Optimal Weighted Algorithm Based Cognitive Radio Networks for Cooperative Spectrum Sensing

Girish Tiwari[1], Aakash Thakkar [2]

[1]*Prof. Department of Electronics and Communication Ujjain engineering college ,Ujjain (M.P.) India*

[2]*M.E. Research Scholar Department of Electronics and Communication, Ujjain engineering College, Ujjain (M.P.),India*

Abstract---Spectrum sensing is a significant part in construction of cognitive radio network and one of the most mandatory mechanisms of Cognitive Radio (CR) to find the unused Spectrum. As it is essential function performed by cognitive radio and the operation of the other cognitive radio services are based on spectrum sensing. For achievement of accurate and fast detection of the limited and well defined spectrum resources and for improvement of the utilization of idle spectrum in cognitive radio networks, a fusion rule based Weighted Algorithm based theory for cooperative spectrum sensing (CSS) is proposed. Compared with conventional method, the proposed algorithm improves Performance to sense the vacant holes in spectrum primarily in the area where SNR is low. A novel kind Of detection probability and false alarm probability is introduced to estimate the consistency of sensing node.

Keywords--- *Cognitive Radio, Spectrum sensing, spectrum utilization, Spectrum holes, Energy detection, dynamic Spectrum access*

I. INTRODUCTION

Wireless Communication has observed a significant growth in the last few year resultant in the broad range of wireless applications. This show the raise in the requirement of the additional bandwidth for the number of purpose and application. although, throughout the partial and precious bandwidth the challenge for meeting the existing demands cannot be satisfied with the fast growth of wireless communication services and applications, the increasing demand of limited spectrum resources will sooner or later cause problems with spectrum insufficiency. Latest investigations have pointed out that the majority of the allocated spectrum is used infrequently and unproductively. Cognitive radio (CR) is one of the spectrum sharing technologies. It can efficiently improve the spectrum shortage problem and spectrum efficiency. While there is a remarkable increase in the access of limited spectrum recent years to satisfy the desired demand for spectrum, Cognitive Radio is found to be a desired approach for improvement in spectrum efficiency[3]. The technology permit unlicensed secondary users (SUs) to use the spectrum only when they do not Interfere with the existing licensed primary users (PUs).[1]

A necessity of cognitive radios is that their communication should not cause any unwanted and destructive interference to PU. specifically, cognitive users which are willing to use licensed spectrum can use it as long as the PU is absent. On the other hand, as the PU comes back into procedure, the cognitive users must evacuate the spectrum immediately for avoiding interference causes with the PU. The primary user (PU) of a existing spectrum has the special right to utilize that band. at the present time, the demands for the RF band is continually increasing due to the expansion of different wireless services and applications, although it has been showed that the efficiency of spectrum utilization is enormously small ,the problem is solved by the Cognitive radio (CR) for dealing with problem of spectrum utilization .

An necessary condition of CRs is rapidly fill in spectrum holes (i.e., portions of the licensed but unused spectrum) without interference to primary user. This assignment is facilitate by spectrum sensing, which is denoted as a procedure to achieve alertness regarding the opportunities for dedicated spectral and continuation of Primary User in specified location.[2]–[4]

For spectrum sensing, there are several methods such as energy detection, feature detection, matched filter detection, covariance and wavelet based detection. If the appearance of a signal is not known, it is realistic to consider and use the energy detector (ED). In [4], it is understood that the noise is having characteristics of zero mean Gaussian, thus the energy can be described as a addition of the square of statistically self-determining Gaussian variables. In order to resolve the problems of hidden terminal, cooperative spectrum sensing (CSS) is imposed in cognitive radio systems. Reference [6] examined the cooperative spectrum sensing optimization with energy detection. As in [7], for the soft cooperative spectrum wideband sensing scheme based on the subspace method is discovered. Reference [8] intense on the scheme of spectrum sensing using linear soft combined schemes, by supplying beam-forming along with secondary users to a common fusion center. In [9], a cooperative spectrum sensing scheme for cognitive radio networks working on particle swarm optimization is introduced.

In this paper, our center of attention is problem of cooperative spectrum sensing. Established on the construction of weighted cooperative spectrum sensing, a number of linear soft combination schemes are executed at the fusion center, combined with the characteristics of Weighted algorithm we considered the cooperative outcome to find out the weighted factor and then decision threshold performing in favor of more logical weighted value distribution. The results confirms that the proposed algorithm with the purpose of detection is performed is significantly improved.

