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Improvement in Co-Operative Spectrum Sensing Using ILP and GA in Cognitive Radio Network

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Abstract **- Wireless technologies have grown at a speed and with the passing year, it shows clearly that their consumers are also increasing, that increment in wireless spectrum consumer increases the demand for spectrum. But for our wireless systems, the spectrum is divided into two categories: the first is licensed and the second is unlicensed. Licensed spectrum is used by authorized users and unlicensed spectrum is free for all users. But most of the time it is shown the hat licensed spectrum may not be properly utilized by primary users (PUs), at that time spectrum band is free. To mitigate that inappropriate use of spectrum cognitive radio (CR) network is used. In CR there is one challenge that among the CR node some nodes experience an impact of multipath and shadowing, and another is to sense the spectrum under a lower signal to noise ratio. To overcome the effect of multipath and shadowing co-operative spectrum sensing has been used but it has large energy utilization. This extra energy is consumed in sensing the spectrum and reporting each nodes local decision to Fusion Centre (FC). In this paper we discuss three different schemes for total sensing time and energy decrement or throughput improvement. Here we go after for the genetic algorithm and integer linear programming scheme for overall energy minimization and throughput maximization.**
Keywords**: Cognitive Radio Network (CRN), Co-Operative Spectrum Sensing (CSS), Genetic Algorithm (GA), Integer linear Programming (ILP)**

I. INTRODUCTION

Radio spectrum may be an expensive source and it happens many times that, most of allotted band isn't properly used by licensed users in any respect the time. Currently, the fast growth of wireless technologies will increase the need for radio-frequency spectrum band. Federal Communications Commission (FCC) used the steady (static) Spectrum Allocation (SSA) theme to portion spectrum bands to users. But licensed users don't occupy radio-frequency spectrum fully and as a result spectrum is underutilized. As an answer to the spectrum unskillfulness drawback, Cognitive radio (CR) is associate degree exciting and adaptive new rising technology, that has projected by Joseph Mittola to reinforce the employment of restricted resources. CRs have two main characteristics; first is the cognitive capability and the second is Re-Configurability. Cognitive capability is defined as the ability of radio to detect the data from radio (wireless) environment and the definition of Re-Configurability is that it is the ability to swap its task in according to the sensed environmental parameters. To achieve higher spectrum utilization authorized users (PUs) have existence with the unauthorized users (SUs) within the same waveband in CR network. Additionally, SUs can use the authorized spectrum sometimes when it is free but should not disturb PUs. By applying CR Radio network utilization scheme, the band sources may be assured to reinforce the spectrum (band) potency so considerably will increase the number of users that will use wireless amenities that might solve the matter of spectrum inadequacy. Though detection performance could also be plagued by shadowing impact, multipath impact, and the hidden terminal drawback and because of this drawback, SU might not discover the action of the element inside the small duration of sensing amount. To mitigate those problems co-operative spectrum sensing is employed.

This paper is organized in the manner as below. First, the fundamentals of co-operative spectrum sensing are discussed in section II in which the algorithms like genetic algorithms and Integer linear Programs are also simplified. In section II there is also performance parameters were mentioned. In section III there is a brief literature survey is there. Section IV contains experimental results that are obtained by simulation using different parameter variations. In section V there is a conclusion that is gained from the results.

II. CO-OPERATIVE SPECTRUM SENCING

In a cognitive radio network by using co-operative spectrum sensing each and every nodes sense the spectrum and submit its own conclusions to fusion centre (FC) so by using the all over prospect of detection the all over conclusion is acquired. The aim of sensing the spectrum for the cognitive users is to make the decision that PUs uses the channel or not. If a SU identify that r(y) signal is present then, the decision of sensing the spectrum D(y) can be consider under a twice steady theorem examination [2].

$$D(y)=\begin{cases} H0 & if\ r(y)=n(y) \\ H1 & if\ r(y)=s(y)+n(y) \end{cases} \quad (1)$$

Here H_0 designate that the gained signal is only unwanted signal n(y), i.e., the bunch of that frequency is empty, and H1 indicates that the r(y) is the addition of authorised user signal s(y) and noise signal i.e., that frequency band is not empty some PU use that channel [2].

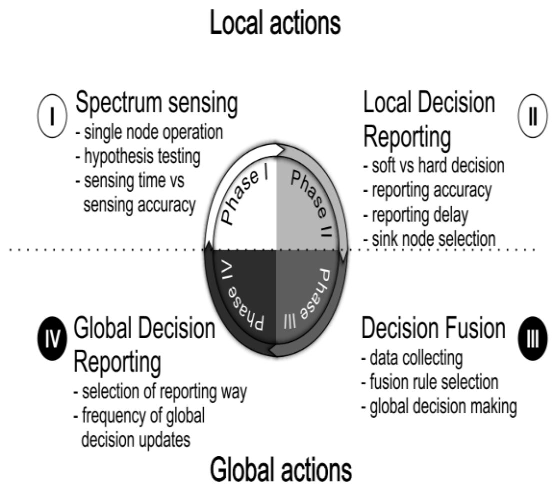

Fig. 1 Cooperative spectrum sensing procedure [2]

Above figure describes the procedure of co-operative spectrum sensing. In which first phase is spectrum sensing, second phase is local decision reporting, third phase is global decision reporting, and fourth phase is decision fusion.

In accordance with the co-operative spectrum sensing, there are so many different methods use for the optimization of sensing energy and throughput. From that method we have analysed two methods in this paper, those are genetic algorithm (GA) and particle swarm optimization (PSO).

A. Genetic Algorithm

GA is a method that changes parameters according to the situation to solve the search problem. It is based on parallel search of the chromosome group, selecting operations with guessing, switching operations, and mutation operations. So, GA has the following characteristics [3].

GA begins its search from the collection of problem solutions, instead of the singular solution. At that point there is a wise difference between GA and conventional optimization algorithms. The conventional (earliest) optimization algorithms get local optimal solutions easily because they obtain the optimal solution from only one initial value iteration. GA begins its search from the set of problem solutions. So, it covers a wide area, and it is good for global choice [3].

