Cooperative Spectrum Sensing in Cognitive Radio using Flower Pollination Optimization Algorithm

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Abstract- *Due to the rapid increased in the day by day users for spectrum cause scarcity of it. So due to its limitation and for the effective utilization of spectrum Cognitive Radio (CR) technology came into existence. This CR consists of its four main modules, which are: Spectrum sensing, mobility, sharing and management. Among which spectrum sensing is the keystone part, as due to the dependency of other parts on it. For this many evolutionary algorithms are applied, so may that an optimized result may be obtained. This paper focuses on the optimization problem of spectrum sensing in cognitive radios. The algorithms which are used as genetic, particle swarm, ant colony, simulated annealing, flower pollination, cuckoo search and so more, also they are directly related to the natures, among which FPA (Flower Pollination Algorithm) is one of these. This FPA has compelling qualities. This is somehow related to the pollination process of flowers. Due to its good convergence rate, is used for spectrum sensing.*

Keywords: *Cognitive radio, cooperative spectrum sensing, Flower pollination, evolutionary algorithms, Levy distribution.*

I. INTRODUCTION

Cognitive radio is the most emerging technology now a day. It enables effective utilizations of spectrum. That is the reason it as an efficient approach in wireless communication to reduce the spectrum scarcity issue. The unlicensed users who are also called Secondary users are allowed to use the spectrum band of licensed user or called Primary users (PU), without causing interference to PU. Now this was the critical issue to detect those bands of spectrum for the purpose of requirement by SU using this cognitive radio (CR) technology. These CR users are itself secondary users.

The present spectrum sensing techniques can be broadly classified into three main categories namely: 1) Non-cooperative, 2) Cooperative and 3) Interference based sensing techniques. Further Non cooperative technique consists of three parts, which are as follows: a) Energy detection, b) Matched filter detection and c) cyclo-stationary based detection. Among these techniques Cooperative spectrum sensing has been widely used, since it follows cooperation among all secondary users. As spectrum sensing becomes difficult task, due to the fading, shadowing and time fluctuating natures of remote channels [6].To overcome these effects, cooperative spectrum sensing schemes have been proposed to have the spatial diversity among all SUs. Among the entire modules of CR, spectrum sensing has more importance, because if spectrum is sensed and detected then only remaining part will be concerned on. This is the reason it is called as keystone part of cognitive radio technology. The presence of Primary User leads to probability of detection P_d and absence leads to probability of false detection P_f. The classification for sensing techniques as a block diagram is shown in the Figure1.

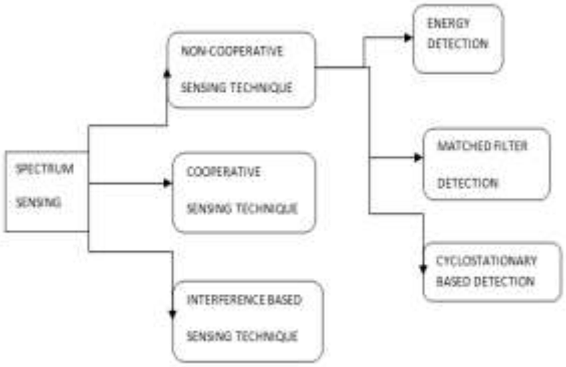

Fig1. Block diagram for the spectrum sensing techniques.

The main objective is to maximize the probability of detection (P_d) by having maximum value for P_d, while keeping an appropriate value for probability of false detection ($P_{f.}$)[5].

II. SYSTEM MODEL

As discussed above in the introduction part, that there are three types of sensing techniques, out of which energy detection is mostly used, due to its less complexity. For the signal detection this energy detection method will be effective which uses an energy detector to identify the presence or the absence of the signal in the respective spectrum band. It is the most common approach for spectrum sensing due to its lower computation required and no need of any prior information about the primary signal [7]. It is a simple detector which detects the total energy of the received signal. A threshold value is required for comparison of the energy detected by the detector for each of the SUs. If the value of energy signal is greater than the threshold value indicates the presence of the primary user and less indicates absence.

In the below block diagram, the concept of hypothetical test is used, in which two of the parameters, i.e. H_0 = absence of the signal, H_1 = presence of the signal are used.

