Optimized Base Station Sleeping and Renewable Energy Procurement Scheme Using PSO

Qiang Wang, Guangdong University of Technology, Guangzhou, China
Hai-Lin Liu, Guangdong University of Technology, Guangzhou, China

ABSTRACT

Energy efficiency of the wireless networks has drawn more and more attentions due to the requirement of the green communication. The base station sleeping strategy and resource allocation can effectively improve the energy efficiency for the wireless networks. Meanwhile, renewable energy is important to decrease the carbon emission. In this paper, the authors propose a joint BS sleeping strategy, resource allocation and renewable energy procurement scheme to maximize the profit of the network operators and minimize the carbon emission. Then, a joint optimization problem is formulated, which is a mixed integer programming problem. To solve it, they adopt the bi-velocity discrete particle swarm optimization (BVDPSO) algorithm to optimize the BS sleeping strategy. When the BS sleeping strategy is fixed, the authors propose an optimal algorithm based on Lagrange dual domain method to optimize the power allocation, subcarrier assignment and energy procurement. Numerical results illustrate the effectiveness of their proposed scheme and algorithm.

KEYWORDS
The BS Sleeping Strategy, Distributed Algorithm, Resource Allocation, Smart Grid Energy Procurement

1. INTRODUCTION

With the exponential increasing of the number of the mobile terminals and traffic demands, reducing the power consumption of the cellular radio networks becomes more and more urgent to reduce the cost of the transmission and the pollution on the environment. Indeed, the carbon emission caused by the information and communication technologies (ICT) accounts for more than 2%. Meanwhile, the energy cost constitutes a significant portion of the expenditure of the operators. Thus, the technologies of green communication become more and more popular in industry and academia. Especially, base station (BS) sleeping strategy is a well-known technique to improve the energy efficiency. Indeed, for the wireless communication system, over 70%-80% power is consumed by base stations, and an active base station in idle status expends more than 50% of the energy because of circuit processing and air conditioning (Wu, Zhou & Niu, 2013; Marsan, Chiaraviglio, Ciullo, & Meo, 2013). Therefore, switching off redundant BSs is an efficient technology to decrease the energy consumption of the wireless networks. BS sleeping can enable the BS in light sleep mode in the low-load time slot to decrease the energy consumption.

On the other hand, the integration of the wireless networks and smart grids is also investigated to decrease the carbon emission (Huang, Crow, Heydt, Zheng, & Dale, 2011; Yu, Zhang, Xiao, & Choudhury, 2011; Erol-Kantarci and Mouftah, 2011; Lu, Wang, & Ma, 2013; Bu, Yu, Cai, & Liu, 2011).
Smart grids are new generation electricity grids, and they can significantly improve the energy efficiency of the wireless network since smart grids can enhance energy savings and reduce carbon emission to achieve the green goals of consumers through using the massive renewable energy (wind energy, solar energy and conventional energy, etc.). Furthermore, smart grids make customers have more feasible procurement strategy due to the intelligent scheduling. Due to the limited availability and the uncertainty about the timing and the quantity of renewable energy (e.g., the solar energy can be used only in the daytime.), the smart grid should determine to sell power to each BS from which energy retailers and sell how much power from each energy retailer, which is called smart grid procurement strategy in this paper. Besides BS sleeping and the smart grid procurement, the energy efficient for the OFDMA cellular networks is also important to improve the system energy efficiency since suitable subcarrier and power allocation can significantly enhance the system throughput with the same energy consumption (Ghazzai et al., 2014).

As aforementioned, obviously, it will create a lot of advantages to jointly consider the BS sleeping, resource allocation and smart grid procurement decision to decrease the system energy consumption. It is worth nothing that these issues are not independent but have strong correlation. In fact, the smart grid procurement decision is dependent on the radio resource allocation and power control which determines the energy consumption of the cellular network. Meanwhile, the BS sleeping strategy is dependent on the smart grid procurement decision, resource allocation and power control. Therefore, joint optimization is necessary to achieve high system energy efficiency. Nonetheless, to the best of our knowledge, there are no paper which consider these issues at the same time, and most of the relation works only consider the subset of the above issues.

Evolutionary algorithm (EA) is a strong optimization approach which can be used to solve a lot of complicated optimization problems. Due to its simpler implementation, faster convergence speed and strong global search ability, EA has been wildly adopted in wireless communication system, such as (Xu, Li, Ji, & Du, 2014; Scott-Hayward and Garcia-Palacios, 2012; Li, Guo, Zeng, & Barnawi, 2014; Sadeque, Ahmed, & Vaughan, 2011; Bendib and Djeffa, 2011). Xu et al. (2014) consider the energy efficient resource allocation problem in the OFDMA downlink networks from a systematic perspective, where the BS transmission, BS circuit, and user equipment (UE) circuit energy consumption are all taken into account. Next, the resource allocation problem is formulated as a mixed combinatorial and nonconvex optimization problem, and then a binary quantum-behaved particle swarm optimization (BQPSO) is provided to solve the optimization problem.

In this paper, we combine the BS sleeping with subcarrier and power allocation to decrease the wireless network energy consumption due to their strong complementarity. Meanwhile, we consider the scenario in which the cellular network is powered by the smart grid, and there are some different retailers in the smart grid to provide power with different prices and pollutant levels depending on the nature of the generated energy. As already noted, the wireless network should determine to procure power form which retailers and procure how much power from each retailer. To maximize the system energy efficiency, our objective is to give an optimal scheme which can determine the BS should be turned into BS sleeping mode in which time slots to maximize the profit of network operators and minimize the carbon emissions at the same time. Unfortunately, the more profits the network operators gain, the more carbon dioxide is emitted. Thus, we should achieve a good trade-off between the system throughput and energy consumption. To this end, we propose a joint optimization problem involving the BS sleeping mode selection, smart grid procurement decision, power allocation and subcarrier assignment. The joint optimization problem is formulated as a mixed integer programming problem in which there are both integer variables (BS sleeping mode selection and subcarrier assignment) and continuous variables (power allocation and procurement decision). The mixed-integer programming problem becomes more and more intractable with the increase of the number of users, subcarriers and
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