Available online at www.sciencedirect.com
ScienceDirect

August 2012, 19(4): 14–21
www.sciencedirect.com/science/journal/10058885

The Journal of China Universities of Posts and Telecommunications

http://jcupt.xsw.bupt.cn

Coverage and capacity optimization in LTE network based on non-cooperative games

XU Sen[1] (✉), HOU Meng[1,2], NIU Kai[1], HE Zhi-qiang[1], WU Wei-ling[1]

1. School of Information and Communication Engineering, Beijing University of Posts and Telecommunications, Beijing 100876, China
2. School of Electronic Engineering and Automation, Shandong Polytechnic University, Jinan 250353, China

Abstract

As to provide the optimal coverage and capacity performance, support high-data-rate service and decrease the capital expenditures and operational expenditures (OPEX) (CAPEX) for operator, the coverage and capacity optimization (CCO) is one of the key use cases in long term evolution (LTE) self-organization network (SON). In LTE system, some factors (e.g. load, traffic type, user distribution, uplink power setting, inter-cell interference, etc.) limit the coverage and capacity performance. From the view of single cell, it always pursuits maximize performance of coverage and capacity by optimizing the uplink power setting and intra-cell resource allocation, but it may result in decreasing the performance of its neighbor cells. Therefore, the benefit of every cell conflicts each other. In order to tradeoff the benefit of every cell and maximize the performance of the whole network, this paper proposes a multi-cell uplink power allocation scheme based on non-cooperative games. The scheme aims to make the performance of coverage and capacity balanced by the negotiation of the uplink power parameters among multi-cells. So the performance of every cell can reach the Nash equilibrium, making it feasible to reduce the inter-cell interference by setting an appropriate uplink power parameter. Finally, the simulation result shows the proposed algorithm can effectively enhance the performance of coverage and capacity in LTE network.

Keywords coverage and capacity, power control, non-cooperative game, Nash equilibrium

1 Introduction

The optimization of coverage and capacity is an important and complex work for telecom operator. A well designed network can provide the required capacity and offer good quality of service (QoS) for subscribers. In the forepart of network deployment, the coverage optimization is usually more important than the capacity optimization. But the capacity of cellular will gradually become the main restricted problem in system along with the increasing number of users. In 2G/3G network, the operator usually uses some method (e.g. increase base station (BS), adjust the antenna tilt, and cell power level) to cope with this problem. A large number of parameters need to be optimized simultaneously in legacy network. Often changes in these network parameters will need to be coordinated across technologies and layers, and varied over a wide range of loads, applications, and time scales [1]. In the 3rd generation partnership project (3GPP) R8 SON function had been introduced, the objective of which is to enhance the performance of network and reduce CAPEX and OPEX [2]. The self-organization capability of a mobile network mainly includes three aspects: self-configuration, self-optimization, and self-healing. And the CCO is one of the key research use cases in self-optimization.

Power control is a crucial radio network function in cellular systems. Power control provides an intelligent way of determining transmitting power to achieve the Qos goals in wireless channels. The single carrier frequency division multiple access (SC-FDMA) technology had been adopted as the radio access technology in uplink. This technology eliminates the uplink intra-cell interference. However, the time/frequency resource is not orthogonal in neighbor cells, the inter-cell interference can not be

Received date: 20-09-2011
Corresponding author: XU Sen, E-mail: xusen.bupt@gmail.com
DOI: 10.1016/S1005-8885(11)60277-X

eliminated. Since the transmission power of user equipment (UE) is much less than that of the outdoor BS, the cellular coverage is usually denoted by the uplink coverage. Some factors (e.g. the intra-cell and inter-cell interference, resource allocation scheme, etc.) affect the performance of coverage and capacity in single cell. For the LTE systems, the SC-FDMA is adopted as the uplink access technology. In the ideal case, no interference between users in the same cell but only the interference between cells exists. However the time/frequency resource is not orthogonal in neighbor cells, the inter-cell interference can not be eliminated. The effect of antenna electrical tilt as one of the inter-cell interference reduces technology had been studied in Refs. [3–4]. But adjusting antenna tilt may affect network topology and bring other system performance loss (e.g. handover failure). Appropriate power control scheme not only achieves the Qos goals in wireless channels but also reduces the inter-cell interference. Some literatures had proposed to utilize the uplink power control to obtain the cellular coverage and advance the cellular capacity. In Refs. [5–6], Jindal et al. proposed a fraction power control algorithm to achieve the tradeoff the performance between the center and edge users. Legacy power control algorithm has two schemes: maximization average throughput (capacity performance) and maximization cell-edge throughput (coverage performance). In Ref. [7], Suh et al. proposed a linear algorithm to tradeoff these metrics. And in Ref. [8] Tao et al. proposed a central coordination algorithm based on distributed Gibbs sampling to achieve the CCO in downlink. These papers mentioned above only consider optimization problem in single cell but not in the whole network. Since each cell hope to maximize its performance but optimizing operation in a cell may deteriorate the performance of other cells. Therefore, how to coordinate the benefit of each cell is a complex nonlinear problem. In order to get a whole and local objective at the same time, this paper formulates this problem into a non-cooperative game model. And a multi-cell power coordinate algorithm which allows each BS to negotiate with its neighbor BS is proposed.

The rest of the paper is organized as follows. In Sect. 2 we describe the system model, and analyze the uplink resource schemes impacted on the performance of coverage and capacity. In Sect. 3, a multi-cell power coordination algorithm based on non-cooperative game is given. In Sect. 4, a hybrid architecture had been proposed to implement the optimization algorithm. In Sect. 5 the simulation assumptions and analyses the simulation results are presented. And finally this paper is concluded in Sect. 6.

2 System model

2.1 System model

A LTE wireless system is considered with M cells serving N users which are randomly spread throughout the service area. All the cells have the same K physical resource block (PRBs). Suppose the user n is serviced by cell m. And k PRB are allocated to the user n. The cell m receives the signal to interference and noise ratio (SINR) of k PRB from the user n can be written as:

$$\gamma_{n,k}^m = \frac{P_{n,k}^m g_{n,k}^m}{I_n^m + N_0} \tag{1}$$

where the N_0 denotes the thermal noise. Therefore the rate $R_n^m(k)$ achieved by user n can be described as the follow:

$$R_n^m(k) = \sum_{l=0}^{k-1} \mathrm{lb}(1+\gamma_{n,l}^m) \tag{2}$$

The system model can be described as the Fig. 1. The UE 1 is served in cell 1 and K PRBs are allocated to it. The UE 2 and UE 3 that served by other cells used the same time-frequency resource as UE 1. Therefore the signal comes from UE 2 and UE 3 makes up of the interference signal in the K PRBs.

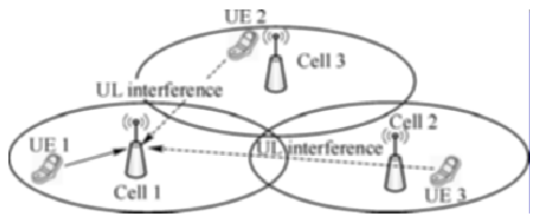

Fig. 1 The system model of UL interference

The power control in LTE uplink (UL) has an open loop and a closed loop component scheme. The open loop component is used to compensate the slow variations of the received signal due to the pathloss. The closed loop component is used to further adjust the user's transmission power so as to compensate for errors and rapid variations as well as potentially optimize the system performance. The 3GPP specifications define a formula to describe the setting of the UE transmit power for physical uplink shared channel (PUSCH) by Ref. [9]: