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Comparison of Cognitive Radio Spectrum Sensing and Quiet Period Management Schemes

Shruthi P Murali [1], Noble C Kurian [2]

PG Student, Department of Electronics and Communication Engineering ,SNGCE, Kolenchery, India [1]

Assistant Professor, Department of Electronics and Communication Engineering , SNGCE, Kolenchery, India [2]

ABSTRACT : Cognitive radio arises to be a promising solution to the spectral congestion problem caused by fixed spectrum assignment strategy. It allows opportunistic usage of the frequency bands that are not heavily occupied by licensed users to other secondary users. Spectrum sensing and quiet period management are two most challenging issues in cognitive radio systems. In this paper, a survey of spectrum sensing methodologies and quiet period management schemes is presented. It also gives a comparative study of various methodologies used in these areas.

KEYWORDS: Cognitive radio ; spectrum sensing ; spectrum monitoring ; quiet period ; energy ratio algorithm

I. INTRODUCTION

Static spectrum access is the main policy for wireless communications. Under this policy, fixed channels are assigned to licensed users or primary users for exclusive use while unlicensed users or secondary users are refrained from accessing those channels even when they are unoccupied. This leads to under utilization of spectrum. The idea of a cognitive radio was proposed to provide better utilization of RF spectrum.

One of the main approaches used in cognitive networks is the overlay network model. Primary and secondary users are not allowed to operate simultaneously. Spectrum sensing is performed to detect the presence of primary users in the frequency band. If the primary user is idle, the secondary user can then use the spectrum but it will have to vacate the spectrum as soon as the primary user reappears. Generally the spectrum is kept vacant during sensing and this period is termed as quiet period. In order to maximize channel utilization we should minimize quiet periods.

II. RELATED WORKS

A number of spectrum sensing techniques are available in the present scenario. Some of them used in the previous works are listed below

A. Energy Detection

It detects the primary signal based on the sensed energy [1]. It does not require a priori knowledge of primary user signal .Due to its simplicity energy detection is the most popular sensing technique used in cooperative sensing [2] .

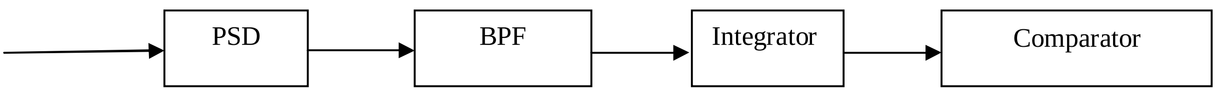

Fig 1-Energy detector block diagram

The block diagram for the energy detection technique is shown in the Figure 1. In this method, signal is passed through band pass filter and is integrated over time interval. The output from the integrator block is then compared to a predefined threshold. This comparison is used to detect the presence or absence of the primary user.

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$y(k) = n(k)\ldots\ldots\ldots\ldots\ldots\ldots H_0$ eq. (1)

$y(k) = h*s(k) + n(k)\ldots\ldots\ldots\ldots H_1$ eq. (2)

Where y (k) is the sample and n (k) is the noise at instant k. Then decision rule is given by

$H_0\ldots\ldots\ldots$ if $\varepsilon < \nu$ eq. (3)

$H_1\ldots\ldots\ldots$ if $\varepsilon > \nu$ eq. (4)

where ε denotes the energy of received signal and ν represents the threshold.

B. Matched Filter

Fig 2-Block diagram of matched filter

This type of detection uses priori knowledge of primary user signal. The block diagram of matched filter is shown in fig 2.The received signal is first passed through a band pass filter whose output is given to a matched filter. Here the unknown signal is convolved with the filter whose impulse response is the mirror and time shifted version of a reference signal which is derived from the priori information. The convolved output is then analysed in the comparator to detect the presence of primary user. Mathematically it can be expressed as:

$$Y[n] = \sum_{k=-\alpha}^{\alpha} h[n-k]x[k] \quad \text{eq. (5)}$$

where 'x' is the unknown signal (vector) and 'h' is the impulse response of matched filter.

