DYNAMIC SPECTRUM SENSING USING MATCHED FILTER METHOD AND MATLAB SIMULATION

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Abstract:- *The growing demand for wireless radio, spectrum utilization challenges to cognitive radio network (CR). Spectrum sensing is the main objective for CR network to detect spectrum white space in unused frequency band and opportunistically access the underutilized frequency band without any harmful interference to primary user. In this paper primary and secondary signals are detected and give access to the secondary user in vacant space of primary user based on the matched filter based spectrum sensing technique.*

Keywords—Matched filter; primary user; spectrum sensing; cognitive radio.

INTRODUCTION

THE utilization of radio spectrum resources and the detected policies of radio emissions are synchronize by national regulatory bodies like the Federal Communications Commission (FCC). The FCC assigns spectrum to licensed holders, also known as *primary users*, on a long-term basis for large geographical regions. After the appearance of wireless personal communications technologies it became unreasonable to use these regulations and depends on static spectrum allocation due to economical and technical considerations. In order to solve this, Industrial, Scientific and Medical (ISM) bands have been provided as an efficient solution to handle these types of networks. After a while ISM bands get overcrowd and over-utilized which affects the quality of communication on those bands and to overcome this, The Software Defined Radio (SDR) was introduced for handling multiple communication technology followed by cognitive radio (CR) networks based on dynamic spectrum access have been proposed as a promising solution[1,3].

The Cognitive radio is a radio that modify to the conditions of the environment by analyzing, observing and learning. The cognitive network makes use of this modification for future decisions. CR network is basically used for maximum utilization of the radio bandwidth. The core of the performance optimization is the cognitive process which is shared by the cognitive radio and the cognitive networks. The main part of this process is to learn from the previous decisions and make use of it for future decisions [4].

One of the most important components of the cognitive radio concept is the capability to measure, sense, learn, and be vigilant of the distinguishing feature related to the radio channel attribute, availability of spectrum and power, radio's operating environment, user requirements and applications, available infrastructures and nodes, local policies and other operating limitation. In cognitive radio nomenclature, *primary users* can be defined as the users who have greater priority on the utilization of a specific part of the spectrum. On the other hand, *secondary users*, which have lower priority, use this spectrum in such a way that they do not cause interference to primary users. Therefore, secondary users need to have cognitive radio capabilities, such as sensing the spectrum reliably to check whether it is being used by a primary user and to change the radio parameters to use the unused part of the spectrum [5].

In CR, three leading cognitive tasks are critical: sensing analysis, spectrum analysis, and transmission power control, spectrum management. With the three tasks, the unlicensed users can obtain knowledge of the ecosystem and accordingly fit their spectrum access strategy so as to achieve desired performance and protect the licensed users as much as possible [6].

Being the focus of this paper, spectrum sensing by far is the most weighted component for the settlement of cognitive radio. Spectrum sensing is the task of acquiring awareness about the spectrum utilization and existence of licensed users in a geographical area. An important issue in CRNs is the licensed user detection, in which the unlicensed users monitor for the presence of licensed user signal on the target channels. If licensed user a signal is detected, the unlicensed users should not use those channels to avoid interfering with the transmission of the primary user. In this the performance of matched filter based spectrum sensing technique is investigated. Matched filter detection is better than energy detection as it starts working at lower SNR. Additionally, a complete system is described to determine the threshold of the matched filter to obtain stricter requirements of the probability of false alarm and the probability of miss detection.

