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Sensing of Thespectrum Enable the use of Cognitive Radios

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Abstract: *Spectrum scarcity is one of the major problems faced in Wireless communication technology. The growing demand for wireless services has placed enormous burden on valuable resources such as spectrum. It has resulted a major rethinking in resource allocation policies culminating in an explosion of research activity in the field of Cognitive Radio (CR) .Efficient spectrum utilization is of utmost importance to alleviate the problem of interference and reduced data rates. Cognitive Radios adapt themselves according to the available spectrum and thereby enhance transmission and reception of data, without affecting adjacent band users. Spectrum sensing is one of the crucial tasks for enabling the use of the cognitive radios. Many methods have been suggested and revised from time to time. In this paper we will discuss some methods of spectrum sensing.*

Keywords: *Cognitive radio, Spectrum Sensing, Energy Detection, Preamble Detection*

1. INTRODUCTION

Cognitive Radio (CR), which was first coined by Mitola III, is an enabling technology that helps using spectrum efficiently. In Cognitive radio technology, Spectrum sensing is crucial for efficient utilization of the given bandwidth. By precisely locating the spectrum boundaries one can effectively prevent the problem of interference between adjacent bands and increase the data rates in the channel. Of various attempts that have been made to accurately detect the spectral boundaries, Energy detection is a method which is widely utilized. Spectrum sensing is an important task in cognitive radios (CR). In CR, unlicensed users implement spectrum sensing not to interfere with licensed users. Cooperation in spectrum sensing improves the signal detection performance under fading, shadowing or noisy conditions. Spectrum sensing can be defined as examining the radio spectrum to determine the used or unused frequency bands. The three most common spectrum sensing methods are: 1) Energy Detector-based Sensing, 2) Cyclostationary-based Sensing, and 3) Matched Filtering. Energy detector-based sensing uses the energy of the received signal to decide on the presence of the signal. Energy detector-based sensing, also known as radiometry, is the optimal spectrum sensing method, when the information about the signal of interest is not known. It is easy to implement and has low computational complexity. In the cyclostationary-based sensing method, cyclostationary features of the modulated signals are exploited, such as sinusoidal carriers, pulse trains or cyclix prefixes. Due to this built-in periodicity, modulated signals are cyclostationary with spectral correlation. Matched filtering is a spectrum sensing method that uses a priori knowledge of the characteristics of the received signal. This a priori knowledge may include modulation type and order, pulse shaping, packet format, bandwidth format, frequency, etc. Matched filtering is the optimal spectrum sensing method when the information about the signal of interest is known.

2. MULTI-RESOLUTION SPECTRUM SENSING

MRSS is a kind of energy detector. The basis for MRSS is the sensing of a spectrum at two different resolutions: coarse resolution and fine resolution. In MRSS techniques, coarse resolution spectrum sensing is applied to the entire bandwidth of the system. This provides a quick examination of the spectrum of interest. Then, fine resolution sensing is performed on the spectral bands in which further bandwidth of the system is not examined exhaustively therefore, sensing time and power consumption are reduced significantly.

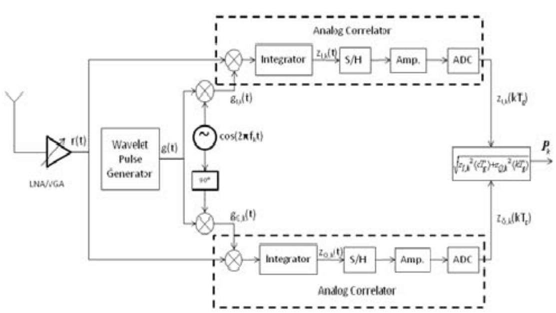

Fig. 1: Functional Block Diagram of Wavelet-based MRSS

In wavelet-based MRSS the pulse duration of the wavelet generator and frequencies of the sinusoidal functions are changed to sense the spectrum with different resolutions. In particular, to obtain different sensing resolutions, wavelet pulse width *Tg* and frequency increment *fsweep* are adjusted, and to scan the frequency band of interest, inspected frequency value *fk* is changed. The use of a large *Tg* or a smaller *fsweep* provides fine resolution sensing, whereas the use of a smaller *Tg* or a large *fsweep* provides coarse resolution sensing. As can be seen in Fig. 1, first, a wavelet pulse with duration *Tg* is multiplied by a cosine and sine functions having the same frequency as the inspected frequency. Then, the results of these multiplications are multiplied by the received RF signal. After that, integration and digitization are applied in the analog correlators. The outputs of the analog correlators are first squared and then summed. The square root of this sum gives the spectral density at *fk* .

