A FUSION BASED COOPERATIVE SPECTRUM SENSING DETECTION TECHNIQUES

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ABSTRACT:

Recent advances in communication technologies and the proliferation of wireless computing and communication devices make the radio spectrum overcrowded. However, experiments from the Federal Communication Commission (FCC) reveals that the spectrum utilization varies from 15% − 85%. Consequently, Cognitive Radio Networks (CRNs) are proposed to utilize the radio spectrum opportunistically. Therefore, FCC is currently working on the concept of unlicensed users "borrowing" spectrum from incumbent license holders temporarily to improve the spectrum utilization. This concept is called dynamic spectrum access (DSA). Cognitive radios offer versatile, powerful, and portable wireless transceivers enabling DSA.

For complex computer networks with many tunable parameters and network performance objectives, the task of selecting the ideal network operating state is difficult. To improve the performance of these kinds of networks, this research proposes the idea of the cognitive network. A cognitive network is a network composed of elements that, through learning and reasoning,

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dynamically adapt to varying network conditions in order to optimize end-to-end performance. Therefore, a new channel selection strategy is required which cause less harmful interference to PR nodes and try to maximize the chances that the message is delivered to the neighboring cognitive radio receivers, thus increasing the data dissemination reachability.

Keywords: Cognitive radio networks, channel selection, dynamic spectrum access networks, spectrum sensing, cooperation, Receiver Detection, OR and AND rule.

I.INTRODUCTION

Cognitive radio (CR) is one of the new long term developments taking place and radio receiver and radio communications technology. After the Software Defined Radio (SDR) which is slowly becoming more of a reality, cognitive radio (CR) and cognitive radio technology will be the next major step forward enabling more effective radio communications systems to be developed.

The idea for cognitive radio has come out of the need to utilize the radio spectrum more efficiently, and to be able to maintain the most efficient form of communication for the prevailing conditions. By using the levels of processing that are available today, it is possible to develop a radio that is able to look at the spectrum, detect which frequencies are clear, and then implement the best form of communication for the required conditions. In this way cognitive radio technology is able to select the frequency band, the type of modulation, and power levels most suited to the requirements, prevailing conditions and the geographic regulatory requirements. The radio will need to determine the occupancy of the available spectrum, and then decide the best power level, mode of transmission and other necessary characteristics. Additionally the radio will need to be able to judge the level of interference it may cause to other users. This is an equally important requirement for the radio communications system if it is to operate effectively and be allowed access to bands that might otherwise be barred.

The use of a cognitive radio network provides a number of advantages when compared to cognitive radios operating purely autonomously like improved spectrum sensing, improved coverage and by setting up cognitive radio network, it is possible to relay data from one node to the next. In this way power levels can be reduced and performance maintained.

Cognitive Radios are used in collaborative networks, maintenance and fault detection networks, self organized networks, and cognitive multiple input multiple output (MIMO). In addition, the cognitive radio approach can be useful in other applications such as home environment, utilization of vacant TV bands, messaging devices and other non-real time communication systems. The cognitive radio could improve communications in emergency situations when the traditional network becomes congested with calls for help due to the limited availability of spectrum bands.

II.PROBLEM FORMULATION: In this section, we first present the general model for channel sensing using fusion techniques, and then review the energy detection scheme and analyze the relation between the probability of detection, probability of miss detection and probability of false alarm.

III.RELATED WORK

General System Model for Spectrum Sensing:

Cognitive radio technologies can be used in lower priority secondary systems that improve spectral efficiency by sensing the environment and then filling the discovered gaps of unused licensed spectrum with their own transmissions.

The three major tasks of the cognitive radio include

(1) radio-scene analysis,

(2) channel identification, and

(3) dynamic spectrum management and transmit-power control.

The radio-scene analysis includes the detection of spectrum holes by for example sensing the radio frequency spectrum. The channel identification includes estimation of the channel state information which is needed at the receiver for coherent detection. The transmitter power control and dynamic spectrum management select the transmission power levels and frequency holes for transmission based on the results of radio scene analysis and channel identification. The first two tasks are carried out in the receiver (RX) while the third task is carried out in the transmitter (TX), which requires some form of feedback between RX and TX.

Two conditions are possible under hypothesis test

1. When the primary user is not active, the received signal at the secondary user can be represented as

$$y(n) = u(n) \qquad (1)$$

Where $y(n)$ is the signal received by the secondary user and $u(n)$ is noise.

