Improving Efficiency in Resource Allocation Of OFDMA Femtocell Networks

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***Abstract**: Interference control is one of the fundamental challenges in resource allocation of femtocell networks that use* **orthogonal frequency-division multiple access (OFDMA)**. *In this paper, a method is proposed that reduces the interference between femtocells. This method is implemented by the femtocells in a self organizing manner and increases frequency reuse factor. Thus, the network throughput will increase and the fairness between femtocells remains reasonable we also propose a mechanism that can be applied increase the frequency resources assigned to each femtocell. These new frequencies can be used when femtocells require more frequency resources to carry higher traffic loads. Results of simulations show the improvement of the first method compared to the previous methods. It is also demonstrated that by applying the second mechanism in a high-load condition of the network, a considerable improvement is observed in its throughput. (Between 20-120% improvements).*

Keywords: femtocell, resource allocation, **orthogonal frequency-division multiple access (OFDMA)**, frequency reuse, throughput.

1. Introduction

Modern wireless networks need high-quality and high-data rate communication. One of the solutions that have been proposed in recent years is to use femtocells. Femtocells are small cells that help to share traffic loads from macrocells and improve the coverage and capacity of network in modern cellular networks. In this architecture, two tier network is formed in which the first tier is macrocells and the second tier consists of femtocells.

Femtocells are used to provide connectivity where broadband wired networks are locally available. Connecting users to femtocells can reduces the load of macrocells up to about 70-80% [2],[3]. The economic aspect is also very important to use femtocells because energy consumption is reduced for service clients and the coverage of network is also improved. One of the key challenges of using femtocells is the allocation of network frequency resources between different femtocells and macrocells such that the interference between them is minimized.

There are two classes of femtocell interference specified by the network tier. These classes are specified as co-tiered and cross-tiered interference in a tiered network [7],[8]. In the co-tiered interference, the source node and the interfered node are in the same network tier. For example, a femtocell is disturbed by unwanted signals sent from another femtocell. When a larger number of neighbours are densely deployed, severe co-tiered interference arises more often and is difficult to manage [5], [9],[10]. The deployment of femtocells in an urban area typically leads to overlapping coverage areas of multiple neighbouring femtocells [5]. For example, the deployments are likely to be in adjacent houses or blocks of apartments [3].

In cross-tiered interference, the source and the interfered node belong to different network tiers. The problem of cross-tiered interference has been widely studied through techniques of spectrum allocation [6] ,[8], [11],[12], power adjustment [12],[13] and open versus closed access operation [14],[15]. The cross-tiered interference is independent of co-tiered interference, as shown in [3]. We focus on the control of co-tiered interference in this paper.

In a practical network scenario, there could be a lot of femtocells in the network; therefore the available approaches in bandwidth allocation can't be used since, the problem gets more complex and Convergence time is much. Thus a method of "self organizing" should be used. In accordance to 3GPP (3rd Generation Partnership Project), a structure of femtocell network consists of 3 parts; the first part is FUEs (Femtocell User Equipment) which constitute of the connected user equipments such as mobiles and laptops to femtocells. The second part is the femtocells themselves. And the third is the FMS (Femtocell Manager System). FMS is the network part which receives the required information and requirements from femtocells and assigns the necessary resources to them. Fig.1 shows a view of the network structure.

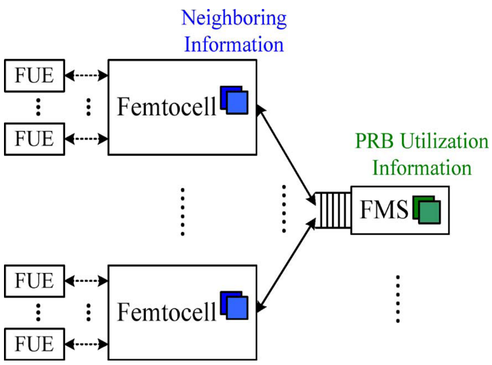

Fig. 1: femtocell network structure

The LTE standard (3GPP Long Term evaluation) uses OFDMA. In OFDMA different channels are orthogonal to each other; therefore there is no interference in other channels. In this paper, the use of OFDMA is assumed. The basic frequency-time resources are considered in equivalent bandwidth of 180 kHz and equivalent time of 0.5 ms [1] and we call each resource, a Primary Resource Block (PRB).

The rest of this paper is organized as follows. In section 2 the related previous efforts are introduced. In section 3 the proposed scenario is defined and the problem assumptions are explained. In section 4 the proposed method is explained and in section 5 the results of simulation are presented. In section 6 we provide the conclusion.