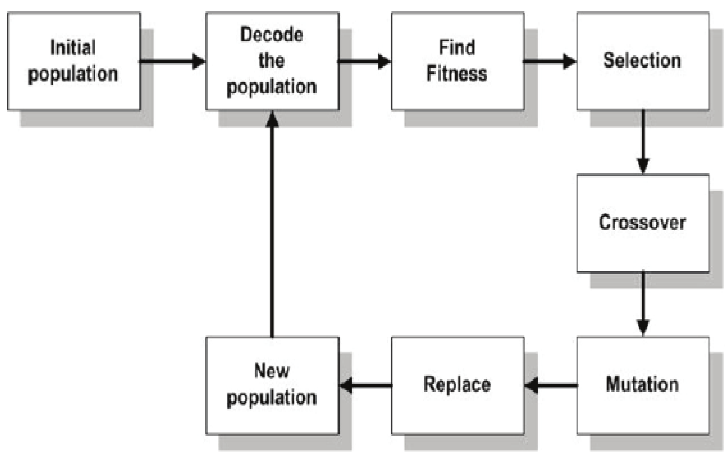

Fig. 2 Genetic Algorithm Block Diagram [21]

GA does not need additional information; it uses the fitness function value to determine individuals and takeaway genetic operations. The fitness function is not limited to continuously differentiable functions, and its definition domain can be set randomly. This feature greatly elaborates the application range of GA. GA adopts the changing rules of probability rather than deterministic rules to guide its search direction [3].

To organize the search when information on the evolution process is used by the GA, the individual with a large fitness value has a more probability of survival and can get a more adaptive genetic structure [3].

B. Integer Linear Programs

An integer linear programming problem is a mathematical optimization or feasibility program in which some or all the variables are restricted to be an integer. Here the objective function and constraint are integer [18]. Linear programming (LP) is the problem of maximizing/ minimizing a linear function over a convex polyhedron. Linear programming is extensively used in engineering. Linear programming can be solved using the simplex method, which runs along polytope edges of the visualization solid to find the best answer [18].

An LP problem can be expressed in *standard form* as follows

$$\min c^T y$$
$$subject\ to: \begin{cases} Ay = b \\ y \geq 0 \end{cases} \qquad (2)$$

where y is the vector of variables to resolve, A could be a matrix of identified coefficients, and c and b are vectors of identified coefficients. The expression $c^T y$ is termed the target perform, and therefore the equations Ay = b is known as the constraints. The matrix A is mostly not sq. and frequently A has additional columns than rows, and Ay = b is so quite probably to be under-determined, departure nice latitude within the alternative of x that reduces $c^T y$ [18].

Generally, the quantity of variables exceeds the number of equations. The distinction between the quantity of variables and the number of equations offers the degrees of freedom related to the matter. Any answer, optimum or not, can thus embrace variety of variables of capricious worth [18].

The simplex formula uses zero as this capricious worth, and therefore the variety of variables with worth zero equals the degrees of freedom. Variables of non-zero values are known as basic variables, and variables of zero values are known as non-basic variables within the simplex formula. The increased kind simplifies finding the initial basic possible answer. The simplex technique provides AN economical systematic search bound to converge in a very finite variety of steps. The algorithm is as follows [18]

1. Begin the search at associate extreme (i.e., a basic possible solution).
2. Confirm if the movement to associate adjacent extreme will improve on the improvement of the target perform. If not, this resolution is perfect. If, however, improvement is feasible, then proceed to the following step.
3. Move to the adjacent extreme that offers (or, perhaps, seems to offer) the foremost improvement within the objective perform.
4. Continue Steps a pair of and three till the optimum resolution is found or it is shown that the matter is either boundless or unworkable.

C. Performance Parameters

The performance parameters of various papers are as follows.

i. Detection Probability: It is the probability that recognises a busy channel as busy and idle channel as idle.

$$PD = 1 - (1 - PDS)^{Ns} \qquad (3)$$

Where Ns is the number of sensing nodes and *PDS* is the singular probability of detection.

ii. False Alarm Prospect: It is the prospect that the FC recognise an unused channel as used (P(H1/H0)) and used channel as unused.

$$PF = 1 - (1 - PFS)^{Ns} \qquad (4)$$

Where PFS is the singular probability of false alarm.

iii. Sensing Energy Consumption: It is the energy utilize in the sensing by the NS CR nodes is given as follow.

$$\mathrm{Es} = \sum_{i=0}^{Ns} Ti\, s^{\times} \rho s \qquad (5)$$

And T^i_s is the sensing time of i^{th} number of CR node and ρs is the energy utilized in sensing per unit time.

iv. Reporting Energy Consumption: It is given as follows.

$$Er = \sum_{i=1}^{Ns} \mathrm{D}^2 i - FC^{\times}\tau^{\times}\rho r \qquad (6)$$

Where D^2i-FC is the distance square among the FC and i^{th} number of CR node and ρr is the energy utilized in reporting per unit time.

v. Achievable Throughput: It is the average of correctly transmitted bits in single frame (T).

$$Th = P0^{\times}(1 - PF)^{\times} Dt^{\times} Tt \qquad (7)$$

Where Dt is on the channel data transmission rate in bits/second and Tt is Transmission Rate.

vi. Energy Efficiency Maximization: Energy efficiency is defined as the ratio of throughput to energy consumption. Therefore, maximizing it achieves the balance point between energy consumption and average throughput.

$$\max\mu(N, Ts) = \mathrm{ax(N,Ts)}\,\frac{\mathrm{P0*(1-PF)*Dt*Tt}}{\mathrm{Es(N)+Er(N)+Pfree*Et(N)}} (8)$$

III. RELATED WORK

This section articulates the details about the background literature study we have done on the technologies, algorithms and papers proposed on cooperative spectrum sensing using GA and ILP. Provided below are the reference papers we have leveraged upon to develop a base of this paper and creating the foundation of our research.In March 2016 Ramzi Saifan, Ghazi Al-Sukar, Rawaa Al-Ameer and Iyad Jafar [1] proposed “Energy efficient cooperative spectrum sensing in cognitive radio”. In this paper, authors work on two targets which are reducing the sensing stage energy is the sum of sensing, reporting, and transmission. The second objective is maximizing energy efficiency which is the ratio of good throughput to the consumed energy. For that objective, they jointly find the time of sensing required per CR node and the number of nodes who should perform cooperative sensing. Their purpose is to Maximize throughput, maximize energy efficiency and Minimize power consumption. And the technique they used is a Joint optimization energy efficient algorithm.

