OPTIMIZATION OF COOPERATIVE SPECTRUM SENSING WITH CONVENTIONAL AND IMPROVED ENERGY DETECTORS

by

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Certificate

This is to certify that the thesis entitled **"Optimization of Cooperative Spectrum Sensing with Conventional and Improved Energy Detectors"** being submitted by Ajay Singh to the Department of Electrical Engineering, Indian Institute of Technology, Delhi, for the award of the degree of Doctor of Philosophy is the record of the bona-fide research work carried out by him under my supervision. In my opinion, the thesis has reached the standards fulfilling the requirements of the regulations relating to the degree.

The results contained in this thesis have not been submitted either in part or in full to any other university or institute for the award of any degree or diploma.

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Abstract

In this thesis, we consider a cognitive radio network containing two cognitive radios (CRs) and one primary user (PU). The CRs utilize *finite number of received data samples* for estimating the energy of the primary signals and forward these energy estimates to a fusion center (FC). The FC combines the energy estimates and utilizes a global threshold based on exact knowledge of local thresholds of the CRs for determining the presence or absence of the primary signal. We propose selective and semi-selective soft combining schemes for this set-up. For the proposed schemes, we derive the total probability of error of detecting a spectrum hole. By minimizing the *total probability of error* in sensing a spectrum hole, we find optimized local and global thresholds. Moreover, we also discuss optimization of conventional non-selective soft and one-bit hard combining schemes with multiple (equal to or more than two) collaborative CRs under the total probability of error minimization criterion. The proposed selective soft combination based scheme significantly outperforms the conventional non-selective schemes based on soft combination and one-bit hard combination. Moreover, the proposed selective soft combining scheme along with the total probability of error minimization criterion is able to properly utilize a spectrum hole with interference level less than the standard specified value.

The key goal of this thesis is to reduce the performance gap between the conventional non-coherent energy detector and the coherent detector. This can be achieved by trying something between the generalized likelihood function and the decision variable. In this thesis, instead of utilizing the squaring operation over the received sample, we use an arbitrary positive power of the amplitude of the sampled value of the primary signal. We call it is an *improved energy detector*. The *improved energy detector* shows significant improvement over the conventional energy detector. The performance gain of the *improved energy detector* over the conventional energy detector is due to the fact that a squaring operation may understate the signal component in the received sample when the signal-to-noise ratio (SNR) is large and overstate the signal component in the sample when the SNR is small. The results obtained in this thesis show that changing the squaring operation to an arbitrary positive power p operation is effective in improving the performance of the cooperative CR system using conventional energy detector where the binary decision of each CR is forwarded over a reporting channel (perfect or imperfect) to a FC which makes a final decision on the presence of the PU. We obtain an expression of the total error rate of detection of a spectrum hole for this cooperative set-up. The optimized values of p, sensing threshold and optimal number of CRs are obtained by minimizing the total error rate. The proposed scheme significantly outperforms an existing scheme that uses the conventional energy detector. A multiple antennas based CR cooperative spectrum sensing scheme with an improved energy detector over imperfect reporting channel is studied. It is refereed by analysis and numerical computation that by using the total error rate minimization criterion in a multiple antenna based collaborative cognitive system, it is possible to significantly improve utilization of the spectrum hole and reduction in interference level for the primary user at very low SNR range.

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