ENERGY EFFICIENT COGNITIVE RADIO HYBRID VOTING RULE –PSO

A Dissertation submitted in the partial fulfilment of requirement for the award of

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In

Wireless Communication

Submitted by

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CERTIFICATE

I, Parth Gulati , hereby certify that the work which is being presented in this dissertation entitled "**ENERGY EFFICIENT COGNITIVE RADIO HYBRID VOTING RULE – PSO**" by me in partial fulfilment of the requirements for the award of degree of Masters of Engineering in wireless communication Engineering from Thapar University (Deemed University), Patiala is an authentic record of my own work carried out under the supervision of **Dr. Rajesh Khanna.**

The matter presented in this dissertation has not been submitted in any other university / Institute for the award of any other degree .

Date: 02/07/2014

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It is certified that the above statement made by the student is correct to the but of my knowledge and belief.

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ABSTRACT

Cognitive Radio (CR) was the proposed technology to make the coexistence between Pus and SUs a possible reality. A CR is an intelligent wireless communication system capable of obtaining information from its surrounding environment and, by adjusting its radio operating parameters

Spectrum sensing (SS) is one of the possible techniques to find the unused parts of the spectrum, called white spaces (WS). Despite not being necessarily a new area of research, it has been lately subject to fundamental innovations due to the increasing interest on the cognitive radio technology.

Cognitive radio sensing structure refers to identifying a secondary node when the primary node faces an overhead of data transmission . In such a case if the network goes for searching the entire network to identify a secondary node , it might consume more time and mean while the data packet might expire . To prevent such hazard in the network , we need to find a path through which the data packets would be send. To achieve the above written statement an optimization technique name PSO (Particle Swarm Optimization) has been applied . When so ever a primary user searches for a secondary user , the PSO looks in the neighbor of the random selected radio node to be transmitted and searches the entire radio connected nodes of the random selected node . The searching is done on the basis of the energy consumption of the nodes . Once the nodes are sorted out , we compute the overhead of the dynamically selected node. The transmitter side sends only that much data packet which the receiver can handle. To compute the capacity of the destination node , we compute the receiving power of the destination radio node and its coverage node and by the end we take an average accuracy of the spectrum sensing node. Then the procedure is achieved by applying quantization method to the data packets to save the data from external hazards and data losses. The entire procedure is repeated till the last receiving node is not achieved .

The selection of a secondary node is made on the basis of several factors like energy utilization of the node getting selected as a secondary node. The optimal selection rule can be done through various algorithms . One of the node selection algorithm is optimal voting rule . The current research work has been made on the basis of the optimization of the cognitive radio sensing spectrum to check the energy dissipation of the secondary node selection. This research work has added and edge to the optimal voting rule in which all the nodes of some category adds their opinion to the network about the selection of one node.

This voting rule here has been tried to optimized by using PARTICLE SWARM OPTIMIZATION METHOD in combination with probable false alarm detection and the results have been expected to be improved by 5 to 10 percent.

Keywords: Cognitive Radio, Energy Detection, BER, PSO, SNR, Cooperative Spectrum Sensing, Optimization

CONTENTS

LIST OF ABBREVATIONS

AWGN	Additive White Gaussian Noise
AR	Amplify and Relay
AF	Amplify and Forward
CD	Cyclostationary Detection
CDR	Constant Detection Rate
COP	Combinational Optimization Problems
CP	Cyclic Prefix
CR	Cognitive Radio
CRN	Cognitive Radio Networks
CSI	Channel State Information
CSS	Cooperative Spectrum Sensing
CSSA	Cooperative Spectrum Sensing and Acess
DF	Decode and Forward
DR	Detect and Relay
DRM	Detection Result Modification
DRP	Detection Result Prediction
DSA	Dynamic Spectrum Access
DSP	Digital Signal Processor
ETSI	European Telecommunication Standards Institute
ED	Energy Detection
FC	Fusion Center
FCC	Federation Communication Commissions
FFT	Fast Fourier Transform
FCC	Federation Communication Commissions
FFT	Fast Fourier Transform
FPGA	Field Programmable Gate Arrays
GA	Genetic Algorithm
GLRT	Generalized Likelihood Ratio Test
GPS	Global Positioning System
HDR	Hard Decision Rounding
ISM	Industrial Scientific Medical Band
MF	Matched Filter
NPRM	Notice of Proposed Rule Making

OFDM	Orthogonal Frequency Division Multiplexing
PSD	Power Spectral Density
PSO	Particle Swarm Optimization
PU	Primary User
PUE	Primary User Emulation
QOS	Quality Of Service
RF	Radio Frequency
SARP	Selfish Avoidance Routing Protocol
SDR	Software Defined Radio
SDR	Software Decision Rounding
SNR	Signal to Noise Ratio
SS	Spectrum Sensing
SU	Secondary User
TDMA	Time Division Multiple Access
WLAN	Wireless Local Area Networks
WS	White Spaces

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CHAPTER 1

INTRODUCTION

1.1 Cognitive Radios

Ever present demand for wireless services lead us to realize the need for more resources . But Present wireless networks followed the fixed spectrum assignment policy .As a result ISM 2.4 GHz band is generally available for future applications .The unauthorized band access is generally risky as it leads to increased chances of interference and hence leads to degradation of the system performance in this both the licensed and unlicensed bands are now full to their capacity .Current inclination towards uninterrupted association leads wireless technology expensive and limited resource. RF is an important resource and it should be utilized efficiently .

In [1] this perspective, FCC allowed spectrum policy task force to perform the changes in the spectrum strategy and they had concluded that the difficulty is the shortage of spectrum and it often becomes a trouble to access the spectrum . In this authorized users given a spectrum have not properly used and there are gaps in the spectrum. These gaps are known as spectrum holes. As shown in the figure 1.1.The most important mission of CR is spectrum sensing since the mission device needs to reliably detect the week licensed signals so that it can be accommodated by other unlicensed signals without causing any interference. Sensing of spectrum is desired to minimize the total error rate and also enhances the utilization of the vacant spectrum.

Spectrum insufficiency is becoming one of the important and most demanding problems to the expansion of new unwired communication technologies. In agreement with the traditional spectrum portion policies, diverse wireless networks should function in different bands, so intervention doesn’t become an concern. However, research have shown that this method is leaving a great percentage of the spectrum underutilized [2]. To solve this difficulty DSA was one of the planned solutions. It consists in a current spectrum allotment pattern that allows unauthorized secondary users to access the spectrum gaps or white spaces opportunistically in the licensed bands that were, usually, just occupied by primary users.

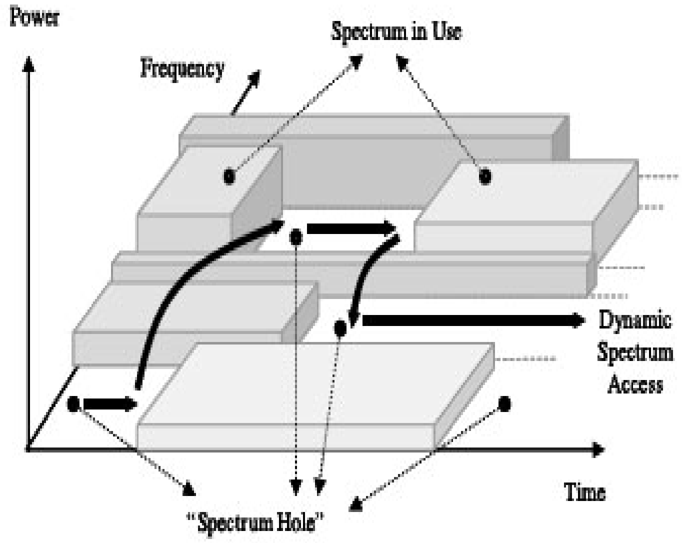

Figure 1.1: A Spectrum Hole[2]

Cognitive Radio, projected by Joseph Mitola in 1999 [4], is defined a thinker wireless communication system that is paying special attention of the radio environment and able to settle in to its varying parameters. It was recommended as a mode to increase radio spectrum deployment efficiency and to increase the communication consistency of present wireless technologies.

According to Haykin [3], the CR three basic units are:

- White Space recognition unit.
- Channel recognition unit. It deals with channel parameters estimation, in exacting, the channel capacity.
- Dynamic spectrum managing unit. Its main idea is to build up strategies to use the spectrum resources in an proficient and effectual way.

There are several white space recognition methods projected in the literature as explained below

- In the geo-location technique, the CR approximates its location and queries a database for in sequence of the close by licensed channel handling. This technique has quite a few disadvantages such as the reality the CRs have to use a geo-location method and a record which restrict its their self-determination of the network. In addition, geo-location needs changes in the inheritance systems so the central database can be reorganized autonomously.

- In the beacon detection technique, the CR gets in sequence of the radio environment from the beacons transmitted by the PUs. Like the geo-location technique, this requires changing the inheritance systems.
- Spectrum sensing (SS), on the other hand, only requires detecting PUs transmissions during their normal process. However, the CR has to be capable to detect these signals at very low SNRs in a small amount of time so it doesn't create any destructive interference. One of the main task to SS is to triumph over the hidden terminal problem.

1.2 Cognitive Radio Architecture and Design

To get acquainted to substantial background the CR has to transmit and convene at dissimilar spectrum using different inflections and organize techniques and other specifications used in the radio band .Since the convectional dedicated hardware does not allow such flexibility .All the operations digital processing are usually executed in software .The approximation is in full understanding with the aspect of SDR which consist of bringing software close to the antenna.
The illustrative cognitive radio design is shown in Figure 1.2. It can be divided into 3 sub-parts: Digital Transceiver, Channel Monitoring and Spectrum Sensing module and Communication Management and Control unit. The digital transceiver, in turn, can be further divided into the RF front-end and the baseband processing unit [5].

The RF front-end constituent corresponds to the hardware component of the CR whose task is the reaction, below alteration, enhancement, combining, filtering, permeates and analog to digital conversion of the signal of interest. The RF front-end of a CR must be capable of understanding a wideband spectrum which force upon strict necessities in the hardware apparatus namely in the antenna, power amplifier and adaptive filter.

The baseband processing unit, is implemented in software, is reliable for all the necessary digital dispensation of the signal, such as, the inflections and organizes techniques. It is usually accomplished over a FPGA, DSP or GPP.

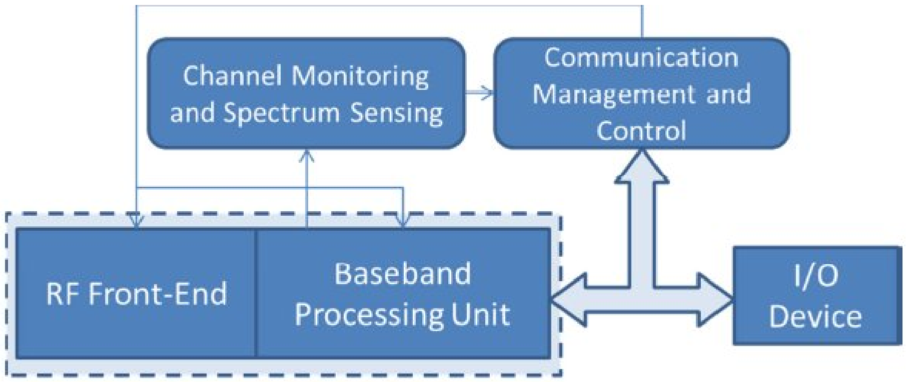

Figure 1.2: Cognitive Radio physical architecture[5]

The channel monitoring and spectrum sensing part is competent of collecting information from the radio surroundings, in the course of spectrum sensing or other white space acknowledgment methods and sending its response to the communication organization sub-system so, the CR can regulate its utility parameters in the RF front-end and baseband processing unit.

The communication management and manage subsystem responsibility is to direct every CR process, specifically switching mode decisions and spectrum sensing scanning based on standards given by recital metrics.

