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Survey on Optimization Methods For Spectrum Sensing in Cognitive Radio Network

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***Abstract*—A cognitive radio is a capable Technology, which has provided a great innovation in wireless communication system as to improve the efficiency of the electromagnetic spectrum utilization in wireless network. The technology allows unlicensed user or secondary user to use the vacant spectrum of licensed user through dynamic channel assignment strategies to improve the spectral utilization and hence cognitive radio avoids spectrum shortage. Cooperative sensing is one of the fastest growing areas of research and it is likely to be a key enabling technology, for efficiently spectrum sensing in future. For this several spectrum sensing are available, which can detect the white spaces or spectrum holes and share them to the secondary user without interfering with the movement of licensed user. In order to reliably and swiftly detect spectrum holes in cognitive radios, optimization must be used. In this paper we study different optimization for spectrum searching and sharing and also compare this optimization on the basis of probability of total error on fading channel.**

***Index Terms*—Cognitive Radio, Co-operative sensing,Optimization,Spectrum sensing.**

I. INTRODUCTION

The free radio spectrum is limited and it is getting compact day by day as there is increase in the number of wireless devices and application. It is found that the allocated radio spectrum is inefficiently utilized because has been statically allocated not dynamically. Also the techniques of radio spectrum management is not flexible, because each user has a license for appropriate spectrum band while the licensed user are not completely utilized the whole band. The main challenges with cognitive radio are that it should not interfere with primary users and should clear the band when required. For this purpose CR should sense the spectrum faster.[1][2]

Fig.1 shows the dynamic spectrum access technique, it is a way to overcome the spectrum management and improve the utilization efficiency. A spectrum hole or white space is band of frequencies assigned to a primary user but at a specific time and particular geographic area, the band is not being utilized By that user. These white spaces can occur in two fashions, in time or in space. When a primary user is not transmitting at a given specific time, then there's a temporal spectrum hole, if, a primary user is transmitting in a certain portion of theSpectrum or frequency at a given specific time but it is too far away from the secondary user so thatthe secondary user or cognitive user can reuse the frequency, then a spatial spectrum hole exists. The main concept of the cognitive radio is to continuously monitor the radio spectrum, detect the occupancy of the spectrum and then opportunistically use spectrum holes with minimum interference with primary user. [1] - [3]

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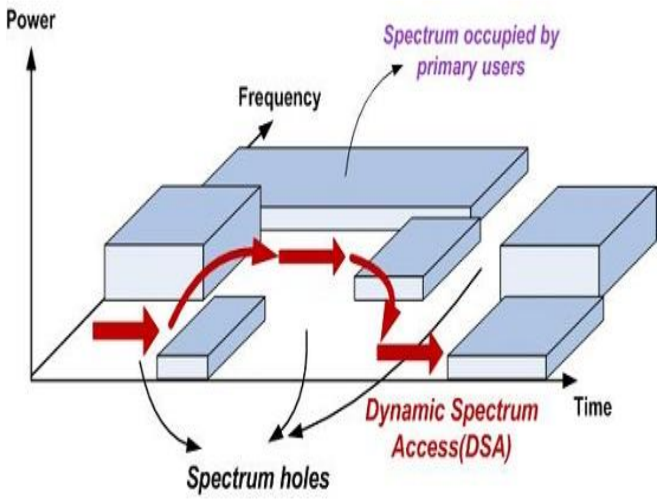

Fig.1: Spectrum Hole Concept

CR has following function which is very essential for spectrum sensing. [4]

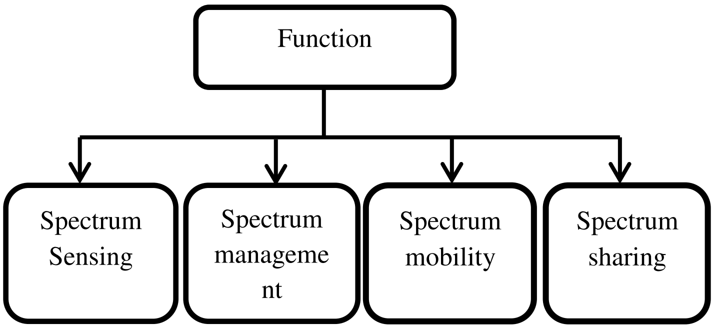

Fig.2: Cognitive Radio Function

- Spectrum sensing detects the unused spectrum/spectrum hole of licensed spectrum or user and determining if a primary user is present, detecting the spectrum hole.
- Spectrum management is a process of CR in which it captures the best suitable spectrum which is fulfills the communication requirement of user.
- Spectrum mobility is the case when a secondary user speedily allocates the channel or spectrum band to the primary user when a primary user wants to retransmit again.
- Spectrum sharing is a process in which the best suitable channel having coordination with others.

