Optimal Femto Placement in Enterprise Building

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***Abstract*—Deployment of Femtocell Base Stations a.k.a Femtos for improving network coverage and data rates in indoors is an emerging practice in cellular systems. However, if Femtos are not placed optimally they do not provide these improvements, thus defeating the purpose of their deployment in indoors in the first place. In this paper, we propose a novel heuristic solution for Femto placement which guarantees minimum Signal to Interference plus Noise Ratio (SINR) using fewer number of Femtos. We define a mathematical model taking into account the installation requirements and threshold SINR for each Femto. Consequently, resulting LPP model is solved to obtain the optimum number of Femtos and their placement locations. Our proposed placement scheme offers 10% improvement in SINR when compare to random placement of Femtos.**

I. Introduction

The ubiquity of bandwidth-hogging smart phones and tablet computers means that mobile telecom operators need to regularly upgrade their network infrastructure. The current bandwidth crisis in cellular networks is forcing operators to deploy next-generation systems like LTE which promises to deliver high data rates for User Equipments (UEs). According to a recent survey [1], [2] 70% of the data traffic is generated from indoor environments. Though Macro base stations offer high data rates for outdoor UEs, indoor UEs suffer from lower data rates due to wall attenuation, path loss and interference. In order to address this problem, operators are deploying Femtos (low power, small base station) for improving network coverage and data rates in indoors like workplaces and homes. In an enterprise building scenario, many Femtos have to be deployed to improve coverage and offer high data rates for indoor UEs. Contrary to this random placement of Femtos defeats the very purpose of them due to requirement of higher uplink power and poor SINR at UE side, resulting in UEs battery drain and low data rates. The goal of the method proposed here is to improve indoor data rates by efficient placement of Femtos.

The rest of the paper is organized as follows. Section II describes the related work. SINR, capacity and proposed work are discussed in Section III. Section IV contains the simulation setup and performance results. Finally, Section V contains the conclusions and future work.

II. Related Work

Algorithms for optimal placement of Femtos inside an enterprise building are discussed in [3]. However, the effect of Macro Base Station (BS) interference on UEs connected to Femtos has not been addressed. Interference from Macro BS on Femtocell networks is investigated in [4]. In furtherance to [4], authors of [5] proposed an automatic deployment prediction technique for Femtos in heterogeneous networks (*i.e.,* networks consisting of both Macro BSs and Femtos) by utilizing interference and physical network environment. However, queries like how many number of Femtos required and where exactly place these Femtos are not addressed. In this work, we have considered Macro BS interference and then determine minimum number of Femtos to place in the physical enterprise femtocell environment such that it guarantees minimum SINR at UEs connected to Femtos.

III. Proposed work

The objective of our work is to determine the minimum number of Femtos required to achieve minimum SINR for all UEs inside enterprise building and place Femtos efficiently considering obstructions representing practical deployment scenarios. SINR varies with respect to distance. SINR at a distance r is given by

$$\gamma(r) = \frac{P_f}{P_b + N}, \tag{1}$$

where P_f is the received power from the attached Femto, P_b is the interference from Macro BSs and N is the noise. Ignoring noise, SINR in dB scale is given by

$$\gamma(r) = \log_{10} P_f - L_x - 10\alpha \log_{10}(\frac{r}{x}) - \log_{10} P_b, \tag{2}$$

where L_x is the loss at reference distance x. According to Shannon, capacity is directly proportional to SINR. The capacity C is given in [4] and its saturation value for LTE network is taken as 5.6 b/s/Hz. We use the following relation to determine the capacity obtained at UE side:

$$C = min(\log_2(1+\gamma), 5.6) \tag{3}$$

We assume there is interference from Macro BSs on Femto connected UEs but no interference between Femtos. This can be achieved by dividing radio resource blocks (RBs) among the Femtos. We also assume that every Femto can service a Hexagonal Coverage Area (HCA). Within a given HCA of a Femto, SINR decreases along the distance r. At some particular distance ($r = a$), SINR reaches its threshold γ_{min}. a is the maximum distance that can be covered by a Femto. SINR within HCA should hold the relation

$$\gamma(r) \geq \gamma_{min}(r = a) \tag{4}$$

Distance between the neighbouring Femtos D is determined by [Appendix A]:

$$\sqrt{3}a \le D \le 2a \tag{5}$$

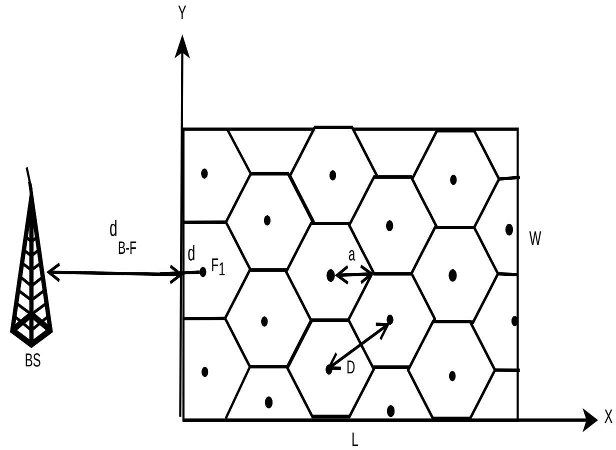

Fig. 1. Placement of first Femto and obtaining a and D.

