Open Loop Sensor based System used for Mitigation of Cross-tier Interference in Femtocell Networks

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Abstract — **The paper is concerned with the study of the cross-tier interference between the femtocell and macrocell layers of a mobile communications network. The main point of interest is consisted by the interference generated by the femtocell to the macrocell user. A mixed indoor-outdoor environment is analyzed and the corresponding problems identified. A solution is proposed consisted in using the existing security alarm system in order to control the transmit power and radiation pattern of the femtocell, performing in this way cross-tier interference mitigation.**

Keywords — **Femtocell, Interference, Macrocell, Radiation, Sensor.**

I. Introduction

OVER the past years technology has faced a rapid and important growth, resulting in better facilities for users. First, individual solutions were given to individual problems. Now-a-days, all the market players tend to combine and integrate more and more adjacent domains, in the hope to create the so called "intelligent house". That is why, in our article we present one such possible approach: the integration of the common security alarm system, present in every home, office building, course rooms, etc. with the newly introduces femtocell network. This method was developed in order to minimize the cross-tier interference between the femtocell and macrocell layers, at the macrocell user site, as well as to reduce the power consumption of the FAP (Femtocell Access Point).

Femtocells, also known as Home Base Stations, represent cellular network access points, created to enhance both indoor coverage and capacity for mobile cellular networks. Studies have shown that in cellular networks, about 60% of all voice calls and 90% of all data services, take place in indoor environments [1]. That is why, a good coverage for these places is crucial. Technical papers relate the fact that is quite difficult to obtain a good indoor coverage using the "traditional" approach. Some of the disadvantages of the macro cellular approach are: it is very costly to obtain a good indoor coverage, due to the penetration losses of the waves. Especially in the UMTS standard, the capacity of a cell is related to level of the received signal at the receiver site; in order to obtain a high capacity network, the operator would need a high number of base stations, a fact difficult to realize especially in dense areas; in these regions the planning and optimizations becomes very difficult; there is no guaranty for the performances of the network, these being in a strong relationship with the transmission conditions.

Using the fact that this equipment has a reduced transmit power, it can be implemented with a much larger density than macrocells. That is why the deployment frequency is very high, leading to an enhanced spectral efficiency. The main arguments in favor of choosing femtocells are:

- Coverage and capacity enhancement. Due to the short distance between the Tx and Rx, femtocells can operate with a low transmit power, thus leading to a longer lifetime of the terminals batteries; also, a good signal-to-noise and interference ratio is obtained. The high spectral efficiency is also an important factor that needs to be taken into consideration.
- Enhancement of the macrocellular network. Taking advantage of the fact that the indoor users are handled by the femtocells, the macro BS can redirect its resources to offering better services for outdoor users.
- Reduced implementation and maintenance costs for the operators as well as for the users.

Given the fact that femtocells operate in the license spectrum owned by the wireless operators, and share the spectrum and resources with the macrocellular network, an important problem inevitably rises – cross-tier interference between the macrocellular and femtocellular networks.

Previous studies have presented different methods used for controlling cross-tier interference, adopting different strategies. For example, in [2] and [3] the method of transmit power control is used, while [4] uses a different approach, using time hopping coupled with antenna sectoring, all of these for UMTS networks.

In [5] two methods for interference mitigation are proposed, in which femtocell users adjust the maximum transmit power using open-loop and closed-loop

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techniques. In the first case, a femtocell user adjusts the maximum transmit power to suppress the cross-tier interference, which results that the cross-tier interference is less than a fixed interference threshold. The closed-loop control adjusts the maximum transmit power to satisfy an adaptive interference threshold based on the level of noise and uplink interference (UI) at the macrocell BS (Base Station).

The next section presents the possible interference cases that might appear while implementing a two-tier cellular network. Section III deals with a case scenario that has been studied for the downlink communication. The following section presents a proposed solution to mitigate the cross-tier interference, based on intelligent use of the existing sensor based alarm system. Finally, the last section draws some conclusions regarding the studied topic.