1.3 Functions and Components of Cognitive Radio

The main task of CR is to access the spectrum so that the given spectrum is optimized i.e used to its maximum extent without causing any interference .The main functions of the CR are its spectrum sensing ,spectrum management and spectrum mobility.

- Spectrum Sensing : The function of spectrum sensing is to access the spectrum so that it can find out or detect the gaps in the spectrum so that the vacant spaces can be filled by the unlicensed users to increase the spectrum efficiency. Allocation of spectrum should be done in such a way so that it does not cause any interference to the licensed user.
- Spectrum Management: Based on the knowledge of spectrum sensing the CR allocates the best available spectrum band .
- Spectrum Mobility: CR user must vacate the spectrum to the licensed user and moves to the next best available spectrum band. We can also say that it generally control the change in the frequency bands that usually takes place in a given process.

- Spectrum Sharing: CR network has to provide a fair and optimal spectrum allocation method among multiple CR users.

The function of CR is to accumulate information related from the enviorment to recognize the vacant spaces so that it can be utilized by other unauthorized user and hence increases the efficiency of the spectrum. Figure 1.3 shows the components of cognitive radio.

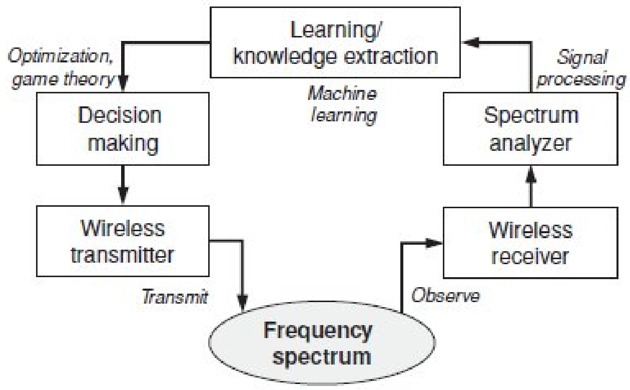

Figure1. 3 Components of cognitive radio [7]

1.4 Non-Cooperative Spectrum Sensing

There are several spectrum sensing techniques recommended in the literature, such as, Energy Detection (ED), Matched Filter (MF) and Cyclostationary detection (CD).The option between one sensing methods over another reliant greatly on the circumstance and the CR system necessities. Prior information of the PU signal features, computational and hardware cost and detection time restrictions are a few of the factors that manipulate this option.

1.4.1 Hypotheses Testing

The signal finding problem is solved by the decision between the two hypotheses:

$$H_0 \ : \text{Primary user is not present}$$
$$H_1 \ : \text{Primary user is present} \qquad (1.1)$$

The signal under the hypothesis will takes the following form:

$$H_0 \ : y[n] = w[n] \ , n=1,2,3\ldots\ldots..N$$
$$H_1 \ : y[n] = x[n] + w[n] \ , n=1,2,3\ldots..N \qquad (1.2)$$

where y[n] is a two dimensional vector with the I and Q components of the received signal, w[n] is a zero mean Additive White Gaussian Noise with variance σ^2 and x[n] the signal sent by the primary user after reduction and deformation from the channel. N is the number of samples of the expected signal used in the spectrum sensing process.

The judgment between the two hypotheses is made by comparing a test statistic T with a threshold γ. The detector presentation is primarily described by two metrics: probability of detection and probability of false alarm. Low likelihood of detection increases the intervention inflicted on primary users, whereas high likelihood of false alarm increases the quantity of missed spectral opportunities in the secondary network. The likelihood of false alarm and detection are specified by the equations.

$$P_f = P(T > \gamma/H_0). \tag{1.3}$$

$$P_d = P(T > \gamma/H_1) \tag{1.4}$$

According to Neymann-Pearson's theorem, for a fixed prospect of false alarm The assessment guide that maximizes the likelihood of detection is the LRT. In order to use the LRT, just right information of the $p(y/H_j)$ parameter, such as, the noise and source signal distributions as well as the channels uniqueness, is usually essential. Nevertheless, in cognitive radio scenarios, this in sequence is sometimes not available. In such cases, other techniques like the Bayesian method and the GLRT are more ample.

1.4.2 Energy Detection

Energy Detection (ED) is one of the the popular basic sensing schemes. It is most favorable if together the signal and the noise are Gaussian, and the noise variance is completely known. However, its presentation falls rapidly when there is ambiguity in the noise power value and is also incompetent to distinguish between signals from dissimilar systems and among these signals and noise. Its benefit lies in its ease and not needed prior information of the PU signal making it finest suited for quick and uncouth spectrum sensing.

The ED test guide can be defined as follows:

$$T^{ED} = \frac{1}{N}\sum_{n=0}^{N-1}]y[n]^2 \tag{1.5}$$

Since $y[n]^2$ has a central chi-square distribution under H_0 and H_1 the probabilities of false alarm and detection becomes

$$P_f = P(T^{ED} > \gamma/H_0) = \frac{\Gamma(N,\frac{\gamma}{2\sigma^2})}{\Gamma(N)} = P(N, \gamma/2\sigma^2) \tag{1.6}$$

$$P_d = P(T^{ED} > \gamma/H_1) = Q_l(\sqrt{\frac{u}{\sigma^2}}, \sqrt{\frac{\gamma}{\sigma^2}}) \tag{1.7}$$

where Γ( ) is the lower incomplete gamma function, and Q_l is the global Marcum-Q function. It can be conditional that defining a verge based on the likelihood of false alarm requires proper knowledge of the noise power (σ_n^2).The number of samples needed to estimate P_f and P_d is specified by (1.5) equation where

$$N=2[Q^{-1}(P_f)-Q^{-1}(P_d)(1+SNR)]^2SNR^{-2} \quad (1.8)$$

1.4.3 Matched Filtering

Matched filtering (MF) is a articulate detection technique that employs a correlator coordinated to the signal of concentration or convinced parts of it, such as pilots, preambles, spreading codes and training sequences. It shows most favorable performance results making it a good alternative for applications where the transmitted signal is well-known a priori like radar signal processing. However, its recital degrades severely with harmonization errors and multipath fading. In addition, taking into portrayal that distinct matched filter implementations are required for each dissimilar type of licensed signal, its practice can enlarge the CR's difficulty noticeably. If we assume that the noise is Gaussian and x[n] can be determined and known by the receiver,
the variable y[n] has the distribution:

$$y[n]\sim\begin{cases} N(0,\sigma_n^2)\text{ , under H}_0 \\ N(x[n],\sigma_n^2)\ under\ H_1\end{cases} \quad (1.9)$$

The stationary test of the matched filter is reduced to:

$$T^{MF}=\sum_{n=0}^{N-1}x[n]y[n]\lessgtr\gamma \quad (1.10)$$

The chance of false alarm and detection are given below:

$$P_f=Q(\frac{\gamma}{\sigma_{n\sqrt{E}}}) \quad (1.11)$$

$$P_d=Q(\frac{\gamma-E}{\sigma_{n\sqrt{E}}}) \quad (1.12)$$

$$\text{Where ,}E=\frac{1}{N}\sum_{n=0}^{N-1}x[n]^2 \quad (1.13)$$

γ is the defined verge for and P_f is chance of false alarm. Not like the energy detector, the probabilities of false alarm and detection of the matched filter Does not depend on the power of the noise but its square root, revolving it less responsive to noise ambiguity than the ED. The number of samples desired to meet the necessary P_d and P_f is:

$$N=[Q(P_f)^{-1}-Q(P_d)^{-1}]^2/SNR \tag{1.14}$$

1.4.4 Cyclostationary Detection

Any communication signals exhibit fundamental periodicities in their signal structures added by modulation, preambles, pilots or cyclic prefixes for coordination and signaling purposes. As a result, these signal can be used as cyclostationary processes since their mean and autocorrelation are periodic. Such built-in cyclic features can be used for distinctive licensed user signals from AWGN which, by meaning, is a inactive process. The cyclostationary recognition has better performance than the energy recognition under low SNRs, does not require information of the noise level but, as a disadvantage, its difficulty and sensing time every now and then become too expensive.

1.4.5 Cyclic Prefix Based Detection

The recurrence of data in the cyclic prefix (CP) adds some connection between the samples of an OFDM symbol. There are quite a few detectors that exploit this attribute of OFDM signals, such as correlation coefficient-based (CCE), nonparametric autocorrelation (NAC) [6], second-order statistics based, and CP-based sliding window detectors [7]. CP-based sliding window which, according to the literature [7], has the best detection results

1.5 Cooperative Sensing

In practice, quite a few factors such as multipath fading, shadowing and, as a result, the hidden terminal problem may control the detector's performance. These factors could be, however, be removed if the CR users public their sensing results with the other CRs. This method is called cooperative spectrum sensing [8].The enhancement brought by cooperative sensing results from the deployment of the spatial diversity between the interpretation made by different CR users at different positions.

The common sensing information is then turned into a shared decision whose performance enhanced compared to individual outcomes is called cooperative gain. However, cooperative sensing also adds some working cost to CRs by increasing delay or spending additional energy or other resources in the cooperative operations. Additionally, it typically implies the usage of a control channel where the share of sensing information is made which consequences in additional wasted bandwidth to the arrangement.

There are three varied cooperative sensing categories based on how CRs hand out information in the network: centralized, distributed and relay-assisted.

- In the centralized type, a body called fusion center (FC) control all the cooperative sensing technique by selecting the frequency range of significance, asking, through a control channel, for the individual sensing results of other CRs and in receiving of and then combining those sensing results to construct a choice on the presence or absence of a licensed user. Then, the combined decision is broadcasted to the neighbor CRs.
- In the case of distributed cooperative sensing, no FC is distinct and the CRs switch among themselves and converge to a combined solution by repetitions.
- The relay-assisted considers that the sensing and exposure channels in the cooperative sensing network are not ideal. If a CR1 has a weak sensing channel and a strong report channel to the FC and a CR2 the opposite, they can balance each other by sending the CR2 sensing penalty through the path CR2-CR1-FC. The relay-assisted method can be central or discrete depending on the existence of a FC or not.

A key part of a cooperative sensing model design is the data combination. The reported sensing consequences can be of different forms, types or sizes, depending on the administer channel bandwidth requirement. There are three main ways of combining the sensing results: soft combining, quantized soft combining and hard combining.

- In soft combining the CR users transmit the whole local sensing samples or their test information to the FC or other CRs. The mutual data is then shared using variety of techniques such as equal or maximum gain combining. Soft combining brings the greatest sensing performances in view of the fact that there is extra information to practice by the FC, however, it also incurs in the utmost operating cost to the control channel in terms of necessary bandwidth.
- In the quantized soft combining, the information transmit by the CRs is a quantized form of the information sent in standard soft combining method in organizes to diminish the operating cost to the control channel. The common data is used in a weighted linear arrangement and, then, turned into a mutual decision.
- The hard combining is the practice that incur less working cost to the arrangement. Each CR makes a local personage decision and sends it as a one bit message to the FC or other CRs. The FC, then, combines the frequent information using linear fusion rules such as

OR, AND and greater part, i.e. M out of N rules. In the AND rule, the path is measured engaged if all CRs have calculated it occupied. In the OR rule, the channel is measured busy if at at least one CR have decided so. The M out of N is a middle term of the preceding two. Highly developed fusion rules can also be used such as linear-quadratic method that considers the correlation between CR users.

1.6 Secondary User

Those users which are not allowed th access the licensed band are known as secondary users .But the spectrum resources are not utilized to its full capacity so secondary users are allowed to use the authorized band when the licensed user is not present. The utilization of spectrum band is done in such a way that it does not cause any interference to the primary user . The spectrum sensing techniques that are used to sense the spectrum are Energy detection, matched filter, cyclostationary detection. We generally use energy detection as it does not require any information about the type of signal so this technique is simple as compare and less complicated related to other techniques. The problems related to spectrum sensing are evanescent, shadowing and time varying character of the unwired channel. Simple sensing is generally not efficient because of the presence single user whereas in cooperative spectrum sensing multiple users are allowed to sense the channel and all the information of each individual result are combined at the fusion center to find the presence and absence of licensed user.