In June 2017 above authors [4] developed another work which is like the optimization of CSS. Another difficulty for spectrum sensing is that it’s full of weakening and shadowing results, which can lower the detection performance. So collaboration is projected within the previous articles as a solvable answer of those issues to extend the detection likelihood and reduce the warning prospect. In CSS a fusion centre (FC) collects the sensing outcomes from all the CRs and takes the decision on the position of a CRN. This call is then informed to any or all element nodes, but this process needs the additional energy. The energy is consumed throughout CSS in 2 stages: sensing and coverage. Here the goal is to as same as above to Maximize throughput, maximize energy efficiency and Minimize power consumption, the method used is Integer linear programming algorithm 1 to reduce all over sensing time, Integer linear programming algorithm 2 is to decrease all over sensing energy and Integer linear programming algorithm 3 to increase achievable throughput.

In February 2015 Masoud Moradkhani, Paeiz Azmi, and Mohammad Ali Pourmina [5] proposed "Optimized energy limited cooperative spectrum sensing in cognitive radio networks". One of the foremost vital functionalities of every chromium network is spectrum sensing, with the aim of recognizing idle frequency bands to boost the spectrum potency. Among numerous spectrum sensing ways, the foremost common is energy detection, because of its low implementation complexness and need no info regarding element. The energy detection method is administrated by comparison a threshold with the check statistics that is AN estimation of received element signal energy. Thanks to Cooperative Bi-Threshold methodology additional energy consumption is there, that may be an important issue for low powered wireless communication. Therefore, there is a desire to attenuate energy consumption and maximize outturn. Protrusive improvement analysis is conferred to collectively get the best values of sensing time and detection thresholds.

Introduction of associate degree improvement of the likelihood of warning and likelihood of Detection psychological feature Radio Networks victimization GA was done by Subhasree Bhattacharjee, Priyanka Das, Swarup Mandal, and Bhaskar Sardar [6] in 2015. During this paper to decrease error likelihood (probability) (BER) of a specified SU during a centralized CRN victimization Genetic rule (GA) they optimize palladium and PF in CRN. The motive is to decrease likelihood of error (BER) and finding optimum values of probability of occupancy detection or probability of detection and probability of warning. Centralized cooperative sensing framework is considered during this paper. Here the most motive of authors was to decrease error probability of j^{th} CR node (Pjerror) of a specified j^{th} SU. Likelihood of error is the total of 2 terms. 1st term is Pf increased with the likelihood of Pu being absent, the Second term is likelihood of misdetection increased with probability of Pu being gift. Therefore, the objective of this paper is to seek out optimized values of probability of detection and false alarm of a specific j^{th} SU in order that Pjerror of that unauthorized use is reduced.

GAs are accommodative unvarying search algorithms. GA has been quite successful optimization technique which is able to solve fully numerous unnatural or at liberty optimisation problems. Differential evolution (DE) is another organic process algorithmic rule that has been used for developing most effective system that has multiple motives. Diamond State is incredibly easy but noticeably effective feature, developed by worth and Storn. During this article, authors examine the results of GA and collate them with Diamond State to seek out that algorithmic rule is additionally appropriate in resolving the actual optimization drawback. The results collated with the Differential Evolution algorithmic rule and it's evident from the comparison that Diamond State finds the higher answer and takes abundant lesser range of evaluations to seek out optimum answer. Additionally, to it for a hard and fast population size Diamond State takes lesser time for one iteration than GA.

In April 2016 Krzysztof Cichon, Adrian Kliks and Hanna Bogucka [2] introduced "Energy-Efficient Cooperative Spectrum Sensing: A Survey". Aim of CSS is to detect the existence of SU at a particular location, at a particular time and in a very fixed waveband. CSS in its simple non-collaborative type is considered as only one node. Sensing, wherever every node makes AN freelance call on the provision of a waveband and works consequently. From this attitude, varied CSS schemes are projected. However, many investigations recognized by single devices, only one decision is not enough for making the outcome that SU is present or not. Thus, it's typically united that one among the ways in which to extend the reliableness of CSS is to use collaboration between nodes. In CSS each node in a very cognitive radio network senses the spectrum, and reports native sensing results, that are then used for deed a world call characterized by the world likelihood of detection.

IV. SIMULATION RESULTS

In our experiment, we take the below-mentioned values into account for our reference. The detection and false alarm probabilities are assumed to be 0.9 and 0.1 severally. These values are assumed to go with the IEEE 802.22 standard, which indicates the least detection probability as 0.9 and the highest false alarm probability as 0.1 in order to eve good spectrum utilization [5].

The length of the sensing slot is taken as 1 s with the upper bound of 2 s as specified in. As for the distribution of the CR nodes, they are assumed to be randomly scattered in a 200 × 200 m2 area. These nodes recognize the presence of the PU in 400 × 400 m2 area. Typically, the physical limit of area of the PU location to be sensed is larger than the CR nodes area that performs sensing. The sampling frequency is assumed to be 104 sample/s, unless otherwise explicit. As for the SNR values, they are assumed to be related to the distance to the PU and multiplied by a factor to make the average of −13 dB [5]. We have considered our specifications of parameters as per given in reference to the paper [1].

TABLE I PARAMETER VALUES

Parameter	Value
CR nodes (Nt)	25 nodes
CR area	200×200 m^2
PU area	400×400 m^2
PD	0.9
PF	0.1
SNR	Random with average = -13dB
T	1 s
fs	10^4 sample/second
Sensing Nodes (Ns)	7

The 3 algorithms were examined once completely non-identical cooperation call rules are thought about. Simulation results well-tried the power of the planned algorithms in specifying the same network parameters that attain the specified objective [5].

In the next subsection simulation results for the different integer linear programming algorithms are shown. From that graph, we conclude that by varying the value of particular factor how it will affect on the desired parameter value. Here we represent the results by varying the value of number of sensing nodes (NS) and SNR. Also, we can get results by changing the values of sampling rate, detection probability (PDF), sensing time per CR node (τ), sensing energy consumed per unit time (ρs) and reporting energy consumed per unit time (ρr). Here the results for the all over sensing time minimization, all over sensing energy minimization and achievable throughput maximization are given as below.

