ISSN (Print) : 0974-6846
Indian Journal of Science and Technology, Vol 9(2), DOI: 10.17485/ijst/2016/v9i2/80490, January 2016 ISSN (Online) : 0974-5645

A Femtocell Cross-Tier Interference Mitigation Technique in OFDMA-LTE System: A Cuckoo Search based Approach

Motea Al-omari*, **Abd Rahman Ramli, A. Sali and Raja Syamsul Azmir**

Department of Computer and Communication Systems, University Putra Malaysia, Serdang, Selangor, Malaysia; omari.motea@gmail.com, arr@upm.edu.my, aduwati@upm.edu.my, r_syamsul@upm.edu.my

Abstract

Background/Objectives: In wireless broadband access networks, most indoor environments encounter serious coverage problem. Femtocells have been introduced as an efficient solution to improve cell coverage, enhance area spectral-efficiency and provide better Quality-of-Service (QoS) to mobile users. However, cross-tier interference issues continue to be the major technical challenge associated with femtocell deployment. **Methods/Statistical analysis:** This study introduce a resource allocation technique-based cuckoo search algorithm RACSA for cross-tier interference mitigation in Orthogonal Frequency Division Multiple Access based Long Term Evolution (OFDMA-LTE) system. The innovative RACSA technique takes upon itself the task of maximizing the throughput of network according to a specified threshold for the interference. Cuckoo search Algorithm is extensively employed to successfully address the problem of resource optimization by finding and allocating the suitable power and bandwidth for all the users and this ultimately, leads to mitigating the cross-tier interference for OFDMA macro-femtocell networks. **Results/Conclusions:** The simulation results reveal that RACSA mitigate the cross-tier interference and improve the system performance. In addition, an assessment is carried out and it confirmed that RACSA gives (38%) and (21%) higher system throughput and (14%) and (35%) higher in spectral efficiency and (55%) and (33%) lower in the outage probability when comparing with results of genetic algorithm and auction algorithm respectively.

Keywords: Cross-Tier Interference, Cuckoo Search Approach, Femtocell, Interference Mitigation, Resource Allocation, OFDMA-LTE, RACSA

1. Introduction

There has been a skyrocketing surge in the number of mobile phone users, who currently exceed four billion in the hi-tech universe we inhabit. Under such a scenario, there is an ever-zooming requirement for more and more mobile phones. As a result, the next generation wireless networks have emerged as a promising avenue to offer high data rates to quench the ever-escalating thirsts of the informed users[1]. According to the statistics of an industrial report released recently the mobile data utilization is well-set to advance at geometric proportions by the onset of 2015 and about a whopping 90% of mobile data is expected to originate indoors[2]. With an eye on successfully addressing such crucial scenarios and fine-tuning the signal-strength in controlled areas, it is high time the mobile operators invest their time and energy to usher in an efficient solution. Obviously, there will be a host of potential solutions in the upcoming days, but it is certain that femtocell will be the shining star in the galaxy of such solutions. Femtocells have attracted a significant attention in the mobile industry because of their unique features[3]. It has been identified as an emerging technology to offer broadband access in wireless cellular networks. Femtocells, in essence, represent a small low cost, low power base station with a short service range, generally in the range of 10m to 15m, and they are habitually labeled as Femto Base Station[1] (FBS). It is competent to assist as a short range stationary or mobile data access point placed on high consumer density hotspots[2]. A typical femtocell

* Author for correspondence

can be connected with the Internet and the network of cellular operators by means of a Digital Subscriber Line (DSL) router, cable modem or dedicated wireless[3]. In a nutshell, femtocell can be used to stand for a coverage area induced by a Femtocell Access Point (FAP) in spite of the fact it is generally used for hardware device[4].

Interference issue is considered as the biggest technical challenge associated with femtocells deployment as a second overlaid layer in the existing macrocell layer. This interference arises from the fact that the radio resource is scarce, and as such, the existing macrocells have to share the available spectrum with the newly deployed femtocells resulting in a sever interferences among the femtocells and between the macrocells and femtocells[5]. Additionally, femtocell is self-deployed and it is installed by users in an adhoc manner rather than deploying them in preplanned scenario as it occurs with macro cellular. It is true that random deployment have considerably scaled up interference, though it is badly in need of interference management[6]. A typical interference can be classified into two classes which are cross-tier interference and co-tier interference. The former is triggered by network elements that are in different tiers of the network whereas the latter takes place between network elements belonging to the same tier[7,8].

A simple solution to avoid cross-tier interference is by operating the femtocells with a dedicated transmission frequency but the frequency resources would be more and appropriate resource allocation mechanisms are required[9]. Despite the fact that a solution could be found out to avoid co-tier interference, cross-tier interference tends to have a negative impact on degrading the macrocell system performance[10]. With a view to effectively tackle the related scenario, well self-organized techniques are required based on the channel conditions to adjust the femtocell parameters and to mitigate cross-tier interference[11]. With the supreme motive of discovering the solutions, various investigations are habitually carried out to assess the interference and spectrum allocation mechanisms for co-channel deployments in macro cell and femtocell[12]. Many researchers are working to locate potential solutions and propose several techniques to mitigate the interference by means of power control and spectrum allocation mechanisms[13]. The remainder of the paper moves as per the following roadmap: Section 2 introduces all interference scenarios for OFDMA-based femtocell networks. Section 3 provides a brief account of the latest literature on the subject at hand. Section 4 introduces an overview of a metaheuristic cuckoo search algorithm. Section 5 provides the system model mathematical formulations of the proposed cross-tier interference mitigation approach. Section 6 provides the simulation environment and the performance evaluation metrics. Section 7 lists all simulation parameters. While the simulation results are presented in section 8, the ensuing section 9 provides concluding remarks.

