RANDOM CELL IDENTIFIERS ASSIGNMENT

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Abstract. *Despite integration of advanced functions that enable Femto Access Points (FAPs) to be deployed in a plug-and-play manner, the femtocell concept still cause several opened issues to be resolved. One of them represents an assignment of Physical Cell Identifiers (PCIs) to FAPs. This paper analyses a random based assignment algorithm in LTE systems operating in diverse femtocell scenarios. The performance of the algorithm is evaluated by comparing the number of confusions for various femtocell densities, PCI ranges and knowledge of vicinity. Simulation results show that better knowledge of vicinity can significantly reduce the number of confusions events.*

Keywords

Femtocells, home base stations, LTE network, physical cell identifier.

1. Introduction

Based on market investigations on mobile networks, more than 60 % of traffic (including both voice and data) is generated in indoors [1]. At the same time, the proportion of home-equipped broadband connections is rapidly increasing. On the other hand, the use of macrocell coverage is very expensive for indoor users. Therefore, femtocell technology has emerged as a cost-effective means to enhance indoor coverage and capacity for growing demands for mobile services within a home or an enterprise environment.

Femtocells are small cells covered by inexpensive, low-power base stations that are, in general, deployed by customers themselves. They are connected to mobile operator's networks using either a wired or wireless backhaul; e.g., ADSL, optics, or WiMAX. The femtocell base station is denoted as Femto Access Point (FAP) in this paper. The employment of femtocells bring benefits as to subscribers as to operators. Better coverage (i.e. higher data throughput), femto-zone tariffs or new services on the subscriber's side, and macrocell offloading, faster new technology deployment, low capital and operational costs among others on the operator's side.

As in case of a macrocell, a newly introduced femtocell also needs to be assigned a unique cell identifier in the given area. The identifier is called Physical Cell Identifier (PCI); notice that PCIs are shared among femtocells and macrocells. The PCIs are used to identify cells, and as time and frequency reference. Thus, it should be allocated in such a manner to avoid collision (i.e. the PCI is unique in the area that the cell covers) and confusion (i.e. a cell has no neighboring cells that have identical PCI) events.

Number of these identifying signatures is not unlimited; there are 504 available PCIs in LTE/LTE-A networks [2]. Therefore, it's not always possible to guarantee collision/confusion free allocation. In cases where a lot FAPs (i.e. more than 503) under a Macro Base Station (MBS) are deployed, there are more FAPs having same PCIs. Thus, the network is unable to unambiguously identify the femtocell in the measurement report. This is called cross-tier PCI confusion. The cross-tier PCI confusion may lead in macrocell-to-femtocell handover failure due to incorrect selection of targeted femtocell [3].

This paper analyzes a distributed PCI assignment approach. We evaluate a random based algorithm to assign PCI under diverse femtocell scenarios. The performance of the algorithm is evaluated by comparing the number of collision/confusion events for various femtocell densities, PCI ranges and sizes of neighborhood area. Simulation results show that mainly the knowledge of vicinity can significantly reduce the number of confusions events.

The rest of the paper is organized as follows. The next section provides a brief overview of related works. Section III describes the principle of the random algorithm. Simulation model and obtained results are presented in section IV. Finally, Section V concludes are findings.

2. Related Works

In the last years, several methods were proposed for the conventional macrocell level to solve collision/confusion issues [4]. The methods can be classified as distributed (e.g., random or radio scanning methods) and centralized (e.g., use of specific network entity or network planning approach). However, none of them really addresses the femtocells.

In 3GPP Release 9 [5], a Cell Global Identity (CGI) was proposed to be used to solve the cross-tier PCI confusion problem. However, the CGI employment instead of PCI has a couple of disadvantages. For example, a larger measurement gap is needed to learn the CGI (up to 160 ms instead of 20 ms, [5]), during a measurement gap UE (User Equipment) cannot transmit/receive any data (a service interruption can occur, [6]), or shorter UE battery life (due to longer measurement intervals, [4]).

A policy-based automation PCI allocation method, which can modify the assignment policy according to the PCI utilization and the scale of a base station, is proposed in [7]. In [8], authors discuss partially distributed identifier assignment. However, this particular solution is usable for a relatively small number of static base stations. An automatic assignment of femtocell PCIs depending on different access modes for network optimization in order to reduce the operational expenditure for PCI allocation is discussed in [9]. The proposed method detects the neighboring cells of target femtocell and sends the neighborhood information to the center controller. By using a center controller, the PCIs can be assigned in an optimal way. On the other hand, authors supposed the knowledge of FAPs' positions which is in case of indoor environment quite challenging task due to weak GPS signals inside of buildings. In our work, we focus on the assignment method itself considering various femtocell scenarios.