3. COOPERATIVE SPECTRUM SENSING

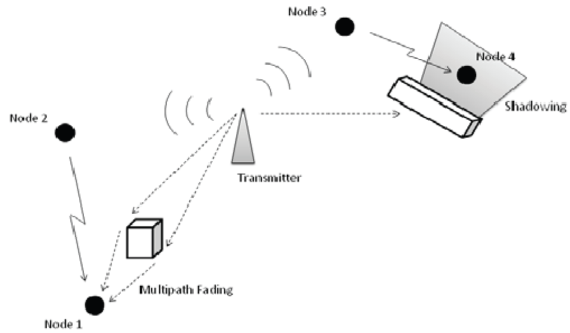

Fig. 2: Cooperation of Nodes to Detect the Signal of Interest under Fading and Shadowing Conditions.

The idea of cooperative spectrum sensing in a RF sensor network is the collaboration of nodes on deciding the spectrum band used by the transmitters emitting the signal of interest. Nodes send either their test statistics or local decisions about the presence of the signal of interest to a decision maker, which can be another node? Through this cooperation, the unwanted effects of fading, shadowing and noise can be minimized. This is because a signal that is not detected by one node may be detected by another. Fig. 2 illustrates the cooperation of nodes in the detection of a signal of interest under shadowing and fading conditions. Cooperation in spectrum sensing also improves the overall detection sensitivity of a RF sensor network without the requirement for individual nodes to have high detection sensitivity. Less sensitive detectors on nodes means reduced hardware and complexity. The trade-off for cooperation, however, is more communication overhead. Since the local sensing results of nodes should be collected at a decision maker, where the decision is made, a control channel is required between the decision maker and the other nodes. There are two forms of cooperation in spectrum sensing: hard combination and soft combination. These two cooperation forms are also known as decision fusion and data fusion, respectively. The difference between these two forms is the type of information sent to the decision maker. In the hard combination scheme, local decisions of the nodes are sent to the decision maker. Every node first performs local spectrum sensing and makes a binary decision on whether a signal of interest is present or not by comparing the sensed energy with a threshold. All nodes send their one bit decision result to the decision maker. Then, a final decision on the presence of the signal of interest is made by the decision maker based on some predefined decision criteria. Two of the decision rules used by traditional hard combination schemes are logical-OR rule and majority rule. The major advantage of the hard combination scheme is that it requires only one bit of overhead. In the soft combination scheme, nodes send their sensing information directly to the decision maker without making any decisions. The decision is made at the decision maker by the use of this information. Soft combination provides better performance than hard combination, but it requires a wider bandwidth for the control channel. It also requires more overhead than the hard combination scheme. Two-bit hard combination was recently proposed and can be thought of as a hybrid combination scheme. The main idea behind the two-bit hard combination scheme is to divide the whole range of observed energy into more than two regions and to assign different weights to these regions. By doing this, nodes that observe higher energies in upper regions have greater weights than nodes that observe lower energies in lower regions. Thus, the two-bit hard combination scheme has the advantage of lower overhead, as demonstrated in hard combination approaches and greater performance gain, as demonstrated in soft combination approaches. Using the main idea of the two-bit hard combination scheme proposed in, a new three-bit hard combination scheme for collaborative spectrum sensing is proposed. In this case the whole range of observed energy is divided into more than four regions. In particular, seven thresholds are used to divide the whole range of observed energy into eight regions. Each node sends to the decision maker a three-bit value that indicates the region in which its observed energy fell. The eight regions and the corresponding three-bit representations can be seen in Fig. For example, if a node observes an energy level falling in Region 7, it sends “111” to the decision maker. But if a node observes an energy level falling in Region 0 it does not send any information to the decision maker.