II. TECHNICAL CHALLENGES

Femtocell implementation represents a new challenge for mobile network operators. This is due mainly to uprising problems related to cross-tier interference, which appears especially in the case of co-channel deployments. This issue is manifested both on the uplink communication, as well as on the downlink side. The possible interference problems are the following:

- **a.** Femtocell to macrocell UE (User Equipment) on the DL (downlink) communication;
- **b.** Macrocell to femtocell UE on the DL communication;
- **c.** Macrocell UE to femtocell on the UL (uplink) communication;

There is also the possibility to have femtocell – to – femtocell interference, but this could only occur in the case of close femtocell implementation like two adjacent apartments, for example.

When femtocells are added to the network, a problem rises through the appearance of the so called "dead coverage zones", resulting in a non-uniform coverage. On the uplink, the macrocell user situated at the edge of the cell, will cause interferences to the FAP. On the downlink, at the cell edge, a macrocell UE experiences interference from the neighboring femtocells.

III. INTERFERENCE SCENARIO

This scenario studies the femtocell to macrocell user interference. This situation occurs mainly at the macrocell edge where the level of the MacroBS signal strength is low, and the signal from the FAP has a sufficiently high level to create an interference which can cause outage for the macro user.

One possible place of occurence is near the locations in which femtocells are deployed, especially near windows, because, there is a known fact that, the glass environment has a much larger permittivity than walls, for example. Therefore, is our scenario we consider the case when we have a fixed MacroBS with the parameters given in the table below (TABLE 1), and a fixed receiver location, situated at three meters from the window of an indoor environment in which a femtocell deployment has occurred. In this case, the variation of the environment conditions consists in varying the position of the FAP, relative to the position of the window.

The main technical parameters for the MacroBS and FAP, implemented in the scenario, are presented below:

TABLE I. MACRO BS AND FAP TECHNICAL PARAMETERS

	MacroBS	***FAP***
Antenna type	Dipole	Omnidirectional
Antenna Gain	2.2 dB	0 dB
Polarization	Linear vertical	Linear vertical
Orientation of the antenna	Phi = 90 deg.	Phi = 0 deg.
	Theta = 0 deg	Theta = 0 deg
Antenna height	7 meters	3 meters
Transmit power	33 dBm	10 dBm
		15 dBm
		20 dBm
		25 dBm
Carrier frequency	2.045 GHz	2.045 GHz
Distance to the indoor location boundary (window)	38 meters	Variable, from 3 m to 21 m.

In order to have a more complex view of the situation involved, for the femtocell access point, we consider four different transmit powers [6].

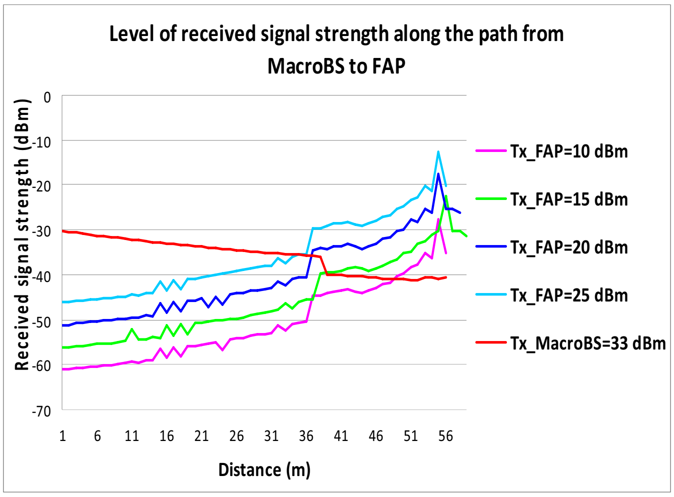

Fig 1. Level of the received signal strength along the path from MacroBS to FAP

First, considering the four transmit powers for the FAP and a fixed location for it, we have studied the level of the received signal strength along the path from the MacroBS to the FAP. The obtained results are presented in Fig. 1. The starting point in measuring the distance is considered to be at the MacroBS site. Practically, the MacroBSs transmit power is the highest at point "zero", on the graph,