Based on the **Neyman-Pearson** [9] criterion we obtain an optimal soft combination scheme that maximizes the detection likelihood for a given false alarm likelihood. It is confirmed that soft arrangement schemes, even uncomplicated equal gain arrangement, have noteworthy performance enhancement over the conformist hard arrangement. Hopeful by the performance gain of soft arrangement, we additional propose a new hybrid combination scheme with only two-bit in service cost for every CR user, which, on the other hand exhibits much enhanced performance than the predictable one-bit hard arrangement method. Normally it is assumed that there is a spectrum scarcity in the frequency range that is easily accessible for wireless communication so there is a fight between the users to use the frequency below 3 GHz . The FCC frequency allotment chart indicates overlapping allocations over all of the frequency bands, which reinforces the insufficiency mindset. On the other hand, actual capability taken in downtown.CR technology as a applicant to put into the process of bargain or strategic spectrum allocation. Wireless systems today are attributed by overgenerous static spectrum allocations, firm radio task, and restrained network coordination. Some systems in unauthorized frequency bands have accomplish great spectrum efficiency, but are facing a problem of increased intervention that limits network capability and scalability. Cognitive radio systems offer the chance to use DSA techniques to help prevent interference, become accustomed to immediate local spectrum easiness of use by creating time and location reliant in unlicensed band, i.e. they are sharing their band with the licensed users. Exclusive to cognitive radio process requirement is to able to sense the gaps in the spectrum so that it can be used by the unlicensed users.Since radio does not have any primary rights to any preassigned frequencies.

1.7 Radio Functionality

In order to convene the challenging radio sensitivity necessities and wideband frequency alertness. The radio functionality will involve the design of analog digital and network processing techniques. Spectrum sensing is best addressed as a cross layer design and its alertness can be increased by enhancing the sensitivity of the front end of RF, exploiting gain for correct primary user signal and cooperation among the network where user share spectrum sensing measurement. The growing demand for wireless network requires the need of more and more resources to accommodate the growing demand but the present wireless system follows the fixed assignment policy as a result unlicensed user have to use ISM band which is available for all the applications . This band is not able to accommodate all the applications of the unlicensed user and hence the chances of interference are more. To overcome this CR is being known for intelligent ability to rapidly adapt to the changing conditions and make the best use of the spectrum.The important task of CR is to rapidly detect the week ongoing primary signals so that the give spectrum of that primary user can be given to some other secondary user and because of this spectrum is utilized efficiently.

1.8 Severe Fading

Among different spectrum sensing techniques such as the matched filter detection and the cyclo stationary feature detection energy detection is a popular method and addressed in the literature due to its low computational complexity and does not requires any knowledge of the primary signal. When there is a single user detection suffers from malicious wireless channel circumstances including deep vanishing and shadowing effects as well as the noise of the instrument . To overcome these challenges, cooperative spectrum sensing in which multiple secondary users work together to perceive the occurrence of the primary users can significantly recover the sensing performance. Specifically, SUs pass on their results or decisions to a fusion centre , which is in charge for making the final decision regarding the presence of the PU cooperative spectrum sensing process consists of two aspect: a observation aspect in which the SUs execute confined spectrum measurement and a reporting aspect during which they forward the results to the FC, where the final decision about the existence of the PU is obtained [12] . The channel defacement on the reporting channel between a unlicensed user and the union centre also influence the overall administration of the sensing process however, in most of the preceding works have deserted this issue by conceited ideal or without error reporting channels.. The optimization problem of CSS with energy detection to diminish the total error rate is interrogated in for an error free coverage channel. Moreover, Quan et al. in , have projected a linear CSS framework with condensed complexity based on the alliance of confined statistics from different unlicensed users and it was supposed that there will be a noisy reception at the fusion center. In recent times, has countered defective coverage channels when beam forming technique is applied to administer the total broadcast power of the unlicensed user . Furthermore, the author in planned blend method based on deflection measure which considers shadow-fading in both sensing and reporting channels. To replace an allternative we come up to, under data fusion algorithm, assumption is made that the unlicensed users utilize the licensed band to transmit their analysis to the FC, however; in this unlicensed user limits its transmitting power in a manner so that on the whole outage likelihood of licensed user remains below a predefined threshold. Entirely researchers imagine that unlicensed users transmit their results over the orthogonal sub-channels and they are separated from the main channel in time domain TDMA manner toward the FC. We primary attain the utmost allowable broadcast power of the unlicensed users with the guarantee to maintain the required QOS of main transmission. Then we study the consequence of the section of surveillance phase and number of the cooperative unlicensed users on the whole sensing performance .Recreation results confirm that there is an optimal surveillance phase time and optimal number of SUs which leads to the maximum achievable performance for a given set of network parameters. CSS and changing to the environment, a cognitive radio is able to fill spectrum gaps and hand round devoid of causing harmful intervention to the primary user. We consider optimization of CSS with energy detection to reduce the total error rate. Cooperative spectrum sensing with conventional energy detector in single antenna based cognitive radio networks for getting better consistency in detecting a spectrum hole has been studied significantly in recent times .Performance of CR can be enhanced by utilizing a energy detector that has enhanced the performance in cognitive radios from the conventional energy detectors. It is shown that reliability of spectrum sensing can be enhanced in the CR by using multiple antennas. We consider optimization of a CSS with an enhanced energy detector, several antennas at each CR, and finding the least used primary channels and try to minimize the total error rate i.e sum of probabilities of false alarm and missed detection.

1.9 Constant Detection Rate

Since the CDR only considers spectrum sensing constraint in finding threshold level, it cannot gives guarantee to minimize the spectrum sensing error. In accumulation the CDR make available to us on the whole constant detection prospect even in high SNR region where signal strength is much stronger than noise power to be effortlessly renowned we think about an optimization of threshold level with energy detection to diminish the spectrum sensing inaccuracy for a given sensing constraint. The false alarm and miss detection probabilities are monotonically increased and decreased in that order, as the threshold level increases. Therefore, the spectrum sensing imprecision function has concave or convex properties for definite threshold level period. To optimize threshold level, in calculation to spectrum sensing error, spectrum sensing limit which is given by difference situation should also be calculated. Based on properties of spectrum sensing inaccuracy function and disparity spectrum sensing constraint, we derive an adaptive optimal spectrum sensing threshold level minimizing spectrum sensing error while satisfying spectrum sensing constraint.[13] Through the use of the proposed spectrum sensing scheme, the spectrum sensing performance can be improved compared to earlier known schemes. Cognitive radio has achieved noteworthy investigate consideration due to its elevated impending to raise spectrum competence in recent years . Spectrum sensing is a essential problem for understanding of cognitive radios networks especially in the low SNR caused due severe fading

1.10 Problem Statement:

Cognitive radios are knows for their transfer values and rate of recognition of the secondary nodes. The problem with the cognitive radios is the minimum consumption of energy should be there to prevent the system from the high consumption of power utilization .The problem of this research work is categorized as follows

a) The selection of a secondary node is made on the basis of several factors like energy utilization of the node getting selected as a secondary node. The optimal selection rule can be done through various algorithms . One of the node selection algorithm is optimal voting rule . In this rule the other nodes provide a voting scheme on the basis of which a secondary rule has to be selected .
b) The problem with the optimal voting rule is the error rate produced through it .
c) The problem of this research work is to enhance the voting rule using optimization algorithm called PSO(particle swam optimization). PSO works with distributed particles and generates values for the each and every iteration . By the end of all iteration, the optimal node is selected.
d) The PSO algorithm is combined with false alarm reduction technique which provides PSO an edge over normal PSO as it saves time , the PSO stops its iteration when so ever a false alarm is detected and the time getting consumed in completing the next iterations will be saved .PSO has to be combined with probability of detection to reduce the probability of false alarm detection and to reduce the chances of increase in bit error rate.

1.11 Organization of the report

This report is is organized in six chapters.

- Chapter 1 Summarize the basic problem statement of the research work and gives the introduction to cognitive radio networks
- Chapter 2 We review related work done in the area of spectrum sensing in cognitive radio networks
- Chapter 3 Optimal voting rule in cognitive radios and optimization techniques.
- Chapter 4 PSO algorithm for cognitive radios.
- Chapter 5 We showed simulation results of spectrum sensing in cognitive radio with and without PSO
- Chapter 6 We gave the conclusion and future scope.

<u>CHAPTER 2</u>

LITERATURE SURVEY

2.1 Research Papers

This section involves the work done by the various researchers in the field of cognitive radios for the efficient utilization of licensed spectrum .

Yi Zheng *et al*., presented that there is an need of small amount of information is required by unlicensed user to access the available spectrum. But sensing due to energy detection is used to a limited extent due to the noise problem .Blind band credit does not require any information of the signal and also improves the result that has lead to the CSS based on blind basis.Numerical results shows an improvement over noise which is not there in case of energy detection. [23]

Wen-Bin Chien *et al*., analysed that CSS nowdays are greatly used because there is a problem when there is a single user used for band sensing .However in CSS a large number of user are not used at every instant so there is a large amount of wastage in terms of energy .To combat this problem DRP and DRM is proposed to reduce the energy and designed an energy saving ideology for CR. It reduces the energy exertion by about 64% compared to previous schemes. [24]

Chongjoon You *et al*., analysed that SS is generally used to gather information realted to primary user i.e wheather it is present or not so that it can be used by the unlicensed user but it should be used in such a way so that it does not cause any intrusion. Same type of users are used to reduce error and the most favourable time to increase the transmission productivity. Amodel is proposed where the TV band is not utilized by it competently is used by the Wi-Fi networks owing to augment demand .[25]

Shengli Xie *et al*., worked on the scheme that either use single or multiple user to perform sensing on the single and the same channel during each stage .Proposed a new parallel sensing skill where a large number are selected which are most favourable to to evaluate the the spectrum .In a given period each selected user senses different channels and hence in a given period a large number of channels are sensed simultaneously and this leads to higher throughput compared to earlier techniques .[26]

Wei Zhang *et al.,* discussed CSS when used over Rayleigh fading channel give us the error so proposed a broadcast variety based sensing to triumph this problem. Multiple CR are used an practical antenna over flat and frequency selective fading channels . Proposed relay variety based CSS improve the detection when some cognitive radios are in deep fade .When used with algebraic coding further enhances its performance. [27]

Qian Chen *et al*., studied that CSS for cognitive radio is generally used to allocate the spectrum to those users that have no license to use the spectrum of accredited users. Two sensing techniques were AR and DR that is generally used to improve the performance i.e gives the spectrum to accredited users when the come to lively state .These two techniques lead us to to derive the detection and false prospect for single and multiple relay models .Simulation results shows an enhancement over the previous used techniques. [28]

Tao Cui *et al*., discussed CSS and understood when multiple users join by means of handover scheme .The swapping and transmitting of knowledge are the two techniques that are investigated and gives the result to the requisite controller .Proposal of handover at each unlicensed user is maximized with either average or peak power impulsion .For local CS the optimal handover scheme give the impression of being like AF for low SNR and DF for high SNR . For Global CSS coherent and non coherent sensing are proposed depending upon how the unlicensed user is coordinated. Articulate detection a decentralized approach is used that maximizes handover function locally and in noncoherent detection we use energy blend detector to decouple handover task for weighing coefficients maximization. Techniques shows an enhancement over the earlier protocols.[29]

Kris Sujatmoko *et al*., proposed a new sensing technique based on distinguish analysis assess spectral lines to be classify into noise or signal. Blind detection of telecommunication signals in a broadcasting band is very cooperative in cognitive radio environment in particular, when the second user does not have sufficient in sequence about the main user.. The outcome is 10 dB improved from the earlier techniques.[30]

Wei Zhang *et al.,* evaluated that CSS detect the gaps in the licensed bandthrough energy detection and examined the maximum value of CSS with an aspire to improve the identification attainment in an pertinent and available way .Optimal voting rule detector useful for CSS is maximize the energy detection and threshold .Rapid sensing algorithm is premeditated for few no of users while maintain the agreed miscalculation conditions .[31]

