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Multi-Antenna Assisted Spectrum Sensing for Cognitive Radio in Nakagami-M Fading Channel

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Abstract: *CR (Cognitive Radio) is a key technology that enables the limited and inefficiently used frequency bands to be used more effectively with an opportunistic approach. Communication performance and continuity in cognitive radio networks are highly dependent on whether the spectrum sensing function is performed correctly or not. Spectrum sensing is a critical issue of cognitive radio technology because of the shadowing, fading, and time-varying natures of wireless channels. To sense the limited or unused frequency bands, different methods for spectrum sensing have been proposed. Here, improved energy detection is used for this work. Energy detection is a spectrum sensing technique based on measuring the received signal energy and deciding the presence or absence of the primary user by comparing the received energy level with a threshold. Fading channels shows that the speed of the SU increases, the energy detection performance decreases in deterioration in detection probability.*

Keywords: Cognitive Radio Networks, Energy Detection, Nakagami m Fading Channel, Spectrum Sensing

I. INTRODUCTION

In CR systems, the use of diversity branches for spectrum sensing has emerged as a potential solution for reliable, efficient sensing and to combat the effect of fading. In an early work by Urkowitz, energy detection (ED) based spectrum sensing was proposed. By investigating the performance of ED for various diversity combining schemes. Diversity branches in these prior works were assumed to be sufficiently apart and thus independent. As diversity branches increase, antennas become closely spaced due to space limitations on user terminals. Thus, the diversity branches become spatially correlated, and inter branch correlation among them cannot be neglected

Antenna correlation can be classified as uniform, exponential, or arbitrarily correlated. Even though the uniform and exponential correlation are mathematically convenient, these models are seldom applicable. Practically, there may be cases when the antennas need not be evenly/uniformly spaced.

For instance, a linear array of antennas may be arbitrarily correlated depending on the spacing between the antennas, height of the antennas or the incident angle. Under such circumstances, it is important to analyze the impact of arbitrary antenna correlation on the sensing performance of mobile CR users.

II. SYSTEM MODEL OF COGNITIVE RADIO NETWORK

In cognitive radio, the CU establishes communications on the PU channel in such a way that the PU communication remains unaffected by following a cognitive engine cycle, which comprises the following steps, namely, spectrum sensing spectrum analysis and decision, spectrum accessing and spectrum mobility. Initially, the CU performs spectrum sensing on the channels to detect the status of the channel that is idle (free) or active (busy). Furthermore, the CU selects the most suitable idle channel for the communication and starts the data transmission on that channel by using the appropriate spectrum accessing technique. The reappearance of the PU communication is an important phenomenon during the CU communication, and if it happens the CU needs to switch its communication to the other available channel, and this process is termed spectrum mobility. Interference avoidance to the PU communication by the CU communication is achieved by using various spectrum accessing techniques: interweave, underlay, overlay, and hybrid spectrum accessing techniques.

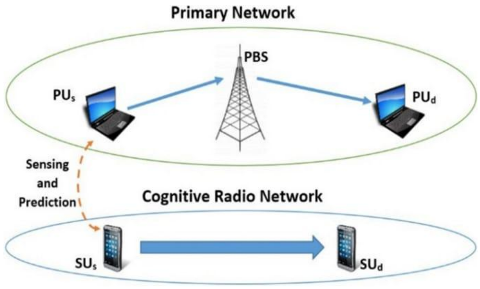

Figure 1: System Model

III. SENSING MODEL

At every time PU channel may be either busy or idle. When PU channel may be either busy, no SU can transmit its own data. They can only operate with PU, when PU channel is idle, SU can transmit their own data in appropriate power levels by renting the spectrum from the PU. Compared to other policies this provides a higher PU throughput. All the decision variables can be computed offline.

3.1 Channel Model

The system architecture consists of one PU and multiple SUs along with the Primary Base Station (PBS) and the Secondary Base Station (SBS) as shown in Qs (t) and Q p (t) are the queues for SUs and PU respectively. PU is the licensed owner of the channel and it will lease transmission opportunities to SUs when it is idle. SUs will cooperate with PU whenever the channel is busy. This is done by allocating a part of transmit resources of Secondary Users for the sake of Primary User. The cooperation of SUs with PU has been studied in many works that span over communication layers. This architecture covers the generality of all those methods. One SU can cooperate with PU when the channel is busy. When the channel is sensed busy all the SUs together decide that which one of them will cooperate with PU at which power level. When the channel is idle SUs will decide that which SU can transmit its own data at which power level. The following represents the system model parameters and available controls.