RELATED WORK

Spectrum sensing is fundamental for the successful deployment of CRs. The main focus of current spectrum sensing schemes for CRs is divided into two main streams: the first is to improve local sensing performance, and the second is to improve performance by having cooperation between SUs. In local sensing, each SU performs spectrum sensing on the received signal and makes a decision about the presence or absence of a PU. In cooperative spectrum sensing, SUs perform local sensing and send their sensed information to the fusion center, and a final cooperative decision is taken at the fusion center. Therefore, in order to improve cooperative performance, it is necessary to improve local sensing. Many two- stage spectrum sensing schemes are proposed in literature to improve local spectrum sensing. A number of different methods have been proposed for identifying the presence of signal transmissions. The mostly used spectrum sensing techniques are given as:

- Matched Filtering
- Waveform-Based Sensing
- Cyclostationary Based Sensing
- Energy Detector Based Sensing
- Radio Identification
- Other Sensing Method

Energy detection: Energy detection indicates as non coherent detection. Energy detection is most popular sensing technique in cooperative sensing [7]. Energy detection is always attended by a number of disadvantages:

1. Sensing time taken to achieve a given probability of detection may be high.
2. ED cannot be used to detect spread spectrum signal.
3. Detection performance is subject to the uncertainty of noise power.

Cyclostationary feature detection: It is a spectrum sensing technique which can differentiate the modulated signal from the additive noise. A signal is said to be Cyclostationary if its mean and autocorrelation are periodic function. Disadvantage of this method is its high computational complexity and long sensing time [10].

Matched filter detection: The matched filter detector is known as the optimum method for detection of primary users when the transmitted signal is known [2]. It overcomes the drawbacks of above sensing technique as follows:

1. It is very accurate since it maximizes the received signal to noise ratio (SNR).
2. Correlates the signal with time shifted version
3. Predetermined threshold to decide the PUs presence or absence

Wavelet Detection: The wavelet approach offers advantages in terms of both implementation cost and flexibility for signal detection over wideband channels, in adapting to the dynamic spectrum in contrast to the conventional implementation of multiple narrowband bands pass filters. By employing a wavelet transform of the PSD of the observed signal $x(t)$, the singularities of the PSD $S(f)$ can be sighted and thus the vacant frequency bands can be found. One major issue in the implementation of this approach is the high sampling rates characterizing larger bandwidths [8].

Radio Identification Based Sensing: In radio identification based sensing, many features which are sunder out from the received signal are used for the selection of the most probable Primary user technology by employing a range of classification methods. Features based on energy detector methods are used for organization. Total energy detected and its circulation across the spectrum is included in this classification. Channel bandwidth is set up to be the most selective parameter among others. By using energy detector based methods, centre frequency of a received signal and operational bandwidth are extracted. In order to find spectrum opportunities and for determining the active PU, the above two characteristics are fed to a Bayesian classifier.

SYSTEM MODEL

The 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. This arrangement will make it possible to decide whether the signal is present or absent with minimum probability of error. The filter which accomplishes this is known as matched filter as shown in fig.1. Main purpose of the filter is, to decrease the noise component and to increase the signal component at the same instant. This is obviously equivalent to maximizing the signal amplitude to the noise amplitude ratio at some instant at the output. It proves more convenient if we go for square of amplitudes. Hence the matched filter is designed in such a way that it will maximize the ratio of the square of signal amplitude to the square of the noise amplitude [11].

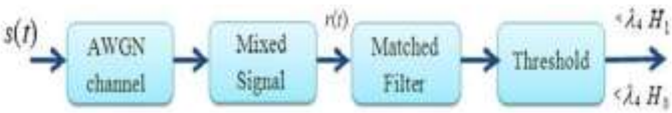


Fig.1 Block diagram of matched filter

The matched filter also referred to as coherent detector, is known as the optimum method for detection of PUs when the transmitted signal is known. It is very accurate since it maximizes the received signal-to-noise ratio (SNR) [12]. Matched filter correlates the signal with time shifted version and compares between the final output of matched filter and predetermined threshold to decide the PU presence or absence. However, matched-filtering requires CR to demodulate received signals. Hence, it requires perfect knowledge of the PUs‟ signaling features such as bandwidth, operating frequency, modulation type and order, pulse shaping, and frame format. The operation of matched filter detection is expressed as:

$$Y[n] = \Sigma\, h\,[n-k]\, x[k]$$

Where, 'x' is the unknown signal (vector) and is convolved

With the 'h', the impulse response of matched filter that is matched to the reference signal for maximizing the SNR. Detection by using matched filter is useful only in cases where the information from the primary users is known to the cognitive users [16].