Toru Sakaguchi *et al.,* discussed cooperative spectrum sensing based on energy detection t where the performance of cooperative spectrum sensing is fundamentally corrupted if the sensing devices are out of order. Pre-filtering and weighting methods are used to remove the effects of out of order nodes in cooperative spectrum sensing. Three types of the nodes that repeatedly create false values far above or below the threshold have been measured. Anything other than the three kinds of malicious nodes has not been measured. By results of simulations, we show that the planned algorithm and the technique used can identify all those malevolent nodes, and can take away their damaging effects.[32]

Amal S Kannan *et al.,* studied the radio spectrum is being underutilized and cognitive radio has been planned as a answer to tackle the difficulty of spectrum not utilized properly .It allow the secondary users to use spectrum allocated to primary users if primary are not present at the current time and location. Detection of unused spectrum cognitive radio must execute spectrum sensing. Either single or multiple users can take part in spectrum sensing process. Later one is called CSS. Enhancement in sensing is performed by including a number of cognitive users rather than a single solitary. In CSS, each CR perform there spectrum sensing by any of the obtainable methods and all sensing results are combined according to certain rules. Current algorithms require signal information, noise information or the both to carry out spectrum sensing. Blind spectrum sensing based on QR decomposition and linear prediction and extends it to cooperative sensing and they does not require either signal information or noise information to perform spectrum sensing. Simulation results show that the proposed method produces better results than conventional energy based cooperative spectrum sensing under noise uncertainty.[33]

Jing Jin *et al.,* analysed that cooperation is offered to get better the routine of range sensing. Former schemes uses the piece of information that each and every supportive unlicensed users utilize the indistinguishable phase on sensing and cost are then combined and then gives the results to union hub in progression. As the number of unlicensed user are rising, the more data desires to be reported to a union hub, thus the added coverage time in commission cost would be consumed and has no responsibility in the presentation of cooperative spectrum sensing. Proposed a superposition-based CSS framework where the combination of reporting and sensing time is done. Each supportive client adapts a dissimilar sensing time because they are overlap on dissimilar coverage period. Proposed structure makes cooperative spectrum sensing in a more defined without totaling supplementary probable time overhead. Simulation results shows an enhancement over previous schemes and significant recognition presentation expansion may be achieved through our predictable idea.[34]

Chen Guo *et al*., studied that CSS is used to improve the performance of spectrum sensing in CRN . Channel bandwidth and delay have the huge effect on spectrum sensing when the user are increased to a large extent. Thus censor based technique is proposed to reduce the time and overhead and thus improves the alertness of CR which shows that nodes with reliable information is only allowed to broadcast to get appropriate results. Numerical results shows an enhancement in the utilization of spectrum . [35]

Junyang Shen *et al.,* analysed that in CRN we generally use CSS with an aim in mind to maximize sensing and finds the gap in the spectrum so that to allocate these holes to the user that are not licensed .In this each channel sense and reports the result to the union hub so that the combined decision can be taken by union hub about the presence of licensed user or not..Concentration on sensing setting should be done to make the most of the throughput . Two Schemes were considered. In the first scheme we sense the channel only once and try to maximize the capacity. In the second scheme the problem related to maximization is converted into convex optimization problem which can be solved effectively .[36]

Yogesh Kondareddy *et al.,* designed a Cross-Layer game which is a mixture of the spectrum sensing game in the physical layer and packet forwarding game in the network layer. Spectrum sensing and allocation the sensing results is one of the most significant duty for the process of a cognitive radio network. Since communicating the sensing outcome from time to time to other user uses noteworthy quantity of energy, users tend to save energy by not share their outcome. This non-cooperation will front to lesser clearness in spectrum possession map. Therefore, suitable techniques are required to implement cooperative allocation of the sensing outcome. The classic Tit-For- Tat plan cannot be used because grueling a node by not spreading the sensing results also makes other nodes as malicious. The solution to this trouble by utilizing the distinctive uniqueness of cross-layer communication in cognitive radios to maintain cooperative spectrum sensing. In this technique, those users are punished which do not share there results by refusing to cooperate with the network layer. We prove that the Nash Equilibrium of this plan is mutual cooperation and that it is vigorous against attack on spectrum sensing and sharing meeting.[37]

Kiam Cheng How *et al.,* investigated that cognitive radio is mainly giving importance to the supervision and allotment of the given spectrum. But there are some another important factor that has to be considered which is the security issue i.e cognitive radios propsed many protocols for finding direction of nodes but they are no longer justified because of lack of reliable significance .QOS suffers from self-centered nodes which might shift the behavior in arrange to make the most of it .Simulation results shows that cross layer SARP shows a much superior performance in terms of delay superior throughput and handover proportion compared to the existing protocols .[38]

Alireza Attar *et al.,* offered a wide-ranging record of major well-known security intimidation within a CRN arrangement. Attack techniques are systematized based on the type of assailant, namely exogenous attackers, probing spiteful nodes as well as ravenous CRs. Intimidation connected to underpinning-based CRNs and root-less networks are discussed . In addition the short-term belongings of attacks is shown over CRNs, and also talk on the subject of the frequently ignored distant term changes that are obligatory by such attacks by means of the understanding potential of CRN. Subsequent to extending on various attack strategy, we discuss probable way out to wrestle these assault. An universal design of strong CR connections is in addition to be had. In conclusion intricate on prospect learning instructions valid to CRN sanctuary.[39]

Simon Haykin provided a approach for improving the consumption of the spectrum .CR based SDR is defined as the unwired communication sytem that gives response to the surrounding and understand to learn from the surrounding and adjust accordingly with the two main aims in the mind that to use the band efficiently and also there should be continuous communication wherever it should be required.[40]

Gunwoo Lee *et al.,* discussed that CRN are gaining consequence because of the capability of cognitive radio to vigorously become accustomed to the changes and hence leads to the proficient exploitation of radio band .Proposed a channel distribution scheme where client select that channel where licensed user comes least and allocate that spectrum to the secondary user with the thing in mind to reduce the intervention .Proposed scheme enhances the results and the limits the interfearence of secondary user with primary user by 80%. [41]

Jerzy Martyna studied CR where licensed users make conciliatory band entrance to support CRs within its revelation areas. In CRNs cognitive radio nominate yourself for broadcasting wherewithal and can barricade with others. Conflicting targets of customer create it extremely improbable for any client to augment extra revenue devoid of disserve other client. In addition direct task and power manage have to be approved away in the CRN so so as to cause no tremendous intrusion is caused to client of the main arrangement. Known this restraint, we are caught up in the power distribution crisis; n the midst of the aim of optimizing the whole sum of supported CRs. Proposed a innovative mock-up where the possibility of curtailed in sort is fretful in the Bayesian game and displayed that to enlightenment to the broadcasting resource problems in many user secondary networks. Simulations proved that explained proposal can perk up the competence of CRNs.[42]

Stergios Stotas *et al.*, created a new beneficiary and support for band distribution cognitive radio networks and revise the complexity of obtaining the most favorable power allotment plan that distend the ergodic competence of the planned cognitive radio system beneath average send out and impediment power compulsion. Band distribution has immersed a lot of awareness inside CR in recent times as an proficient routine of removing the band deficiency intricacy by allowing unlicensed users to subsist all along with approved users beneath the condition of protecting the latter from injurious impediment. Paying attention on the output maximization of band distribution cognitive radio networks and advise an original CRS that noticeably progress their realistic output.. In accumulation, we study the outage competence of the intended CRS under a variety of problems that embrace average broadcast and intervention control compulsion, and max out interfering control compulsion. Lastly, recreation consequences, which reveal the enhanced ergodic and outage throughput obtained by the intended CRS in comparison with former band distribution CRS.[43]

M. T. Mushtaq *et al.*, studied that electromagnetic spectrum is the most precious creation in the unwired communication .Communicating in cognitive radios changing the fixed bands into the active bands that changes accordingly to the condition so that to get the maximized performance at the individual level or at complete level .Also studied about SDR, CR and CRN and an idea of cross layer design is also presented .The performance at the node level and also at the network level is also evaluated. [44]

Hang Hu *et al.*, analysed to get better the sensing results, cooperation between cognitive users can be utilize to gather space diversity. A novel time-domain cooperative spectrum sensing framework is suggested, in which the time devoted by coverage for one cognitive user is also used for other cognitive users sensing. The novel time-domain mixing cooperative spectrum sensing is derived for time varying channels. Our center of attention on the optimal sensing settings is to maximize the throughput of the secondary network under the restriction that the primary users are adequately sheltered. Algorithms are also projected to calculate the best possible results. Simulation results show that fundamental development of the achievable throughput can be achieved by most favorable sensing settings. The novel time-domain cooperative spectrum sensing method shows a much better throughput than cooperative sensing based on common frame structure.[45]

Xiaolei Hao *et al.*, discussed that CSS is an effective technique that is generated and employed to increase the efficiency of the band with an aim not to increase intrusion .CSSA scheme sense the channel through unlicensed user and found the channel to idle then send the data packet for transmission .Multichannel and channel admittance trouble as a hedonic amalgamation arrangement technique .The intention of every grouping of unlicensed user are selected to maximize the sensing accuracy and the energy .Proposed algorithm are stable and adaptable to changes in network circumstances .Simulation results shows an enhancement over the previous schemes. [46]

Gianmarco Baldini *et al.*, discussed that SDR and CR are the most important skill that are used to increase the efficiency of the band keeping in mind that there is no interference in it. Flourishing use of these skills leads to the new type of hazards and disputes also it includes the download of malevolent software and PU aping and rudeness of user .Due to attacker basic function of CRN get disturbed . In this we study the SDR and CR skills and try to combat the effects of attack in these skills so that to improve the spectrum precision .Finally we discuss future evolution of these skills.[47]

Ruiliang Chen *et al.*, analysed that CR is a capable skill that can improve the band shortage crisis by sanctioning unauthorized users prepared with CRs to exist together with serving users in authorized spectrum bands devoid of suggesting intrusion to present infrastructure. Spectrum sensing is one of the crucial skill of CRs that has fascinated large consideration from analysers in recent times. Even though the complete condition of spectrum sensing are being explored vigorously, its protection conditions have acquire modest concentration. Attacks which is called the PUE attack, an opponent CR transmits signals whose uniqueness copy of in progress signals. These attacks can brutally block the spectrum sensing process and appreciably reduce the channel resources obtainable to officially permitted unauthorized users. To conquer this risk, we propose a teller authentication method that is incorporated into the band sensing component. The teller authentication method employs a site substantiation arrangement to make a distinction in serving signals from unauthorized signals masked as present signals. Two technique are proposed to understand position confirmation: DRT and DDT. Simulation consequences of the two skills as well as examination of their protection. [48]

Saed Alrabaee *et al.*, presented the state of art in safety of cognitive radio network as in Cognitive Radio Networks (CRNs) come into view as a probable solution for the scarcity of licensed band. However, the Security in cognitive radio network becomes a demanding subject, since additional prospect are given to attacker by cognitive radio technology compared to general unwired network. These chances may cause deprivation the network quality of service but at present there are no precise protected protocols for cognitive radio networks. By this motivation,. In accumulation, we present the accessible game theory models and non-game theory model for safety issues in CRN. The attacks in dissimilar protocols layers were also evaluated.[49]

Zhihui Shu *et al.*, explored the security issues on substantial layer for CRNs . Most important a broad design on moderately a small number of obtainable collateral defilement to the substantial layer in CRNs. Conversation associated to be against proceedings on how to oppose these defilement . Further exploration on important substantial layer collateral parameter, the mystery capability of a CRNs, and also study the outage prospect of mystery competence of a authorized user from a faltering point of view. Additionally, we here presented the effects for mystery capacity and outage prospect in between nodes and its neighbors. Our effort concluded the at hand advancement of the substantial layer guard and gives an imminent on substantial layer security investigation in CRNs.[50]

Minho Jo *et al.*, discussed that cognitive radio is an opportunistic communication skill intended to help unlicensed users make the most of the utmost available licensed bandwidth. Cognitive radio in recent times attracted a lot of researchers for research interest. However, little research has been done concerning security in cognitive radio, while much additional research has been completed on spectrum sensing and allotment problems. A self-interested cognitive radio node can occupy all or part of the resources of multiple channels, not allowing other cognitive radio nodes from accessing these resources. Self-centered cognitive radio attacks are a severe security problem because they considerably corrupt the performance of a cognitive radio network. We identify a new self-centered attack kind in cognitive radio ad-hoc networks and suggest an effortless and competent selfish cognitive radio attack finding technique, called COOPON, with many channel resources by cooperative nearest cognitive radio nodes.[51]

2.2 Conclusion

The above literature summarizes the cognitive radio spectrum sensing methodology . The literature concludes that the CR sensing gets performed in such a manner that optimal selection of the secondary users is done in an efficient manner to reduce the interference occurred with the primary users . The literature also tries to minimize the chances of external attack so that the bandwidth of the system is utilized completely to reduce the consumption of the energy .

