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**User Association and Load Balancing In 5G Network**

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Abstract:

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# General Introduction

## Introduction:

## Motivation and problem statement:

## Report outline:

# Background and Related Work:

## Scope:

### Heterogeneous networks (HetNets):

### Massive MIMO Networks:

### MmWave Networks:

### Energy Harvesting Networks:

### Other 5G Candidate Technologies:

#### Device to Device communication (D2D):

#### Full Duplex communication:

#### Cloud radio access network(C-RAN):

#### Self-organizing networks(SONs):

### Summary:

## Optimization techniques

### Game Theory

#### Non-Cooperative:

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#### Challenges:

### Combinatorial optimization

### Stochastic geometry

#### How to model and analyze network geometry?

#### Point Process Fundamental of Stochastic Geometry

### Evolutionary algorithm

## Metrics

### outage/coverage probability

### QOS

#### TRAFFIC IN 5G NETWORKS

#### QOS MANAGEMENT IN 5G NETWORKS

### Energy efficiency

#### User Association in HETNETS Network:

#### User Association in Massive MIMO Network:

#### User Association in MMWave Network:

### Spectrum Efficiency:

#### User Association in HETNETS Network:

#### User Association in Massive MIMO Network:

#### User Association in MmWave Network:

# Proposed Method and Analyses

## Problem definition:

In the last few years the number of users has grown dramatically, which resulted the main big companies to start thinking how to maintain this huge capacity growth, this significantly growth in users resulted in more and more energy consumption and on the other hand the shortage of spectrum channels, these two factors pressured the need for energy and spectral efficiency solutions.

So, our problem will be focused on associating the users to the base station based on the spectrum and energy factors in mobile network, where to assign the user to achieve less power consumption from the user size and maximum network capacity from the company size by achieving maximum spectrum efficiency, since these are the main two factors companies are looking forward to maximizing the number of users connecting in a mobile network and saving as much as we can energy and spectrum for the next generation of mobile networks (5G) Heterogenous Mobile Network (HMN).

## System model:

A Heterogenous Mobile Network consists of multi-tiers, a main Macro cell tier and other small cell tier (Pico-cell, Femto-cell, …), our analysis will be on a Heterogenous () two tiers network, a first tier Macro cell tier that contains of other femto-cells a secondary tier. Also, the frequency deployment is a Co-channel deployment, where the small cells operate on the same frequency band of the macro cells, each macro cell contains of channels called (resources block (RB)), whereas the femto cells also contains a resources block, some of the resources blocks are fixed as only a single base station uses these channels in the resources blocks, on the other hand, some of the channels are allocated dynamic and controlled by a Channel Allocation Center (CAC) that contains a pool of unused channels where the base stations that has shortage in its channel can borrow some channels from the Channel Allocation Center. Besides, the small cells (Femto-cells) communicate wirelessly with the macro cell assuming they are on the same line-of-sight. The mobile stations (MS/user) can connect to a macro-cell or a femto-cell where the femto cell is connected to the macro cell directly (Single-hop). The macro cell is separated into three sectors that work on the same channels to increase the network capacity and they are operator deployed planned, also the femto cells are an operator deployed plan. Each tier (macro -tier1- or femto -tier2-) has a transmission power where the power of the macro cells are much more than the power of a femto cell (radius of the macro cell is larger than the radius of a femto cell. The distance between every two nodes is calculated based on the Euclidian distance calculation, and the path loss model is a free space path loss. Figure ‎3‑1shows the architecture of our network.

