International Journal of Emerging Technology in Computer Science & Electronics (IJETCSE)
ISSN: 0976-1353 Volume 25 Issue 9 – AUGUST 2018.

Performance of Spectrum Sensing in Cognitive Radio

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***Abstract*— In recent technologies the effect of communication has increased widely. The recent advancement in the communication system has improved the communication parameters. The recent use of cognitive radio for spectrum analysis gives hands on for prosperous communication. Radio spectrum sensing (SS) has been an active topic of research over the past years due to its importance to cognitive radio (CR) systems. However, in CR networks (CRNs) with multiple primary users (PUs), the secondary users (SUs) can often detect PUs that are located outside the sensing range, due to the level of the aggregated interference caused by the PUs. This effect known as spatial false alarm (SFA), degrades the performance of CRNs because it decreases the SUs' medium access probability. This paper characterizes the SFA effect in a CRN, identifying possible actions to attenuate it. Adopting energy-based sensing(EBS) in each SU, this paper starts to characterize the interference caused by multiple PUs located outside a desired sensing region. The interference formulation is then used to write the probabilities of detection and false alarm, and closed-form expressions are presented and validated through simulation.. However, it is shown that by increasing the number of samples needed to increase the sensing accuracy, the SUs may degrade their throughput, namely if SUs are equipped with a single radio that is sequentially used for sensing and transmission (split-phase operation). Assuming this scenario, this paper ends by providing a bound for the maximum throughput achieved in a CRN with multiple active PUs and for a given level of PUs' detection inside the SUs' sensing region. The results presented in this paper show the impact of path loss and EBS parameterization on SUs' throughput and are particularly useful to guide the design and parameterization of multihop CRNs.**

***Index Terms*— Spectrum sensing (SS), Cognitive radio (CR), Primary users (PUs), Secondary users (SUs)**

I. INTRODUCTION

Digital communications and signal processing refers to the field of study concerned with the transmission and processing of digital data. This is in contrast with analog communications. While analog communications use a continuously varying signal, a digital transmission can be broken down into discrete messages. Transmitting data in discrete messages allows for greater signal processing capability. The ability to process a communications signal means that errors caused by random processes can be detected and corrected.

Digital signals can also be sampled instead of continuously monitored and multiple signals can be multiplexed together to form one signal. Because of all these advantages, and because recent advances in wideband communication channels and solid-state electronics have allowed scientists to fully realize these advantages, digital communications has grown quickly. Digital communications is quickly edging out analog communication because of the vast demand to transmit computer data and the ability of digital.