2. When the primary user is active, the received signal is given by

$$y(n) = h(n)s(n) + u(n) \qquad (2)$$

Where $s(n)$ the signal is transmitted by the primary users and received by secondary users over a channel $h(n)$. When the channel is non-fading, $h(n)$ is constant. It is assumed that noise samples $u(n)$ are independently and identically distributed (i.i.d.) with zero mean and variance $\mathrm{E}\left[|u(n)|^2\right] = \sigma_u^2$ based on the received signal.

First we detect whether there is a signal present or not we provide the separation between H_0 and H_1

$$\left.\begin{array}{ll} y = w & \mathrm{H}_0: \text{ signal is absent} \\ y = x + w: & \mathrm{H}_1: \text{ signal is present} \end{array}\right\} \qquad (3)$$

Local Spectrum Sensing:

The performance of a given spectrum sensing scheme is fundamentally limited by the radio propagation channel. Typically, the effects of a radio channel can be divided into three main parts: path loss, small-scale fading, and large-scale fading (shadowing). Path loss effects are incorporated in the received SNR at a cognitive radio terminal. Small-scale fading causes rapid, random variations in the signal strength at the CR receiver and is modeled by Rayleigh fading in this paper. Shadowing is the slow variation of received signal power as the cognitive radio moves in and out of the shadow of large structures like mountains, buildings, and so forth. Shadowing is often modeled as a lognormal distributed random process that varies around a local mean given by the path loss and with the standard deviation σdB which depends on the environment.

Cognitive radio spectrum sensing methodologies

Cognitive radio cooperative spectrum sensing occurs when a group or network of cognitive radios share the sense information they gain. This provides a better picture of the spectrum usage over the area where the cognitive radios are located. The methodology and attributes assigned to the spectrum sensing ensure that the cognitive radio system is able to avoid interference to other users while maintaining its own performance.

Spectrum sensing bandwidth: There are a number of issues associated with the spectrum sensing bandwidth. A narrow bandwidth will reduce the system noise floor and thereby improve the sensitivity, but it must also have a sufficiently wide bandwidth to detect the likely transmissions on the channel.

Transmission type sensing: The system must be capable of identifying the transmission of the primary user for the channel. It must also identify transmissions of other units in the same system as itself. It should also be able to identify other types of transmission that may be spurious signals, etc.

Spectrum sensing accuracy: The cognitive radio spectrum sensing mechanism must be able to detect any other signal levels accurately so that the number of false alarms is minimised.

Spectrum sensing timing windows: It is necessary that the cognitive radio spectrum sensing methodology allows time slots when it does not transmit to enable the system to detect other signals. These must be accommodated within the frame format for the overall system.

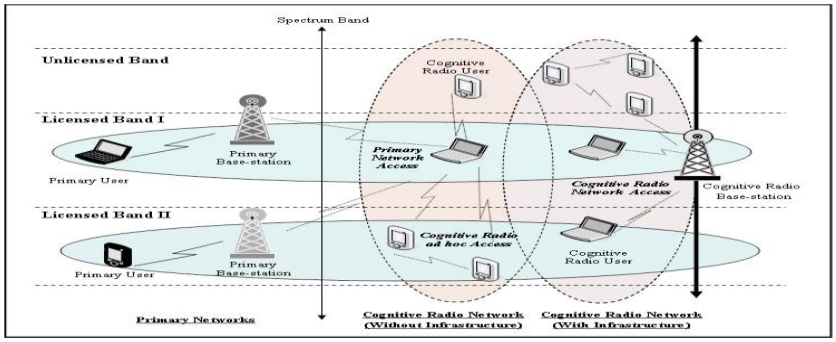


Fig 1: The considered scenario

The local spectrum sensing is accomplished by the energy detection. An energy detector is implemented at each secondary user by calculating a decision metric out of all samples and antennas used. The purpose of energy detection is to make a correct decision between two hypotheses after observing samples. The energy detection should be carried out over all logical channels defined by the CR network. Assuming that the channel is time-invariant during the sensing process, the energy detection on the given channel is performed by accumulating the energy of samples and comparing it with the predefined threshold, to decide whether signal is present or not.

IV.PROPOSED WORK

Information of local signal observation from all cognitive users transmits to data fusion centre. They forward 1-bit local detection to avoid communication overhead when CR users increased. Then, the final decision is performed whether signal is present (H_1) or absent (H_0) by regarding to decision rule. There are two decision fusions commonly used in cooperative spectrum sensing, hard and soft decision.