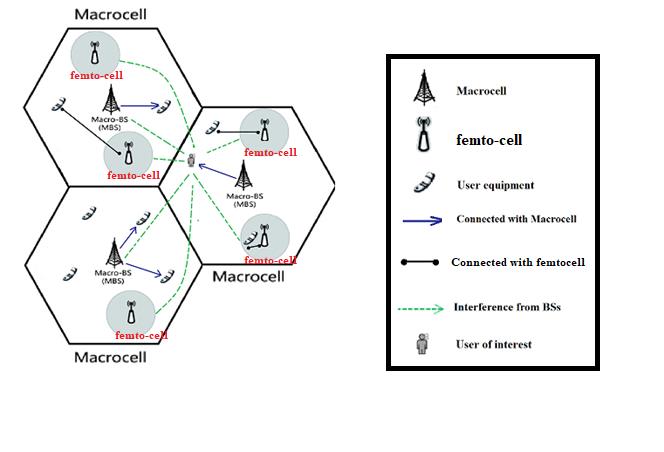


Figure ‎3‑1 Network Architecture

To determine the total Channels available in the spectrum, we assume an equal bandwidth per Channel, therefore we calculate the total Channels by using *Equation (‎3‑1)*.

|  |  |  |
| --- | --- | --- |
|  |  | *Equation (‎3‑1)* |

Then we combine a group of channels to form a Resource Block, the number of resources blocks is determined from the Cluster (Combine a group of macro Cells) size and the number of femto cells in each macro cell ( without reusing the resources blocks and the size of the resource block is determined from number of channels used for static allocation (calculated from the number of channels used for dynamic allocation and the total available channels) and the total w here the number of Resources Block and size are calculated based on *Equation (‎3‑2)* and *Equation (‎3‑3)*.

|  |  |  |
| --- | --- | --- |
|  |  | *Equation (‎3‑2)* |
|  |  | *Equation (‎3‑3)* |
|  |  |  |

### SINR Calculation:

The base stations are distributed on its Base stations is based on a homogenous Poisson Point Process (PPP), . where the location for the Cell is given by . And also, the distribution of the BSs in multitier HMNs is governed by a Poisson point process where the .

The PPP model is also used for the distribution of users, each user (MU) has an independent PPP denoted by for MUs associated with the Kth tier, is the location of the user in the cell and served with the nearest with a distance between them.

The noise we are considering here is the thermal noise denoting by , thermal noise is modeled here as an additive white Gaussian noise (AWGN). The variance is denoted by , and a mean of zero.

If consider a given BS x and a desired MS y. Then the desired signal power Pxy received at y is expressed as in *Equation (‎3‑7)*:

|  |  |  |
| --- | --- | --- |
|  | [1] | *Equation (‎3‑4)* |
|  | [2] | *Equation (‎3‑5)* |
|  | [2] | *Equation (‎3‑6)* |
|  | [2] | *Equation (‎3‑7)* |

Where

* + - * and are the receive and transmit antenna gains.
      * is the wavelength
      * is the distance between x and y.(Euclidean)
      * where d>d0
        + Typical value for :

Indoor:1m

Outdoor: 100m to 1 km

* + - * is the transmitted power
      * is the received power
      * and are in same units
      * and are dimensionless quantities.

From the above assumptions we can express the SIR as shown in *Equation (‎3‑8)*.

|  |  |  |
| --- | --- | --- |
|  | [2] | *Equation (‎3‑8)* |

Where are all Base stations that cause Interference without MS that is connected to x base station. To calculate the signal to interference plus Noise ratio as in *Equation (‎3‑9)*.

|  |  |  |
| --- | --- | --- |
|  | [2] | *Equation (‎3‑9)* |

Where N is the terminal noise (additive white gaussian Noise).

### Power Calculation:

The coverage area for each cell should be known to know that the user sees the BS or not and it is calculated by *Equation (‎3‑10)*.

|  |  |  |
| --- | --- | --- |
|  | [3] | *Equation (‎3‑10)* |

Where the constant calculated using the frequency as in *Equation (‎3‑11)*.

|  |  |  |
| --- | --- | --- |
|  | [3] | *Equation (‎3‑11)* |

Where:

:Path loss

The power consumed by each user is differ than the transmitted power from the BS that the user connected with, and it can be calculated in different ways like in [4], *Equation (‎3‑7)* was used because it is the best equation that fit our topology where the Gains, the transmitted power and the wavelength are parameters and the distance calculated.