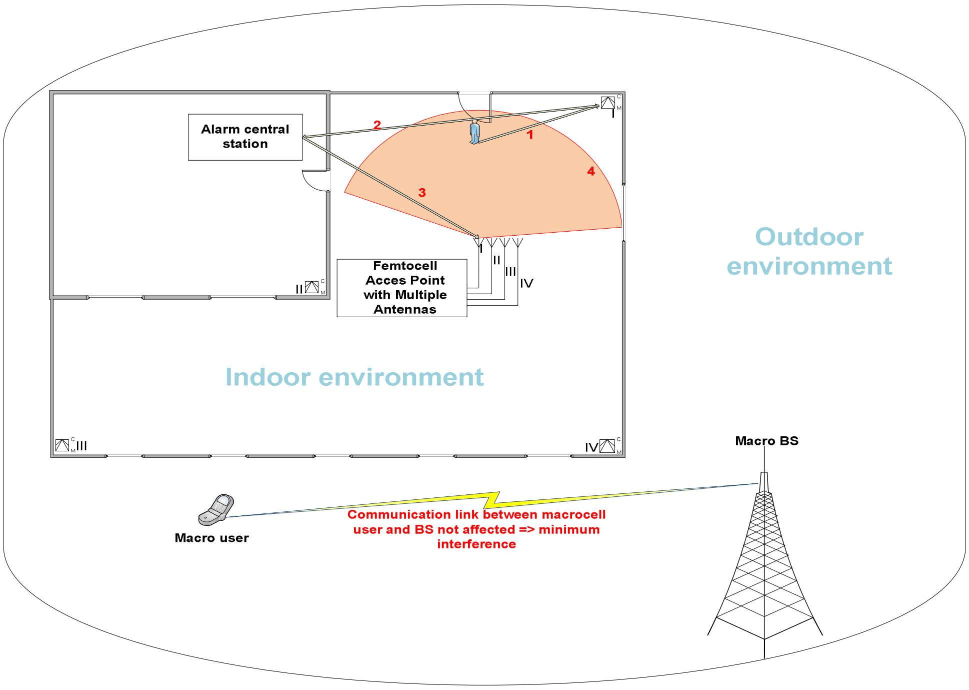

Fig. 2. Proposed cross-tier minimization technique

and decreases towards point "56", while the FAPs transmit power has a mirrored evolution. The influence of the medium, i.e. the wall of the indoor environment, is visible through the fact that we have a reduction of the signals strengths from the MacroBS and from the FAP, each of them in its corresponding direction. The deviation from the linear variation is present at about 38 meters from the starting point, i.e. exactly the position of the wall of the indoor environment. Especially in this region, at the boundary of the two environments, the level of the SINR (Signal to Interference and Noise Ratio) is very low and needs adjustments.

The next results obtained refer to the level of the SINR at the receiver site situated outside, three meters from the environment boundary, by varying not only the level of the transmitted power of the FAP, but also its position relative to the environment boundary. In this sense, Fig. 3 illustrates the variation of the SINR calculated at the specified position.

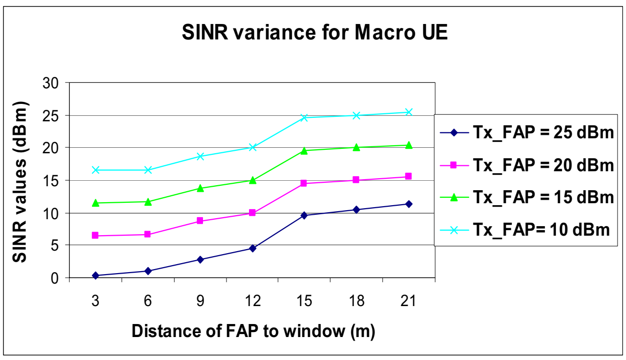

Fig. 3. SINR variance in the case of femtocell to macrocell user interference.

Considering a threshold level of the obtained SINR of 10 dB [7], an adaptive power control mechanism is absolutely necessary. Taking for example the distance of 12 meters between the window and the FAP, its transmit power must not exceed 20 dBm. Considering the macrocell user point of view, the femtocell acts as an interference source, which degrades the SINR value. That is why, if the transmit power of the femtocell is the lowest (10 dBm), the level of the SINR is the highest, and vice-versa. Of course, the influence of the femtocell on the macrocell user decreases as the receiver position moves further away from the indoor location.

One important fact that needs to be mentioned here, is that when deploying a femtocell network, a tradeoff must be realized between the transmit power of the FAP and the original intended purpose, which is to enhance the coverage. Therefore, the radiation power of the femtocell needs to have a sufficiently high value, in order to assure the desired level of the received signal at the femtocell user position. Considering this idea in the next chapter we propose one possible method for cross-tier interference mitigation.