2. OFDMA Femtocell Networks Interference Issue

Interference issue is considered as the major technical challenge associated with femtocells deployment as a second overlaid layer in the existing macrocell layer. This interference arises from the fact that the radio resource is scarce, and as such, the existing macrocells have to share the available spectrum with the newly deployed femtocells. This phenomenon is referred to as co-channel deployment. In co-channel deployment, the femtocells and macrocells fully or partly share/reuse the available bandwidth, thereby resulting in a sever interferences between the macrocells and femtocells. Additional to, a femtocell not only provide coverage within the owner's home or in the office, but also radiates outside, as well as extends coverage to nearby premises and other outdoor spaces, leading to interference among the neighboring femtocells. Moreover, the deployment of new femtocells may result to disturbances in the operations of the existing femtocells in the network. Besides, the femtocell base stations will be set up randomly by the users themselves, with no prior planning by either the user or the Internet Service Provider (ISP), thereby making interference management even more challenging[14].

Anyway, it should be noted that in OFDMA femtocell networks, the interference only occurs when the aggressor and victim use the same sub-channels. Interferences in general can have negative impacts on the performance of femtocells, and also hinders the performance of other devices connected to the macro cellular network. Moreover, extreme cases of interference may result to "Dead zones," (i.e. regions experiencing degrading QoS thereby making it impossible to establish communication). In general, the received signal quality at the receiving end is determined quantified using the Signal to Interference plus Noise Ratio (SINR). Specifically, the SINR depends on the BS's transmitted power, transmitted power from each of the interfering transmitters, shadowing, fading as well as path losses[15] . For communication to take place, the prevailing SINR reading must surpass a particular threshold. If the SINR reading falls below this threshold as a result of interference, the communication link cannot be established thereby creating a dead zone. In general, the threshold of the SINR is defined based on the radio frequency being utilized, and may also be different in accordance with the various QoS requirements of the different technologies[16]. Generally interference can be classified into two classes including co-tier interference and cross-tier interference as shown in Figure 1.

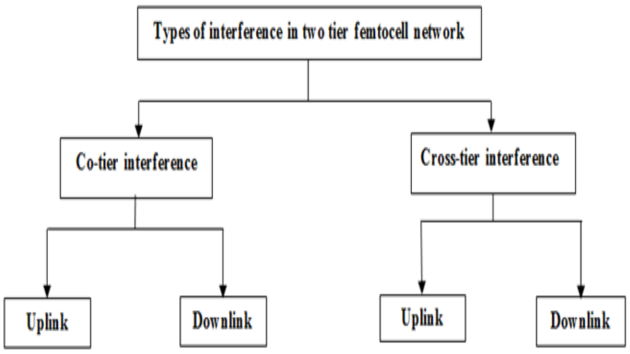

Figure 1. Types of interference in two-tier femtocell network.

2.1 Co-Tier Interference

Refers to the interference occurring among networks of an identical tier within the network. In other words, this type of interference takes place between a femtocell and other nearby femtocells. A femtocell user equipment FUE (aggressor) may cause uplink co-tier interferences to a nearby femtocell base station FBS (victim), while a FBS (aggressor) may also cause downlink co-tier interferences to a nearby FUEs (victim). For femtocell networks based on OFDMA, the occurrence of co-tier uplink/downlink interferences is primarily associated with the use of the same sub-channels for transmission by both the aggressor and the victim.

2.2 Cross-Tier Interference

Refers to interference results from the occurrence of interference between network elements belonging to dissimilar tiers of the network (e.g., between elements of the macrocell tier and those of the femtocell tier and vice versa. Here, the user equipment of the femtocell and macrocell (FUE, MUE) are the sources of uplink cross-tier interferences towards the serving Macrocell's Base Station (MBS) as well as the nearby Femtocell Base Stations (FBS). Conversely, the serving MBS, together with the FBS, result in forward link cross-tier interferences on to the FUEs as well as the neighboring MUEs.

In OFDMA networks, cross-tier forward/reverse link interferences are exclusively experienced when an interference source utilizes the same sub-channels as the victim. Thus, efficient channel allocation is indeed vital for interference avoidance is such systems. Table 1 summaries the various possibilities of interferences scenarios in OFDMA-based femtocell networks which depicted in Figure 2 in terms of the source of interference (aggressor), victim, and interface type and transmission mode. The problem of cross tier interference is considered more importance than co-tier because it tends to have a negative impact on degrading the performance of macrocell system. So, adopting a suitable interference management technique, co-tier interferences can be effectively avoided, while cross-tier interferences can be considerably minimized in order to improve the overall system throughput[17,18].

Table 1. Details of all interference scenarios for OFDMA-based femtocell networks[17]

Index	Interference type	Aggressor	Victim	Transmission mode
1	Cross-tier	MUE	FBS	Uplink
2	Cross-tier	MBS	FUE	Downlink
3	Cross-tier	FUE	MBS	Uplink
4	Cross-tier	FBS	MUE	Downlink
5	Co-tier	FUE	FBS	Uplink
6	Co-tier	FBS	FBS	Downlink

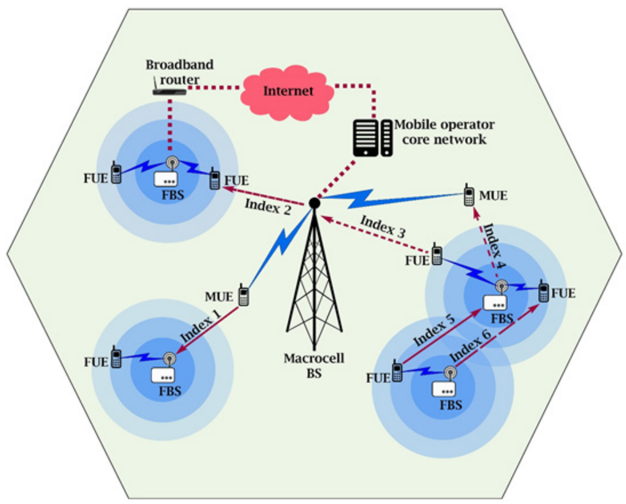

Figure 2. OFDMA-based femtocell networks interference scenarios17.

