

# Optimal Femto Placement in Enterprise Femtocell Networks

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**Abstract**—Targeting the indoor users, Femtocells are deployed inside the buildings to boost the signal strength and provide higher data rates. Femtos play an important role in 4G LTE standard and an optimal placement is of immense importance for realizing full benefits of 4G LTE to indoor users. Minimizing the number of Femtos within an enterprise building and promising a minimum threshold SINR for all UEs is the goal of this proposed method. Optimal placement of Femtos in turn provides a maximum throughput level at each UE.

**Index Terms**—LTE; Femto Cells; SINR; Throughput;

## I. INTRODUCTION

In 4G LTE, cellular networks assure high data rates to UEs (User Equipment). Based on a statistical analysis [1], [2], it has been found that more than 70% of the data traffic is from indoor environment. The Macrocell Base stations fail to provide high data rates for indoor UEs. Hence, small cells (short range base station) for example Femto, are deployed inside the building to provide high data rates.

In an enterprise scenario, many Femtos have to be deployed to provide high data rates to all UEs. It is assumed that all Femtos work in an open access mode. So placing the Femtos optimally within the building is important. Random placement of Femtos results in more up link power to UE, which thereby increases battery drain and  $CO_2$  emission to the atmosphere. The goal of the method proposed here is to increase the capacity for indoor UEs by optimal placement.

The rest of the paper is organized as follows. Section II describes the related work. SINR and Capacity are discussed in Section III. Section IV discusses the proposed work. The simulation setup and results along with analysis is presented in, Section V. Finally, Section VI contains conclusion and the problems that need to be addressed.

## II. RELATED WORK

Authors of [3] provide an algorithm to place the Femtos within the building. However the effect of Macro on SINR has not been addressed and algorithm becomes evermore computationally expensive with increase in the building size. Interference from base station has been investigated by [4]. Authors of [5] have recommended placing a Femto in two tier network.

The objective of our work is to determine the minimum number of Femtos required and placing them optimally inside the building and increase the SINR provided to UEs taking the Macro interference into account.

SINR refers to the Signal Power to Interfering Noise Ratio and it varies with respect to distance. SINR at a distance  $r$  is given by

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

where,

$P_f$  → Received power from the Femto;

$P_b$  → Interfering power from the base station;

$N$  → Noise;

Ignoring Noise, SINR in  $dB$  scale is given by

$$\gamma(r) = \log_{10} P_f - L_x - 10\alpha \log_{10}\left(\frac{r}{x}\right) - \log_{10} P_b \quad (2)$$

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 [2] and its saturation value for LTE is taken as 5.6 b/s/Hz. We use the following relation to determine the capacity obtained at UE end.

$$C = \min(\log_2(1 + \gamma), 5.6) \quad (3)$$

## III. PROPOSED WORK

### A. Basic Idea

To get a good signal strength inside the building, small cells like Femtos are deployed. Random deployment of Femtos causes throughput degradation and imposes further increase in Femtos. Optimal placement of Femtos inside the building ascertains maximum capacity with minimum number of Femtos and minimum power consumption at UE end. We assume there is interference from Macro to Femto but no interference between Femto to Femto.

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  $\gamma_{min}$ .  $a$  is the maximum

distance that can be covered by a Femto. SINR within HCA should hold the relation

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

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

$$\sqrt{3}a \leq D \leq 2a \text{ --- (5)}$$

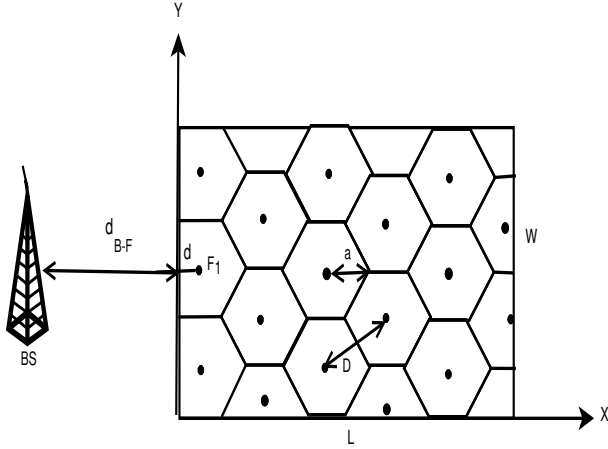


Fig. 1. Placement of first Femto and obtaining  $a$  and  $D$ .

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

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

where,

- $L \rightarrow$  is the length of the building;
- $d \rightarrow$  is the distance from wall to Femto;
- $\omega \rightarrow$  is the wall loss;
- $\alpha \rightarrow$  is the path loss constant;
- $d_{B-F} \rightarrow$  is the distance from BS to building;

Now we can equate  $d$  to  $x$  co-ordinate of the first Femto (F1).  $d$  is less than  $\frac{a}{2}$  in real situation. Hence, no voids are created along  $y$ -axis.  $y$  co-ordinate of the first Femto was assigned some value and HCA mesh was drawn for all other Femtos across the building.  $y$  co-ordinate 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 an optimal number of Femtos  $M$  is given by [Appendix B]

$$\lceil \frac{LW}{2.6a^2} \rceil \leq M \leq \lceil \frac{LW}{2.6a^2} \rceil + \lceil \frac{L}{3a} \rceil + \lceil \frac{W}{\sqrt{3}a} \rceil \text{ --- (7)}$$

By knowing  $a$ ,  $D$ ,  $d$  and  $M$ , HCA mesh can be drawn for any building of size  $L \times W$ .

The center of every HCA gives the co-ordinates of all the Femtos to be placed optimally within the building, and thereby

bringing maximum number of users with SINR greater than  $\gamma_{min}$ .

