Chapter 19
Physical Cell Identifier Assignment in Dense Femtocell Deployment

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ABSTRACT

In this chapter, the authors deal with a mechanism of Physical Cell Identifier (PCI) assignment for dense femtocell scenarios within LTE/LTE-Advanced networks. After describing the need for femtocells in future Self-Organizing Networks (SONs), the problem is presented. The chapter discusses background information such as related works in this research field and current assignment methods. Subsequently, challenges are defined, and two mechanisms to assign PCIs are proposed. Both the mechanisms are capable of assigning collision-free PCIs and solving any future confusion events that may occur as the network grows in terms of the number of femtocells. To evaluate the algorithms, a model is described and simulation results for two different scenarios are presented.

INTRODUCTION

As the numbers of various mobile devices such as laptops, or recently very popular smart phones and mostly tablets, is increasing, the demand for reliable high speed mobile data by customers is growing as well. Zhang and De la Roche (2010) estimate that up to 2/3 of calls and overwhelming 90% of data transfers in cellular networks take place indoors and, at the same time, poor signal coverage affects up to 30% of businesses and 45% of households. Therefore, a solution for improving such an unacceptable situation has to be developed otherwise operators and third party service providers will suffer from high opportunity costs.

Customers expect the same service quality anytime and anywhere, but that is very challenging for operators mainly when taking into account the higher operating frequencies and capacity requirements. With higher frequency, higher penetration signal loss and worse signal propagation make signal quality indoor massively reduced. Such a problem could be solved easily by various approaches. The easiest one is building
more macrocells; however, such a naive approach is very time-consuming, technically and legally complicated, too costly, and brings new issues, e.g. higher interference among adjacent macrocells, higher total energy consumption of the network, etc. This is why employing small cells, primarily femtocells, into mobile networks is shown as the most promising solution.

Small cells, such as picocells, metrocells and femtocells, are a family of Base Stations (BSs) with smaller covered area compared to conventional outdoor microcells or macrocells. In fact, this kind of BSs is usually deployed indoors, e.g. at homes, in offices, residential towers, shopping malls, city centres, etc. Macrocells, microcells and picocells are installed, owned and operated by operators and usually have greater capacity. Metrocells and primarily femtocells are, in general, installed, owned and operated by customers. They can place and switch on-off their BS anywhere and anytime without any operator’s intervention. Customers only have to plug it into electricity and a decent Internet Protocol (IP) backhaul, such as Digital Subscriber Line (DSL), Wireless Fidelity (Wi-Fi), cable, etc., to connect the BS to the operator’s core network.

Small cells are an essential constituent of a Self-Organizing Network (SON), which is a concept representing future mechanism of operating a mobile network (Hämäläinen, Sanneck, & Sartori, 2012). This concept allows automatic configuration, continuous optimization and autonomous healing of all kinds of problems. The SON approach will decrease capital expenditure using resource optimization and reduce operating costs by minimizing human work. It is basically the only way how to properly and primarily efficiently operate a mobile network with growing number of cells of various types.

Nowadays, the SON concept still poses certain challenges that have to be satisfactorily solved in order for this concept to be reliable, efficient and finally adopted by operators. These challenges among others include frequencies reuse, interference mitigation, power consumption optimization, backhaul security, or cell identification.

One very important part of the whole small cell family represents femtocells. Femtocell Access Points (FAPs) are small, low-power and low-cost personal or enterprise BSs intended for improving (mainly indoor) signal coverage, enhancing capacity and Quality of Service (QoS), offering new services to customers and also for increasing customer retention (Chambers, 2008; Zhang & De la Roche, 2010). FAPs also might help new mobile operators to enter the market. When new operators reach roaming agreements with existing operators to use their outdoor Macrocell Base Stations (MBSs), they can build a new network without huge financial investments at the beginning.

There are three different operational FAP modes – open, closed and hybrid mode. Open mode is very similar to classical macro/micro BS – any user in the area covered by the FAP can connect and make calls or data transmissions. The closed mode is the very opposite, only users being part of a given Closed Subscriber Group (CSG) can connect to and use the FAP. The hybrid mode is a mix between the previous two modes, so defined users can connect and utilize the FAP; however, undefined users might connect and use the FAP with low priority when the FAP is in idle mode. Open mode is preferred by operators because they achieve expansion of their network with almost no expenses. Contrary to that fact, customers prefer closed mode as none except allowed users can use the FAP.

Metrocells, basically femtocells with greater transmitting power and larger covered area, are deployed in trial runs in the streets of Newcastle and Bristol in the United Kingdom (Curtis, 2012a) to offload data traffic from mobile devices to Virgin Media’s fibre optic network. In the trials, data transmission was three times faster within 200m radius of the metrocell compared to existing 3G networks. In addition to faster data rates, signal strength is sufficient to penetrate most buildings while achieving high user experience.