3. Previous Works

This section, presents some previous studies for interference management techniques used in two-tier Heterogeneous (macrocell and femtocell) networks. Most of researches for interference mitigation are based on resource allocation. The resource allocation for (frequency and power) is playing an essential role in interference management for wireless communication system. The optimal and effective algorithms for resource allocation is needed to reduce the interference in two-tier HetNet, increase the spectrum and power efficiency, and therefore enhance the data rates and Quality of Service (QoS) Many optimization algorithms for radio resource allocation for both downlink and uplink in OFDMA system have been introduced in the previous studies. In[19], an optimization algorithm for radio is proposed for downlink OFDMA system. The proposed algorithm increase spectrum and power efficiency. However, this algorithm was designed only for one macrocell tier and it's not suitable for two-tier heterogeneous network as it is not consider the resource allocation for femtocells.

In[20] a mathematical model has proposed which offers the solution for joint resource allocation and optimal admission control. It enhances the Quality of Service (QOS) in two-tier femtocell networks by implementing the concept of Semi Markov Decision Process (SMDP). In the proposed model, game theory is used to promote a distributed femtocell power adaptive algorithm to achieve energy efficiency in femtocell networks. This model has been capable of reducing cross-tier and co-tier interference while achieving a significant power saving in OFDMA femtocell networks.

The authors in[21] have discovered that, the deployment of femtocells with close subscriber groupe of users will causes a sever co-tier interference among the neighboring femtocells. A Femtocell Network Controller (FNC) for resource allocation with a different femtocell access mode has been proposed to avoid such interference. The proposed scheme to avoid the co-tier interference through orthogonal resource allocation for closed access femtocells, while the open access femtocell coverage area are divided into inner and outer coverage areas. The inner region uses the resource used by the nearby closed access femtocells and the outer coverage uses the resource which applied to a faraway closed access femtocells. However, the FNC will have both time and computational complexity to apply the resource allocation in such a way for all femtocells deployed inside macrocell. However, the FNC has both time and computational complexity to apply the resource allocation in such a way for all the femtocells deployed under the macrocell coverage zones.

An extensive study has carried out in[22] for OFDMA based femtocell networks with partially co-channel deployment. At the outset, they have launched an inter-tier interference mitigation technique unaccompanied by the femtocell user's power management forcing the femto-interfering macro cell users to employ only certain dedicated subcarriers. The non-interfering macro cell users, in turn, are competent to employ either in the dedicated subcarriers, or in the shared subcarriers. Subsequently, they have brought to spotlight the subcarrier allocation techniques based on the auction algorithm for macro cell users and femtocell users, and correspondingly, to separately mitigate the intra-tier interference. The proposed interference mitigation technique for femtocell networks has a clear and unsurpassable edge over some techniques in terms of performance improvement by substantially scaling down the inter- and intra-tier inferences in the network. However, partial co-channel deployment limits it down over the spectral efficiency scale.

A resource allocation technique for OFDMA macro-femtocell networks has proposed in[23]. The proposed model assumes hybrid-access femtocell to grant access to public users in their vicinity and to reduce interference perceived by femto users. Full spectrum sharing is investigated to increase system capacity. The proposed system has been modelled to maximize the network throughput for a specified interference threshold. To do so, the proposed model determines the best serving base station based on link conditions. Genetic Algorithm (GA) is employed to tackle the resource optimization problem by locating the suitable bandwidth and power assignments for every user. Simulations were carried out along with an evaluation and contrast with a modified version of the weighted water filling algorithm. However GA is getting popular in benchmark optimization operation, it is still a new approach for such live network optimization application. Random convergence of solutions in QoS problems with respect to a fitness function is the major limitation of genetic algorithm. Besides, the time consumed by the optimization algorithm is also high making it unsuitable for the real time execution. Another disadvantages of GA is that it easily trapped in local minima problem.

An easy decentralized frequency-domain resource allocation technique combined with uplink power optimization for Long Term Evolution (LTE) Femtocell Base Stations (FBSs) has been highlighted in[24]. Femtocells are considered as an overlaying network which reuses spectral bands of the existing macro cell. The proposed technique seeks to maximize the uplink throughput of FUEs without causing performance downgrade to MUEs. System-level simulations are performed to examine the power optimization problem by delving deep into the Power Control (PC) parameter space. In accordance with the parameters selection, the FUEs uplink throughput is assessed by means of the resource allocation technique which approximately separates the macro- and femtocell users in frequency by imposing different allocation probabilities on various parts of the spectrum.

A diverse power control techniques for femtocell networks were discussed and compared in[25] where the focus was on the distributed power control techniques. It is substantially proved from the review that the distributed power control techniques using pilot power control schemes are a simple and efficient method of optimizing the coverage of femtocell in addition to paving the way for a considerable dip in power utilization for FBS. Still, what is eagerly expected is an innovative technique well-set to carry out the power control optimization in femtocell networks.

4. Overview of Cuckoo Search Algorithm (CSA)

Cuckoo Search Algorithm (CSA) is considered to be one of the most recent metaheuristic and/or Swarm Intelligent algorithms (SI) like Genetic Algorithms (GA), Particle Swarm optimization, Ant Colony Optimization (ACO), and Differential Evaluation (DE). A metaheuristic can defined as an iterative generation process that guide a subroutine heuristic by combining intelligently different concepts to explore and exploit the search space to find optimal solutions. It's based on breeding and levy flight foraging behavior of the cuckoo birds[26]. CSA is considered a superior algorithm which surpasses some other optimization algorithms like GA and Auction algorithm. A CS can avoid the local minima problem which it considered as a disadvantages of GA[27]. Cuckoo birds rivet our attention on account of their unique belligerent reproduction technique. Cuckoos invariably show a tendency to deploy brood parasitism, in which a bird (brood parasite) lays and throws away its basic types of brood parasitism like intra-specific brood parasitism, cooperative breeding, and nest takeover. It is known that several species such as the Ani and Guira cuckoos lay their eggs in collective nests, though it is possible they are subjected to a temptation of capturing others' eggs to augment the hatching potential of their own eggs. Several host birds take an aggressive stance towards the intruders and carry out straight fight with them. In such scenarios, host bird throws the unknown eggs. In some other occasions, further sociable hosts just go away from its nest and build a new nest at some other place. In this regard, Cuckoo Search algorithm has emerged as one of the outstanding population based stochastic global search meta-heuristics methods where potential solutions characterize Cuckoo eggs. Normal networks are complex and, hence, cannot be developed by computer algorithms in its basic form. Simplification of standard systems is highly essential for successful execution of computer algorithms[28].