Let us consider a digital communication system that transmits digital information. Thus, the input sequence to the modulator is subdivided into k-bit blocks or symbols and each of the $M=2^k$ symbols is associated with a corresponding baseband signal waveform from the set $\{S_m(t), m= 1, 2…M\}$. Each signal waveform is transmitted within the symbol interval or time slot of duration T. we can consider the transmission of information over the interval $0\le t \le T$. The channel is assumed to corrupt the signal by the addition of white Gaussian noise (AWGN). Thus the received signal in the interval $0\le t \le T$ may be expressed as [7]:

$$r(t)= S_m(t)+n(t), \quad 0\le t \le T$$

Where n (t) denotes the sample function of additive white Gaussian noise (AWGN) with the power spectral density Sn (f) = N0/2 W/Hz. Instead of using a bank of N correlates to generate the variables {rk}, we may use a bank of N linear filters. Impulse responses of the N filters are

$$h_k(t)= \psi_k(T-t), \quad 0\le t \le T$$

Where $\{\psi k\ (t)\}$ are the N basis functions and $h_k(t) = 0$ outside of the interval $0\le t \le T$. The outputs of these filters are:

$$y_k(t)= \int_0^t r(\tau)h_k(t-\tau)d\tau$$

A filter whose impulse response h (t) = s (T - t), where s (t) is assumed to be confined to the time interval $0\le t \le T$, is called the matched filter to the signal s (t). Matched filter is a coherent detection technique that employs a correlator matched to the signal of interest or certain parts of it, such as pilots, preambles, spreading codes and training sequences. It shows optimal performance results making it a good choice for applications where the transmitted signal is known a priori like radar signal processing. The correlation can be viewed in term of a filtering process of the data. Since we have a summation of a finite number of samples, we take a FIR filter into considerations. If we now let *x*[*n*] be the input to such a filter, then the output *y*[*n*] at time *n* is given by the convolution operation as

$$y[n] = \sum_{k=0}^{n} h[n-k]x[k]$$

Where *h*[*n*] is the impulse response the FIR filter. The proper choice of the impulse response is the 'flipped around' version of the signal, and it is denoted as:

$$h[n] = s_p[N-1-n] \qquad n = 0,1,\dots, N-1$$

The probability of detection can be defined as:

$$\begin{aligned} P_D &= P(T > \gamma \mid H_P) \\ &= P\left(T' > \frac{\gamma}{\sqrt{\sigma^2 \varepsilon_P}} \mid H_P\right) \\ &= Q\left(\frac{\gamma - \varepsilon_P}{\sqrt{\sigma^2 \varepsilon_P}}\right) \\ &= Q\left(\frac{\gamma}{\sqrt{\sigma^2 \varepsilon_P}} - \frac{\varepsilon_P}{\sqrt{\sigma^2 \varepsilon_P}}\right) \\ &= Q\left(\gamma' - \sqrt{\frac{\varepsilon_P}{\sigma^2}}\right) \end{aligned}$$

To reduce interfering between wireless technologies which are sharing the 2.4GHz unlicensed radio spectrum, a new feature named as adaptive frequency hopping (AFH) is integrated to the Bluetooth standard. Bluetooth transmission with and without adaptive AFH is used for identification for transmissions in the industrial, scientific and medical (ISM) band but remains away from their frequencies. Therefore transmit power is reduced, better bit error rate (BER) performance is achieved and narrow band interference can be avoided. In this paper the Bluetooth device is used as primary and secondary user for communication. When primary Bluetooth user is transferring data at that time secondary user is in idle state and when white space is detected by secondary Bluetooth then it uses that primary user spectrum for accessing data.

