MATCHED FILTER BASED SPECTRUM SENSING in COGNITIVE RADIO USING OFDM for WLAN

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Abstract - *When unlicensed users need to use the licensed spectrum, it is necessary to detect the unused frequency bands called white spaces. Cognitive radio can be used to do this particular task by dynamic spectrum sensing. This paper explains about detection of unused spectrum for OFDM WLAN (IEEE802.11a) in minimum time by using matched filter based detection and increasing the accuracy in sensing and interference reduction of secondary network.*

Key Words: Cognitive radio, Matched filter, Spectrum efficiency, Spectrum sensing, OFDM, WLAN.

1. INTRODUCTION

The increasing demand of wireless applications had put a lot of limitations on the use of available radio spectrum is limited. Usually, the spectrum bands have been assigned to license holders for long term and over large geographic areas, which led to spectrum scarcity for potential new spectrum users. Some parts of spectrum are unoccupied, and most of the frequency bands are used less and specific bands are over utilized. Of course, the scheme of spectrum licensing and its usage leads to static and inefficient usage.

The need of different technologies and demand leads to spectrum scarcity and unbalanced usage of frequencies. Cognitive radio system is the best technique to improve the spectrum utilization. Spectrum sensing is one of the most challenging problems in cognitive radio systems. Spectrum Sensing is the main key of cognitive radio which senses the radio environment continuously to explore unused frequency bands which can be exploit by cognitive radio.

Orthogonal Frequency Division Multiplexing (OFDM) is a modulation format that is presently used for many of the latest wireless and telecommunications standards. OFDM has been adopted in the Wi-Fi arena where the standards like 802.11a, 802.11n, 802.11ac and more. It has also been chosen for the cellular telecommunications standard like LTE / LTE-A, and in addition to this it has been adopted by other standards such as WLAN.

Orthogonal frequency division multiplexing (OFDM) has also been adopted for a number of broadcast standards from DAB digital Radio to the Digital Video Broadcast standards, DVB. It has also been adopted by other broadcast systems including Digital Radio used for the long medium and short wave bands. Even though orthogonal frequency division multiplexing (OFDM) is more complicated, it provides some distinct advantages in terms of data transmission, especially where high data rates are needed along with relatively wide bandwidths.

2. SPECTRUM SENSING

Spectrum sensing is defined by "as the task of finding spectrum holes by sensing the radio spectrum in the local neighbourhood of the cognitive radio receiver in an unsupervised manner". A number of schemes have been developed for detecting whether the primary user (PU) is present in a particular frequency band. The various spectrum sensing techniques were proposed to identify the presence of primary user signal and if the primary user is absent then the spectrum will be allocated to the secondary user. The most popular spectrum sensing techniques are classified under three major categories Non-Cooperative detection, Cooperative detection and Interference based detection. Most commonly used spectrum sensing methods are

- Energy Detection
- Cyclo-stationary Feature Detector
- Matched Filter Detection

2.1 ENERGY DETECTION

Energy detector is also known as radiometry and it is most common method of spectrum sensing because of its low computational and implementation complexities. Moreover, the cognitive user's receivers do not need any prior knowledge of the primary user's signal. The signal is detected by comparing the output of energy detector with threshold which depends on noise floor.

The most advantages of using energy detection, low computational cost, easy implementation, less complexity and does not need any prior knowledge of primary user. In contrast, in this technique the signal detection depends on comparing the power of the received signal to the threshold level, whereas threshold level rely on the noise floor which can be estimated but the signal power is difficult to estimate as it changes relying on two factors, distance between primary user and cognitive radio, another factor is ongoing transmission characteristics.

Energy detection is popular till now, but the major drawback with energy detection method is that the poor performance under low SNR conditions and also no proper distinction between primary users and noise. Rather the matched filter detection maximizes the SNR.

2.2 MATCHED FILTER DETECTION

Matched filter is specialized in decision making on whether the signal is present or not can be facilitated if we pass the signal through a filter, which will accentuate the useful signal sig(t) and suppress the noise w(t) at the same time. Such a filter which will peak out the signal component at some instant and suppress the noise amplitude at the same time has to be designed. This will give a sharp contrast between the signal and the noise, and if the signal sig (t) is present, the output will appear to have a large peak at this instant. If the signal is absent at this instant, no such peak will appear.

