Optimization of Spectrum Sensing in Cognitive Radio Networks with Noise Uncertainty

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Abstract: Cognitive Radio is used to automatically determine the channels allocated in wireless frequency range and it alters the factors responsible for transmission which will further help in simultaneous many communications that helps in improving the efficient utilization of spectrum. Spectrum sensing is the major task to perform in Cognitive Radio. This study introduces a novel hybrid approach to perform spectrum sensing in an effective manner even in the presence of noise. The study is analyzed over different values of signal sampling sizes and noise uncertainties. The comparison analysis is done among proposed work, Energy Detection (ED), Covariance Absolute Value (CAV) and Joint Estimation mechanism. The results assure that the proposed work outperforms the traditional techniques.

Index Terms- **Cognitive Radio, Spectrum Sensing, PSO Optimization, GA Optimization, Probability of Detection.**

I. INTRODUCTION

The need of flexible and robust wireless communication has become more evident. The development in internet technologies and mobile communication systems comes as a wireless network future that helps in providing various services to customers [1].
The available spectrum has been used inefficiently due to the use of conventional method of electromagnetic spectrum licensing. The spectrum scarcity issue has been seen due to unbalanced use of spectrum for fulfilling the different technologies need and market demand [2]. So, proper co-ordination infrastructure and innovative licensing policies need to be introduced as a solution to above given problems. This results in increase of spectrum efficiency by enabling dynamic use of radio spectrum [3].
These challenges can be solved using cognitive radio that consist of smart layers for performing environment learning that helps in having better results in case of dynamic situations. The electromagnetic spectrum utilization easy way is given by it that also gives communication resources between regulations, technologies and market [4].
The cognitive radio origin to its development steps are given below [5]:

- In 1999, Joseph Mitola has given a term of cognitive radio in his doctoral thesis [6].
- The Defence Advanced Research Projects Agency (DARPA) funded to Next Generation (DARPA-XG) program in 2002. One policies based spectrum management framework is created as main objective of program so that spectrum holes can be used by radios.
- The spectrum bands underutilization has been confirmed by Federal Communications Commission (FCC). The Notice for Proposed Rule Making (NPRM) issues has also been considered by FCC that enables the efficient management of spectrum by CR technology [7].
- In 2014, the 802.22 working group was designed by Institute of Electrical and Electronic Engineers (IEEE) to define a specifications of Medium Access Control (MAC), Physical (PHY) and Wireless Regional Area Network (WRAN) layer.
- In 2005, IEEE has started the project 1900 standard task group for next generation electromagnetic and radio spectrum management. The radio systems access dynamic spectrum, co-existence analysis, interference analysis and spectrum management standard terms are cleared by this project.
- In 2006, CROWNCOM is the first conference based on cognitive radio organized by IEEE. This helps in getting new ideas related to cognitive radio from various researchers.
- In 2008, FCC has launched a various cognitive device rules that let it to work under white spaces in TV band.
- In 2010, memorandum order and opinion is defined by FCC that helps in determining the secondary wireless users defined rules for using white space [8].
- In 2011, IEEE 802.22 (WRAN) is issued as official standard by IEEE [9, 10].
- The 802.22 systems positioning and installation commended practice standards are focused by IEEE [11].

The need of the more resources has been found by the increase in demand for wireless services but the used wireless network has fixed assignment policy. Now for future applications only ISM 2.4 GHZ band is available and licence interferences will increase by giving access to unauthorized band. This issue also result in degradation of fully occupied unlicensed and licensed bands. The limited resources and expense of wireless technology get increased by the current inclination towards uninterrupted association and there should be efficient utilization of RF like important resources.
In the spectrum strategy changes are forced to be done by the spectrum policy task done by FCC and less spectrum availability is the main difficulty that creates an issue while accessing the spectrum. There will be gaps in the spectrum as it is not properly utilized by authorized users and those gaps are spectrum holes.