A. Results of Algorithm 1 for Total Sensing Time Minimization: Flow diagram of algorithm 1 is shown in figure 3 below. In that, a reference value for the performance is initialized. If optimization is of minimization type, then the reference value is infinity. Then it keeps on decreasing as it reaches the minimum value. In each iteration, the calculated performance value is compared with the reference value but for the optimization of maximization type, minimum sensing time is first seta s to minus infinity and then keeps on increasing to the desired value. For the singular sensing time, singular false alarm probability and singular detection probability were calculated as per their equations. After that, the singular performance value is calculated. Then, based upon that value, CR nodes were sorted and the summation of the singular performance values of the first v nodes will be calculated. The sorting is in ascending order if the algorithm is minimization and in descending order if the algorithm is maximization. Then, the summation is compared with the reference value. The 'Better than' phrase means 'less than in the case of minimization and 'greater than in the case of maximization. The first For loop in Line 2 iterates over all possible number of CR nodes who perform sensing, in iteration v we assume that v CR nodes perform sensing. The second for loop iterates over all possible FC nodes. The second for loop will be needed in case of minimizing the total sensing energy (Algorithm 2) and will be removed in Algorithms 1 and 3.

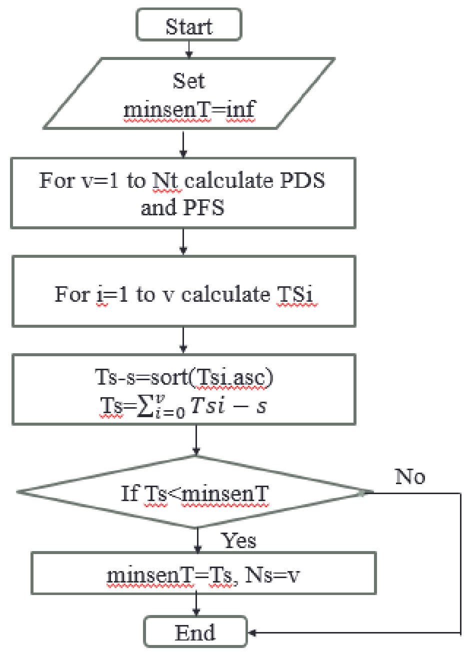

Fig. 3 Block diagram of Algorithm 1

1. When Ns nodes vary from 3 to 25 we obtain values of PDS, PFS, T^i_s, and Ts. By setting up the above parameters we obtain a graph of number of sensing CR nodes (NS) verses Total sensing time.
2. When SNR changes from -14 to -2 at that time we obtain a graph of SNR verses Total sensing time.
3. When we change PD from 0.86 to 0.96 at that time, we obtain a graph of PD verses Total sensing time.
4. When we change sampling rate from $1{\times}10^4$ to $10{\times}10^4$ at that time we obtain a graph of sampling rate verses Total sensing time.

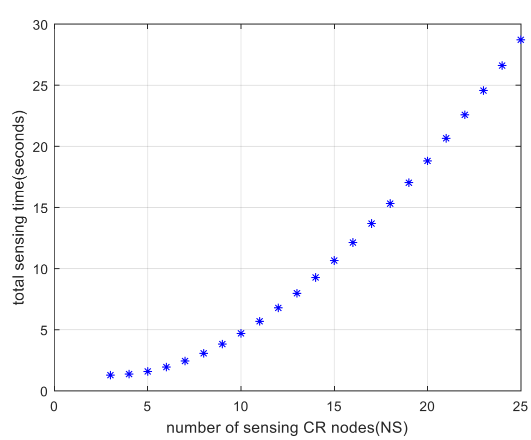

Fig. 4(a) Nt verses Total sensing time

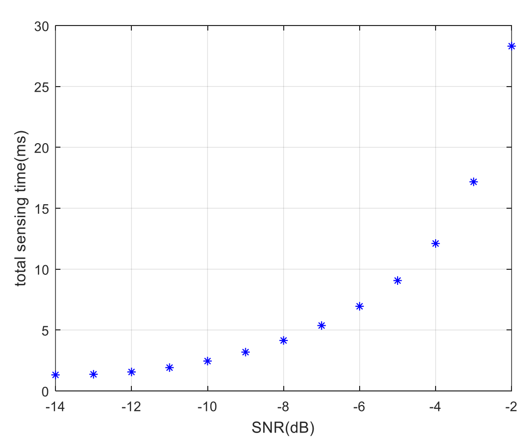

Fig. 4(b) SNR verses Total sensing time

We have evaluated the performance by varying Nt, Sampling rate, Probability of detection and SNR. Results of figure 4 (a) shows that when we vary number of sensing nodes according to that total sensing time will vary. It is clearly shown by graph that when NS is less total sensing is also less, by increasing the NS the sensing time is also increase. And for the maximum number of nodes the time for sensing is higher than all others. Results of figure 4(b) shows that when SNR increases the total sensing time increases according to that.

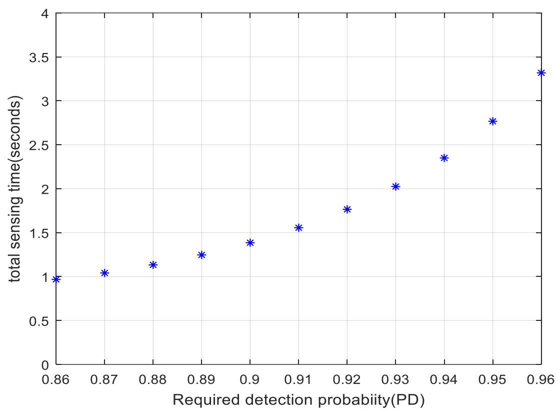

Fig. 4(c) PD verses Total sensing time

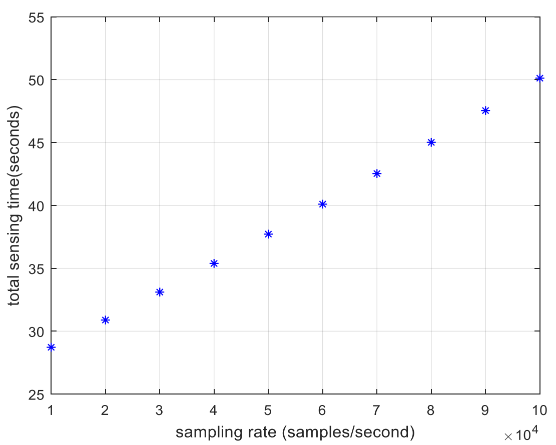

Fig. 4(d) Fs verses Total sensing time

We thought of learning the impact of fixing the desired detection probability PDth. Effectively, the detection prospect is changes between 0.86 and 0.95. The outcomes are pictured in Fig. 4 (c). These outcomes are according to the fact that expanding the desired detection likelihood demands expanding the whole sensing time since the sensing nodes are required to pay more time in sensing. The time of sensing is inversely proportional to the rate of sampling. Results of figure 4(d) shows that when fc increases the total sensing time is increase according to that.