The underlying method is to configure a simpler innovative Cuckoo Search algorithm with the help of the following three approximation rules:

- Cuckoos choose arbitrary nest for laying their eggs. The artificial cuckoo is capable of playing only one egg at a time.
- The selection task is performed, with the result only the eggs with superior quality are handed over to the succeeding generation.
- Host nest number cannot be adapted. Host bird locates cuckoo egg with probability [0, 1]. If cuckoo egg is disclosed by the host, it is possible that it is discarded, or the host may give up its own nest and hand it over to the cuckoo intruder[26].

The assumption c can be approximated as a fraction: pa of the n nests replaced with new nests (with new random solutions at different locations). Lévy flight behavior, rather than simple random walk behavior, can be used to increase the performance of the CS. The following formula can describe Lévy flight behavior when generating new solutions

$$x_i^{(t+1)} = x_i^{(t)} + \alpha \oplus Levy(n)$$

Where $\alpha > 0$ is the final size that has to be related to the problem of interest scale, and the product $\oplus$ refers to an entry-wise multiplication.

5. Proposed Cross-Tier Interference Mitigation Technique

5.1 System Model

This model considers two-tier macro and femtocell network based OFDMA-LTE system. The macro coverage area is composed of four separate concentrated circle zones as indicated in Figure 2. According to the assumptions presented in[29]. The decomposition of macrocell into regions because the received signal strength decrease when the users get further from the base station as a result of path loss. The SINR target and modulation scheme for each zone is shown in Table 2.

Table 2. Modulation scheme and target SINR for macrocell zones[29].

Zone	Modulation Scheme	Target SINR (dB)	No. Bits/ Symbol
Z1	64-QAM	22.4	6
Z2	16-QAM	16.24	4
Z3	QPSK	9.4	2
Z4	BPSK	6	1

A cluster of neighboring femtocells are randomly deployed under the macrocell coverage. This model is considered a hybrid access mode for femtocell. The subscriber' UE has the priority to connect to FBS if and only if it is located within the coverage area of his own femtocell, otherwise it will be considered as a public user. When a public user is near or moves towards the FBS coverage, then decision for base station selection has performed depends on a link condition to specify whether, the user use high power and communicate with the far MBS or use low power and communicate with the nearest FBS. Figure 3 shows the two potential communication links as L1 and L2 respectively. The condition of the link depends on the used modulation technique in the area where the subscriber UE is located. The L1 link status depends on type of modulation used in femtocell zone whereas the L2 link status depends on the type of modulation used for macrocell zone. For example, MU2 has two options, even to connect to FBS using link L1 or connect to MBS using link L2. However the used modulation scheme by MBS zone Z3 is QPSK whereas the used modulation scheme by FBS is 16-QAM, then it's better for MU2 to communicate with FBS instead of MBS because it's required less bandwidth and power due to the fact that the number of bits is higher in the modulation scheme used by FBS. Subsequently, an investigation on the link condition between base stations and public users should be considered before the decision of base station selection.

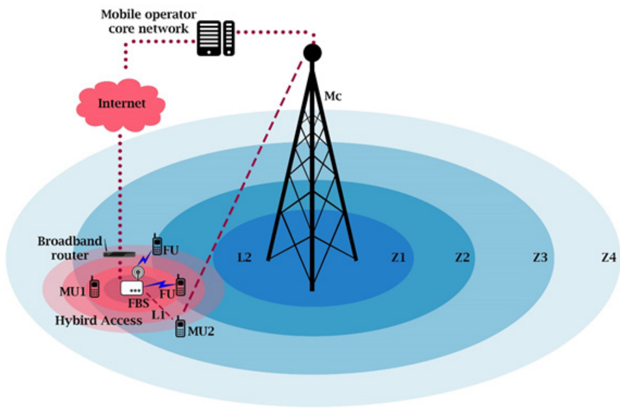

Figure 3. Model of two-tier macro and femtocell network based OFDMA-LTE system[29].

5.2 Problem Formulation

The issue of optimization seeks to achieve the maximum network sum rate and subsequently minimize cross-tier interference. The ultimate aim in this regard is to maximize the aggregate achievable network sum rate (aggregate achievable throughput) which can be expressed by Shannon's Law and calculated by Equation (1)[30].

$$T = \sum_{i \in \{N\}} b_i \log_2 (1 + SIN\,R_i) \tag{1}$$

Where b_i is the allocated bandwidth given to user $i \in \{N\}$, N. Express the total of all mobiles in the network (both macrocell and femtocells users).The link between user i and his selected BS can be measured using signal-to-interference-and-noise ratio $SINR_i$ which can be calculated by the Equation (2).

$$SINR_i \text{ - } P_i \,/\, PL_i \times (I_i + N_o) \tag{2}$$

Where P_i is the user i transmission power, PL_i is the user i path loss and N_o is the system average noise. I_i is interference on user i connection, and is expressed as the sum of all users j transmitted power which uses the same subcarriers of i divided by the path loss of the connection of user i and the base station of interfering users as given by the Equation (3).

$$I_t = \sum_{j,i\in\{N\}} \frac{P_j}{(PL_i \mathrm{x} N_0)} \tag{3}$$

The calculation of path loss is given by Equation (4).

$$PL_i - PL_i\,(d) + X_\sigma \tag{4}$$

Where path loss PL_i (d) depends on the distance d d, X_σ is the value (in dB) log-normal shadowing with standard deviation σ as in [31]. PL_i (d) can be calculated using Equation (5) which represents a propagation model of Non-Line-of-Sight (NLOS) as stated in[23,32].

$$PL_i(dB) = \begin{cases} 10\ Log(\mathrm{d_{im}})^{\gamma m} + 149.85 & for\ MC\ users \\ 10\ Log(\mathrm{d}_{if})^{\gamma f} + 37 & for\ FC\ users \end{cases} \tag{5}$$

