ES, while total throughput is considered as the evaluation metric.

The residual of the paper is organized as follows: Section II outlines the proposed system and channel models. In Section III the problem formulation takes place [9]. Section IV describes the exhaustive solution and reduced-complexity algorithms. Furthermore, Section V provides a simulation-based comparison of the system throughput performance for ES, FAABF and FAAB algorithms with respect to SNR and number of users. Conclusions and future work are mentioned in Section VI.

II. HETNET MULTI USER MIMO-OFDMA NETWORK MODEL

A heterogeneous multi-user MIMO-OFDMA network is suggested, and it is composed of one macrocell overlaid by P picocells with N_u user equipment (UEs) distributed overall cells as depicted in Fig. 1. Indeed $Q \subset N_u$ UEs will be selected to be served. All *BSs* are equipped with N_t transmit antennas, and each UE with N_r receive antennas.

One of the most attracted characteristics in MIMO systems is the spatial multiplexing, literally because each BS can serve up to $\frac{N_t}{N_r}$ UEs simultaneously for each resource unit, in a

particular case when users used all antennas at once to receive data. The inter-cell interference is roughly negligible, due to the fact of associating the 4G frequency spectrum for the macrocell, while associating the mmwaves that fall in the spectrum range of 5G for picocells. Moreover, picocells are far enough from each other in order not to affect each other by any kind of interference. Thanks to fiber optic backhaul links, macro and pico BSs are connected to a centralized control unit. Indeed, MIMO system rely on channel reciprocity and employ uplink pilots to acquire channel state information (CSI) at BSs, it is generally assumed that massive MIMO systems can only operate in efficiently TDD mode [13], thus it is desirable to have pilot-based schemes that are scalable in terms of the required pilot symbols and provide high quality CSI for uplink data detection and downlink precoding. Worth to be mentioned, that we are dealing with a highly dominant channel.

A. MULTI USER MIMO-OFDMA System Model

In this subsection, we will consider only one single *BS* with N_t transmit antennas employing *OFDMA* system, thus we assume that interference between macro-cells and pico-cells is roughly negligible, due to the fact of associating the 4G frequency spectrum for the macrocell, while associating the mmwaves that fall in the spectrum range of 5G for picocells.Moreover, picocells are far enough from each other in order not to affect each other by any kind of interference. This can be provided by appropriate frequency allocation to each macro cell. By mean of digital beam forming (*DBF*), $Q \leq N_t$ users are simultaneously served with the same time and frequency resources. Following the *MU-MIMO* scheme, let $s[k] = [s_1[k], \cdots, s_Q[k]]^T \in \mathbb{C}^{Q \times 1}$ be the data symbol vector transmitted on the k-th subcarrier. The user data are precoded with *DBF* matrix $W_D[k] \in \mathbb{C}^{Q \times N_r}$, such that

$$s_d[k] = W_D[k]^T s[k] \in \mathbb{C}^{N_r \times 1} \qquad (1)$$

is the precoded vector. Let $H(k) \in \mathbb{C}^{N_t \times N_r \times Q}$ be the multiuser (MU)-multiple-input multiple-output (MIMO) channel corresponding to N_t transmitter antennas and $Nr \times Q$ multi-antennas users.

From now on, the sub-carrier k is dropped for the simplicity of notations. In order to compute W_D, first we need to find the unit-norm vectors $\{w_q\}$ in addition to the individual implicit power P_q. We assume that the data samples are uncorrelated with the energy per symbol E_s, and the power constraint $\sum_{q=1}^{Q} P_q = Q$ must be fulfilled. The received signal model $y_q(t)$ of the q-th user can be expressed as

$$y_q[k] = \sqrt{P_q} h_q^H[k] w_q[k] s_q[k] + \underbrace{\sum_{i \neq q} \sqrt{P_i} h_q^H[k] w_i[k] s_i[k]}_{\text{IUI}} + v_q[k].$$

$$(2)$$

where $v_q[k]$ is the noise vector power, h_q^H is the hermitian of the channel vector for a particular user, and w_q refers to the unit norm-vector of the digital beamforming matrix for all selected users.

