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Performance Evaluation of Local and Cooperative Spectrum Sensing

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Abstract: Cognitive Radio (CR) is a self-monitoring wireless communication system. CR can utilize the radio frequency spectrum more efficiently. The CR user is able to opportunistically use those idle spectrum bands without causing harmful interference to the licensed primary user. There are several spectrum sensing techniques which can serve the purpose. Here non-cooperative spectrum sensing is carried out using energy detection spectrum sensing and cyclostationary (both one-order and two-order) feature detection technique. Using the results obtained the energy efficient and time efficient techniques are determined. Using the results obtained from local spectrum sensing, cooperative spectrum sensing with five CRs is evaluated. Performance assessment is also done with respect to the number of CRs used in cooperative spectrum sensing. Using MATLAB programming, the receiver operating characteristics curve of these spectrum sensing techniques are plotted. The concept of spectrum management and spectrum sharing is implemented through a posixpthread program in Linux platform. It explores the scheduling principle involved in allocating the spectrum to secondary users.

Keywords: Cognitive Radio, MATLAB, Cyclostationary Detector, Energy Detector.

I. Introduction

Wireless communication is present everywhere today. Emerging needs such as high-definition good quality video streaming and fast downloading over wireless channels keeps on rising. The demands for higher data rates and long-distance wireless communications will never end. As a result, more and more radio frequency (RF) spectrum bands are required. However, the physical resource of usable RF spectrum band is limited. Radio frequency spectrum is a valuable resource. In recent years, the requirement for wireless communication services has increased abruptly. This resulted in severe shortage of radio spectrum. The radio spectrum usage is controlled by government. The conventional fixed radio spectrum allocation resulted in lower utilization of radio spectrum. Actual measurements in [1] reveal that the allocated spectrum is mostly under- utilized. This radio spectrum utilization varied from 15% to 85% in the frequency bands below 3GHz [1]. Studies by the FCC show that, in some locations, the average spectrum occupancy is only 5.2% with a maximum occupancy of 13.1% at any point in time. At frequencies above 3GHz, the actual spectral utilization is significantly less. This inefficient spectrum utilization by the primary users (The users who have legacy rights on the usage of a specific bandwidth of the spectrum), lead the spectrum regulatory policy revised. The FCC (Federal Communications Commission) released a statement in November 2002 that is produced by the Spectrum-Policy Task Force. In this report reveals that, “In many radio frequency bands, physical scarcity of spectrum is a less significant problem than spectrum access”.

The Federal communications commission then gave the permission that these unoccupied bands can be used by the secondary users (i.e. those users with lower priority to utilize the spectrum). This revised policy lead to the concept of Cognitive Radio which can dynamically access the radio frequency spectrum [3]. Therefore, the apparent lack of radio resources can be solved, if the empty frequency bands can be detected and opportunistically used through a suitable mechanism. The comparison of different Spectrum sensing schemes which are used in this system are given below:

Table 1: Comparison of different Spectrum sensing scheme

Sensing Scheme	Advantages	Disadvantages
Matched Filter	(1) It needs less time for detection (2) Easy to implement	(1) It requires prior knowledge of the PU signal. (2) Require a dedicated sensing receiver for all primary user signal types
Energy Detector	(1) No prior knowledge of the PU signal required (2)Easy to design and implement	(1) Very poor performance at low values of SNR (2) It is unable to differentiate the interference from other secondary user sharing
Cyclostationary Detector	(1) More robust way to handle noise uncertainty than energy detection (2) Better performance at low SNR	(1) Detection is very complex to implement than energy detector.

II. RELATED WORK

Cognitive Radio (CR) is an intelligent wireless communication system. It senses the channel availability and uses the ideal channels without any harmful interference to licensed users. It is capable of modifying its operation parameter in accordance with behavior of the network and its users. This will improve the efficiency of radio frequency spectrum utilization. The name "cognitive radio" is coined by Joseph Mitola in the year 1999. He illustrated how the flexibility of personal wireless services could be enhanced through cognitive radio. CR is still at a conceptually developing phase. However, it has a great potential in bringing up an important change to the way in which the radio spectrum can utilized. A trustworthy communication services must be provided by a CR whenever needed.

CR works on the principle, of "learning by understanding". This principle's application on radio spectrum utilization gives the new description of CR. CR is an intelligent wireless system which is aware of its environment. It can study various parameters (like transmitted-power, transmitted frequency, kind of modulation used etc.) of its surrounding wireless network.