Where d_{im} is the macrocell UE to the MBS distance in Km and d_{if} is the FBS to FUE distance in m. Y^m is the outdoor users' attenuation factor and yf is the indoor users' attenuation factor. There are some constraints that need to be taken into consideration in terms of the objective function detailed in (1). The aggregate allocated bandwidth for all users should be less than or equal to the available total bandwidth B_{tot} as furnished by Equation. (6). Likewise, the aggregate power allocated to users has to be below or same to the total allowed transmitted power as illustrated by Equation (7).

$$\sum_{i=1}^{N} b_i \le B_{tot} \tag{6}$$

$$\sum_{i=1}^{N} P_i \le P_{tot} \tag{7}$$

According to Shannon's law, for both Macro Base Station (MBS) and Femto Base Station (FBS), the number of bits per symbol has to exceed or identical to bits of modulation used in macrocell zone m,z concurrently, the number of bits per symbol has to exceed or be equal to bits of modulation used for femtocell f as given by Equations (8) and (9) respectively.

$$\log_2(1 + SIN\ R_i) \ge L_{m,z}^{\mathrm{mod}} \tag{8}$$

$$\log_2(1 + SIN\ R_i) \ge L_{f}^{\mathrm{mod}} \tag{9}$$

Thus, the interference noise per subcarrier should be less than or equal to the system noise threshold.

$$I_{subscriber} \le I_{threshold} \tag{10}$$

5.3 Resource Allocation based Cuckoo Search Algorithm (RACSA).

This section describes the proposed Resource Allocation based Cuckoo Search Algorithm (RACSA). In its initial phase, the proposed technique is devoted to locate better BS for all mobile users depending on the link condition. Subsequently, the optimization problem of resource allocation is solved by employing the bio inspired cuckoo search algorithm.

5.3.1 Base Station Selection

Hybrid access mode is considered in the FBSs. For each user attempting to join the network, the Autonomous Control Module unit (ACM),deployed in MBS in order to collect locations of FBS and demands of users and additional to ACM, can discover any change in user's demands or locations and respond accordingly. So ACM should determine whether the user gets access to the core network by the macro or a femtocell. The decision of BS selection depends on link condition from the UE to the BS, and on the FBSs capacity as well. Paying subscribers have the priority to be connected to the femtocells. Public users are allowed to join a nearby femtocell only if their connection does not affect subscribers' transmissions. Below is a list of constraints which are taken into account for the BS selection procedure:

- User i only can connect to one BS.
- Number of FBS users should be below or same to maximum users allowed, N_f.

5.3.2 Resource Allocation

The resource allocation is performed according to the strategy of full bandwidth reuse. In this strategy the whole available bandwidth can be reused by both macrocell and femtocell keeping into account that the interference level does not exceed a certain threshold. The idea is to divide the available bandwidth into subcarriers that can be grouped in subsets of sub channels which must be less than or equal to the maximum available bandwidth to $b_i^{\max}$. The allocated bandwidth to macrocell user must be less than or equal to its demand and less than the maximum allowed capacity per zone $C_z^{\max}$. In contrast, the allocated bandwidth to femtocell user must be less than or equal to its demand. The maximum allocated bandwidth to all users in both macro and femto tiers are given by the Equations (11) and (12) respectively.

$$b_i^{\max} = \min(S_i, C_z^{\max}) \Big/ L_{m,z}^{\mathrm{mod}} \tag{11}$$

$$b_i^{\max} = S_i \Big/ L_f^{\mathrm{mod}} \tag{12}$$

The smallest subcarrier bandwidth is 15 KHz which is used for voice call. To formulate the Resource Allocation problem based Cuckoo Search Algorithm (RACSA), initially, bandwidth population is randomly generated. A solution for the resource allocation problem is represented as a sub bands vector and each sub band in this vector is allocated to user *i*.

$$\vec{b} = [b_1, b_2, b_3, \ldots, b_N]$$

The population can be represented as $N \times N$ matrix.

$$b = \begin{bmatrix} b_{1,1} & b_{1,2} & \cdots & b_{1,N} \\ b_{2,1} & b_{2,2} & \cdots & b_{2,N} \\ \vdots & \vdots & \cdots & \vdots \\ b_{N,1} & b_{N,2} & \cdots & b_{N,N} \end{bmatrix}$$

Each element or sub band b in the matrix represents a group of sub channels, and the value of b can vary from 0 to $b_i^{\max}$ which has been previously defined by Equations (11) and (12). The interference I_i is set to equal the threshold of interference $I_{threshold}$, and according to the target *SINR* of the zone where the user is located, the DL transmitted power is calculated. So we can get a power matrix corresponding to each bandwidth matrix.

$$P = \begin{bmatrix} p_{1,1} & p_{1,2} & \cdots & p_{1,N} \\ p_{2,1} & p_{2,2} & \cdots & p_{2,N} \\ \vdots & \vdots & \cdots & \vdots \\ p_{N,1} & p_{N,2} & \cdots & p_{N,N} \end{bmatrix}$$

The RACSA steps are performed for both bandwidth and power matrixes, targeting to maximize the SINR and the system throughput as represented in the objective function given by Equation (1) and in this case RACSA minimizes the interference. The cuckoo search is executed with an eye on attaining a new solution by means of levy flight equation and used for ordinary cuckoo search algorithm which is shown below:

$$x_i^{(t+1)} = x_i^{(t)} + \alpha \oplus Levy(n) \tag{13}$$

Where, α > 0 is the step dimension which should be linked to the issue of concern? It can be employed in several cases, with the intention of accommodating the difference between solution qualities. The proposed resource allocation based cuckoo search algorithm RACSA for subcarrier assignment is stated bellow.

Input: for every Transmission Time Interval (TTI) the Macro Base station collects

S: the demand of each user.

d: the location of each user with respect to MBS and FBS.

L_f^{mod}: Modulation scheme in the femtocell.

Output: determine the best serving BS, Bandwidth, and power for all users.

While new users join the network **do**

- For all mobile users find the optimal base station depends on their location s and the link condition.
- Formulate the CSA to do the resource (bandwidth and power) assignments.
- Randomly create an initial population. **Repeat**

Step *1***:** Obtain new solutions by using Levy flights

Step 2: Evaluate the best fitness value by using Levy flights and update to generate best solutions

Step 3: Choose randomly a nest M among N Nests

Step 4: If the new solution is best, then replace y by the new solution.