IV. RELATED WORK

The probability of detection P_d and false alarm P_{fa} for spectrum sensing cognitive devices, employing correlated multiple antenna elements using linear test statistics. Detection performance of such spectrums is severely degraded due to the correlation among antennas, in addition to that, fading channel conditions may further deteriorate the performance. Here, a energy detection strategy at the secondary Base Station to improve the performance by exploiting collaborative gain is proposed. Region of Convergence (ROC) is also evaluated. Communication performance and continuity in cognitive radio networks are highly dependent on whether the spectrum sensing function is performed correctly.

Spectrum sensing is a critical issue of cognitive radio technology because of the shadowing, fading, and time-varying natures of wireless channels. To sense limited or unused frequency bands, different methods for spectrum sensing have been proposed in the literature like matched filtering, cyclostationary-based sensing, waveform-based sensing, wavelet-based sensing, eigen value-based sensing, and energy detection sensing. Matched filtering detection methods with shorter detection periods are preferred if certain signal information is known, such as bandwidth, operating frequency, modulation type and grade, pulse shape, and frame structure of the primary user . The detection performance of this method largely depends on the channel response. To overcome this, it requires perfect timing and synchronization in both physical and medium access control layers. This situation increases the complexity of calculation. Cyclostationary detection is a method for detecting primary user transmissions by exploiting the cyclostationariy features of the received signals. It exploits the periodicity in the received primary signal to identify the presence of primary users. In this way, the detector can distinguish primary user signals, secondary user signals or interference. However, the performance of this detection method depends on a sufficient number of samples, which increases the computational complexity. Waveform-based sensing is only applicable to systems with known signal patterns. Such patterns include preambles, midambles, regularly transmitted pilot patterns, and spreading sequences. A preamble is a known sequence transmitted before each burst and a midamble is transmitted in the middle of a burst or slot.

In the case of a known model, the spectrum detection function is performed by associating the received signal with a copy of itself. Wavelet transform is a powerful method for analyzing singularities and edges. In the wavelet-based spectrum sensing method, the frequency bands of interest are usually decomposed as a train of consecutive frequency sub-bands. By using wavelet transform, irregularities in these bands are detected and the spectrum is decided whether it is full or empty. Eigen value-based spectrum sensing does not require much prior knowledge about the primary user signals and noise power. The concept of this detection technique is presented in 2007 In the eigenvalue-based spectrum sensing methods, the decision threshold has been obtained based on random matrix theory to make a hypothesis testing. In order to determine the presence or absence of the primary user signal, the decision threshold is compared with the test statistic formed using the ratio of the maximum or average eigenvalue to the minimum eigenvalue. Nevertheless, having a high operational complexity is a disadvantage of this method. Similarly, if the information of the primary users is not known precisely, energy detection-based methods with low mathematical and hardware complexities are preferred.

Table 1: Nomenclature

SYMBOL	DESCRIPTION
Pd	Probability of detection
Pfa	Probability of false alarm
PU	Primary user
CRN	Cognitive Radio Network
ROC	Receiver Operating Characteristics
SU	Secondary User
RF	Radio Frequency
SS	Spectrum Sensing
CU	Cognitive User
DTMC	Discrete Time Markov Chain
P_m	Probability of Miss detection
FC	Fading Channel
SC	Selection Combining
λ	Decision threshold
n(t)	Noise
Σ	Arbitrary correlated Matrix
T_i	Idle/busy period duration
γ	Instantaneous SNR
R	Protection Range of PU
S	Sensing Range of SU
m	Nakagami fading channel parameter

V. PROPOSED WORK

Spectrum Sensing (SS) plays an essential role in Cognitive Radio (CR) networks to diagnose the availability of frequency resources. For dynamic allocation of frequency hole to unlicensed user/secondary user, cognitive radio (CR) network requires detection of licensed user/primary user. Spectrum sensing phenomenon is used to estimate the unutilized frequency band in the available spectrum area. This is one of the important functions and challenging task in cognitive radio. Here, using improved energy detection method for spectrum sensing over Nakagami m Fading channel.

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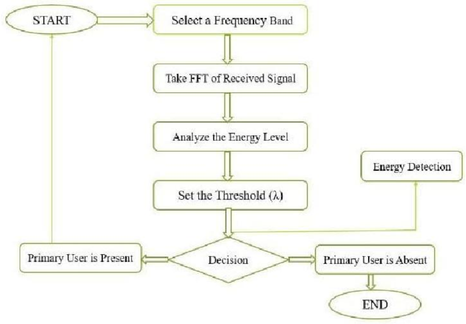
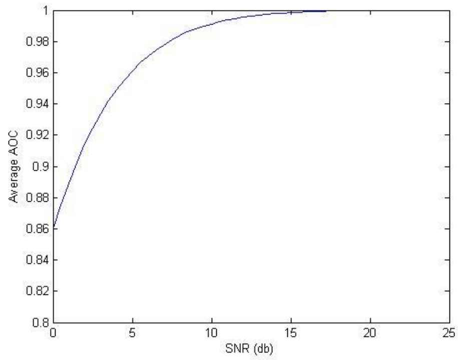


