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PERFORMANCE EVALUATION OF SPECTRAL COVARIANCE BASED SPECTRUM SENSING TECHNIQUE IN COGNITIVE RADIO

Maya Singh, Gauri Singh

ABSTRACT

Abstract— In past few years wireless communication has attracted numerous researchers to make this field more advance day by day. For that the proper utilization of available frequency band is the prime and challenging task. The identification of vacant frequency band i.e. spectrum sensing problem gives the new aspects through cognitive radio with opportunistic spectrum access concepts. In this paper, an algorithm is proposed for spectrum sensing methodologies in cognitive radio network. Through this paper, we focus on the maximization the decision accuracy under different noisy condition of spectrum sharing cognitive radio networks and implementation though software define radio system that tremendously enhance the desirable throughput. Cognitive radio, an smart intelligent phenomena with the capabilities to understand the surrounded environment by the mean of sense, learn and adjust in real time operating parameter according to specific need of unlicensed user. The allotment of detected opportunistic spectrum band can be simulated by using priority mechanism so that the demand of higher data rates for the transmission in wireless communication can be made possible. Finally, we come to conclusion through simulation results after successive approximation, in order to demonstrate the improved performance with more accurate decision accuracy. The achieved throughput by the proposed algorithm is giving better performance as compared to conventional spectrum sensing method.

Index Terms: *Cognitive radio, Software Define Radio, spectrum sensing, spectrum sharing (SS), throughput maximization.*

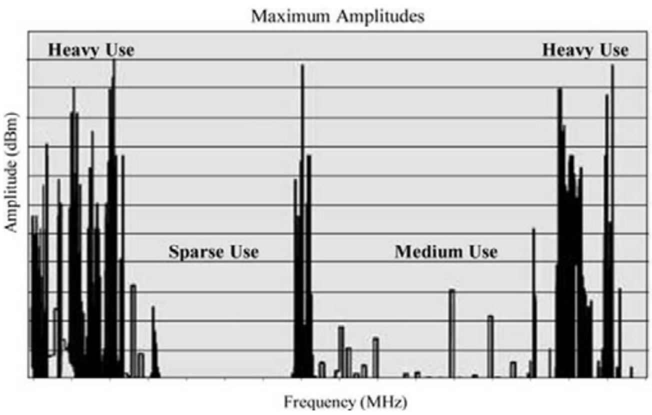
1. INTRODUCTION

Cognitive radio (CR) gives promising technique for upcoming wireless communication systems. In this technology, dynamic spectrum access technique with spectral covariance method is implemented to avoid the major issue of spectrum scarcity. As an advantage the secondary (unlicensed) user can access the service by utilize the spectrum resources when it is sure that it will not create any kind of interference to the licensed users. An important key aspect is related with the ability of secondary user's to smartly detect the presence of the primary user in radio environment. So by the mean of that the spectrum sensing technique is counted as a crucial part the implementation of the idea behind this methodology. [1] From the various studies and the fact provided by, the Federal Communications Commission (FCC) is encouraging the occupancy for the tremendous possibility of underutilized spectrum by secondary users [2] to enhance the model by overall spectrum utilization. The transmitter end of TV broadcasting stations and receivers at the other end will execute and enhance the primary network with an assurance of, whenever unlicensed users wish to access their own spaces opportunistically then no interference will occurs. The users comes under unlicensed must be recognized as cognitive.

The proper and efficient spectrum sensing algorithm might have critical to implement which is very sensitive with operating parameter of primary as well as secondary users in specific licensed bands [4].

As we are approaching for the detection of possible vacant frequency band the actual mechanism of frequency utilization band can be understood with the help of figure shown below:

Figure 1: Signal strength distribution over the wireless spectrum [10].



Here the wrong decisions or false alarm at a level of sensing may cause to two different issues like; i) miss-detection of active licensed users may give the results of harsh interference of primary and secondary signal cause the losses of valuable information, and the next one is ii) missed transmission opportunistic when a primary channel is relatively free but the secondary users has fails to optimize this vacant band. so, the performance parameter can be calculated in two aspects:

a) probability of false alarms (primary users is available and active but it may detected as idle by secondary users) and another one is probability of miss-detection (vacant bands may also be detected as active by secondary users) are two operating parameters as: i) the sensing threshold & ii) the sensing duration.[3]

Moreover the underutilization of the electromagnetic spectrum leads us to think in terms of spectrum holes, for which we offer the following definition [4]:

A spectrum hole is a band of frequencies assigned to a primary user, but, at a particular time and specific geographic location, the band is not being utilized by that user.