Hard decision is the one in which the individual cognitive radio makes the one-bit decision regarding the existence of the primary user. The bit-1 indicates that primary user uses spectrum channel, so that cognitive radio user cannot access. Spectrum channel is available to be accessed if cognitive radio user makes bit 0. After observing the primary user signal, the local detection forwards them to data fusion centre for further process. The final decision then is taken by combining all local detection/observation. The two simple rules of hard decision are OR and

AND rule. Under OR rule, at least one of the CR users involved in sensing decides that primary user is present. Whereas AND rule decides primary user is present when primary signal is detected by all cognitive radio users or in other word that all local decision of cognitive radio user is H1. In the case of soft decision, the decision is taken by correlating the measurement made by individual users in signal detection. It is more accurate than hard decision. However, it will cause data transmission overhead when number of CR users increase. In this case of study, we focus on hard decision combining where individual users forward their one bit decision to fusion centre.

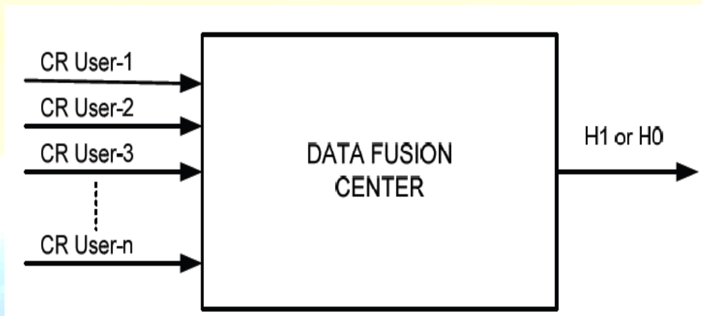


Fig:2 Data fusion center

Logical-OR Rule: In this rule, if any one of the local decisions sent to the decision maker is a logical one (i.e., any one of the nodes decides that the signal of interest is present), the final decision made by the decision maker is one (i.e., decision maker decides that the signal of interest is present)

Logical-AND Rule: In this rule, if all of the local decisions sent to the decision maker are one (i.e., all of the nodes decide that the signal of interest is present), the final decision made by the decision maker is one (i.e., decision maker decides that the signal of interest is present)

Mathematical approach for Energy detector:

The secondary users are required to sense and monitor the radio spectrum environment within their operating range to detect the frequency bands that are not occupied by primary users. In this section we discuss the most popular spectrum sensing scheme, the energy detector. The energy detector employs a non-coherent detection technique, which does not require prior knowledge of pilot data

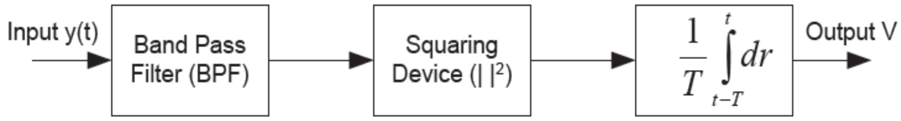


Fig. 3 Block diagram of an energy detector

Energy detection is an efficient and fast non coherent technique that essentially computes a running average of the signal power over a window of pre specified spectrum length.

The block diagram of the energy detector is shown in Figure 3. The received signal $x(t)$ is first pre- filtered by an ideal band pass filter (BPF) with center frequency f_c and band width ω in order to normalize the noise variance. The noise in the output of the filter has a band-limited, flat spectral density. Next, the output of this filter is then squared and integrated over a time interval T to finally produce a measure of the energy of the received waveform.

We denote that the normalized output of the integrator in Fig. 3 by T which serves as the decision statistic. The test statistic for the energy detector is given by,

$$\mathrm{T}(y) = \frac{1}{\mathrm{N}}\sum_{n=1}^{\mathrm{N}} |y(n)|^2 \qquad (4)$$

Where N is the number of samples. The test statistic $\mathrm{T}(y)$ is a random variable whose PDF $p_0(x)$ is a Chi-square distribution with $2\mathrm{N}$ degrees of freedom for complex valued case [10].

Finally, this output signal Y is compared to the threshold λ, in order to decide whether a signal is present or not. The threshold is set according to the statistical properties of the output Y when only noise is present. Thus, spectrum sensing is equivalent to detect the presence of an unknown.

The PDF of the y is given by

$$f_Y(y) = \begin{cases} \frac{1}{2^u \Gamma(u)} y^{u-1} e^{-y/2} & : \mathrm{H}_0 \\ \frac{1}{2}\left(\frac{y}{2\gamma}\right)^{\frac{u-1}{2}} e^{-\frac{2\gamma+y}{2}} \mathrm{I}_{u-1}\left(\sqrt{2\gamma y}\right) & : \mathrm{H}_1 \end{cases} \qquad (5)$$

Where $\Gamma(\bullet)$ is the gamma function, $I_n(\bullet)$ n^{th} order modified Bessel function of I^{st} kind $u = T\omega$, where T and ω are choosen to restrict u to an integer value.