Fig 2. Basic block diagram for energy detection mechanism

In the fig2, the received signal, s(t) and n(t) is passed through the BPF (band pass filter) with bandwidth B and than by integrator for a specific time interval. The output y(t) from the integrator block is then compared to a threshold which is predefined. Based on the comparison value absence or presence of PU is decided. The value of the threshold will be constant or may vary it is based on the channel conditions [1]. In the fig.3 [3] there is M number of SUs collectively considered for identifying the presence or absence of the primary user signal. In this cooperative spectrum sensing, all the Cognitive users (CU) send their sensing information about the presence of the PU to a common decision centre, named as Fusion Centre (FU). Depending upon the decision of availability a binary hypothetical test is performed which is as:

$$X_j[n] = \begin{cases} W_j[n] \ldots\ldots\ldots\ldots\ldots.\ldots..H_0 & .1 \\ g_j S[n] + W_j[n] \ldots\ldots\ldots H_1 & .2 \end{cases}$$

From the above1 and 2 equation, $X_i[n]$ is the received signal at the j^{th} SU receiver, $j = 1,2,3\ldots.M$, $n = 1,2,..L$. The total number of samples is given by 2BTs which is L.B and Ts are the bandwidth as well as sensing period for the signal. $W_j[n]$ is the additive white Gaussian noise (AWGN) with zero mean and variance of σ^2_{wj}, g_j is channel gain between the Primary User and j^{th} SU respectively. The signal which is transmitted by the PU is S[n], where this signal is considered to be independent [2]. At the decision centre, the received signal of SU is in the form: $y[n] = \sqrt{P_{Rj}} h_j x[n] + N[n]$, where P_{Rj} is the power transmitted by j^{th} Secondary Users, h_j is the channel gain for the j^{th} Secondary User and Fusion Centre link and N[n] is an AWGN noise in the j^{th} Secondary User and Fusion Centre link by assuming that its mean is zero and its variance is δ_j^2. When all the Secondary User signals are received and before a decision can be made, at the decision centre the total energy for all the secondary user paths is evaluated and summed up by $Z = \sum_{j=1}^{M} \omega_j Z_j$,where ω is the weighting coefficient of the j^{th} path and $Z_j = \sum_{n=1}^{k} U|[n]|^2$ is the energy from the j^{th} Secondary User signal. The energy is calculated over all samples for the j^{th} Secondary User signal.

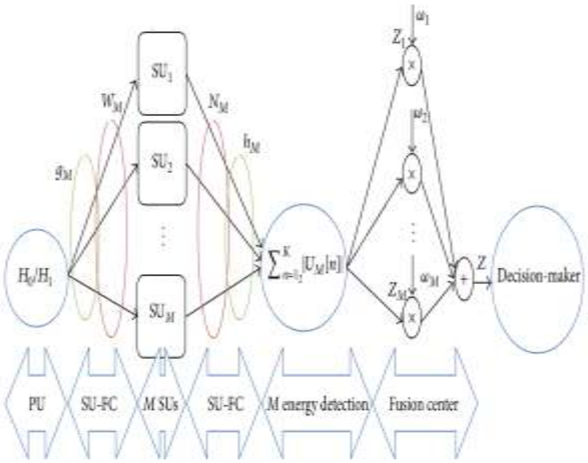

Fig 3[3]. Block Diagram for the soft decision based cooperative spectrum sensing.

The mean and variance for the calculated test statistics Z under both hypotheses H_0, H_1 are given by:

$$En(Z/H_0) = \sum_{j=1}^{M} \omega_j K\sigma_{0.j}^2 \qquad .3$$

$$En(Z/H_1) = \sum_{j=1}^{M} \omega_j K\sigma_{1.j}^2 \qquad .4$$

$$Vari(Z/H_0) = \sum_{j=1}^{M} 2\omega_j^2\, K(\sigma_{0,j}^2 + \delta_{1,j}^2)^2 \qquad .5$$

$$Vari(Z/H_1) = \sum_{j=1}^{M} 2\omega_j^2\, K(\sigma_{0,j}^2 + \sigma_{1,j}^2)^2 \qquad .6$$

Also variance for equation 5 and 6 is given as,

$$Vari(Z/H_0) = \omega^T \phi_{H_0}\omega \quad and \ Vari(Z/H_1) = \omega^T \phi_{H_1}\omega$$

Where, $\omega_i = [\omega_1, \omega_2, \ldots\ldots\ldots\ldots \omega_M]^T$ is defined as the weighting coefficients vector transpose.$\sigma_{0,j} = P_{Rj}\, |h_j|^2 \sigma_{wj}^2 + \delta_j^2$ and $\phi_{H0} = diag(2K\sigma^4_{0,j})$ are the variance and covariance of $y_j[n]$ under *H0* while $\sigma^2_{1,j} = P_{Rj}\, |hj|^2|g_j|^2 \sigma^2_s + \sigma^2_{0,j}$ and $\phi_{H1} = diag(2K(P_{Rj}\, |hj|^2|g_j|^2\, \sigma^2_s + \sigma^2_{0,j})^2)$. After finding the test statistics Z, the likelihood ratio test is used for identifying both hypotheses. In this α is the energy threshold [9]. So P_d and P_f can be summarized as [2]:

$$P_d = P(Z > \alpha/H_1) = Q\left(\frac{\alpha - En(Z/H_1)}{\sqrt{Vari(Z/H_1)}}\right) \qquad .7$$

$$P_f = P(Z > \alpha/H_0) = Q\left(\frac{\alpha - En(Z/H_0)}{\sqrt{Vari(Z/H_0)}}\right) \qquad .8$$