2. A REVIEW OF SPECTRUM SENSING

The overall implementation part of this spectrum sensing technique has gone though software defined radio (SDR). Which is a widely popular for smart and intelligent device and that have the ability to sense smartly about its surrounded environment and then after rearrange its operating parameter in accordance with any specific demand, then the spectrum management can apply to decide and finalize by priority algorithm so that whom we can allot these available band of spectrum for variety of application.

2.1 Cognitive Radio

Now talk about the intelligence system behind this technique. This is directed to cognitive radio. The term cognitive radio was initially introduced by young a researcher Joseph Mitola [2]. The Cognitive radio is a smart and self adjustable radio that adapts from conditions of its environment by deeply analyzing, observing & then learning. The cognitive network gives us an use of these adaptations having requisite in future decisions [4]. Cognitive radio is commonly utilized for maximum utilization of allotted the radio bandwidth to ant licensed users. The core part of the performance evaluation is the cognitive process which is shared by various cognitive radio and the available cognitive networks [5].

2.2 Previous work by researchers

As it is introduced in 1992, numerous spectrums sensing algorithm has been proposed which can be well summarized in [3], [6] and [7]. The whole Studies on spectrum sensing can also be divided in to two different classifications: a) blind detection and b) feature detection. Blind detection is universal and most popular technique because it does not required any kind of prior information like signal characteristics, channel used and available noise power, but the performance of such algorithm is relatively not up to the mark. Although Feature detection sense particular characteristics of a known signal only, and it gives relatively better performance than blind detection at a cost of not require in all form of possible primary signals. The hardware complexity is quite tough in feature detection mechanism. One of the simplest (blind) sensing algorithm is nothing rather than energy detector but it may suffer from different degradation in presence of uncertain noise power. A novel and robust blind detection method called covariance absolute value (CAV) detection [8] enhance the uncorrelated phenomena of the environment noise, whereas the primary signal is correlated.

2.3 Software defined Radio

As far as the wireless communication mode is basically depends on the signals, physical hardware and their various attributes. In the recent years, communication technology reached straightforward signaling, analog hardware and very limited functionality. So to perform the variety of operations for cognitive radio, the software define radio was came into picture. The Software Defined Radio (SDR) was specially used for the operating of more than one communication technology (e.g. GSM and CDMA) [5].

2.4 Contribution and Organization

Through this paper, we introduced an updated spectral covariance sensing (SCS) algorithm that give more advance outcome by using different statistical correlations within the signal & available noise in the mode of frequency domain. The SCS methods detect the available spectral features to get maximum sensitivity for detection. First of all we analyze this method theoretically and after that we simulate in Matlab for verification of result with different signal to noise ratio. Various comparisons among different methods like, FFT based pilot energy detector [3] & the CAV detector [7] clearly specify that SCS has achieves better sensitivity than any other method like energy detection (and an even larger gain vs. CAV) with the same sensing time or comparatively equal, obtained the same sensitivity in almost 20% of the sensing time. In the extreme condition of low SNR, the improved gain is an important improvement in performance of spectral covariance method.

The SCS method gives best result by achieving the best sensitivity for spectrum sensing approach as proposed in the literature earlier, to based on our knowledge. The rest of this paper is organized as follows. The SCS algorithm is presented in Section III. Section IV analyzes detection performance of the SCS, especially in the low SNR segment. The theoretical results are verified by using Matlab simulator with assuming twenty active users in radio environment using assumption of specific data. Detection performance with various parameter selections is explored and comparisons with the successive approximation are also presented. Section V has a conclusion note in this paper.

3. SPECTRAL COVARIANCE ALGORITHM

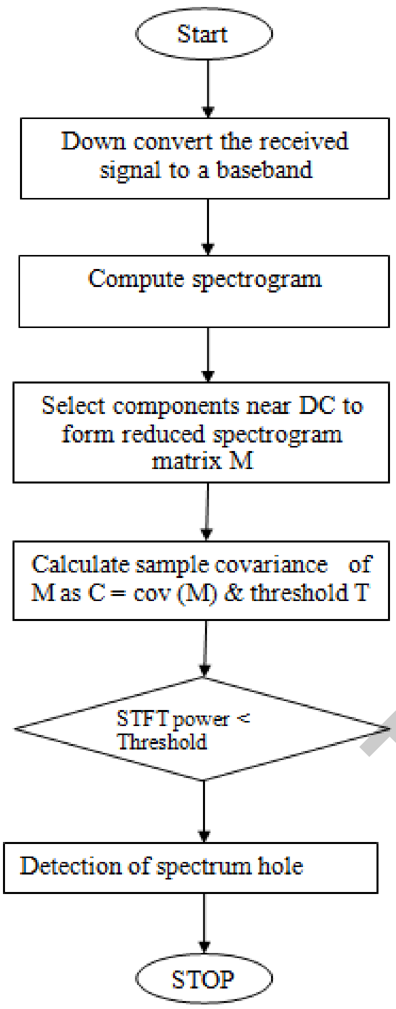
The implementation part of this algorithm can be easily understood by the flow chart as shown in figure 2. So check its flow of mechanism properly for better understanding of entire logic.