C. Cyclostationary Feature Detection

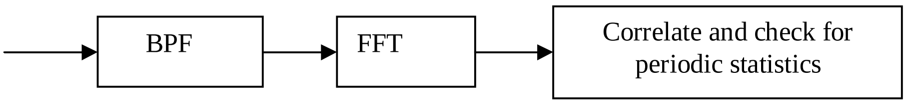

Fig 3-Cyclostationary feature detector block diagram

It uses the periodicity in the received primary signal to identify the presence of primary users . The periodicity is generally exhibited by sinusoidal carriers, pulse trains, spreading code, hopping sequences or cyclic prefixes of the primary signals. So these cyclostationary signals exhibit the features of periodic statistics and spectral correlation, which is not found in stationary noise and interference [3]. Fig 3 shows the block diagram of cyclostationary feature detection. The incoming signal is first passed through the band pass filter. Then FFT is applied on the signal to convert it into frequency domain. On this converted signal a check for periodic statistics is carried out to detect the presence of primary signal.

D.Waveform-Based Sensing

In waveform based sensing primary user detection is done using known patterns that are generally used for synchronization purpose. Such patterns include preambles, midambles, regularly transmitted pilot patterns, spreading sequences etc. If such patterns are present ,then sensing can be performed by correlating the received signal with a known copy of itself . This method is only applicable to systems with known signal patterns, and it is termed as waveform-based sensing or coherent sensing. It is shown in [4] that wave form based sensing is better than energy detector based sensing in reliability and convergence time.

E. Radio Identification Based Sensing

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Knowledge about the spectrum characteristics can be obtained by identifying the transmission technologies used by primary users. It provides high accuracy .For example, assume that a primary user's technology is identified as a Bluetooth signal. Cognitive radio can use this information for extracting some useful information in space dimension as the range of Bluetooth signal is known to be around 10 meters. For radio identification, feature extraction and classification techniques are used . Feature extraction is done by energy detector based methods. After extracting features it is then subjected to classification.. For classification, radial basis function (RBF) neural network is employed.

III. COMPARISON OF VARIOUS SENSING METHODS

Waveform-based sensing is more robust than energy detector and cyclostationarity based methods .It is because of the coherent processing. However this method can be used only when primary users transmit known patterns or pilots. The performance of energy detector based sensing is limited when two common assumptions do not hold . The noise may not be stationary and its variance may not be known. Other problems with the energy detector include baseband filter effects and spurious tones . Cyclostationary-based methods perform worse than energy detector based sensing methods when the noise is stationary. It performs well when the noise becomes non stationary. But it is seriously affected by channel fading.

IV. QUIET PERIOD MANAGEMENT SCHEMES

Since the secondary users borrows spectrum from the primary user, it has to vacate the spectrum as soon as the primary user reappears .In traditional spectrum sensing since the secondary users do not access the spectrum during the primary user detection, this period is called the "quiet period." it lowers the utilization of radio spectrum and long quiet periods cause the QoS degradation

A. *Combined use of different sensing methods*

In [5] a combined use of energy detection and feature detection is presented to manage quiet periods. Here the feature detection is invoked after a predefined number of consecutive energy detection alarms. The predefined number is used as the parameter controlling the trade-off between the detection delay of primary user and the efficiency for CR user.

