Spectral Efficiency of Cognitive Radio Systems with Correlated Fading Channels

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***Abstract*— In this contribution, we investigate the idea of using *cognitive radio* to reuse locally unused spectrum to increase the total system capacity. We consider a multiband/wideband system in which users wish to communicate to the base station, subject to correlated scattering. We assume that each user knows only his channel and the unused spectrum through adequate sensing. Under this scheme, a cognitive radio will listen to the channel and, if sensed idle, will transmit during the voids. We impose the constraint that users successively transmit over available bands through proper water filling. Within this setting, we derive the total spectral efficiency of the cognitive radio system and show that we can improve the overall system spectral efficiency by considering cognitive communications in the system.**

***Index Terms*— Cognitive radio, capacity, spectral efficiency, band factor gain, water filling, correlated channels.**

Introduction

The recent boom in personal wireless technologies has led to an increasing demand in terms of spectrum resources. To combat this overcrowding, the Federal Communications Commission (FCC) has been investigating new ways to manage RF resources involving progressive redefinition of rules for accessing to the radio spectrum and posing several tasks in the management and in the sharing strategies for such a precious resource. The FCC has recently recommended [?] that significantly greater spectral efficiency could be realized by considering *cognitive radio* [?]. Cognitive radio systems offer the opportunity to improve spectrum utilization by detecting unoccupied spectrum bands and adapting the transmission to those bands while avoiding the interference to primary users. This novel approach to spectrum access is therefore based on reliable detection of primary users and adaptive transmission over a wide bandwidth. However, there are many challenges across all layers of a cognitive radio system design, from its application to its implementation.

As in [?], we consider a TDD-uplink communication scenario in which the primary and the cognitive users wish to communicate with the base station (BS), subject to mutual interference in a heterogeneous network where devices operates in a wideband/multiband context. However, contrary to the work addressed in [?], in this contribution we study the total spectral efficiency of a cognitive radio system with *correlated scattering*. This work was motivated by the fact that, in practice, realistic channels corresponding to scattering clusters exhibit correlated fading and can significantly compromise the performance of such techniques. Analogous to the i.i.d. idealized statistical model, we impose that only one user can simultaneously transmit over the same sub-band and show that the overall system spectral efficiency can be considerably enhanced by considering cognitive communications with respect to the traditional system (without cognition). Under the proposed protocol, cognitive users listen to the wireless channel and determine, either in time or frequency, which part of the spectrum is unused. Then, they *successively* adapt their signal to fill detected voids in the spectrum domain. Specifically, a primary user communicates with the BS while a set of cognitive radio terminals that are able to reliably sense the spectral environment over a wide bandwidth, decide to communicate with the BS only if the communication does not interfere with the primary user. Thus, under our opportunistic approach, a device transmits over a certain sub-band only when no other user does. Moreover, within this setting, each user l is assumed to know only his own channel gain and the statistical properties of the other links. We further assume that the coherence time is sufficiently large so that the channel stays constant over each block fading length.

The idealized statistical model corresponding to a rich scattering environment assumes that the elements of the channel gain h are i.i.d. complex Gaussian random variables. However, the elements of h are correlated in realistic environments and the statistics of h are dictated by the scattering and array characteristics. In this work, we adopt the channel representation used in [?] to capture the statistical structure of correlated fading channels imposed by clustered scattering environments. In this case, the system performance represented by the sum spectral efficiency deteriorates with respect to the i.i.d. case. A key idea behind our study is to characterize the behavior of such systems in terms of spectral efficiency and, above all, to compare such performance to our previous analysis based on the i.i.d. statistical model.

References

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