By assume that there is either one or zero primary transmitter to detect, so the secondary node which can be located anywhere like inside or outside to the primary cell boundary. The detection problem can then be evaluated on the basis of binary decision (i.e. on, off) under two hypotheses as in:

H0: z(n) = w(n), (1)

H1: z(n) = s(n) + w(n) (2)

Figure 2: Flow mechanism of spectral covariance method [8].



In which z(n) belongs to baseband signal, s(n) is the signal component at the received samples and w(n) denotes the noise component. The signal part i.e. s(n) can have a DC component (sd(n) = sd) & an AC Component (sa(n)). Its estimation cab be taking out by considering the mean E[s(n)] = sd and the variance σ2 s =E[sa(n)2]. The noise samples w(n) is showing with zero-mean value similarly white Gaussian noise is considered with variance σ2w [8].

For simplicity the description of each stage is mentioning here with its mathematical notation:

1) In stage one we need to down convert the received radio signal $s(t)$ to a baseband complex signal $y(t) = x(t)e^{-j2\pi fct}$.

2) Then after Low pass filter (LPF) and down sample $y(t)$ by appropriate sampling rate *Fs or (1/Ts)* to create an sample function $z(n)$.

3) Now we can compute $z(n)$'s spectrogram by considering the squared magnitude of its short-time Fourier transform (STFT) as

(3)

where N is the number of FFT points, and τ ∈ {0, 1, ... ,Nd − 1} shows the index of the sensing window as we have taken rectangular window, Nd specifies the total number of sensing windows and k ∈{−N/2, ... , 0, ... ,N/2 − 1} is the frequency index. Hence, the FFT is calculated at every dwell time (ts) for Nd times.

4) Select components near DC according to

$$M = \begin{bmatrix} Z_0(-K) & \cdots & Z_{Nd-1}(-K) \\ \vdots & \ddots & \vdots \\ Z_0(K) & \cdots & Z_{Nd-1}(K) \end{bmatrix}$$

In this matrix K represents the index value of low pass filter cut off frequency (Bf) in FFT, i.e. K = [N · Bf/F]. Now the matrix reduction requires a low pass filter, which can select the parameter of primary signal and reduces noise power.

5) After that we has to find the sample covariance of M as

C = cov(M)

= Ek[(M−1NdM)T(M−1NdM)] (4)

By taking M = μM = [μ0, μ1… μNd−1].

Here it can be noted that the covariance matrix C is symmetric in nature.

6) Compute the test statistic T = T1/T2, where the value of T1 and T2 are respectively [8]:

$$T_1 = \frac{1}{N_d}\sum_{\tau=0}^{N_d-1}\sum_{u=0}^{N_d-1} c_{\tau u}$$

$$T_1 = T_2 + \frac{2}{N_d}\sum_{\tau=0}^{N_d-1}\sum_{u=\tau+1}^{N_d-1} c_{\tau u} \quad (5)$$

$$T_2 = \frac{1}{N_d}\sum_{\tau=0}^{N_d-1} c_{\tau\tau} \quad (6)$$

In which cτu denotes the element of C at the τ-th row and u-th column, which is the covariance of mτ and mu. Means it is giving the covariance with its near place value. In other words, T2 = sample mean of the matrix C, which are the auto covariances of the spectrograms, and T1 sum of all the elements of the covariance matrix.

7) In this stage compare T with decision threshold to obtain the different hypothesis results.

8) Measure the output for every individual SNR versus the decision accuracy, after multiple time executions we achieve the desired output.

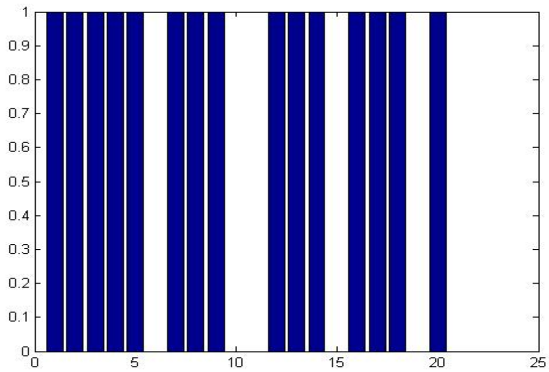
4. PERFORMANCE ANALYSIS

Although the theoretical simulation part helpful for determining the performance of the Primary User spectrum availability prediction model, But detailed and more accurate analysis can be carried out through actual spectrum measurement. May be in actual environment the simulation result will have small tolerance in result. Here for algorithm execution we have taken some initial parameter as total no of users are 20, total no of frames is 10, nfft is considered 256, and the range for signal to noise ratio of -20:4:20, The range of SNR is selected based on certain execution and it comes to end that for the range of above specified the simulation part will giving more accurate results Bit duration Tb = 0.4e-3, Sampling time is taking Ts = 1e-6/128; Number of bit is taken one n_bits =1.

