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A dynamic and weighted spectrum decision mechanism based on SNR Tracking in CRAHNs

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ABSTRACT

The spectrum decision concept in Cognitive Radio Ad-Hoc Networks (CRAHNs) introduces important challenges. These include the time-dependent SNR observations of individual CRAHN users due to the fading and shadowing effects in the licensed channels, the necessity of fusion mechanisms for accurate decisions, and the difficulties depending on multi-hop deployment. Considering these challenges, in this paper, we propose a dynamic, cooperative and distributed spectrum decision mechanism in order to decide the channel usage in CRAHNs accurately. The proposed mechanism introduces the SNR Tracking System which considers the time-varying local SNR observations and decisions of the CRAHN users. The proposed mechanism employs a distributed Weighted Fusion Scheme (WFS), to combine the individual decisions and hence, to obtain the cooperative decision. The proposed spectrum decision mechanism adapts itself dynamically to the multi-hop architecture of the network. The performance of the proposed mechanism is compared to some conventional fusion mechanisms based on the AND, OR and MAJORITY rules, and it is shown that the proposed weighted mechanism gives lower false alarm and higher detection probabilities compared to the conventional fusion mechanisms.

1. Introduction

Cognitive Radio Ad-Hoc Networks (CRAHNs) has emerged as a promising technology for wireless ad-hoc networks, in order to overcome the underutilization problem of the licensed spectrum bands [1,2]. To achieve this, the autonomous and self-configurable CRAHN users, which are deployed without an infrastructure support, first monitor the activities of the licensed users (primary users,PUs), then decide to use the spectrum in an opportunistic manner if there is no PU. This concept, so-called *Spectrum Decision*, brings some crucial design challenges in CRAHNs.

The challenges related to the spectrum decision in CRAHNs include the PU behaviors and heterogenous channel characteristics. Specifically, the possible PU detection errors, path losses, fading and shadowing effects make the local spectrum decision of a CRAHN user misleading and less accurate. Therefore, the CRAHN users should cooperate for more accurate decisions. Such a cooperation could be done by sending local observations and decision results through a Common Control Channel (CCC) [2,3]. Moreover, the effects of the multi-hop network architecture, such as transmission delay while collecting and disseminating local decisions through the network, should also be considered when studying the performance of the cooperation.

Besides the coordination of the CRAHN users, the spectrum decision in CRAHNs should also be done in a distributed manner. In order to minimize the errors made by a centralized authority like Base Station (BS). Moreover, it is very practical if each CRAHN user reaches the cooperative decision locally using a fusion mechanism. Due to the possible PU detection errors and wireless channel conditions, the local decisions can be heterogenous and misleading. Hence, instead of using the conventional

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AND, OR, MAJORITY fusion rules which give equal weights to all gathered decisions, a new fusion mechanism interpreting each local decision independently may reach more accurate cooperative decisions.

In this paper, we propose a cooperative and dynamic Weighted Fusion Scheme (WFS) for the spectrum decision in CRAHNs. WFS gathers the individual SNR observations and decisions of CRAHN users distributedly, via a novel message dissemination system called SNR Tracking System. The proposed mechanism reaches the cooperative decision by combining local SNR observations and decisions of the CRAHN users according to some weight values which will be described in the following sections. The proposed WFS is compared to some conventional fusion mechanisms based on the AND, OR and MAJORITY rules, and it is shown that the proposed weighted mechanism gives lower false alarm and higher detection probabilities compared to the conventional fusion mechanisms.

The rest of the paper is organized as follows: In Section 2, we give related studies in the CR literature about the cooperative spectrum sensing and decision. Here, we also emphasize the main differences of the proposed mechanism from the mechanisms introduced earlier, as well as our contributions. In Section 3, the overall network architecture and the proposed system model are described. Section 4 gives a detailed evaluation of the proposed spectrum decision mechanism and the performance comparison with the conventional mechanisms. The paper is concluded in Section 5 by summarizing the contributions and giving future directions.

2. Related studies

There exists some efforts in the recent studies to deal with the aforementioned spectrum decision challenges in CRAHNs. In [4], an optimum spectrum decision framework is proposed by considering the basic QoS-specific CR user applications. In [5–7], the authors propose effective spectrum sensing decision mechanisms based only on the local sensing observations of CR users without cooperation. A cluster-based cooperative spectrum sensing and decision mechanism only for AND–OR decision rules is proposed in [8]. The data and decision fusion techniques employing the AND–OR decision rules are introduced in [9]. Novel frameworks and analytical models for spectrum sharing in cognitive radio mesh networks are studied in [10–12]. In [13], an energy efficient spectrum access mechanism exploiting a cooperative message dissemination is proposed. Here, messages contain only the local-SINR observations of CRAHN users. Similarly, in [14], a PU notification protocol for CRAHNs is designed based on the dissemination of warning messages containing the local decisions of CRAHN users. In [13,14], the cooperation is provided by disseminating information messages.

However, in these aforementioned studies, the assumed messaging and cooperation systems could be misleading due to fact that their contents have limited information about the other CRAHN users in the network. We believe that the content should provide the necessary information about the heterogeneous channel conditions observed by the node monitoring the channel. However, those systems only provide either the local SNR values or the local decisions concerning PU detection. Such an approach may mislead the cooperative decision taken by an individual CRAHN user. In this paper, local SNR observations and decisions obtained by CRAHN users are shared with all the other users in order to get more accurate cooperative decisions.

Overall, considering these challenges, our work differentiates from the previous studies by proposing a fully cooperative, dynamic and weighted spectrum decision mechanism with the following contributions:

- The full cooperation among CRAHN users is provided by a novel message dissemination system, so-called *SNR Tracking System*. The special message format provided by the SNR Tracking System contains both the local SNR observations and decisions of each ad-hoc user. Therefore, all the CRAHN users get the necessary information about the ad-hoc network for more accurate spectrum decision. The proposed SNR Tracking mechanism also provides a dynamic solution to CRAHNs. This is achieved by periodic distribution of the local observation updates to the ad-hoc users who can adapt their own decisions according to these updates.
- After collecting the SNR observations and decisions of the CRAHN users, a distributed *Weighted Fusion Scheme (WFS)* which is introduced in this work is employed to reach the cooperative decision by each CRAHN user. The proposed WFS assigns weights to each CRAHN user concerning its position relative to corresponding CRAHN user and the SNR observations. Then, the cooperative decision is calculated accordingly.

The performance of the introduced mechanism is compared with some well-known decision fusion schemes with respect to the false alarm, detection and miss detection probabilities.

3. The system model

3.1. The network architecture

The network architecture consists of a centralized PU network and a CRAHN with multiple CRAHN users, as seen in Fig. 1. The CRAHN is integrated into a licensed PU network which operates on multiple spectrum bands. The CRAHN users in the system collect the heterogeneous SNR observations for the PU. All the CRAHN users are equipped with multiple software-defined radio (SDR) transceivers to monitor all spectrum bands [4]. Moreover, each CRAHN user gets information about the other CRAHN users and disseminates its control messages through a Common Control Channel (CCC) [8]. CCC can be accessed by all the nodes, therefore we assume that all the necessary information gathered by the nodes are distributed to the network through a single CCC. We do not consider the hidden terminal problem among CRAHN users and assume that CCC employs a Time Division Multiplexing (TDM) based mechanism for the CRAHN users to communicate.