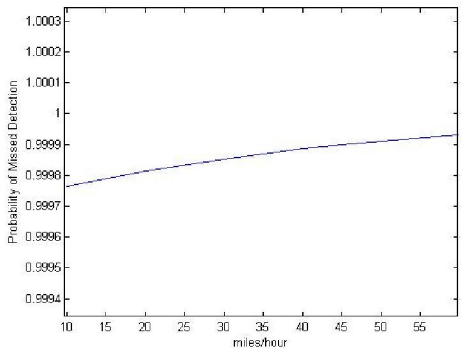
Figure 2: Flowchart for Proposed Spectrum Sensing for Cognitive Radio using Energy Detection

VI. RESULTS

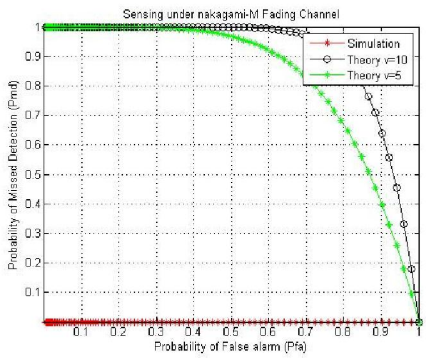
6.1 Average AUC for Linearly placed antenna over Nakagami m channel for m=3



6.2 Impact of PU activity on sensing performance of mobile SU at SU speed=50mph



6.3 Effect of m and *v* on CROC for sensing under Nakagami m fading channel



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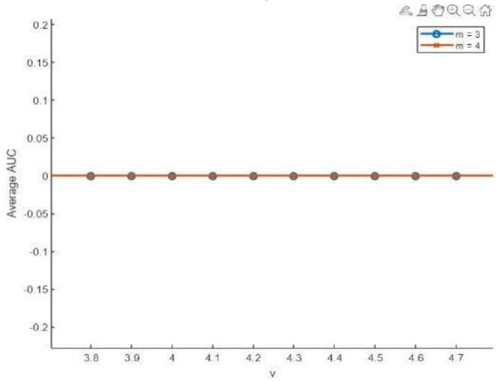
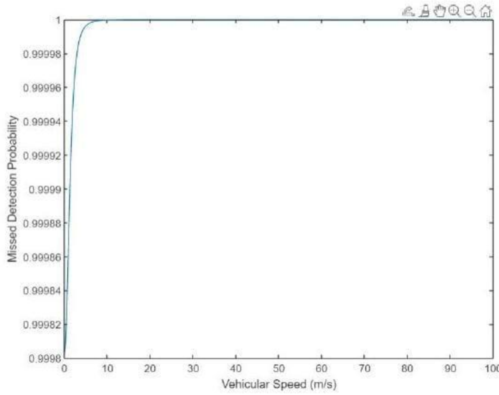
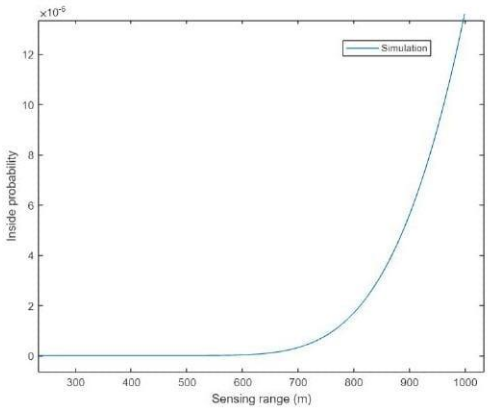
6.5 Average AUC for Linearly placed antenna over Nakagami m channel for m=3 and m=4



6.5 Missed Detection vs Vehicular Speed *v* for Nakagami m fading channel P_f=0.01



6.6 Inside Probability vs Sensing Range for *v* = 25 mph, R= 100m and D_0 = 200m



VII. CONCLUSION

In this study, Energy detection of spectrum sensing for cognitive radio network is discussed. Vacant signal is detected and provided to the secondary user. And ROC curves of P_d & P_{fa} is discussed. The probability of detection and false alarm probability are varied based on SNR using Monte Carlo simulations in MATLAB R2022a. It can be shown that detection probability decreases with decreasing false alarm probability with respect to increase in SNR and vice versa. Cognitive Radio (CR) has emerged as a leading and promising technology of wireless communication. Exponential growth in wireless communication applications with spectrum scarcity demands dynamic spectrum allocation. Analysis of discussed work gives great results of using unused spectrum bands. It can be concluded from all the results that Energy detection offers best performance than Matched filtering and Cyclostationary detection over Nakagami m

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Fading channel. All these characteristics make the Cognitive Radio to sense the unused Spectrum Effectively by Energy Detection over Nakagami-m Fading Channel

REFERENCES

[1]. Brijesh soni, Dhaval k Patel, Zhiguo Ding, and Sumei sun, "On Sensing Performance of Multi-Antenna Mobile Cognitive Radio Conditioned on Primary User Activity Statistics," IEEE Wireless Commun. J., vol. 1,no. 4, pp.289–299,May.2022.