2. Related work

In LTE networks, the indoor access networks are supported by the deployment of femtocells. Because femtocells can deploy by clients anywhere in the network, the co-channel and co-tiered interference problems are severe. Jun *et al.* proposed inter cell interference cancellation techniques. Jun and Andrews [13] proposed the inter cell interference cancellation techniques, but the approach is often disregarded due to errors in the cancellation process. Another idea is to use sectored antennas to reduce interference [7]. This approach reduces the possibility of neighboring interference. Claussen and Pivit [17] introduced a dynamic selection of predefined antenna patterns to reduce the unwanted power leakage. The preceding hardware-based approaches usually increase hardware cost.But it should be considered that the methods using power control and resource management are optimum in terms of cost [12]. While the power control techniques at femtocells mitigate the co-channel interference, it may significantly modify the performance of FUEs. In addition, reduction of the power of a femtocell also reduces the total throughput of femtocell users [12].

From the point of view of resource management, López-Pérez *et al.* [6] suggested a framework to allocate different resources with different users' requirements. Rahman and Yanikomeroglu [16] presented a dynamic interference avoidance scheme to coordinate a group of neighboring cells.

One group of methods are based on cognitive networks [18] in which the interference is sensed by femtocells. With this sensed information, femtocells use the frequency resources so that interference does not occur.Huang and Krishnamurthy [19] proposed the implementation of cognitive femtocell base stations for resource allocation by using a game-theoretic framework. But these methods need to sense all frequency resources. The problem is that while the antenna is listening to the channels, it can't receive or transmit any data [22]. In addition, Tan *et al.* [20] presented a graph coloring based dynamic sub-band allocation (GC-DSA) as a graph coloring based dynamic sub-band allocation technique to avoid downlink interference. Uygungelen *et al.* [21] also developed a graph-based dynamic frequency reuse (GB-DFR) as a resource allocation method based on graph coloring. With graph coloring algorithms, the assignment of PRBs to a femtocell is restricted since a group can only be assigned a single color.

The dynamic frequency planning (DFP) was also proposed by López-Pérez *et al.* [22] to decrease interference and reuse available sub channels in OFDMA networks.This method offers an algorithm that assigns a fixed group of frequency resources to each femtocell which should use their own resources for transmission. In [10] a method is offered in which a group of femtocells are bunched together and a group of frequency resources allocated to each bunch of femtocells. It should be considered that these femtocells use the resources in a random manner. In the methods proposed in [10],[22] frequency resources are allocated to each femtocell in a fixed manner and if they are not be used, they are wasted. In [1] a method is proposed that the frequency resource assignment is flexible. In this method the network throughput increases because of the fact that the unoccupied frequencies are used by other femtocells.

3. Scenario definition and assumptions

We assume a cellular system with femtocells deployed in restricted indoor areas, such as homes and offices. It is assumed that femtocells are distributed all over the network in a complete random manner. Each femtocell has a random number of clients that can be mobiles or laptops and each of these clients require a different number of frequency resources. We assume the power of all femtocells is equal.

We can imagine a scenario in which femtocells are deployed as several groups in a dense area, where the femtocells connected to one FMS are considered as a group. This grouping scheme assumes that femtocells in different groups do not interfere with each other.

In this network all femtocells in one group are connected to FMS via backbone network and they gather information from their environment and transmit to FMS. Also it is assumed that the frequency resources assigned to each client is sufficient both for uplink and downlink. It is also assumed that the only cause of power attenuation is air loss and the path loss factor (n) is equal to 2 (The shadowing effect and fading are negligible). In addition, it is assumed that the femtocells send their ID to their neighbours with a power equal to 4 times greater than normal power in order to 2 fold-out the distance that the Signals are received by other cells. This operation is done in a periodic manner and after a specified time or after connecting a new femtocell to the network, the task is repeated. As a result, each femtocell has a list of its neighbours and sends to FMS. The spacing between the neighbours is less than double coverage radius of each femtocell in normal condition. This mechanism prevents occurrence of interference between neighbours. For example, if two femtocells are hidden from each other, in Fig. 2 this occurred, users located on the border of these two overlapping femtocells will be safe from interference.

Afterwards, each femtocell repeats this process with its normal power and produces a list of neighbours hearing in normal operation and transmits this list to FMS. In FMS the first and second order interference graph is generated based on information received from femtocells. In this graph, the edges connecting the two overlapping femtocells are present. Following this graph, the first and second order matrix is produced in a way that if two femtocells interfere with each other, the element in row and column related to those femtocells will be 1. Otherwise, the element would be zero. The first order matrix being formed based on the neighbors that are closer than radius of the femtocells and the second order matrix being formed based on the other neighbors. Therefore this matrix would be symmetric.

$$\begin{cases} y_{ij} = 1 \rightarrow if\ femtocells\, overlap \\ y_{ij} = 0 \rightarrow o.w \end{cases} \qquad (1)$$

Furthermore, it is assumed that transmitted power of femtocells is equal.