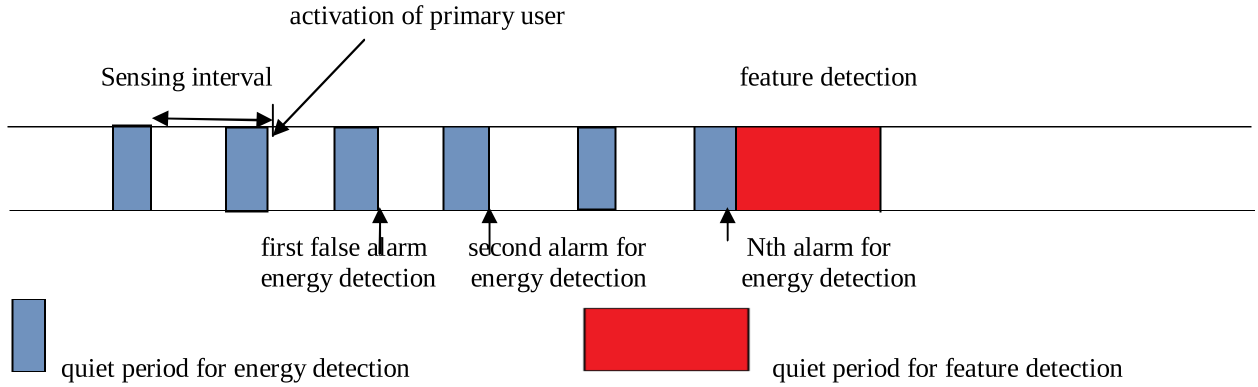

Fig 4 – Combined use of energy detection and feature detection for quiet period management

Here there are two types of quiet period: a short quiet period for measuring the energy level (energy detection) and a long quiet period for classifying whether the energy source is a primary user or not (feature detection). Consider fig.4 which gives the pictorial representation of the above mentioned quiet period management scheme. Here the area in blue colour represent energy detection period and that in red colour represent feature detection period. Since the measurement for energy detection is done for the relatively short time, the result might be incorrect. That is, a false

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alarm can be issued even when primary user is absent. Since the feature detection evaluates the energy source in more detail and should make a final decision for the existence of primary user, it needs long time as compared with energy detection. Therefore, the feature detection decreases the channel utilization of CR system. For high channel utilization, the feature detection due to false alarm needs to be decreased. In this scheme feature detection is performed only when the energy detection alarms are issued *N* times consecutively. This scheme can reduce the possibility of invoking feature detection due to the false energy detection alarm.

B. *Using optimization algorithms*

In [6] a non linear optimization algorithm that minimizes the total time required to find an idle channel is used as quiet period management scheme.

Total time taken to find an idle channel (T_{total}) = monitoring time(t_m) + Time taken to search for idle channel(t_{search})

eq (6)

Monitoring time is the time taken to detect whether the spectrum is vacant or not. Once the spectrum is found to be vacant then it searches for idle channel. Search for idle channel is performed in two cases.

1.When the channel is idle but detected as busy
2.When the channel is indeed busy.

So here in this method we use optimization techniques to minimize the term T_{total} in order to reduce the length of quiet periods.

C. *Using spectrum monitoring techniques*

Traditional spectrum sensing requires the secondary radios to refrain from communicating while they check for the presence of primary signals. Spectrum monitoring techniques allows the secondary radios to continue their communications while simultaneously monitoring the band to detect the reappearance of the primary radios .

1. Using receiver statistics

In [7] a receiver statistics based spectrum monitoring is discussed. This method uses statistics that are developed in the receivers of the secondary radios. If the secondary receivers employ iterative decoding then the receiver statistics will be iteration count. This count is compared with a predefined threshold. If the value is greater than the threshold then it indicates the presence of primary user. Depending on decoding method receiver statistics varies. Each secondary receiver monitors the statistics during the reception of each packet. If one of the statistics indicates that a primary signal may be present in the band, then the secondary radio can refrain from transmitting while it performs traditional spectrum sensing to verify the presence of a primary signal. This decision can be made individually by the secondary radios or they can cooperate to improve detection performance.

2. Using energy ratio algorithm

Another spectrum monitoring technique is discussed in [8] which employs an energy ratio algorithm based spectrum monitoring. Here OFDM based cognitive radio is employed. This is done by sensing the change in signal strength over a number of reserved OFDM sub-carriers or reserved tones. Consider fig 5 which represents the methodology of energy ratio algorithm. Here portion marked as (1) and (2) represents collected reserved tones at the receiver end with and without primary user. The reserved tones represented in black indicates the presence of primary user while that in white represents the absence of primary user .The sliding window concept used is shown in portion (3) and in the final step the threshold comparison is shown.

