Implementation of Cooperative Spectrum Sensing using Energy Detection for Cognitive Radio Networks

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ABSTRACT
In this paper, describe the development of an optimal number of nodes in cooperation using energy detection method in a cognitive radio network(CRN).

Keywords
Cognitive Radio Networks; Cooperative spectrum sensing; Energy detection.

1. INTRODUCTION
The tremendous ongoing growth of wireless communication has resulted spectrum shortage which in turn becomes an obstacle for growth of new wireless devices. However, radio-spectrum usage has the poor utilization of frequency band due to rigid licensing policies. The spectrum shortage and inefficient utilization of spectrum make it necessary to develop a cognitive radio network (CR) technology to exploit the existing wireless spectrum opportunistically. The fundamental task for CR is spectrum sensing, which enable CR users to adapt to the environment by detecting white spaces without causing interference to the primary user (PU). Several signal processing techniques are being used for spectrum sensing. Popular methods among them are Matched filtering, Energy detection, and cyclostationary feature detection.

The sensing performance of the system depends on the two parameters: detection probability (Pd) and false alarm probability (P*f*). Licensed/primary users (PU) are well protected when the Pd of the system is high. To achieve higher value of Pd, the Sensing/Observation period (ts) effect on CR user transmission time (*T*). As the observation period is more, the transmission period for CR user becomes less within an available vacant space (white space). On the other hand, lower the P*f* will facilitate the opportunistic usage of unused radio spectrum. In practice, sensing performance of singe CR is often reduced with multipath fading, shadowing, and receiver uncertainty issues in the channel. To mitigate the impact of these issues, cooperative sensing is effective method to enhance the detection performance. The cooperative sensing can be done using hard decisiontechnique at fusion center (FC). In this hard decision, each node takes its own decision and transmits a binary value to the FC.

2. SPECTRUM SENSING
For validating the algorithm Quadrature phase shift keying (QPSK) signal under additive white Gaussian noise (AWGN) and fading environment is considered as PU signal. Sensing performance is analyzed using Monte-Carlo methods. In this work, first determined the optimum value of sensing period to maximize the achievable throughput for the Cognitive Radio Network (CRN) with constraint that licensed users are sufficiently protected as per the IEEE 802.22 rules. Secondly, optimum number of users required in cooperation using AND/OR/MOST rule based on total error rate is determined.

Finally, the cooperative sensing algorithm is implemented with optimum values of sensing period. The rest of paper is organized as follows.

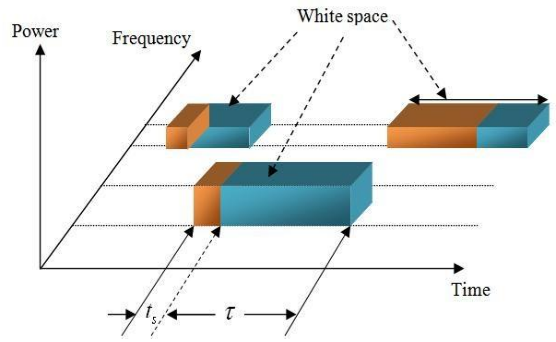

Figure 1.Sensing period effect on CR user transmission time

3. SPECTRUM SENSING ALGORITHM
3.1 Single Node Sensing Algorithm
The fundamental problem of spectrum sensing in CR is to discriminate between the following two hypotheses H0 (Signal is absent in the channel) and H1 (signal is present in the channel) respectively.

H0: r (n) = w (n)

H1: r (n) = hs (n) + w (n), n=0, 1, 2, …. , N-1

Where H0 and H1 are the null (signal absent) and alternate hypothesis respectively (signal present),

r[n] = [r(0),r(1),r(2),….., r(N - 1)] is the received signal sequence by CR user, N is the sample size, and h is the channel gain. Here, Noise w (n) and signal s (n) are assumed as Gaussian,Independent and identically distributed (iid) random process.With both has zero mean.In addition, we assumed that the primary signal is independent of the noise.

$$T(r) = \sum_{n=0}^{N-1} |r[n]|^2 \underset{H1}{\overset{H0}{<\lambda}} \quad (I)$$
$$>\lambda$$

Where λ is the detection threshold. The probability of detection (Pd) and probability of false alarm (Pf)for a given$\lambda$and observation period (ts) are:-

$$Pd(\lambda, ts) = P(T(r) > \lambda(H1)) \quad (II)$$

Where ts is the observation period in a total available vacantperiod (T), fs is the sampling rate.

3.2 Sensing throughput tradeoff

The optimal sensing period is computed at which the highest throughput for the CR Network is achieved with desired (Pd)and (Pf) based on energy detection. Figure 1 shows the sensing period effect on CR transmission time. In this figure is the total vacant space or unused frequency band at a particular time duration, ts is the sensing period of CR user, and t is the transmission time available for CR user. From the figure, as the sensing period is more, the transmission time for CR user becomes less within an available vacant space (white space). Here, the objective of sensing throughput trade-off is to find the optimal sensing period (ts) for each frame (T) such that the achievable throughput of CR network is maximized while the PUs are sufficiently protected. Let $C0$ and $C1$ as the throughput of the CR network when it operates in the absence and presence of licensed user respectively. It is assumed that the primary and secondary user's signal are Gaussian, white and independent of each other.

Then, $C0$ and $C1$ are computed as

$$C0 = \log2\,(1 + \gamma s) \qquad (1)$$

$$C1 = \log2\,(1 + \gamma s/1 + \gamma p) \qquad (2)$$

Here, ($H0$) and ($H1$) are the priori probabilities forwhich the licensed user is inactive and active in the frequencyband respectively. Obviously, ($H0$) + ($H1$) = 1.