B. Channel Model

We consider a heterogeneous network, thus the proposed system model will be applied for the macro and picocells. Let $h_{nq}[k] \in \mathbb{C}^{1 \times N_t \times N_r}$ to be the channel vector between the $(1,p)$th BS and the q-th UE in the kth sub-carrier. Where p is the indices of the distributed picocells in the network, knowing that $p \in [0 \ldots P]$, for clarification $p = 0$ identified the macrocell BS. Then, the received signal at the qth UE in the kth resource unit, $y_{nq}(k)$, is given by

$$y_{nq}[k] = \sqrt{P_{nq}} h_{nq}^H[k] w_{nq}[k] s_{nq}[k] + \underbrace{\sum_{i \neq q} \sqrt{P_{ni}} h_{nq}^H[k] w_{ni}[k] s_{ni}[k]}_{\text{IUI}} + \tilde{v}_{nq}[k]. \qquad (3)$$

$$\forall \; n = (1,p) \; with \; p \in [0 \ldots P]$$

Furthermore, $h_{nq}[k] = l_{nq}[k] g_{nq}[k] \tilde{h}_{nq}[k]$, where $l_{nq}[k]$, $g_{nq}[k]$, represent respectively the path loss, shadowing, where they are generated using Rapapport model [11], Then, $\tilde{h}_{nq}[k]$, are small scale fading coefficients generated using [12] that provides a statistical channel model. In addition, $\tilde{v} \sim \mathcal{N}(\mathbf{0}, \sigma^{\mathbf{2}} I_{nq}[k])$ is the additive white Gaussian noise (AWGN) corrupting the received signal with zero mean and variance σ^2 and $I_{nq}[k]$ is the inter-user interference (IUI).

III. PROBLEM FORMULATION

We formulate an optimization problem based on angular approach for a heterogeneous MU-MIMO-OFDMA network, aiming to optimize user selection and manage the resource allocation in a way to maximize the total average system throughput, under the use of Jain's fairness index $\mathbb{J}$ and angular constraint. We have used digital beamforming techniques ZF zero-forcing for interference cancellation.

A. System Performance Evaluation Metric

In this subsection, we state the system performance evaluation metric to evaluate our proposed system, hence system throughput will be used as a metric unit in this paper. The instantaneous channel throughput for the qth user of the nth cell in the kth resource unit is given by

$$R_{nq} = B_w \log_2(1 + SINR_{nq}),$$
$$\forall n = (1,p) \, with \, p \in [0 \ldots P] \qquad (4)$$

where B_w is the channel bandwidth and $SINR_{nq}$ denotes the received signal-to-interference-plus-noise-ratio for qth given by:

$$\text{SINR}_{nq} = \frac{E_s P_q w_q^H h_q h_q^H w_q}{\sum_{i \neq q} \left[E_s P_i w_i^H h_q h_q^H w_i \right] + \sigma_q^2}, \qquad (5)$$

where σ_q^2 is the noise power, and $Q_n \; \forall n = (1,p)$, denotes the set of UEs served by macro and each pico BSs.

The performance evaluation metric for the proposed problem formulation is the average system throughput, which is defined by $\mathbb{V}$ as the total average number of bit/s/Hz/BS successfully received at the qth UEs, The corresponding expression is given by

$$\mathbb{V} = \frac{1}{P+1} \sum_{p=0}^{P} \sum_{q \in Q} \sum_{k=1}^{K} R_{nq}(k)$$
$$\forall n = (1,p), with\, p \in [0 \dots P] \qquad (6)$$

P is the total number of picocells in the network.

B. Angular Constrain and Jain's Fairness Index

As shown in the context of this study our proposed algorithm is based on angular constraint, and provides fairness between the selected users in the domain of frequency allocation, therefore, Jain's fairness index is used to guarantee the fairness :

$$\mathbb{J} = \frac{(\sum_{i \in Q} k_i)^2}{U_Q \sum_{i \in Q} k_i^2}$$
$$\forall n = (1,p)\, with\, and\, p \in [0 \dots P] \qquad (7)$$

$\mathbb{J}$ is the Jain's fairness index, where k refers to the subcarrier assigned for the served users, U_Q is the total number of the served users in the system where $\mathbb{J} = 1$ represents the best fairness and when $\mathbb{J} = \frac{1}{U_Q}$ represents the worst fairness.

