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EFFICIENT ROUTING PROTOCOLS FOR COGNITIVE RADIO NETWORKS OF ENERGY-CONSTRAINED DEVICES AND DISSIMILAR DELAY-SENSITIVE LEVELS

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Date & Venue

Thursday April 21, 2022

at 9:00 PM

Building F1, Room 0046

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Abstract

The Cognitive Radio (CR) overwhelms spectrum deficiency by employing the underutilized licensed spectrum, which offers a considerable communication environment to accommodate numerous future finite-energy IoT devices demanding connectivity and prompt arrival of their sensed data. CR is required to hit an evenness between network energy consumption for efficient data transmission and network end- to-end delay for cost minimization of delivering a payload. This makes the CR an open interdisciplinary research area and provides the motive for building routing protocols for CR networks (CRNs). The perceived shortage in CR routing protocols concerning delay and energy consumption leads to the novel proposal of two multi-hop routing protocols that suit IoT networks, Efficient Routing protocol for Cognitive Radio (ERCR) networks and Efficient Hybrid Routing protocol for Cognitive Radio (EHRCR) networks. An analytical model for estimating the performance of the proposed protocols in a network with CR devices employing D/M/1/K queuing systems is investigated to reflect the selected-route stability and make predictions about adjustments with demands. It aims to analyze the queuing model entitled to estimate the network behavior in a retrial service system with a probability of transmission failure due to a single licensed-channel occupation. The effectiveness of the proposed model is verified through a simulation that inferred a perfect match with the analytical results. By applying the proposed queuing model, the location based ERCR succeeds in shrinking the effect of licensed users' activity and balancing the energy consumption among network nodes by establishing/reconstructing routes with a minimum number of nodes and sufficient remaining energy. This increases the per- node capacity, reduces the end-to-end latency, and preserves the limited energy of battery-powered devices leading to high data-transfer throughput, low overhead, and prolonged network lifetime. Employing the ERCR protocol, delay-sensitive applications can distinctly operate with an end-to-end delay below 200 ms providing a probability of PU activity that reaches 0.3 and an average duration of PU activity up to 30 ms. The novel EHRCR, as an enhancement to ERCR, swiftly amends to spectrum and network load changes and efficiently establishes routes based on nodes delay (in terms of queuing, transmission, and service) and energy consumption, with the consideration of reducing the propagation delay. Different weights for energy and delay costs are assigned to fulfill the expectations of IoT applications with their different Quality of Service (QoS) requirements. With three schemes examined to demonstrate energy, balanced, and delay scenarios, the results report the suitability of the EHRCR delay scheme to serve delay-sensitive applications in the existence of 50% licensed user activity with a duration of 10 ms achieving a delay that does not exceed 200 ms. The delay-tolerant applications can get the advantage of the energy scheme with maximum energy consumption that reaches 30% of the initial node energy at high licensed user activity that reaches 40%. It is revealed that the proposed EHRCR reduces and balances energy consumption to suit battery-powered and outlet-powered IoT devices with the different delay-sensitivity levels of the running applications.

Keywords: Cognitive radio networks, IoT, routing, energy, delay, D/M/1 queuing model.