Journal of Engineering Technology
Volume 8, Issue 2, July 2019, PP. 73-85
RESEARCH ARTICLE -ENGINEERNG TECHNOLOGY

An Innovative Combined Model-Based Goal Attainment For Interference Mitigation In Heterogeneous Network

Samira ACHKI *[1], Fatima GHARNATI [2], Abdellah AIT OUAHMAN [2]

[1]Science Department, Faculty of Science and technique Cadi-Ayyad University, Marrakech, Morocco,
[2]Physics Department, Faculty of Science Semlalia, Cadi Ayyad University40000 Marrakech, Morocco

Abstract: This article discusses the interference mitigation for an uplink heterogeneous network (HeNet). In this study, we propose a new management of resource allocation model with an unsupervised learning step. The proposal starts with a clustering stage where users are classified via signal interference noise radio (SINR) in HeNet. Next, a power control optimization is considered for the uplink HeNet. With this strategy, the device users are separated in two different clusters according to the improved signal-to-leakage-plus-noise ratio (SLNR), SINR weighed, and by considering shadowing. Moreover, to maximize both the system capacity and control power, which mitigates the interference, we use the goal attainment method. Simulation results demonstrate that almost of low inter-cell interference can be canceled. This latter allowed us to have a better capacity a system.

Keywords: Heterogeneous network HetNet, Smallcell, Macrocell, uplink Interference, power control, SINR, goal attainment.

1 Introduction

Nowadays, the cellular mobile [1] radio systems intensely rely on greatly and highly hierarchical network architectures that agree service workers to control and share radio resources among base stations and clients in a centralized style. The communication systems mobile undergo a constant growth in terms of many subscribers. With the foreseen exponentially increasing number of users and traffic in the 4G and future wireless networks, existing deployment and practice becomes economically indefensible [2].

Moreover, these users always require a better quality of service and a vast cover characterized by a strong signal [3], in particular in the zones with weak cover. To cope with these dies, a new concept of heterogeneous network was adopted. The Heterogeneous network (HeNet) [4] is a network deploying various types of cells (Small and macros cells), to improve the performance of the network and to cure the problems of zones to weak cover. However, the coexistence of these various layers of cells generates interference on the level of the downward link that can affect the quality of signal offered to the users. This interference results thus in a degradation of the performances of the Heterogeneous network.

HetNets can be accomplished by deploying unplanned resources, low power small cells base station (BS) (picocells, femtocells, and relays) in coverage challenged areas by a high power planned macrocell. As LTE-Advanced is elected and designed for a frequency reuse of one, these small cells use the same spectrum that is worn by the overlay macrocell [5]. The distribution of small-cells users inside the coverage zone of macro-cells users (MUEs) takes harmful inter-tier interference as a by-product along with the capacity enhancement. In LTE Advanced homogeneous networks, conventional fractional power control scheme is used to minimize the co channel inter cell interference; though, in HetNet no proper frequency is planning in environment, there is among tiers to cope with interference from small cells users and neighboring MUEs. This severe intertie -intercell interference appropriate the user's signal to interference plus noise ratio (SINR) which results in an improvement in the user's failure ratio; for the majority, the users close to cell edges are typically vulnerable to this harmful and dangerous interference [6]. Since, the macrocell is displayed with high priority radio network and not for small cells; therefore, MUEs need higher priority of network coverage. Hence, it is necessary to control interference from small cells and guarantee protection of MUEs in heterogeneous deployment. So, be there a strong need for intertier-intercell interference management for HetNets. Here, it is perceptible that intra-cell interference is ease by the orthogonality feature of OFDMA (orthogonal frequency-division multiple access) and the single-carrier frequency-division multiplexing access (SC-FDMA) worn in the downlink and uplink of LTE-Advanced, respectively [7]. Also, the major interference scenario of interest in this work is the inter-tier interference from small cell users and intercell interference from small cell-user and macrocell users to the uplink traffic in a HetNet environment.

The majority of the above-mentioned techniques and strategy are specified for downlink HetNets. In a conventional uplink system, fractional power control (FPC) [8] is a characteristic scheme for uplink channels. However, the FPC is generally applied in homogeneous networks so such it is shown not efficient enough in HetNets. The FPC strategy has been considered as a primitive rule for uplink users to regulate their transmit power. Usually, the FPC satisfied the long-term path loss as well as the shadowing effect in order to guarantee an acceptable strength of receives power at the BS. Mathematically, the FPC strategy at user k is resolute by the following formulate [9]:

$$p_k = min\{p_{max}, p_0 + \alpha p_{loss,k} + 10\log_{10} N_l\} \quad (1)$$

Where P_{max} is the maximum transmit power permitted at user k, the P0 is a UE power received, α is the path loss compensate factor, $p_{loss,k}$ is the estimated downlink path loss from the user k to its allocation BS, and N_l is the number of RBs attribute to the k uplink user in a cell l.

This paper is organized as follows. In Section 2, related works are presented. Section 3 refers to the System model and problem formulation. Section 4 presents simulation results and discussions. Finally, Section 5 concludes the paper.