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#### Algorithm 1 Optimal Femto Placement Algorithm

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**Input 1 :**  $\gamma_{min}$  (Threshold SINR)

**Input 2 :**  $L, W$

*Step1 :=* Obtain  $a$  for given  $\gamma_{min}$  using (2) and (3)

*Step2 :=* Obtain  $d$  to get  $x$  co-ordinate of the first Femto by (6)

*Step3 :=* Fix the  $y$  co-ordinate of the first Femto and decide  $M$  for given building using (7)

*Step4 :=* Plot HCA for all Femto by extending first Femto HCA

**Output:** Co-ordinates of the Femtos which are optimally placed

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## IV. SIMULATION SETUP

In Matlab simulation, we have considered a building of size 300 X 200 m with a single corridor and without any walls in between. Assuming user distribution as random, cumulative distribution of SINR for random and optimal placement of Femtos are explained below. We tested two scenarios, one with the lower bound of number of Femtos ( $M$ ) as 10 and the other with the upper bound as 15. In first scenario, some coverage voids are created due to lack of Femtos, as a result some users may get SINR less than  $-5dB$ . The UE hence requires more power to maintain the link with Femto. To reduce the UE power and to fill the coverage voids, extra 5 Femtos are added to existing Femtos. With these additional Femtos deployed, all users will get a minimum SINR of  $-5dB$  as shown in Fig 2. With optimal placement, the indoor UEs achieve maximum capacity as shown in Fig 3.

It was observed that optimal placement of Femtos guaranteed a good SINR and capacity all over the building, when compared to random placement.

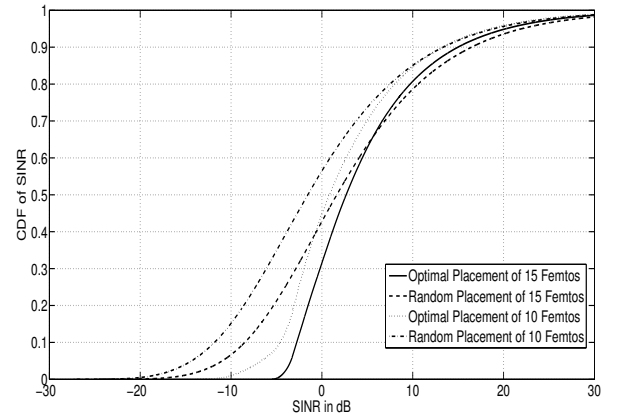


Fig. 2. Optimal Placement of Femto and Random Placement of UE

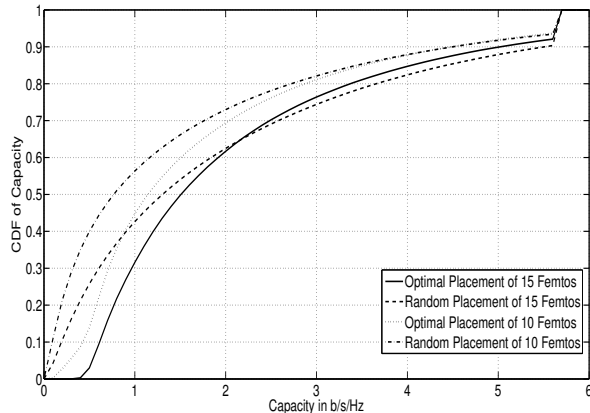


Fig. 3. Variation of Capacity for Optimal Placement of Femtos and Random Placement of Femtos.

TABLE I  
MODELING PARAMETERS

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

## 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 an efficient 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 Index) to derive minimum threshold power level at UE. The attenuation factor due to inner walls will also be considered.

### Appendix A

In the relation (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  $\gamma_{min}$  SINR for all UE.

### Appendix B

In the relation (7), for a building of dimensions  $L$  and  $W$ , area of the building is  $L \times W$  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. 4. But, the users at the edges of the building, where voids are created will not get the threshold SINR  $\gamma_{min}$ .

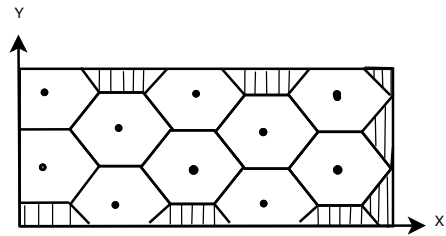


Fig. 4. If the lower bound of  $M$  is considered, voids at the building edges are created as shown by the shaded part.

To cover the voids, more number of Femtos need to be deployed. To reduce the number of extra Femtos, we can fix  $y$  co-ordinate of the first Femto to be placed as 0 as shown in Fig. 5. so that voids are not created along  $x$ -axis and  $y$ -axis. 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. 5. Once this is achieved, every randomly situated UE in the building can get SINR greater than  $\gamma_{min}$ .

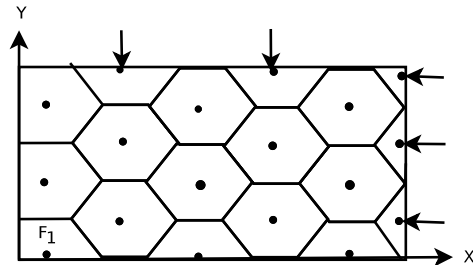


Fig. 5. If the upper bound of  $M$  is considered, voids are serviced by extra Femtos at an extra cost.

## A ACKNOWLEDGMENT

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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, no. 3, pp. 652–663, 2012.
- [4] W. Guo and S. Wang, "Interference-aware self-deploying femto-cell," 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, no. 5, pp. 46–53, 2013.