[2]. K. D. Singh, P. Rawat, and J.-M. Bonnin, "Cognitive radio for vehicular ad hoc networks (CR-VANETs): Approaches and challenges," EURASIPJ. Wireless Commun.Netw.,vol.2017,no.1,p.49,2019.

[3]. D. Jiang and L. Delgrossi, "IEEE 802.11 p: Towards an international standard for wireless access in vehicular environments," in Proc. IEEEVTC, May 2018, pp.2036–2040.

[4]. J. Mitola and G. Q. Maguire, Jr., "Cognitive radio: Making softwareradios more personal," IEEE Pers. Commun., vol. 6, no. 4, pp. 13–18,Apr. 2016.

[5]. H. Urkowitz, "Energy detection of unknown deterministic signals,"Proc. IEEE,vol.55,no.4,pp.523–531,Apr.2016.

[6]. F. F. Digham, M.-S. Alouini, and M. K. Simon, "On the energy detection of unknown signals over fading channels," IEEE Trans. Commun.,vol. 55, no. 1, pp. 21–24,Jan.2014.

[7]. S. P. Herath, N. Rajatheva, and C. Tellambura, "Energy detection of unknown signals in fading and diversity reception," IEEE Trans. Commun., vol. 59, no. 9, pp.2443–2453,Sep.2013.

[8]. V. A. Aalo, "Performance of maximal-ratio diversity systems in a correlated Nakagami-fading environment," IEEE Trans. Commun., vol. 43,no. 8, pp. 2360–2369,Aug.2013.

[9]. W. C. Y. Lee, Mobile Communications Design Fundamentals, 2nd ed.New York,NY,USA:Wiley,2012.

[10]. V. R. S. Banjade, N. Rajatheva, and C. Tellambura "Performance analysis of energy detection with multiple correlated antenna cognitive radio in Nakagami-m fading," IEEE Commun. Lett., vol. 16, no. 4,pp. 502–505, Apr. 2012.

[11]. Y. Huang and X. Huang, "Spectrum sensing over frequency-selective fading channel with tap and spatial correlations," in Proc. IEEE PIMRC,Sep. 2012, pp. 2143–2148.

[12]. S. Al-Juboori and X. Fernando, "Correlated multichannel spectrum sensing cognitive radio system with selection combining," in Proc. IEEEGLOBECOM, Dec.2011,pp.1–6.

[13]. S. Al-Juboori and X. N. Fernando, "Multiantenna spectrum sensing over correlated Nakagami-m channels with MRC and EGC diversity receptions," IEEE Trans.Veh.Technol.,vol.67,no.3,pp.2155–2164,Mar.2011.

[14]. S. Al-Juboori, X. Fernando, Y. Deng, and A. Nallanathan, "Impact of interbranch correlation on multichannel spectrum sensing with SC and SSC diversity combining schemes," IEEE Trans. Veh. Technol., vol. 68,no. 1, pp. 456–470,Jan.2009.

[15]. A. W. Min and K. G. Shin, "Impact of mobility on spectrum sensing in cognitive radio networks," in Proc. ACM Workshop Cognit. Radio Netw.,2005, pp.13–18.

[16]. A. S. Cacciapuoti, I. F. Akyildiz, and L. Paura, "Primary-user mobility impact on spectrum sensing in cognitive radio networks," in Proc.IEEE 22nd Int. Symp. Pers., Indoor Mobile Radio Commun., Sep. 2002,pp. 451–456.

[17]. L. Gahane, P. K. Sharma, N. Varshney, T. A. Tsiftsis, and P. Kumar,"An improved energy detector for mobile cognitive users over generalized fading channels," IEEE Trans. Commun., vol. 66, no. 2,pp. 534–545, Feb. 2000.

[18]. O. Thakkar, D. K. Patel, Y. L. Guan, S. Sun, Y. C. Chang, and J. M.-Y. Lim, "On the joint impact of SU mobility and PU activity in cognitive vehicular networks with improved energy detection," in Proc. IEEE 89th Veh. Technol. Conf.,Apr.1996,pp.1–6.

[19]. S. Zhu, C. Guo, C. Feng, and X. Liu, "Performance analysis of cooperative spectrum sensing in cognitive vehicular networks with dense traffic," in Proc. IEEE83rdVeh.Technol.Conf.,May1991,pp.1–6.

[20]. Y. Zhao, P. Paul, C. Xin, and M. Song, "Performance analysis of spectrum sensing with mobile SUs in cognitive radio networks," in Proc. IEEE ICC, Jun. 1985, pp. 2761–2766.