2. Related Work

Interferences [10] introduce when two or more devices communicate each other nearly figure 1. The 'near' designates devices that divide and share one or more communication dimensions, for example, time, frequency, space, or code. The wireless communication has different types of interference. For example, inter-symbol interference offers when a symbol correspondence with succeeding symbols because of a delayed multi-path signal. Meantime, inter-carrier interference is the alteration of a carrier with other carriers. Co-channel interference occurs when a device transmits on the same channel being used by a nearby and adjacent device.

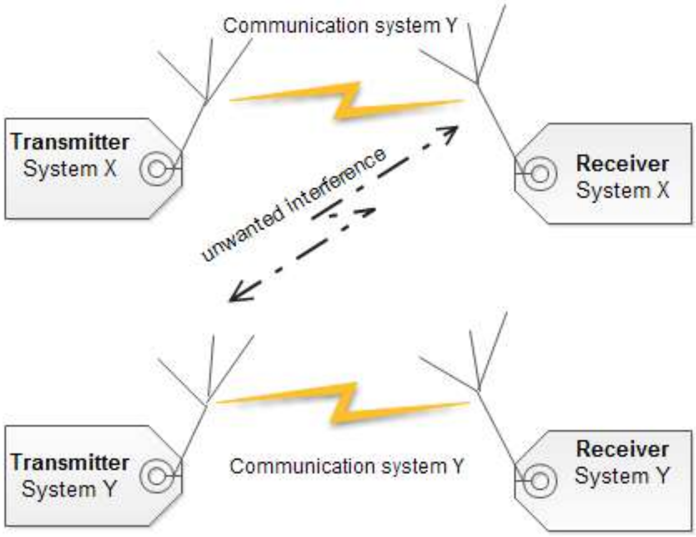

Figure.1. Interference in wireless system

In other words, the interferences disturbing the reception of the signals of an antenna can come from various origins. In general, there are three types of important interferences [11]: Self-interference, Multiple access interference, Co-channel interference, and adjacent channel interference. Interference in the communication networks comes as undesirable trouble which causes limiting the benefits derivable from this important technology. Interference poses a high major problem in cellular networks for service contractors as it reduces the quality of service for service contractors, which could result a reduction in revenue. Multiple access interference is induced by transmission from multiple radios utilize the same frequency resource.

In literature there are many studies and different approaches and techniques that resolve the interference reducing, among these solutions power control technique, user association, frequency planning methods, Genetic algorithms, Ordering heuristic, Ant colony, multi-agent optimization and Artificial neural networks.

3GPP [12] proposed different improvements over intercell interference coordination (ICIC) approach, all new approaches concentrate and focused on power control techniques to attack inter-tier interference. In [13]., authors classify the unique uplink interference for LTE networks and proposed two learning-based algorithms. This work is determined by a set of data measurement, which updates the cell-specific optimal power parameters. Thus, authors realized an important gain in overall throughput, and reduced the MUE throughput cost. Similarly, in [14], the transmit power is attuned based on a high interference indicator (HII) parameter, where authors consider interference only from neighboring macrocells in the LTE environment. In [15], the authors used FPC method in order to handful interference. The closed-loop FPC is proposed for LTE networks; so, it does not consider the path loss and interference generate by small cells in a HetNet environment. Also, in [16], an uplink power control algorithm based on fixed and dynamic thresholds of the interference is suggest and proposed orderly to reduce inter-tier interference from FUEs to MUEs. Though this algorithm corrects for the throughput degradation of MUEs, it does not guarantee the defense of MUEs while adjusting the uplink power. In addition, the outage of FUEs may not be controlled and FUE throughput may radically reduce.

Our work is based on the objective of proposing, a new method to enhance the throughput performance of the uplink HetNet, in the following sections, we will consider the uplink interference control by developing a user-classification resource allocation as well as power control strategy using goal attainment method.

3. System model and problem formulation

We consider a two-tier HetNet system model shown in Figure 2 In this studied system model, there are one Macrocell BS referred to as cell {O}, number of Smal BSs indexed by {1,…, L}, and multiple users UE randomly falling within the cell coverage, and the cell association is given according to the downlink reference signal received power of each individual user .The Macro BS and Small BSs are armed with multiple antennas for applying the massive MIMO technique. In the system, there are overall N Resource Block (RBs) available for data transmission. Let the antenna number of the Macro BS and l Small are K_O, K_l respectively.
The main objective for this section is to calculate the signal-to-noise-interference ratio SINR of each user in an optimal way. Hence, the (SINR) was adopted as a metric to disregard link quality measures. The linkage measures model extracts the measures that will be used to adapt the link and allocate resources. This model aims to reduce the execution time and computational complexity by pre-generating the most necessary parameters. In this measurement model, special attention is taken into account in the modeling of the spatial and temporal correlations of the channel present in the cellular system.