$$(A) : \begin{cases} & \text{if } \Delta\theta(v_i, v_{i+1}) > B_m \\ \left| \begin{array}{c} (v_i, f_a) \\ (v_{i+1}, f_b) \end{array} \right| & \begin{array}{c} f_a = f_b \\ \\ \text{if } \Delta\theta(v_i, v_{i+1}) < B_m \\ f_a \neq f_b \end{array} \end{cases} \qquad (8)$$

knowing that B_m is the beam width, which will be considered standard for all the study [7]. $\Delta\theta(v_i, v_{i+1})$ is the angular resolution which is the difference between two consecutive AoAs. The system (A) describes the frequency distribution under an angular constraint v_i and v_{i+1}, where if the beam width is larger than the angular resolution for two consecutive users, that means users are covered by the beam signal energy. Henceforth, the base station should attribute different frequency sub-channels to avoid interference. Otherwise, both users could be served using one frequency sub-channel by mean of spatial multiplexing.

C. Formulation of the Optmization Problem

In this subsection, we formulate an optimization problem for user selection, frequency allocation based on the angular constraint, and scheduling in heterogeneous multi-user MIMO-OFDMA networks [9]. The overall problem is formulated as

$$\begin{cases} (N_Q)^* = arg \max \mathbb{V}(N_Q) \\ s.t,\ C1 : S_{nq}(k) \in \{0,1\},\ \forall n = (1,p), q, k \\ \quad C2 : \sum_{k \in U_n} S_{nq}(k) \leq \frac{Nt}{Nr}, \forall n = (1,p), t \\ \quad C3 : \frac{1}{U_Q} < \mathbb{J} \leq 1\ (7) \\ \quad C4 : \sum_{q \in U_n} \sum_{k=1}^{K} S_{nq}(k) \|w_{nq(k)}\|^2 \leq P_n, \\ \quad \forall n = (1,p)\ \ with\ p \in [0 \dots P] \end{cases}$$

Where $(N_Q)^*$ refers to the optimal set of users selected. The main objectives of our optimization problem are maximizing the total system throughput, maximizing the spectrum efficiency [3] and achieve fairness between served users.

Concerning the listed constraints, C1 indicates whether the subcarrier is allocated to the user equipment UE or not, in each macro or picocells. C2 guarantees that a subcarrier is only assigned to all most $\frac{Nt}{Nr}$ UEs in a one-time slot, again in each macro or picocells. C3 is the Jain's fairness index constraint, which is used to achieve fairness in the proposed system. C4 represents an individual transmit power constraint for each base station BS.

IV. EXHAUSTIVE SEARCH AND LOW-COMPLEXITY ALGORITHMS

In this section, we will present our proposed heuristic algorithms FAABF-algorithm and FAAB-algorithm for frequency allocation and user selection based on the angular constraint. The ES algorithm is used to provide the best solution, it takes into consideration the same constraints and objective of the optimization problem (P). Accordingly, the distributed power between users should be less or equal to the maximum power in each BS. The number of users that share the same resource unit should not exceed the number of antenna elements installed on a BS.

A. Exhausitve Search Algorithm using standard Zero-forcing

Important to realize, getting the optimal solution by applying the exhaustive search algorithm, would be ideal to achieve the goal. Precisely, this algorithm checks all the possible combinations in a way to get the optimal solution by selecting a set of users that achieve the maximum total throughput. By the same token, higher throughput means responding to user demands, thus it achieves their satisfaction.

In Algorithm 1, as in our previous work [9] we apply the ES algorithm that selects $q \leq Q$ from N_u users, by trying all the possible combinations $C_{N_u}^{N_t}$ to achieve the maximum total throughput. Power is uniformly distributed among the selected users.

B. Frequency allocation angular based with fairness FAABF

The objective of the optimization problem is to select an optimized set of users that respects all the aforementioned

Algorithm 1 Exhaustive search [9]

Require: N_u, N_t, N_r, P_{max}
Ensure: The set $\mathbf{N_Q}$
1: **while** $Q \in C_{N_u}^{N_t}$ **do**
2:     **Compute** $\forall q \in Q$, $p_q = \frac{P_{max}}{N_u}$
3:     $\forall q \in Q$, $w_q = H^*(HH^*)^{-1}$ ZF-zero forcing
4:     $\forall q \in Q$, $SINR(q)$ (5)
5:     $R(Q) = \sum_{\forall q \in Q} R(q)$ (4)
6:     **if** $R(N_q) < R(Q)$ **then**
7:        Let $N_Q = Q$
8:     **end if**
9: **end while**

