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Reactive routing for mobile cognitive radio ad hoc networks ☆

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ABSTRACT

Although more than a decade has passed from the proposal of the Cognitive Radio paradigm, in these years the research has mainly focused on physical and medium access issues, and few recent works focused on the problem of routing in cognitive networks. This paper addresses such a problem by evaluating the feasibility of reactive routing for mobile cognitive radio ad hoc networks. More specifically, we design a reactive routing protocol for the considered scenario able to achieve three goals: (i) to avoid interferences to primary users during both route formation and data forwarding; (ii) to perform a joint path and channel selection at each forwarder; (iii) to take advantage of the availability of multiple channels to improve the overall performance. Two different versions of the same protocol, referred to as Cognitive Ad-hoc On-demand Distance Vector (CAODV), are presented. The first version exploits inter-route spectrum diversity, while the second one exploits intra-route spectrum diversity. An exhaustive performance analysis of both the versions of the proposed protocol in different environments and network conditions has been carried out via numerical simulations. The results state the suitability of the proposed protocol for small mobile cognitive radio ad hoc networks.

1. Introduction

The *Cognitive Radio* paradigm has been recognized in 1999 [1] as an effective way to deal with bandwidth scarcity and/or un-efficient usage. Although more than ten years have passed, the research on cognitive radio networks has mainly focused on physical and medium access issues [2,3], including the definition of effective spectrum sensing, decision and sharing mechanisms. Only recently the research community started to work in the area of cognitive radio routing, and few works address the problem of routing in Cognitive Radio Ad hoc Networks (CRAHNs).

In this paper, we contribute to such a problem by proposing a reactive routing protocol, referred to as Cognitive Ad-hoc On-demand Distance Vector (CAODV), that aims to provide end-to-end connectivity in mobile CRAHNs characterized by dynamic primary user (PU) activity [4]. In such a scenario, the cognitive user (CU) communications experience time-variant spectrum availability. Therefore, a spectrum dynamic awareness is required at the network layer to guarantee, at the same time, minimal interference to PUs and efficient utilization of the licensed spectrum.

The main characteristics of the proposed protocol can be synthesized as follows:

– in-band based communications: CAODV exchanges control packets only through the licensed (primary) portion of the spectrum, avoiding to resort to dedicated out-of-band control channels;

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– local spectrum knowledge: CAODV does not require a complete knowledge about PU activity, since each node is able to route the data packets and to exchange the control ones without interfering with PU communications, by exploiting only its local spectrum sensing capabilities;
– spectrum dynamic awareness: CAODV is able to adapt to PU activity changes, provided that the changing rate is reasonable (order of magnitude of minutes), by recomputing new routes when changes in the spectrum availability arises due to PU arrival or departure;
– imperfect spectrum sensing support: CAODV aims to minimize the interference to PU communications due to an imperfect physical spectrum sensing;
– local route decision: CAODV allows all intermediate nodes to cooperate to the route process decision by adapting both the next hop and the channel selection to the environmental conditions during the data forwarding;
– independence of underlying technologies: CAODV does not require underlying data-link technologies dedicated to the cognitive paradigm, although it can clearly benefits from their availability.

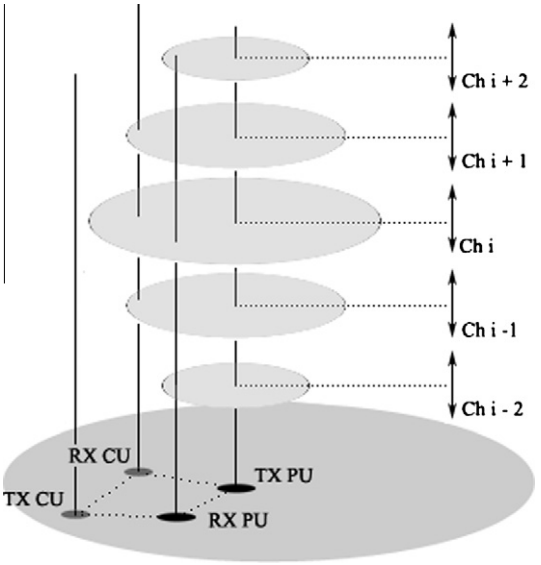

Fig. 1. Hidden primary user problem: due to the uncertainty about the location of the PU receivers, a CU can cause interference to PU communications also if it adopts a spectrum sensing mechanism. In the figure, the transmitting CU can not sense the PU transmission since it is located far from the transmitting PU, but it can cause interference to the receiver PU.