Step 5: Terminate if a section of worse nest are abandoned and new ones are built.

Step 6: Keep the finest solutions or nest with finest quality solutions

Step 7: Rank the solutions and find the current nest.

Until stopping conditions are met.

End while

Algorithm1: Resource Allocation based Cuckoo Search Algorithm RACSA

5.3.3 Cross-Tier Interference Mitigation

The interference mitigation is done for the scenario of full frequency reuse, using resource allocation technique based Cuckoo search Algorithm RACSA. Full frequency reuse phenomenon means each base station can utilize any valid bandwidth to make a connection without having an interference by the near base stations. The innovative RACSA technique takes upon itself the task of maximizing the network throughput and guarantees that interference does not exceed the specified interference threshold and this ultimately, leads to mitigating the cross-tier interference for OFDMA macro-femtocell networks. Therefore, with an eye on achieving this, RACSA technique decides the best serving base station in accordance with link condition. Cuckoo search Algorithm is extensively employed to successfully address the resource optimization problem by finding and allocating the appropriate bandwidth and power for all the users. The solution is rejected if the calculated interference per subcarrier for each population is more than a certain threshold.

6. Performance Evaluation Metrics

The new method for resource allocation is simulated using Vienna LTE system level simulator in MATLAB environment and its performance has been evaluated compared to different schemes that recently used for optimization in the literature like auction algorithm and Genetic Algorithm (GA) in terms of average network throughput (or network sum rate), spectrum efficiency, and outage probability. The system throughput is calculated using Shannon law as given by Equation (1), Spectrum Efficiency (SE) is expressed as the average of bits per second successfully received by the UE device per unit spectrum. The average network spectral efficiency, SE, is thus given by Equation (14).

$$SE = \frac{\sum_{i\in\{N\}} b_i \log_2(1 + SINR_i)}{B_{tot}} \quad (14).$$

Outage Probability is defined as the probability SINR of UE in a given sub channel is less than the SINR $_{threshold}$ and it's given by Equation. (15).

$$\mathbb{P}(outage) = (SINR_i < R_{threshold}) \quad (15).$$

7. Simulation Parameters

The input parameters to the proposed two-tier network model include demand and the location for each user (Si, di). Output parameters are the determination of serving base station for each user as well as the resource allocation of bandwidth and power for users. The other used simulation parameters are shown in Table 3.

Table 3. Simulation parameters

Parameter Description	Symbol	value
Macrocell radius	R_m	500 m
Femtoell radius	R_f	20 m
Maximum transmitted power for MBS	P_{tot}	50 dBm
MBS power rang	P_m	46- 50 dBm
FBS power rang	P_f	11-21 dBm
Total available bandwidth	B_{tot}	50 MHz
Subcarrier bandwidth	B_{rub}	15 kHz
Maximum number of mobiles users	$N_{\square}$	100
Maximum number of users per FBS	N_f	4
Average noise in the system	N_o	-135 dBm
Attenuation factor of outdoor environment	ym	3.7
Attenuation factor of indoor environment	yf	3
Lognormal shadowing of outdoor environment	$X_{\sigma m}$	8 dB
Lognormal shadowing of indoor environment	$X_{\sigma f}$	10 dB
Maximum capacity per zone	C_z^{max}	(10,7,5,1) Mbps
macrocell's bits per symbol per	$L_{m,z}^{mod}$	(6,4,2,1)
Femtocell's bits per symbol	L_f^{mod}	(6,4,2)

8. Results and Discussion

Here, the focus will be on the achievable throughput, spectral efficiency and outage probability of the proposed innovative technique, for diverse structures of the evaluated two-tiered system. Now, all through the assessment, a brief account is made regarding the upshots achieved along with the consequential debate thereon. The test linkages along with reproduction outcomes are colorfully carved out below. The simulation has been extensively employed for acquiring the best output. To evaluate the performance of the system, a SINR, throughput, spectral efficiency and outage probability are determined. The performance evaluation of the proposed resource allocation based cuckoo search algorithm RACSA technique have been done by comparing the results to those of other conventional techniques like genetic algorithms and auction algorithm which were used as optimization algorithms in the previous related researches. The following figures illustrate the result data for number of femtocells *Vs.* Throughput, spectral efficiency and outage probability for diverse methods like the GA, auction and our proposed RACSA algorithms. In this case, the results of our resource allocation based cuckoo search algorithm RACSA technique acquire high throughput and spectral efficiency and reduce the outage probability. As far as the subject is concerned, we have evaluated the system performance through the following metrics:

8.1 Throughput and Number of Femtocells

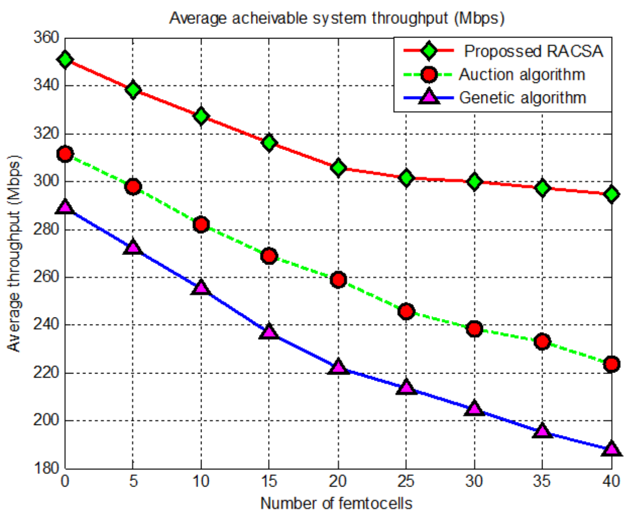

Figure 4. Number of femtocells vs. throughput for different techniques.

The average achievable system throughput has been calculated as the sum of Shannon's law stated in Equation (1) which expresses the maximum data rates over a communication channel.

