Towards a Realistic Primary Users' Behavior in Single Transceiver Cognitive Networks

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***Abstract*—Most of the models intended to describe the throughput of Primary (PUs) and Secondary (SUs) users of Cognitive Radio Networks (CRNs) assume that PUs only change their activity state (ON/OFF) in the beginning of each SU's operation cycle, admitting that PUs are synchronized with SU's operation cycle. This letter characterizes a more realistic scenario where PUs can randomly change their activity state during the SU's operation cycle. We derive an analytical model for the PU's throughput and its validation is assessed through simulation results. The analysis shows that assuming synchronized PUs leads to an undervaluation of the interference caused to PUs, and the interference decreases as more SU's operation cycles are performed per ON/OFF PU's activity state.**

***Index Terms*—Cognitive radio, network modeling.**

I. Introduction

In single radio Cognitive Radio Networks (CRNs), non-licensed users (SUs) are equipped with a single transceiver, meaning that SUs are unable to sense and transmit simultaneously. Due to this limitation, SUs adopt an operation cycle where sensing and transmission operations occur in a consecutive manner. SUs start to sense the spectrum during a fixed amount of time (sensing period) and, depending on the output of the sensing, they can transmit during a fixed amount of time (transmission period). SUs repeat the operation cycle periodically to minimize the amount of interference caused to licensed users.

Most of the existing single radio CRNs schemes, such as IEEE 802.22 standard [1], adopt Energy-based sensing (EBS) to characterize the activity of licensed users (PUs). Several works considering EBS and single-radio nodes propose a solution for the optimal spectrum sensing and transmission periods [2]–[4]. However, they consider that PUs only change their behavior in the beginning of the sensing period, which is a quite unrealistic assumption because it considers PU's synchronization.

The work in [5] considers random PU's arrivals and departures to characterize the performance of the EBS. Differently from [5], which studied the performance of the EBS without considering SU's transmissions, this work characterizes the interference caused to PUs when a randomized arrival or departure of a PU can occur in the entire SU's operation cycle. In other words, we consider the case when a PU can change its ON/OFF state during the sensing period, which impacts on the spectrum sensing decision, and the case when a PU can change its state outside the sensing period (in the transmission period). Consequently we consider the cases when the EBS decides in one direction (absence or presence of PUs) and the opposite behavior may be observed during the transmission period. The main contribution of this paper is its innovative approach to characterize the interference caused to PUs when they behave realistically. The interference caused to PUs is compared with the case when timing synchronization is assumed, concluding that the synchronization assumption leads to an underevaluation of the level of interference caused to PUs. It is also shown that the interference caused to PUs decreases as more SU's operation cycles are performed per ON/OFF PU's activity state.

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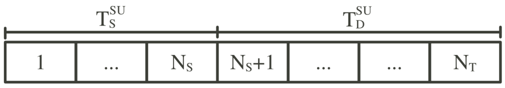

Fig. 1. SU's frame structure representing SU's operation cycle.

In the next section we introduce the adopted system. Section III describes the analytical model. Model and simulation results are analyzed in Section IV. Finally, a few concluding remarks are summarized in Section V.

II. System Description

We consider a pair of PUs accessing the channel and a pair of SUs that access the channel in an opportunistic way. SUs are equipped with a single radio transceiver. However, because SUs are unable to distinguish SUs and PUs' transmissions, SUs' operation cycle includes the sensing and transmission periods, which facilitates the synchronization of the sensing task. Sensing and transmission period durations are represented by T_S^{SU} and T_D^{SU} respectively, as illustrated in Figure 1.

The SU's frame, $T_F^{SU} = T_S^{SU} + T_D^{SU}$, contains N_T slots, where each slot duration is given by the channel sampling period adopted in the spectrum sensing task. The first N_S slots define the sensing period duration, and the remaining ones ($N_S + 1$ to N_T) represent the transmission period duration. It is assumed that SUs always have data to transmit and all SUs are synchronized.

Since the PUs are licensed users, it is possible to characterize their active period duration, T_F^{PU}, and the inactive period duration, $\overline{T_F^{PU}}$. Because the system performance heavily relies on SU's sensing reliability, the SU's operation cycle duration should be shorter than the PU's active/inactive period $\left(T_F^{SU} < \min\left(T_F^{PU}, \overline{T_F^{PU}}\right)\right)$ [2]–[4], [6]. This means that a PU can change its state at most once during a SU's operation

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