II. SYSTEM MODEL

1. Cooperative Spectrum Sensing Model:
For detection of primary user when all Secondary and Primary users access the spectrum which allotted commonly. Each SU executes energy detection separately at their individual spectrum and then transmitted their sensing information to the Data Fusion centre. The final decision is made at the DFC. Assume N cognitive radios in the system convey the locally sensed data to Fusion centre. The test of binary hypothesis on the *n* th time instantaneous is calculated as

$$Y_0: \quad P_i(n) = W_i(n) \quad ; \quad i = 1,2\ldots\ldots N \qquad (1)$$

$$Y_1: \quad P_i(n) = G_i h(n) + W_i(n) \quad ; \quad i = 1,2\ldots\ldots N \qquad (2)$$

Where h(n) , $P_i(n)$ and $G_i(n)$ denote the signal transmitted by the primary user, the received signal by the *i* th secondary user and the channel gain . Besides, W_i is denoted as the sensing noise for the *i* th secondary user, which is set to zero mean additive white Gaussian noise. In Cooperative spectrum sensing individual cognitive radio perform its personal 1 bit decision. $G_i(n)$ is the channel gain between Primary User and the i-th Secondary User, which contain any channel effects, such as shadowing, propagation path loss and multipath fading. Considering flat fading channels in between Primary User and the cooperative Secondary User, in which the coefficients fading vary from time to time, whereas their probability distribution functions are calculated from the channels fading characteristic.

2. Energy Detection:
For energy detection method of spectrum sensing decision method is primarily single threshold and double threshold energy detection, single threshold method is compares values of detected energy with the predetermined threshold, and build the tough decision of Primary Users with and without.

$$E = \frac{1}{N}\sum_{N=1}^{N}|Y(n)|^2 \qquad (3)$$

where y(n) is received signal, N is the number of observations, E denotes the energy of received signal.

$$P_f = Q\left[\frac{U - N\sigma_w^2}{\sqrt{2N(\sigma_w^4)}}\right] \quad (4) \qquad P_d = Q\left[\frac{U - N(\sigma_x^2 + \sigma_w^2)}{\sqrt{2N(\sigma_x^2 + \sigma_w^2)^2}}\right] \quad (5)$$

where, σ_w^2 and σ_x^2 are the noise variance and signal variance, respectively and P_f and P_d are probability of false alarm and probability of detection. Q denotes the Gaussian tail

$$U = Q^{-1}(P_f)\sqrt{2N\sigma_w^4 + N\sigma_w^2} \qquad (6)$$

where Q^{-1} denotes the inverse Gaussian tail probability Q function If double threshold energy detection threshold value are λ_{1i} and λ_{2i} single threshold value is λ_i decides result M_i then M_i is given for the single threshold energy detector

$$M_i = \begin{cases} 1 & E \geq \lambda_{i1} \\ 0 & otherwise \end{cases} \qquad (7)$$

For double threshold energy detector

$$\begin{aligned} M_i &= \{1 \quad E \geq \lambda_{2i} \\ M_i &= \{0 \quad 0 \leq E \leq \lambda_{1i} \\ M_i &= \{E \quad \lambda_{i1} \leq E \leq \lambda_{2i} \end{aligned} \qquad (8)$$

therefore, individual Secondary users obtains two variety of detection results, i.e. observed energy value E_0 and local decision , here we have

$$E_0 = \sum_{j=1}^{N} X_{IJ}^2 \qquad (9)$$

Where X_{IJ} is jth sample of the received signal and N=2TW where T is detection time and W is the signal bandwidth, where N is kept large. The Probability of detection and false alarm denoted by P_d and P_f are related to higher threshold λ_{2i}. In this if at least n cognitive radio takes the decision in favor of primary user then only the decision at fusion centre will be in favor of primary user. Optimum value of Energy given as

$$E_{opt} = \min\left(z, \left|\frac{z}{1+\alpha}\right.\right) \qquad (10)$$

where z is represents general voting rule in decision fusion centre

$$\text{Where} \quad \alpha = ln\left[\frac{P_F}{1-P_M}\right] / \ln\left[\frac{P_M}{1-P_F}\right] \qquad (11)$$

Where P_F and P_M is probability of false detection and probabilty of missed detection.when the cognitive radio is having equal signal to noise ratio of primary user,in that case the probability of detection and probability of false alarm at fusion centre is given as

$$Q_d = \sum_{n=r}^{z} \binom{z}{k} P_d^r (1-P_d)^{z-r} \qquad (12)$$

$$Q_f = \sum_{n=r}^{z} \binom{z}{k} P_f^r (1-P_f)^{z-r} \quad (13)$$

Q_d and Q_f denotes Gaussian tail probability function of detection and missed probability