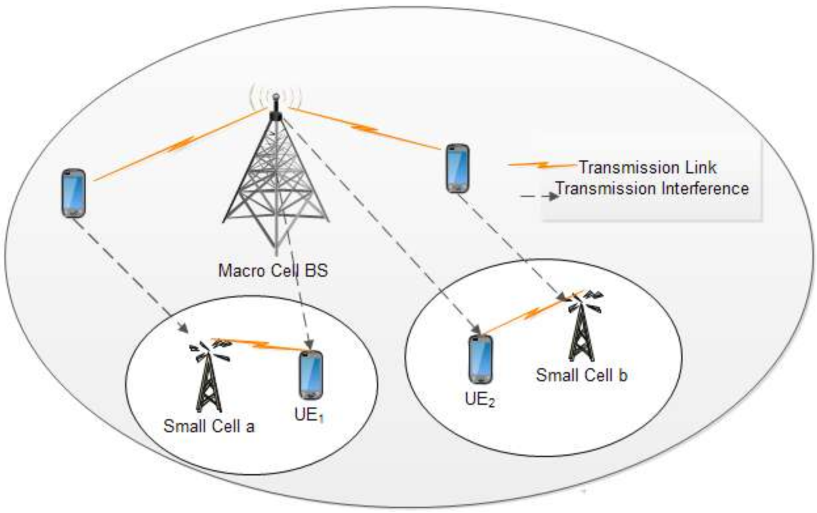

Figure.2. Description of interference in an uplink HetNet

In order to reduce the impact of interfering signals on the SINR received by the user. we only consider the resource and power control across different RBs while supposing simple equal power allocation across subcarriers within each RB, let the H_k^l the signal channel from the macrocell or the l smallcell (for l=1…, L) to the k user.

Indeed, each user UE calculates his SINR received at each radio resource block (RB), at each moment of transmission, by using the following expression [17]:

$$SINR = \frac{\alpha_{k,n}^{O} p_{k,n}^{O} H_{k}^{O}}{\sum_{l=1}^{L} \sum_{i=1}^{K_l} \alpha_{i,n}^{l} p_{i,n}^{l} g_{i}^{l,O} + \delta^2} \qquad (2)$$

Where:

$g_i^{l,O}$: The interference channel from the user i associated with the j cell.
$p_{i,n}^{l}$: The power uplink transmits of user i at then n RB in cell.
$\alpha_{i,n}^{l}$: The cell association index with values {0, 1}.
δ^2: The variance of Gaussian noise (AWGN) at the receiver by user.
Note that where $\alpha_{i,n}^{l} = 1$ designate that user i is associated with the l cell on the n RB, alternatively $\alpha_{i,n}^{l} = 1$ that means the n RB of cell l is assigned to other users.

Also, the received SINR at the n RB of the l smallcell for the k UE is [18]:

$$SINR = \frac{\alpha_{k,n}^{l} p_{k}^{l} H_{k}^{l}}{\sum_{i=1}^{k_o} \alpha_{i,n}^{0} p_{i,n}^{0} g_{i}^{0,l} + \sum_{j=1, j\neq l}^{L} \sum_{i=1}^{k_l} \alpha_{i,n}^{j} p_{i,n}^{j} g_{i}^{j,l} + \delta^2} \qquad (3)$$

The problem of uplink power control and resource allocation of all users in heterogeneous network HeNet is formulated as weighted sum velocity maximization problems, from equation (2) and (3) the problem of uplink power control and resource allocation is formulated by [19]:

$$\mathrm{Max}_{\alpha_{k,n}^{l} p_{k,n}^{l}} \sum_{l=0}^{L} w_l \sum_{n=0}^{N} \sum_{k=1}^{K_l} \log\left(1 + \delta_{k,n}^{l}\right) \qquad (4)$$

Subject to $p_{k,n}^{l} \leq p_{max}^{l}, \forall\, l$

$\sum_{n=1}^{N} \alpha_{k,n}^{l} = N_l\,, \forall\, l, K;$

$$\sum_{K=1}^{K_l} \alpha_{k,n}^{l} = 1, \qquad \forall\, l, n;$$

$$\alpha_{k,n}^{l} \in \{0,1\}, \qquad \forall\, l, K, n;$$

$$p_{k,n}^{l} \geq 0, \qquad \forall\, l, n$$

Where w_l the weighting factor with respect to the attainable corresponding to the different cells and $N = \left({}^{N}\!/_{K_l}\right)$, $\forall\, l \in \{0,1,\ldots,L\}$ is the maximum permissible number of RBs allocated to each user in the l cell.

In order to perform the problem flexible with reasonably good solutions, in the next, we will simplify the problem by presenting a classification user-specific power and RB allocation algorithm for the HetNet in the next section.

3.1 Classification of users under HeNet

In traditional homogeneous networks, the users are usually classified as either at the edge of the cell or in the center of the cell based on classified by considering shadowing and the received SINR for coordinated multicell joint processing.