Probabilities of Detection and False Alarm

Energy detection has already been recognized as an efficient sensing method for cognitive radio.

The test statistic Y is compared with the predefined threshold λ.The probabilities of detection P_d and false alarm P_f can be generally evaluated by $P_r\left(Y > \lambda / H_1\right)$ and $P_r\left(Y > \lambda / H_0\right)$

For the hypothesis H_0, for a chosen threshold value λ the probability of false alarm can be

$$P_f(\lambda,\tau) = P_r\left(T(y) > \lambda / H_0\right)$$

$$= 1 - \int_{-\infty}^{\lambda} p_0(y)\,dy$$

$$= \int_{\infty}^{\lambda} p_0(y)\,dy \qquad (6)$$

Where τ =available sensing time

From equation (5) PDF of Y under H_0 is

$$p_0(y) = \frac{y^{u-1} e^{-y/2}}{\Gamma(u)\, 2^u} \qquad (7)$$

Where u is the time band width product and $\Gamma(\bullet)$ is the gamma function

Therefore the probability of false alarm P_{FA} is

$$P_{FA}(\lambda,\tau) = \int_{\infty}^{\lambda} \frac{y^{u-1} e^{-y/2}}{\Gamma(u)\, 2^{u}} dy \qquad 8$$

Therefore P_{FA} is independent of SNR since under H_0 there is no primary signal present

For the hypothesis H_1, for a chosen threshold value λ the probability of detection can be

$$P_d(\lambda,\tau) = P_r\left(T(y) > \lambda / H_1\right) = \int_{\infty}^{\lambda} p_1(x)\, dx \qquad 9$$

Where $p_1(x)$ is the PDF of the test statistics $T(y)$ which can be written as

$$p_1(x) = \frac{1}{2}\left(\frac{x}{2\gamma}\right)^{\frac{u-1}{2}} e^{\frac{-(2\gamma+x)}{2}} I_{u-1}\left(\sqrt{2\gamma x}\right) \qquad 10$$

(or)

$$p_1(x) = \frac{x^{u-1} e^{\frac{-x+2u\gamma}{2}}}{\Gamma(u)\, 2^{u}} F_1\left(u, \frac{u\gamma x}{2}\right) \qquad 11$$

Where $F_1(.......)$ is the confluent hyper-geometric limit function and γ is the SNR is defined as γ

The generalized Marcum Q-function $Q_m(\ ,\ )$ is

$$Q_m(a,b) = \int_{b}^{\infty} \frac{x^{m-1}}{a^{m-1}} e^{\frac{x^2+a^2}{2}} I_{m-1}(ax)\, dx \qquad 12$$

Equations (10) or (11) compare with equation (12)

$$P_d = Q_m\left(\sqrt{2u\gamma}, \sqrt{\lambda}\right) \qquad 13$$

Where $I_{m-1}(\ )$ is the $(u-1)$ th order modified Bessel function of the first kind

Note: CRN (cognitive radio network) used to detect only weak primary user signal. Uncertainties in the model assumptions robust detection is impossible below a certain SNR level.

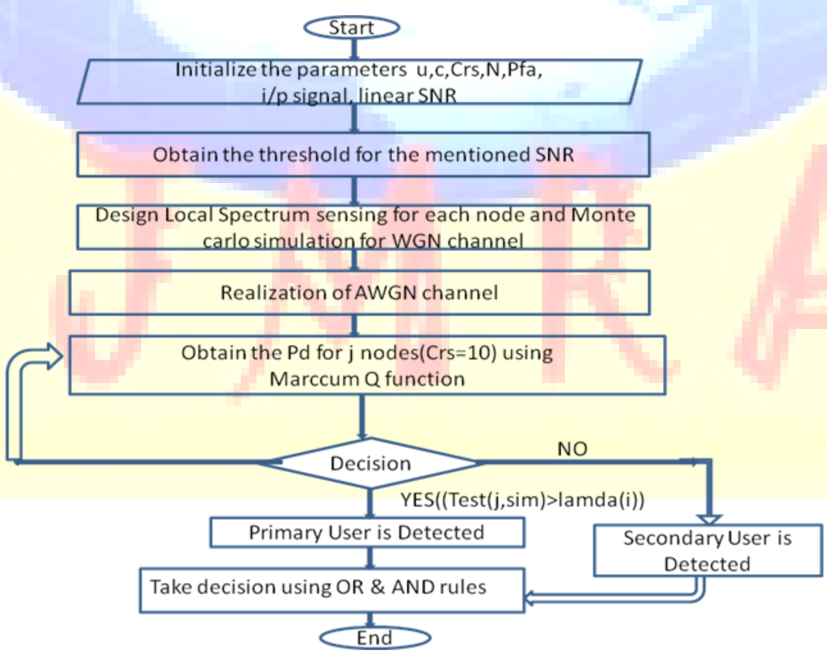
If the decision is H_0 when there is a primary user present, it is called missed detection and its probability is represented as P_m.when both the primary signal and noise are treated as Gaussian processes, energy detector can meet any desired P_d and P_f simultaneously, hence the threshold λ is optimal .Finally ,the probability of missed detection can be evaluated as