3. Random Assignment Algorithm

The simplest PCI assignment method is the use of random algorithm; a newly introduced FAP independently randomly selects its identifier from a set of available PCIs. In this approach, a collision and confusion free assignment is not assured because a newly introduced FAP does not check any neighboring femtocells and their PCIs.

The previous simple random approach can be enhanced by including a radio environment scanning method. This method relies on the capability of base station to scan its radio environment before starting to operate. The scanning phase helps a base station to identify neighboring cells and thus selecting own PCI in such way that collision events can be avoided. On the other hand, confusion events cannot be prevented and can still appear. In order to minimize the number of confusion events, a newly introduced FAP needs to investigate its vicinity in a larger neighborhood area. This means, a new FAP needs to learn not just PCIs of its immediately neighboring FAPs but also PCIs of neighbors of these immediate FAPs.

In 3GPP's Release 10, a direct X2 interface among neighboring FAPs was introduced. Thus, the PCI investigation can be managed by exchanging of signaling messages between FAP via X2 interface. When establishing a communication between two neighboring FAPs, those FAPs interchange their Neighbor Relation Tables (NRTs, [10]). These tables contain a list of neighboring FAPs and their PCIs. The NRT exchange process can be repeated with more distant FAPs to obtain information from a larger neighborhood area. In this way, a new FAP can learn PCIs that are far beyond its own radio range. Subsequently when the FAP randomly selects its own PCI, all the learned PCIs are omitted from the set of available PCIs. The algorithm performance evaluation in section IV is performed for all the above described versions.

4. Performance Evaluation

4.1. Simulation Model

To evaluate the random algorithm, a simulation model has been developed in Matlab. The model structure consists of one macrocell and set of femtocells. The femtocells do not overlap and entirely cover the macrocell surface. They are placed (activated) in the macrocell using uniformly distributed random function. The macrocell's radius, R_M, is set to 564 m (i.e. covered area equals to 1 km^2). The femtocells have a square shape with the side size set to 20 m. The model is illustrated in Fig. 1.

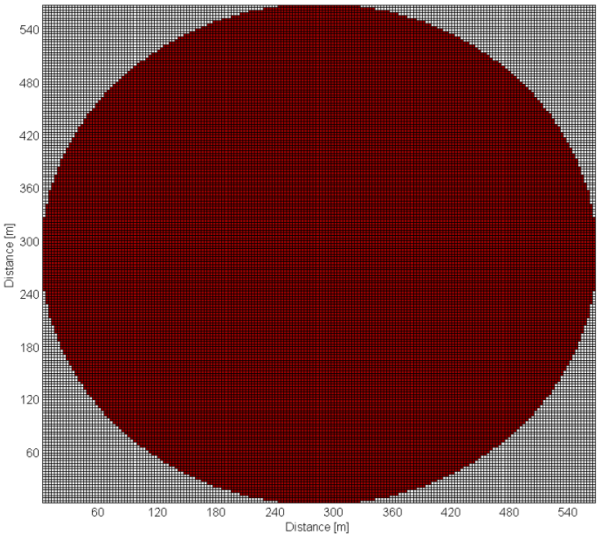

Fig. 1: Simulation model – one macrocell with 2536 femtocells.

In the model, the considered neighborhood area is represented via a notation denoted as hop. For example, the distance between a newly introduced FAP and all its closest neighboring FAPs (there is 8 such FAPs) is equal to 1 hop, or in case of the simplest random algorithm version (i.e. no PCI checking of neighboring FAPs) is equal to 0 hop. There are considered 0, 1, 2 and 3 hops in simulations.

The femtocell density, α, range from 10 to 100 %; α can be expressed as:

$$\alpha = \frac{n}{N} \times 100 \, , \qquad (1)$$

where n is the number of placed (activated) femtocells and N is the max. number of femtocells per macrocell ($N = 2536$). All analyses are provided for three different PCI ranges, N_{PCI}: 54, 204, and 504.

For each parameter setting scenario, an average of 100 simulation runs with different femtocell placements is assumed; the same order of femtocell placement is employed for 0–3 hop scenarios.

4.2. Results

Fig. 2, 3 and 4 show the number of confusions for various femtocell densities, number of hops and PCI ranges. Notice that the 0-hop curve represents the simplest random algorithm (as explained in section III). Thus, the number of confusions comprises both collision and confusion events whereas the other three curves (1–3 hops) really represent just number of confusions as collisions do not already appear.

