Time Domain Analysis of Spectrum sensing in Cognitive Radio by Energy Detection method

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Abstract— Cognitive Radio is an intelligence wireless technology which automatically detects available channels in wireless spectrum and accordingly changes its transmission or reception parameters so that wireless spectrum is utilized efficiently thereby solving spectrum scarcity problem. In cognitive radio the secondary users need to detect the activity of primary users in a licensed spectrum and occupy the frequency band as quickly as possible in order to utilize the spectrum efficiently. The process of sensing the primary user activity in a particular frequency band is called spectrum sensing. Due to its simplicity and no requirement of prior knowledge of primary user signal, energy detection (ED) method is the most popular technique used in spectrum sensing. In this method the primary signal strength is compared with predefined threshold value and based on this the existence or absence of primary user is decided. In this paper spectrum sensing is done in Very High Frequency (VHF) band which has been declared as operating band for Cognitive users by Federal Communication Commission (FCC).

Keywords— Primary user (PU), Cognitive Radio (CR), Spectrum Sensing, Keep-off time (Tᵣ), Energy Detection (ED).

I. INTRODUCTION

This Use of radio frequency bands of the electromagnetic spectrum is regulated by government in most countries by a Spectrum management process known as frequency allocation or spectrum allocation. Radio propagation does not stop at national boundaries. Giving technical and economic reasons, governments have sought to harmonise the allocation of RF bands and their standardization. A number standards bodies including International Telecommunication Union (ITU), European Conference of Postal and Telecommunications Administrations (CEPT), Inter-American Telecommunication Commission (CITEL) have assigned frequency bands in three types of allocation. In this work spectrum sensing scheme based on energy detection is designed and simulated using MATLAB Simulink. Spectrum sensing is done in Very High Frequency (VHF) TV band which is commonly considered for the operation of cognitive users by Federal Communication Commission (FCC). In this spectrum unused spaces called TV white spaces exists [1] and these white spaces reduce the effective utilization of spectrum. They are identified in each frequency band using this proposed spectrum sensing architecture and utilized by the unlicensed secondary users. The agency grants companies licenses to use the spectrum. In the mobile phone market, the FCC has auctioned off spectrum, generating billions of dollars in revenue for the government.

The FCC also decides which frequencies of spectrum can be used for which purposes. For mobile phones, it has allocated spectrum generally between 700 MHz and 2.6 GHz. Most of the spectrum in this range has already been allocated for use. As mentioned before frequency bands for satellite and military applications is not used by other users [2]. But from the figure we can infer that Television band (TV 2-6) is utilized less than 15% by the users which leads to underutilization of electromagnetic spectrum. Likewise most of the wireless services are not efficiently utilized which leads to spectrum scarcity. From [4] it can be inferred that relatively low utilization of the licensed spectrum which is largely due to inefficient fixed frequency allocations rather than any physical shortage of spectrum.

II. SPECTRUM SENSING

The process of sensing the primary user activity in Cognitive Radio is called spectrum sensing. White spaces in wireless communication can be analysed with respect to time, space and frequency. In this work spectrum sensing in done with respect to time which gives information about primary user activity in a particular channel with respect to time. Due to its simplicity and no requirement on prior knowledge of primary user signal, energy detection (ED) is the most popular sensing technique in cooperative sensing. It is a non-coherent detection method that detects the primary signal based on the sensed signal power.

A. Spectrum sensing methods

Spectrum sensing can be done by energy detection method, matched filter and cyclostationary feature detection method. Matched filter and cyclostationary methods of spectrum sensing have better performance compared to energy detection method but former requires the knowledge of primary user signal [3] and the latter involves high computational complexity for its operation [5]. Knowing the signal characteristics before detecting the signal is not feasible in case of real time signal processing since the real time signal processing involves signals having varying amplitudes. Absence of primary user and silence in the input primary user signal is distinguished by keep-off time.

III. PROPOSED DESIGN

All paragraphs must be indented. All paragraphs must be justified, i.e. both left-justified and right-justified.
The simplified block diagram illustrating the flow of spectrum sensing in Cognitive Radio based on energy detection method is shown in Fig. 1. Primary user is (54-88) MHz TV signal passed through the AWGN channel. Then the signal is segmented into frames using buffer and then power of each frame is calculated and compared with predefined threshold. When the signal travels through the channel the addition of noise is inevitable. Here we assume that the noise added during signal propagation is white noise with Gaussian distribution (i.e.) Additive white Gaussian noise (AWGN).