Mainly interference occurs in CR due to the hidden node problem and shadowing effect from different fading channel [1]-[5]. To overcome this problem cooperative communication is used, if PU's presence is detected. The presence of PU is detected with the help of all individual decision of SU's are combining at central fusion center using various scheme.

Fusion center (FC) creates a decision on the presence of PU's based on two type of fusion-Hard decision fusion, Softened decision fusion. In softened decision, all CR users transmit their measured parameter to the FC and fusion center make the global decision for all CR network. In hard decision each node takes its own decision and a binary value is transmitting to the FC. Detection of presence of PU based on SDF scheme gives better performance than HDF based scheme. [5]

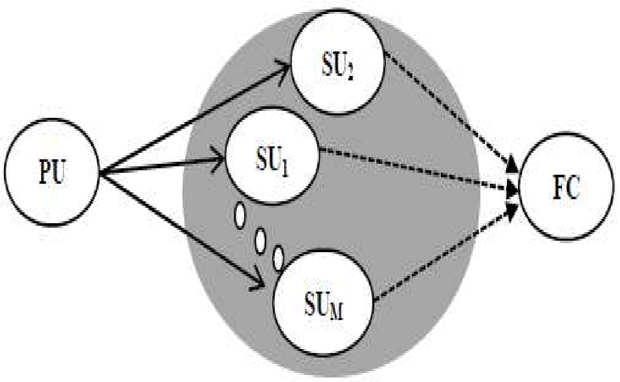

Fig.3: SDF based cooperative spectrum sensing in a CR network

In this paper we consider various optimization techniques for spectrum sensing in wireless communication network.
The paper is organized as follows. In Section I, gives introduction of cognitive radio. In Section II, we describe Spectrum sensing methods for CR. In Section III, we have discussed Cooperative spectrum sensing. Section IV describes optimization of cognitive radio network. Finally, the paper is concluded in Section V.

II.SPECTRUM SENSING

One of the most important elements in the CR network is spectrum sensing [6].when we decreasing the optimal threshold value to decrees the probability of missed detection also increase the probability of false alarm and when increasing the threshold value to probability of false alarm would increase the probability of missed detection. Since both are unwanted and both can't be deceased simultaneously. Many different signal detection techniques can be used in spectrum sensing to improve the detection probability.Fig.4 gives classification of the Spectrum Sensing.
The cognitive radio should describe between used and unused spectrum bands. In spectrum sensing Transmitter detection method is based on the detection of the weak signal from a primary transmitter through the different techniques:

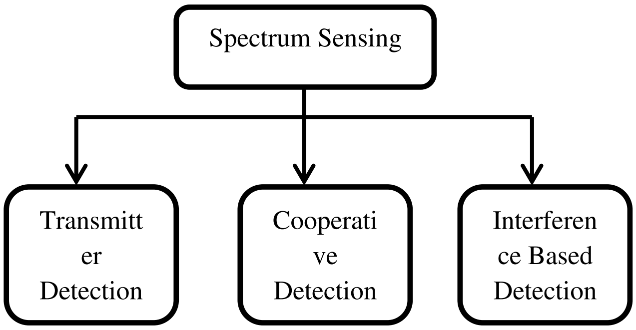

Fig.4 Classification of spectrum sensing techniques

A.Energy detection based spectrum sensing

Energy detector is a non-coherent method of spectrum sensing and it is used to detecting the primary user signal in the frequency spectrumbeing sensed. Energy detection sensing method is more popular because it does not require any prior information of primary signal and it is simple. The energy detector performance is robust in nature. [1]-[7]

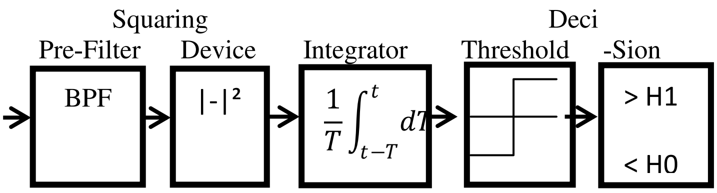

Fig.5 Energy Detector Block Diagram

Fig.4 displays the traditional energy detector. ED consists of a band pass filter or pre-filter matched to the bandwidth of the signal is required in the time domain representation. Time domain representation is inflexible compare to the other. So it is crucial to use the frequency representation for analyzing received signal. Then the output of BPF is fed to the squaring block this block consisting one squaring device followed by a finite time integrator.
ED is also known as Blind signal detector as the characteristic of the signal is ignored by it.
All wireless transmitters has an energy as

$$M=\sum_{n=0}^{N} |Y(n)|^2 \quad (1)$$

Where N is the size of observation vector. The decision that the band are occupied can be obtained by following two hypotheses-