### Throughput:

Total throughput is the product of the total number of active users and the average achievable rate of a randomly chosen user when it is under the coverage of the BS as in Equation (‎3‑12).

|  |  |  |
| --- | --- | --- |
|  |  | Equation (‎3‑12) |

Where:

∶ is the density of the randomly chosen user

: is the total area

: is the averaged coverage probability of mBSs over the plane

: is the averaged coverage probability of pBSs over the plane

: is the average achievable rate of the randomly chosen user in the macro tier

: is the average achievable rate of the randomly chosen user in the pico tier

To find the coverage probability, we use *Equation (‎3‑13)*

|  |  |  |
| --- | --- | --- |
|  | [5] | *Equation (‎3‑13)* |

Where:

* : Target SINR
* : the random distance between the tagged MU and its serving mBS
* , such that:
* : path loss exponent
* : Noise variance
* : mBS density

The averaged coverage probability of pBS over the plane is derived as in *Equation (‎3‑14)*.

|  |  |  |
| --- | --- | --- |
|  |  | *Equation (‎3‑14)* |

Where:

Now, the only thing remaining is to find the average achievable rate, the following equations(*Equation (‎3‑15)*, *Equation (‎3‑16)*, *Equation (‎3‑17)*, *Equation (‎3‑18)*and *Equation (‎3‑19)*) shows how to find it.

|  |  |  |
| --- | --- | --- |
|  | [5] | *Equation (‎3‑15)* |
| Where: | * [5] | *Equation (‎3‑16)* |
|  | * [5] | *Equation (‎3‑17)* |
|  | * [5] | *Equation (‎3‑18)* |
|  | * [5] | *Equation (‎3‑19)* |

Where LI1(s) and LI2(s) are the Laplace transform of a random variables 𝐼1 and 𝐼2 which are the aggregate interference power generated by the() at the tagged macro MU.

## Problem formulation and optimal solution:

Our objective here is to find the maximum spectrum and energy efficiency of the network , at first we can define the spectrum efficiency as the total throughput divided by the total bandwidth, and the energy efficiency as the total throughput divided by the total power consumption. Now, we can express the spectrum and energy efficiency according to the definition above as spectrum efficiency in *Equation (‎3‑20)* and energy efficiency in *Equation (‎3‑21)*.

|  |  |  |
| --- | --- | --- |
|  |  | *Equation (‎3‑20)* |
|  |  | *Equation (‎3‑21)* |

Based on the above analysis, we formulate an optimization problem to balance SE and EE, to maximize the SE under the EE constraint. This optimization problem can be formulated as:

S.t :

## Overall Algorithm:

|  |
| --- |
| Simple Algorithm |
| For new User i  -Find all possible base-stations j [] that the user i can connect with  -For each BS j  Find the total SINR and put it on SINR []  -Sort SINR [] in descending order  -n = SINR.length();  -While (1) {  Take SINR[n]  Calculate the total throughput  Calculate SE and EE  If (EE > EE\_MIN) {  Optimal = SE;  Break;  }  else {  n--;  }  } |

-We take one user per time

-We see all possible base-stations that the user can connect with

-Take all possible scenario and find the total SINR in every scenario

-Find the scenario that gives the maximum total SINR

-Find the total throughput of the best case

-Find SE and EE

-Check if EE > EE\_MIN {

Take this association

} Else {

Take the scenario that gives the next best SINR and check again

}

## Solving Problem Using Evolutionary algorithm:

In this section we will formalize our problem to solve it using Evolutionary algorithm (Genetics algorithm). In which it will give us a possible solution which is as much close to the optimal solution for the topology we formalized.

