DEPLOYMENT OF FEMTO/PICO/MICROCELL IN URBAN INDOOR AND OUTDOOR ENVIRONMENTS WITH HIGH LAYOUT OF SUBSCRIBERS

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In this work, we analyze the ways of optimization of each user’s channel capacity and spectral efficiency in a modern hierarchy of incorporated microcell, picocell and femtocell networks. We consider the co-existence of microcell Base Stations (MBSs), Picocell (PAPs) and Femtocell Access Points (FAPs) with shared and dedicated carrier frequency allocations. The simulation framework, based on the multi-parametric stochastic model of radio propagation for various scenarios, occurring in the urban environment, is introduced for analysis of channel capacity and spectral efficiency improvements in complex urban environment taking, as a real example, the description of one of the urban tested area, consisting integrated micro/picocell and femtocell configurations. The analysis of the network consisting of dedicated and shared femtocells for home coverage in a presence of traditional microcell pattern is presented. The advantages and drawbacks for different deployment strategies are investigated using the proposed simulation framework.

1. Introduction

Nowadays, the cellular network has gone through three generations (from 1G to 3G). The first generation (1G) of cellular networks is analog in nature. To accommodate more cellular phone subscribers, digital TDMA, FDMA and CDMA technologies are used in the second generation (2G) to increase the network capacity. With digital technologies, digitized voice can be coded and encrypted. Therefore, the 2G cellular network is also more secure. The third generation (3G) integrates cellular phones into the Internet world by providing high-speed packet-switching data transmission in addition to circuit-switching voice transmission. By 2009, it had become clear that, at some point, 3G networks would be overwhelmed by the growth of bandwidth-intensive applications like streaming media. And especially in urban or sub-urban environment with different density of calls or data flow which can change at any time. These trends demand fundamentally new network approaches to deploying such infrastructure in a cost-effective manner. A key recent trend in this regard is the use of femtocells overlaid throughout the traditional tower-based network. These small, inexpensive and short-range access points can be deployed either by the end user or the service provider, and typically occupy licensed spectrum and have an IP backhaul [1–8]. To solve the problem of signal-to-noise (S/N) increase, wireless operators want to use the new technologies, such as femtocell, to improve capacity and data rates of the channel [1–8].

The main goal of this work is to investigate an efficiency of the integrated micro/pico/femtocell network; its capacity and spectral efficiency for each individual indoor (e.g. femto) and outdoor (e.g. micro) channel in the urban area for different deployment strategies of microcells incorporation with femtocells. Special scenarios with the concrete densities and deployment strategies for microcell networks, incorporated with femtocell networks, are simulated for real scenarios occurring in the urban scene based on the practical topographic built-up map of the city. We suggest that such numerical analysis will allow the designers of such incorporated micro/pico/femtocell networksto decide of which strategies and scenarios yield the best results regarding the capacity, spectral efficiency and data rates of each subscriber channel “hidden” in a such hierarchical micro/femto cellular structures.

2. The Incorporating Micro/Pico/Femtocell Networks

2.1. Main Definition of Femtocell Concept

Femtocells’ access points (APs) are small cellular base stations that may be deployed in residential, enterprise, or outdoor areas [1–7]. They utilize the available broadband connections of the users (e.g., cable or DSL) and typically have a coverage radius on the order of ten meters or more. Two of the main advantages of these networks include staggering capacity gains for next generation broadband wireless communication systems and the elimination of the dead-spots in a microcellular network. Due to very short communication distances, femtocell networks offer significantly better signal qualities compared to the current cellular networks. As was shown in [4-8], the most important problem in
femtocell networks is the presence of interference between neighboring femtocell APs and between the femtocell networks and the microcell networks.

2.2. Different Deployment Configurations of the Femtocell Networks

Since, as was mentioned in [4–8], interference between femtocells and macro/femtocells is a critical problem in aspect of capacity in communication channel, we will present here some well-known nowadays deployment modes of femtocell network, following results obtained in [4-8], with aspect to improving the capacity of next generation cellular systems. Thus, let us consider a microcell network where there are $\tilde{M}$ microcell mobile stations ($m$MSs) communicating with a microcell base station (mBS). In our work, we analyze three different modes in deployment of femtocells:

- Dedicated channel versus co-channel.
- Open access for open subscriber group (OSG) versus closed access for closed subscriber group (CSG).
- Co-channel interference between subscribers’ group.

3. The Deployment Models in Micro/Pico/Femtocell Configurations

3.1. Model of Radio Propagation

For the investigation of the response of outdoor communication channels for the practical applications to microcell/femtocell networks deployment, the multiparametric stochastic approach for signal strength prediction in urban environment was introduced recently in the previous works [9, 10]. Here, we follow the simplified approach introduced in [9, 10], where multiple diffraction and scattering, have been rearranged in the simple forms of "straight-line" equations, as it is usually proposed by another authors. Depending on elevation of the BS antenna with respect to the building rooftops and the MS antenna, there are several scenarios occurring in the built-up environment were proposed in [9].