H0: Y (k) = n (k) (2)

H1: Y (k) =h*S (k) + n (k) (3)

Where Y (k) is the received signal by the secondary user at each instant k and n (k) is the noise of variancesσ^2. The "probability of primary user detection" and the "probability of false alarm" can be calculated by the given equation-

$$P_d = P\,[\gamma > \lambda/H1] = Q_m\left(\sqrt{2\gamma},\sqrt{\lambda}\right) \quad (4)$$

$$P_f = P\,[\gamma > \lambda/H0] = \Gamma\,(m,\lambda/2)/\Gamma(m) \quad (5)$$

Where,

λ = SNR of the system
$\Gamma(.)$ = complte gamma function
n = TW (time bandwidth product)
Γ (….) = incomplete gamma function
Q_m = Generalized Marcum function

The advantage of the ED, it is easy to implement, computational complexity is low, and no need to priori information of primary user.one of the major disadvantage of ED is that it does not perform well in low SNR condition.

B. *Matched Filter Detector*

Matched filter is designed to maximize the output SNR for a given signal. Matched filter detection required prior knowledge of the primary user. In matched filter detection convolution between unknown signal is done with the filter whose impulse response is time shifted. The expression for matched filter is expressed as

$$Y(m) = \sum_{k=-\infty}^{\infty} x[k]h[m-k] \quad (6)$$

Where x is the unknown signal (h) of matched filter that is matched to the reference signal is convolved with it for maximizing the SNR. [7]

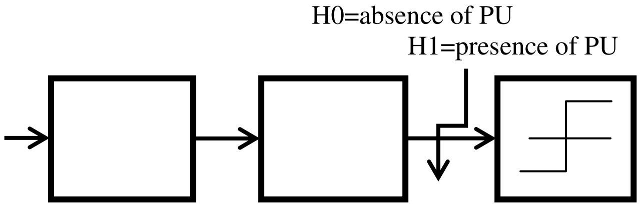

Fig.6: MFD Block Diagram

Advantage-

- Since it maximizes the SNR, it is desirable detector.
- The sensing time is slow as compare to other detectors.

Disadvantage-

- Prior knowledge of the PU signal is required.

C. *Cyclo Stationary Feature based* spectrum sensing

Cyclo stationary feature detection uses the built in periodic component/feature of the modulated signal (carrier). The periodicity is commonly encapsulated in sinusoidal carrier, pulse train, spreading code, hopping sequence of the primary signal. A wide sense stationary process that shows cyclo stationary has both mean and auto-correlation function in time domain. In the cyclo stationary feature detection requires the prior knowledge of the signal and the synchronization is not necessary in case of cooperative sensing. The main disadvantage of the Cyclo stationary feature detection is its long sensing time and high computational complexity. Thus Cyclo stationary method is more robust to noise and perform better then energy detection in low SNR condition.

D. *Wavelet Based Spectrum Sensing*

Waveform Based Spectrum Sensing method is applicable when the system known signal patterns only. These known pattern are used for synchronization .This pattern include preambles, spreading sequences, midambles etc. Waveform Based Spectrum Sensing is more reliable and robust than other method. This method does not require any prior information of the system.

E. *Comparison of Various Method*

TABLE I

Comparison block of various conventional sensing methods

Parameter	ED	MFD	CYCLO	WAVEL-ET
Robustness	Less robust than other methods	Less robust maximizes SNR	Robust to noise and perform better in low SNR	More robust than others
Accuracy	Less accurate than rest other methods	Accurate, but less than waveform	Better accurate than ED	More accurate than others
Complexity	Less complex	More complex	More complex	Less complex than MF and cyclo
Requirement of PU'S information	No	SU'S has priori information of PU'S	It also require priori information	No priori information is required

III. COOPERATIVE SPECTRUM SENSING

Cooperative spectrum sensing is a method in, which multiple cognitive radios collaborate or cooperate to each other either by sending their decisions statistics to a common node and the final decision is made by the base station. This sensing is more powerful than others because it can overcome the hidden terminal problem, which occurs when a PU's is shadowed by an obstacle, so that the cognitive user or SU's can't detect it, resultant of this cause high interference with PU's.[8]

The major challenges of cooperative spectrum sensing are applying best optimization and increased complexity. Cooperative can be implemented in two way- centralized cooperative sensing, distributed cooperative sensing.

