An Energy Efficient Fair Node Selection for Cooperative In-band and Out-of-band Spectrum Sensing

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***Abstract*—In a cooperative cognitive network, multiple secondary user (SU) nodes are selected for spectrum sensing to detect the presence of primary user (PU) nodes in the currently used channel as well as identify other available unused licensed channels. Periodic sensing of such in-band (IB) and out-of-band (OB) channel consumes a considerable amount of energy which is a huge liability to an energy constrained networks. Additionally, SU nodes are selected to meet the requirements such as detection and false alarm probabilities. This results the consecutive selection of same nodes, which depletes the energy of those nodes rapidly shortening the lifetime of nodes and network itself. In this paper, we propose a fair and energy efficient node selection scheme for joint IB and OB spectrum sensing. The SU nodes are grouped based on the energy stored in it referred as residual energy. A joint optimization problem is formulated to minimize energy consumption while ensuring the selected nodes belong to specific group depending on whether sensing is IB or OB. Considering the nature of formulated problem, we use particle swarm optimization to solve it. The results show that proposed scheme not only consumes relatively less energy and reduces the number of dead nodes, but also allows to maintain fair distribution residual energy within the network. Consequently, the network can prolong its spectrum sensing activities for longer duration.**

***Index Terms*—Cooperative spectrum sensing, in-band sensing, out-of-band sensing, fairness, energy efficiency, particle swarm optimization.**

I. INTRODUCTION

A cognitive radio network allows secondary users (SUs) to dynamically access temporarily unused spectrum that is licensed to primary users (PUs) in an intelligent and efficient manner [1]. To detect the unused spectrum bands and avoid harmful interference to PUs, a cognitive radio user is required to perform spectrum sensing periodically. In order to attain high probability of detection and low probability of false alarm, a cooperative spectrum sensing is often used so that spatial diversity can be exploited [2]. The combined cooperative decision derived from the spatially collected observations helps to overcome the limitation of individual observations at each SU in the cooperative spectrum sensing.

Sensing of the spectrum band on which SU is currently operating to detect the occurrence of PU is referred as in-band (IB) sensing. Similarly, sensing of the other spectrum bands besides the one that SU is currently operating is referred as out-of-band (OB) sensing. In other words, IB sensing involves sensing on the current home channel, while OB sensing involves sensing on any other foreign channels except the current home channel [3]. IB sensing allows to avoid interference to PUs and OB sensing provides the opportunity to switch to other channels for seamless connectivity in case its current operating channel is reoccupied by PU. This is an essential requirement for achieving multiband operability in the cognitive radio systems. OB sensing also allows an opportunity to select better channel if the OB channel is found to provide higher signal-to-noise ratio (SNR) than the IB channel.

The SU nodes employed for IB and OB sensing often operate under limited energy budgets. As such, efficient node selection for both IB and OB sensing is a significant research direction in the cooperative cognitive network to conserve energy.

A cooperative IB and OB sensing not only requires cooperation between several number of sensing nodes, but also communication between the sensing nodes and the fusion center (FC) resulting consumption of a considerable amount of energy. The sensing nodes are often selected based on the position and local decision accuracy to meet the spectrum sensing requirements. As such, same set of nodes with better decision accuracy are frequently selected for both IB and OB sensing. Consecutive selection of the same nodes for both IB and OB sensing rapidly depletes the stored energy which we also refer as residual energy. Therefore, in a long run, these sensing node dies off soon reducing lifetime of the network itself. In order to avoid frequent selection of same node and avoid rapid depletion of stored energy, an energy efficient as well fair node selection based on residual energy should be studied that jointly considers IB and OB sensing rather than simply IB or OB sensing separately.

Motivated by these facts, we focus on an energy efficient and fair node selection scheme based on residual energy that considers both IB and OB sensing together. As such, nodes with higher residual energy is preferred over nodes with lower residual energy for sensing while satisfying detection probability requirements. The proposed scheme also takes account of sensing priority and successive sensing interval. The proposed scheme not only minimizes total energy consumption of the network, but also increases the lifetime of the participating nodes by ensuring fair distribution of residual energy within the network. Our main contributions include the

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