Chapter 3

OPTIMAL VOTING RULE IN COGNITIVE RADIOS AND OPTIMIZATION TECHNIQUES

3.1 Voting Based Sensing

In the low SNR administration, because of increased noise power, energy detector will suffer from fading and fluctuations . In this instead of applying detector at one location we do it at other locations also .As there are large number of secondary users some of them will suffer from fading or imperfections due to the value of threshold selected, but few of them will correctly sense the medium. This is the main idea behind the joint spectrum sensing on the basis of voting, studied in a number of works [53,54,55,56 57].

To give its own verdict in the voting spectrum sensing each secondary receiver RXi uses spectrum sensing. The vector of all responses r is considered such that

$$r = [r_1, r_2, r_3, r_4 \ldots \ldots . r_K] \tag{3.1}$$

where ri □ {1, 0} is the binary acknowledgement for each sensor i. After all responses are gathered the voting procedure is applied to take the decision [53, 54, 55]:

$$\text{Decide for} \quad \begin{cases} S_0, \text{ if } V = 0 \\ S_1, \text{ if } V \geq 0 \end{cases} \tag{3.2}$$

$$\text{Where } \mathcal{V} = \sum_{k=1}^{K} r_k \tag{3.3}$$

Briefly, the voting schemes selects S_1 if as a minimum of one of the secondary receivers decides for S_1, which is known as the OR rule. Even though this may perhaps seem too distrustful, as it will support false alarms, in accordance with [53, 54, 55]. This technique has shown an enhancement over the previous simple energy detector scheme for two users. This is logical if we state that as the no of sensors are increased, the probability of reliable spectrum sensing among secondary receivers become higher. The probabilities of detection and false alarm for the cooperative approach are

$$Q_f = 1 - (1 - P_f)^K \tag{3.4}$$

And

$$Q_d = 1 - (1 - P_d)^{K} \tag{3.5}$$

in that order. The work by Sun et. al. [56] revisits this scheme, to calculate approximately the consistency of each node .The nodes with trustworthy sensing are allowed to report their detection. Closer the energy of y(k) to $\mathcal{V}$ is the procedure for the measurement of reliability. This work describe a no decision when the value lies between thresholds, V_1 and V_2, that are used to region. Thus the conclusion rule can be stated as

$$\text{Decide for } \begin{cases} S_0, & \text{if } 0 \leq \epsilon \leq V_1 \\ S_1 & \text{if } \epsilon \geq V_2 \end{cases} \tag{3.6}$$

Secondary recipient finalizes not to report when ϵ value falls in (V1,V2). General decision, based on the OR rule, focus on the information of M users with a reliable detection out of total K users. Results from this shows that there is an enhanced performance over the convectional cases when no consistent information is used .

Cluster based spectrum sensing is an another work from Sun et. al. [57] . In this work, there are clusters of secondary receivers which are generally close to each other .Every cluster have cluster head which is generally used to perform the local decision and report to it to the union hub where all decisions are collaborated to make the final decision.

3.2 Optimization Techniques

Maximum or minimum value of a function or a process is found by a mechanism called optimization. To maximize efficiency, production and other measure many fields such as physics, chemistry, economics and engineering utilize this mechanism. Optimization refers to maximization or minimization. Maximization of a function is equal to minimization of the opposite of the function.

A few commonly used optimization techniques are as following:

3.2.1 Genetic Algorithm

Generational replacement is used in canonical GA's just like other evolutionary algorithms (EA's). known replacements are illitism and steady state replacement [60-62]. In intial case, the best solution is directly copied into the new population whereas in the other case a fraction of population is replaced in each generation. The aim of both variants is the improvisation in the preservation of good genetic material at the expense of a reduced space search exploration.

Shows a comparison between the behavior of generation and steady state replacement [63]. Fitness is the basis for the selection of people for reproduction allocation of mating probability of each person proportional to their fitness is done by canonical GA's. parent sets are also drawn from roulette wheel selection procedure [64]. Fitness ranking and tournament ranking are other known schemes [65]. The reader is referred to Goldberg and Deb for comparing selection procedures [66]. Crossover act like main search operator in GA's and create offspring's by randomly mixing selections of the parental genome. Exchange of the number of the sections vary mainly with GA implementation. One point crossover, two point crossover and uniform crossover are the main crossover procedures. The crossover possibility for each couple in canonical GA's is set. Two offspring's identical to parents are generated by couples not selected for recombination.

A small proportion of offspring's are randomly selected to undergo genetic mutation. Allocation is randomly picked by the mutation operator from a bit-string and its contents are flipped. Main aim of mutation is the preservation of the genetic diversity of the population whereas the importance of the operator in GA's is secondary. In case of steady-state replacement GA's require the tuning of some parameters such as mutation rate, crossover rate and replacement rate. The chosen value may influence the search process strongly. Therefore the task is often not trivial [67 , 68]. Evolution of search process is the basis for getting the optimal value for GA. Several adaptive schemes have been discovered for all these reasons. An optimal mutation rate schedule proposing an offline tuning has been given in [69] showing a survey of adaptation of GA's. Employment of problem specific operators is also done in addition to canonical ones. An increase in the search power of the algorithm is seen as a result of introduction of such operators. Along with the loss of general applications this issue has been analyzed in [70].

3.2.2 Ant Colony Optimization

In the early 1990s, Ant Colony Optimization was proposed by Dorigo et al. as a new nature-inspired meta-heuristic for the explanation of the optimization problems [69]. The nomadic behavior of ants is the source of inspiration of ant colony optimization. Ants explore the area surrounding their nest in randomly search of food. When the food is found they carry it back to their nest . A chemical pheromone trail is deposited by the ant in the return trip. The quantity of this pheromone acts as a guidance for other ants to the source [70].These pheromone trails help the ants to find the shortest path between their nest and food sources using this indirect communication. Stigmergy is the modification in the behavior of other ants done by indirect communication. To find a solution of combinatorial and continuous optimization problems, this characteristics of real ants colonies is exploited by artificial ant colonies. Behavior of a single ant is very simple whereas an ant colony exhibits a very complex adaptive behavior .The ant observes pheromone concentrations and produces an action like stimulus response agent [70]. Artificial ant algorithmically copies the behavior of simple real ants . Simple ant colony optimization can be formulated as follows. To minimize the given error a combinatorial optimization problem is defined , as a sequence of parameters and can be viewed as a path through various nodes is corresponding a solution parameter.

3.2.3 Particle Swarm Optimization:

Particle of space positions of high fitness are attracted by the PSO algorithm and this how it works. The best position that is so far visited and the global best position attained by the whole swarm ,are the most important information according to which each particle having the memory function adjusts its trajectory or path. A whole swarm if considered as society ,the initial information can be seen as a result of particle's memory of its past states, and the later information can be seen as a result of the collective experience of all the members of the society.PSO like other optimization methods has the fitness evaluation function which gives each particle its position and its fitness value global best is the position of the highest fitness value that has visited personally .Both these values are remembered by each particle. [14].

CHAPTER 4

PSO ALGORITHM FOR COGNITIVE RADIOS

4.1 Introduction

Particle swarm optimization is a population based postulated optimization method matured by Eberhart and Kennedy in 1995 [14-16]. It has drawing out in the recreation of social behaviors using apparatus and opinion taken from computer graphics and study social way of thinking. Within the meadow of computer visuals, the work of Reeves was the first background of particle swarm optimization which can be traced back , which cannot be simply represented by polygons or surfaces systems but it is planned particle model items that are active . Fire, smoke, water and clouds are examples of such items. In these systems, particles are self-directed of each other and their actions are governed by a set of rules. Some years afterward, Reynolds (1987) used a particle scheme to replicate the mutual actions of a congregate of birds. In a similar kind of simulation, Heppner and Germander incorporated a place to stay which was attractive to the replicated birds. Both models encourage to arrange down of strategy which was exceptional and is used in particle swarm optimization algorithm afterwards. Social attitude search was motivation in the augmentation of the primary particle swarm optimization algorithm , in scrupulous the vigorous speculation of social impact. The regulations that control the association of the particles in a troubles look for freedom can be regarded as a replica of human social behavior in which folks modify their viewpoint and attitudes to be customary to those of their peers. The PSO algorithm is provoked by communal proceedings of bird flocking or fish instruction[15]. There are many similarities between evolutionary calculation techniques such as Genetic Algorithms and Particle Swarm Optimization. Initialization is done with a population of random solutions and searches for optimal value by updating generations. However, dissimilar from GA, no enlargement operators such as crossover and mutation PSO has. In PSO, the particles, fly through the trouble space by following the recent optimum particles to give the potential solutions. The advantages of PSO are that PSO is easy to apply and there are few parameters to adjust than GA. PSO has been efficiently functional in many fields.

4.2 The Algorithm

PSO simulates the procedures of bird flock as established before. The following scenariois supposed where a collection of birds are randomly probing for food in a surrounding area and food in the area being looking for only single one piece of. All the birds are not familiar with where the food is. However, through each repetition, they gain knowledge via their inter connections, where and how far the food is. So to find the food the best strategy is to hunt a bird which is closest to food. To resolve the optimization predicament PSO is used and it learns from this bird-flocking scenario. Each single result in PSO, is a bird in the search space and we usually described it as particle. Each particle have fitness standards which are premeditated by the fitness function i.e the cost function should be optimized, and have velocities which is used short the path of flying particles. Particles fly through the difficulty space by subsequent the present most favorable particles. Starting of PSO is done with a group of random particles i.e solutions and then it searches for optimal value by updating generations. During every iterations, two "best" values are acknowledged by each particle. Foremost is known as position vector of the finest solution (fitness) this particle has accomplish so far. The fitness assessment is also stored and this position is called pbest. An additional best position that is tracked by the particle swarm optimizer is the best position, obtained by any constituent part so far in the population. This best position is the current global best and is called gbest. After finding these two best values, equations (4.1) and (4.2) are used to change particle velocity and its position

$$V_{k+1}^{i} = WV_{k}^{i} + C_1 r_1 \left(pbest^{i} - x_{i}^{k}\right) + C_2 r_2 (gbest_{k} - x_{i}^{k}) \quad (4.1)$$

$$x_{k+1}^{i} = x_{k}^{i} + V_{k+1}^{i} \quad (4.2)$$

Where V_{k+1}^{i} is the velocity of particle number i at the $(k+1)^{th}$ iteration, x_{k}^{i} is the present particle solution . r_1, and r_2 are arbitrary numbers between 0 and 1. c_1 is the cognitive factor; c_2 is the swarm assurance factor. c_1, and c_2 varies in range from 1.5 to 2.5; inertia factor that takes values in the range from 1 to 0 as usually denoted by w according to the iteration number [16]. The Ist term in equation (4.1) correspond to the outcome of the inertia of the particle, the 2nd term represents the element recollection power, and the 3rd term represents the swarm power. The procedure of the process that usually it follows is shown in the form of flow chart is shown in Figure 4.1. The velocities of the particles on each point may be sticked to a maximum velocity Vmax, which is a limitation specifically told by the user. If the total of accelerations root the velocity on that quantity to exceed Vmax, , then this velocity is restricted to Vmax[15] . Another type of clamping is to clutch forcefully the position of the current way out to a definite choice in which the respond has a meaning otherwise the explanation is meaningless [15].

