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Analyzing the role of spectrum sensing for security enhancement in beyond 5G waveforms using energy detection

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Abstract

Spectrum sensing (SS) plays a pivotal role in bolstering the security of 5G waveforms. In this abstract, we explore how it contributes to safeguarding 5G networks. By continuously monitoring the radio environment, spectrum sensing allows for the early detection of unauthorized or malicious signals. Cognitive radio (CR) technology is a cutting-edge innovation that can alleviate the need for additional spectrum. It has the potential to influence the course of technology if applied effectively. A CR network allows secondary, unlicensed users to make opportunistic use of primary, licensed spectrum without negatively impacting primary, licensed transmission or customers. Spectrum sensing is the most crucial step in implementing opportunistic spectrum access. In the recent decade, many different spectrum sensing strategies have been proposed in the scientific literature. In this paper, the performance of energy detection-based cooperative spectrum sensing has been measured and visualized using MATLAB simulations.

Subject Classification: *94A05.*

Keywords: *Spectrum sensing, 5G security, Energy detection, Cognitive radio.*

1. Introduction

Spectrum sensing in 5G helps enhance security by enabling the detection of unauthorized or malicious signals sharing the same spectrum. By continuously monitoring and identifying potential interference or threats, 5G networks can adapt, mitigate vulnerabilities, and maintain the integrity and reliability of their waveforms, ensuring secure and uninterrupted communication. Cognitive radio systems must be able to quickly and precisely detect the presence of a primary user [1]. The paper proposes a spectrum sensing scheme that takes reliability into account and employs one-order feature detection for users with no reliable data. The performance of the one-order feature detector surpasses that of the energy detector due to its noise tolerance. The detection of time-domain features permits real-time operation and low power consumption. Also analyzed is the efficacy of the proposed spectrum sensing scheme, which demonstrates significant improvements over the energy detector.

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Individual cognitive radios may not be able to identify the presence of a principal user with enough accuracy due to channel fading or shadowing. To overcome this problem, cooperative sensing among secondary users is investigated using the methods outlined in this study [2]. Compared to traditional cooperative approaches, the sensing performance is significantly better, regardless of the decision-fusion rule applied. In a cognitive radio network (CRN), each radio is controlled by a cognitive control system that lets it adapt to changes in the network's topology, operational conditions, or user needs [3]. Joseph Mitola III originally created cognitive radio (CR), which Gerald Q. Maguire, Jr. helped to improve [4]. Radio spectrum resources are crucial for wireless communications, but predetermined allocation criteria determine existing access. The majority of the available spectrum has been wisely distributed as wireless applications and services increase, yet spectrum scarcity is a problem in many nations. Measurement tests reveal low spectrum utilization efficiency. As a result, dynamic spectrum access was created, enabling secondary users to share or reuse radio spectrum that was once assigned to prime users. Dynamic spectrum access requires the use of cognitive radio systems, which include spectrum sensing, cognitive medium access, control, and cognitive networking. In wireless communications, spectrum sensing is the process of examining a range of frequencies to determine whether a signal is present or absent [5]. Due to the system's prior knowledge of the signal's structure or precise waveform, matched detection (or matched filter detection) is a deterministic method. To locate a known signal in additive white Gaussian noise (AWGN), the optimum linear filter is a matched filter [6], which maximizes the SNR. When the matched filter's input is perfectly in phase with the reference signal, the filter's response is maximized. One can determine whether or not the signal is present by comparing the matching filter's output to a predetermined threshold.

2. System Model

The process of designing the matching filter involves the creation of a filter that is the time-reversed conjugate of the known primary user signal. The signal received is a result of the convolution between expected primary user signals and noise, followed by the application of a matching filter. This phenomenon can be interpreted as a convolution process. The resultant signal derived from the matching filter is subsequently compared to a predefined threshold value. If the obtained value exceeds the pre-established threshold, it signifies that the primary user's signal has been detected. The process of decision-making involves an examination of the primary user signal's presence or absence through a comparison with a pre-established threshold. Metrics such as the probability of detection and the probability of a false alert are frequently utilized in order to quantitatively assess the efficacy of detection. The model is depicted in Figure 1. In energy detection spectrum sensing, you compare the energy of the received signal over a certain bandwidth with a predefined threshold to decide whether a primary signal (signal of interest) is present or not. Here's the mathematical equation for energy detection spectrum sensing: Let y(t) be the received signal over a certain bandwidth (for continuous-time signals), and y[n] for discrete-time signals. The Energy for the signal is given by [7]:

$$E = \int_0^T |y(t)|^2 \tag{1}$$

The equation (1) can also be written as for discrete time signal given by [8]:

$$E = \sum_{n=0}^{N-1} |y[n]|^2 \tag{2}$$

After calculating the energy (E), compare it with a predefined threshold (T) to make a decision. The decision can be represented as follows [9]:

$$\text{If } E > T : \text{Signal is detected} \tag{3}$$

$$\text{If} E < T : \text{Signal is not detected} \tag{4}$$

The choice of the threshold depends on factors such as the desired probability of false alarm and the SNR in your system. Adjusting the threshold allows you to control the trade-off between detection probability and the probability of false alarm.