Steps of Practical Implementation

Steps of practical implementation of opportunistic spectrum usage can be summarized as follows:

1. Down-converting the signal to an IF frequency.
2. Sampling the signal at a rate above the Nyquist rate digitizing it.
3. Computing the power spectral density either by taking Fast Fourier Transform (FFT) and squaring, or by applying more advanced power estimation methods such as Welch's method or Thomson's multiplier method.
4. Comparing the obtained power spectral density with Pre- determined power threshold. This way, determining the occupied spectra and the white spaces.
5. Comparing the bandwidths of the white spaces with a pre- determined minimum bandwidth in order to find out if they are wide enough to be utilized, Transmitting the information regarding the usable white spaces to the other party via UWB signaling,
6. Receiving the white space data from the other party.
7. Finding the common white spaces
8. Initiating the cognitive communication and repeating the entire sensing process at a regular period.

Process flow diagram of matched filter detection

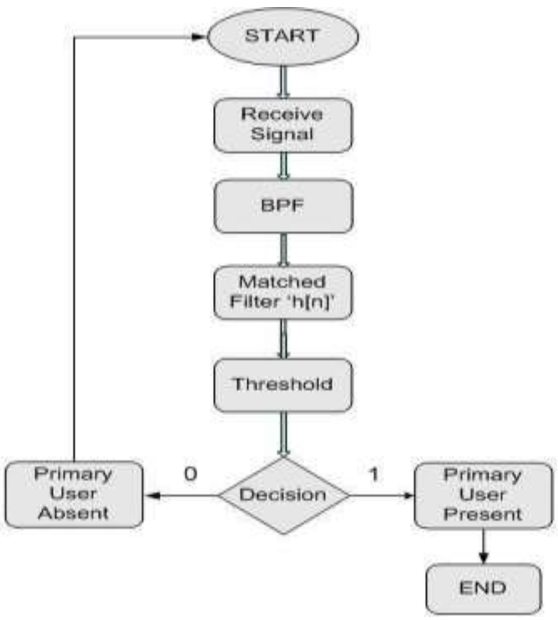
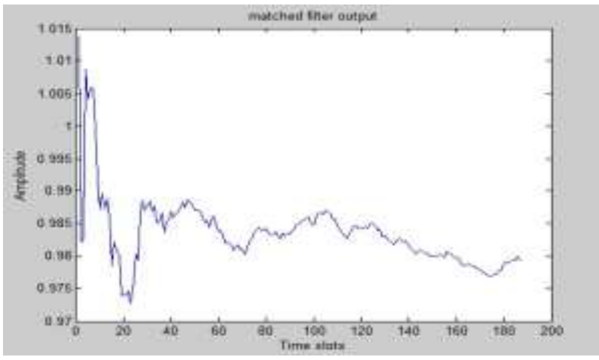


Fig. 6: Process flow diagram of Matched filter Detection

When $0 \leq Pr < 0.5$ for the majority of the channels, the PU waveform is known. Therefore, the SU will perform matched filter detection for sensing most of the channels because the performance of the matched filter is optimal when the PU waveform is known. The mean detection time of the matched filter detection is the least, and therefore the best case for the detection time is when the majority of channels are sensed by the matched filter. The best scenario is when $Pr \approx 0$, and the probability of detection, the probability of false alarm, and the mean detection time can be found by putting $Pr \approx 0$ and $P \approx 0$. From the matched filter output the threshold has been determined as per the discussion above and the signal energy which crosses the threshold is considered to be the primary user's presence. The absence of primary user corresponds to spectrum holes.



CONCLUSION

As the usage of frequency spectrum is increasing, it is becoming more valuable. So we need to access the frequency spectrum wisely. For this purpose we are using Cognitive Radio. In our paper we discussed about the most important technique that is Spectrum sensing and the issues involved in it to establish the communication using Cognitive radio. Matched filter based spectrum sensing technique is the secure spectrum sensing technique.

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