4.3 PSO Flowchart

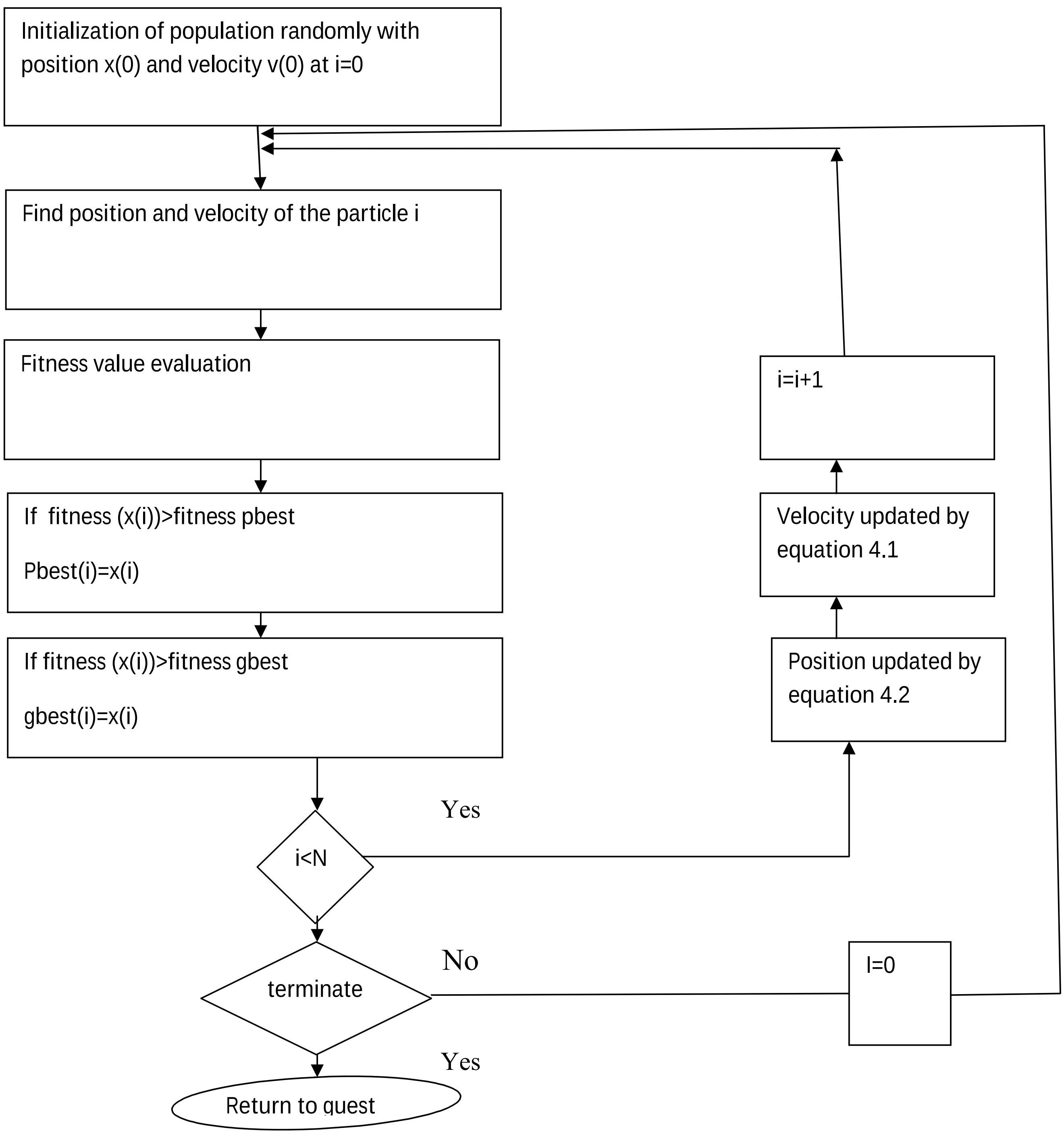

Figure :4.1 PSO Flowchart

4.4 Implementation of PSO

PSO algorithm is written in MATLAB program environment as scripts.

4.4.1 Algorithm input

The input to this plan consist of number of nodes to be entered to the scripts . Every node in this is generally linked with hardware of software. For the purpose of experimentation these parameters are randomly generated. Guidelines that are used is explained below :

1. A Hardware implementation cost: This is the cost related to number of gates or the area . Basically it is the cost which is required to implement a given node in hardware .Cost of hardware is generally in the range from 1 to 99 [19].

2. A Software implementation cost: This is the cost related to completing delay of clock cycles. Basically it is the cost which is required to implement a given node in software.Cost of software is generated in the range from 1 to 99[19].

3. A Power implementation cost: It is generally the cost of power utilization when the node is implemented both in hardware and software. This cost is randomly generated in the range from 1 to 9. The cost of communications is understood and it should be added within the hardware and software costs of the nodes, as interactions between nodes are formerly recognized from the arrangement itself [19].

4.4.2 Initialization

The problem is when undertaken with m nodes is considered .Solution that is credible is a vector with m essentials .In this each part is associated to a given node .The constituent assume a o value when it is used in hardware and assumed a I value when used in software. Basically there are n particles and the initialization of particles is done randomly .Range -1 to 1 is generally used for the initialization of the velocity .In this moving towards 0 generally indicates negative velocity and moving towards1 generally indicates positive velocity.

4.4.3 Main loop

Equation 4.1 and 4.2 are calculated each time the loop is executed .If the constituent part goes out of the range then it is used when again the loop is executed .Cost function is normalized sum of hardware and software. Power cost of each constituent part is given by equation 4.3 .

$$\text{cost} = 100 * \{\frac{\text{HW Cost}}{\text{all HWCost}} + \frac{\text{SWCost}}{\text{all SWCost}} + \frac{\text{PowerCost}}{\text{all PowerCost}}\} \quad (4.3)$$

Where all HWcost denotes the maximum hardware expenditure when mapping of all nodes is done in hardware. In this all SWcost denotes the maximum software expenditure when mapping of all nodes is done in software. In this all Power cost is the sum of both the two .the multiplication by 100 is done for readability only. Cost function is inversely related to fitness function where good solution have lower cost values. According to equation 4.1 and 4.2 node can take any value but the value is rounded to 1 or 0. Two methods that we look for when rounding is done are as shown:

1. **Hard Decision Rounding (HDR)** In this mapping is done in hardware or software depending upon the value.If the value is generally lower than 0.5 then the mapping is done in software and if it is greater than 0.5 then the mapping is done in hardware.
2. **Soft Decision Rounding (SDR)** In the mapping region for hardware is defined once from 0 to 0.7 and another from 0 to 0.3. Cost function in this is denoted by double and in this cost of mapping of the two is compared and the value that is lower is generally considered.

The consequences of the above two methods are compared and the one which gives us the lower cost is generally considered and then the mapping is done for that reason .Results of HDR are always far better than SDR. HDR is generally used to reduce the time required to run an algorithm.

4.4.4 Termination:

The main loop is terminated when the g best value i.e. the global best solution for last number of repetitions generally attained value less than c .Value of E and the number of repetitions are user prohibit parameters.

4.5 Optimization

Maximum or minimum value of a function or a process is found by a mechanism called optimization. To maximize efficiency, production and other measure many fields such as physics, chemistry, economics and engineering utilize this mechanism. Optimization refers to maximization or minimization. Maximization of a function is equal to minimization of the opposite of the function, f [21].

Mathematically, a minimization job is defined as:

$$\text{Given } f: \mathbb{R}^n \rightarrow \mathbb{R}$$

$$\text{Find } \hat{x} \in \mathbb{R}^n \text{ Such that } f(\hat{x}) \leq f(x) \forall x \epsilon \mathbb{R}^n \tag{4.4}$$

Similarly, a maximization job is defined as:

$$\text{Given } f: \mathbb{R}^n \rightarrow \mathbb{R}$$

Find $\hat{x} \in \mathbb{R}^n$ Such that $f(\hat{x}) \geq f(x) \forall x \epsilon \mathbb{R}^n$ (4.5)

Domain $\mathbb{R}^n$of f considered as the parameter space .Each component of $\mathbb{R}^n$ in search space is known as candidate solution with$\hat{x}$ being the most favorable solution. Dimension of search space is usually denoted by n and thus the number of parameters used in optimization problems.F unction f is the aim and used to investigate the function space and it gives a single fitness value for every set of parameters that are given. However there is a lot of difference between the function and the fitness space for multiobjective optimization tasks [19-22].

Differentiable function f can easily give us the value of maxima or minima of a given function f .But in real optimization tasks this task is not directly known .To substitute the aim function is a black box to which we apply the candidate solution and we get an output value .The result of this is known as solution's fitness .Then after this we apply optimization to discover the parameters in look for space that maximize or minimize this fitness.

Forced optimization tasks in which the elements in a candidate solution are subjected to certain constraints[21]. Free optimization task is generally we focus on.

A simple optimization can be explained with the help of figure 4.2.This figure represents the curve as with a selected region f which was established as shown .Function maps from one dimensional parameter with the set of real numbers $\mathbb{R}$ on the x-axis and the y-axis. The x-axis represents the candidate solution and y-axis represents the aim function when applied to these solutions fitness landscape of the optimization problem is as shown by these diagrams [19].Fitness landscape plots for these parameter give us the n-dimensional parameter space against the one –dimensional fitness for each of these parameters.

In this figure along with local maxima global maxima are also marked. A local maxima is generally a value that is maximum in a given region .If we take an example of figure 4.2 in the region of [0 to 2] it will give the maximum value at x=[1.05] the value is known as local maxima. Most of the optimization algorithm gives the local maxima value and ignores the other

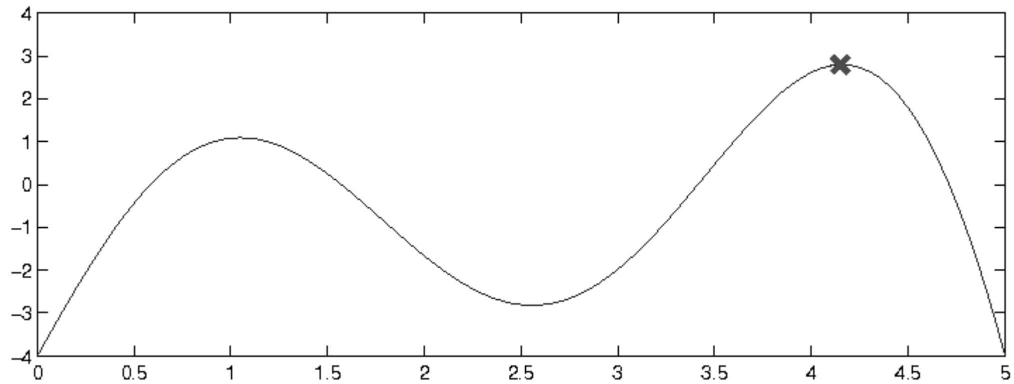

Figure 4.2: Function Maximum

maximum value and the global maximum value. However when PSO is applied it gives the overall maximum value.

CHAPTER 5

SIMULATION OF PSO BASED OPTIMAL VOTING RULE FOR COGNITIVE RADIOS

The optimal selection rule can be done through various algorithms . One of the node selection algorithm is optimal voting rule . In this rule the other nodes provide a voting scheme on the basis of which a secondary rule is selected . The problem with the optimal voting rule is the error rate produced through it . The problem of this research work is to enhance the voting rule using optimization algorithm called PSO. PSO works with distributed particles and generates values for the each and every iteration . By the end of all iteration, the optimal node is selected.