![Fig. 1 Block diagram of ED based spectrum sensing to detect white spaces in TV band with respect to time](image)

**TABLE 1**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Digital TV</th>
<th>Wireless Microphone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel Detection Time</td>
<td>≤ 2 sec</td>
<td>≤ 2 sec</td>
</tr>
<tr>
<td>Channel Move Time</td>
<td>2 sec</td>
<td>2 sec</td>
</tr>
<tr>
<td>Detection Threshold</td>
<td>-116dBm</td>
<td>-107dBm</td>
</tr>
</tbody>
</table>

The presence of primary user signal is decided using energy threshold which is permissible power level of television signals like other television standards as depicted in Table 1.

**A. Primary user signal**

Television band is considered as operating frequency range for cognitive radio users by Federal Communication Commission (FCC).

Hence primary user signal for spectrum sensing in cognitive radio is TV signal which can be either audio or video signal. In any of the above cases the signal will be varying with respect to time as shown in Fig. 3. This primary user signal can be generated using random integer generator and a waveform generator. But in practical cases addition of noise is
inevitable in wireless communication channel. This signal having varying amplitude with respect to time is passed through AWGN channel in which white noise having zero mean is added with signal in Fig.3 which results in a signal shown in Fig.4 which is given as input to the spectrum sensing block as primary user signal.

B. Power calculation

The primary user signal is passed through a buffer which segments the signal into frames. The number of elements in each frame is controlled by adjusting the buffer size which directly gives the number of amplitude values of the primary user signal in each frame.

![Figure 2: Primary user signal corrupted by noise](image)

From each frame peak finder finds and returns the maximum value and this amplitude is considered for power calculation for that particular frame. Taking absolute value and squaring the magnitude gives the power value corresponding to the maximum value in each frame.

![Figure 4: Primary user activity with respect to time](image)

**Table II**

<table>
<thead>
<tr>
<th>Frames</th>
<th>Power (dBm)</th>
<th>Primary user activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame 1</td>
<td>-88.13</td>
<td>1</td>
</tr>
<tr>
<td>Frame 2</td>
<td>-283.4</td>
<td>0</td>
</tr>
<tr>
<td>Frame 3</td>
<td>-98.48</td>
<td>1</td>
</tr>
<tr>
<td>Frame 4</td>
<td>-133.86</td>
<td>0</td>
</tr>
</tbody>
</table>

For comparison with power values fixed by television standards the value obtained is converted into decibel value for each frame as shown in Table 2. The number of frames depends on sensing time which varies for each wireless services.

C. Threshold comparison

The presence of primary user can be decided by comparing the power value of detected signal with the predefined threshold value as in [7]. Power value is calculated for each frame and decision is made on the following hypothesis [9]

\[ y(t) = n(t) \] (1)

\[ y(t) = x(t) + n(t) \] (2)

Where \( n(t) \) is the power corresponding to the AWGN noise added in the channel and \( x(t) \) is the power of primary user signal. Primary user is absent if (1) is true (i.e.) if only noise is present in the channel which is evident from second and fourth frames in Table.2. When (2) is satisfied for any frame then the output will be high which represents that primary user is present at that instant. This can be observed from the first and third frames in Table.2. The three square waveforms in the Fig.4 describes the primary user activity in the channel with respect to time. If the low level in the signal extends beyond keep-off time then we can conclude that primary user is not using the channel and it can be allocated to any secondary users which is done by frequency allocation process.

D. Keep-off time (\( T_k \))

Fixing power threshold alone may produce false alarm [10] that primary user is absent because the primary user signal itself has zero crossings and low power instantaneously due to fading channels. To fix this problem a time threshold need to be fixed like power threshold. The keep-off time (\( T_k \)) is defined as the minimum time duration over which no primary activity is detected before the secondary users access a channel [11]. Substituting the values corresponding to television band the keep-off time is calculated as three seconds.
IV. CONCLUSIONS

Static frequency allocation leads to underutilization of electromagnetic spectrum. Cognitive Radio has the ability of utilizing the unused Electromagnetic spectrum by allocating it to a secondary user without causing interference to primary users by the process of spectrum sensing, spectrum management and spectrum allocation out of which spectrum sensing is the crucial part which mainly determines the efficiency of Cognitive Radio. In this work spectrum sensing using Energy detection method is done in TV band which has been declared as operating frequency band for Cognitive users by FCC. Spectrum Sensing using Energy detection method is designed and simulated using MATLAB Simulink and the simulation results are discussed. Time based spectrum sensing has advantage that it can continuously sense the channel and detect the presence of primary user with respect to time. The primary user activity of a particular frequency band of wireless spectrum by a primary user with respect to time can be viewed from the Simulink output waveform and the primary user activity is observed and decision is made based on keep-off time. Future work focuses on hardware implementation of this spectrum sensing scheme in FPGA using XILINX system generator thereby estimating the hardware resources utilized.

REFERENCES