Power Spectral Density (PSD) of the AWGN signals is given in equation (1).

$$\mathrm{PSD(f)} = \frac{N_0}{2} \qquad (1)$$

Where N_0 is the noise signal and AWGN channel signal to Noise Power measured at the output of the matched filter is given in equation (2).

$$\mathrm{SNR} = \frac{|S(t)|^2}{|N(t)|^2} \qquad (2)$$

The above equations represent the power spectral density and signal to noise ratio of the transmitted signal.

3. OFDM TRANSMITTER

Many of the current and future communication standards, like the Wi-Fi, DVB-T/T2, WiMAX makes use of the principle of multicarrier communications. One of the most widespread representatives of the multi carrier systems is the Orthogonal Frequency Division Multiplexing (OFDM). OFDM is a form of multicarrier modulation. An OFDM signal consists of a number of closely spaced modulated carriers. When modulation has to be in any form - voice, data, etc. is applied to a carrier, then sidebands spread out either side. It is necessary for a receiver to be able to receive the whole signal to be able to demodulate the data. And when signals are transmitted close to one another they must be spaced so that the receiver can separate them using a filter and there must be a guard band between them. This is different in the case of OFDM.

Even though the sidebands from each carrier overlap, they can still be received without the interference because of their property of orthogonality. This is achieved by having the carrier spacing equal to the reciprocal of the symbol period. One requirement of the OFDM transmitting and receiving systems is that they must be linear. Any non-linearity will cause interference between the carriers as a result of inter-modulation distortion. This will introduce unwanted signals that would cause interference and impair the orthogonality of the transmission.

The equipment that are used has the high peak to average ratio of multi-carrier systems such as OFDM requires the RF final amplifier on the output of the transmitter to be able to handle the peaks whilst the average power is much lower and this leads to inefficient performance(fig 1). In some systems the peaks are limited. Even though it introduces distortion results in a higher level of data errors, the system can rely on the error correction to eliminate them.

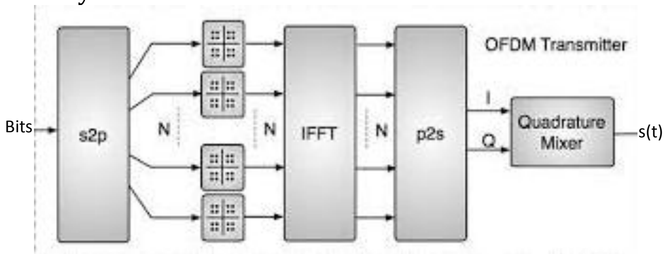

Fig 1.Block diagram of OFDM

The basic structure of OFDM modulator. The input data are divided into parallel streams corresponding to individual subcarriers. The number of data subcarriers usually spans from tens (48 in the case of IEEE 802.11a) to thousands (DVB-T/T2).The data on each subcarrier are mapped according to selected constellation diagram (usually BPSK, QPSK or M-QAM) and the OFDM modulation is implemented using Inverse Fast Fourier Transform operation.

In the proposed work, IEEE 802.11a signal has been generated based on the standard specification parameters. The actual data available for transmission is converted from serial to parallel form. The resulted data is modulated using 64QAM.

The modulated data is subjected to Inverse fast Fourier transform operation and the preambles are added as per IEEE 802.11a standard.

The data is transmitted through AWGN channel. Let sig(t) be the transmitted signal, w(t) is the channel noise, the received signal be sig(t) + w(t), which is given as the input to the matched filter and sig0(t)+w0(t) be the output of the filter.Let the matched filter's impulse response be h(t). It had been proven that, impulse response of the optimum system is the mirror image of the desired message signal sig(t) about the vertical axis and shifted to the right until all of the signal sig(t) has entered the receiver.

It should be realized that the matched filter is optimum of all linear filters. The maximum amplitude is independent of the waveform sig(t) and depends only upon its energy.

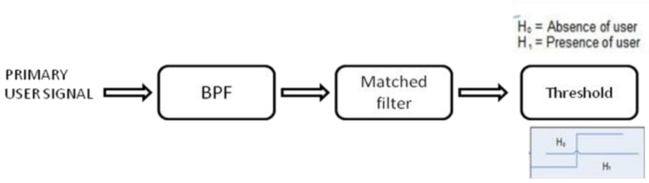

Fig 2. Matched filter detection

Here the transmitted signal is passed through the channel where the additive white Gaussian noise is getting added to the signal and outputted the mixed signal (fig 2). This mixed signal is given as input to the matched filter. The matched filter input is convolved wppith the impulse response of the matched filter and the matched filter output is then compared with the threshold for primary user detection.

