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Clustering Genetic Algorithm for Cognitive Radio Network

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ABSTRACT
The well-known Cognitive Radio Network (CRN) is a promising technology to fulfill the requirements of the need of high data rates. The major mechanism to perform CRN is the ability of detecting the existence of the Primary User (PU). Availability of PU can be detected by cooperative spectrum sensing to avoid the hidden terminal and multipath fading. PU information is transmitted to the nodes or so called Secondary Users (SU). SU will forward the information through different channels to the Fusion Center to make the final decision via Soft Detection Fusion (SDF). From that, Clustering Genetic Algorithm (CGA) is proposed to optimize the probability of detection. In this paper, it is shown that the performance of CGA outperforms the Standard Genetic Algorithm. Moreover, CGA is very applicable for CRN since it is showing good performance for such complex problem where it shows faster convergence speed rather than SGA.
Keywords **–** Cognitive Radio Network, Cooperative Spectrum Sensing, Clustering Genetic Algorithm

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I. INTRODUCTION

The electromagnetic spectrum assigned to each country is restricted and this is the reason behind proposing Cognitive Radio Network. Cognitive Radio Network helps to enhance the utilization of Spectrum given to a country by reusing the wasted frequency which is assigned to absent Licensed User and using it by non-licensed user. In this case, the need of detecting the existing of licensed user or so called Primary User (PU) is the major task to before reutilize its frequency. Once the Secondary User (SU) or the sensing node detected the absence of PU, Secondary User can take over and use the frequency otherwise PU keep using its frequency. In another word, CRN always gives the priority to Licensed User and doesn't allow any influence to its QoS from Secondary User [1]. From that, Spectrum Sensing fails due to many limitations such as: hidden primary user problem. While SU is scanning the PU it is possible to fail due to hidden node which causes multipath fading and shadowing. Cooperative Spectrum Sensing is proposed to enhance the certainty of detection by assigning multi nodes to identify the existence from different locations. Therefore, each node is receiving an information from PU via a particular channel and forward the entire of information to the Fusion Center (FC) [2]. Fusion center is responsible to make the final decision based on the received information from each participated node. Aforementioned type of data fusion is called Soft Detection Fusion (SDF), which makes Decision based on raw information given to it which causes to reduce probability of false alarm and detection. On the other hand, Hard Detection Fusion (HDF) is based on collected initial decision. In this project, cooperative is done by SDF scheme to all the measurement received from nodes.

II. COOPERATIVE SPECTRUM SENSING SYSTEM MODEL.

Cooperative Spectrum Sensing Network contains Primary user which represented as PU and various number of Secondary Users from 1 to M. these SU nodes are used as relays to amplify and forward signal of PU to the Common FC. Fusion center will apply linear weighted SDF to the entire received data. Hence, refereeing to fig (1) we need to study the signal received by each node which represents two binary hypotheses according to the presence of PU signal.

PU signal is absent → H_0: $X_i\ [n] = W_i\ [n]$

PU signal is present → H_1: $X_i\ [n] = g_i\ S[n] + W_i\ [n]$

Where index (i) represent the number of SUs, i=1, 2, 3, 4, …., M. Also, index (n) represent the number of samples of the primary signal, n=1, 2, 3, 4, …., k. Secondary user reports the received signal during scanning the signal of PU as two hypothesis H_0 where the signal of the PU is considered to be absent and only receives noise $W_i\ [n]$ within the link between PU-SU. On the other hand, Secondary user receives PU signal as Hypothesis H_1 where the signal of PU is present and receives PU sampled signal $S[n]$ through channel gain g_i plus noise $W_i\ [n]$ of the PU-SU link on the same i^{th} number of SUs. Wi[n] is considered to be independent and additive white Gaussian with zero mean and variance $W_i[n] \sim N(0, \sigma_{Wi}^2)$. $S[n]$ is assumed to be independent and identically distributed (i.i.d) Gaussian random process with zero mean and variance, i.e., $S[n] \sim N(0, \sigma_S^2)$ All received sampled signal from all nodes are represented as the following two vectors $\bar{\sigma}_W = [\sigma_{W1}^2, \sigma_{W2}^2, \sigma_{W3}^2, \sigma_{W4}^2, \dots, \sigma_{WM}^2]^T$ and $\overline{X} = [X_1, X_2, X_3, X_4, \dots . X_M]^T$. The reporting channels of both links g_i, h_i between PU-SU link and SU-FC link are constant in each sensing period. A noise vector is introduced to each channel in SU-FC link and formed in a vector SU-FC link $\bar{\delta} = [\delta_{W1}^2, \delta_{W2}^2, \delta_{W3}^2, \delta_{W4}^2, \dots, \delta_{WM}^2]^T$. All received signal will reach final terminal FC as $Y_i[n] = \sqrt{P_{Ri}} * h_i * X_i[n] + N_i[n]$ which has the raw information forwarded vis SUs, which will be processed under energy detector to be averaged and squared regarding to estimate the energy received by $Y_i[n]$ in FC as projected in $Z_i = \sum_{n=1}^{K} |Y_i[n]|^2$. Hence, Z_i are utilized to formulate the resultant test statistic which is expressed in the below Equation (1). Equation of P_d expresses the subsequent result test which include the introduced weighting coefficient vector assigned by the fusion Center to optimize the probability of detection P_d of Equation (1) with a given probability of false alarm $\bar{P}_f$ [3].