4. Proposed method

4.1 First method

After generating the first and second order interference matrix, we start the frequency resource assignment according to these matrices. In this algorithm, femtocells compete to achieve the resources in a special order. When a femtocell occupy a frequency resource, other femtocells which interfere with this one, can't try to allocate that resource. In this method, the priority of competing nodes is determined by the following parameters:

A) Number of times that a femtocell had lost the competition due to interference with their neighbours (K).

B) Number of times that it should have competed but there was not any empty resource for it (V).

We regard a parameter Y proportional to the multiplication of parameter K and V. Based on this parameter (Y) the femtocell that has the highest priority will be identified. Simulations show this resource allocation method can lead to the highest frequency reuse; hence the network throughput will increase. Also regarding the fact that if a femtocell not receives any frequency resource in a predefined period, its priority will get high in next period, because the parameter K increases. therefore the fairness between femtocells is observed.

3.2 Second method

After first method is done, a mechanism is implemented which considers the difference between first order and second order interference matrices. In this method, the femtocells which interfere in first order matrix but not in the second order are identified. Then the resources are allocated with the aid of first and second order matrices independently, and the resources which are different in two matrices should be identified. These different resources can be used again in high load condition by femtocells with a specific probability. This is equal to the probability of the common resource using clients not be allocated in common region of the 1st order interference femtocells. Note that these femtocells should not have 2nd order interference. Noting the fact that the distribution of clients in femtocell region is assumed to be uniform; this probability is equal to ratio of common region area to total coverage area of each femtocell. This area is calculated with equation (2), where 'r' is the radius of the circles,'d' is distance between the centres of the circles and 'h' is the distance between the intersection Points of the two circles.

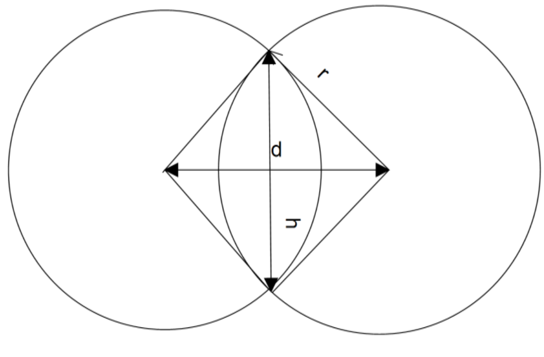

Fig. 2: common area of femtocells

$$s = \frac{2}{\pi} \times \sin^{-1}\left(\frac{h}{2\times r}\right) \times \pi \times r^2 - \left(\frac{h\times d}{2}\right) \qquad (2)$$

$$d = 2 \times \sqrt{r^2 - \frac{h^2}{4}} \qquad (3)$$

So the probability of being a user of each femtocell in the common area is:

$$p = \frac{s}{\pi \times r^2} \qquad (4)$$

Thus the probability that the client of none of the femtocells be in common region is:

$$p_{succ} = (1-p)^2 \quad (5)$$

If each of the mentioned resources be suggested to the user of target femtocell and the user doesn't sense any frequency interference in this frequency resource, it answer to the femtocell antenna and uses that frequency. Otherwise, if any interference is sensed by the user, it doesn't answer to the femtocell and femtocell suggests a new frequency resource after a certain period of time. This mechanism will prevent interference.

5. Simulations

A scenario with the area of 100^mx 100^m is assumed in which the femtocells are randomly distributed in the network. The radio coverage of each femtocell is assumed to be 10^m. Total available frequency bandwidth is 5 MHz and number of PRBs is 25. We arrange a certain number of femtocells that were 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100 for each simulation, where the average numbers of neighbors are 1.40, 4.10, 4.80, 6.30, 7.08, 7.69, 8.49, 9.63, 10.44, and 11.88, respectively. All the femtocells are controlled by an FMS in charge of allocating resources. Note that in all of the simulations it is presumed that network is in high load condition and requests are more than existing resources. The required data rate and the number of required PRBs need to meet the requirement in 64 quadrature amplitude modulation wireless channel quality specified in 3GPP standard [4].
In the beginning, the first method, utilizing the 1^{st} interference matrix, is simulated and results are compared with methods of [1] and [10]. Table I show other parameters of simulation.

TABLE I: parameters of simulation

Parameter	Value
Map Range	100m×100m
Number of femtocell	10-100
Radius	10m
Deployment	Uniform random distribution
Neighbours	1-22
Antenna Pattern	*Omni-directional*
Bandwidth	*5 MHz*
Sub frame Duration	.5 ms
Number of Available PRBs	25

Fig.3 shows a comparison between these three methods in terms of average throughput. It is seen that the proposed method has improved throughput compared to the previous methods.