B. Results of Algorithm 2 for Minimization of Total Sensing Time: Flow diagram of algorithm 2 is as shown in figure 5 as below. In that diagram iterative process for different parameters is shown clearly and by using that process flow we obtain our desire results.

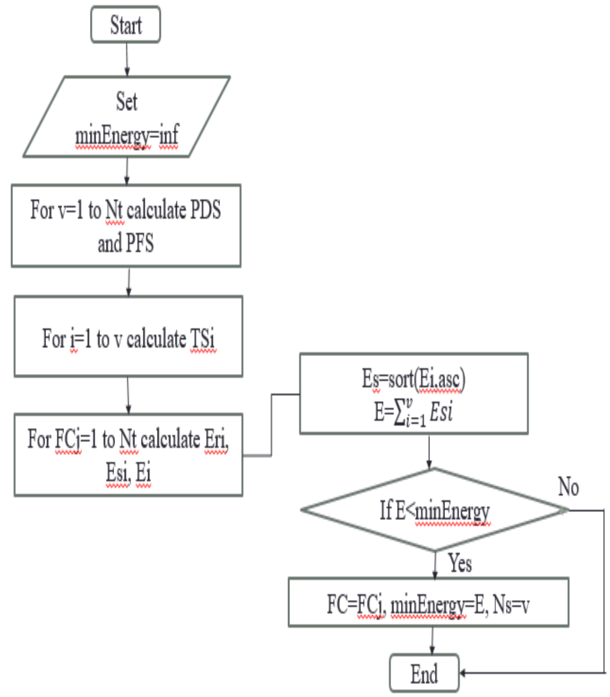

Fig. 5 Flow diagram of Algorithm 2

1. When Ns nodes vary from 3 to 25 we obtain values of PDS, PFS, T^i_s, and Ts. By setting up the above parameters we obtain a graph of number of sensing CR nodes (NS) verses minimum total sensing energy.
2. When SNR changes from -14 to -2 at that time we obtain a graph of SNR verses minimum total sensing energy.
3. When we change t from $1\times10^{(-5)}$ to $10\times10^{(-5)}$ at that time we obtain a graph of t verses Total sensing energy.
4. When we change Ps from 0.01 to 0.1 at that time, we obtain a graph of sensing energy consumed per time unit verses Total sensing energy.
5. When we change Pr from 0.02 to 0.2 at that time, we obtain a graph of reporting energy consumed per time unit verses Total sensing energy.

We have evaluated the performance by varying Nt, SNR, sensing time, reporting energy and sensing energy. Below results of figure 6(a) shows that when we very number of sensing nodes according to that minimum sensing energy will vary. It is clearly shown by graph that when NS is less sensing energy is also less, by increasing the NS the sensing energy is also increase. And for the maximum number of nodes the energy for sensing is higher.

Results of figure 6(b) show that when SNR increases, the minimum sensing energy also increases according to that. The impact of the given news time for every node, Figure 6(c) shows the overall sensing energy once the news time is change in between 1×10^{-5} and 10×10^{-5} s. on paper, expanding t is meant to extend the news energy. The upgradation of the planned formula is said to the very fact that the FC and therefore the sensing nodes are designated put together to scale back the sensing energy.