The Cognitive Radio is an intelligent, adaptive radio that by itself detects an available wireless spectrum channels and helps in communication to run more concurrently by adding the factor of changing transmission parameters that also results in radio operating behaviour improvement. The frequency band used for wireless communication is inadequate that's why permanent allocation strategy is adapted in currently electromagnetic spectrum [12].
The user who buy a given frequency band get a complete permit to use it that leads to underutilization and congestion of spectrum as the band is permanently given to the user either it will be used for all the time or not. The utilization of band become poor because of static or fixed spectrum sharing allocation so in order to overcome it there is need of efficient frequency model. In this if white space of hole is found then that frequency spectrum can be used by others [13].

II. PROBLEM FORMULATION

Cognitive Radio Network (CRN) is growing worldwide that leads such networks area unit tormented by the challenges of efficient spectrum/resource allocation as lack of spectrum. Economical spectrum allocation technique becomes new analysis problem in use of CRN. A significant challenge to the current new technology is the way to build honest assignment of accessible spectrum to unaccredited users. The acceptable allocation of idle frequency spectrum synchronic psychological feature radios whereas increasing total information measure utilization and minimizing interference is needed for the economical spectrum utilization in CRN. The tactic of mounted spectrum allocation results in less spectrum utilization over the whole spectrum. For psychological feature radio systems, Orthogonal Frequency Division Multiplexing (OFDM) widely used the information transmission technique that delivers the pliability for allocating the resources beneath the dynamic conditions. Therefore, OFDM based CRN networks have major challenge of resource allocation. Their area unit completely differentiates things and parameters in dynamic atmosphere further showing the impact of that area unit on total system rate performance. In the current research various drawbacks of the existing schemes are to be improved like probability of detection, MSE estimation etc in case of noisy channels also.

III. PRESENT WORK

The spectrum sensing is the major process to perform in cognitive radios. Traditionally it was done by using the concept of threshold. The threshold depicts a value that is predefined. The issue was that this concept was not efficient to suspect the spectral in case when the variations occur in the signals due to noise uncertainties. There are number of techniques proposed by different authors to perform spectrum sensing. Thus the present study develops an efficient spectrum sensing mechanism by using the hybrid optimization mechanism. This study is analyzed over different values of signal sampling size and noise uncertainty. For the purpose of hybridization, the Particle Swarm Optimization and Genetic Algorithm are used. The proposed technique is tested in MATLAB software in which the results assure that the proposed work outperforms the traditional techniques.

The methodology of the proposed system is defined as follows:

1. Deployment of the network is the first step to implement the proposed mechanism.
2. Next step is to define the primary and secondary users for establishing the communication and message transmission.
3. After defining the users, the next step is to initialize the population for implementing the PSO optimization. The population is generated randomly.
   (Particle Swarm Optimization (PSO) is a global optimization algorithm to deal with problems that can represent an optimal solution as a point or surface in n dimensional space).
4. In this step, the fitness updation is done on the basis of randomly generated population.
5. Next step is to apply the Genetic Algorithm (GA is a metaheuristic inspired by the process of natural selection that belongs to the larger class of evolutionary algorithms). In this firstly it is evaluated that whether the optimized objective function is formed or not. If it is formed then move to step 6, otherwise perform the following steps:
   a. Initialize the population of chromosomes randomly.
      (Chromosomes are the set of parameters which define a proposed solution to problem that Genetic Algorithm is trying to solve)
   b. Perform crossover and roulette selection.
      (Crossover is an operator which enables to create a new solution from existing large number of solution and Roulette selection is basically a fitness function which assigns fitness to the possible solution or chromosomes)
   c. If optimized fitness values are achieved then go to step 6.
   d. If optimized fitness is not achieved then repeat the process until it is not achieved.
6. Evaluate the convergence. If it is obtained then go to step 7 otherwise go to step 4.
7. Optimization of sensing parameters is done.
8. Perform simulation to analyze the performance matrices such as Missed Detection, Probability of detection, MSE, SNR and ROC.

