UNDER-UTILIZED SPECTRUM DETECTION TECHNIQUES IN WIRELESS COGNITIVE RADIO: A SURVEY

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Abstract: In recent days, most of the users relay on wireless applications to do their works. Most of the wireless works carried out through mobile applications. Huge spectrum is necessary for all wireless applications. Since spectrum is precious and less availability, there is a necessity to detect under-utilized spectrum. Cognitive radio take the responsibility to identify the unused spectrum and allot it on opportunistic manner. In this paper, various spectrum detection techniques are discussed. In this paper, discussed merits and demerits of techniques. Challenges in spectrum management is also discussed.

***IndexTerms* - Cognitive Radio, Spectrum, wireless, Mobile Applications**

I. INTRODUCTION

Present day all wireless mobile applications require spectrum. It puts immense pressure on spectrum. Allocation of spectrum is challenging task. Spectrum utilization is shown in the Figure 1. It shows that, cellular applications are fully utilizes spectrum while TV bands are under-utilized.

Fig. 1: Spectrum Usage of users

Spectrum utilization is not uniform in all applications. This is happened due to fixed allocation policy[3] of spectrum management. Because of spectrum scarcity, these policies facing problems to allocate the spectrum for all users at all time. Cognitive radio is an intelligent radio, which allots the spectrum in dynamic access basis. Cognitive radio shares the spectrum of licensed user to the unlicensed user in dynamically without causing interference. Cognitive radio identifies the spectrum holes (white spaces) i.e. unused spectrum.

After identifying the white spaces [2] cognitive radio sends request to the primary base station for utilizing the idle spectrum as depicted in the Figure 2 (a), then CR allots the spectrum to secondary user(unlicensed) in opportunistic manner as shown in the figure 2(b).

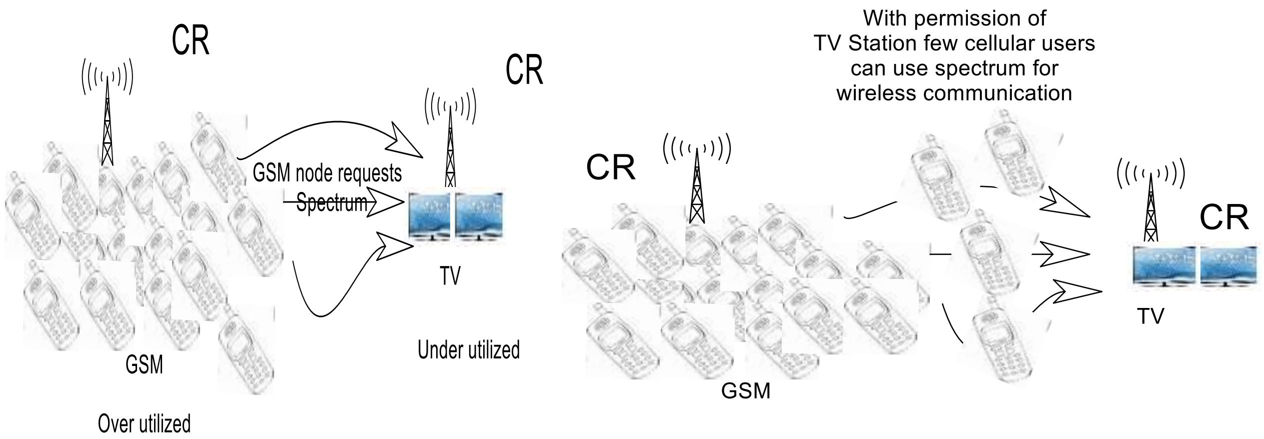

Fig. 2: (a) Spectrum negotiation (b) Usage of underutilized spectrum

However, CR technology facing challenges due to large fluctuation in available spectrum and poor quality of service in some applications. To address these challenges [4][5], CR must

- Find the vacant spectrum
- Choosing of wireless channel
- Coordinating with the other users
- Vacate the spectrum when Primary User detected.

To face these challenges spectrum sensing is used. Various spectrum sensing techniques discussed in this paper. Spectrum sensing techniques [7] broadly categorized into two types. One is non-cooperative and another one is co-operative technique. This paper mainly focused on non-cooperative methods. Energy based detection and matched filer based detection is comes under non-cooperative technique. Matched filter technique requires both primary user signal information and noise power information. Whereas energy based detection requires only noise power information.