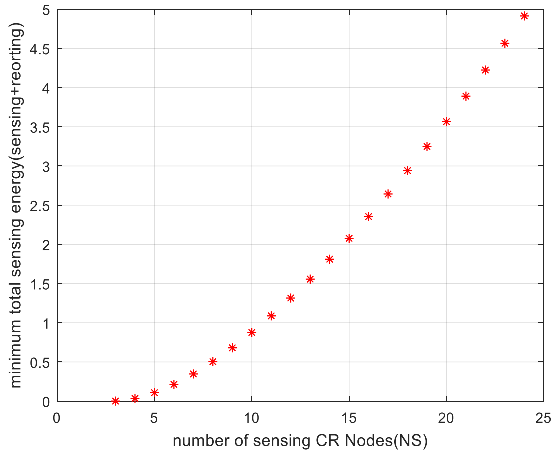

Fig. 6(a) Nt verses Total sensing energy

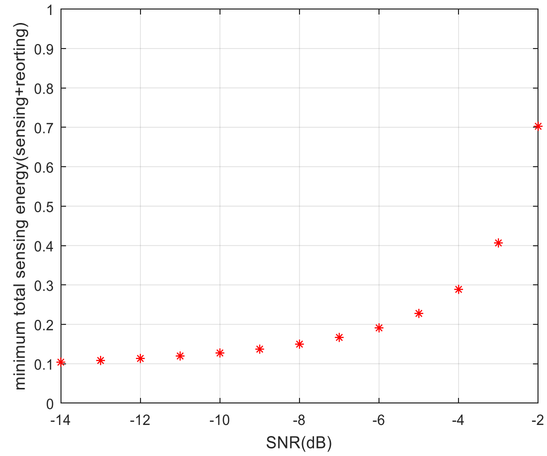

Fig. 6(b) SNR verses Total sensing energy

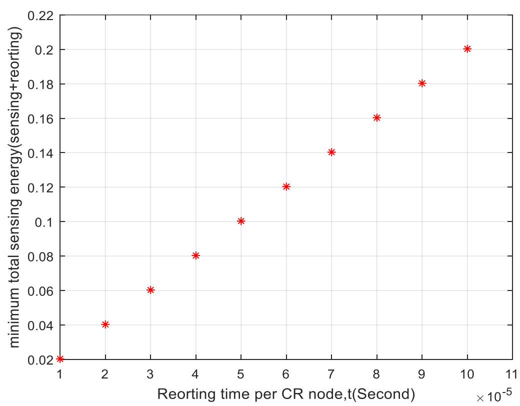

Fig. 6(c) Reporting time (t) verses Total sensing energy

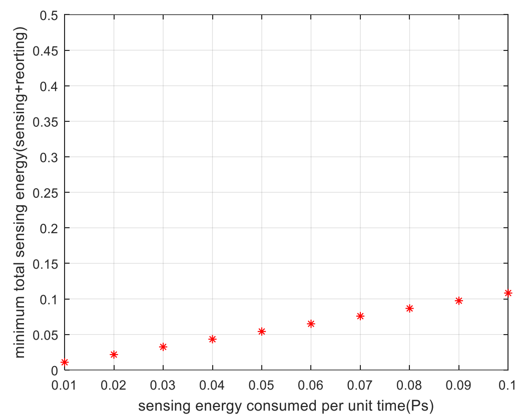

Fig. 6(d) Sensing energy (Ps) verses Total sensing energy

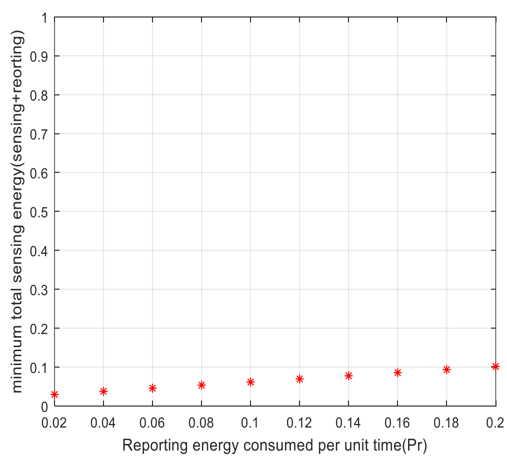

Fig. 6(e) Reporting energy (Pr) verses Total sensing energy

Figures 6(d) and figure 6(e) show the result of adjusting sensing energy per quantity (Ps) and coverage energy per time unit (Pr) on the full sensing energy, severally Pr and PS influence the full sensing energy linearly.

C. Results of Algorithm 3 for Throughput Maximization

Flow diagram of algorithm 3 is as shown in figure 7 as above. In that diagram iterative process for different parameters is shown clearly and by using that process flow we obtain our desire results. We have evaluated the performance by varying Nt and SNR.

1. When Ns nodes vary from 3 to 25 we obtain values of PDS, PFS, T^i_s, and Ts. By setting up the above parameters we obtain a graph of number of sensing CR nodes (NS) verses Threshold.
2. When SNR changes from -14 to -2 at that time we obtain a graph of SNR verses Threshold.

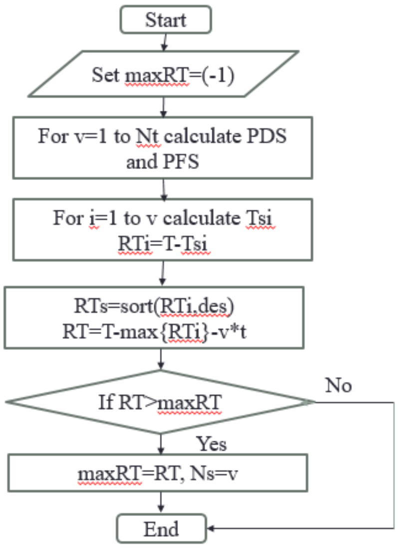

Fig. 7 Flow diagram of Algorithm 3

Above results of figure 8(a) shows that when we very number of sensing nodes according to that threshold will vary. It is clearly shown by graph that when NS is less, throughput is maximum, by increasing the NS the throughput will decrease. And for the maximum number of nodes the throughput is minimum than all others because the time left for the transmission is less when nodes will increase. As nodes increase the time for the sensing and reporting is more and time left for the transmission is less.

Results of figure 8(b) shows that when SNR increases the throughput will change minor

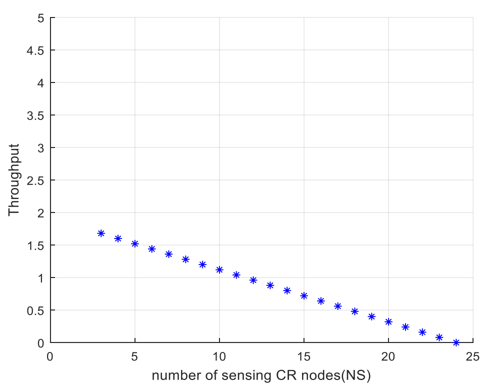

Fig. 8(a) Nt verses Throughput

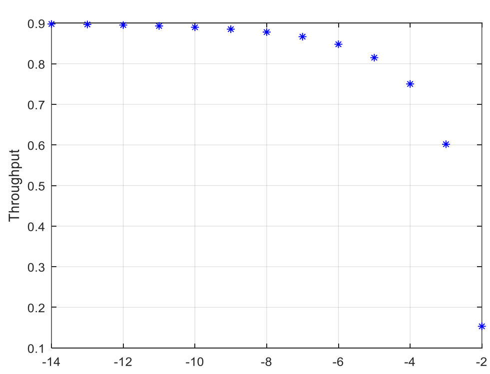

Fig. 8(b) SNR verses Throughput

D. Results of Genetic Algorithm

An important issue to recollect is that it's complicated to urge a precise resolution with GA however the best thing about victimisation the GA for this task is that it is giving multiple solutions for one downside. Consequently, the GA is saved from being stuck at any level of the optimisation method. This conjointly shows that if the GA doesn't offer a precise resolution for an issue, it'll really offer the simplest doable resolution among a spread of various solutions. During this section the results of the GA simulations were given.

A standard GA utilized in a multi-carrier system employing a tiny range of parameters needs a major quantity of your time for crucial associate optimum resolution. Figure shows the fitness convergence for a two channel GA-based implementation for single objective operates. This graph provides data concerning however quickly the system converges to the optimum call.

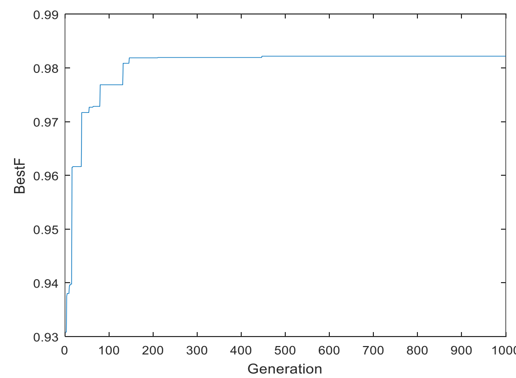

Fig. 9 Fitness converges of genetic algorithm for two Channel single objective function

1. Effect of Number of Generations on System Performance

In this section, I analyse that GA simulation converges in no time to the best worth. Once it is near to its best value, if we tend to increase range of iteration that will increase the time interval with very small improvement within the fitness. time interval is important consider wireless communication. Gained optimum iteration is additionally difficult task.