In the next part we will describe the chromosome we will use, moreover will describe the genes for the chromosome and define our fitness function that will be used in the genetics algorithm and solve the problem using genetics algorithm (NSGA-III).

### Chromosome and Genes Formalization:

#### Chromosome Formalization:

As we made the Macro cells, the Femto cells and the users, numbers and locations as random as possible then also the chromosome will be affected by these changes from one topology to another. Which will make it changeable (dynamic) between topology and another.

In the same topology the chromosome will be static which will contain all users in the topology that are inside the area of our system and can connect to a macro cell or a femto cell. The chromosome will be as shown in Figure ‎3‑2. Each user describes a gene of this chromosome and the crossover will be as changing genes of this chromosome.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | | | | | | |
| User 1 | User 2 | … | User k | … | User (i-1) | User i |

Figure ‎3‑2 Our Chromosome for NSGA-III Algorithm

#### : Genes Formalization:

As we mentioned before the chromosomes will contain the genes which are the number of users that can connect to our network, but each gene will contain all the possible base stations that a user can connect to. As the number of base stations that a user can connect to is changeable from each user to another then in this way the genes also will be changeable in the one chromosome which will affect the crossover, so in order to unify the genes over the chromosome then we will separate the genes into two sub-genes the first will contains only the Macrocells possible connections and the second will contain the Femto cells possible connection and to unify these numbers for all the genes then we will take the maximum number of macro base stations and the maximum number of femto cells a user can connect to and define the genes as the total number of base stations a user can connect to. Shows the description of the genes. Each part of the gene will be either a 0 or 1 (Binary) (1: the user is connected to this base station, 0: user isn’t connecting to this base station) and for the one gene at most and at least one of its parts will be 1 which means that the user is only connected to one base station.

Moreover, the genes consist of the cell Id as shown in Figure ‎3‑3 (Cluster Id , Macrocell Id and Femtocell Id (will be described later in the next chapter)).

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | | | | | | | |
| Possible Macro Cell 1 | Possible Macro Cell 2 | … | Possible Macro Cell M | Possible Femto Cell 1 | Possible Femto Cell 1 | … | Possible Femto Cell F |

Figure ‎3‑3 Our Genes for NSGA-III and genetics Algorithms

### Cross-Over Algorithm:

In this section we will describe how the matting between the chromosomes will happen as also we will explain how to generate a population randomly and what are the constrains for generating a population, on the other hand will make the mating also randomly where the probability of mating is an input, and finally we will explain the mutation and how can it occur and what are the constrains on a mutation process.

The cross over will happen between any two members of the population where each matting will produce two new members which we will call children that have a better qualities than their parents, the cross over will be an exchange of genes between the parents, the place of the genes will remain static so if the first gene transfer from the first parent then it must replace the first gene in the second parent and so on for all genes in the chromosomes, the number of genes to be transferred and the place of genes will be chosen randomly.

This process will be repeated for the number of iterations which is an input for the algorithm and if the system falls in some local maxima then a mutation will help us to get out of this solution.

#### Generating population:

The generation for a population will be randomly as each gene in the chromosome will be generated separately, where there is a constrain on the generation process, that each bit in the gene that represents a possible connection, although the user cannot be connected to more than one base station and the user must be connected to at least one base station, so there must be at least and at most one bit in the gene that is one to insure that the user is connected to a base station and no more than one. The generation process is randomly so that in the population there must be all possible scenario, and for the base stations that are padded to the gene and the user cannot connect to them, then these must not be ones so to ensure that the user isn’t connected to a base station that he from the first cannot connect to it.

#### Probability of matting:

When we choose two chromosomes to be matted then there is a probability that these chromosomes can be matted and produce two new children. This probability must be high enough to make the process faster and to reach the optimal solution. This probability must be greater than 70% and in the best case it can reach to 100% where for each possible choice there is a mating and two new children are created.