It is evident that the cuckoo search based technique ushers in superb efficiency in performance in respect of system throughput. Figure 4 demonstrates the data for number of femtocells *Vs.* throughput for several approaches like the Genetic Algorithm (GA) described in[22], auction algorithm described in[21] and proposed RACSA algorithms. We observe that, the proposed resource allocation based cuckoo search algorithm RACSA technique realizes maximum achievable system throughput when compared to the standard methods. The RACSA gives around (21%) and (38%) increase in the system throughput when it is assessed and contrasted with auction algorithm and genetic algorithms respectively. This improvement due to reduce in cross-tier interference and hence the higher SINR gained by the proposed RACSA.

8.2 Spectral Efficiency and Number of Femtocells

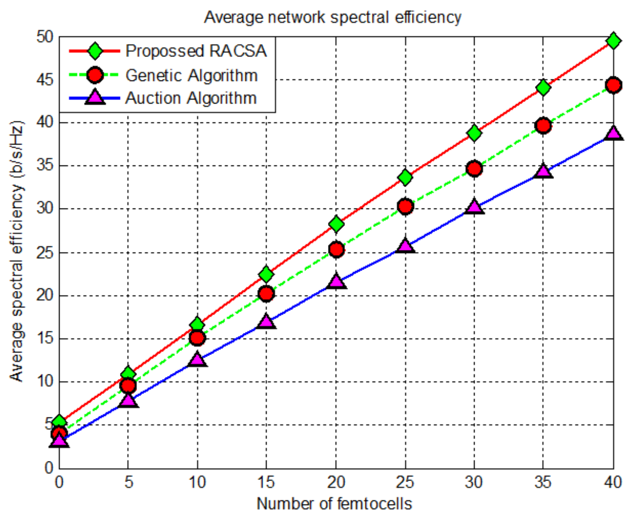

Figure 5. Femtocells vs. spectrum efficiency for different techniques.

Now, Figure 5 illustrates the change of network spectral efficiency as the number of femtocell base stations changes. According to LTE systems, the targeting spectrum efficiency (i.e., 30 b/s/HZ[32]) well satisfied by the proposed RACSA when around 21 of femtocells BS is deployed per macrocell area. The proposed RACSA Cuckoo search based approach is able to attain the greatest spectral efficiency in contrast to parallel approaches as illustrated in Figure 5, it is clearly observed that the proposed RACSA increase the average network spectrum efficiency with (35%) and (14%) when it is assessed and contrasted with auction algorithm and genetic algorithms. This improvement is due to; the full frequency reuse applied in RACSA, in contracts the auction algorithm which applied to partial frequency reuse.

8.3 Outage Probability and SINR Threshold

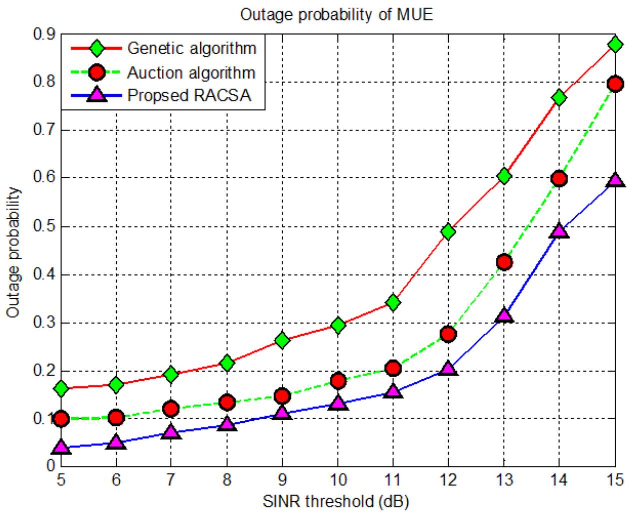

Figure 6. SINR threshold vs. outage probability for different techniques.

Figure 6 illustrate the outage probability of MU with Signal-to-Noise Ratio (SNR) = 10dB for different algorithms such as GA, auction, and the proposed RACSA as the SINR threshold varies. The outage happens when the subcarrier SINR is less than a specific SINR threshold, which is assumed to be 10 dB less than the target SINR. The outage probability can be expressed as the ratio between the number of subcarriers under the SINR threshold and the total number of subcarriers. It is crystal clear that our RACSA cuckoo search based technique comes out with flying colors in decreasing the average interference per subcarrier vis-a-vis the auction and GA technique. Figure 6 illustrates the data for outage probability vs. SINR for various approaches like the GA, auction and our proposed RACSA algorithms. Here also, our proposed RACSA cuckoo search based technique acquired minimum outage probability vis-à-vis peer methods techniques. The simulation results confirmed that the outage probability of proposed RACSA is 55% and 33% lower when assessment and contrasted are done with genetic algorithms and auction algorithm respectively.

9. Conclusion

In this paper, a full frequency reuse resource allocation based cuckoo search algorithm RACSA technique is implemented in two–tier macro and femtoell networks based OFDMA-LTE system. The initial stage of proposed techniques is devoted to obtaining the best serving BS (either MBS or FBS) for every user. The latter stage, the resource allocation optimization problem is solved by employing CSA. The RACSA steps are performed to allocate the appropriate bandwidth and power for all users targeting to maximize the system throughput and ultimately, lead to effectively mitigate the cross-tier interference. The simulation results revealed that RACSA reduce the cross-tier interference and improve the system performance. The performance evaluation showed that, RACSA gives (38%) and (21%) higher in system throughput, (14%) and (35%) increase in spectral efficiency, and (55%) and (33%) reduction for the outage probability when assessment and contrasted are done with the results produced by genetic algorithms and auction algorithm respectively.