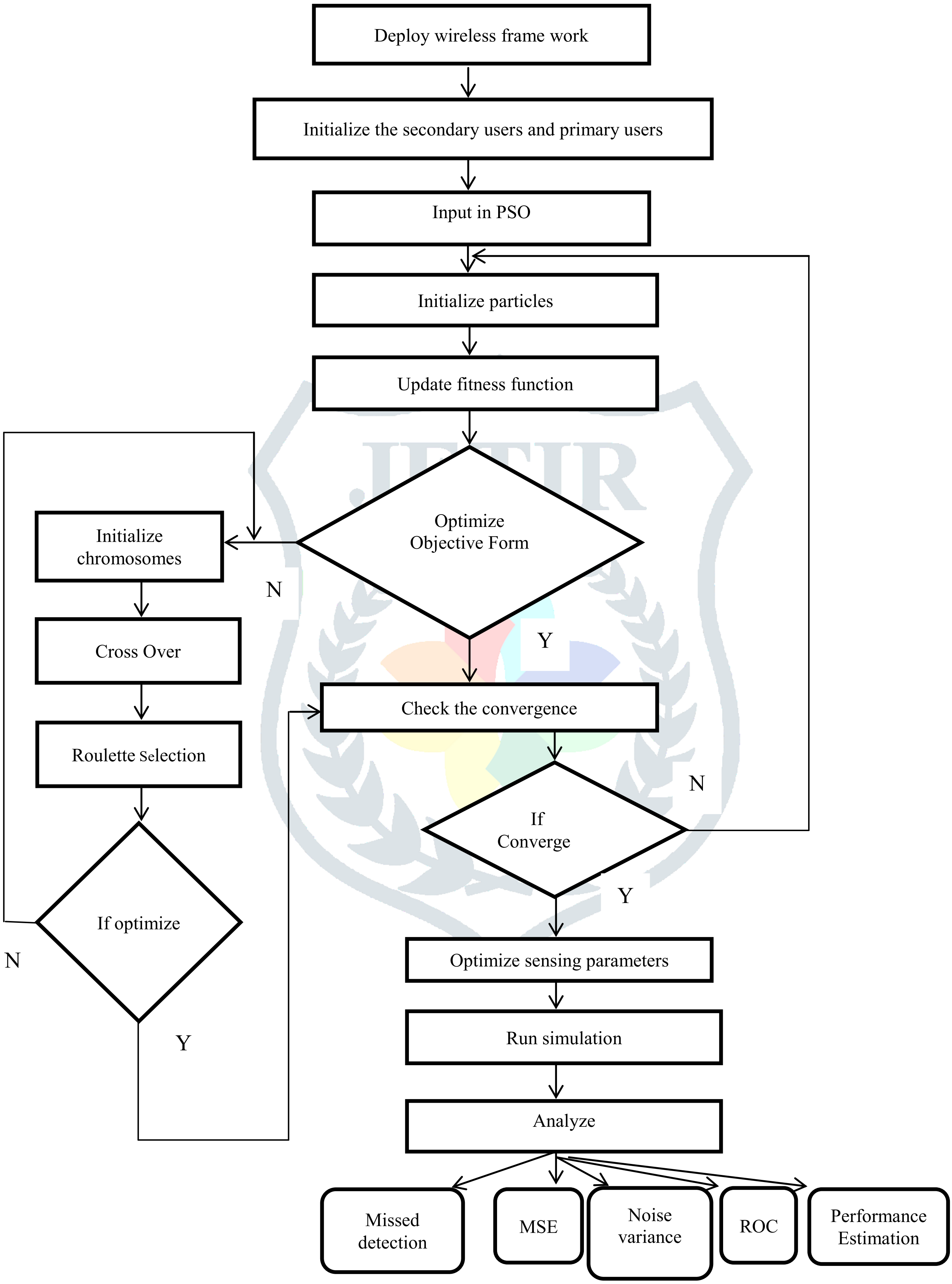

Figure 1 Methodology of Proposed System

IV. RESULTS AND DISCUSSION

The present work aims to analyze the existing spectrum sensing mechanisms and along with this a hybrid optimized approach is developed to efficiently suspect the spectrum from the signals even in the presence of noise in the signals.