#### Probability of mutation:

In this section we will describe the mutation process that may occur in the children chromosomes after the cross over happens, where one gene in the chromosome can be changed and this changing also has some constrains, as if a mutation occur then it will change the one to zero and set one of the possible zeros that represents a possible base station the user can connect to, the probability of a mutation is low and it is less than 1%.

## Fitness Function:

Our fitness function was calculated for each chromosome independently, described by *Equation (‎3‑22)*

|  |  |  |
| --- | --- | --- |
|  |  | *Equation (‎3‑22)* |

Where gene is connecting with the base station or not, is the objective that is used for that base station and the desired user, and N is the number of genes in the chromosome, so we will compare using multi objectives as SINR, Power, and the Load balancing.

### Single Objective Fitness function:

In this section we will describe how to calculate the fitness function using SINR only, Using Power only, Using Power and SINR, and using Power, SINR and load balancing.

#### Using SINR only:

In this technique we will calculate the SINR for each user and each base station that can connect to, and we will calculate the fitness function for each chromosome by adding the SINR for each user for the base station that is connecting to; according to that chromosome.

#### Using Power only:

In this technique we will calculate the received Power for each user and each base station that can connect to, and we will calculate the fitness function for each chromosome by adding the Power for each user for the base station that is connecting to; according to that chromosome.

#### Using Power and SINR without load balancing:

This technique is different for the above since the SINR and Power may have different means and standard deviation, so adding them may result by one dominate the other which will be dominant for one objective. So, to solve that problem we should change the mean and standard deviation for both the SINR and Power to the same mean and standard deviation in order to add them.

In order to make the an array named Var distributed between 0 and 1 we will use *Equation (‎3‑23)* and *Equation (‎3‑24)*.

|  |  |  |
| --- | --- | --- |
|  |  | *Equation (‎3‑23)* |

Where the Var is an array of the numbers (SINR or Power) for all possible connection cells for one user.

Normalized.Var is an array of the new normalized Var in the range of where 99.9% of all the Var values in this range, so to make the range from [0,1] with mean 0.5 we used *Equation (‎3‑24)*.

|  |  |  |
| --- | --- | --- |
|  |  | *Equation (‎3‑24)* |

Dividing by 6 will change the range from to with zero mean and adding 0.5 to the array will change the mean from 0 to 0.5 and the range from to .

Applying the above equations for the SINR and Power Arrays this will unify the mean and the standard deviation for the SINR and Power, (Mean= 0.5 and Unity Standard deviation). This allows us to add the arrays which will result for a new array distributed between with mean=1 and standard deviation equal 2.

After adding the SINR and Power arrays we will calculate the fitness function for each chromosome by adding the Normalized array (SINR+Power) for each user for the base station that is connecting to (its Bit is 1); according to that chromosome.

#### Using Power, SINR and Load balancing:

Adding the load balancing for our calculation is made by dividing the Normalized Power and SINR by the number of users connecting to that base station. *Equation (‎3‑25)* shows how it is done.

|  |  |  |
| --- | --- | --- |
|  |  | *Equation (‎3‑25)* |

And After adding the load balancing to the SINR + Power arrays we will calculate the fitness function for each chromosome by adding the Normalized array with the balancing () for each user for the base station that is connecting to (its Bit is 1); according to that chromosome.

### Multi objective NSGA-III:

To solve our problem, we used the proposed algorithm NSGA-III as proposed in (paper) for our chromosome and solved the problem for the main two objectives SINR and received power.

## Solving Problem Using Game Theory:

Game theory is a mathematical modeling tool, which tries to distribute the interest to all interaction players(Users) by reach a point called "equilibrium point". This happens when users take the best strategy to be associated with only one BS.

In HetNets, the process of spectrum/energy-efficiency user association based on the Game Theory can be described as follows.

### Game Theory approaches:

The Game theory has two main approaches:

#### Cooperative approach:

Each player in the game considers the utility of the rest of players when he tries to maximize its own utility. On other words the players on the network agree to work together and divide the gains based on their individual contributions.