For a two-tier heterogeneous network comprising Macro cells and Femto cells, first Femto BS inside the enterprise building is placed near the wall which is close to the near-by Macro BS to increase spectral efficiency as shown in Fig. 1. And d is the distance between Femto and wall and is given by [5]:

$$d = \frac{L}{1 + \omega^{\frac{-2}{\alpha}}(1 + \frac{L}{d_{B-F}})}, \tag{6}$$

where L is the length of the building, α is the path loss constant, ω is the wall loss that depends on the number of walls inside the building aand d_{B-F} is distance from Macro BS to the enterprise building.

Now we can equate d to X-coordinate of the first Femto (F1). But, d is less than $\frac{a}{2}$ in real situations. Hence, no voids are created along Y-axis. The Y-coordinate of the first Femto was assigned some value and HCA mesh was drawn for all other Femtos across the building. The Y-coordinate of the first Femto is again adjusted to diminish the voids at the building edges. In a building of length L and width W, relation for the optimal number of Femtos M is given by [Appendix B]:

$$\lceil \frac{LW}{2.6a^2} \rceil \le M \le \lceil \frac{LW}{2.6a^2} \rceil + \lceil \frac{L}{3a} \rceil + \lceil \frac{W}{\sqrt{3}a} \rceil \tag{7}$$

By knowing values of a, D, d and M, HCA mesh can be drawn for any building having dimensions L X W. The center of every HCA gives the coordinates of all the Femtos to be placed heuristically within the building and thereby bringing maximum number of UEs with SINR greater than γ_{min}. The proposed Femto placement scheme is given in Algorithm 1.

Algorithm 1 Heuristic Placement Algorithm

Input 1 : γ_{min} *(SINR-Threshold)*
Input 2 : *L, W* (Building dimensions)
`Step 1`: *Obtain a (hexagonal radius) for given γ_{min} using Eqn* (2) *and Eqn* (3)
`Step 2`: *Obtain d to get X-coordinate of the first Femto by Eqn* (6)
`Step 3`: *Fix the Y-coordinate of the first Femto and total number of Femtos (M) using Eqn* (7)
`Step 4`: *Plot HCA for all Femtos by extending first Femto HCA*
Output: *Coordinates of the efficient placement of Femtos*

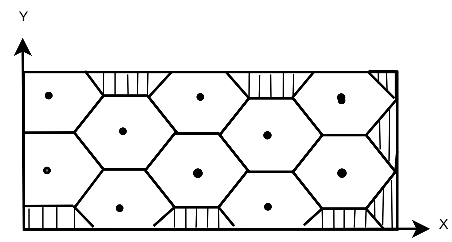

Fig. 2. If the lower bound of M is considered, voids at the building edges are created as shown by the shaded part.

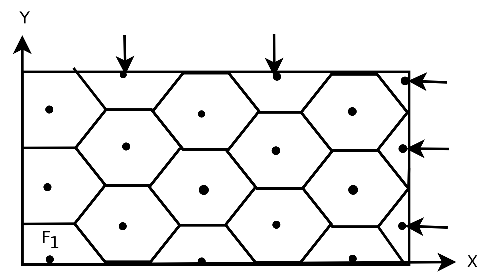

Fig. 3. If the upper bound of M is considered, voids are serviced by extra Femtos at an extra cost.

IV. Simulation Setup

To study the proposed scheme, we considered an enterprise building scenario with dimensions 300 X 200 m^2 with a single corridor and without any walls in between. For this scenario, M should be in between 10 and 15. Table 1 shows other simulation parameters used. Assuming UE distribution to be random, we considered two enterprise Femtocell network scenarios: one with 10 Femtos (M=10) and the other with 15 Femtos (M=15). In first scenario, some coverage voids are created due to lack of Femtos as illustrated in Fig. 2, as a result some UEs may get SINR less than -5 dB. The UEs in these coverage voids require more power to maintain link with Femto. To avoid such coverage voids, 5 more Femtos [from (7)] are added to existing pool of Femtos in the enterprise building. With these additional Femtos deployed, all UEs start getting a minimum SINR of -5 dB as shown in Fig. 3.

Fig. 4 shows the CDF of UEs versus SINR. It is observed that proposed Femto placement scheme always performed better than random placement, further 15 Femto scenario showed all UEs getting SINR greater than -5 dB. Fig. 5 shows the plot of CDF of UEs versus spectral efficiency. It shows that 15 Femto scenario always has greater capacity compared to 10 Femto scenario, further it shows minimum spectral efficiency is high in our proposed scheme when compared to random Femto placement. Hence, we conclude that proposed placement scheme for Femtos guarantees a good SINR and improves capacity all over the building when compared to random placement scheme.