TABLE II GA SETTING FOR VARYING NUMBER OF GENERATION

Multi-objective function	
Number of subcarrier	32
Generation	[500,700,1000]
Objective functions	3
Weight(BER)	0.3
Weight(throughput)	0.6
Weight(power)	0.3
Cross over probability	0.6
Mutation probability	0.01
$[P_{min} P_{max}]$	[0.01 0.64]
$[m_i]$	[2, 4, 8, 16]

2. Channel's Effect on Performance

I begin with the reduce BER of the system. Figure displays a classic fitness convergence graph which is gained from the GA system. It is often observed that a system with one channel converges abundant quicker than the system with a pair of channels. This can be because of the interval required to calculate the fitness over a pair of channel system to focus on the result of adding the variety of channels within the system, Table three shows the best generation wherever the highest fitness was found for every system. Again, for one channel system, the system is ready to search out the simplest price abundant ahead of the system with a pair of channels.

TABLE III GA SETTING FOR VARYING NUMBER OF CHANNELS

$[P_{min} P_{max}]$	[0.01, 2.56]
$[m_{mim} m_{max}]$	[2, 4, 16, 32]
Modulation type	m-ary PSK
$[w_1 w_2 w_3]$	[0.3, 0.4, 0.3]
Number of subcarrier	32
P_c	0.7
P_m	0.01

8bit=6bit (power) + 2bit (modulation index)

TABLE IV NUMBER OF CHANNEL V/S. OPTIMAL GENERATION

Channel	**Iteration (G)**	**Time Elapsed to run code (s)**	**Best fitness**
1	500	29.216909	0.979684996757645
2	500	42.503079	0.976634937764507
1	600	37.253031	0.985027421248863
2	600	51.466062	0.911413775647165
1	700	41.047365	0.978237180397162
2	700	59.682350	0.974258747545068
1	1000	60.303056	0.984600606358658
2	1000	85.574117	0.979216026803572

Following figures 10(a), 10(b), 10(c) and 10(d) shows the generations verses best achievable function value. As the number of generations increase the elapsed time for the sensing is also increase which is shown in Table IV.

So according to the total time slot calculations it is said that with increasing the elapsed time the throughput is also increase with increment in generations.

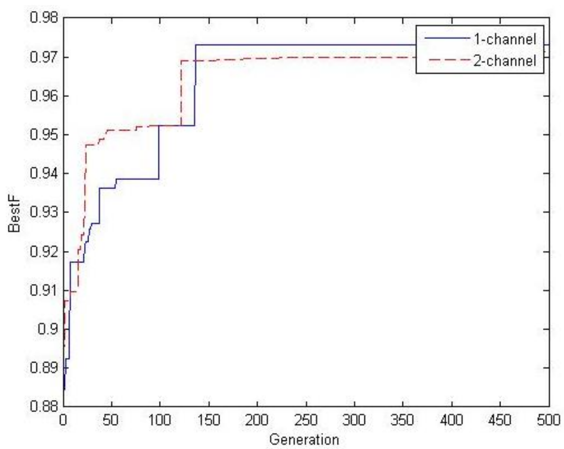

Fig. 10(a) Fitness convergence curve of generations verses Best F for G=500

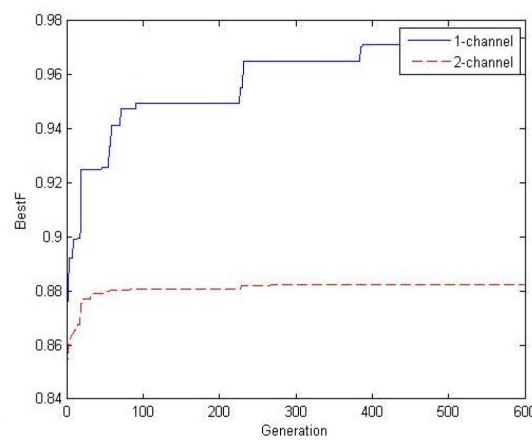

Fig. 10(b) Fitness convergence curve of generations verses Best F for G=600

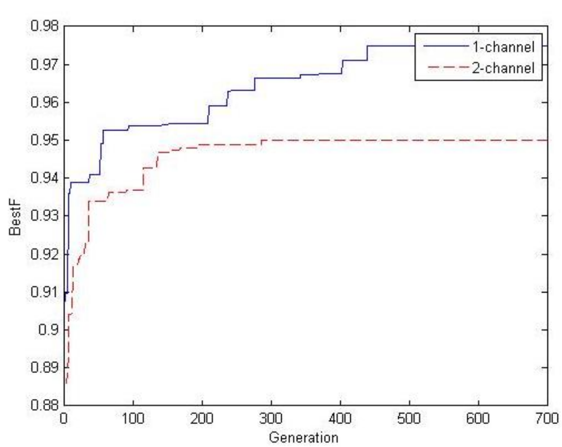

Fig. 10(c) Fitness convergence curve of generations verses Best F for G=700

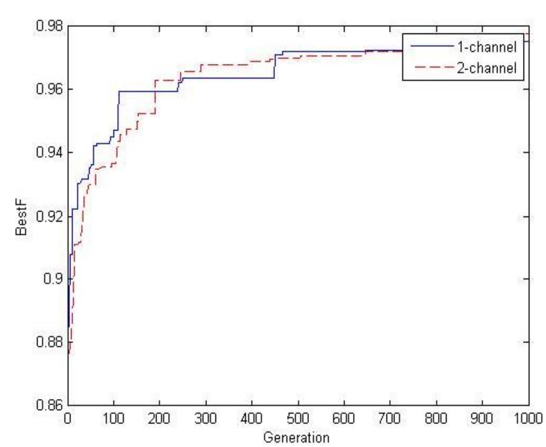

Fig. 10(d) Fitness convergence curve of generations verses Best F for G=1000

TABLE V DIFFERENCE OF ILPS WITH SIMULATED RESULTS

Algorithm	Parameter Value[1]	Obtain Value[Proposed]	ΔT
ILP1(Total sensing time)	0.842560 second (3 nodes)	0.761057 second	0.081509 s
ILP1(Total sensing time)	1.095632 second (25 nodes)	1.078130 second	0.017502 s
ILP3(Throughput)	1.5420 bits/s (3 nodes)	1.6800 bits/s	0.138
ILP3(Throughput)	0.0821 bits/s (25 nodes)	0.0800 bits/s	0.7179