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constraints in a way to jointly maximize the system throughput, spectrum efficiency as well as provide fairness, while applying digital beamforming (ZF-zero forcing) for interference cancellation. Our optimization problem is non-convex and hard to be solved so we proposed a heuristic algorithm, as shown in Figure2. the flow chart of the algorithm which attribute frequencies over the selected users. As an illustration, for FAABF-algorithm, the base station first selects a group of users that have the best channel gain, then it calculates their angular resolutions $\Delta(\theta)$, afterward base station starts to allocate frequencies for users following the system presented in (8). This process will not stop unless we served the maximum number of users possible corresponding to the available resources. FAABF provide also fairness, by the mean that users could not have more than one resource at once in order to respond to other users demands and achieve balance as well as maximize the spectrum efficiency. Furthermore, as a special case, if the sum of angular resolutions of group of users is less than the standard beam width B_m then we should start to eliminate users that has the lowest channel gain because we are limited by the number of receiving antennas Nr and the available sub-carriers. Finally, the base station should replace the number of eliminated users by other random users that respect the proposed angular constraint illustrated in (8).

C. Frequency allocation angular based without fairness FAAB

In the same way, FAAB-algorithm is quite similar to FAABF-algorithm. The only difference is that users could have more than one resource at once, in this way we may have a lack of fairness. Additionally, we would not apply for FAAB our suggested system in (8), consequently, users that experience high frequency could not be served together when $\Delta\theta(v_i, v_{i+1}) < B_m$.

V. EVALUATION AND PERFORMANCE ANALYSIS

In this section, we evaluate the performance of FAABF and that of FAAB. Afterward, we compare the proposed algorithms with the exhaustive search, via Monte-carlos simulations. Hence we average the total system throughput over 100 random channel realizations. All base stations are assumed to transmit with identical power when using the exhaustive

algorithm. Water-filling is adopted for power allocation. The simulation parameters are given in Table II.

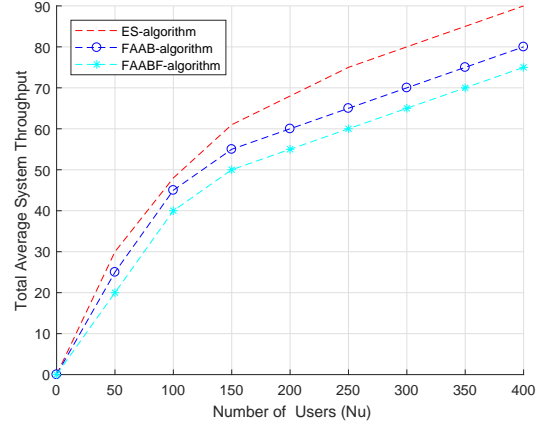### A. Total System Throughput versus Number of Users

Figure 3. Total system throughput versus total number of users.

Figure 3 depicts the total system throughput for FAABF, FAAB to be compared with the exhaustive search ES. As the number of users increases, ES outperforms FAAB and FAABF as the total system throughput increases, for a high SNR=25 dB. Even if FAAB-algorithm provides higher throughput than FAABF-algorithm but referring to Table I where we display the three algorithms, the average number of users served simultaneously as the total number of users in the system increases. Hence, the result shows that FAABF-algorithm provides fairness as it achieves the maximum spectrum efficiency, notably this because it uses efficiently the spectrum better than the other algorithms.