III PROPOSED FUSION RULE BASED WEIGHTED ALGORITHM

When the process of Cognitive Radio spectrum sensing is done, some practical problems arrived and causes effect to process, like problem of hidden terminal and the harmful impact of fading channel, which are entirely depends upon the optimization and realization of local spectrum sensing. It may not consistent enough to make sure for achieving the sensing performance condition. In actuality, by taking benefit of the spatial diversity gain of multi-user, numerous spatially circulated Secondary Users are regularly incorporated to carry out cooperative spectrum sensing. During cooperative spectrum sensing, performance of sensing can improved efficiently. In the procedure of cooperative spectrum sensing, each Secondary User initially performs the spectrum sensing locally and then reports the result of observation to the fusion center separately, and then the fusion center creates the global decision. In fusion center, to make the perfect global decision, we have logically three types of fusion operation, i.e., OR-operation, AND-operation, and K-out-of-N-operation.

In the OR-operation, the global decision states that the Primary User exists as long as until one Secondary User senses the Primary User.

In the AND-operation, Primary User is examined to be emerged only when all Secondary Users report Primary Users presence.

In the K-out of- N operation , the global decision declares the emergence of Primary User when at least *K* Secondary Users determines a Primary User existence. For the purpose of ease in our study, we suppose that each Secondary User has the equal sensing ability. therefore, the probabilities of false-alarm and miss-detection of the three types of fusion rules throughout cooperative spectrum sensing are specified as

OR- operation :

$$P_m = P_m i^N \quad (14)$$

$$P_f = 1-(1-P_{fi})^N \quad (15)$$

AND-operation :

$$P_m = 1-(1-P_{mi})^N \quad (16)$$

$$P_f = P_f i^N \quad (17)$$

K-out of N-operation:

$$P_m = 1-\sum_{n=k}^{N} \binom{N}{n}(1-P_{mi})^j P_m i^{N-n} \quad (18)$$

$$P_f = \sum_{n=k}^{N} \binom{N}{n}(1-P_{fi})^{N-n} P_{fi}^n \quad (19)$$

Where P_{mi} and P_{fi} are the probabilities of missed detection and probabilities false detection at the ith distributed secondary user, whereas N is the total number of Secondary Users participating in Cooperative spectrum sensing. therefore, the problem of optimization in cooperative spectrum sensing arises naturally, which is the optimal fusion rule with the given total collaborative number.

Both OR-operation and AND-operation are two special cases of the K-out-of-N-operation, correspondingly to K=1 and K=N cases, as a result, the it can optimize fusion rule for cooperative spectrum sensing which can be cause the problem of derivation of the optimal parameter K for decreasing the total detection errors probability. In particular, since the miss-detection and false-alarm errors take place corresponding to Y_0 and Y_1 respectively. Our objective function is then calculated in terms of the linear grouping of such two types of detection errors probabilities with the spectrum use weights information of Primary Users. Using Equation (1) and (2)

$$P_0 = P(Y_1) P_{mi} + P(Y_0)P_{fi} \quad (20)$$

Where $P(Y_1)$ and $P(Y_0)$ represent the probability of primary user presence and absence respectively ,and also they satisfies the law of probability i.e. $P(Y_1)+ P(Y_0) = 1$

After Substituting equation (18) and (19) into equation into (20) we can get the desired function for the optimization of parameter k

$$P_0= P(Y_1)[1-\sum_{n=k}^{N}(1-P_{mi})^n]P_{mi}^{N-n} + P(Y_0) \sum_{n=k}^{N} P_{fi}^n (1-P_{fi})^{N-n}$$

as k is a discrete variable, the optimization method for parameter k therefore it can be build up by performing the discrete difference operation on it

Then, the optimal parameter value of fusion rule k for cooperative spectrum sensing can be obtained as

$$\acute{K} = \min \frac{\left[N ln\frac{1-P_{fi}}{P_{mi}}\right] - \ln\frac{P(Y_1)}{P(Y_0)}}{ln\frac{1-P_{fi}}{P_{mi}} + \ln ln\frac{1-P_{mi}}{P_{fi}}} + 1, N$$

$\acute{K}$ for being the function integer. we can note down that the optimal fusion rule depends on the spectrum occupancy and availability statistics of Primary User and then to detect condition of channel as it directly affects P_{mi}

III. SIMULATION RESULTS

We have comparison and simulation results of weighted cooperative spectrum sensing with the fusion rule base based cooperative spectrum sensing algorithm using a weighted approach with a enhanced decision strategy. The algorithm combines soft and hard information fusion rules by utilizing the detection model. Furthermore, it takes into consideration diversity of the local observations of distributed Secondary users by weighting the basic probability assignment function to enhance the influence of more reliable users to the global decision of evidence fusion. Simulation results show that the proposed algorithm performs better than the traditional weighted cooperative method of detecting spectrum holes.

