Using Incoming Traffic for Energy-Efficient Routing in Cognitive Radio Networks

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ABSTRACT

This paper proposes an energy-efficient routing scheme that is based on a resource intensive traffic-aware approach, enabling for the maximization of the energy conservation in cognitive radio networks. The proposed approach interrelates the moments of the backward difference traffic, together with the sleep-time duration, towards tuning the activity periods of the network nodes. The effective operation of the proposed scheme, in terms of minimum energy consumption, minimum delays and maximum number of the routing paths established, is achieved through the exploitation of a signaling mechanism. The validity of the proposed traffic-aware scheme is tested, through several simulation tests, by obtaining multiple performance evaluation results. The experimental results verified the proper operation of the proposed scheme to maximize the energy conservation, optimize the data exchange among the network nodes and minimize the routing delays.

Keywords: Cognitive Radio Networks, Energy-Efficient Scheme, Routing Schemes, Traffic-Aware Energy Conservation, TV White Spaces

1. INTRODUCTION

Cognitive Radio (CR) networks (Akyildiz et. al, 2006) enable for the efficient exploitation of radio spectrum parts to deploy emerging mobile computing and wireless networking architectures. CR technological solutions consist of nodes that are able to change their transmission settings, according to the available radio spectrum at local level. Such nodes support the capability for sensing large parts of the radio spectrum, by dynamically using locally un-exploited frequencies. This capability enables for the proper design and development of novel

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wireless networking architectures, based on new policies for the opportunistic access of the available radio spectrum in specific geographical regions, such as the “television white spaces” (i.e. TVWS) (Bourdena et. al, 2014). TVWS consists of television/broadcasting channels that are available after the digital switchover process or are totally un-exploited due to frequency planning issues (i.e. Interleaved Radio Spectrum) (Bourdena et. al, 2011, December). Hence, the deployment of CR networking architectures, operating over the TVWS, is highly related with the radio spectrum management models that will be exploited (Bourdena et. al, 2012, October; Bourdena et. al, 2012, December) in emerging communication systems. In this direction, “Spectrum of Commons” model can be adopted in ad-hoc cognitive radio networking architectures, where the allocation of the available resources is performed at local level by the nodes, instead of exploiting a centralized unit, like a spectrum broker (Hossain et. al, 2009). This dynamic radio spectrum access by the CR nodes causes new challenges in the design of novel networking protocols at different layers. The design and development of effective routing schemes, is an important process for the proper operation of such emerging computing environments. The ad-hoc CR networks are based on self-configuring architectures (Hossain et. al, 2009), where the routing process is challenging, in comparison with the routing schemes adopted so far in conventional wireless networks. The main difference is that the radio spectrum availability in CR networks is highly related with the presence of primary nodes (e.g. television services broadcasting sites), making challenging the use of a Common Control Channel (i.e. CCC), to create and maintain a stable route among secondary CR nodes.

On the other hand, the energy conservation issues are crucial for the efficient deployment of future ad-hoc CR networks. The energy conservation schemes that will be adopted have to be reactive, in order to tune the energy levels of the nodes based on estimated parameters (e.g. traffic, capacity (Mavromoustakis, 2012, May)). In addition, the energy-efficient schemes have to consider the bounded end-to-end delays of the data transferred among the nodes. Since the network lifetime is strictly associated with the transmission characteristics that are exploited by the source node to transmit data to a destination node, as well as the routing protocol used (Shpungin, 2011, June), a scheme that associates the temporal traffic-aware behaviour of the nodes (Mavromoustakis et. al, 2010, September) in an end-to-end path is crucial to be studied. In (Charalambous et. al, 2012, June), the sleep-proxy nodes calculate the interval of the nodes activity periods, based on the capacity and the estimated inter-cluster total energy consumed within a time frame. The authors of the previous scheme applied the traffic model, as well as evaluated the traffic volume characteristics for a specific time window frame but not in CR ad-hoc network architectures.

In this framework, this paper progress beyond the current state-of-the-art, by elaborating on the design, the development and the evaluation of a resource intensive traffic-aware scheme that is suitable for ad-hoc CR network architectures. The proposed scheme enables for the efficient data transfer among secondary nodes, operating based on the “Spectrum of Commons” policy. In addition, a signalling mechanism that is combined with the proposed energy-efficient scheme is presented, according to the backward traffic difference estimation (Mavromoustakis, 2012, May; Charalambous et. al, 2012, June; Mavromoustakis et. al, 2010, September), in contrast to the end-to-end bounded delay of the transmission. Taking into account the proposed routing scheme, as well as the volume of the traffic that is transmitted among the nodes, the proposed approach targets towards the minimization of the energy consumed, by applying asynchronous, non-periodic sleep-time assignment slot to the secondary CR nodes. Following this introductory section, the next two sections elaborate on the related work and the research motivation of this paper, as well as the design and the development of a novel routing scheme adopted in CR ad-hoc networks. The proposed scheme offers energy-efficient data transfer, among secondary CR nodes with
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