IV. PROPOSED SOLUTION FOR MITIGATING CROSS-TIER INTERFERENCE

Our solution consists in integrating the femtocell equipment with the largely deployed security alarm system based on movement detection sensors. Practically, we will use a multi-antenna femtocell which is controlled by the alarm central station. This method is designed under the assumption that the scenario studied in the previous chapter already has an integrated security alarm system. An important fact that needs to be mentioned is that the alarm system is cabled, therefore, there are no problems regarding interference with other wireless systems, and also the attenuation of the transmitted signal is avoided. Therefore, we will use the movement sensors to control the transmission of the antennas. A brief presentation of the scenario is given in Fig. 2.

Each sensor is placed in a different area of the indoor environment and controls a specific directional antenna which covers that typical zone. Thus, the femtocell will only need to cover the zone where movement is detected, and in consequence the transmit power is lower. Also, the system is equipped with a hold-on circuit which maintains the transmission of the signal for an additional configurable time, after the movement has stopped.

The whole process is developed following the next algorithm:

1. The sensor detects movement in its corresponding area.
2. The sensor sends this information to the alarm central station.
3. The central station commands the turning on of the corresponding antenna.
4. The antenna emits signals in order to cover the corresponding area.
5. The process is active an additional configurable time after the movement has stopped.

Considering the descried sequence of steps, resulting in a system without feedback and given the fact that the whole process stops only through the action of a human operator, the deployment can be considered an open loop system.

In order to present the advantages of such a proposal, we realized a couple of simulations which demonstrate the SINR enhancement, displayed in Fig. 4 . Therefore, the this figure presents a comparison of the results obtained regarding the level of the SINR at the macrocell user site, for the case of a transmit power of the FAP of 20 dBm, with and without radiation control using the proposed method. One must not forget the importance of the adaptive power control mechanism which is mandatory if we were to implement the proposed solution

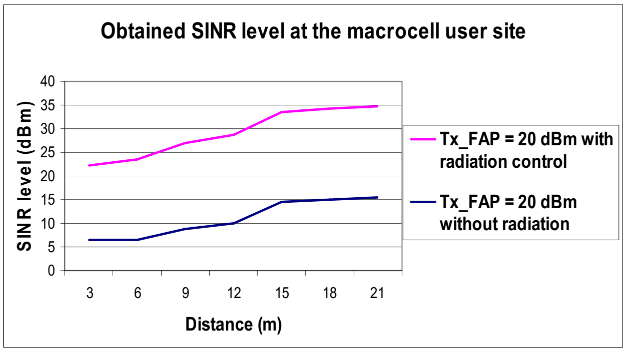

Fig. 4 Comparison for the same transmit power of the FAP

By implementing the system from Fig. 2, not only that we have little interference between the femtocell layer and macrocell layer, due to the directivity of the antennas and the low transmit power, but also the tradeoff mentioned before in minimized. This is explained by the fact that by using multiple antennas, each one can cover a shorter range, thus the necessary emitting power is therefore lower. By doing so, we obtain all the advantages of using a high transmit power femtocell, but with the benefits of low cross-tier interference.

V. CONCLUSION

This paper presents a different approach in the continuous battle towards minimizing the cross-tier interference. By integrating in the same system two adjacent domains, not only that we take a step forward in the process of creating the "intelligent home" environment, but also the cost will be minimized for the beneficiary of the facilities. The presented results are obtained using the RPS (Radiowave Propagation Simulator) and Matlab programs. It was demonstrated that by using this technique the mitigation of cross-tier interference is realized in a simple and elegant manner. Another advantage in favor of the proposed method is that the power consumption of the equipments is reduced. However, the method needs further studying and evaluation, regarding the delay introduced by the addition of the alarm system. Another important issue is the sensibility of the movement sensors, which need to detect even the slightest movement. The method presented treats the problem of cross-tier interference on the downlink communication. Further investigations need to be done in order to reduce the interference on the uplink communication as well. Besides this, other problems like enhancing the handover process between the femtocell and the macrocell, synchronizations of femtocells and macrocells, assuring a high QoS level by the backhaul connection, selecting the operating mode (open or close access), handoff management techniques, relocation of femtocell equipment or assuring emergency call localization for femtocells, etc., also need to be further studied in order for the femtocell networks to become feasible solutions.

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