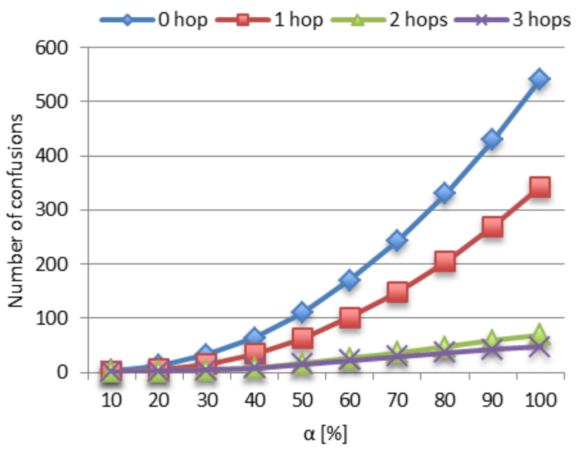

Fig. 2: Number of confusions for various femtocell densities and number of hops, $N_{PCI} = 54$.

As can be seen from these figures, by learning PCIs of more distant FAPs (2 or 3 hops), the number of confusions can be significantly reduced. The values for 2, 3 hops are about five times lower compared to the 1 hop curve. Though, the 2 and 3 hops look like providing roughly the same results, the 3 hops scenario leads in better distribution of PCIs from the point of view of the spatial distibution and frequency of occurrence of each PCI. On the other hand, the more hops, the longer time and higher network overhead because more signaling messages have to be exchange among involved FAPs.

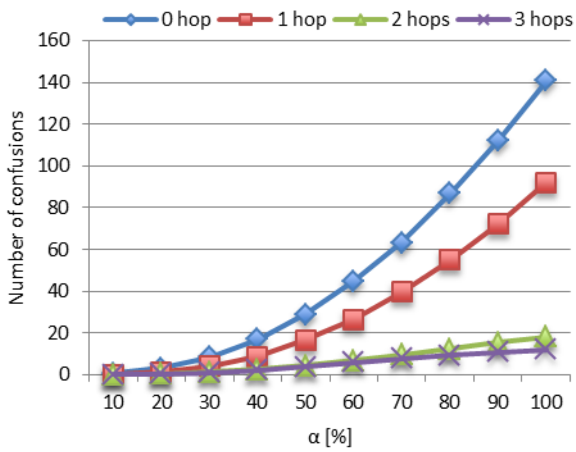

Fig. 3: Number of confusions for various femtocell densities and number of hops, $N_{PCI} = 204$.

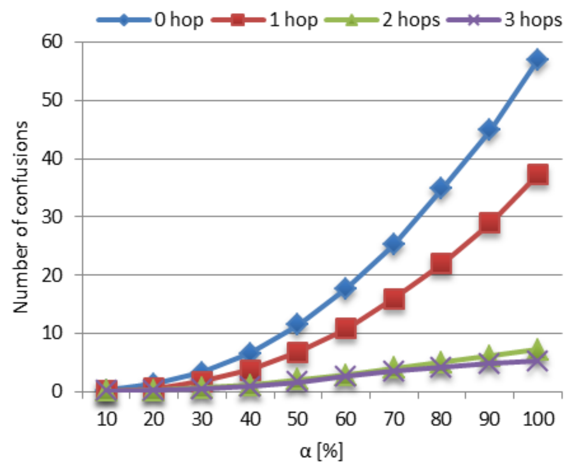

Fig. 4: Number of confusions for various femtocell densities and number of hops, $N_{PCI} = 504$.

Moreover, Fig. 2, 3 and 4 indicate that small femtocell density (10 %–20 %) leads in about the same number of confusions no matter how many hops are considered or number of available PCIs. However, for the highest femtocell densities (80 %–100 %) every increase of available PCIs by a factor of two results in about halving the number of confusions.

5. Conclusion

In this paper, we investigate an assignment of PCIs to femtocells when using random algorithm. The performance of the algorithm is evaluated for various femtocell densities, PCI ranges and knowledge of neighborhood areas. Simulation shows that learning PCIs of distant neighboring femtocells (2 or 3 hops away) results in a significant reduction of confusion events - about 5 times. Additionally, in a highly dense femtocell environment, the doubling of available PCIs leads in a decrease of confusion event by two. In our future work, we plan to compare the effectiveness of different assignment algorithms (e.g., based on FAP positions or femtocell density).

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