Classification users by considering shadowing. We consider an environment, illustrate in Figure 3, the users of C1 are located edge of the cell. The rest of the cell is devoted to the users of C2 taking into consideration the PL. Let d denote the distance between each user and its serving BS. The classification of users is performed according to d:

$$\begin{cases} UE \in C_1 & such\ that\ d \leq r \\ UE \in C_2 & such\ that\ d > r \end{cases}$$

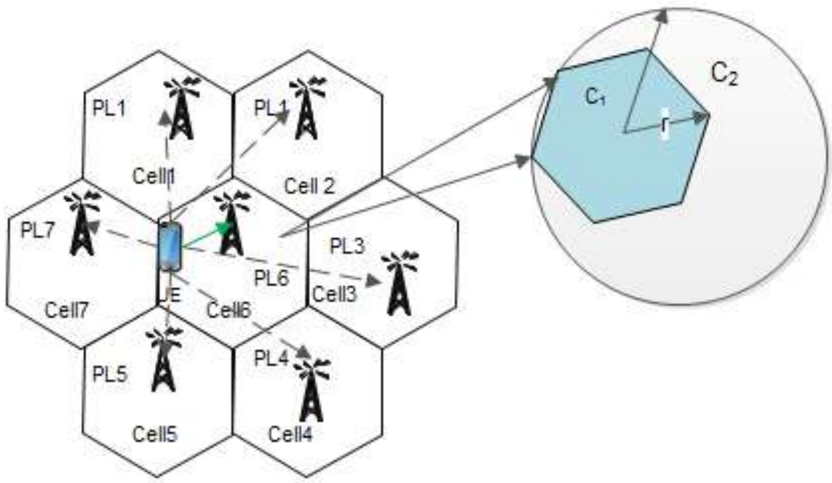

Figure. 3. Classification of user

According to our system model, the interference in each cell is only caused by the six adjacent cells. As show in figure, each user only disturbed the users of the nearest six cells.

Let us consider one user UE1 who is allocated $\mathrm{RB}_{\mathrm{p}}^{\mathrm{i}}$we calculate the difference of pathloss PL between $\mathrm{PL}_{\mathrm{ip}}^{\mathrm{j}}$ and $\mathrm{PL}_{\mathrm{ip}}^{\mathrm{p}}$ .then we determine and calculate the lowest difference of pathloss $\mathrm{D}_{\mathrm{PL}_{\mathrm{ip}}}$by expression:

$D_{PL_{ip}} = Min_{j\neq p}\left(\left|PL_{ip}^{p} - PL_{ip}^{j}\right|\right)$ (5.1)

The difference pathloss $\mathrm{D}_{\mathrm{PL}_{\mathrm{ip}}}$ corresponds to the BS which is the most disturbed by the allocate $\mathrm{dRB}_{\mathrm{p}}^{\mathrm{i}}$, when the $\mathrm{D}_{\mathrm{PL}_{\mathrm{ip}}}$is low, we observe that the user causes elevated and high interference to one of adjacent cell. We denote the threshold TH of $\mathrm{D}_{\mathrm{PL}_{\mathrm{ip}}}$ to classify UEs according to C1 or C2 where:

$$\begin{cases} UE \in C_1 & such\ that\ D_{PL_{ip}} > TH \\ UE \in C_2 & such\ that\ D_{PL_{ip}} \leq TH \end{cases}$$

Classification users by SINR. In HeNet the signal interference noise radio SINR is metric when we can be infective in user classification; each user must not only consider its received SINR but also eliminate the interference caused to other users. So, we present to use the SLNR measurement for user classification. Though SLNR has been generally utilized for beamforming purpose in multi-antenna [20] and multi-cell systems, we considered for resource allocation under the HetNet scenario. Here, the SLNR at the macro/small BS for a single user K in cell l is defined by expression:

$$\delta_k^l = \frac{p_k^l H_k^l}{\sum_{j=1, j\neq l}^{L} p_k^l g_k^{l,j} + \sigma^2} \qquad (5.2)$$

Note that when we estimate and evaluate the SLNR metric δ_k^l for a user k connected with cell l, either μ_l value as the SINR threshold for users in the cell l, we can classify the users into two different locate according C_1 or C_2 where:

$$\begin{cases} UE \in C_1 \quad such\ that\ \delta_k^l \ \geq \mu_l \\ UE \in C_2 \quad such\ that\ \delta_k^l \ < \mu_l \end{cases}$$

All users the $C_1(\delta_k^l \ \geq \mu_l)$ can be treated as good users because have o good enough signal power while causing very restricted inter-cell interference, therefrom resulting in a large SINR value, for that the good user we let all cells share the same RBs for them due to their low inter-cell interference and comparatively large signal strength.
For all users the C_2 $(\delta_k^l \ < \mu_l)$ can be treated as interference users, the low SLNR evaluation concerned that the users have either or both, that low SINR due to large distance between the user and its related cell station causing severe interference to adjacent cell.

3.2 Goal Attainment Method

The method described here is the goal attainment approach of Gembicki [21].is a powerful tool to find the best compromise solution in multi-objective problems.
This involves expressing a set of design goals$\mathrm{F}^* = \{\mathrm{F}_1^*, \mathrm{F}_2^*, \mathrm{F}_3^*, \dots, \mathrm{F}_\mathrm{m}^*\}$, which is associated with a set of objectives:

$$\mathrm{F(x)} = \{\mathrm{F}_1(\mathrm{x}), \mathrm{F}_2(\mathrm{x}), \mathrm{F}_3(\mathrm{x}), \dots, \mathrm{F}_\mathrm{m}(\mathrm{x}),\}$$

The problem formulation allows the objectives to be under- or overachieved, enabling the designer to be relatively inaccurate about initial design goals. The relative degree of under- or overachievement of the goals is controlled by a vector of weighting coefficients,
$w = \{w_1, w_2, w_3, \dots, w_m\}$,
Coherent step is the following:

- choose an initial objective function F;
- choose a direction of research (we provide, somehow, coefficients of weighting, as for the objective function weighting method) w;
- Try to minimize a scalar coefficient l which represents the deviation from to the initial goal F that we had set.