10. References

1. Han K, Choi Y, Kim D, Na M, Choi S, Han K. Optimization of femtocell network configuration under interference constraints. 7th International Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks. Seoul: IEEE; 2009. p 1–7.
2. Chandrasekhar V, Andrews JG. Uplink capacity and interference avoidance for two-tier femtocell networks. IEEE Transactions on Wireless Communications. 2009; 8:3498–3509.
3. Yavuz M, Meshkati F, Nanda S, Pokhariyal A, Johnson N, Raghothaman B, Richardson A. Interference management and performance analysis of UMTS/HSPA+ femtocells. IEEE on Communications Magazine. 2009; 47(9):102–9.
4. Gutierrez-Estevez DM, Canberk B, Akyildiz IF. Spatio-temporal estimation for interference management in femtocell networks. IEEE 23rd International Symposium on Personal Indoor and Mobile Radio Communications (PIMRC). Sydney: IEEE; 2012. p. 1137–42.
5. Elsherif AR, Ahmedin A, Ding Z, Liu X. Adaptive precoding for femtocell interference mitigation. IEEE International Conference on Communications (ICC). IEEE: 2012. p. 4315–20.
6. Rangan S. Femto-macro cellular interference control with subband scheduling and interference cancelation. IEEE on GLOBECOM Workshops (GC Wkshps). Miami: FL. 2010. p. 695–700.
7. Zahir T, Arshad K, Nakata A, Moessner K. Interference Management in Femtocells. IEEE on Communications Surveys and Tutorials. 2013; 15:293–311.
8. Mhiri F, Sethom K, Bouallegue R. A survey on interference management techniques in femtocell self-organizing networks. Journal of Network and Computer Applications. 2013; 36(1):58–65.

9. Bouras C, Kavourgias G, Kokkinos V, Papazois A. In Interference management in LTE femtocell systems using an adaptive frequency reuse scheme. Wireless Telecommunications Symposium (WTS). London: IEEE; 2012. p. 1–7.
10. Pantisano F, Bennis M, Saad W, Debbah M. Spectrum leasing as an incentive towards uplink macrocell and femtocell cooperation. IEEE Journal on Selected Areas in Communications. 2012; 30(3):617–30.
11. Lopez-Perez D, Ladanyi A, Jüttner A, Zhang J. In OFDMA Femtocells: Intracell Handover for Interference and Handover Mitigation in Two-Tier Networks. IEEE on Wireless Communications and Networking Conference (WCNC). Sydney, NSW: IEEE; 2010. p. 1–6.
12. Nakata A, Arshad K, Moessner K. Interference tolerable threshold analysis in cognitive femtocells. Wireless Innovation Conference and Product Exhibition. Washington: USA. 2011.
13. Chu F, Chen K. Mitigation of macro-femto co-channel interference by spatial channel separation. IEEE 73rd on Vehicular Technology Conference (VTC Spring). Budapest. 2011. p. 1–5.
14. Lopez-Perez D, Valcarce A, De La Roche G, Zhang J. OFDMA femtocells: A roadmap on interference avoidance. IEEE on Communications Magazine. 2009; 47(9):41–8.
15. Tang R. Indoor propagation in cellular/PCS system design. Emerging Technologies Symposium on Wireless Communications and Systems. IEEE; 1999. p. 8.1–.4.
16. Huan S, Lining K, Jianhua L. Interference avoidance in OFDMA-based femtocell network. IEEE Youth Conference on Information, Computing and Telecommunication YC-ICT '09. 2009. p. 126–9.
17. Saquib N, Hossain E, Le LB, Kim DI. Interference management in OFDMA femtocell networks: issues and approaches. IEEE on Wireless Communications. 2012; 19:86–95.
18. Vadivel M. Optimization of radio resource allocation in energy efficient OFDMA systems. Indian Journal of Science and Technology. 2015; 8: 24–7.
19. Ngo DT, Le LB, Le-Ngoc T, Hossain E, Kim DI. Distributed interference management in femtocell networks. IEEE on Vehicular Technology Conference (VTC Fall). San Francisco, CA: IEEE; 2011. p. 1–5.
20. Saleem S, King H. Avoidance of co-tier interference between femtocells with different access modes. International Journal of Information. 2012; 2(8):617–25.
21. Sun Y, Jover RP, Wang X, Uplink interference mitigation for ofdma femtocell networks. IEEE Transactions on Wireless Communications. 2012; 11:614–25.
22. Marshoud H, Otrok H, Barada H, Estrada R, Dziong Z. Genetic algorithm based resource allocation and interference mitigation for OFDMA macrocell-femtocells networks. 6th Joint IFIP on Wireless and Mobile Networking Conference (WMNC). Dubai: IEEE; 2013. p. 1–7.
23. Zhong Z, Hamalainen J, Yang Y. On uplink power control optimization and distributed resource allocation in femtocell networks. 73rd IEEE Vehicular Technology Conference (VTC Spring). Yokohama. 2011. p. 1–5.
24. Saad SA, Ismail M, Nordin R. A survey on power control techniques in femtocell networks. Power. 2013; 8(12):845–4.
25. Abu-Srhan A, Daoud EA. A hybrid algorithm using a genetic algorithm and cuckoo search algorithm to solve the traveling salesman problem and its application to multiple sequence alignment. International Journal of Advanced Science and Technology. 2013; 61:29–38.
26. Shair EF, Khor SY, Abdullah AR, Jaafar HI, Mohd Ali N, Zainal Abidin AF. A brief review of Cuckoo Search Algorithm (CSA) research progression from 2010 to 2013. International Review of Automatic Control. 2014; 7:428–35.
27. Yang XS, Deb S. Cuckoo search via Lévy flights. World Congress on nature and biologically inspired computing NaBIC. coimbatore: IEEE; 2009. p. 210–4.
28. Tarhini C, Chahed T. On capacity of OFDMA-based IEEE802. 16 WiMAX including Adaptive Modulation and Coding (AMC) and inter-cell interference. 15th IEEE Workshop on Local and Metropolitan Area Networks. IEEE; 2007. p. 139–44.
29. Marshoud H, Otrok H, Barada H. Macrocell–femtocells resource allocation with hybrid access motivational model. Physical Communication. 2014; 11:3–14.
30. Bai Y, Chen L. Hybrid spectrum arrangement and interference mitigation for coexistence between LTE macrocellular and femtocell networks. EURASIP Journal on Wireless Communications and Networking. 2013; 13:1–15.
31. Sector IR. Guidelines for evaluation of radio transmission technology for IMT-2000. Recommendation; 1997.
32. Rumney M. Introducing LTE Advanced. Agilent Technologies. May 2011. p. 22.