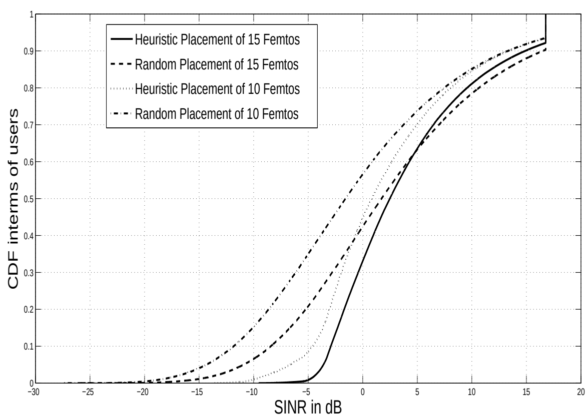

Fig. 4. CDF of UEs vs SINR

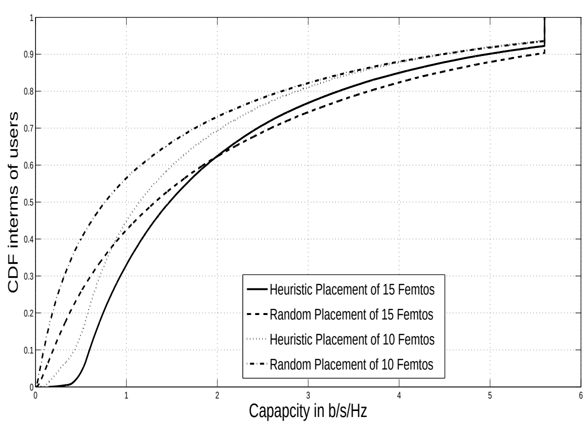

Fig. 5. CDF of UEs vs Spectral efficiency

V. Conclusion and Future work

In this paper, we have considered the Femto placement using minimum level capacity constraint at UE end. This constraint plays an important role in ensuring good throughput for each UE. This procedure also reduces the total number of Femtos required to cover the entire building area. In future, we intend to include more number of constraints based on the QoS (Quality of Service) and CQI (Channel Quality Indication) to derive minimum threshold power level at UE. The attenuation factor due to inner walls will also be considered.

TABLE I
Modeling Parameters

Parameters	Values
Simulation dimensions	300 m X 200 m
No of Femtos	10, 15
No of UEs	200
Range of Femto	50 m
γ_{min}	-5 db
UEs Distribution	Random

Appendix A

In the relation in Eqn (5), if adjacent Femtos are placed according to HCA mesh, inter distance between the Femtos D is equal to $\sqrt{3}a$. If it is not possible to place neighboring Femto at $\sqrt{3}a$, distance between adjacent Femtos (D) can be relaxed to $2a$ to assure γ_{min} SINR for all UEs.

Appendix B

In the relation in Eqn (7), for a building of dimensions L and W, the area of the building is $L\ X\ W$ and area of each HCA is $2.6a^2$. The minimum number of Femtos required is the lower bound of the relation. If the lower bound of M is considered, the Femtos placed are as shown in Fig. 2. But, UEs at the edges of the building, where voids are created will not get the threshold SINR γ_{min}.

To cover the voids, more number of Femtos need to be deployed. To reduce the number of extra Femtos, we can fix Y-coordinate of the first Femto at 0 as shown in Fig. 3 so that voids are not created along X- and Y-axes. Voids are created for every $3a$ distance along the length, and at every $\sqrt{3}a$ distance along the width. Hence, a maximum of $\frac{L}{3a}$ Femtos are required along length and $\frac{W}{\sqrt{3}a}$ Femtos are required along width. This value defines the upper bound of the relation. If the upper bound of M is considered, the Femtos can even be placed in the corners and edges of the building as shown in Fig. 3. Once this is achieved, every randomly situated UE in the building can get SINR greater than γ_{min}.

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References

[1] S. Nielsen, "Lte evolving towards local area in release 12 and beyond." Future Radio in 3GPP, Nokia Corporation, 2012.

[2] "Views on rel-12 and onwards for lte and umts." Future Radio in 3GPP, Huawei Technologies, 2012.

[3] J. Liu, T. Kou, Q. Chen, and H. D. Sherali, "Femtocell base station deployment in commercial buildings: A global optimization approach," *Selected Areas in Communications, IEEE Journal on*, vol. 30, pp. 652–663, April 2012.

[4] W. Guo and S. Wang, "Interference-aware self-deploying femto-cell," *Wireless Communication Letters, IEEE Journal on*, pp. 609–612, December 2012.

[5] W. Guo, S. Wang, X. Chu, J. Zhang, J. Chen, and H. Song, "Automated small-cell deployment for heterogeneous cellular networks," *Communications Magazine, IEEE*, vol. 51, pp. 46–53, May 2013.