II. PREVIOUS WORK

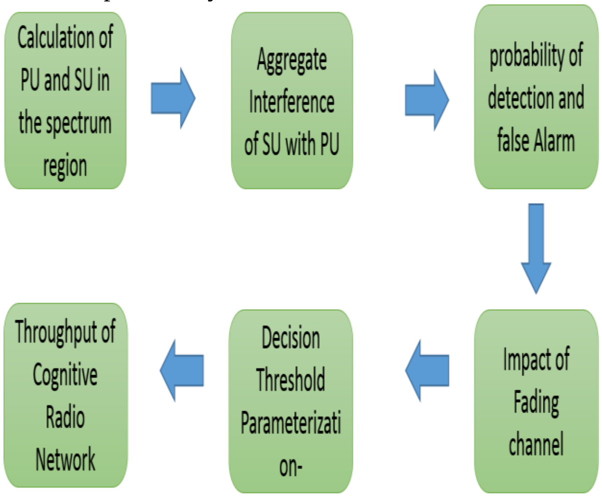
Research has been performed on efficient spectrum usage since it was reported that considerable licensed spectra exclusively allocated to conventional wireless communication systems have been under-utilized. For efficient spectrum utilization, the cognitive radio will mostly likely be the most promising technology due to its inherent spectrum sensing capability and frequency-agile radio functions. Spectrum sensing has the especially important missions of finding the white space of licensed spectra and protecting the primary licensed users from interference caused by cognitive radio communications. Accordingly, spectrum sensing has been widely researched as a key technology for allowing cognitive radio communication within the real world. Spectrum sensing can be performed by various detection techniques using a matched-filter, a statistical feature of the primary signal called feature detection, and a simple energy measurement. Although the first two detection techniques outperform the energy detection technique, they require prior information about the primary signals, and have a primary system-dependent performance. Heterogeneous wireless communication systems licensed to different primary spectra may overlap within a geographical region. In such circumstances, matched-filter detection or feature detection are too costly for sensing multiple primary spectra, while energy detection can operate with no prior information about primary signals. Accordingly, only the energy detection technique corresponds to the general purpose of spectrum sensing for heterogeneous wireless communication systems. That is why energy detection is the most intensively investigated sensing technique and is also the focus of this paper. In general, for the purpose of protecting primary users from the interference caused by secondary communication, cognitive radios are operated in a geographical far distant from the primary system. Hence, the primary signal is received by the secondary sensing node in a low signal-to-noise-ratio(SNR) region below zero decibel where energy detection is very poor. A failure in spectrum sensing means a missed opportunity for secondary users to utilize the white space of the spectrum or harmful interference to the primary users. Therefore, sensing performance enhancement should be required for both increasing the throughput of the secondary users and also for protecting the primary users from unintended interference. The sensing performance enhancement of energy detection can be achieved by using multi-antennas at the sensing node or by cooperation between sensing nodes .Advances in multi-antenna and cooperative sensing are reviewed and in this paper. The aim of this study was to provide a macroscopic view of spectrum sensing, especially with energy detection, in the cognitive radio. In order to do so, a generalized sensing performance evaluation is given first, which allows for greater understanding of the multi-antenna and the cooperative sensing performances. For multi-antenna sensing techniques, the performances were analyzed and compared in consideration to practical problems. For cooperative sensing, complicated scenarios and practical considerations were arranged into a technical tree in order to describe the technique in general. The relationship between branches is also discussed in detail. Finally, a summary describes the overall structure of the research performed on the performance enhancement of energy detection. Also, technical challenges for spectrum sensing are discussed for future consideration.

In underlay spectrum sharing, if the interference caused by the secondary communication is received by the primary receiver under a predetermined threshold, the interference is treated as harmless. Therefore, while the harmless interference condition is maintained, a secondary transmitter is permitted to transmit its signal even if the primary link is communicating. This category is interestingly termed 'spectrum sharing. In order to satisfy the interference constraint condition, the secondary transmitter must possess information about the interference channel gain between the secondary transmitter and the primary receiver. Hence, channel estimation using a known signal and a feedback process between a primary receiver and a secondary transmitter should be required with an extremely high accuracy for the interference channel measurement1. In order to realize this, the secondary user should equip a dual-mode system as follows: one is for the secondary communication and the other for the interference measurement and feedback between the secondary transmitter and the primary receiver. Although indirect interference channel measurement schemes are presented, they cannot provide an accurate interference channel measurement for fading environments. Therefore, developing effective schemes for interference channel measurement and feedback may be a bottle neck for the practical implementation of the underlay spectrum sharing scenario.

While the matched filter and feature detection capabilities require prior information about primary signals, no primary signal information is required for the energy detection technique. The only process required for the energy detector is that the primary signal energy isable to be measured within a specified duration. Next, the detector simply determines whether or not the measured signal energy is over the predetermined threshold level.

III. PROPOSED METHODOLOGY

The performance of the cognitive network in terms of the conditional throughput achieved by the SUs. In this way, the impact of the number of samples needed to reach the required PU's level of protection is taken into account. This is an important point because the number of samples needed to impose the required level of detection may be too high under certain circumstances. Moreover, and even more important, the throughput also accounts with the case when a node accesses the medium without success due to a false alarm, being less optimistic than the probability of medium access characterized in . Since the path-loss coefficient deeply impacts on the SFA effect, we present several results showing the impact of the path loss on the probabilities of detection and false alarm and on the conditional throughput achieved by the SUs. As shown in the last figure in this paper, as the path loss coefficient increases, the throughput achieved by the SUs decrease. Moreover, important is the fact that the path-loss coefficient may restrict the level of interference protection to PUs to values where it is forbidden to operate due to the non tolerable probability of miss detection.