#### Non-Cooperative approach:

In this approach there will be some winners and losers between players. Where, each user tries to maximize its own utility no matter what other players(opponents) decides to do.

### Formalization:

#### Players:

Game Theory describes each user or BS as a player and in our topology the users were assumed to be the players.

Each UE in a specific area that is served (by Macro/Femto) is denoted as a player. Assume that M users, each one of them has a selection {… … }. Each UE can choose to be associated with any BS within the range. Therefore, each UE in this range can be modeled as a player of the Game Theory.

#### Strategy:

The strategy in game theory of each user refers to the selection of a BS where, each UE can select any BS to be associated with.

The Probability of each to selects can be denoted as , since ∈ {0,1}, and . That means each user can be associated with only one BS.

Each user can connect with more than one BS needs to determine which BS to connect with by consider multi-objective (SINR, Power-Received, Load balancing).

For the SINR we collect the best SINR for each user, whereas the minimum SINR that allows the user to connect with a BS should be greater than (0.2), otherwise the user will not be considered. Then store the users SINR values in an array and find the mean value of all SINR values for all users. At the same way we find the mean value of power.

Now the distributions for each user () should follow *Equation (‎3‑26)*.

|  |  |  |
| --- | --- | --- |
|  |  | *Equation (‎3‑26)* |

#### Normalizing SINR and PR:

The values of SINR and PR are not in the same range, so we need to scale them to be close to each other. To do that we normalize these quantities using*Equation (‎3‑27)* and *Equation (‎3‑28)*.

|  |  |  |
| --- | --- | --- |
|  |  | *Equation (‎3‑27)* |
|  |  | *Equation (‎3‑28)* |

Where STD means the standard deviation, for both (SINR, PR) calculated as in *Equation (‎3‑29)*:

|  |  |  |
| --- | --- | --- |
|  | σ (STD) | *Equation (‎3‑29)* |

where, for each value, subtract the mean and square the result, then work out the mean of those squared differences and take the square root of that and we are done.

The normalized value for SINR and PR will differ in each run and applied to previous equations.

We should notice that the value of (V) is not enough because it can give us greedy search of BSs that gives the best possible value from the array, so we need to consider the load balancing as the 3rd objective in our decision.

#### Load Balancing Objective:

The load balancing objective is implemented by considering the BS capacity, where the BS should not be full to allow some users to connect with it when necessary, and take into account the number of connected user and the value of V (SINR with the power) as ratio.

Each user ( ) can see more than one BS, the decision is determined by dividing the value of V over the number of connected users for each BS, and the best result we get will determine which BS the user will connect with. See *Equation (‎3‑30)*.

|  |  |  |
| --- | --- | --- |
|  |  | *Equation (‎3‑30)* |

that the user can connect with. So that, our decision takes these 3 objectives to assign any user to a specific BS.

#### Utility function:

The utility function is calculated after assigning each user to a BS, depending on multiple objectives (SINR, Power received, Load-balancing), and it can be calculated in different ways. In our topology the utility for each user was calculated as the ratio of the throughput over the SINR as the equation below. And the payoff (gain) of a player is determined by its net utility.

|  |  |  |
| --- | --- | --- |
|  |  | *Equation (‎3‑31)* |

where i ∈ {UE}. and the total utility can be calculated as in *Equation (‎3‑32)*.

|  |  |  |
| --- | --- | --- |
|  |  | *Equation (‎3‑32)* |

where M number of user connected.

# Used Tool and Results

## Tool:

## Experiments setup:

### Building topology:

### Simulation Parameters:

## Results:

## Metrics we Will Compare to Other Methods:

# Conclusion

# References:

[1-5]

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4. Nasim, I. and S. Kim, *Human Exposure to RF Fields in 5G Downlink.* arXiv preprint arXiv:1711.03683, 2017.

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