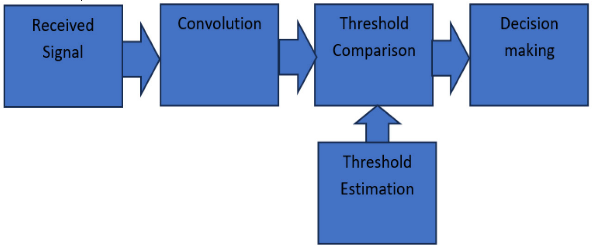

Figure 1

System model

3. Simulation Results

Figure 2 illustrates the relationship between the bit error rate (BER) and the signal-to-noise ratio (SNR) across various signal processing approaches, including cyclostationary (CS), matching filter (MF), and energy detector (ED). Upon analyzing the graph, several potential comparisons can be derived. All four lines exhibit a consistent negative trend, suggesting that an increase in signal-to-noise ratio (SNR) corresponds to a decrease in bit error rate (BER). This observation aligns with the theoretical proposition that an increased (SNR) corresponds to diminished noise levels and enhanced signal fidelity. The ED line exhibits the lowest BER values, while the MF line, CS line, and original signal line follow in ascending order of BER. This implies that the employment of the ED technique is the most effective approach to identifying signals in situations characterized by high levels of noise. Additionally, both the MF and CS techniques exhibit superior performance compared to utilizing the original signal without any form of processing. The line representing the ED variable exhibits a nearly horizontal trajectory, in contrast to the other lines, which display a more pronounced incline. This shows that, in contrast to other techniques, which require a higher SNR in order to achieve a reduced bit error rate (BER), the ED methodology is less sensitive to variations in signal-to-noise ratio (SNR). Compared to the original signal line, the CS line shows a closer proximity to the MF line. This implies that the field of CS can benefit from the cyclostationary properties of the original signal, including modulation or periodic patterns, in order to improve the quality of the signal. The P) for many signal processing methods, such as cyclostationary (CS), matching filter (MF), and energy detector (ED), are compared as a function of the signal-to-noise ratio (SNR) in Figure 3. Starting from the graph's lower left corner, each of the three lines shows a positive slope as it moves toward the right side. This suggests that for all three techniques, the Pd increases in proportion to the SNR. The theoretical presumption that a higher SNR equates to a better signal quality and improved detectability is supported by this finding. High levels of resemblance can be seen between the ED and CS lines; in contrast, the MF line shows a little lower level of similarity than the other two lines. This observation suggests that whereas MF performs slightly worse in this aspect, both ED and CS are equally effective at recognizing signals in high-noise environments. This discrepancy could be explained by the fact that ED and CS use cyclostationary properties, such as periodicity or modulation, but MF only considers the structure of the

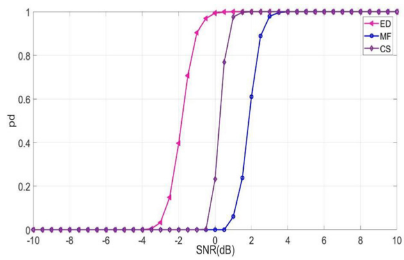

Figure 2

Pd vs SNR

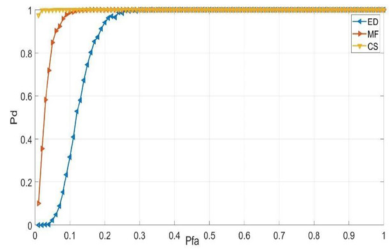

Figure 3

Pfa vs Pd

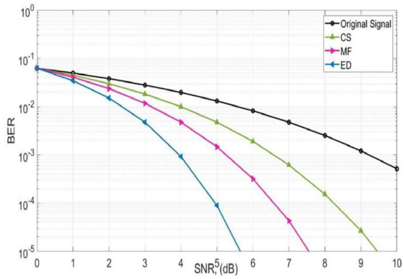

Figure 4

BER analysis

signal. The ED and CS lines have steeper slopes than the MF line. This shows that whilst MF algorithms' performance is less influenced by changes in SNR, ED and CS algorithms' performance is more affected. The fact that CS and ED have higher detection thresholds than MF could be one reason for this phenomenon. Consequently, increasing the SNR for ED and CS is necessary to achieve a high Pd. For a variety of signal processing methods, including CS, MF, and ED, the Pd is shown in Figure 4 as a function of the probability of false alarm (Pfa). Examining the characteristics of the false alert is essential. The attributes will affect how reliable the spectrum sensing techniques are in a noisy environment. One major issue in sensing algorithms that could affect the framework's performance is identifying noise as the genuine signal. The SS techniques' PFA versus PD performance is estimated. Therefore, it is expected that the accuracy of detection normally declines as the false alarm rate increases. This is due to the fact that a higher false alarm rate suggests that there are more false alarms, where non-target events are mistakenly classified as targets. The system is seen to become increasingly prone to missing real targets, which lowers the likelihood of detection. It represents a compromise between the volume of false alarms and the accuracy of real signal detection. We have calculated the false alarm probability performance for a scenario in which noise is identified as a necessary signal. When compared to the MF and CS approaches now in use, it is evident that the ED requires more time to detect the erroneous signal. Therefore, it can be said that even in fading conditions, the ED achieved optimal performance.

4. Conclusion

The performance of cooperative spectrum sensing based on energy detection has been measured as the primary goal of the proposed work. Improve the spectral performance and quality of service to make efficient use of the spectrum. It is noted that the suggested method lowers the Pfa and improves Pd and BER performance. According to the simulation results, the suggested technique has a shorter sensing time and achieves detection at the lowest SNR possible for a static threshold setting. We found that spectrum sensing with matching filter detection is the best spectrum sensing method currently used in cognitive radio because it works better, needs less SNR for signal identification, and needs fewer iterations to reach a high processing gain.

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