B. Average System Spectral Efficiency versus SNR (dB)

In Figure 4 we show the average system spectral efficiency in $bit/s/Hz$ for both macro and picocells, aiming to clear out the importance of using mmwave links in increasing the system throughput. The bandwidth used for macrocell is $B_w = 180 \ kHz$ and that of picocells is $B_w = 800 \ MHz$. As illustrated in Figure 4, in low and mean SNR the FAABF-algorithm outperforms FAAB-algorithm, this due to the high interference and high noise that affect the signal. In such a case, as proposed in the FAAB-algorithm, users with high channel gain and high interference could not be served because we could not suppress the interference. Consequently, in a high SNR regime, FAAB-algorithm outperforms FAABF-algorithm. We can conclude that the concept of densification and heterogeneous network plays a role in maximizing the total system throughput and spectral efficiency, because it gives the opportunity for uncovered users to be covered and to reply to their requests.
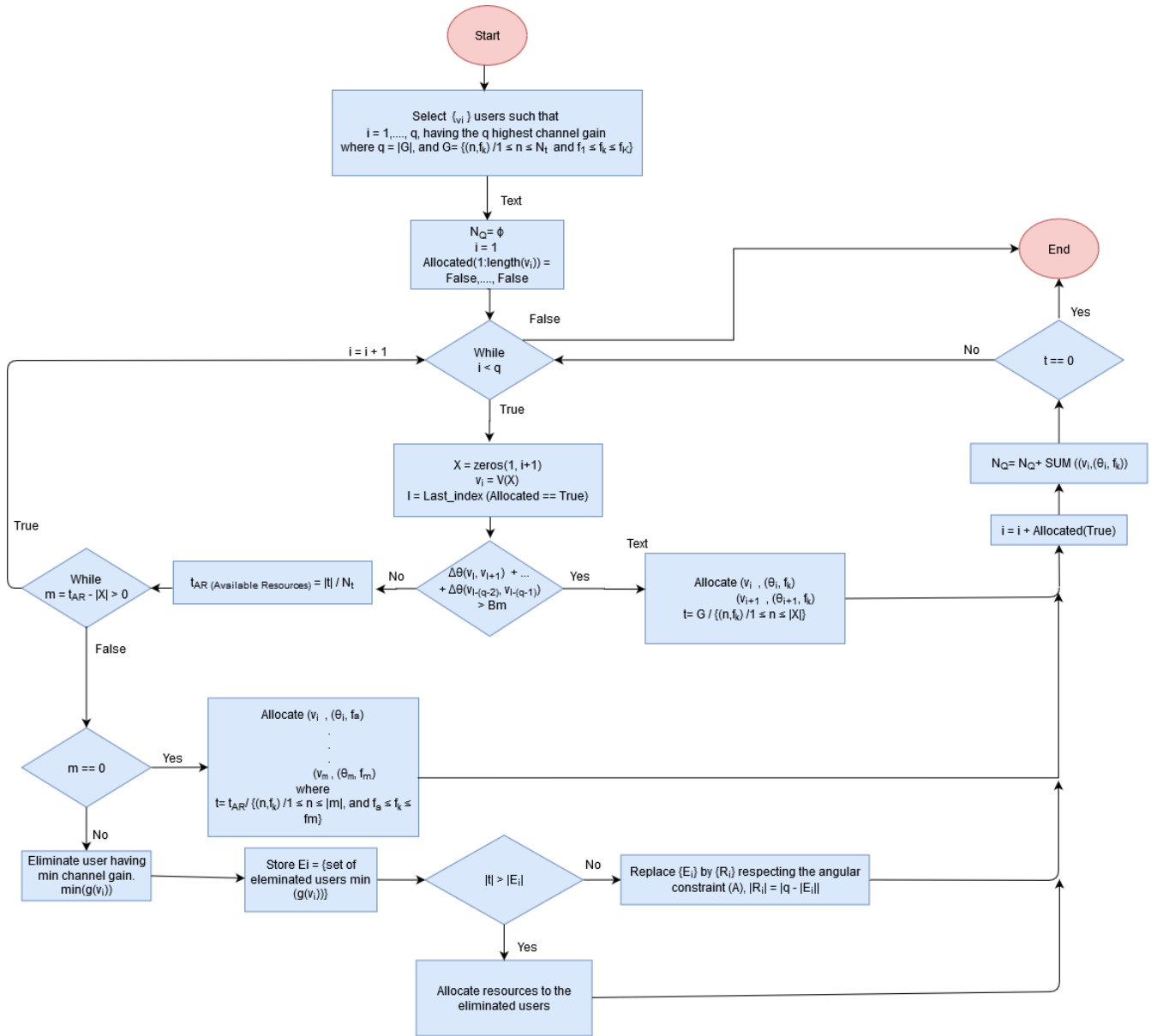
Figure 2. Frequency allocation for multi-user scenario based on angular constraint with fairness.