Cyclostationary feature detection based spectrum sensing:

A signal is said to be cyclostationary if it obeys the property periodicity. If a signal is periodic in a time interval T, it can be detected in the presence of noise using cyclostationary feature detection technique. This technique is more advantageous because if the signal has lower signal to noise ratio [11]. In this sensing technique, there are two different approaches to detect the signal. The two cyclostationary detection techniques are one-order cyclostationay detection and two-order cyclostationary detection. The two- order cyclostationary detection technique is more robust to noise and is more efficient than the one-order cyclostationay detection. Both these techniques are more efficient than the energy detection technique when detecting the signals with lower signal to noise ratio. The following sections, explains each of these cyclostationary detection techniques in detail.

One-Order Cyclostationay Feature Detector:

In cyclostationary feature detection, the modulated signals are exhibits periodicity since their mean and autocorrelations exhibits cyclostationarity. We deal with the cyclostationary detection technique in time domain. Consider a deterministic sine signal s(t) such that

$$s(t) = A\sin(2) \qquad (1)$$

where A is the envelope, is the periodic frequency and is the phase of signal. In the transmission of s(t) through an AWGN channel, $x(t) = s(t) + n(t)$.

The mean function of x(t) can be written as

$$= E[x(t)] = s(t) \qquad (2)$$

where E denotes the expectation operator.

If the signal is travelled through a AWGN channel then we can observe that the mean of the signal is time varying when it is sampled. Let us denote the periodicity of the signal be.

The mechanism of this sensing technique can be explained through a block diagram as shown in Fig. 1

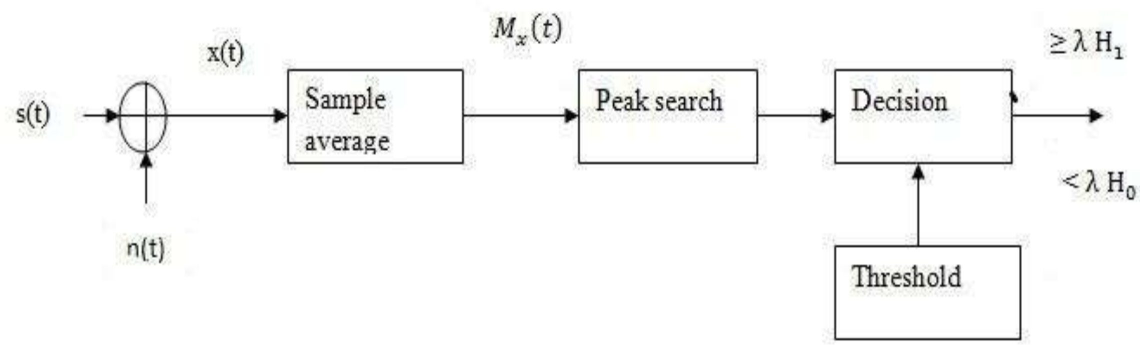

Fig. 1: One-order Cyclostationary feature detection

The mean of the signal is then compared with a predetermined threshold value to obtain the test statistics. The test statistical will have two hypotheses and .Where corresponds to the hypotheses with no signal transmitted and corresponds to the hypotheses with signal transmitted. The probability of detection and probability of false alarm are approximated over Gaussian channel [09]. Theoretically the threshold value can be computed from the equation:

$$\text{OFD} = \exp \qquad (3)$$

Where is the threshold and is the variance with the non-centrality parameter A. If we assume the value for and the variance then we can get the value of the threshold.

CONCLUSIONS AND FUTURE SCOPE

The complementary receiver operating characteristic curve for the spectrum sensing techniques are plotted. It can be observed that as the probability of false alarm is increasing, the probability of miss detection is decreasing exponentially. For high values of probability of false alarm, value of probability of miss detection is low, which implies that the probability of detection is more. We can also see that the probability of miss detection is significantly lower for two-order cyclostationary detection technque than the one-order cyclostationary detection technique. The order of performance of spectrum sensing techniques with respect to increased probability of detection is two-order cyclostationar detection technique, followed by one-order cyclostationary detector and then the energy detection technique. Cyclostationary detector is very complex to build but is very efficient in low SNR regimes.

The receiver operating characteristic curve for cooperative spectrum sensing using energy detector is also plotted. The detection performance is increased for cooperative sensing compared to local non-cooperative sensing. Cooperative spectrum sensing is structurally complex to design. Moreover, there is need of additional bandwidth for control channel is required. The concept of spectrum management and sharing is studied by a software Pthread program. The necessity of spectrum scheduling among secondary users is also studied. Spectrum sharing increases the effective spectrum utilization and hence proves the concept of cognitive radio.

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