$$P_d = Q\left(\frac{Q^{-1}(\bar{P}_f) * \sqrt{\vec{w}^T \Sigma_{H0} \vec{w}} - \vec{w}^T \vec{\theta}}{\sqrt{\vec{w}^T \Sigma_{H1} \vec{w}}}\right) \qquad (1)$$

Where

$\vec{Z} = [Z_1, Z_2, Z_3, Z_4, \dots, Z_M]^T$, $\vec{w} = [w_1, w_2, w_3, w_4, \dots, w_M]^T$

$Q(x) = \int_x^{+\infty} \frac{1}{\sqrt{2\pi}} * e^{-\frac{t^2}{2}} dt$

$\vec{\theta} = [\theta_1, \theta_2, \theta_3, \theta_4, \dots, \theta_M]^T$

$\theta_i = K P_{Ri} |g_i|^2 * |h_i|^2 \sigma_S^2$. P_{Ri}

$\Sigma_{H0} = diag(2K\sigma_{0,i}^4)$

$\Sigma_{H1} = diag(2K(P_{Ri}|g_i|^2 * |h_i|^2 \sigma_S^2 + \sigma_{0,i}^2)^2)$

Where P_{Ri}, $\sigma_{0,i}^2$, Σ_{H0}, Σ_{H1} and *diag(.)* are the parameters of each relay transmission power. Hence, the detection Probability equation represents detection performance of linear SDF at FC for cognitive Radio. The P_d equation depends on maximizing the weighting coefficient vector $\vec{w}$. Consequently, we need to use a type of algorithm from the famous evolutionary algorithm Genetic Algorithm (GA) called Clustering Genetic Algorithm (CGA) for optimizing such complex application. Accordingly, the optimal weighting vector of the constrain optimization problem will become normalized as in Equation (2).

$$\vec{w}^* = \arg\max P_d(\vec{w}) \quad s.t. \|\vec{w}\|_2 = 1 \qquad (2)$$

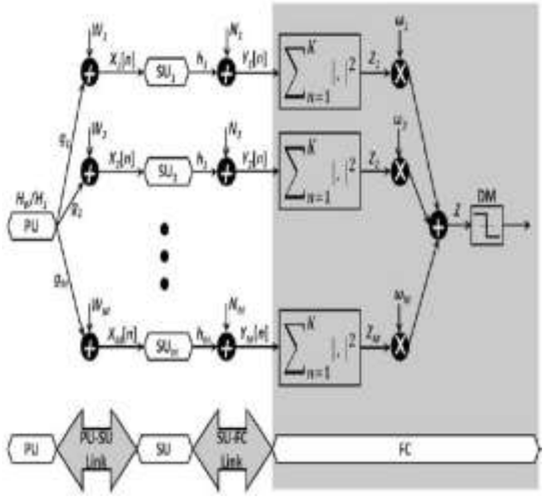

Figure 1: System model of linear SDF-Cooperative Spectrum Sensing of CRN [3]

III. CLUSTERING GENETIC ALGORITHM FOR CRN.

Clustering Genetic Algorithm has similar concept of Gene Grouping Genetic Algorithm (GGGA) with a different partition way [4]. Clustering Genetic Algorithm splits the entire *chromosomes (n)* in the population to multiple numbers of clusters *(c)* instead of dividing the chromosomes into groups. Hence, the number of clusters can be calculated by dividing the chromosome lengths over the cluster size *n/c*. After splitting the population into clusters, treat every cluster as a new population and apply the simple genetic algorithm which contains of different operators with different methods such as: selection, crossover and mutation. Final step is to combine all the results/solution from every cluster and result an overall result/solution. There are five main steps in genetic algorithm as the following pseudo-code Table (1) [5]:

