Incentivize Cooperative Spectrum Sensing in Cognitive Radio using data fusion

M.Divya, Dr.V.Saravanan

Abstract**—** Cooperative spectrum sensing for cognitive radio network with different data fusion rules are proposed in this work. Centralized sensing is used to collect sensing information through central unit from other cognitive devices. The main objective of this work is to prevent the interference with Primary Users (PU) and identifies the available white spaces to enhance spectrum utilization. Energy detection technique is used to sense the existence of primary user (PU) signal. Cooperative spectrum sensing intensify the reliability of detecting primary users by data fusion rule. The performance of cooperative spectrum sensing is evaluated with the hard combination OR, AND and MAJORITY rules. The simulation results show that MAJORITY rule is near optimal for the desirable amount of false alarm and detection rates.

Keywords -Cooperative sensing, Cognitive radio, AWGN channel, Data fusion, Probability of missed detection / false alarm.

I. Introduction

The fleeting extension in wireless communications has come up to a huge desire on the deployment of advanced wireless services in both the licensed and unlicensed frequency spectrum. The basic idea behind cooperative transmission rests on the observation that, in a wireless environment, the signal transmitted or broadcast by a source to a destination node, each employing a single antenna, is also received by other terminals, which are often referred to as relays or partners [1]. In this paper, we propose durable cooperative spectrum sensing technique to address these challenging affair. With speedy and agile sensing ability, CR can opportunistically fill in spectrum holes to improve the spectrum occupancy utilization [1]. However, once the PU returns to access the licensed band, the CR should immediately stop operating in the PU licensed band. This rapid switching off of the CR can guarantee least interference to the primary system. However, from the point of perspective of the cognitive system, the interruptive transmissions will lead to a discontinuous data service and intolerable delay [2]. To manage with this complication, we propose a cognitive relay network in which distributed cognitive users participate each other so that they can divide their distinct spectrum bands.

In this proposed method, centralized sensing is used to collect sensing information from cognitive devices, distinguishes the accessible spectrum, and report thisinformation to other cognitive radios or directly controls the cognitive radio traffic [3].Based on the sensing results, unlicensed users should revamp their transmit powers and access strategies to protect the licensed communications. The requirement naturally presents challenges to the implementation of CR.

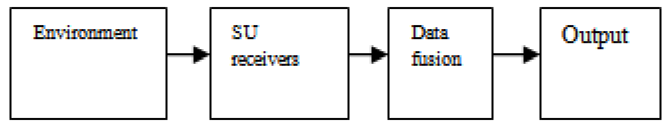

Fig .1.Cooperative Sensing

A.Local Sensing

As shown in fig 1 Local measurements in the environment should be made at the band manager to be processed into a decision concerning the occupancy state of the primary bandIn pursuance of minimizing the communication overhead and hence the bandwidth required for this control channel, users may only report their final 1-bit decisions (i.e., white space or occupied) in lieu of actual measurements [3].

B. Cooperative Sensing

As shown in Fig.1. CR1-CR5 performs local sensing of presence of PU by a specific detector through sensing channels then sending the sensing results to CR0 (which represents central unit) through reporting channel[4]. The CR0 collects these results of all nodes then takes a cooperative decision about the medium status, which is then transmitted back to receivers also through reporting channel (or control channel)[5].

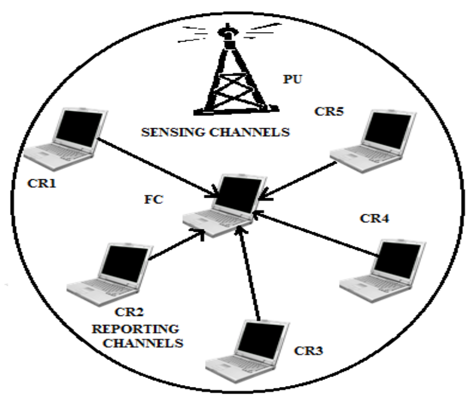

Fig.2. Cooperative Sensing

The remainder of this paper is organized as follows. In Section II, the Cooperative spectrum sensing under AWGN channel will be briefly reviewed. In Section III,power spectral

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Density (PSD) v/s frequency is similar for both KaiserWindow and Taylor win window for first three channels. The limitation of cooperative spectrum sensing in realistic cognitive wireless networks is then derived. In Section III.A., complementary ROC curve of cooperative sensing is obtained with data fusion rules **.**In Section 1II.B.Complementary ROCcurve of cooperative spectrum sensing with different values of SNR is obtained. In Section IV, we draw our conclusions.