The comparison graph in Figure 2 shows the contrast analysis of proposed and joint estimation technique with respect to various values of M (Sampling Size). The comparison is done on the basis of the SNR and Detection Probability. The objective behind showing this contrast is to prove the performance efficiency of proposed work over joint estimation technique. The detection probability of proposed work is higher in both cases whereas the detection probability of joint estimation is lower in contrast. The SNR of proposed work is comparatively low.

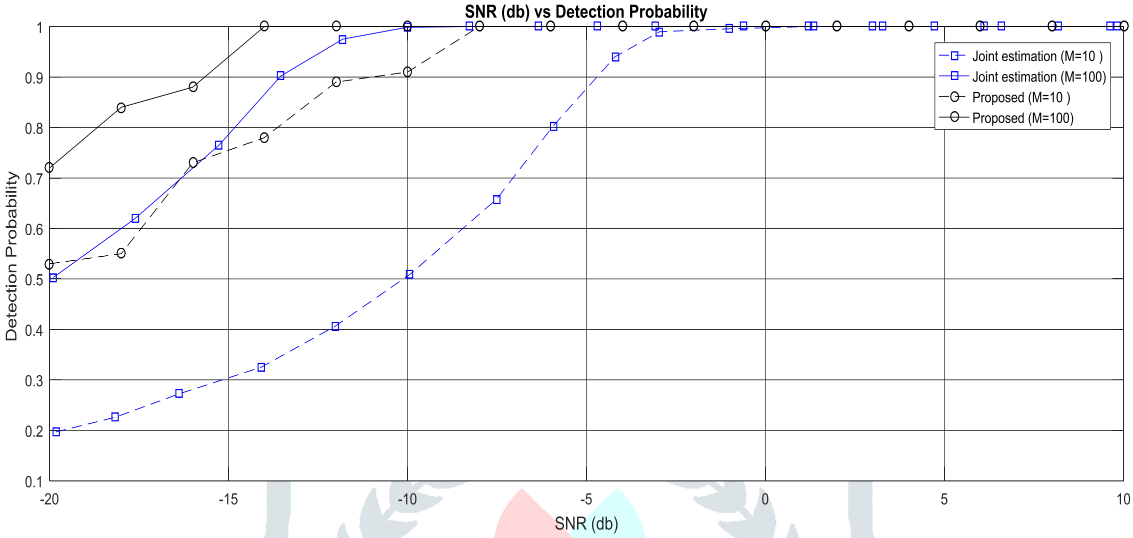

Figure 2 Detection performance comparison of Proposed and Joint Estimation mechanism with respect to different values of M.

Table 1 shows the detection performance of Proposed and Joint Estimation Mechanism at sampling sizes M=10 and M=100. It shows that as the sampling size increases, Detection performance also increases.At sampling size M=10 Proposed Method shows the better detection probability as compared to the Joint Estimation mechanism. But at M=100 Proposed Method shows the higher detection probability as compared to the performance at M=10.

Table 1 Detection Performance of Proposed and Joint Estimation Mechanism at M=10 and M=100

SNR (db)	Pd of Joint Estimation at M=10	Pd of Proposed Method at M=10	Pd of Joint Estimation at M=100	Pd of Proposed Method at M=100
-20	0.2	0.53	0.5	0.72
-16	0.28	0.73	0.78	1
-12	0.41	0.89	0.98	1
-8	0.63	1	1	1
-4	1	1	1	1

The graph in Figure 3 depicts the comparison of ED method, CAV method, Joint Estimation and proposed work. Two different criteria's for sampling size is considered for the purpose of comparison in each and every technique. The graph assures the higher detection probability and lower signal to noise ratio for proposed work. The CAV method poses the lower detection probability among defined mechanisms and joint estimation suffers from the issue of highest SNR value. The curve in black colour represents the proposed work, the curve in blue colour shows the joint estimation technique, curve in pink colour depicts the performance of CAV method and curve in green colour shows the performance of ED method.