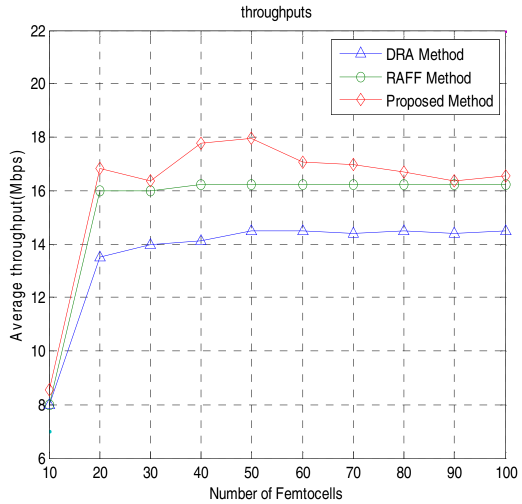

Fig. 3: average throughput of previous method and 1th proposed method

In order to have criteria for fairness between femtocells in the proposed method and previous methods, we define a parameter 'h'. This parameter is a ratio of variance of throughput such that if we go along from average throughput with this step length, just two of the femtocells have lower throughput than this throughput. The smaller the 'h' shows the femtocells are more close to the average throughput and the fairness is more heeded. If 'h' in this proposed method is compared with the method of [1], it will be seen that in proposed method, the fairness between femtocells is as good as previous method, fig.4 shows this fact.

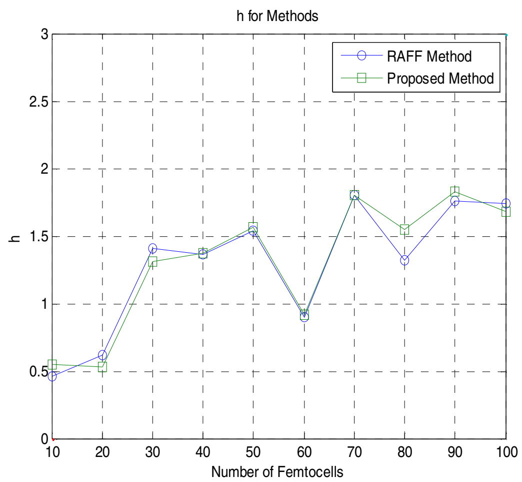

Fig. 4: parameter 'h' for methods

Now if the 2^{nd} order matrix mechanism is also applied on the first method, the throughput shown in Fig. 5 is achieved. Fig.5 shows that this mechanism results in a considerable increase in the throughput. This increase is better observed in the case where there are more femtocells in the network.

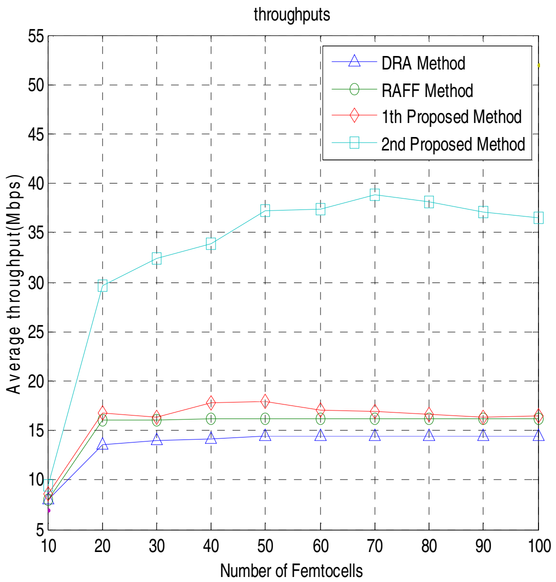

Fig. 5: average throughput of previous methods and proposed methods

6. Conclusion

New generation mobile networks use femtocells to provide better service coverage and reduce the demand on network frequency resources. They use FMS to coordinate the frequency usage of femtocells. In this paper, we focused on the design of efficient frequency resource management schemes and proposed two methods. As observed, in order to avoid interference between femtocells, in specific time periods, femtocells send their IDs to their neighbours. Then information related to neighbours' interference is measured by each femtocell and transferred to FMS. Based on this information, the resource allocation is done such that the channel efficiency and frequency reuse is increased. Simulation results show that the throughput is more improved by the first method compared to the previous methods, also this Method is observed fairness between femtocells. Afterward, a group of resources were assigned to femtocells that these frequency resources are the difference between 1st order and 2nd order interference matrix. These frequency resources were wasted in previous methods. The femtocells can have access to these frequency resources with an acceptable probability in high-load period. In this mechanism, the network throughput got an outstanding improvement.

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