The below mentioned graph representing the availability of active users out of total number of users in figure, in which few of the users are not utilizing the allotted the band of frequency.

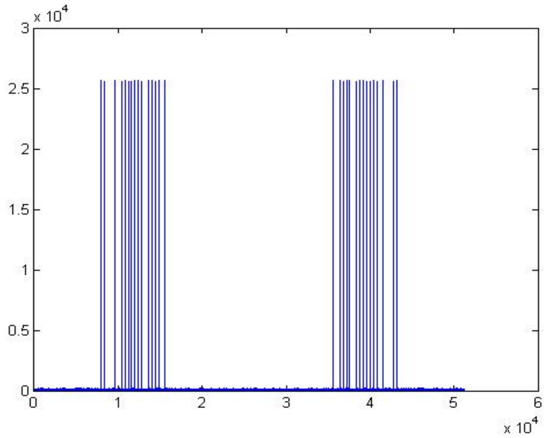
If we execute the same algorithm, n number of time then every time random signal characteristics will occur in which we cannot initially predict that which of the primary customer if not utilizing the band of the frequency.

Figure 3: Status of number of active users at a time of simulation



Subsequent the another figure shown below has illustrating the frequency spectrum utilization graph with different active user in the frequency range of Mega Hertz. As we assigned the different frequency to all twenty users starting with 20 Mhz to 39 Mhz respectively to make differenced with all user and the possible interference can be avoided .

Figure 4: utilization of available frequency band by primary users.



After that now we finally calculate the performance of spectral covariance method by considering the percentage of occupancy of 0.7 and the probability of false alarm id 0.001 taking in to accounts. In the output graph the three different line of graph is mentioning here included blue, green, and red. These color difference is specifying the accuracy level in successive approximation under different noise environment. In each of successive iteration the random signal availability has generated. This is clearly specifying in range of -20:4:20 for signal to noise ratio level. Here observe the graph carefully to determine the performance of spectral covariance method.

Figure 5: SNR and Decision Accuracy

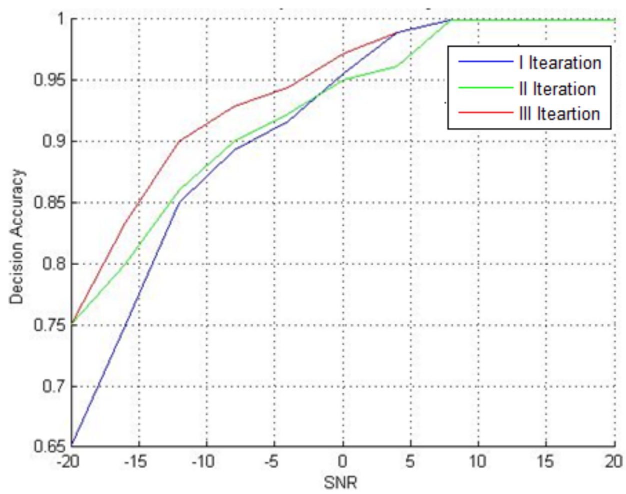


Figure 5: SNR and Decision Accuracy

In our simulation model, after successive approximation we achieved very proper and significant outcome as shown in figure 5. The different color waveform shows different outcome for same experiments.

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Table 1: SNR verse Decision Accuracy

S.NO	SNR	Decision Accuracy		
		I Iteration	II Iteration	III Iteration
1	*-20*	*0.666*	*0.751*	*0.752*
2	*-15*	*0.781*	*0.820*	*0.850*
3	*-10*	*0.824*	*0.834*	*0.924*
4	*-5*	*0.917*	*0.921*	*0.943*
5	*0*	*0.959*	*0.950*	*0.972*
6	*5*	*0.989*	*0.926*	*0.989*
7	*10*	*0.998*	*0.998*	*0.998*
8	*15*	*1.00*	*1.00*	*1.00*
9	*20*	*1.00*	*1.00*	*1.00*

5. CONCLUSION

As wireless communication is giving more and more advantage for wide variety of data communication today, the proposed method will surely work for the advancement in spectrum sensing technique so that optimum utilization of available frequency band can be made possible.

In our simulation we successfully analyzed the performance of spectral covariance based spectrum sensing algorithm in cognitive radio with an improved performance. From the various observations as mentioned in table above it can be concluded that the decision accuracy is improved through different noise level present in environment as well as we can achieve high efficiency.

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