

Chapter 5

Spectral Efficiency Self-Optimization through Dynamic User Clustering and Beam Steering

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ABSTRACT

This paper presents a novel scheme for spectral efficiency (SE) optimization through clustering of users. By clustering users with respect to their geographical concentration we propose a solution for dynamic steering of antenna beam, i.e., antenna azimuth and tilt optimization with respect to the most focal point in a cell that would maximize overall SE in the system. The proposed framework thus introduces the notion of elastic cells that can be potential component of 5G networks. The proposed scheme decomposes large-scale system-wide optimization problem into small-scale local sub-problems and thus provides a low complexity solution for dynamic system wide optimization. Every sub-problem involves clustering of users to determine focal point of the cell for given user distribution in time and space, and determining new values of azimuth and tilt that would optimize the overall system SE performance. To this end, we propose three user clustering algorithms to transform a given user distribution into the focal points that can be used in optimization; the first is based on received signal to interference ratio (SIR) at the user; the second is based on received signal level (RSL) at the user; the third and final one is based on relative distances of users from the base stations. We also formulate and solve an optimization problem to determine optimal radii of clusters. The performances of proposed algorithms are evaluated through system level simulations. Performance comparison against benchmark where no elastic cell deployed, shows that a gain in spectral efficiency of up to 25% is possible depending upon user distribution in a cell.

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I. INTRODUCTION

The tremendous increase in the number of mobile devices part of connectivity of anything to anything (also called Internet of Things (IoT)) and frequent emergence of diverse technologies are exerting extra pressure for dynamic data rate demand on wireless networks. Spectrum, which is regarded as one of the scarcest resources, must be efficiently utilized to meet those demands alongside the innovation and invention of new technologies and architectures. On one hand, there are a number of schemes being researched including, among others, Massive- Multiple Input Multiple Output (MIMO), Base Station (BS) densification, mmWave networks, and decoupled control and data plane architectures, that target the 5G and beyond networks to improve overall network efficiency. This paper, on the other hand, proposes to improve network spectral efficiency by optimizing the existing network parameters such as antenna azimuth and tilt angles, within the available resources. However, the diversity of users and their spatio-temporally varying requirements mandate the future networks to be not only heterogeneous and dense but also highly elastic. High network node density further increases the complexity to manage them. Hence, manual optimization of the network becomes highly challenging (Imran, Zoha & Abu-Dayya, 2014). Self-Organizing Networks (SON) has emerged as a technique to replace the manual handling by embedding intelligence and elasticity into the network (Aliu, Imran, Imran & Evans, 2013). SON enables the network to adapt to the changing environment by adjusting the network parameters autonomously. SON not only makes network highly efficient but also yields significant reduction in the network operational expenses (OPEX). In this article, we propose to optimize spectral efficiency (SE) by adaptively and simultaneously adjusting both antenna azimuth and tilt (i.e., in self-organizing manner) to steer the beam with respect to ever-changing user density and environment. To determine the highly dense regions of users within a cell, we propose and investigate three clustering algorithms, which when implemented, determine focal points in each cell. Once the clusters and their focal points are found, SE optimization algorithm is utilized to calculate new optimal azimuth and tilt values. Such online dynamic beam steering in real network could potentially be exploited using e.g., multi element antenna systems such as MIMO or massive MIMO which are being considered for emerging networks. The kind of beam steering proposed in this paper is much simpler and easier to implement as it does not require 1) tracking of individual users, 2) estimation of angle of arrival 3) estimation of channel. Instead the proposed solution requires simple antenna adjustments to change its azimuth and/or tilt by a few degrees as we will explain later.

The rest of the paper is organized as follows. Section II provides review of related work and outlines the novelty and contributions of this work. Section III presents system model while the self-optimization framework has been discussed in Section IV. Section V evaluates the performance using the numerical and simulation results. Section VI presents key conclusions.

II. RELATED WORK

There are various techniques proposed in literature to enhance spectral efficiency by optimizing antenna parameters. In Seifi, Coldrey and Viberg (2012), user's average throughput has been maximized using BS-coordinated tilting. Authors in Muhammad, Abou-Jaoude, Hartmann and Mitschele-Thiel (2010), propose to adaptively adjust antenna tilt and pilot power to meet varying traffic load in the system. However, they take into consideration only the tilt and do not consider azimuth optimization. A similar

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