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Channel availability for mobile cognitive radio networks

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ABSTRACT

Channel availability is defined as the probability of a licensed channel being available for the communications of unlicensed users. Channel availability is a key parameter for an effective design of channel selection strategies as well as routing metrics in cognitive radio networks. In static scenarios, the availability of a channel depends only on the primary user's activity. Differently, in mobile scenarios, the availability of a channel dynamically varies in time due to the changes of the users' relative positions. In this paper, we design a channel-availability estimation strategy by explicitly accounting for the features of mobile scenarios. The simulation results reveal the benefits of adopting the proposed strategy in cognitive radio networks.

1. Introduction

Channel availability is defined as the probability of a channel licensed to a Primary User (PU) being available for the communications of unlicensed users, referred to as Cognitive Users (CUs). Channel availability is a key parameter for an effective design of channel selection strategies as well as routing metrics (Caleffi et al., 2012; Abdelaziz and ElNainay, 2014) in cognitive radio networks. In fact, the knowledge of the channel availabilities enables a CU to select the channel providing the highest communication opportunities. Moreover, it enables the CU to effectively measure the quality of a route through a routing metric.

In static scenarios, the availability of a channel depends only on the PU activity probability, i.e., on the probability of the channel being occupied by the PU transmissions. Differently, in mobile scenarios, the availability of a channel dynamically varies in time due to the changes of the relative positions between the PUs and the CUs. Let us consider the example in Fig. 1a and b. At time t, since the CU is outside the PU *protection range*,[1] the channel availability is independent of whether the PU is active or not. Differently, at time t', the CU is inside the PU protection range due to the mobility. Hence, the channel availability is not anymore independent of the PU activity. Therefore, in mobile scenarios, the knowledge of the PU activity probability is not enough for an actual channel-availability estimation.

In this paper, we design a channel-availability estimation strategy by explicitly accounting for the features of mobile scenarios. Specifically, we propose a channel-availability estimation strategy based on the relative distances between PUs and CUs. The proposed strategy takes advantage of the non-stationarity of the network topology induced by the user mobility. Thus, with reference to mobile scenarios, such a strategy is expected to outperform the traditional methods, based only on the PU activity. The simulation results confirm the benefits of the proposed strategy in cognitive radio networks.

The rest of the paper is organized as follows. In Section 2 we introduce the problem statement. In Section 3 we describe the network model. In Section 4 we present the proposed channel-availability estimation strategy, and we evaluate the performance through numerical simulations in Section 5. Finally, Section 6 concludes the paper.

2. Problem statement

In this section, we describe how the channel availability in static scenarios differs from the mobile scenarios and then we discuss our proposal. Finally, we present the related work.

2.1. Challenges

In static scenarios, the geographic location of each user is fixed (i.e., both PU and CU). Therefore, the relative distance between PU and CU does not vary on time. In this case, the channel-availability

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[1] The CUs are able to detect active PUs within a range, referred to as *protection range*, determined by the PU transmission range and by the CU interference range (Cacciapuot et al., 2013; Ghasemi and Sousa, 2007).

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estimation, referred to as *static method*, depends only on the PU inactive probability (Jha et al., 2011; Xue et al., 2010; Caleffi et al., 2012). This probability can be *a priori* known or simply estimated according to the channel occupancy history (Chowdhury and Akyildiz , 2011).

In mobile scenarios, the geographic location of each user is not fixed. Therefore, the relative distances between PU and CU vary in time. Consequently, the channel availability is affected by the time variant nature of the network topology.

We clarify this issue with an example. As shown in Fig. 2a, let us assume that at time t_0 a CU, denoted as u_i, is inside the protection range of two different PUs, denoted as v_l and v_n, transmitting on channel a and b, respectively. Moreover, we assume that the inactivity probability of v_l on channel a is higher than the inactivity probability of v_n on channel b. At time $t_0+\Delta$, due to v_n movement, u_i is inside the protection range of only v_l, as shown in Fig. 2b.

According to the *static method*, since the inactivity probability of v_l is greater than the inactivity probability of v_n, u_i would choose always channel a as the channel with the highest availability. However, since at time $t_0+\Delta$ u_i is out of v_n protection range, the channel providing the effective highest availability is channel b. In fact, u_i can freely transmitting on channel b without causing harmful interference to the primary network, independently from the v_n activity.