II. SYSTEM MODEL

. Consider a system model,

$$H_0 : y[n] = w[n] \qquad n = 1,2, \dots . \dots \dots , N \qquad (1)$$

$$H_1 : y[n] = x[n] + w[n] n = 1,2, \dots \dots . . , N \qquad (2)$$

Here H_0 is a binary null hypothesis, which says that primary user is not utilizing the spectrum.
H_1 is alternative hypothesis, which says primary user utilizing the spectrum.
Following are performance measures in binary hypothesis testing.

Detection Probability

Probability that detecting primary user, when primary user actually occupies the spectrum.

False Alarm Probability

Probability that detect the primary user, when primary user actually not utilizing the spectrum

Misdetection Probability

Probability that primary user is utilizing the spectrum, which is not detected by the algorithm

Rejection Probability

Probability that primary user not utilizing the spectrum, which is not detected by the algorithm

III. SPECTRUM SENSING TECHNIQUES

Energy Based Detection

Based on receiving signal energy, it detects the primary user. Because of simplicity in structure and low cost, it is so popular. At Low SNR, it does not give better results.

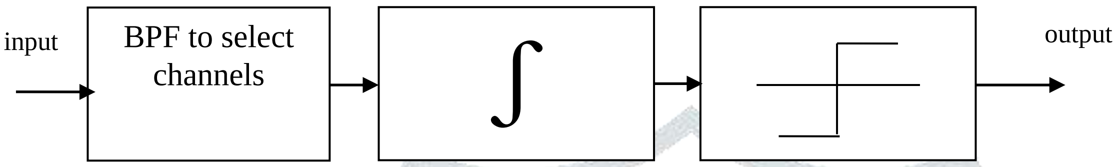

Fig. 3 Block diagram of Energy Based Detection

Block diagram of energy based detector [8] is shown in Figure 3. Received signal energy is compared with threshold values. If signal energy is more than threshold, it conclude that primary user is present.

Matched filter detection:

When secondary user have primary user information this method is better. It gives better performance at Low SNR's compared to Energy based detection.

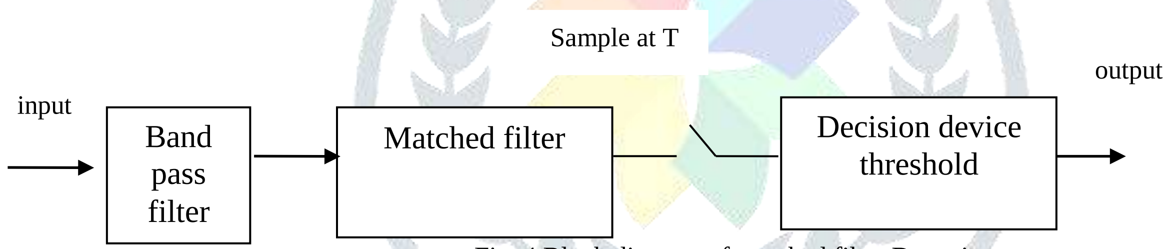

Fig. 4 Block diagram of matched filter Detection

For the given false alarm probability and missed detection probability, this method requires less sensing time.

Matched filter detection [9][10] requires perfect knowledge of primary user signal. Figure 4 show the block diagram in which input signal passes through BPF and then to matched filter then to threshold block.

Feature Detection sensing method:

Based on feature detections [1] it detects the Primary user. Practically in communication, some of the features such as preamble, synchronizing bits, and cyclic prefix bits are included in primary user signal. These features are used to signaling and synchronize purpose. This sensing technique shares the features of primary user to the detectors. At receiver, test statistics are formed and those are compared (correlated) with the known parameters. If the result is above threshold, it declares that user is present. Otherwise it takes decision as user is not present.

IV. TEST STATISTICS AND THRESHOLD CALCULATION

Test statistic in energy based detector is

$$T_j(y_j) = \sum_{n=1}^{N} \left|y_j(n)\right|^2 \underset{<H_0}{\overset{>H_1}{}} \quad (3)$$

Detection Probability is

$$PD = Q_{\aleph^2_{2r}}\left(\frac{k}{0.5(\|\bar{x}\|^2+\sigma^2{}_n)}\right) \qquad (4)$$

False Alarm Probability is

$$PFA = Q_{\aleph^2_{2r}}\left(\frac{k}{0.5(\sigma^2{}_n)}\right) \qquad (5)$$

where $Q_{\aleph^2_{2r}}(x)$ denotes the chi-square distribution function random variable with 2r degree of freedom.

