Chapter 8
Game Theory-Based Coverage Optimization for Small Cell Networks

Yiqing Zhou
Chinese Academy of Sciences, China

Lin Tian
Chinese Academy of Sciences, China

Liang Huang
Coordination Center of China, China

Jinglin Shi
Chinese Academy of Sciences, China

ABSTRACT

Focusing on the coverage optimization of small cell networks (SCN), this chapter starts with a detailed analysis on various coverage problems, based on which the coverage optimization problem is formulated. Then centralized and distributed coverage optimization methods based on game theory are described. Firstly, considering the coverage optimization with a control center, a modified particle swarm optimization (MPSO) is presented for the self-optimization of SCN, which employs a heuristic power control scheme to search for the global optimum solution. Secondly, distributed optimization using game theory (DGT) without a control center is concerned. Considering both throughput and interference, a utility function is formulated. Then a power control scheme is proposed to find the Nash Equilibrium (NE). Simulation results show that MPSO and DGT significantly outperform conventional schemes. Moreover, compared with MPSO, DGT uses much less overhead. Finally, further research directions are discussed and conclusions are drawn.

INTRODUCTION

Recently, small cell networks (SCN) have been widely adopted to provide seamless cellular coverage for large indoor or outdoor areas. However, coverage optimization is a big challenge for SCN because these small cells are usually omnidirectional and ad-hoc deployed plug-and-play devices without precise network planning as traditional cellular networks. Game theory is promising to provide self coverage optimization for SCN. Aiming to minimize coverage problems such as coverage holes, loud neighbor overlap and cell overload, this chapter presents how to carry out self-optimization for the coverage in SCN

DOI: 10.4018/978-1-5225-2594-3.ch008

based on game theory in centralized and distributed ways. Two algorithms are introduced, respectively, i.e., modified particle swarm optimization (MPSO) and distributed optimization using game theory (DGT). Their performances are evaluated via simulations.

BACKGROUND

With the development of smart phones, tablet computers and mobile application, the requirement for mobile data has increased exponentially these years. The cliffy increase has imposed great pressure on cellular networks. Small cells are regarded as a promising solution to the ever growing wireless capacity needs (Chandrasekhar, Andrews & Gatherer, 2008), with low-power (e.g. less than 20dBm) and low-cost (e.g. target cost 100$) wireless access points (WAP) that operate in licensed spectrum and are operator-managed and featured with edge-based intelligence ("Small Cell Forum", 2011; Hoydis, Kobayashi & Debbah, 2011). There are various types of access points, such as Femtocell, Picocell and Metrocell. Small cells have already been successfully used in residential environment to offload traffic from macrocells, improve user experience and lower cost per bit. Operators are now exploiting the potential of small cells to provide high capacity cellular service in both indoor and outdoor environments (Hoydis et al., 2011) through densely deployed small cell networks (SCN). SCN, also known as small cell grid, enterprise small cells and small cell clusters, is a group of densely deployed small cells together to extend the usage of small cells from residential environment to enterprise, urban and rural environments, i.e. high-traffic business environments, including office, retail malls, metro and municipal buildings, and so on ("Small Cell Forum", 2011). Thanks to Self-Organizing Network (SON) capabilities of small cells, SCN can outperform picocells or distributed antenna systems (DAS) by increasing system capacity and reducing radio planning and network deployment cost. However, new challenges arise for the coverage optimization because small cells are plug-and-play devices and deployed without precise network planning as macrocells.

Although self-configuration and self-optimization enabled small cells can automatically adjust their radio parameters (Claussen, 2007; Claussen, Ho &Samuel, 2008; Jo, Mun, Moon & Yook, 2010; Li, Qian & Kataria, 2009; Li, Macuha, Sousa, Sato & Nanri, 2009), most existing studies consider a heterogeneous network consisting of small cells and macrocells but not small cell clusters, focusing on maximizing indoor coverage while minimizing interference to public space without neighboring small cell collaboration. Downlink power control is studied for macrocell small cell overlay to guarantee quality of services (QoS) of users in both femtocells and macrocells (X. Li et al., 2009). A pilot and data power control method is also proposed, which can ensure a constant femtocell coverage radius and mitigate uplink interference to macrocells (Claussen, 2007). In addition, a cognitive femtocell scheme is introduced in the sense that channel reuse pattern is cognitively determined according to each femtocell's channel environment to avoid interference (Y. Li et al., 2009). Moreover, different auto-configuration and self-optimization methods are studied and a mobility event based self-optimization is proposed to optimize the coverage of femtocells in house environment in (Claussen et al., 2008). Finally, for two-tier femtocell networks, a self-optimized coverage coordination scheme is presented in (Jo et al., 2010), based on statistics of the signal and the interference power measured in the downlink of a femtocell. The proposed method can provide sufficient indoor coverage and reduce coverage leakage to outdoor areas.

It can be seen that most of the existing research focus on auto-configuration and self-optimization of a single small cell or with the overlap of a macrocell. If these traditional self-optimization methods are