II. COOPERATIVE SPECTRUM SENSING UNDER AWGN CHANNEL

Let *N* insinuate the number of users sensing the PU.Particular CR user makes its individual selection regarding whether the primary user present or not, and uphold the binary decision (1 or 0) toward fusion center (FC) for data fusion [6]. The PU is located more distant from all CRs. All the CR users receive the primary signal with same local mean signal power, i.e. all CRs form a cluster with distance between any two CRs negligiblecompared to the distance from the PU towards a CR [6]. For ease we have assumed that the noise, pale statistics and average SNR are the same for each CR user [7].Assuming independent decisions, the fusion problem where *k* out of *N* CR users are needed for decision can be described by binomial distribution based on Bernoulli trials where each trial represents the decision process of each CR user[7]. With a hard decision counting rule, the fusion center implements an *n*–out-of-*M* rule that decides on the signal present hypothesis whenever at least *k* out of the *N* CR user decisions indicate 1.Assuming uncorrelated decisions, the probability of detection at the fusion center is given by

$$P_d=\sum_{l=k}^{N}\binom{N}{l}P_{d,i}^{\,l}(1-P_{d,i})^{N-l} \qquad (1)$$

$$P_f=\sum_{l=k}^{N}\binom{N}{l}P_{f,i}^{\,l}(1-P_{f,i})^{N-l} \qquad (2)$$

Where $P_{d,i}$ is the probability of detection for each individual CR user.

AND-Rule:-In the indicated rule, if all of the local decisions sent to the decision maker are one, the final decision made by the decision maker is one[7].

The cooperative probability of detection using AND rule is

$$P_{d,AND}=\Pr\{\text{Fusiondecision}=1|H_1\}=\prod_{i=1}^{N}Pd_I \qquad (4)$$

The cooperative probability of false alarm using AND rule is

$$P_{f,AND}=\Pr\{\text{Fusiondecision}=1|H_0\}=\prod_{i=1}^{N}Pf_I \qquad (5)$$

The cooperative probability of misdetection using hard decision AND rule is

$$P_{Pm,AND}=1-(\prod_{i=1}^{N}Pd_i) \qquad (6)$$

OR-Rule:-In this rule, if any one of the local decisions sent to the decision maker is a logical one, the final decision made by the decision maker is one[7].

The cooperative probability of detection using OR rule is

$$P_{f,OR}=\Pr\{\text{Fusiondecision}=1|H_0\} = \prod_{i=1}^{N}(1-Pd_i) \qquad (7)$$

The cooperative probability of false alarm using OR rule is

$$P_{f,OR}=\Pr\{\text{Fusiondecision}=1|H_0\}$$

$$=\prod_{i=1}^{N}(1-Pf_i) \qquad (8)$$

The cooperative probability of misdetection using OR rule is

$$P_{Pm,OR}=1-(\prod_{i=1}^{N}Pd_i) \qquad (9)$$

MAJORITY-Rule:-In this rule, if half or more of the local decisions sent to the decision maker are the final decision made by the decision maker is one[7]. Cooperative detection performance with this fusion rule can be evaluated by setting $k = N/2$

$$P_{d,MAJ}=\sum_{l=\lceil \frac{N}{2}\rceil}^{N}\binom{N}{l}P_{d,i}^{\,l}(1-P_{d,i})^{N-l} \qquad (10)$$

III. NUMERICAL RESULTS

All simulation was done on non-fading AWGN channel. In the proposed design, there is one primary user which uses a channel of carrier frequency of value 9 kHz and four secondary users and they are kept at same distances from PU transmitter. When the SU is at large distance from PU transmitter, may be sense empty channel medium due to path loss. In addition, the threshold value is assumed to be same at SUs' detectors. In Environment block, a PU's message is modulated by using amplitude modulation as shown in the PU transmitter block .Then it's transmitted through AWGN channel. Then the SUs receive the sampled signal and begin to sense the channel as shown in SUsreceivers block. Moreover, every secondary user make local sensing and local binary decision.