Expression of a standard optimization by using following formulation [22]:

$$\underset{\boldsymbol{\gamma} \in \mathfrak{R}, \boldsymbol{x} \in \Omega}{\boldsymbol{minimize}} \quad \boldsymbol{\gamma}$$

Such that $F_i(x) - w_i\gamma \leq F_i^*$ $\quad i$ =1, 2, 3… m, $w_i \in$ A

Where x is a set of desired parameters which can be varied, $\boldsymbol{\gamma}$ is a scalar variable which introduces an element of slackness into the system, Ω is a feasible solution region that satisfies all the parametric constraints:
$A_{\varepsilon} = \{w_i \in R^n \ st. w_i \geq \varepsilon , \sum_{i=1}^{n} w_i = 1 \ and \ \varepsilon > 0\}$.

3.3 Power control

As we discussed in previous sections, the operation of the allocation RB is effectuated by the user's classification with this strategy we specify the interfering users and good users in order to decreasing the interfering users and to reduce the problem of power control for good users for the HetNet uplink channels, it follows by [23]:

$$\mathrm{Max}_{p_{k,\mathrm{n}}^{l}} \sum_{l=0}^{L} w_l \sum_{\mathrm{n}=0}^{\mathrm{N}} \log\left(1+\delta_{k,n}^{l}\right)$$

Subject to $p_{k,\mathrm{n}}^{l} \leq \mathrm{p}_{\mathrm{max}}^{\mathrm{l}}, \ \forall \ \mathrm{l}, \mathrm{K};$ (6.1)

$$p_{k,\mathrm{n}}^{l} \geq 0, \qquad \forall \ \mathrm{l}, \mathrm{n}, \mathrm{K}$$

Where the uplink the received uplink SINR for each user becomes:

$$\delta_{k,n}^{l} = \frac{p_k^l H_k^l}{\sum_{j=1, j\neq l}^{L} p_{k,n}^{j} g_k^{l,j} + \sigma^2} \quad (6.2)$$

Where:
K: index the user assigned in the cell l
In order, we consider the power control strategy for good users which usually have a much better and superior achieved SINR than average. The power control problem can be approximately casted to a typical goal attainment programming which admits a globally optimal solution by using efficient algorithms [24]. Let C denote the number of good users in the l cell, the problem is finally casted to a standard Form of goal attainment. It gives by:

$$\min_{x_n p_{k,n}^{l}} \coprod_{l=0}^{L} \coprod_{n=0}^{C_l} x_{n,l}^{-1}$$

Subject to $\frac{\sigma^2}{H_k^l}\left(p_{k,n}^{l}\right)^{-1} x_{n,l}^{1/w_l} + \sum_{j\neq l} \frac{g_{kj}^{l}}{H_k^l}\left(p_{k,n}^{l}\right)^{-1} p_{kj,n}^{j} x_{n,l}^{1/w_l} \leq 1$

$$\frac{1}{p_{max}^{l}} p_{k,n}^{l} \leq 1, \quad \forall \ \mathrm{l}, \mathrm{n}.$$

The approximation $\log(1+\mathrm{X}) \approx \log\mathrm{X}$ for these users with large X. The power control optimization problem e.g., "Eq. (6.1)" to:

$$\max_{p_{k,n}^{l}} \log \coprod_{l=0}^{L} \coprod_{n=0}^{C_l} \left(\delta_{k,n}^{l}\right)^{w_l}$$

Subject $\quad p_{k,n}^{l} \leq p_{max}^{l}, \ \forall \ \mathrm{k}, \mathrm{l};$

$$p_{k,n}^{l} \geq 0, \ \forall \ \mathrm{l}, \mathrm{n}, \mathrm{k}.$$

4. Simulation model and evaluation criterion

In this section, we constructed a system simulator for evaluating and assessment the performance of our proposed management of resource allocation as well as strategy of power control optimization for the uplink channel in HeNet, detailed of our system parameters is summarized in table 1.

Here we consider that there are one macro cell base stations with fixed locations as shown in Figure 4 and several small cell base stations and number of users UEs which are randomly located in the geographical area. The maximum transmit power of macro and small cell base stations are 46 and 30dBm, respectively. In the simulation, we consider a simple system where α = 0,8 and each user only takes one channel.