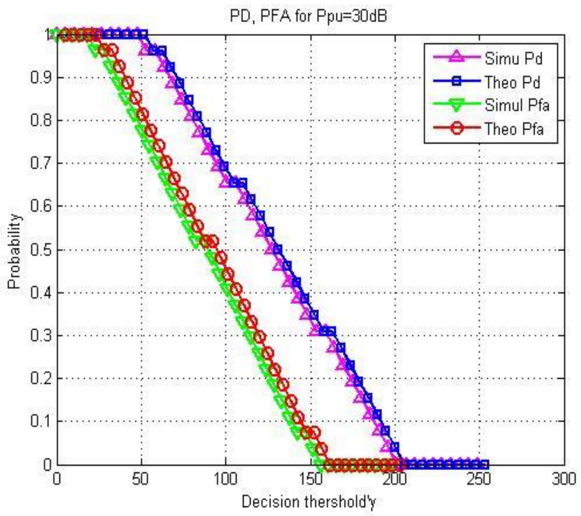
Departing from the observation that the number of samples required by the energy detector to reach the sensingrequirements is usually high, we have observed that fading channels improve the detection probability. In line with this observation, we simplify the methodology of energy-detector decision threshold parameterization bynot considering the fading effects in the amplitude of the received signals. In this way, only path loss is considered, which frequently represents the worst-case scenario in terms of the probability of detection. Apart from the given contributions, our approach introduces several contributions related with the methodology proposed to characterize the probabilities of detection and false alarm, as well as the throughput achieved by the SUs.

A Gaussian approximation is first derived for the distribution of the aggregate interference caused by the Pus located in a circular ring, and its accuracy is assessed through simulation. Considering that the PUs are spatially distributed according to a 2-D Poisson point process and are active with probability ρON, We derive the SU's probability of detecting and erroneously detecting (false alarm) PU's activity in the sensing region. These probabilities are then used to formulate a solution to parameterize the energy detector decision threshold.

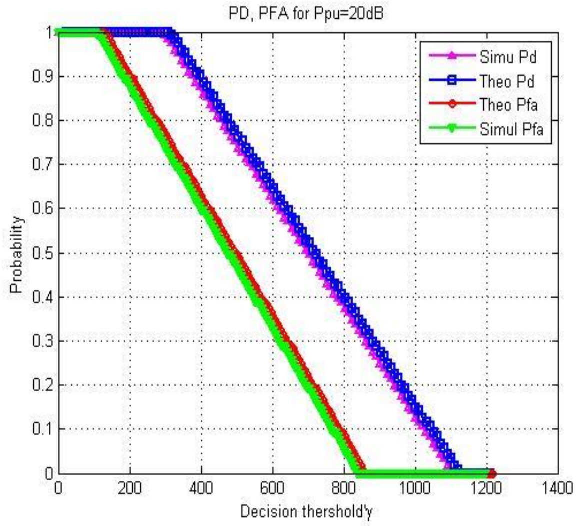
Using the distribution of the aggregate interference generated within and outside the sensing region to parameterize the decision threshold, we propose an optimization problem to find the minimum number of samples required to meet the PUs' protection level, which simultaneously maximize the throughput achieved by the SUs. While similar optimization problems aiming to maximize the SUs'throughput subject to detection constraints have been proposed, our contribution is essentially related with the statement of such an optimization for the SFA scenario.

Different results are presented for the probabilities of PUs' detection and false alarm in different propagation scenarios and considering different numbers of channel samples. The results presented in this paper show that depending on the path-loss coefficient and on the number of samples to support the channel's occupancy decision, the SFA effect may be attenuated and/or almost neglected. Finally, the upper bound for the throughput achieved by a CRN where each SU is equipped with a single radio is provided and characterized for several propagation conditions and EBS parameterizations. The bound captures the impact of the SFA for different CRN conditions.