TABLE VI DIFFERENCE OF GENETIC ALGORITHM WITH SIMULATED RESULTS

Generations	Elapsed Time[15]	Obtained Value[Proposed]	ΔT
500 Single channel	29.216909 s	30.548606 s	1.331697 s
500 Two channel	42.503079 s	45.023165 s	2.520086 s
600 Single channel	37.253031 s	38.023568 s	0.770537 s
600 Two channel	51.466062 s	53.215497 s	1.749435 s
700 Single channel	41.047365 s	43.156321 s	2.108956 s
700 Two channel	59.682350 s	60.123457 s	0.441107 s
1000 Single channel	60.303056 s	62.134567 s	2.042604 s
1000 Two channel	85.574117 s	88.124356 s	2.550239 s

V. CONCLUSION

In cognitive radio networks, co-operative spectrum sensing is used to compensate for the effect of deep fading and shadowing but there is a problem with extra energy utilization in sensing and reporting results to the fusion center. From the literature survey here, there is a trade-off between the cooperation of nodes at FC and energy, which means that at a time we cannot optimize all the parameters. So, we must select one parameter and apply the proper algorithm to optimize that one and likewise for all the parameters. By using the ILPs we reduce a total sensing time up to 0.081509 seconds for 3 nodes and 0.017502 seconds for up to 25 nodes. Similarly, the throughput increment for 3 nodes is 0.138 and for node 25 it is up to 0.7179 s. So, as we increased the number of sensing nodes the residual time for transmission decreases, and according to that throughput is decreased. Also, for the Genetic Algorithm for single-channel, the residual time for sensing is increase as the number of generations increase from 500 to 1000, and then for the two-channel, it will also increase as the number of generations increase from 500 to 1000 and this both is shown in Table [6] that proposed value is better than reference paper value. An increase in the initial population will decrease the chances of premature convergence of the algorithm, but the execution time will increase accordingly.

REFERENCES

[1] Ramzi Saifan, Ghazi Al-Sukar, Rawaa Al-Ameer and Iyad Jafar, "Energy efficient cooperative spectrum sensing in cognitive radio," International Journal of Computer Networks & Communications (IJCNC), Vol. 8, No. 2, pp. 13-24, March 2016.

[2] Krzysztof Cichon, Adrian Kliks and Hanna Bogucka, "Energy-Efficient Cooperative Spectrum Sensing: A Survey," *IEEE Communications Surveys & Tutorials*, Vol. 60, pp. 1861-1886, April 2016.

[3] Liu Miao, Zhenxing Sun and Zhang Jie, "The Parallel Algorithm Based on Genetic Algorithm for Improving the Performance of Cognitive Radio," *Wireless Communications and Mobile Computing*, Vol. 2018, pp. 1-6, march 2018.

[4] Ramzi Saifan, Iyad Jafar and Ghazi Al Sukkar, "Optimized Cooperative Spectrum Sensing Algorithms in Cognitive Radio Networks," *The computer Journal*, Vol. 60, pp. 835-849, June 2017.

[5] Masoud Moradkhani, Paeiz Azmi and Mohammad Ali Pourmina, "Optimized energy limited cooperative spectrum sensing in cognitive radio networks", *Computers and Electrical Engineering*, Vol. 42, pp. 221-231, February 2015.

[6] Subhasree Bhattacharjee, Priyanka Das, Swarup Mandal and Bhaskar Sardar, "Optimization of Probability of False alarm and Probability of Detection in Cognitive Radio Networks Using GA", *IEEE 2nd International Conference on Recent Trends in Information Systems (ReTIS)*, pp. 53-57, July 2015.

[7] Abdulkadir Celik, and Ahmed E. Kamal, "Multi-Objective Clustering Optimization for Multi-Channel Cooperative Spectrum Sensing in Heterogeneous Green CRNs", *IEEE Transactions on Cognitive Communications and Networking*, Vol. 2, No. 2, pp. 150-161, June 2016.

[8] Ibrahim Salahl, Waleed Saad, Mona Shokair and Mohamed Elkordy, "Minimizing Energy of Cluster –Based Cooperative Spectrum Sensing in CRN using Multi Objective Genetic Algorithm," *12th International Computer Engineering Conference (ICENCO)*, pp. 178-183, February2017.

[9] Woongsoo Na, Jongha Yoon, Sungrae Cho, David Griffith and Nada Golmie, "Centralized Cooperative Directional Spectrum Sensing for Cognitive Radio Networks," *IEEE Transactions on Mobile Computing*, Vol. 17, pp. 1260-1274, November 2017.

[10] Srijibendu Bagchia, and Jawad Yaseen Siddiquib, "Throughput optimization using availability analysis based spectrum sensing for a cognitive radio", *AEU-International Journal of Electronics and Communication*, Vol. 85, pp. 12-22, February 2018.

[11] Maninder JeetKaur, Moin Uddin and Harsh K. Verma, "Performance evaluation of qos parameters in cognitive radio using genetic algorithm," *World Academy of Science, Engineering and Technology*, Vol. 46, 2010.

[12] Niranjan Muchandi and Rajashri Khanai, "Cognitive radio spectrum sensing: A survey," *Electrical, Electronics, and Optimization Techniques (ICEEOT), International Conference on IEEE,* 2016.

[13] Goutam Ghosh, Prasun Das and Subhajit Chatterjee, "Simulation and Analysis of Cognitive Radio System Using Matlab,"*International Journal of Next-Generation Networks,* Vol. 6, No. 2, pp. 31-45, 2014.

[14] Vibhuti Rana and P. S. Mundra, "A Review on QOS Parameters in Cognitive Radio Using Optimization Techniques," *International Journal of Engineering and Innovative Technology (IJEIT),* Vol. 5, No. 12, June 2016.

[15] Pyari Mohan Pradhan and Ganapati Panda, "Cooperative spectrum sensing in cognitive radio network using multiobjective evolutionary algorithms and fuzzy decision making*", Journal of Ad Hoc Network*, Vol. 11, No. 3, pp. 1022-1036, November 2012.

[16] Deepa Das and Susmita Das, "A Cooperative Spectrum Sensing Scheme Using Multiobjective Hybrid IWO/PSO Algorithm in Cognitive Radio Networks," *2014 International Conference on Issues and Challenges in Intelligent Computing Techniques (ICICT),* pp. 225-230, Feb 2014.

[17] Fette B.A. (ed), *Cognitive Radio Technology*.

[18] Ekram Hossain, Dusit Niyato, Zhu Han, *Dynamic Spectrum Access and Management in Cognitive Radio Networks,* 2009.