Table 1:Clustering Genetic Algorithm pseudo code

1. [**Start**] initialize random population $P(t)$ of n chromosomes.
2. Cluster population according to $P(t)$ / cluster size
3. [**Fitness**] chromosomes in each cluster are evaluated to result the fitness function $f(x)$.
4. [**Reproduction population**] reiterate *(t)* the following steps to generate new cluster chromosomes to reach the best population within a with the best individuals which fulfill the desired solution for all clusters.
5. [**Selection**] choosing the best two chromosomes within each cluster according to tournament selection method.
6. [**Crossover**] altering the parents

have been selected in each cluster to produce children (offspring) via uniform crossover. The offspring are carried out based on the crossover probability P_c.
7. [**Mutation**] is the process of inverting number of genes of the chromosomes based on the Mutation probability P_m.
8. **[Replace]** put the new children into a new clusters and sort the clusters accordingly.
9. **[Test]** terminating the process when meeting the end condition and keep the best solution within the current population since it represents the final result. Otherwise, redo from step 2

The following parameters are examined in [6] and studied in many trials and found out the most efficient parameters:

- Encoding: Binary encoding,
- Selection: Tournament Selection with 10 % elitism
- Crossover: Uniform Crossover at Crossover Probability of 90%
- Population size: 60.

Indeed. CGA has shown good performance in many different applications. Therefore, CGA is one of the best choices of Genetic Algorithm types to use for optimization problems with large-sized problems. Indeed, CGA is a very good to be implemented for Cognitive Radio Spectrum Sensing problem according to its way of functioning.

IV. RESULTS AND DISCUSSIONS.

In this letter, we define the parameters of P_d equation mentioned earlier for Cooperative spectrum sensing as in below schedule:

CRN Parameters	Values
Number of weighting coefficient vector *(M)*	*20*
Number of Samples *(K)*	*150*
Relay Power (P_{Ri})	*12 dBm*
Variance of PU signal(σ_s^2)	*25 dBm*
Variance range of PU-SU channel noise	*-60* $\geq \sigma_{W_i}^2 \leq -47$ *dBm*
Variance range of PU-SU channel gain	*-50* $\geq g_i \leq -40$ *dBm*
Variance range of SU-FC channel noise	*-60* $\geq \delta_i^2 \leq -47$ *dBm*
Variance range of SU-FC channel gain	*-40* $\geq h_i \leq -30$ *dBm*
False alarm probability P_f	*0.25*

Standard Genetic Algorithm (SGA) has parameters which plays major role to enhance the convergence. Each parameter value differs from application to another application. In cognitive radio the most suitable parameters are selected for CGA and SGA are as below:

CGA and SGA Parameters	Domain
Population size	90
Crossover rate	95%
Mutation rate	5%

The number of simulation for both CGA and SGA =1000, Number of iteration to stop the generation for both algorithms = 100 times. From the above initialization, the convergence performance of cluster genetic algorithm for CRN problem clearly shows good performance as shown in fig (2). Besides that, as you can see at generation No. 30 the best fitness is 0.9723 for CGA and best fitness is 0.9548 for SGA, which proves the enhanced convergence speed. In addition, a fair comparison is made between previous work by using standard genetic algorithm and our work cluster genetic algorithm with same parameters. As we can see in fig (2). the best converged fitness and mean converged fitness of CGA outperforms SGA. In fact, CGA also shows better probability of detection compared with SGA as in fig (3)

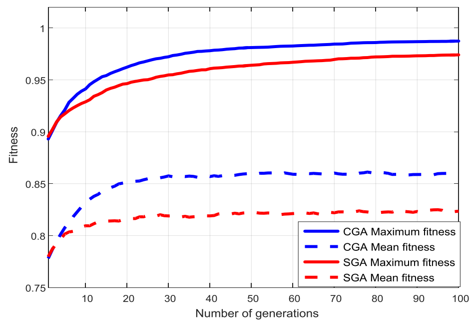

Figure 2: Comparison of convergence performance between CGA and SGA

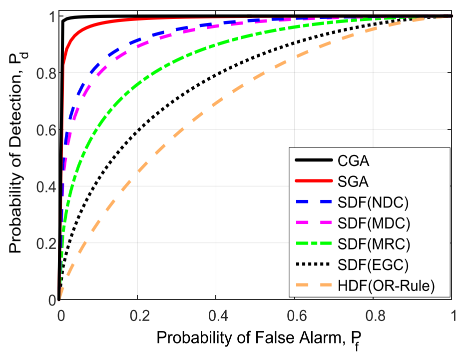

Figure 3: Probability of detection performance of CGA against SGA and other SDF&HDF schemes

V. CONCLUSION

In conclusion, as we all know CRN is a promising area for researchers to achieve best way of spectrum sensing without causing harm to the licensed user. In this paper, we proposed using Clustering Genetic Algorithm for cognitive radio network and compare its performance with the existing Standard Genetic algorithm. Clearly, it is proven that CGA is better than SGA in convergence speed and in finding the most optimum solution. Furthermore, the simple method of CGA which can enhance the performance of probability of detection. As a result, CGA is a good optimization tool to be used upon cognitive radio network

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