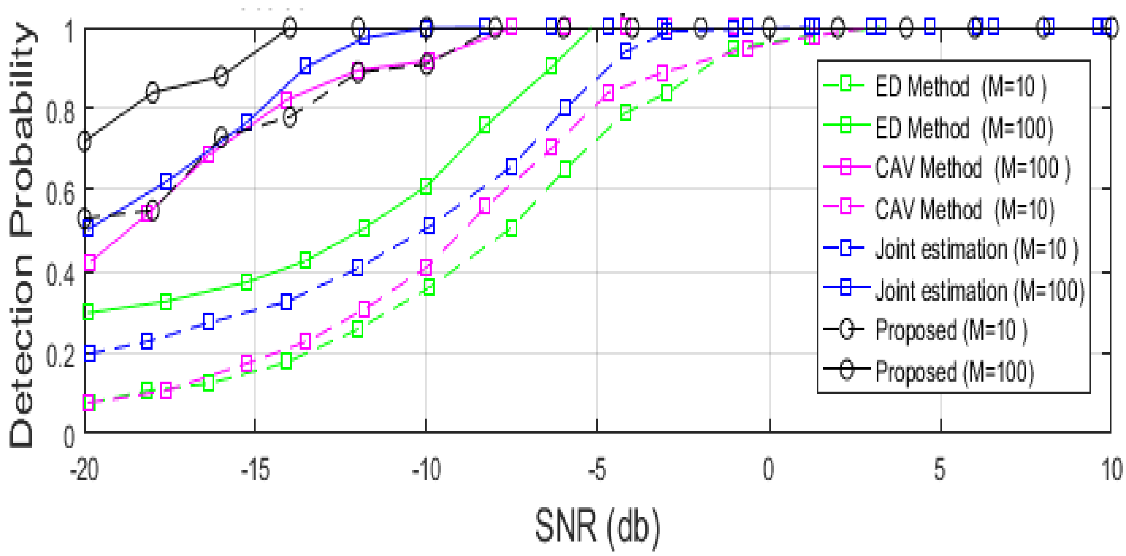

Figure 3 Comparison of Detection probabilities vs. SNR (db) with respect to different values of M.

Table 2 shows the detection performance comparison of Energy Detection, Covariance Absolute Value, Joint estimation and Proposed method at sampling sizes M=10 and M=100. It shows that increasing sampling size enhance the detection probability. Here proposed method outperforms the traditional techniques.

Table 2 Detection Performance Comparison at M=10 and M=100

SNR(db)	Pd of Energy Detection		Pd of Covariance Absolute Value		Pd of Joint Estimation		Pd of Proposed Method	
	M=10	M=100	M=10	M=100	M=10	M=100	M=10	M=100
-20	0.1	0.3	0.1	0.41	0.2	0.5	0.51	0.72
-12	0.28	0.5	0.3	0.88	0.4	0.99	0.8	1
-10	0.39	0.6	0.4	0.9	0.5	0.99	0.9	1

The graph in Figure 4 depicts the SNR and Missed detection of proposed work. This is evaluated on the basis of the different values of M. The y axis in the graph shows the missed detection from 0.1 to 1 with the interval of 0.1. The x axis in the graph shows the SNR from -20 to 10 with the difference of 5. The missed detection in both cases is low and SNR is also low. But missed detection and SNR are much lower in the case when M=100.