Through the paper we propose two different versions of CAODV. Both the versions are able to take advantage of the spectrum diversity provided by the cognitive paradigm, but they exploit two different approaches. The first version, referred to as intEr-Route dIversity CAODV (ERI-CAODV), exploits *inter-route spectrum diversity*, namely, it is able to discover several routes and to use different channels for different routes, but each route is restricted to evolve through the same channel. The latter one, referred to as intrA-Route dIversity (ARI-CAODV), exploits *intra-route*

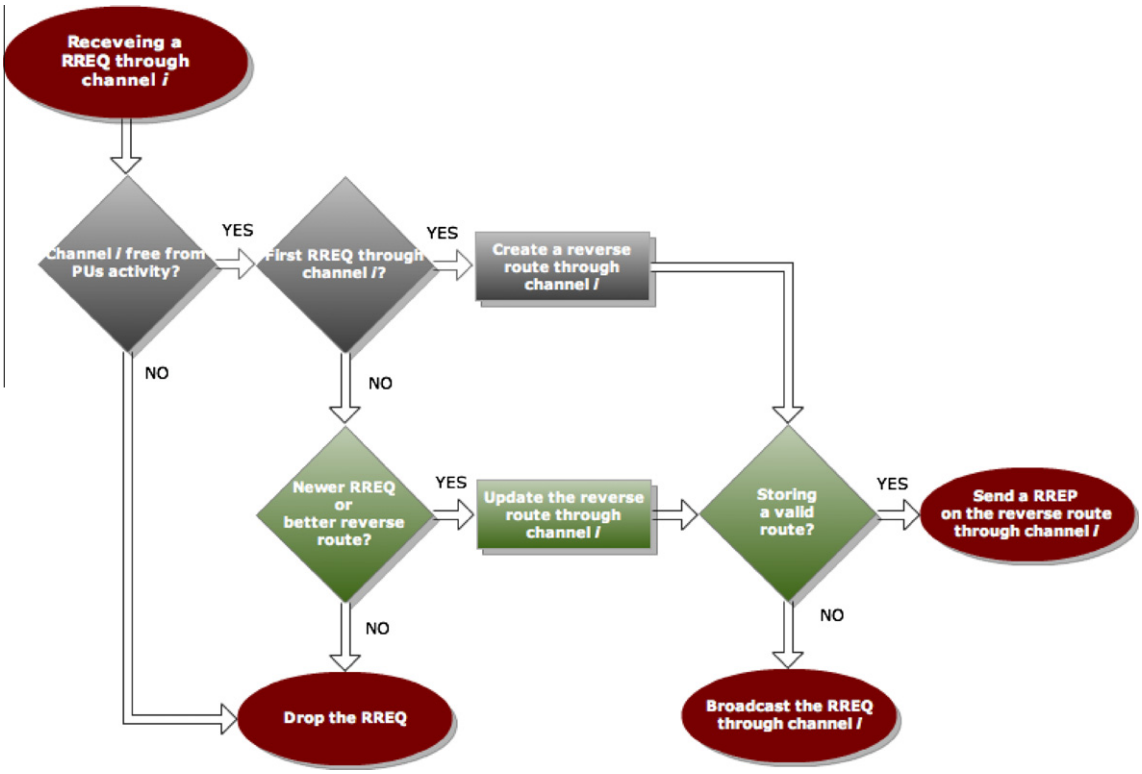

Fig. 2. Route request flow chart for ERI-CAODV.