Hence, from the above example, it is evident that in mobile scenarios it is necessary for a proper estimation of channel availability by explicitly accounting for the features of mobile scenarios.

2.2. Channel-availability estimation design in mobile scenarios

In this paper, we propose a novel channel-availability estimation for cognitive radio networks that explicitly accounts for the features of mobile scenarios. More in detail:

- We derive a closed-form expression of the channel availability in mobile scenarios by accounting for two different PU spectrum occupancy models.
- We analyze the impact of the localization error on the channel-availability estimation.
- We verify through numerical simulations that the proposed method is able to take advantage from the dynamic variation of the channel availability caused by the user mobility.

2.3. Related work

Most of the works available in the literature propose to estimate the channel availability basing only on the PU activity probability. In Jha et al. (2011), the authors propose an opportunistic multi-channel Medium Access Control (MAC), according to which the CUs estimate the channel availability basing on the previous channel scanning results. In Xue et al. (2010), the authors propose another MAC protocol by assuming that each CU obtains the channel availability from the physical layer. In Chowdhury and Akyildiz(2011), the authors introduce a routing metric that aims to minimize the interference of the CUs against the PUs, by estimating the channel availability through the channel history. In Salameh and Badarneh(2013), the authors propose a probabilistic channel quality- and availability-aware cognitive radio MAC, whereas they assume that the spectrum sensing method is in place for determining the list of idle channels. Based on the same assumption, in Talay and Altilar (2013), the authors propose a self adaptive routing for dynamic spectrum access on cognitive radio networks. In Parvin et al. (2013), the security issues on cognitive radio networks are addressed. In Ning et al. (2014), a channel estimation technique is proposed, however, this approach is not suitable in cognitive paradigm due to the PU activities. In Avokh and Mirjalily (2014). an interference-aware routing solution is provided including channel diversity features, which is not also suitable due to the same reasoning. Finally, in Caleffi et al. (2012), the authors propose an optimal routing metric for both static and mobile cognitive radio scenarios, according to which the channel availability depends again on the channel occupancy history. Unlike all the aforementioned works, in this paper we design a channel-availability estimation strategy by explicitly accounting for the main features of mobile scenarios.

3. Network model

In this section, we describe both the PU and CU network models.

3.1. PU network model

The PUs move according to the well-known Random Way Point Mobility (RWPM) model (Camp et al., 2002) inside a network region $\mathcal{A}$, assumed as a square for the sake of simplicity. $v_l(t)$ denotes the position of the l-th PU at time instant t. The l-th PU traffic on the

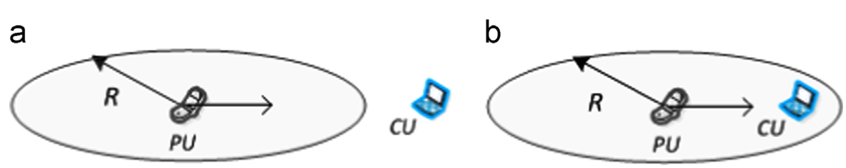

Fig. 1. Channel availability in mobile scenarios.

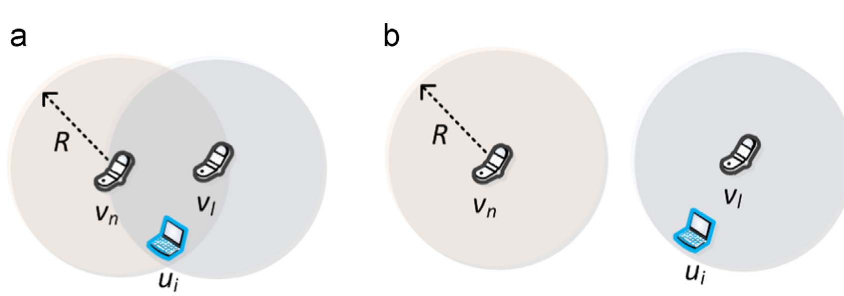

Fig. 2. Channel with the highest availability.