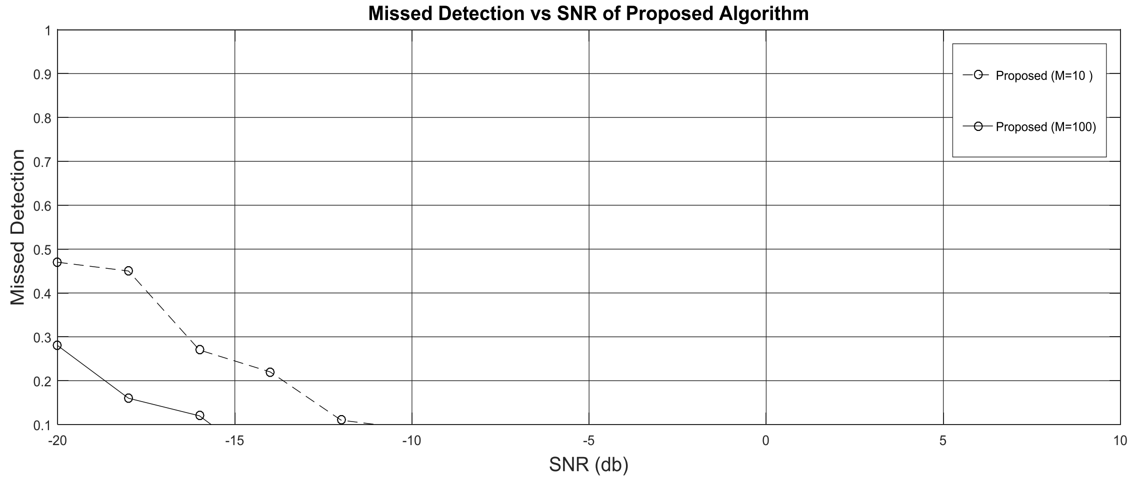

Figure 4 Missed Detection vs. SNR of proposed method

The graph in Figure 5 shows the comparison of proposed and traditional joint estimation technique on the basis of SNR and MSE. The curve in black color shows the performance of proposed work and curve in blue color shows the performance of the joint estimation mechanism. On the basis of the facts that are observed from the graph, it is delineated that the MSE and SNR of proposed work is lower in comparison to the traditional joint estimation techniques. This approves the efficiency of the proposed work over traditional mechanism.

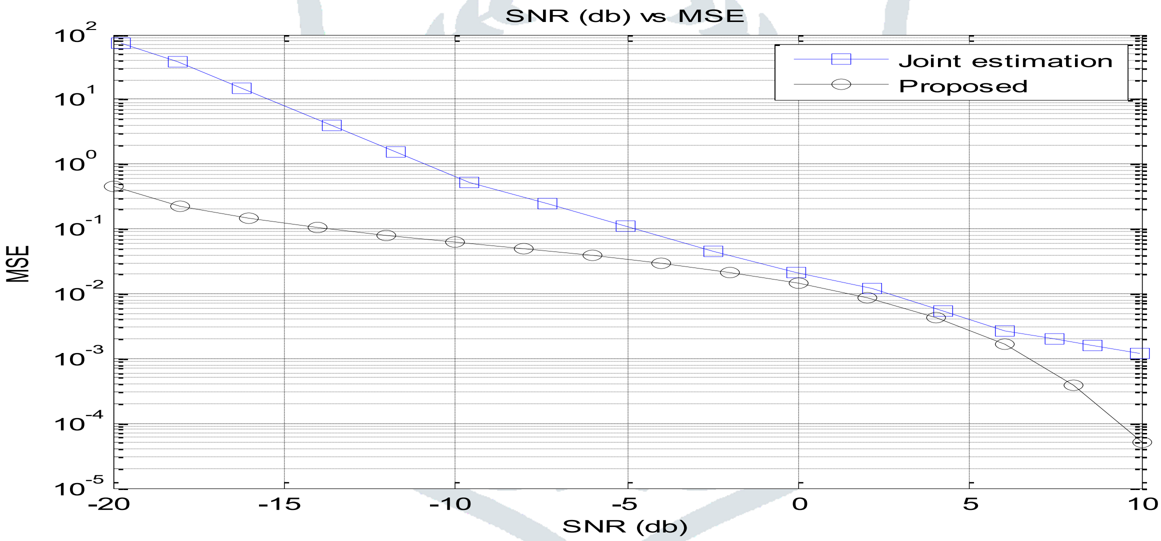

Figure 5 MSE Estimation of proposed method compared with Joint Estimation mechanism

The graph in Figure 6 shows the comparison of ROC curves of Proposed Algorithm with ED mechanism, CAV method and Joint estimation respectively. The comparison analysis is done on the basis of the probability of detection that ranges from 0.75 to 1. The probability of detection is higher in case of proposed work. Whereas the probability of detection of ED mechanism is lower, the CAV mechanism has second higher probability of detection, the joint estimation has higher probability than CAV mechanism. The y axis in the graph depicts the probability of false alarm.