Table 1. Denotation of the used parameters

Parameters	Assumed value
Cell layout	1Macrocell/4 Smallcell
Radius	500m (Macrocell)
Bandwidth	50 RBs (10MHz)
Carrier frequency	2,0 GHz
Traffic Model	Full buffer
Antenna gain	14 dBi
Antenna type	Omnidirectional
power control	User classification: SLNR threshold
UE power Tx power	selected α =0,8
Pmax	23dBm
UE configuration	30 UEs per cell

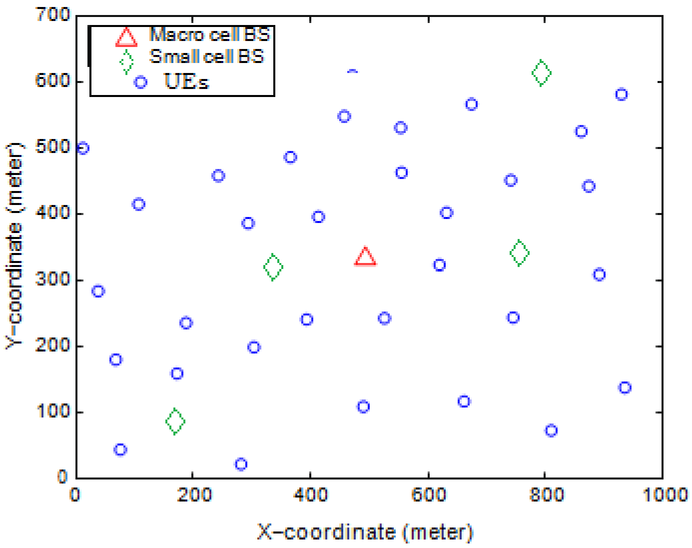

Figure. 4. The geographic location of macro and small cell BS (example)

4.1 Simulation Results

Before presenting and discussing the simulation results, we first donate a brief planning on system level simulation, for informality, we concentrate on the performance of a macrocell with four Smallcell base stations figure 5 and with several of users randomly located within the macro coverage.

In our simulations, we evaluate the performances of the proposed strategy power control and management of resource allocation based on goal attainment method. in the simulation, we focused of performance macrocell and smallcell are presented in table 2, we used a cumulative distribution function (CDF) of the macro and small cell average throughput, CDF of the received interference and the CDF of the average received interference at the macrocell in HeNet.

For the previously discussed model, the CDFs of the average received interference and the average throughput of Macrocell users MUEs and Small users SUEs are simulated for the three proposed, and FPC and the result are plotted in figures 5,6 and 7. from the throughput CDF curl. the information can be deduced following:

The MUE throughput of the RB-PC-GA (goal attainment) proposed significantly outperforms the MUE throughput RB and PC as can be seen in figure 5, this because the RB-PC-GA update the transmit power, thereby reducing the interference result and improving the average throughput.

Table .2. Performance with different cell.

Type Cell	Capacity	gain
MacroCell (Mbps)	15,6	30,3%
SmallCell (Mbps)	55,7	60%
All-cell (Mbps)	503,7	45%

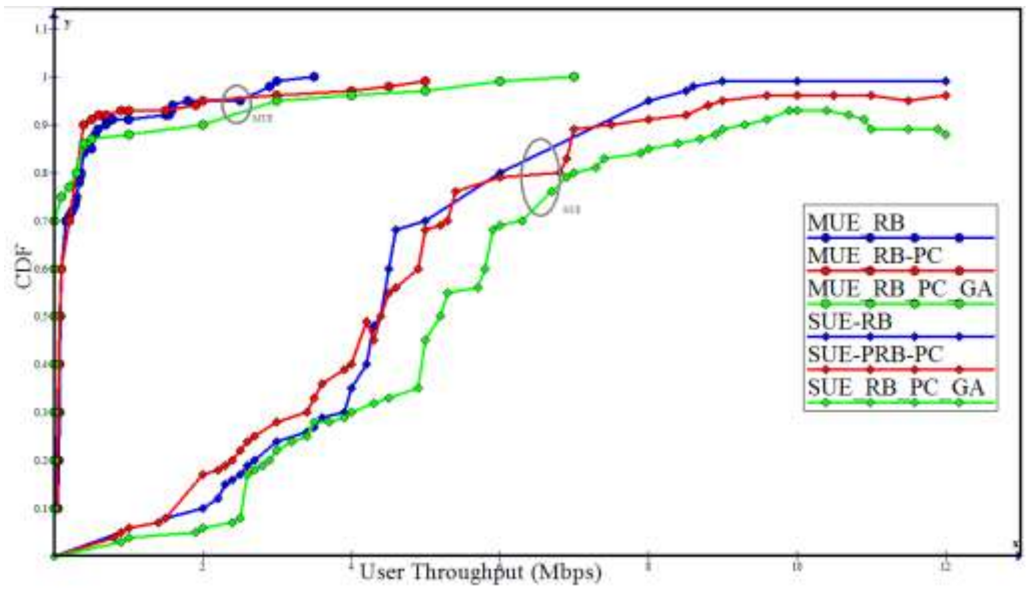

Figure .5. CDF of the user throughput with users per smallcell

In figure 5 that the shows, the cumulative distribution function (CDF) of the user throughput by different strategy are compared. For comparison, the user throughput of macro users and small users separately depicted in the figure. From this figure, the advantage of our proposed are also evidenced especially for the small users. This scenario with number of Pico user's is also tested in our simulator with different power control and resource allocation using goal attainment, it shows a more the performance comparison of the three our proposed for the SU-RB, SU-RB-PC and SU-RB-PC-GA, that the shows the performance of throughput respectively is more.