When, equations 3, 4, 5 and 6 are put into 7 and 8,we have this generalized form of an equations,

$$P_d(\omega) = Q\left(\frac{Q^{-1}(P_f)\sqrt{\omega^T \varphi_{H_0}\omega} - \omega^T\theta}{\sqrt{\omega^T \varphi_{H_1}\omega}}\right) \qquad .9$$

Where, this Q is nothing but Q(x) function and $\Theta = [\Theta_1, \Theta_2, \Theta_3, \ldots\ldots\ldots, \Theta_M]$, $\Theta_j = \sigma_s^2 K P_{R,j}|h_j|^2|g_j|^2$.

This optimized $P_d(\omega)$ will give the accurate result in soft decision based cooperative spectrum sensing and in the above equation it clear seems that final probability of detection with ω depends on the, weighting coefficient vector and this algorithm is having an appropriate value for the weighting coefficient, so may that $P_d(\omega)$ can be maximized.

III .FLOWER POLLINATION ALGORITHM

A significant number of this present reality design issues in engineering and industry are based on the multi-objective or multi-criteria type. These type of problems many of the time campaign to each other the reason makes it difficult to utilize any single configuration choice without trade off, so common approaches are utilized to give great approximations to the approach [10]. According to the survey of researchers there are millions of flowering plants are available in nature and about 85 per cent of all plant species are flowering species. The principle motivation behind a flower is eventually propagation by means of pollination. Flower pollination is ordinarily connected with the exchange of dust, and such exchange is regularly connected with pollinators, for example, insects, winged creatures, bats and different creatures [4].Insects generally follow two ways, either leave the fleck and fly to another fleck of the same species, or stay within the fleck but switch to an alternative species [12].The concept of Flower Pollination Algorithm (FPA) was inspired by the same process of flower pollination in flowering plants. This FPA algorithm has been reached out to multi-objective issues and observed to be extremely effective. This algorithm is based on the four guidelines:

Rule I. Biotic and cross-pollination together forms global pollination process, and pollen carrying pollinators move in such a way that they follow Levy flights.

Rule II. Abiotic pollination and self-pollination are used in local pollination method.

Rule III. Insects as pollinators basically develop flower constancy, which is equivalent to a reproduction probability that is directly linked to the similarity of two flowers involved.

Rule IV. The collaboration and exchanging of global pollination and local pollination can be obsessed by a switching probability given as $p \epsilon$ [0, 1], by slight inclination towards local pollination.

To figure the upgrading formulas, these rules have to be converted into proper updating equations [4]. In the global pollination step, it is mentioned that flower pollen gametes are carried by pollinators such as birds, insects and the reason makes pollen to travel over a long distance as carried by these insects. On considering Rule I and Rule III together they can be formulated as [11]:

$$x_i^{t+1} = x_i^t + \gamma L(\lambda)(g_* - x_i^t) \qquad .10$$

In the above equation, x_i^t is the pollen i or x_i as a solution vector at t number of iterations. The current best solution is g_*, which is found among all solutions upto the current iterations. γ is defined as a scaling factor to control the step size. L(λ) is a Levy flight based step size, that is related to the strength of the pollination also termed as step size parameter. As the tendency of insects to move over a distance with different steps . To describe this feature levy flight distribution is used[10], with considering condition i.e. L > 0 is drawn,

$$L \sim \frac{\lambda \Gamma(\lambda) \sin(\pi\lambda/2)}{\pi} \frac{1}{s^{1+\lambda}} \ , s \gg s_0 \gg 0 \qquad .11$$

Here, Γ(λ) is the standard gamma function with a condition that this distribution is valid for value of s > 0 i.e. for larger steps. Generating the pseudo-random step size is not having much importance which correctly obeys this levy distribution. There are many other methods are available for drawing such random numbers. Mantegna algorithm is one of the efficient way for drawing step size s by using two C and D Gaussian distributions [4],

$$s = \frac{\mathrm{C}}{|\mathrm{D}|1/\lambda} \qquad .12$$

Here, $C \; as \; N(0, \sigma^2)$. This is the samples which are drawn from Gaussian normal distributions also $D \epsilon \; N(0,1)$. This can be easily analyzed by the pseudo code described. And the for the local pollination the equation is given by,

$$x_i^{t+1} = x_i^t + \epsilon(x_j^t - x_k^t)$$

From above equation x_j^t and x_k^t are pollens from the different flowers of the same type. This equation will be followed when rand value is less than the switching probability P. It will be more clear by the pseudo code of FPA.