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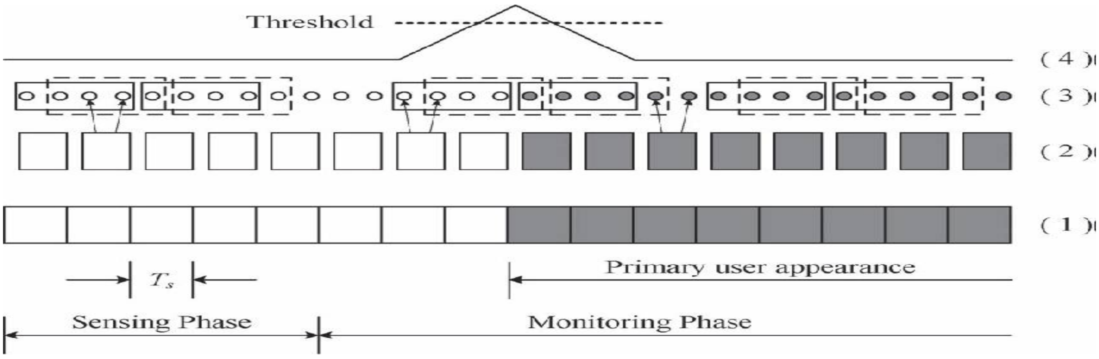

Fig 5 - Energy ratio processing details

At the secondary receiver the reserved tones from different OFDM symbols are combined to form one sequence of complex samples. Two consecutive equal-sized sliding windows are passed over the reserved tone sequence in the time direction. The energy of the samples in one window is evaluated and the ratio of the two energies is taken as the decision making variable. In mathematical form the decision making variable, Xk, can be defined as given by eq. (7) where Uk is the energy of the second window, Vk is the energy of the first window, and *k* is an integer such that *k* = 1,2,3, . . .

$$X_K = U_K / V_K \qquad \text{eq. (7)}$$

If there is no primary user in band, then the energy of each window involves only the strength of the unwanted signals like the noise. Therefore, if number of samples is large enough, the ratio will be very close to unity since the strength of the unwanted signals does not cause significant changes over time.

Once the primary user appears, the second window will contain the primary user interference and the unwanted signals. Whereas, the first window will only contain the unwanted signals without the primary user interference. Then the ratio of the two energies will result in higher values when compared to one. When the two windows slide again, the primary signal plus the unwanted signals will be present in the two windows and the decision making variable returns to the initial state in which the ratio is close to unity. Thus, the decision variable produces a spike when the primary user is detected.

V. COMPARISON OF QUIET PERIOD MANAGEMENT SCHEMES

When combination of energy and feature detection is used the secondary users is refrained from transmission during primary user detection. The same holds for optimization algorithms. In addition the optimization algorithm complexity is also high. Whereas spectrum monitoring techniques allows the secondary users to transmit during primary user detection. Receiver statistics based method employs the use of priori knowledge about the primary user. On the other hand energy ratio algorithm based method was found to have less complexity and does not require the use of priori information. Hence we can say that energy ratio algorithm based methods outperforms other schemes in many aspects.

VI. CONCLUSION

Cognitive radio is a promising solution to spectral congestion problem. Spectrum sensing methods are used to detect the presence of primary users and also it helps to extract information about spectrum usage .In this paper different basic sensing methods used for cognitive radio is discussed along with its advantages and disadvantages. It also surveys previous works on quiet period management schemes and an effective comparison is also presented.

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BIOGRAPHY

Shruthi P Murali is a PG student at SNGCE, Kolenchery ,kerala, India. She received B.Tech degree in Electronics and communication Engineering from MG University, Kerala in 2013 and currently pursuing M.Tech in communication engineering from the same university.

NobleC.Kurian is working as an assistant professor in the department of Electronics and Communication at SNGCE, Kolenchery ,kerala ,India. He received his M.Tech degree in Electronics and Communication Engineering (Optoelectronics and Optical communication) and PGDHRM from University of Kerala, Kariavattom Campus. He started his career as lecturer and then served as Project Trainee at BARC, Department of atomic energy, Mumbai. He executed many projects in instrumentation field when he was working as Optical engineer at bangalore. He has been working at SNGCE since December 2009. He completed more than 7.5 yrs in different organisations and published papers in several national journals.