3.3 Distributed sensing using hard decision fusion logic

In this section, distributed sensing using multiple distributed CRs are considered. Figure 2 shows the cooperative sensing with selected nodes. In this figure, all CR nodes are detecting the PUs activity in the selected band to be scanned. However,all the nodes, The selection of nodes depends on the environment in which CR senses the band and belief on CR (it should not be malicious user).Assume that there are m number of nodes are selected for cooperation to achieve the global decision. And the received signals of all nodes are independent, then, the hypothesis test takes the following form,

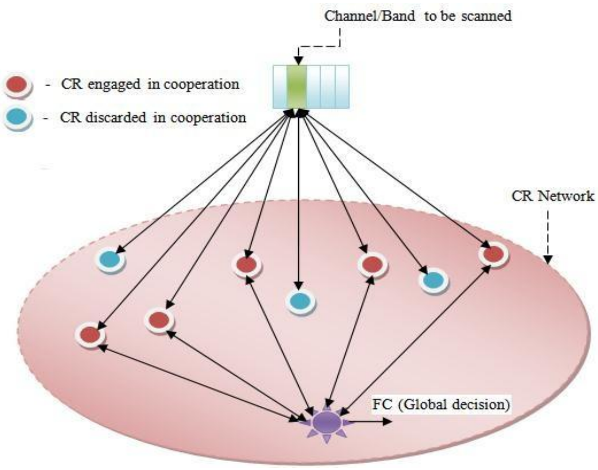

Figure 2. Cooperative sensing model

$$H0: rm(n) = wm(n), m = 0,1,2, \ldots, M-1$$

$$H1: rm(n) = hmSm(n) + wm(n), n = 0,1,2, \ldots, N-1$$

The cooperative detection probability and false alarm probability of OR fusion is,

$$\mathbf{Q}f - OR = \prod_{m=1}^{M}(1 - Pf, m) \qquad \text{-----}\ (3)$$

In case of AND logic, the FC decides H1, if and only if all of the nodes in the cooperation have decide H1. The sum of the binary bits is equal to number of nodes in the cooperation.The cooperative detection probability and false alarm probability of AND fusion is,

$$\mathbf{Q}d - AND = \prod_{m=1}^{M}(Pd, m)$$

$$\mathbf{Q}f - AND = \prod_{m=1}^{M}(Pf, m) \quad \text{- - - -}\ (4)$$

Finally, the MOST logic decides H1 based on the voting rule. The sum of binary bits is more than half of the nodes in the cooperation.The cooperative detection probability and false alarm probability of MOST fusion is,

$$\mathbf{Q}d - MOST = \sum_{m=nd}^{M}\binom{M}{m} Pd, m(1 - Pd, m)^{M-m}$$

$$\mathbf{Q}f - MOST = \sum_{m=nd}^{M}\binom{M}{m} Pf, m(1 - Pf, m)^{M-m}$$

-----(5)

3.4 Simulation Results

In order to illustrate the performance of proposed spectrumsensing algorithm, QPSK signal is considered under AWGN and Rayleigh fading channel environment. The energy detector estimates the energy of the received signal within the desired frequency band and compares it with a threshold (λ) as given in equation 1. In the simulation, the prior probabilities ($H0$) and ($H1$) are considered as 0.8 and 0.2. Since the non- existence of closed form solution for $Pd$and Pf,the performance of the detection is analysed using Monte-Carlo methods of 10000 iterations.

Figure3 illustrates the relation between achievable throughput verses sensing period. From the figure, it is seen that the achievable throughput of the CR user is more when the licensed user is inactive in the channel. Figure 4 illustrates the Optimal sensing period for distributed spectrum sensing using different hard decision logic.From the figure, it is clear that the sensing time reduces as the number of CR users increases. It is also seen that, the MOST logic requires less sensing time compared to OR, AND fusion logics with same number of CR users in cooperation.

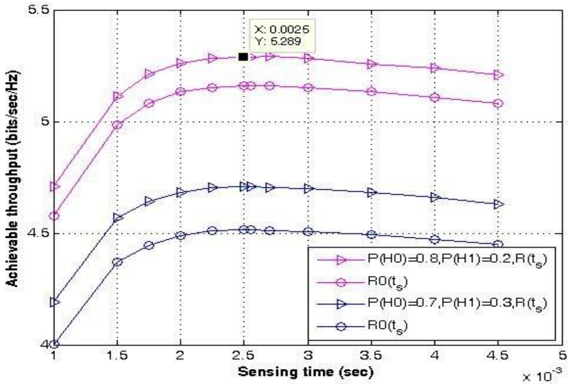

Figure 3.Achievable throughput Vs observation time the fixed SNR

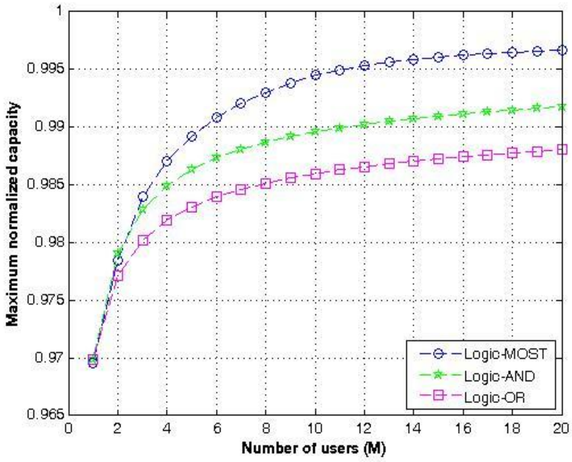

Figure 4.Optimal sensing period for distributed spectrum sensing using hard decision fusion

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