CITY UNIVERSITY OF HONG KONG
香港城市大學

Routing on Cognitive Radio Ad-Hoc Networks: Link Availability, Efficiency and Virus Propagation
基於自組織認知無線網絡的路由研究：鏈路有效性、效能與病毒傳播

Submitted to
Department of Electronic Engineering
電子工程學系
in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy
哲學博士學位

by

HOU Ling
侯令

September 2014
二零一四年九月

Abstract

Cognitive radio (CR) is widely viewed as a promising technology to improve the utilization efficiency of radio spectrum. It enables CR Users (CUs) to sense the spectrum environment and thus to exploit the spectrum opportunities while avoiding any imposed harmful interference to the primary users (PUs). Cognitive radio ad-hoc networks (CRAHNs) are distributed multi-hop networks connecting CUs together through an ad-hoc manner. CRAHN can provide an ultimate spectrum-aware and infrastructure-free communication paradigm. In this thesis, routing and its related issues including link availability, efficiency, and virus propagation are studied for CRAHNs.

Compared with classical ad-hoc networks, a routing path in CRAHNs is particularly unstable. Routing path formed over multiple links may experience disconnections caused not only by the mobility of CUs but by the activities of PUs as well. A link is considered connected/available if the two CUs associated with this link are within the transmission range of each other and spectrum used on this link is also available. It is desirable that CR routing should favor links with higher link availability so as to improve the path stability. A link availability prediction approach is thus proposed to be forward looking in link selection. Simulation results are presented to show the effectiveness of the proposed approach. Based on the prediction, we further describe how to perform topology control in order to construct a more reliable topology and hence reduce path disconnections.

Based on the topology constructed, routing protocol design is studied for CRAHNs. Since energy and spectrum are two fundamental resources for CRAHNs and they are always scarce, energy efficiency and spectrum efficiency are both considered in this thesis. Based on them, spectrum- and energy- efficient routing (SEER) protocol

is proposed. Simulation results show the advantages of SEER in terms of energy consumption, network lifetime and system throughput. But SEER adapts to environment changes in a passive manner after the changes already lead to route failures. Thus, SEER performs better in relatively stable networks than in rapidly changing networks.

To adapt to environment changes actively, a Q-learning based routing protocol is proposed. Q-learning is a model-free learning technique that allows groups of agents to monitor the state of their local environment and take actions to solve system optimization problems online. In the proposed protocol, energy efficiency is used as the optimization objective. Simulation results are presented to show the effectiveness of the proposed protocol in terms of energy consumption and network lifetime. Additionally, discussions on the drawbacks of only considering energy efficiency as well as the potential for enhancement are given.

Security is also a main concern for routing design in CRAHNs. CRs can be taught malicious behaviors easily, because CRs learn from their environments through sensory input and develop their beliefs based on historical experiences. The malicious behaviors could be propagated among CUs, leading to CR virus. And no spreading properties specific to this kind of virus have been reported in the literature. Taking a representative self-propagating AI virus as an example, we study the virus propagation model. Several important observations are made from simulation results based on the model. From these observations, some recommendations are provided for CR designers, such as determining the learning belief validation/checking period based on the network size. Moreover, the simulation results also provide some inspirations for immunization in CR networks, such as immunizing those devices with highest degree first.

Table of Contents