3.2. Channel Capacity Models

To analyze the potential of channel capacity of mobile users in networks with integrated femtocell deployments, Shannon's equations are introduced in this section considering different FAP (femto access point) available configurations and channel assignment strategies. The following assumptions for channel capacity model were made:

a) The total spectrum $B$ is assigned to FAPs and MBSs according to the considered configuration;

b) All users receive the same available bandwidth which assigned to comply with the highest available demand of service in the network, i.e. each MS receive the equivalent part of the $B$;

c) All FAPs and MBSs are transmitting simultaneously to all active users;

d) The unified propagation models mentioned above for outdoor to outdoor, outdoor to indoor, indoor to indoor cases, were used to calculate the average received signal strength (RSS).

In computations, we accounted for slow and fast fading phenomena and additional propagation characteristics such as multiple scattering and diffraction, and absorption.

A. Shared spectrum assignment (SSA) with Close Subscriber Group (CSG).
B. Shared spectrum assignment (SSA) with Open Subscriber Group (OSG).
C. Dedicated spectrum assignment (DSA) with Closed Subscriber Group (CSG).
D. Dedicated spectrum assignment (DSA) with Open Subscriber Group (OSG).

4. Results of Numerical Simulations and Discussions

4.1. Femto/Pico/Microcell Configuration

For small town (see Fig. 4.1), we model different scenarios mentioned above with the different percentages of MS-users arranged inside buildings, which have FAPs, that is, of {50%, 70%, 100%}. Different positions of FAPs between MS-users was modeled: regular and homogeneous, with 80% of MS located at the boundary of femtocell, and with 20% of MSs located at the center of femtocell, and conversely. Were analyzed all deployments of FAPs – CSG and OSG for models from 3A to 3D (see definitions in the previous sections). All derivations during numerical experiment were carried out at the range of seen central cells (7 cells, see Fig. 4.1) with the proposed reuse frequency algorithm. The users’ layout was estimated roughly ~460 users per km².

Figure 4.1 presents position of seven microcell stations at the map of the town with population of 60-70 thousands taken from [5] with femtocells “embedded” inside. Radio coverage of these 7 micro-
stations with layout of pico- and femtocell accesses points was evaluated according to multiparametric stochastic model depending of the corresponding channel “response” described in [7–9].

We had totally 192 different variants for each approach (CSG or OSG). Then, were taken average results of computations for 10 different numerical experiments for each scenario, that is, for 1920 tests accounting for each condition of network – dense and rare.

![Figure 4.1. Cellular map of town consisting microcell APs and femtocell Aps](image)

4.2. Results of Numerical Computations

Based on the data of computation, the corresponding diagrams were performed (in numbers) for each desired network deployment and its configuration. We present below only those of them that have practical applications for the current regime of the femto/pico/microcell network (CSG-SSA, CSG-DSA, and so forth). Results include 64 points, each group of 16 points - at the separate line, which determines a group of scenarios, having the same amount of FAPs in the center and at the edge of femtocells. As the result of numerous computations, we present in Figs. 4.2a and 4.2b the percentage of users in CSG-SSA scenario, 25% of which are located inside buildings and the users’ capacity distribution area shown for FAPs located at the centers and at the edges of femtocells, respectively.

![Figure 4.2. The percentage of users and their capacity distribution for the case of 25% of them located inside buildings: FAPs in the center (top panel), and FAPs at the edges (bottom panel)](image)
Similar results have been obtained for other hierarchy of femto/pico/microcell deployment and scenarios which can be searched in [7, 8].

Summary

Obtained results of numerical experiment of hierarchy model of cellular network, consisting femtocells "embedded" into pico- and microcells (Fig. 4.1), have shown that it is difficult to obtain any optimal configuration of femto/pico/microcell deployment. At the same time during numerous variants analysis were found important results that can be summarized as follows:

* Amplification of general signal to interference noise ratio (SNIR) inside the network not always yields increase of users’ capacity, mostly in conditions of optimal deployment of FAPs inside pic- and micro-cells.

* It was found a tendency in the network depending on the percentages of FAPs deployment: lesser amount of users in the center of femtocells should use the corresponding FAPs. However, for users located at the boundaries of femtocells the FAPs deployment is optimal.

Finally, during numerical analysis it was shown that without detailed analysis of propagation conditions in urban environment for different scenarios occurring in the urban scene, it is impossible not only to perform complicated structures in cellular map hierarchy, but also to predict the level and quality of service for any subscriber located in the desired cell of cellular network – from femtocell to micro- and macrocell.

The obtained results are fully agree with those obtained by other researchers, namely in [11, 12]. Moreover, the obtain results not only cover the results obtained there, but also generalize various propagation situations and different scenarios with servicing of outdoor and indoor subscribers for each specific configuration and hierarchy of integration of femto/pico/microcells.

BIBLIOGRAPHY