A. *Centralized sensing*

In centralized cooperative sensing, a central unit is present which collect all sensing information from cognitive devices or secondary user and identifies available spectrum, then broadcast this sensing information to other secondary user without causing any interference. This central unit or fusion Centre makes a global decision that the PU is present in the channel. The crucial task of the centralized sensing is to mitigate the fading effects of the various channels and increase detection performance. [9]

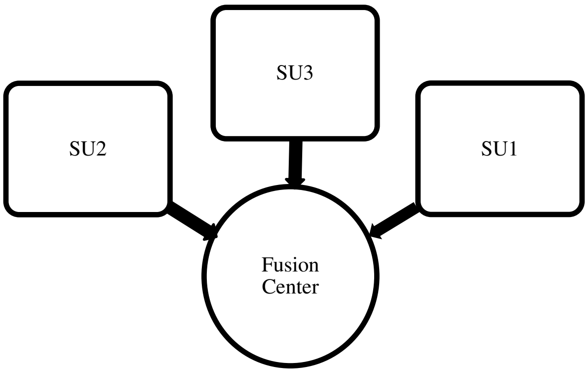

Fig.7: centralized cooperative sensing

B. *Distributed cooperative sensing*

Distributed sensing has one more advantage over centralized sensing, there is no need for a backbone infrastructure and it reduced cost. Collaboration is performed between two or more cognitive user. The main concept of distributed sensing is secondary user share their sensing information among themselves. Only final decision is shared in order to minimize the network overhead due to collaboration. This method can improve the sensing performance as well as detection capability of system.

IV. OPTIMIZATION IN COGNITIVE RADIO NETWORK

Various modern heuristic algorithms have been developed for solving numeric optimization problems.These algorithms can be divided into different groups depending on the criteria being considered, such as population based, iterative based, stochastic, etc. There are mainly two groups of population based algorithms: evolutionary algorithms (EA) and swarm intelligence based algorithms.

A. Genetic Algorithm

The most reliable evolutionary algorithm is the genetic algorithm which is adaptable to the radio environment. Among the artificial intelligence techniques proposed in the research field of cognitive radio networks, there are expert systems, artificial neural networks, fuzzy logic, hidden markov model and genetic algorithm. These entire decision algorithms adopt different types of reasoning to achieve an optimal solution. But each algorithm has severe limitations that reduced their operational value in real time in cognitive radio network. Fuzzy logic allow approximate solutions to be found in uncertain inputs which do not permits proving that the system has an optimal behavior. Neural networks are most applicable in this field but their computational complexity is higher than other methods. Genetic algorithm is more popular for their rapidity to cover a large space of possible configuration, and thus find the most suitable solution. [10]

What is genetic algorithm?

The genetic algorithm is a method for solving both constrained and unconstrained optimization problems, basically which is based on natural selection, the process that drives biological evolution. The genetic algorithm repeatedly renovates a population of individual solutions. We can apply the genetic algorithm to solve a several optimization problems that are not well suited for standard optimizationalgorithms, including various problems in which the objective function is discontinuous, non-differentiable, or highly nonlinear. The main advantage of genetic algorithm is its rapidity to cover a large space of possible configuration and thus find most suitable optimal solution. More advantage of the GA is its random nature and flexibility.

GA characterize a radio in form of a chromosomes and genes the users quality of service needs given as input to the GA procedure. We analyze two parameter, available spectrum resources size which is defined by the GA as a population size and the number of defined chromosome genes in the efficiency of spectrum allocation. This approach starts with the definition of the structure of a chromosome. The structure of a chromosome is a sets of genes i.e. frequency, modulation, bit error rate (BER)[13]. The main advantage of the GA is its multi-objective handling capacity [10]. Genetic algorithm has three main features for performing any optimal solution:

- Selection: It randomly selects individuals called parents which contribute to the population at the next generation.
- Crossover: crossover rule combines two parents to form a child for the next generation.
- Mutation: It is a process random change to individual parents to form children.

GA found that best value of parameter to obtain requires QOS specification for cognitive radio. [9][10]

B. Particle Swarm Optimization

A popular swarm-intelligence-based algorithm is the Particle Swarm Optimization (PSO) algorithm. PSO is a population based stochastic optimization technique, which is inspired by social behavior of bird Flocking or fish schooling.PSO shares many similarities with evolutionary computation and search techniques such as Genetic Algorithms (GA).PSO is a simple, fast and efficient computational method that optimizes a problem iteratively and trying to improve a detection performance and other parameter's. PSO uses the behavior of these social organizations or so called swarm intelligence algorithm.