IV. FPA PSUEDO CODE

Step 1

**Define the population size, number of iterations and switch probability $p \in [0,1]$.

**Define the d-dimension for the search space with upper and lower conditions, considering weights.

**Initialize the population of n gametes or n flowers with random solutions.

**In the initial population, go for g_* best solution.

- for t=1 : N_iter (number of iterations) € (1…N_iter).
- for i=1:n ,where n is all the flowers in the population.
- if rand > p
- Form a step vector (L), by levy distribution approach bound in dimension (d). If simple bound condition is fulfilled then ok, and if not then go for local pollination and assign the random value in variable.
- end for
- end for

Step 2

**Evaluate new solution in the form of function with the total energy which was calculated for all the secondary users.

**Check this new evaluated function with that of fitness function, if the value for fitness function is greater than the new function, update the equation.

**Depending upon the above criteria update the global best to get an optimized solution.

Fig 4.The pseudo code for Flower Pollination Algorithm is defined above.

The activities in pollination of the flower occur at both level of global and local [11]. It can be applied in two ways like exploitation and exploration as local and global pollination.

V. PARAMETERS FOR SIMULATION AND BASED RESULT

MATLAB software is used for the implementation purpose. The parameters [2][5] are shown below which are used in this paper. In [5] it is mentioned that channel noise and channel gains are randomly generated.

Receiver Parameters	***Value***
Probability of false detection	*0.25*
PU transmit power σ^2_s	*0.369*
SU transmit power P_{Rj}	*0.1523*
Channel Gains g_j	$0.01 \leq g_j \leq 0.1$
Channel Gains h_j	$0.01 \leq h_j \leq 0.1$
Bandwidth B	*6000000 Hz*
Sensing time Ts	*0.000025 sec*
Switching Probability p	*0.2*
Population size/secondary user's	*10*
PU-SU channel noise σ_{wj}^2	$0.1 \leq \sigma_{wj}^2 \leq 1.0$
SU-FC channel noise δ_j^2	$0.1 \leq \delta_j^2 \leq 1.0$

The values taken above are practical, range for p is 0 to1.Considering all the above parameters this algorithm is analyzed. The results will vary for every run, because as process is random. While running 10 times an average solution is considered and is optimized. In fig 5, a graph is shown which average solution is 0.8327, nearly 83 per cent, which results without applying any algorithm.

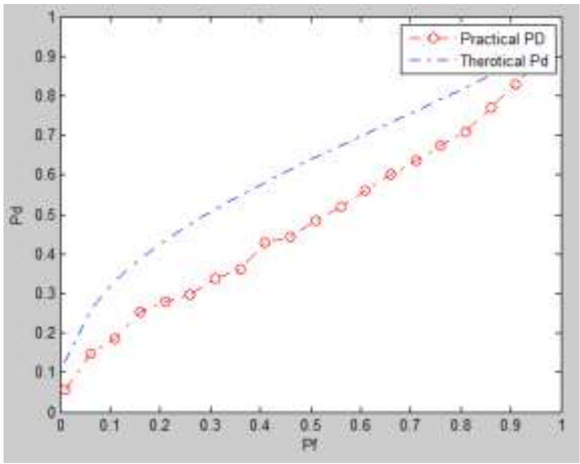

Fig 5. General graph for P_d and P_f

In the above graph two lines are drawn, based on practical as well as on theoretical approach.

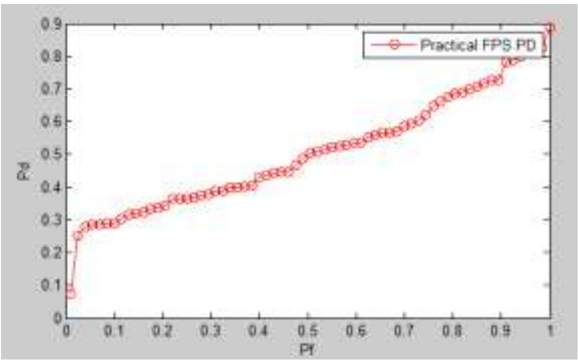

Fig 6. P_d Vs P_f while applying FPA algorithm

The above graph fig 6. shows that with increase in probability of detection, the value for Pd extent up to 0.8869, which means near to 89 per cent. Hence this is the optimized result, which comes by flower pollination algorithm.

VI. CONCLUSION

The algorithm which is applied in this paper is stochastic in nature. This is having an optimized results among other algorithms used. The levy distribution concept is used in this paper for the motion study of levy flights or in other words for the study of random motions by pollinators which respectively depends on value of s (step size). There are various methods for drawing such random number. Due to dependency on s, it becomes challenging task to set a value for step size(s). Also other methods can be used instead of levy distribution, for the improvement of quality and speed requirements.

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