Chapter 12
Pricing Methodology and Its Applications in Cognitive Radio and Multi-Tier Heterogeneous Cellular Networks

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ABSTRACT

In this chapter, we concentrate on different technical applications and research directions of pricing theory and methodology, where we investigate following technical applications and functions of pricing including cooperative incentive mechanism design, Pareto- and social optimality improvement, distributed algorithm design with the low signaling overhead. We first clarify different concepts of pricing, summarize the motivation, present a taxonomy according to these different technical applications. Then, we survey applications of pricing theory and methodology with understandings and observations in cognitive radio and multi-tier heterogeneous cellular networks. We emphasize some of the recent critical problems, such as the cooperation incentive, resource and interference management and economics of small cells. Finally, we conclude this chapter with the possible research directions and more potential network applications of pricing theory and methodology.

INTRODUCTION

Wireless communications have experienced explosive growth, and will encounter the promising 1000x traffic enhancement challenge, which are further fueled by the popularity of smart devices, rich multimedia services, and high definition mobile Internet video. Three dimensions have been identified to achieve the required traffic increase in unit of bits per second per square kilometer (Soret et al., 2015),

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(Bhushan et al., 2014). This is equivalent to bits per second per Hertz per cell (spectral efficiency) × Hertz (more spectrum) × cell per square kilometer (network densification). First, it is known that physical layer technology has approached its ceiling, and there exists limited space for spectrum efficiency enhancement, even though most of the recent transmission techniques, for instance, massive MIMO, really has really improved the spectrum efficiency. Second, we know that it is technically hard to explore and exploit more spectrum, and it is also expensive since most of valuable spectrum below 6GHz has been allocated to specific applications, in addition to the most latest research on the mmWave communications. These are why cognitive radio networks (Mitola, 2000), (Haykin, 2005), (Goldsmith et al., 2009) and the related dynamic spectrum access (Akyildiz et al., 2006) have found extensive studies from academia, industry, and standardization communities.

As the third dimension, dense deployment of small cells can both increase coverage and attain a capacity leap (Soret et al., 2015), (Bhushan et al., 2014), which is recognized as the most powerful dimension to address the 1000x capacity increase challenges. Certainly, it really introduces novel technical challenges, for instance, the mutual interference and serious traffic imbalance problems. Ultra-dense heterogeneous and small cell networks will contribute 56-fold traffic demand enhancement in a full frequency reuse way, thus improving the spectrum efficiency. At the same time, energy efficiency enhancement and green communications have been poured much research attention due to awareness of environment of common people and high energy consumption list of network operators. In summary, most of the current research has been focused on the spectrum efficiency optimization and the most recent energy efficiency optimization in cognitive radio and heterogeneous cellular networks.

However, wireless network operators encounter an embarrassing situation, which is the contradiction between the increasing network operation and maintenance cost and the disproportionately decreasing lower or flat monetary income. Such a situation is expected to be continuing for a long time due to the new proliferation of intelligent terminals with various resource-hungry service requirements and the promisingly challenged networking architecture and paradigm. According to the recent 5G activities, spectrum, energy, and cost efficiency are perceived as the three dimensional efficiency metrics (Bousia et al., 2014), (Leem et al., 2014). Cost efficiency optimization should be another critical performance metrics in 5G cognitive, ultra-dense green and cost effective networks, which has been the consensus of academia, industrial, and standardization communities. It is generally concluded that compared with 4G, 5G should have 5 to 15 times improvement on spectrum efficiency and more than 100 times improvement on energy and cost efficiency.

Joint consideration of the multiple dimensions of efficiency performance metrics involves the players of both operators and subscribers. Multiple network operators investigate various factors to better price resources or services, while multiple subscribers are always pursuing the better quality of experience (QoS) from network operators with less cost. These interactions and behaviors between operators and subscribers, or among themselves always involve both marketing and technical considerations. Therefore, it is necessary to jointly combine these economic factors into the technical design. Pricing techniques from economics provide researchers a new methodology to understand wireless networks (Huang & Gao, 2013), (Jiang et al., 2015), (Zhou et al., 2015). In (Jiang et al., 2014), the economic issues in cognitive cellular networks were studied from the perspectives of game theoretic modeling and mechanism design. Considering the selfishness of the owners of femtos, authors in (Zhou et al., 2014) formulated the two-tier interference coordination as pricing game.

Meanwhile, interactive dynamics and rational behaviors should be well investigated in cognitive radio and multi-tier heterogeneous cellular networks. Technical perspective and applications of pricing