$$P_m(\lambda) = 1 - P_d(\lambda)$$

$$P_m = 1 - P_r\left(Y > \lambda / H_1\right) = 1 - Q_u\left(\sqrt{2\gamma}, \sqrt{\lambda}\right) \qquad 14$$

In the CR system, the probability that the presence of the primary user is not detected should be minimizing to prevent unexpected interference to the primary user such that the probability of false alarm is maintained below a certain level. The fundamental tradeoff between P_m and P_f has different implications.

THE PROPOSED ALGORITHM:



V.SIMULATION RESULTS

We use this metric to indicate that CR users experience different channel fading. The information of local detection from each cognitive radio users are forwarded to data fusion centre and combined to obtain final decision. The simulation is performed by using probability of detection as a metric at different SNR values.OR rule decides H1 when at least one user detects primary user signal while AND rule decides H1 if all cognitive radio users forward their bit-1 local detections.

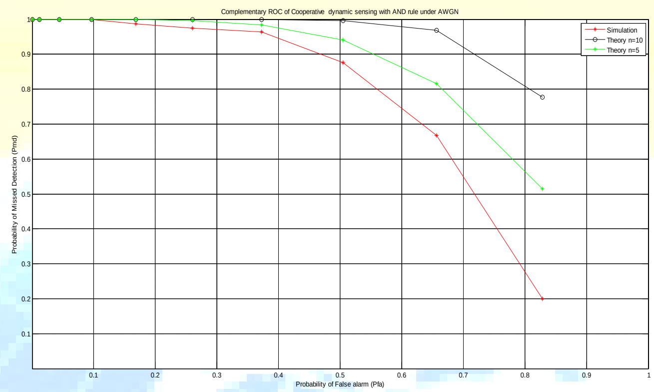


Fig: 4 Spectrum sensing using AND and OR rule

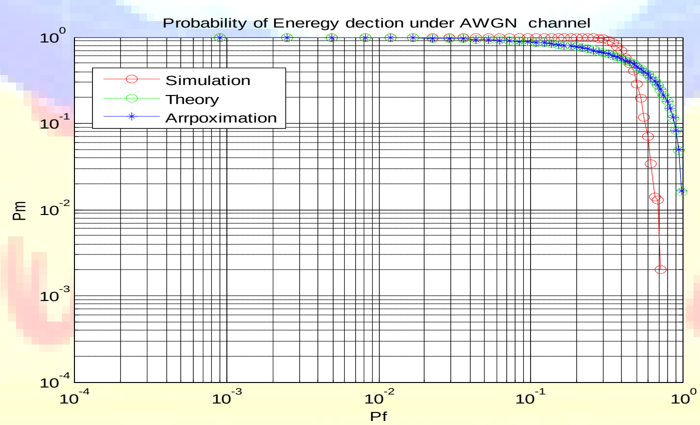


Fig 5: Perfect energy detection under AWGN channel

VI. CONCLUSION

In co-operative technique, OR and AND rules are employed and evaluate the system performance by using probability of detection (Pd) and SNR as metric. The OR rule decides H1 when at least one CR user forward bit-1 while the AND rule decides H1 when all CR users forward their bit-1 to data fusion centre. The numerical results show that cooperative technique has better performance compared with non cooperative one and employing OR rule can improve probability of detection than AND rule and non cooperative signal detection at different SNR values. Cooperative technique is more effective when received SNR in cognitive radio users is low due to fading and shadowing. Cognitive radio offers hope to meet this demand with a system that is compatible with existing deployed wireless systems, stimulates new innovation, reduces regulatory burden, encourages market competition, preserves the rights of incumbent spectrum license holders, and benefits the populace overall.

FUTURE WORK

In future, we would like to explore other types of feature detection and evaluate their performance comparatively with energy detection. In-band sensing of wireless micro-phones should be another subject of our future work.

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