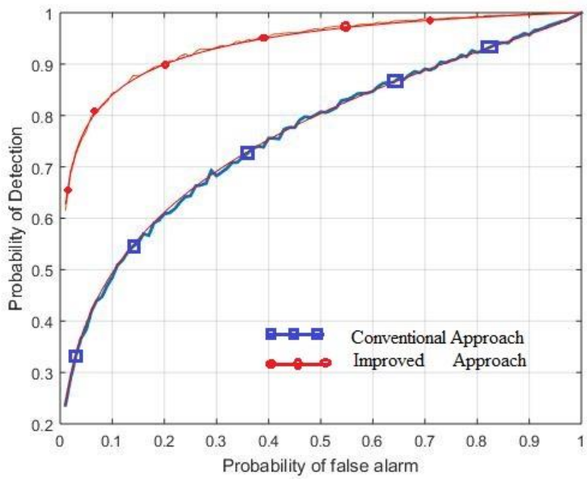


Fig 1: showing Results of Probability of detection Vs Probability of False alarm

In the simulations we have considered the total number of participating CR i.e. N=10 and number of samples n=1000. It is verified from the curves that proposed algorithm gives better detection probability than conventional algorithm. Plots in figure 1 shows the increase in the detection probability of primary user as probability of false alarm is increased in which proposed algorithm gives improved detection probability than conventional algorithm.

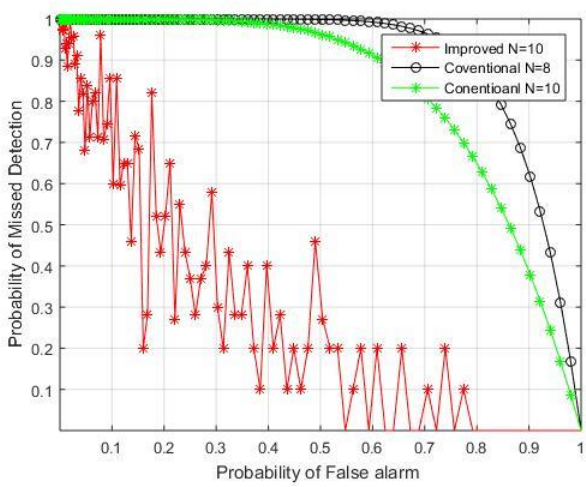
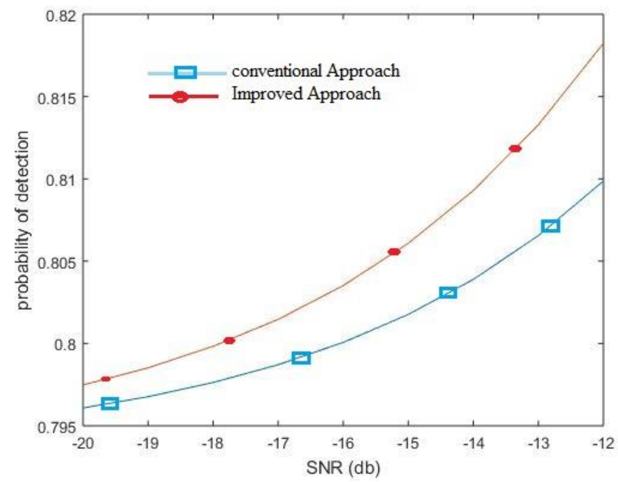


Fig 2 showing the Results of Probability of False alarm Vs Probability of Missed detection

Probability of error is sum of probability of false alarm and probability of missed detection. It is visible from the curves that proposed algorithm gives lower error. Fig 3 represents the increase in the detection probability of primary users as the number of cooperative CRs increases for different values of primary user SNR. As it is expected detection probability of cooperative spectrum sensing increases with the increase in SNR of the primary user.



IV. CONCLUSION

In this paper, In order to improve the performance of spectrum sensing, we have proposed the fusion rule based cooperative spectrum sensing algorithm using a weighted fusion rule with strategy of enhanced decision. The algorithm combines soft and hard information fusion rules. We achieve the required expression of the cooperative spectrum sensing using optimal fusion rule. On performing desired simulations and then discussing results with modified spectrum vacancy and occupancy information and statistics of Primary User. We examined the expression for the probability of the false-alarm detection. By seeing the beginning of simulation results, we verified that performance of Spectrum sensing is improved. Simulation results also indicates that the proposed algorithm performs better with AND operation decision combination rule and Logical OR operation combination rule

V. REFRENCES

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