Then these decisions are sent through reporting channel to CR controller (decision fusion) which make a final decision (may be called cooperative decision) based on any one of the three rules discussed. In the proposed model, we use only three rules: OR rule, AND rule and MAJORITY rule for cooperative decision. Table 1 gives the model parameters used for cooperative sensing. The primary/secondary user is designed in MATLAB/SIMULINK environment.

PARAMETER	VALUES	BLOCK
Operating frequency	9 kHz	carrier signal
Antenna Gain	1.5dB	environment
SNR	15dB	AWGN
Buffer size	512	buffer block
FFT length	512	FFT block
Window function	Kaiser, Taylor win	window function

Table 1 Cooperative sensing parameters

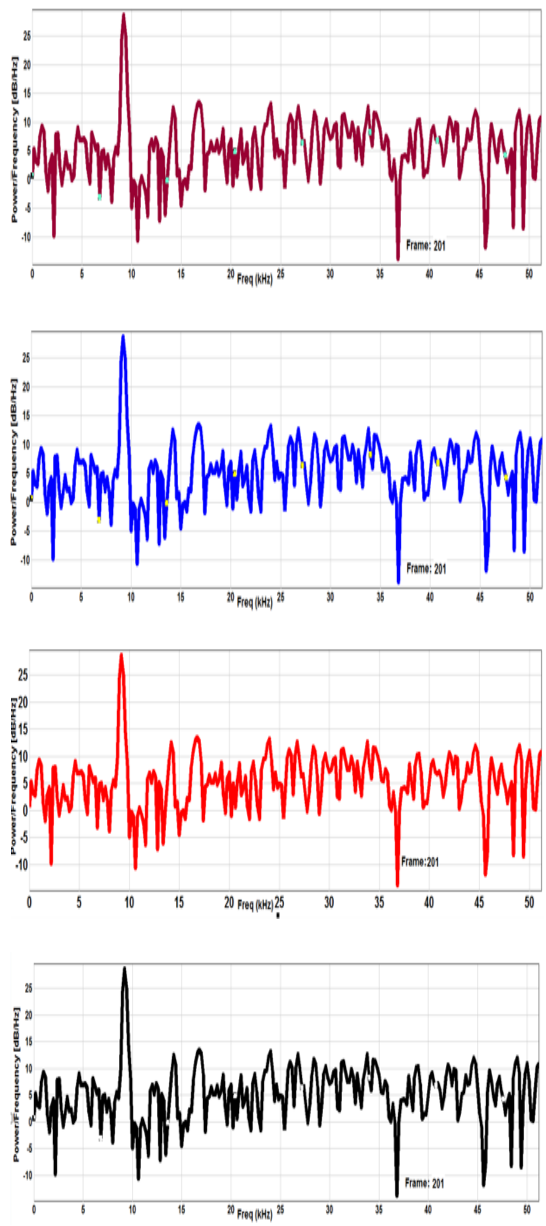
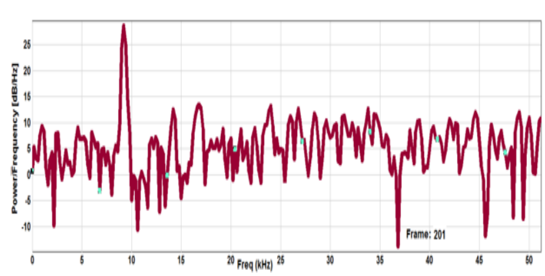


Fig.3. Power Spectrum Density v/s frequency in kHz for cooperative spectrum sensing under AWGN channel for SNR=15dB (for Taylor win window)