The threshold of a signal, determined by two possible ways has been discussed here. One way is to estimate the energy of the signal and reduce it to half, fix it as a threshold. Another way is to compute the standard deviation of the signal by computing the mean and use it as threshold. Of the two methods, the former one is theoretically proved to be optimal.

Once the threshold is chosen, presence of signal is determined based on the following decision rule

Rxd(t) > a : signal present

Rxd(t) < a : signal absent, where Rxd(t) is the matched filter output given by

Rxd(T) = sig0(T)+w0(T)

from eqn.

Rxd(T) = E + w0(T)

If there is no primary user signal, then received signal be Rxd(T) = w0(T) indication of only noise.

4. RESULTS AND DISCUSSION

The simulation commences with generation of IEEE 802.11a signal. The actual data to be transmitted is 64QAM modulated before it is given to OFDM modulator. For generating IEEE 802.11a signal, the following are the parameters to be considered. The IEEE 802.11a frame structure consists of preamble followed by predetermined OFDM symbols. There are 10 short preambles and 2 long preambles. Rest of the symbol consists of user data.

The below simulation output (fig 3) is obtained by plotting the graph between the probability of detection and probability of false alarm of matched filter detection and energy detection method where the topmost curve indicates the graph of matched filter detection.

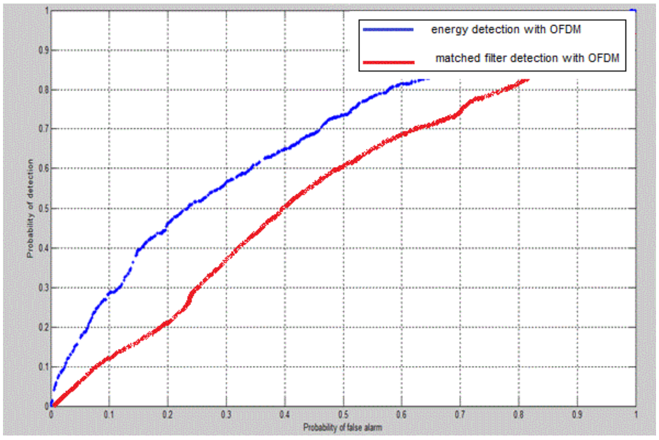

Fig 3. P_d vs P_f

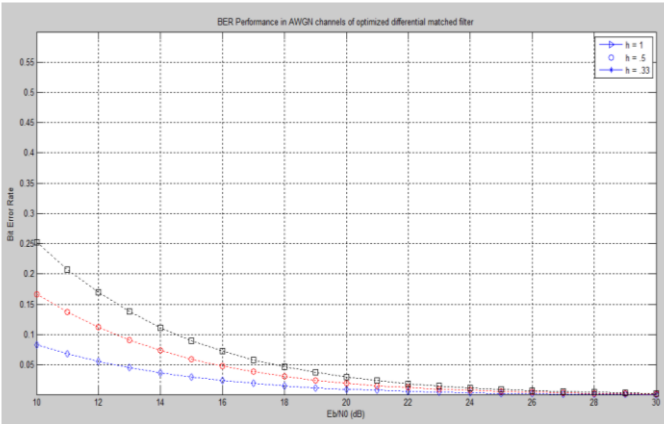

Fig 4.BER vs E_b/N_0

The modulation index of a modulation scheme describes by how much the modulated variable of the carrier signal varies around its unmodulated level. The random values of modulation index (h) are taken to simulate the bit error performance of matched filter detection considering bit error rate and SNR (Eb/N0) (fig 4).

5. CONCLUSION

Nowadays, development of the wireless communication technology leads to increase in the usage of frequency spectrum. So we need to access the frequency spectrum wisely. The concept of using cognitive radio for wireless communication will be more beneficial to address the current spectrum scarcity problem. In the cognitive radio cycle, Spectrum sensing plays the most crucial role. Matched filtering performs well when SNR is high. The software simulation on improving the sensing accuracy for OFDM WLAN's by optimal prediction of primary users presence in minimal time with the help of optimal threshold fixing in matched filter has been done in MATLAB. Though this sensing technique is implemented to detect IEEE802.11a waveform, it can be modified to detect signal of any standard.

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