Chapter 4
Energy-Efficient Cooperative Spectrum Sensing for Cognitive Radio Networks

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ABSTRACT

One of the main problems of Cooperative Spectrum Sensing (CSS) in cognitive radio networks is the high energy consumption. Energy is consumed while sensing the spectrum and reporting the results to the fusion centre. In this chapter, a novel partial CSS is proposed. The main concern is to reduce the energy consumption by limiting the number of participating users in CSS. Particularly, each user individually makes the participation decision. The energy consumption in a CSS round is expected by the user itself and compared to a predefined threshold. The corresponding user will participate only if the expected amount of energy consumed is less than the participation threshold. The chapter includes optimizing the participation threshold for energy efficiency maximization. The simulation results show a significant reduction in the energy consumed compared to the conventional CSS approach.

1. INTRODUCTION

Recently, energy efficiency in wireless networks has received a significant amount of research. This is because mobile users are usually battery-powered. The limited energy resources represent a challenge hindering wide implementation of some recent technologies (Fettweis & Zimmermann, 2008). Some wireless systems, such as cognitive radio (CR), implies more energy consumption than other systems. Cognitive radios in general require more energy to operate, as compared to the conventional transceivers due to the additional tasks required to perform cognitive transmission. In CR, a licensed spectrum can be exploited by unlicensed users when it is (temporarily and spatially) unused by licensed users. This requires awareness of spectrum status, which is performed by a process termed as spectrum sensing (Mitola & Maguire, 1999), (Haykin, 2005).

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In order to identify the unused spectrum portions, the unlicensed users, also called cognitive users (CUs), are enforced to sense it for specific period, inducing energy consumption which does not exist in the typical wireless systems. Moreover, aiming at improving the reliability of spectrum sensing, cooperative spectrum sensing (CSS) is proposed (Mishra, Sahai & Brodersen, 2006), (Di Renzo, Imbriglio, Graziosi & Santucci, 2009), (Ghasemi & Sousa, 2007). In CSS, the local sensing results are reported to a central entity, called fusion centre (FC). The FC is in charge of making a global decision regarding the spectrum occupancy by applying a specific fusion rule (FR). Although CSS decreases the probability of erroneous decision considerably by mitigating the effects of multipath fading and shadowing, it causes extra delay, security risks (I.F. Akyildiz, Lo & Balakrishnan, 2011) (Di Renzo Graziosi & Santucci, April 2009) and more energy consumption.

The high energy expenditure in CSS is caused by the individual sensing and reporting the sensing results to the FC. In case of large number of CUs and/or large number of sensed channels, energy-efficient CSS becomes a pressing need for CR systems. Aiming at reducing energy consumption, limiting the amount of reported results has been widely investigated. In general, two well-known schemes for results’ reporting (S. Chaudhari, Lunden, Koivunen & Poor, 2012) (Viswanathan & Varshney, 1997), soft scheme (SS) and hard scheme (HS). In SS, the sensing result of each CU is quantized locally by a multiple number of bits and sent to the FC. On the other hand, the result is quantized by only one bit in HS. As a CU employing HS reports only one bit, it is clear that the energy consumption is lower than if SS is employed (Maleki, Chepuri, & Leus, 2011). Thus, in this work, we consider only HS.

Many works have investigated the reduction of energy consumption in CSS. These works can be classified into four different approaches: (i) Reducing the number of sensing users, (ii) Reducing the sensing time, (iii) Reducing the reported sensing data, and (ii) Optimizing the decision-making rule.

In the first approach, (Maleki et al., 2011), and (Pham, Zhang, Engelstad, Skeie & Eliassen, 2010) have proposed algorithms that use the minimum number of sensing users based on different setups while satisfying predefined thresholds on the detection accuracy. In (Cheng et al., 2012), the CUs are divided into non-disjoint subsets such that only one subset senses the spectrum while the other subsets enter a low power mode. The energy minimization problem is formulated as a network lifetime maximization problem with constraints the detection accuracy. An algorithm for user selection is proposed in (Najimi et. al., 2013), where the user subset that has the lowest cost function and guarantees the desired detection accuracy is selected. The cost function is related to the system energy consumption.

The works in (Zhao et al., 2012), (Feng et al., 2012) and (Pham, Zhang, Engelstad, Skeie & Eliassen, 2010) consider the sensing time as a possible approach to reduce the energy consumption. In (Zhao et al., 2012), the CUs perform an initial sensing stage and report their local decisions to the FC. If a global decision cannot be made (no majority exists), a longer sensing stage is used. In (Feng et al., 2012), a utility function that consists of the difference between the achievable throughput (revenue) and the consumed energy (cost) is maximized by optimizing the sensing time with a constraint on the detection probability. The optimal sensing time that maximizes the energy efficiency with constraints based on the detection accuracy is obtained in (Pham, Zhang, Engelstad, Skeie & Eliassen, 2010). A joint optimization of the number of sensing users, the sensing time and the local detection threshold is presented in (Gao et al., 2013), aiming to maximize the energy efficiency by imposing a constraint on the detection accuracy.

Following the third approach, censoring, confidence voting and clustering have been proposed. Censoring is a promising technique that can significantly reduce the reporting CUs. In censoring, a CU does not report its sensing result unless it lies outside a specific range (Sun et al., March 2007), (Lunden et al.,