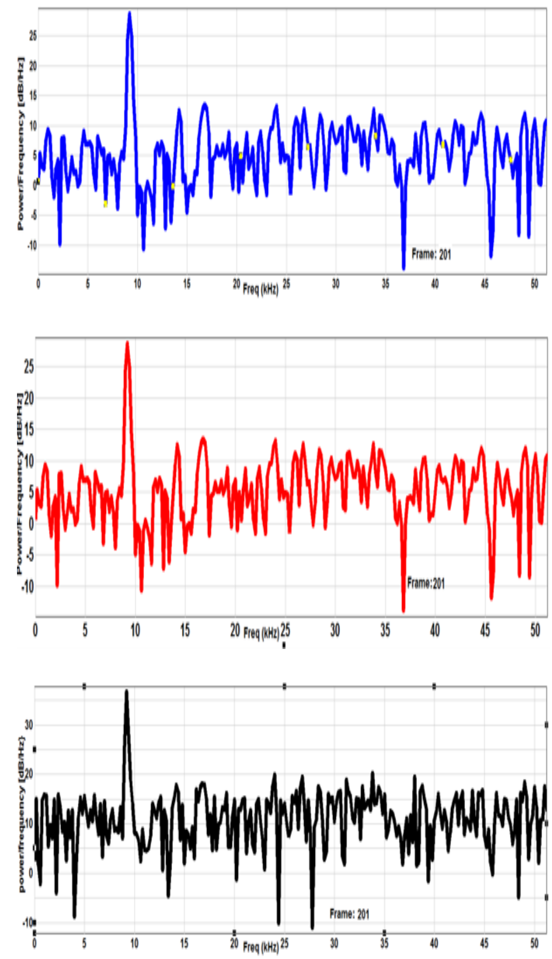


Fig.4. Power Spectrum Density v/s frequency in kHz for cooperative spectrum sensing under AWGN channel for SNR=15dB (for Kaiser Window)

In the Fig.3.and Fig.4. local sensing is made with energy detection after observinghe signal for 201 samples. Power spectral Density (PSD) v/s frequency is similar for both KaiserWindow and Taylor win window for first three channels. PSD is high for fourth channel in Taylor win window when energy detection is done at the transceiver block.

PARAMETER	VALUES
Constant losses	2
Path loss component	2
Time bandwidth factor	1000
Samples	2000

Table 2 ROC curve parameters

A.Complementary ROC curve of cooperative sensing with data fusion rules

The below listed parameters are used for ROC curve performance evaluation .Table 2 Parameters used for ROC curve performance evaluation for cooperative sensing

A network of 10 cognitive users is considered for the simulations. Each cognitive radio accumulates 2000 samples for the local decision in the environmental sensing. The performance of cognitive radio network can be enhanced by minimizing the global probability of false alarm or maximizing the global probability of detection. A high probability of detection represents a high throughput for the cognitive radio. The global probability of false alarm determines the throughput of the cognitive radio network.To improve the chance of utilizing the spectrum the probability of missed detection should be at the lower bound.

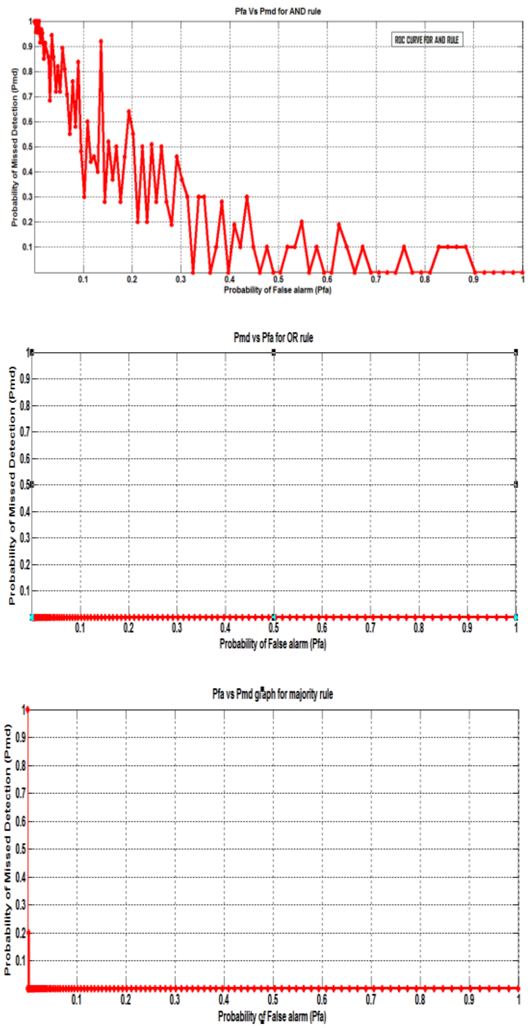


Fig.5.Probability of missed detection v/s Probability of false alarm for AND rules, OR rule and MAJORITY rule