Test statistic for matched filter is

$$T = x^{T}\bar{y} \geq \gamma'$$

If $x^{T}\bar{y} \geq \gamma'$ $\quad$ *choose* H_1

Otherwise $\quad$ *choose* H_0

Detection probability $P_{D=}$ [Q $\left(\frac{\gamma^{|}-\|\bar{x}\|^2}{\sigma\|x\|}\right)$] (6)

All these test statistics are derived from log likelihood ratio test. Figure 5 shows comparison of Receiver Operating Characteristics of energy based detection and matched filter detection.

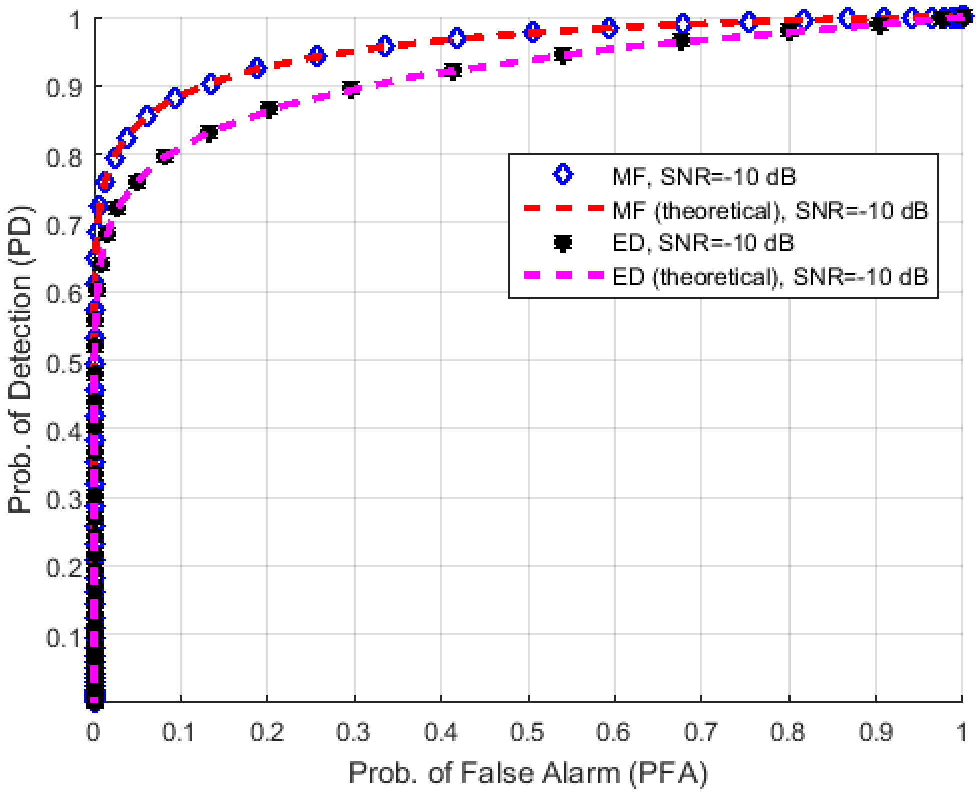

Fig. 5: Receiver Operating Characteristics for SNR=-10 dB

ROC is a graph, which shows how detection probability is varied with respect to False alarm probability and detection probability. Matched filter based detection gives better performance over Energy based detection.

Here SNR is -10 dB considered. Here simulation results compared with theoretical results. For lower values of PFA matched filter based detection gives better performance.

V. CONCLUSION

In this paper, various underutilized spectrum detection schemes reviewed. Energy based detection is simple and less cost sensing technique. This technique gives poor performance at lower SNR values. It does not require primary user information. Matched filter detection is better at higher SNR values. This technique requires primary user information in prior. Feature detection use correlation technique to find primary user. In this paper, ROC of both energy based detection and matched filter based detection is compared at -10dB SNR value.

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