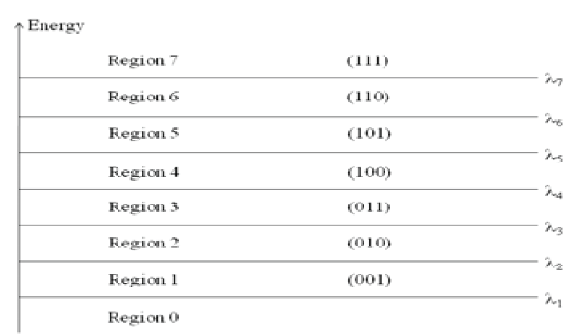

Fig. 3: Energy Regions of the Proposed Three-Bit Hard Combination Scheme.

4. CHANNEL SENSING

There are several core flavors of channel sensing – notably energy and preamble detection - that are collectively known by the general term, CCA. CCA could be implemented in two different ways: the channel is sensed continuously or only when desired. Usually continuous channel sensing is known to be reliable; but it leads to considerable idle energy consumption, an important factor in the shortening of node lifetimes in energy-constrained sensor-net type devices. The purpose of CCA is to detect the presence of ongoing transmissions reliably so as to enable the sensing node to decide whether to proceed with channel access.

4.1 Energy Detection

This has been the traditional approach to *narrowband* CCA - based on estimating the signal energy around the carrier frequency, which is indicative of signal presence. Signal transmission can be detected via a non coherent energy detect (ED) operation (integrating the square of the received signal or extracting signal envelope over a suitable period) with sufficient reliability. ED is a robust, universal mechanism that can be deployed in all systems without requiring any knowledge of the type of underlying modulation scheme employed. However, ED is inherently less reliable at low signal-to-noise ratios.

4.2 Preamble Detection

For coherent detection of wideband signals, the sensing node has to attain time synchronism with the ongoing transmission. In packet based systems, the process of acquiring time synchronism is aided by the transmission of a preamble in front of every packet, typically consisting of repetitions of a sequence of known symbols. The receiver performs a correlation of the known sequence with the received signal with varying time offsets. At the offset corresponding to time synchronism, the correlation is high due to the processing gain resulting from the repetition of the known symbols. This high correlation is both indicative of signal presence and provides an estimate of time offset. This carrier-sense based CCA using correlation of the known preamble with the received signal is called preamble detection (PD).

4.3 ED-PD Comparison

ED is quite unreliable in detecting the presence of wideband signals, whose power levels are not much above the noise floor [8]. However, it requires very little power to keep ED running, one reason for which is its symbol rate sampling, $1/TS$. PD is quite reliable as it takes advantage of the processing gain inherent in the preamble. Its power consumption however may be exorbitant. Note that the PD requires a much higher sampling rate than $1/TS$; it may be the chip rate in spread spectrum systems like 802.11b or the FFT rate in OFDM systems like 802.11a. We denote the sampling rate requirement of PD as $1/Tc$. Although the network examples considered in this paper are of spread-spectrum type, the methods developed are applicable to all wideband networks.

5. CONCLUSIONS

In this paper, we have focused on various spectrums sensing methods and we understand that a energy efficient and reliable clear channel assessment (CCA) method, which combines the energy-efficiency of an energy detector (ED) and the reliability of a preamble detector (PD) is a good approach. And the efficiency of the proposed CCA method can be verified when; cascaded-CCA is applied to IEEE 802.11, as a representative example of networks that require continuous channel sensing and IEEE 802.15.4, of those that do not require continuous sensing. The performances of CCA are compared to the standard ED-only and PD-only CCA methods. For the network with continuous channel sensing such as IEEE 802.11, the proposed CCA reduces idle energy consumption significantly. For networks without continuous channel sensing requirement such as IEEE 802.15.4, provides a means to smoothly trade-off energy consumption for throughput and vice-versa and choose the optimum combination for best performance. In order to reduce the amount of sensing and transmission overhead of cognitive radio (CR) nodes, we can also applied cooperative sensing for spectrum detection in cognitive radio networks.

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