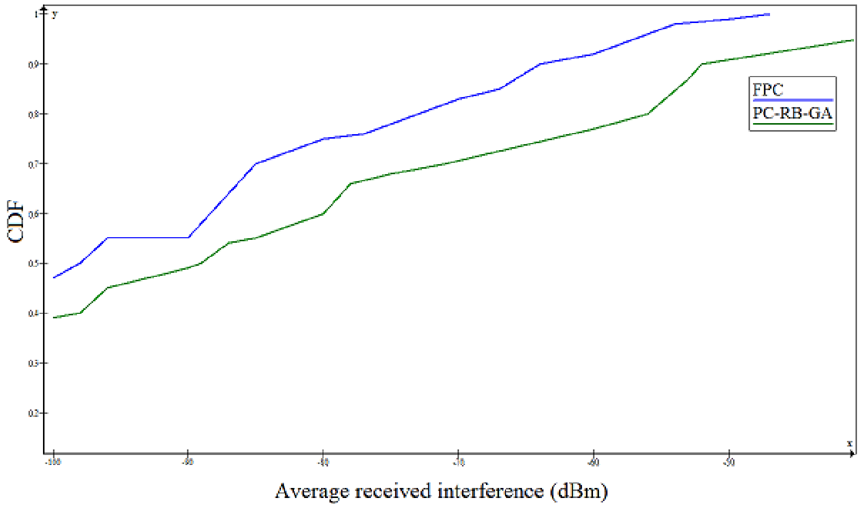

Figure. 6. Received interference at Small cell in HetNet environment

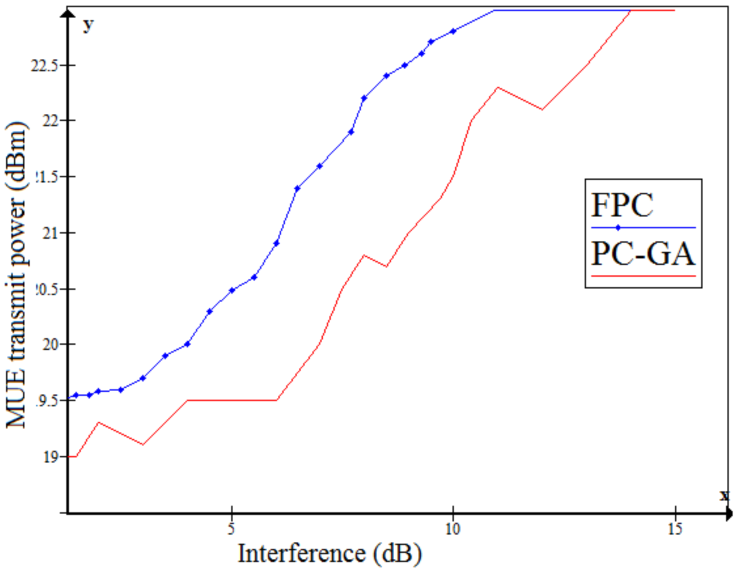

Figure.7. MUE transmit power versus received interference

Figure 6 shows the CDF of the average received interference at the macrocell in HeNet. For average users 50% of the CDF the curves show that the received interference for the PC-GA is almost 15% and 17% less than the conventional FPC algorithm. this is because the proposed strategy of resource RB allocation and power control optimization based on goal attainment method. Next, we show in figure 7 show the allocated transmit power to the MUE and SUE at the varying interference levels. In the case of MUEs, as given, the transmit power is increased regularly with increased interference.

5. Conclusion

In this article, an uplink interference mitigation is presented for uplink heterogeneous networks. The entire users are distributing as two groups via a clustering method. Each group of users is specified with optimized RB allocation as well as power control strategy based annealing goal attainment method. Simulation results verify that the proposed scheme can achieve an improved performance in terms of network throughput, cell edge performance, and the mitigation interference. Our proposed scheme is efficient in noticeably enhancing the small cell performance particularly when there is many user's affliction severe grave interference.

References

[1]. Zhang, J., & Stojmenovic, I. (2015). Cellular Networks. Mobile Communications Systems, 61(4), 654–663.

[2]. Y. S. Bhandari, Y. S. Chauhan). Stable Nodes Based Routing Protocol in Heterogeneous Ad-Hoc Networks. International Journal Journal of Engineering Technology, Oct. 2018. PP. 1-17.

