Chapter 14

Game Theoretic Infrastructure Sharing in Wireless Cellular Networks

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ABSTRACT

The emerging traffic demand has fueled the rapid densification of cellular networks. The increased number of Base Stations (BSs) leads to augmented energy consumption and expenditures for the Mobile Network Operators (MNOs), especially during low traffic, when many of the BSs remain underutilized. Hence, the MNOs are encouraged to provide “green” and cost effective solutions for their networks. In this chapter, an innovative algorithm for infrastructure sharing in two-operator environments is proposed, based on BSs switching off during low traffic periods. Motivated by the conflicting interests of the operators, the problem is formulated in a game theoretic framework that enables the MNOs to act individually to estimate the switching off probabilities that reduce their financial cost. The authors analytically and experimentally estimate the potential energy and cost savings that can be accomplished. The obtained results show a significant reduction in both energy consumption and expenditures, thus giving the operators the necessary incentives for infrastructure sharing.

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INTRODUCTION

The increasing growth of mobile telecommunication services along with the emerging demand for multimedia applications, driven by the widespread use of laptops, tablets and smart-phones, have led to an impressive data traffic increase during the last few years. According to recent market predictions (Cisco, 2012), mobile video and web traffic will experience an increase of 70% and 20%, respectively, by the year 2016. To meet these demands, Mobile Network Operators (MNOs) extend their infrastructure by installing more Base Stations (BSs). The densely deployed networks not only imply a rise in the Capital Expenditures (CapEx) of the MNOs, but also have a direct impact on the total energy consumption of the network, thus resulting in higher Operational Expenditures (OpEx) as well (Chen, Zhang, Zhao, & Chen, 2010). In particular, the use of information and communication technology currently accounts for 5.7% of the world’s electricity consumption and 1.8% of global carbon emissions, something that translates into electricity bills in the order of $10 billions for the MNOs worldwide (Fettweis, & Zimmermann, 2008). Hence, network operators are strongly motivated to investigate energy efficient solutions that will bring down the energy consumption and the cost of cellular networks.

Since BSs are responsible for the major part of energy consumption in mobile networks (Hasan, Boostanimehr, & Bhargava, 2011), a lot of effort has been devoted on designing methods to reduce their power consumption. In (Correia et al., 2012), the authors focus on hardware enhancement by designing energy efficient power amplifiers and by employing renewable energy resources, whereas other works focus on accomplishing the optimal BS deployment strategies (Hansly, & Mathar, 2002; Richter, Fehske, & Fettweis, 2009; Suryaprakash, Fonseca dos Santos, Fehske, & Fettweis, 2012; Tseng, & Huang, 2012). Recently, in an effort to achieve more drastic energy saving gains, the research community has shifted towards the investigation of BS switching off schemes, since BSs still consume a significant amount of energy for operation, even when their traffic is low. Subsequently, under off-peak traffic conditions, energy can be saved and cost can be reduced by switching off the unnecessary BSs, while the remaining active BSs can extend their coverage range in order to serve the whole network area.

In this chapter, motivated by the aforementioned issues, the authors propose a roaming-based infrastructure sharing strategy, applicable during low traffic periods. A game theoretic framework that captures the conflicting interests of the MNOs, models the switching off decision process for two operators that are willing to share their resources. Besides the expected energy efficiency benefits, the proposed scheme allows the MNOs to significantly reduce their financial costs independently of the strategies of the coexisting MNOs, providing them the necessary incentives to participate in the game. The contribution of the work is threefold and is summarized as follows:

1. A game theoretic switching off algorithm is proposed that aims at minimizing the individual cost of two competing operators that are willing to share their infrastructure in a distributed way. The authors define realistic cost-oriented functions by explicitly taking into account actual roaming and operational costs of each operator. To this end, each MNO is able to estimate a switching off probability (i.e., Nash Equilibrium (NE)) that provides significant gains, independently of the other MNO actions.
2. To address the heterogeneous nature of voice and data traffic in current and future cellular networks, an analytical model for evaluating the network throughput and the energy efficiency for two types of traffic based on a two-dimensional Markov chain is presented.