5.1 Proposed method

Cognitive radio sensing structure refers to identifying a secondary node when the primary node faces an overhead of data transmission . In such a case if the network goes for searching the entire network to identify a secondary node , it might consume more time and mean while the data packet might expire . To prevent such hazard in the network , we need to find a path through which the data packets would be send. To achieve the above written statement an optimization technique name PSO (Particle Swarm Optimization) has been applied . When so ever a primary user searches for a secondary user , the PSO looks in the neighbor of the random selected radio node to be transmitted and searches the entire radio connected nodes of the random selected node. The searching is done on the basis of the energy consumption of the nodes . Once the nodes are sorted out , we compute the overhead of the dynamically selected node. The transmitter side sends only that much data packet which the receiver can handle. To compute the capacity of the destination node , we compute the receiving power of the destination radio node and its coverage node and by the end we take an average accuracy of the spectrum sensing node. Then the procedure is achieved by applying quantization method to the data packets to save the data from external hazards and data losses. The entire procedure is repeated till the last receiving node is not achieved.

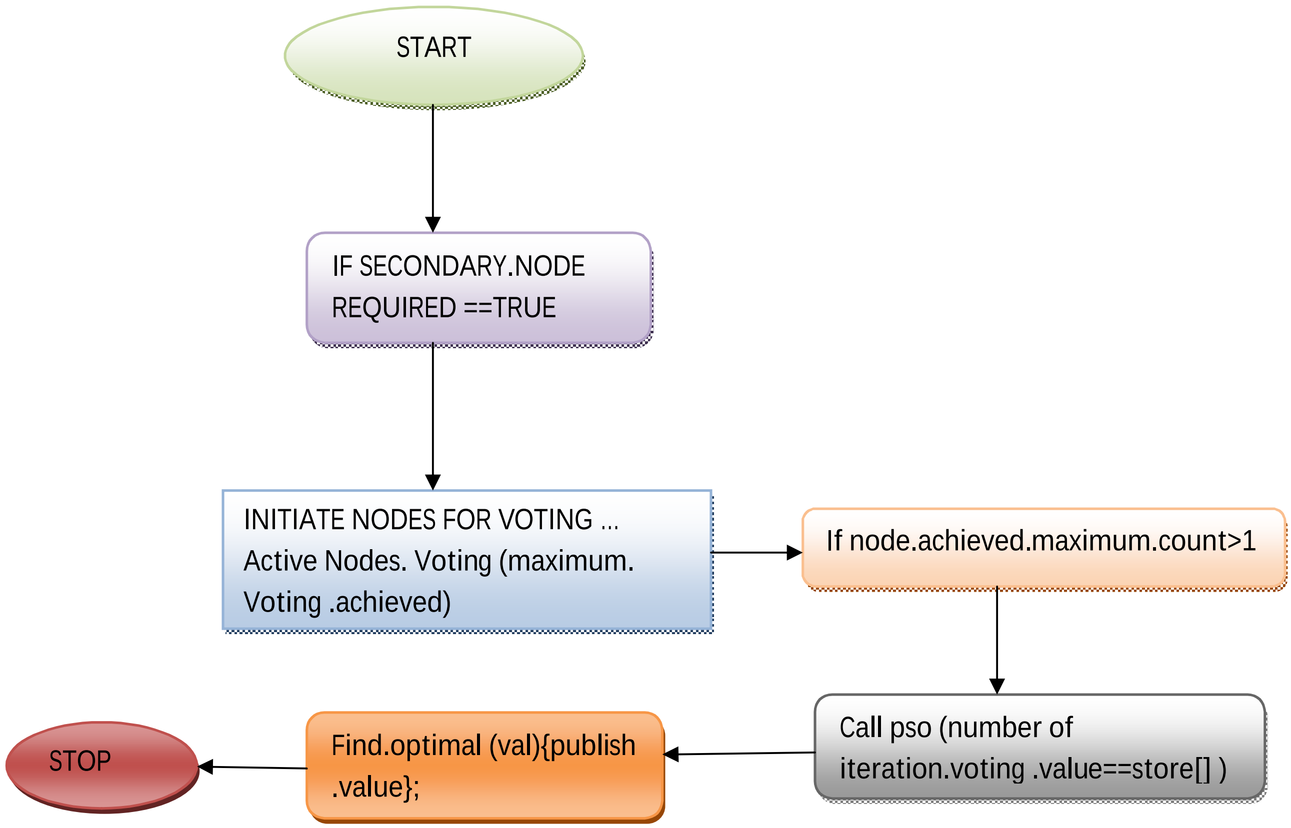

Figure 5.1: Flowchart of Voting Rule Selection

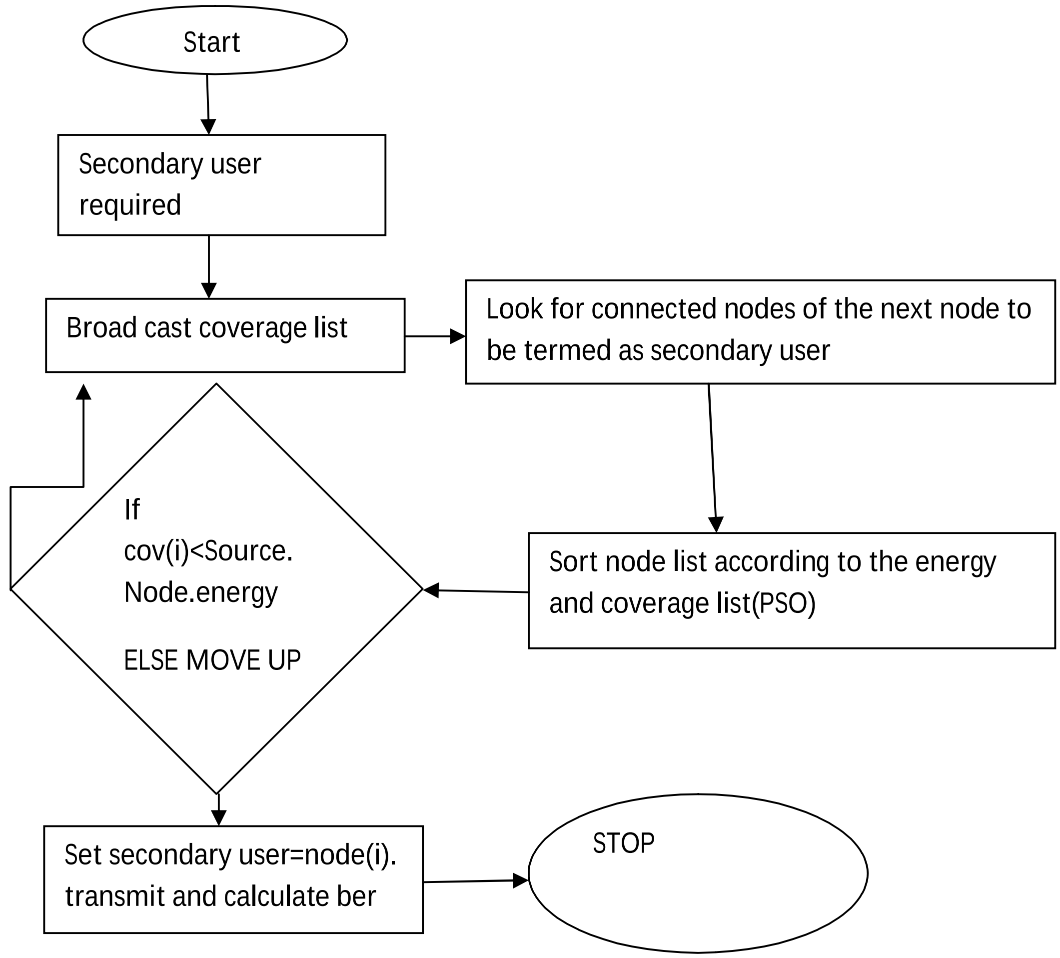

Figure 5.2: Implementation of PSO in proposed method

5.2 MATLAB Result

The work proceed possesses the following results of comparison using PSO and without using PSO.

Particle swarm optimization runs on different iteration values . The normal velocity provided to the optimization algorithm is 100 . The velocity of the particles changes with every iteration . The total number of particles taken at one time is 500. The total number of iterations is 50 for the particle swarm optimization. For different velocities v1 , v2 ….. vn the optimization function sets the value as 2 / average for the optimization . If the current value of the particle exceeds the velocity limit, it is ignored. The distribution under the algorithm is uniform and for the first iteration the pick scenario of the PSO is random .With each and every increase in the PSO step , the velocity is updated. The PSO has a major impact over the parameter selection , the basic belief of the researchers for this optimization algorithm is the border value optimization in which the values are taken exactly on the border side i.e if the value is 100.3356 , it would not consider this value as 100.34 , it would be treated as 100.3356 only and hence in terms of accuracy the fitness function puts an effective value over rule selection . The fitness function also might change its criteria over selection of velocity if more number of nodes are involved

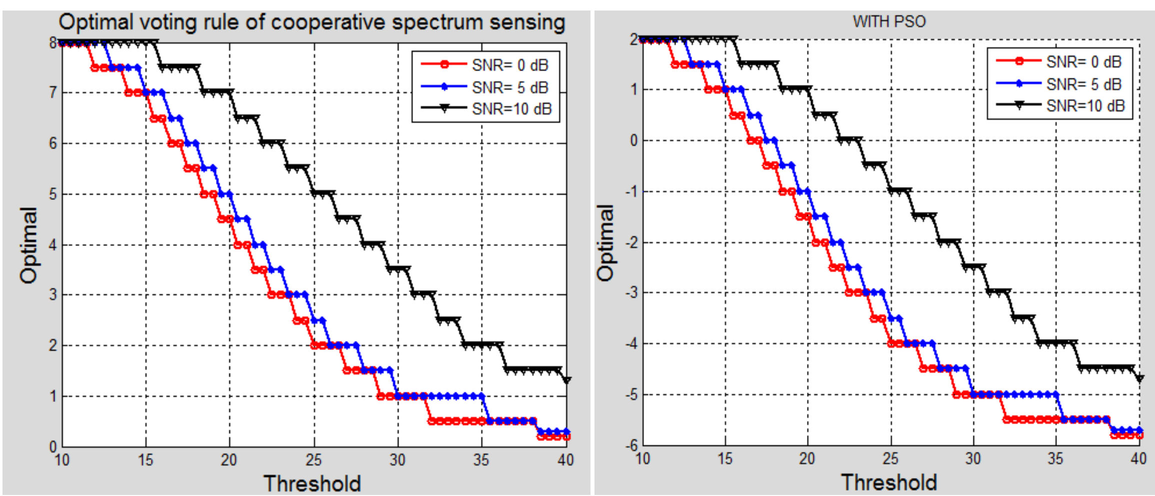

Figure 5.3: Optimal voting rule versus detection threshold of CSS in AWGN channel with PSO and without PSO and SNR = 0, 5, and 10 dB.

The above figure represents the optimal voting rule. According to it if the optimal voting rule is found in a lesser node the optimization is successful. From the above figure it is quite clear that without using PSO and with PSO has difference of six .

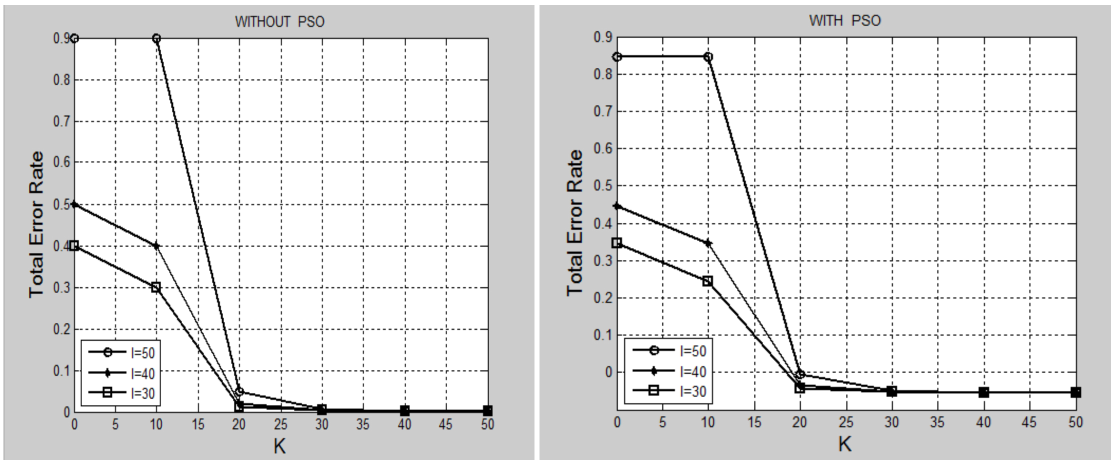

Figure 5.4: Total error rate of CSS versus number of collaborating cognitive radio network with 50 CRs in AWGN with SNR = 10 dB.

