An MMSE Overlay Cognitive Wireless System

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ABSTRACT

In this paper, the authors propose a framework that allows an overlay (new) system to operate simultaneously with a legacy (existing) system. By jointly optimizing the transmitter and the receiver filters of the overlay system, the sum of the mean-squared error (MSE) of the new system plus the excess MSE in the existing system due to the introduction of the overlay system is minimized. The effects of varying key parameters such as the overlay transmitter power and the amount of overlap between the legacy and the overlay systems are investigated. Furthermore, the sensitivity of the system to accuracy of signal-to-noise ratio (SNR) estimate and the channel estimate is also examined.

Keywords: *Cognitive Radio (CR), Crosstalk, Mean Square Error (MSE), Overlay System, Signal-to-Noise Ratio (SNR)*

INTRODUCTION

The increasing demand for high data rate services such as streaming video and file sharing motivates the need to develop schemes that can more efficiently exploit the limited availability of the electromagnetic radio spectrum. It has been previously noted that in conventional fixed frequency allocation schemes a large portion of the assigned spectrum is used in a sporadic manner, with the usage of the licensed frequency bands ranging from 15% to 85% (Akyildiz *et al*., 2006). As a consequence, emerging wireless devices are being designed to exploit the temporal vacancies in licensed frequency bands (Yucek *et al*., 2009).

Cognitive radio (CR) is a low-cost, highly flexible alternative to the classic single frequency wireless devices that offers a novel approach for improving the utilization of the precious natural frequency spectrum (Mitola, 1999; Devroye *et al*., 2006; Haykin, 2005). A completely adaptable physical layer is offered by CR devices where the radio features are altered autonomously according to the conditions of the wireless channel and to the user's requirement by sensing the spectrum. CR devices are different from traditional radio devices

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due to their ability to equip users with cognitive capability and reconfigurability (Gandetto *et al*., 2005; Wang *et al*., 2011).

In a CR system, the new (overlay) user has a lower priority in using the spectrum licensed to the legitimate (legacy) user. The CR is required to sense the spectrum properly in order to ensure that there is minimal interference to the existing system while utilizing the available bandwidth. Various detection techniques can be used to sense the presence of an existing user. However, the performance of most of these techniques degrades with channel shadowing or fading (Yucek *et al*., 2009); thus, using a paradigm which allows the overlay system to operate simultaneously with the legacy user, rather than an approach that needs continuous spectrum sensing to determine when the channel is vacant, unveils more efficient usage of the shared spectrum. However, the introduction of the overlay system to the legacy system leads to mutual interference between the systems, as shown in Figure 1. Additionally, the legacy system already exists with a fixed infrastructure that cannot be altered. This imposes a constraint on the design of the overlay system.

In this paper, we employ an MSE (mean-squared error) based criterion to design an overlay system for cognitive radio application. This CR system allows the legacy and the overlay users to simultaneously share the spectrum under the constraint that the overlay user does not cause significant degradation in the performance of the legacy system while maintaining acceptable performance for its own link.

REVIEW OF LITERATURE

Joint transmitter/receiver optimization under the MSE criterion has been widely studied in wireless and wireline communications (e.g., Mir *et al*., 2004; Xiaogeng *et al*., 2008; Kumar *et al*., 1996; Cho, 2004; Yun *et al*., 2007, 2010). For instance, Mir *et al*. (2004) consider the introduction of an overlay system to a legacy system in a non-coordinated digital subscriber line. The performance metric consists of the overlay system MSE and the excess MSE to the legacy system caused by the introduction of the overlay system. An iterative optimization method for transmit/receive frequency domain equalization (FDE) was proposed in Xiaogeng

Figure 1. Interference between overlay/legacy systems