Chapter 13

Performance Studies for Spectrum–Sharing Cognitive Radios under Outage Probability Constraint

Abdallah K. Farraj
University of Toronto, USA

Eman M. Hammad
University of Toronto, USA

Scott L. Miller
Texas A&M University, USA

ABSTRACT

This chapter investigates the performance of primary and secondary users in a spectrum-sharing cognitive environment. In this setup, multiple secondary users compete to share a channel dedicated to a primary user in order to transmit their data to a receiver unit. One secondary user is scheduled to share the channel, and to do so, its transmission power should satisfy the outage probability requirement of the primary user. Secondary users are ranked according to their channel strength, and performance measures are derived as a function of a generic channel rank. The performance of different scheduling schemes is also investigated. Further, the performance of the primary user is investigated in this environment. Numerical results are presented to verify the theoretical analysis and investigate the relation between the parameters of the communication environment and the performance measures of the users of the system.

INTRODUCTION

Extensive use of wireless technologies made the frequency spectrum a very limited resource for modern wireless communication systems; although limited, recent studies indicate that the spectrum is actually under-utilized (Federal Communications Commission, 2002). Cognitive communications technology represents a promising solution to achieve more efficient spectrum utilization (Mitola, 2000). In a cog-
nitive communication environment, the primary user (PU) refers to a transceiver unit that is licensed to use a specific wireless channel. Further, the cognitive radio, also referred to as the secondary user (SU), refers to a radio unit that adapts its communication settings in order to transmit its data over the primary channel even though the secondary user is not licensed to operate over that channel.

Cognitive communications can be carried out using spectrum-sensing or spectrum-sharing methods. In a spectrum-sensing mode, the secondary user can only communicate over the channel when the channel is detected as idle. In a spectrum-sharing technique, the secondary user can transmit data simultaneously along with the primary user over the same channel as long as the secondary user’s transmission does not deteriorate the quality of service (QoS) of the primary user below a certain requirement. In order to make a successful cognitive communication system, the channel under consideration has to be detected, the channel parameters have to be estimated, and the cognitive communication settings need to be chosen in order to meet the quality of service requirements of the primary user of the channel. Quality of service requirements might include limiting the maximum or average interference caused by the secondary user, having a minimum value of the signal-to-interference plus noise ratio (SINR) of the primary user’s signal, or limiting the primary user’s outage probability to some threshold. In a multiuser cognitive environment, multiple secondary users compete to transmit their data over the wireless cognitive channel. Some authority decides which secondary user is assigned to use the channel according to a defined scheduling criterion. In addition, because the channels of the secondary users can change over time, a dynamic channel scheduling is anticipated.

Cognitive communication systems have seen a surge in research activity in the past few years. Some recent work on resource allocation and performance in cognitive systems includes Le & Liang (2007), Hamdi et al. (2007), Kang et al. (2009), Zhang et al. (2008), Ban et al. (2009), Li (2011), Ekin et al. (2009), and Li (2010). A fuzzy logic system was proposed in Le & Liang (2007) to opportunistically control the transmission power of the secondary users in order to provide them the ability to coexist with primary users in the same frequency band. In order to limit the interference caused by a secondary user over the primary user, a power control approach was designed in Hamdi et al. (2007). This approach adjusts the transmission power of the secondary user, depending on side information, while maintaining a quality of service requirement for the primary user’s signal. The power allocation problem of a single secondary user under the primary user’s outage probability loss constraint was considered in Kang et al. (2009), and both the average and peak cognitive power constraints were considered. The fading cognitive multiple-access channel was studied in Zhang et al. (2008), and the maximum sum-rate capacity of secondary users that share the wireless spectrum with an existing primary network was found. The effect of multiuser diversity in a spectrum-sharing system was investigated in Ban et al. (2009), and both single and multiple primary user cases were studied. The power allocation problem of multiple secondary users was considered in Li (2011). An optimization problem that minimizes the total transmitted power, under the constraint of minimum required secondary user’s signal-to-noise ratio and maximum acceptable interference on the primary user, was developed and numerically solved. The hyper-fading channels case was considered in Ekin et al. (2009), and the capacity limits for such channels in spectrum-sharing systems under the interference-temperature constraint were studied.

The primary user’s outage probability was recently investigated as a quality of service constraint in spectrum-sharing cognitive systems. For example, the queueing model of the secondary user was investigated in Farraj et al. (2011) and Farraj (2013b). The performance of the primary user in a cognitive environment was studied in Farraj & Hammad (2013b) and Farraj (2013a), and the queueing system of the primary user was investigated in Farraj (2014a). Moreover, the quality of service impact on the
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