The above figure represents a comparative result of total error rate versus no of users with and without using PSO.

Threshold	Total error rate without PSO	Total error rate with PSO	% change
l = 50	0.90	0.845	6
l = 40	0.5	0.454	11
l = 30	0.4	0.346	13.75

Table 5.1 Comparison of Total Error Rate with and Without PSO when threshold is given in AWGN channel with threshold value from 50,40 and 30

The above table represents the analysis of total error rate against number of usersin AWGN . The tabular structure clearly shows a decrease in the error rate by 6 to 14 percent on an average. The table also mentions the error rate decrease in percentage with every threshold from 50 to 30

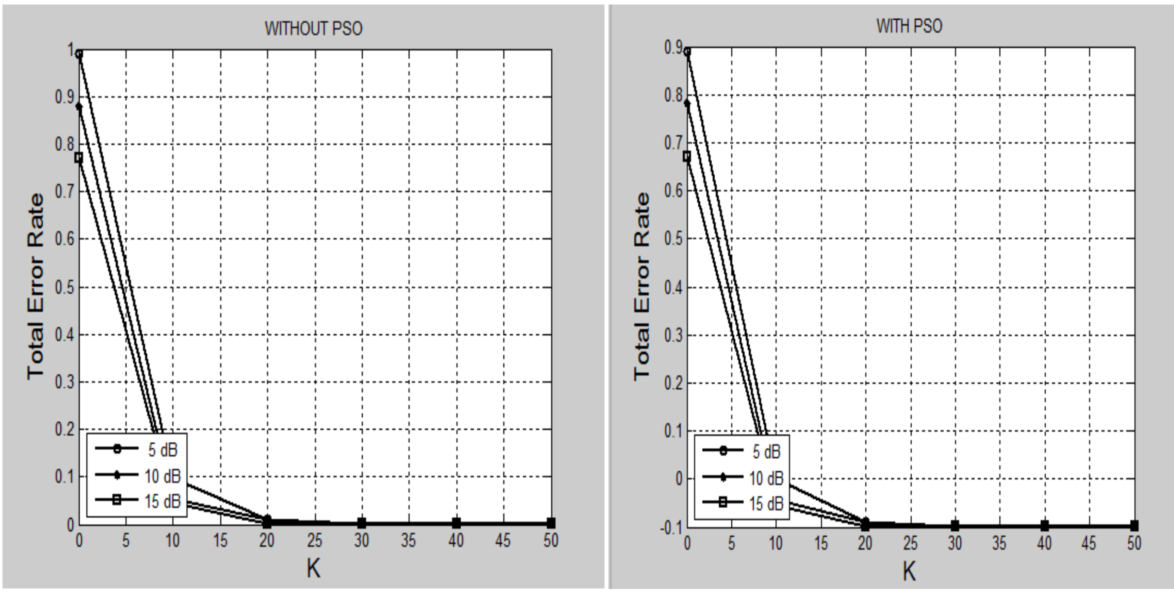

Figure 5.5: Total error rate of cooperative spectrum sensing versus number of collaborating cognitive radios in a network with 50 CRs in Rayleigh fading with SNR = 5, 10, 15 with and without PSO

The above figure represents the comparison with and without using so at different levels like 5db,10 db ,15 db.

SNR	Total Error Rate without PSO	Total Error Rate with PSO	% change
5	0.99	0.891	10
10	0.88	0.78	11.35
15	0.77	0.676	12.85

Table 5.2 Comparison of Total Error Rate with and without PSO when SNR is given in Rayleigh fading channel

The above table represents the analysis of total error rate against different SNR values in Rayleigh channel . The tabular structure clearly shows a decrease in the error rate by 10 to 13 percent on an average. The table also mentions the error rate decrease in percentage with SNR value starting from 5 and ending with 15.

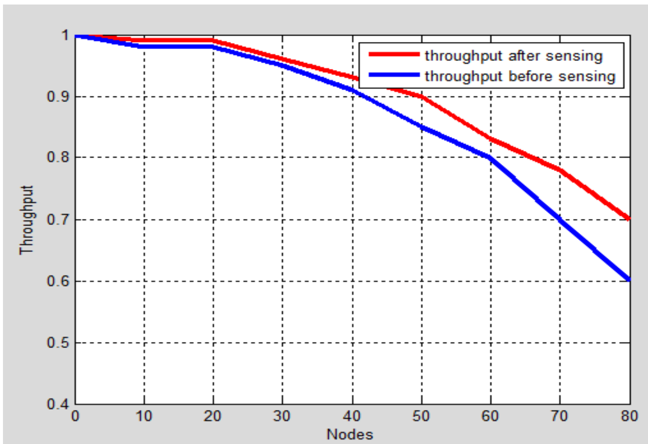

Figure 5.6: Throughput versus the no of nodes before and after sensing

The above figure represents the graph between the throughput and the number of nodes before and after sensing and it was found that the results are enhanced i.e throughput is increased after sensing.

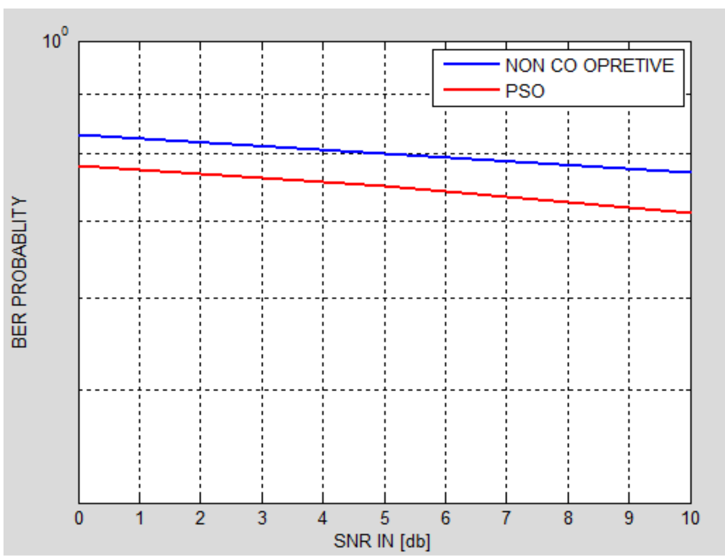

Figure 5.7: BER Versus SNR with and without PSO

The above figures represent the graph between Bit Error Rate and Signal to Noise Ratio with and without PSO and the results are found to be optimized by .25 units.

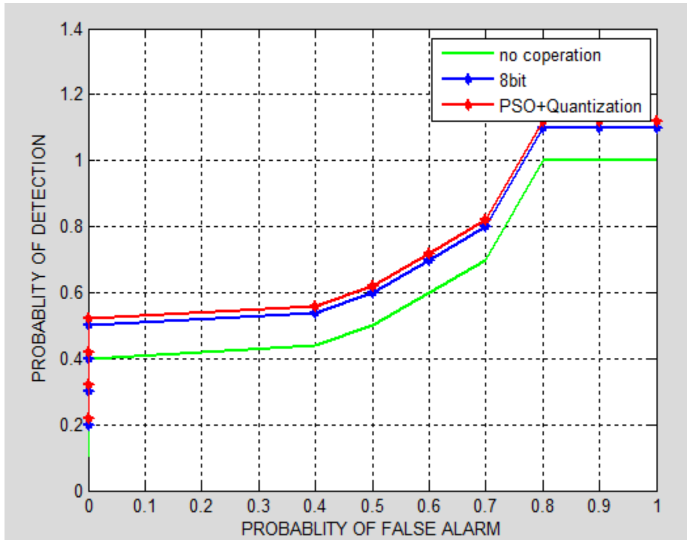

Figure 5.8: Effect of Quantization and PSO+Quanization for cooperation message

The above figure represent the graph between Probability of detection and probability of false alarm in the presence of quantization and PSO + quantization and has shown that the results of detection has been improved by 2% when PSO is used along with quantization then when quantization is used alone.

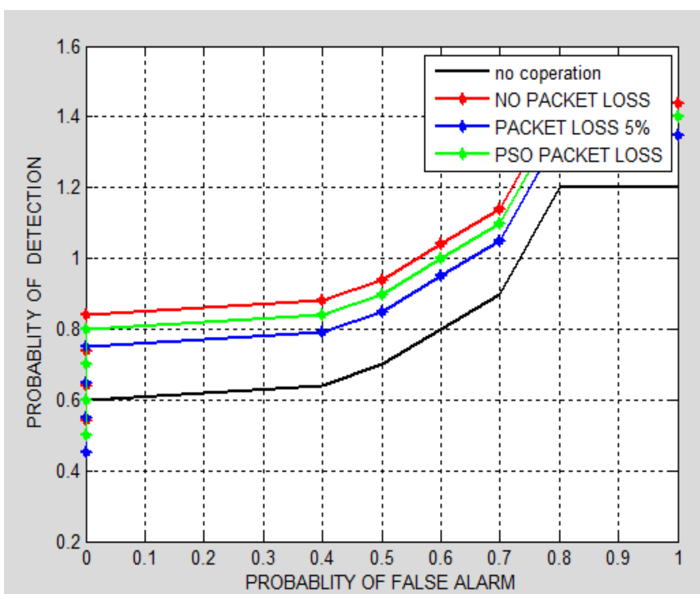

Figure 5.9:Effect of Packet Loss in conveying a cooperation message

The above Figure represents the graph between the probability of false alarm and the probability of detection when the packet loss is considered . The average spectrum sensing performance over the entire CR network declines as the packet loss rate increases. Therefore we can say that in PSO packet loss is less and hence the probability of detection is more when PSO is considered.

Chapter 6

CONCLUSION AND FUTURE SCOPE

6.1 Conclusion

With the proposed work a lot of things has been optimized in terms of energy dissipation ratio optimal voting rule such time deductions and other related stuffs to perform such operations particle swam optimization has been used in this contrast. The particle swam optimization method enhances the input on the basis of particle taken for the processing in the same contrast PSO goes for iterations in which each and every iteration have some values to be considered and evoked .The evoked value is rechecked when all the iterations value are over. The fitness function of the PSO algorithm fetches out on single code out of many particle values which has been provided to to the oriented particles in action. Here in this scenario the energy dissipation is one of the major factors which has to be considered over here. In this process area over which the data is spreaded also plays a vital role in the processing The total area which has been considered here for processing is 1000 and the minimum distance over which other node should have been placed to fit in the range is 250m. If the nodes are placed outside the region of the coverage set then the network leaves them for the next processing. The particles in this area catches the value of every segmented section and takes the optimal value out of it. The values of the results are optimized by 5 to 10 percent.

6.2 Future Scope

The current work proposed a scheme with particle swarm optimization and it shows a significant result in the deduction of total error rate but the current scenario consumes a lot of time in thoroughing out the output due to more no of particles used in it. The ratio of the time can be reduced if the no of iterations can get reduced up to some extent. Reducing the iterations with PSO cannot be the solution as it describes the fitness function based on the iterations .Hence a new proposal is required and that can be neural networks. Neural networks controls the no of iterations very effectively even though you pass it to a maximum of 1000 iterations . In Addition to that neural network just don’t only provides the accuracy in enhancement but also it tells you that how accurate the processing has been in which iteration the optimal solution has been possessed

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