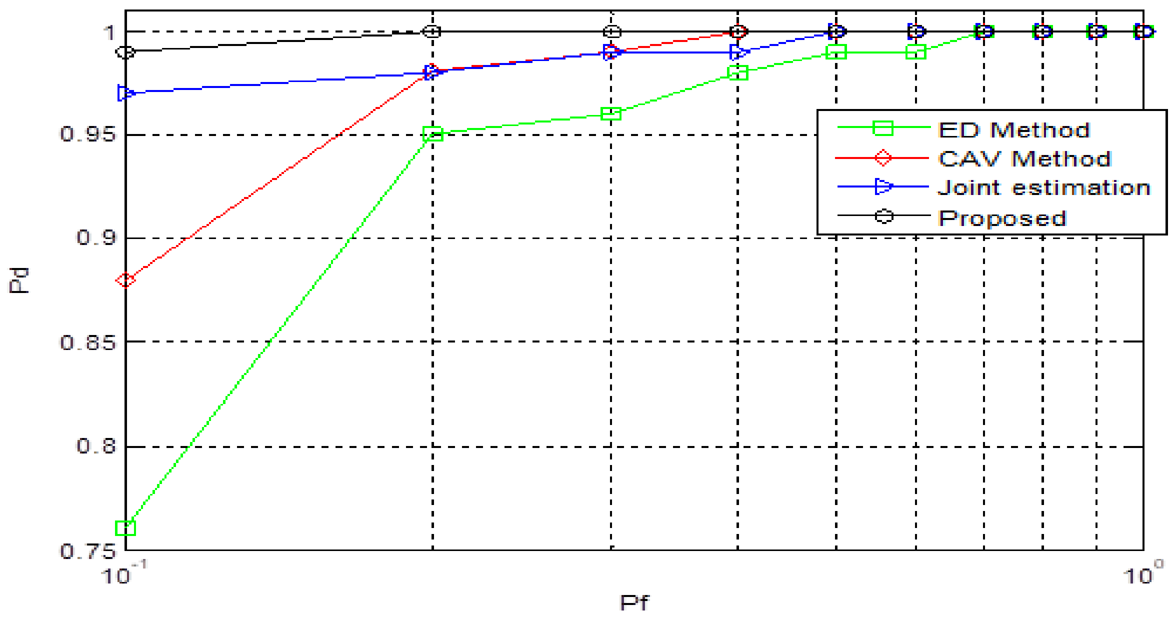

Figure 6 Comparison of ROC curves

Table 3 shows the Comparison Analysis of ROC Curves of Proposed Work, Joint Estimation, Covariance Absolute Value and Energy Detection. Here Detection Probability increases as the Probability of False Alarm increases. At Pf=0.1 Proposed work gives the better detection probability of 0.99 whereas Joint estimation gives Pd=0.97, Covariance Absolute Value gives Pd=0.88 and Energy Detection gives Pd=0.76. Comparing all these values it is seen that proposed work outperforms the traditional techniques.