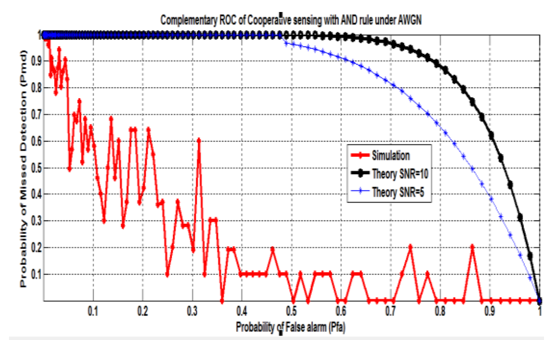
Fig.5. shows the ROC curve obtained by theoretical distribution of H0and H_1 hypothesis testing. The ROC plot between probability of miss v/s probability of false alarm shows abrupt change in AND and OR decision fusion rule. The abrupt change is due to the SNR influence on the detectionprobability of the ROC curve. The detection performance ofMAJORITY rule is better than AND rule and OR rule. Simulation result shows that probability of missed detection is increased in case of AND rule when compared to OR and majority rule. The results obtained through the ROC curve proves that MAJORITY rule outperforms AND and OR rule.

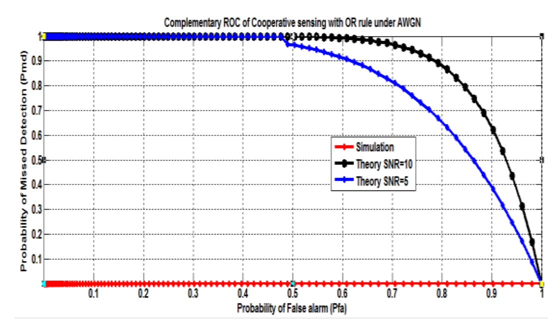
PROBABILITY OF MISSED DETECTION, P md (%)		0	0.1	0.5	0.8	0..9
PROBABILITY OF FALSE ALARM Pfa (%)	AND	1	0.3	0.01	0.01	0.01
	OR	0.01	0.01	0.01	0.01	0.01
	MAJ	0.01	0.01	0.01	0.01	0.01

Table 3:Obtained values of complementary ROC curve of spectrum sensing.

Table 3 shows the values of complementary ROC curve of cooperative spectrum sensing with AND, OR and MAJORITY rule. Probability of false alarm is decreasing with increase in probability of missed detection. The probability of false alarm is high in the case of AND rule compared to OR and MAJORITY rule. The decrease in false alarm raises the spectrum sensing accuracy. From the above results, it is proved the MAJORITY rule has less false alarm compared to AND and OR rule.

B.Complementary ROC of cooperative spectrum sensing with different values of SNR





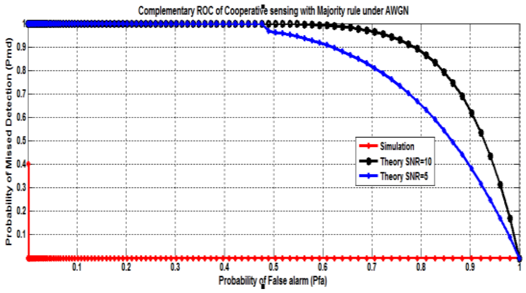


Fig .6. Complementary ROC of cooperative spectrum sensing with AND, OR and MAJORITY rule with SNR 10dB and 5 dB.

Simulation result shows that the probability of missed detection is increased for AND rule if CR also increases. In case of MAJORITY rule probability of false alarm decreases with increase in probability of missed detection. The increase in SNR raises the spectrum sensing accuracy. The performance ofspectrum sensing can be minimizing the probability of missed detection.

IV. CONCLUSIONS AND FUTURE SCOPE

This proposed work presents an extensive analysis of spectrum sensing technique in cognitive radio. The proposed scheme chooses the better data fusion technique to improve spectrum utilization efficiency of the radio spectrum by decreasing interference and sensing time.

The performance of MAJORITY rule is considerably better than AND and OR rule. The probability of missed detection is less in MAJORITY rule. Performance limitations raised by uncertainties at various levels of operations are overcome by a proper combination of local signal sensing processing and system level coordination among different cognitive radio networks.

In the future work, fundamental cooperation can be made at physical, link and network layers to support network coding, network MIMO and cooperative relay in cognitive radio.

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