[3]. Ahuja, K., Singh, B., & Khanna, R. (2017). Network Selection in Wireless Heterogeneous Environment by C-P-F Hybrid Algorithm. Wireless Personal Communications. https://doi.org/10.1007/s11277-017-4998-1

[4]. Yang, L., Draief, M., & Yang, X. (2017). Heterogeneous virus propagation in networks: a theoretical study. Mathematical Methods in the Applied Sciences, 40(5), 1396–1413. https://doi.org/10.1002/mma.4061

[5]. Li, Y., Zhang, L., Chen, H., & Peng, M. (2013). Interference coordination in multiple antenna-based LTE-advanced heterogeneous systems. International Journal of Antennas and Propagation, 2013. https://doi.org/10.1155/2013/167368

[6]. Han, T., Yin, R., Xu, Y., & Yu, G. (2012). Uplink channel reusing selection optimization for Device-to-Device communication underlaying cellular networks. In IEEE International Symposium on Personal, Indoor and Mobile Radio Communications, PIMRC (pp. 559–564). https://doi.org/10.1109/PIMRC.2012.6362848

[7]. Essassi, S., Siala, M., Hamila, R., Hasna, M. O., & Cherif, S. (2016). Power control and RB allocation for LTE uplink. In 2016 International Wireless Communications and Mobile Computing Conference, IWCMC 2016 (pp. 417–421). https://doi.org/10.1109/IWCMC.2016.7577094

[8]. Ahmad, A. W., Yang, H., Shahzad, G., & Lee, C. (2016). Macrocells-User Protected Interference-Aware Transmit Power Control for LTE-A Heterogeneous Networks. Mobile Information Systems, 2016. https://doi.org/10.1155/2016/7043235

[9]. Sivaraj, N., & Palanisamy, P. (2016). Soft Computing Based Power Control for Interference Mitigation in LTE Femtocell Networks. In Procedia Computer Science (Vol. 79,pp.93–99). https://doi.org/10.1016/j.procs.2016.03.013

[10]. Xiao, Z., Li, Z., Zhang, X., Liu, E., & Yi, K. (2015). An efficient interference mitigation approach via quasi-access in two-tier macro-femto heterogeneous networks. International Journal of Communication Systems, 28(5), 901–909.

[11]. Xu, W., & Zhang, H. (2014). Uplink interference mitigation for heterogeneous networks with user-specific resource allocation and power control. Eurasip Journal on Wireless Communications and Networking, 2014.

[12]. Yang, T., & Zhang, T. (2011). Approaches to enhancing autonomous power control at Femto under co-channel deployment of macrocell and femtocell. In IEEE International Symposium on Personal, Indoor and Mobile Radio Communications, PIMRC (pp. 71–75).

[13]. Li, Y., Peng, M., & Hu, W. (2012). Adaptive heterogeneous interference coordination algorithm in uplink LTE-Advanced systems. In IEEE International Symposium on Personal, Indoor and Mobile Radio Communications, PIMRC (pp.536–540).

[14]. Chen, J., Hu, Z., Wang, G., Huang, X., Wang, S., Hu, X., & Liu, M. (2015). High-impedance surface-based broadband absorbers with interference theory. IEEE Transactions on Antennas and Propagation, 63(10), 4367–4374.

[15]. Dong, H. J., Wu, J., Zhang, G. Y., & Wu, H. F. (2012). An improved phase-locked loop method for automatic resonance frequency tracing based on static capacitance broadband compensation for a high-power ultrasonic transducer. IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, 59(2), 205–210.

[16]. Zhang, H., & Pathirana, P. N. (2013). Uplink power control via adaptive hidden-markov-model-based pathloss estimation. IEEE Transactions on Mobile Computing, 12(4), 657–665.

[17]. Liu, J., Kato, N., Ujikawa, H., & Suzuki, K. (2016). Device-To-Device communication for mobile multimedia in emerging 5G networks. ACM Transactions on Multimedia Computing, Communications and Applications, 12(5s).

[18]. Mi, T., Wang, Z., & Li, X. S. (2012). Multi-cell dynamic interference coordination algorithm in LTE uplink system. In Advances in Intelligent and Soft Computing (Vol. 133 AISC, pp. 1003–1010).

[19]. Han, S., I, C., Xu, Z., & Rowell, C. (2015). Large-scale antenna systems with hybrid analog and digital beamforming for millimeter wave 5G. IEEE Communications Magazine, 53(1), 186–194.

[20]. Li, X., Cai, J., & Zhang, H. (2016). Topology control for guaranteed connectivity provisioning in heterogeneous sensor networks. In IEEE Sensors Journal (Vol. 16, pp. 5060–5071).

[21]. Tabak, N. T., Link, P. C., Holden, J., & Granholm, E. (2015). Goal attainment scaling: Tracking goal achievement in consumers with serious mental illness. American Journal of Psychiatric Rehabilitation, 18(2), 173–186.

[22]. Dobeš, J., & Míchal, J. (2011). An implementation of the circuit multiobjective optimization with the weighted sum strategy and goal attainment method. In Proceedings - IEEE International Symposium on Circuits and Systems (pp.1728–1731).

[23]. Xu, W., & Zhang, H. (2014). Uplink interference mitigation for heterogeneous networks with user-specific resource allocation and power control. Eurasip Journal on Wireless Communications and Networking, 2014.

[24]. Wang, M., Gao, H., & Lv, T. (2017). Energy-{Efficient} {User} {Association} and {Power} {Control} in the {Heterogeneous} {Network}. IEEE Access, 5, 5059–5068. https://doi.org/10.1109/ACCESS.2017.2690305