Table 3 Comparison Analysis of ROC Curves

Probability of False Alarm(Pf)	Pd of Proposed Work	Pd of Joint Estimation Technique	Pd of Covariance Absolute Value	Pd of Energy Detection
0.1	0.99	0.97	0.88	0.76
0.2	1.00	0.98	0.981	0.95
0.3	1.00	0.99	0.99	0.96
0.4	1.00	1.00	1.00	0.98
0.5	1.00	1.00	1.00	0.99
0.6	1.00	1.00	1.00	0.99
0.7	1.00	1.00	1.00	1.00
0.8	1.00	1.00	1.00	1.00
0.9	1.00	1.00	1.00	1.00
1.0	1.00	1.00	1.00	1.00

The comparison graph in Figure 7 is derived on the basis of the detection probability of different techniques corresponding to the different values for noise uncertainties. The graph depicts the lower detection probability of various techniques which proves that these mechanisms are more sensitive to the noise uncertainties in the signals. The comparison analysis shows that the proposed work is less prone to noise uncertainties in the signals where as the mechanisms like joint estimation, CAV and ED suffers from lower probability of detection.

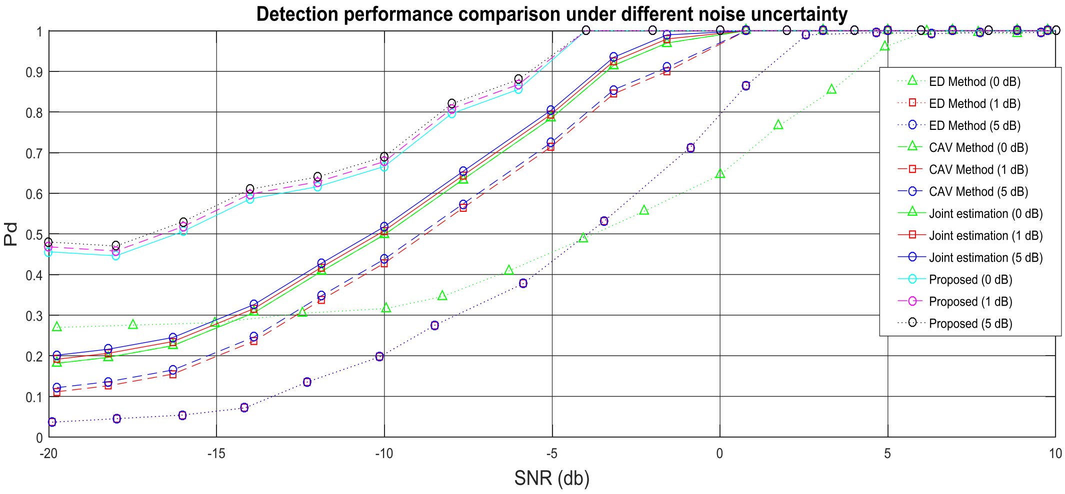

Figure 7 Detection Performance Comparison under different noise uncertainties.

Table 4 shows the Detection Performance Comparison on the basis of different noise uncertainties 0, 1 and 5db. This table shows that the proposed technique, Joint Estimation and CAV method are less sensitive to noise uncertainties as there are little variations in Detection Probabilities of about 0.01 and 0.02 at 0, 1 and 5db. But in case of ED method there is variation of about 0.2564 in Detection Probability, this shows that ED method is more prone to noise uncertainties. Comparing all these values at 0, 1 and 5db, it is seen that proposed technique gives higher Detection Probability.

Table 4 Detection Performance Comparison on the basis of the different noise uncertainties

Techniques	0dB	1dB	5dB
Proposed Technique	0.45	0.46	0.48
Joint Estimation Mechanism	0.18	0.19	0.2
CAV mechanism	0.10	0.11	0.12
ED Mechanism	0.26	0.0036	0.0036

V. CONCLUSION

This study develops a smart and novel spectrum sensing techniques for cognitive radios. The spectrum sensing is a vital task to perform in cognitive radio. A large number of techniques are developed to sense it efficiently but fails when the noise with the little variations is added to the signals. Thus the proposed spectrum sensing technique is analyzed over the variations of noise uncertainties in the signals. The result section proves the efficiency of proposed work over traditional techniques in terms of Probability of Detection, SNR and MSE. On the basis of the facts from resultant tables the performance of the proposed work is validated.

In future, more enhancements are possible in proposed work to increase the performance capability of the system. Artificial Intelligence based techniques can be used for spectrum sensing.

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