C. System Execution Time

Execution time is an important factor to be taken into consideration. Regarding Figure 5, execution time of FAABF-algorithm does not exceed 5 s when $N_u = 400$ users, while FAAB needs more time for the same number of users. But regarding the ES algorithm, its execution time increases exponentially as the number of users increases. To interpret this result, we can see that FAABF outperforms FAAB and ES using the metric of time, and it gives an acceptable throughput in low and middle SNR regime compared to the optimal solution, thus it could be considered as a trade-off algorithm between FAAB and ES.

Table I
AVERAGE NUMBER OF USERS SELECTED (ALGORITHMS VERSUS N_u)

Number of users	100	200	300	400
ES_algorithm	5 users	6 users	6 users	7 users
FAAB_algorithm	5 users	7 users	8 users	10 users
FAABF_algorithm	15 users	15 users	15 users	15 users

VI. CONCLUSION

In this paper, we have formulated an optimization problem to optimize user selection using standard digital beamforming. The problem aims to total throughput maximization for the downlink OFDMA MU-MIMO system, for different radio access technologies (4G) and (5G) heterogeneous, as well
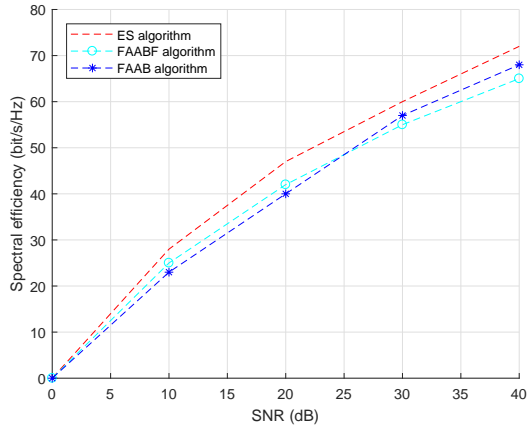
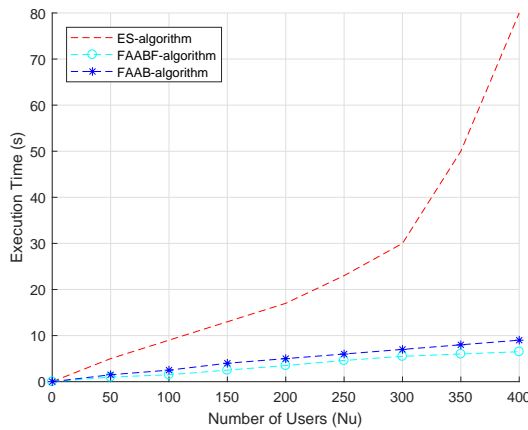Figure 4. System spectral efficiency for macro & pico cells.

Figure 5. Execution time versus number of users

Table II
SIMULATION PARAMETERS

Parameter	Value
Channel model	Statistical channel [12]
Center frequency f_c	Macro BS: 2.6 GHz, pico BS: 73 GHz
Signal bandwidth	Macro BS: 180 kHz per resource unit, pico BS: 800 MHz
Inter-site distance (ISD) for macro	500 m
Number of macro cells	1
Number of pico cells	2
N_s : spacing	$\frac{\lambda}{2}$
Number of transmit & receive antenna	$N_t = 5$, $N_r = 3$
Transmit power	Macro BS: 46 dBm, pico BS: 26 dBm
Noise power σ	$\sigma = -174 + 10 log B_w \ dB$
UE distribution	N_u users uniformly distributed in all system
CSI at transmitter	Perfect knowledge

as maximize the spectrum efficiency. We have proposed a robust and well-structured system model where we used a realistic channel model for mmwaves 5G. We have proposed two metaheuristic FAAB-algorithms with and without fairness to select a set of the users that provides all the constraints. In parallel, we have applied the exhaustive search algorithm to get the optimal solution. Numerical results revealed that FAAB-algorithm outperforms FAABF-algorithm in low and middle SNR regimes while FAABF-algorithm outperforms FAAB-algorithm in high SNR regime as it provides higher system throughput. It is worth mentioning that FAABF-algorithm outperforms FAAB-algorithm and ES because it needs less execution time. As a conclusion, FAABF-algorithm could be considered as a trade-off algorithm between FAAB-algorithm and ES, where it guarantees fairness and maximize spectrum efficiency as it serves simultaneously the highest number of users.

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