In PSO, each single solution of given problem is a "bird" in the search space.it is called "particle". All of particles in the area have fitness values which are evaluated by the fitness function to be optimized, and have velocities which direct the flying of the particles. The particles fly through the problem space by following the current optimum particles.PSO is initialized with a group of random particles (solutions) and then searches for optima by updating generations. In every iteration, each particle is updated by following two "best" values. The first one is the best solution (fitness) it has achieved so far. (The fitness value is also stored.) This value is called pbest. Another "best" value that is tracked by the particle swarm optimizer is the best value, obtained so far by any particle in the population. This best value is a global best and called gbest. When a particle takes part of the population as its topological neighbors, the best value is a local best and is called lbest.After finding the two best values, the particle updates its velocity and positions. PSO has two main features: position and velocity. These are changed according to the number of iteration and assign best value of position and velocity on each iteration into the current value of particle. [5]

C. Artificial bee colony

Artificial bee colony (ABC) algorithm of spectrum sensing was proposed by Karaboga in 2005. It is a swarm intelligent optimizationalgorithm inspired by honey bee foraging.ABC algorithm is better than to other population-based algorithms with the advantage of employing fewer control parameters.In ABC algorithm, the colony of the artificial bees mainly contains three groups of bees: employed bees, onlookers and scouts.The first half of the colony consists of the employed bees and second half includes the onlookers.Each employed bee is associated with a food source, in other words, the number of the employed bees is equal to the food sources. An employed bee finds a food source or position by modifying the position in her memory and calculates the nectar amount of each new source and memorizes the better one, i.e. greedy selection. Employed bees share information related with the quality of the food source they are exploiting information, on the dance area. Onlooker bees find food sources based upon the information coming from employed bees. More profitable food sources are more likely to be chosen by onlookers. An onlooker bee chooses a food source depending on this information and produces a modification on this source. Greedy selection is applied for finding better food source in ABC algorithm.The ABC algorithm is very simple and flexible, especially suitable for engineering application.

C. Firefly Algorithm

Firefly is a metaheuristic algorithm that is inspired by the Behavior of fireflies. There are about two thousand firefly species, and most fireflies produce short and rhythmic flashes. The primary purpose for a firefly's flash is to act as a signal system to attract other fireflies. The pattern of flashes is often unique for a particular category. Females respond to a male's unique pattern of flashing in the same category. We know that the light intensity at a particular distance 'r' from the light source obeys the inverse square law. The air absorbs light becomes weaker and weaker as the distance increases. Here, the attractiveness is proportional to the brightness. The flashing light can be formulated in such a way that it is associated with the objective function. For the simplicity fireflies uses three idealized rules:

- All fireflies are unisex so that one firefly will be attracted to other fireflies regardless of their sex.
- Attractiveness is proportional to their brightness, thus for any two flashing fireflies, the less brighter one will move towards the brighter one. If there is no brighter one than a particular firefly will move randomly.
- The brightness of fireflies is determined by the landscape of the objective function.

V. RESULTS

In this section, we compare the various optimization techniques in CR using different parameter mentioned in Table II. This work mainly concentrates on the spectrum allocation mechanism in RF environment which has been sensed by the Cognitive Radio.

Table-2
Comparison block of various optimizations in CR

Parameter	GA	PSO	FFA	ABC
Control parameter	Generation rate, crossover rate, mutation rate	Cognitive, social factors, inertia weight	Attractiveness coefficient, randomization coefficient	Maximum cycle number, colony size
Convergence Rate	Less	More than GA	More than PSO	Better than GA
Complexity	More	Less complex	Near about ABC	Less than GA,PSO
Convergence speed	Less in large space	Better than GA	Similar to PSO, but better than GA	Better than GA
Flexibility	Flexible	More than GA	More	More Flexible than PSO
Computational time	More	Less than GA	Less than PSO	Less than GA, but more than PSO

VI.CONCLUSION

The allotment of spectrum as per the QOS of the applications is a major research filed in cognitive radio application. CR is an adaptive intelligence radio and network technology that can automatically detect available channels in wireless spectrum and improve the spectral efficiency of the spectrum. In the cognitive radio network several appearance of spectrum sharing and spectrum sensing problem are studied. Most of the application of cognitive radio suffers from primary hidden terminal problem due to different fading channel present in environment. The use of cooperative spectrum sensing can overcome this problem in most application.

Traditional method for spectrum sensing and their merit and demerit were discussed. Then different optimizations for spectrum management in cognitive radio network like genetic algorithm, PSO, Artificial bee colony, firefly algorithm is compared provide optimal solution from available spectral frequencies.

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