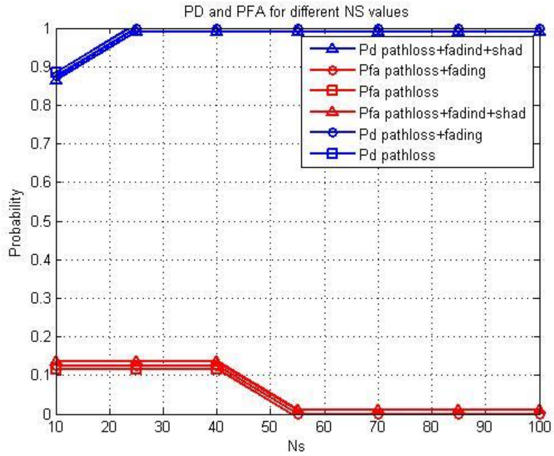
IV. RESULTS



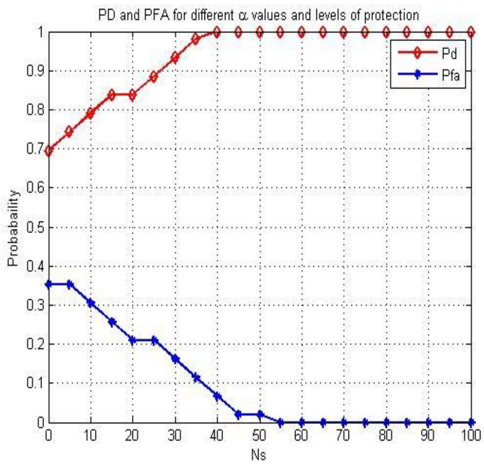
Above figure shows Probability of Detection and False alarm for PU transmission power 30dB.



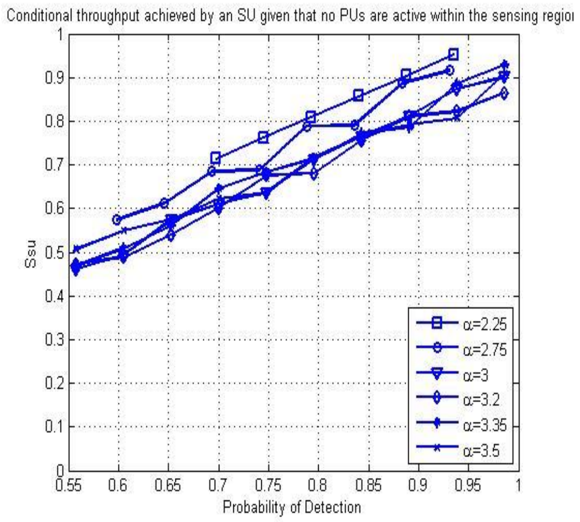
Above figure shows Probability of Detection and False alarm for PU transmission power 20dB.



Above figure shows Probability of detection and False Alarm for different values of Ns.



Above figure shows Probability of detection and False Alarm for different values of alpha(α) and level of protection.



Above figure shows conditional throughput achieved by an SU given that No PU are achieved within the sensing region.

V. Conclusion

Adopting EBS in each SU, this paper starts to characterize the aggregate interference caused by multiple PUs located outside the sensing region. We have started with the characterization of the aggregate interference observed by a single SU, concluding that the interference can be approximated by a gamma distribution. Moreover, we assumed that, in some cases, it can also be approximated by a normal distribution, showing results that validate the proposed assumption. The interference formulation is then used to derive the probabilities of detection(*PD*) and false alarm (*P*FA), and closed-form expressions are presented. Several results show that the probabilities *PD* and *P*FA are successfully validated through simulation. By proposing a simple decision threshold criterion, this paper has shown that the SFA can be almost neglected, but its price in terms of number of samples required to meet the level of PUs' protection decreases the conditional throughput achieved by the SUs. Finally, it is shown that the throughput achieved by the SUs decreases as the path-loss coefficient increases. These results are of importance for the further research on CRNs, namely, when multiple PUs are considered.

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