Analysis and Enhancement of Power Control Techniques in Cognitive Radio Networks

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Abstract: **In this paper, we consider the situation where primary user (PU) i.e. licensed user and secondary user (SU) i.e. cognitive radio, coexist and share the spectrum simultaneously in order to enhance spectrum efficiency. The most challenging problem is the interference which occurs, if the SUs fail to detect the presence of the Pus signal, i.e. misdetection (MD), and starts the transmission in the same frequency band with a transmit power larger than a limit which can be decided based on the noise floor and the interference protection ability of the PUs. The objective of this research work is to analyze the performance of different power control schemes which are available in the literature and also to propose new transmit power control scheme for cognitive radio system. In this research work, a distance based an efficient transmit power control scheme for a cognitive radio system (CRS) with multiple antennas has been proposed.**

Keywords:-**wireless, cognitive radio system, dynamic spectrum access, power control**

I. INTRODUCTION

Due to an ever increasing requirement of higher data rate, throughput and efficiency in most of the latest wireless applications, spectrum assets are facing massive demands. There is limited spectrum available for a particular application, regulated by government agencies such as Federal Communications Commission (FCC) in United States. Within the current spectrum regulatory structure, many parts of the spectrum are entirely allocated to specific services and no violation from other users is legitimate. At any given time and location, most of the prized spectrum lies idle. This paradox indicates that Spectrum shortage results from the spectrum management policy rather than the physical scarcity of usable frequencies. To overcome the conflict between spectrum scarcity and spectrum under-utilization [1]. Cognitive radio has been proposed as a promising technology which allows the secondary users i.e. cognitive users to communicate over the spectrum allocated to the primary users when they are not utilizing it. It provides an efficient way to utilize spectrum resources by dynamic spectrum access (DSA) [2]. To achieve DSA, the SU performs spectrum sensing that is, detecting the presence of the primary users. According to this sensing information, SUs starts transmission once the unoccupied spectrum is found. Whenever the primary users become active, the secondary users have to detect the presence of primary users with a high probability and vacate the channel or to control their transmit power levels in order to avoid the interference with it. Cognitive radio [3], including SDR is an intelligent wireless transceiver which can dynamically sense available spectrum holes [4], in operating environment and accordingly change its transmission and reception parameters (i.e. carrier frequency, modulation schemes and transmit power etc.) in such a manner so that more wireless communication may operate in an allocated frequency band simultaneously.

II. OBJECTIVE

The key objective of this research is to take up one of the most critical design challenges in cognitive radio system, by establishing a balance between transmit power level and interference constraint. In achieving this, we attempt to:

1. Carry out a literature survey on performance analysis of various existing power control schemes in cognitive radio system.
2. Verify simulation results and compare existing fixed and adaptive power control schemes based on the parameters such as SNR, BER, and distribution of interference etc.
3. Propose new power control scheme.

Proposed Methodology to Calculate Distance between PU Transmitter and SU Transmitter In this section, we discuss our proposed methodology to calculate the distance d1 between PU Tx and SU Tx which will be used to control and determine maximum allowable transmit power at SU Tx while still guaranteeing decodability of PU signal at PU Rx in the protected region.

III. SPECTRUM SENSING

Spectrum sensing is one of the most vital issues of cognitive radio technology as it should be firstly performed before allowing unlicensed users to access an unoccupied licensed band, to ensure the efficient utilization of the spectrum without disturbing the quality of service of the primary user.

There are many techniques for spectrum sensing available in literature. Some of them are discussed in chapter2. In order to avoid the interference at the PU Rx, the SU should sense the spectrum opportunity. Due to simplicity and extremely low processing load, we use energy detection with selective combining for sensing the available unoccupied frequency band. In this processes of spectrum sensing by using energy detection, energy (E) of the received signal y (t) is collected in a fixed bandwidth and a time slot, then compared with a predefined energy threshold Eth. Let y (t) is the received signal at the SU Tx, x (t) is the transmitted signal from PU Tx, n (t) is the zero-mean additive white Gaussian noise (AWGN) with the variance (σ^2) and h denotes the Rayleigh fading channel coefficient. The objective of spectrum sensing is to decide between the following two hypotheses: If E < Eth then SU assumes that the PU Tx is not active, which is referred to as hypothesis H0, the received signal at the ith antenna of SU Tx is given by:

$$H_0: y(t) = n(t)$$

If E > Eth then the SU considers that PU is in operation or active, which is referred to as hypothesis H_1, the signal received from the PU Tx at the ith antenna of SU Tx can be written as:

$$H_1: y(t) = \sqrt{Gshx(t)} + n(t)$$

Where, G_s represent path loss of sensing channel. Based on these two hypotheses H_0 and H_1, average probability of false alarm (P_f), probability of detection (P_d) and probability of missing (P_m) over Rayleigh fading channel can be determined as follow, [28]

$$P_f = E[\text{prob}\{H_1/H_0\}]$$

$$P_d = E[\text{prob}\{H_1/H_1\}]$$

$$P_m = E[\text{prob}\{H_0/H_1\}] = 1-P_d$$

Where, E represent expectation operator Relation Establishment between SNR and Distance to calculate distance d_2 for controlling the transmit power of SU is very difficult because we do not know the exact location of PU as well as exact channel state information. As mentioned in our system model, discussed above, the problem of finding d_2, is essentially the problem of finding d_1. The distance, d1, can be estimated by measuring the local SNR of the PU Tx (Γ_t) at SU Tx with the help of pilot signal as well as sensing SNR (Γ_s). Here, we have derived the relationship between sensing SNR and distance (d_1). The path loss due to distance d1 between PU Tx and SU Tx is given by [23],

$$\eta = -10 \log (d_1^{(-\alpha_1)}) \quad \text{dB}$$

In term of average sensing SNR (Γ_s) and transmit SNR of PU Tx (Γ_t) above equation can be written as,

$$=10\log(\Gamma t)-10\log(\Gamma_s)$$

From equation above averages SNR of sensing channel can be represented in term of transmit SNR of PU Tx and distance d_1 as:

$$\Gamma_s = \Gamma_t d_1^{(-\alpha_1)}$$

S.No.	Name of Parameters	Value
1	Path loss in the region corresponding to R_d	$\Delta = 100dB$
2	Protection margin	$\mu = 1dB$
3	Transmit SNR of PU	$\Gamma_t = 100dB$
4	False alarm rate	$P_f = 0.01$
5	Number of samples	$N_0 = 5$

Table-1 simulation parameters

The first term on the right hand side of equation 4.18 describes, that how far a PU Rx can travel from the PU Tx and still decode the signal. The second term represents how tolerant the protected primary receivers are to interference. The final term represents how far the secondary transmitter is from the protected receivers.

this maximum allowable transmit power at SU Tx is controlled on the basis of calculated distance d_1 between PU Tx and SU Tx. Then, we considered the case of a single antenna at SU Tx. The result is observed for different values of false alarm rate. Keeping other simulation parameters same. The results are presented in figure1. Which shows that the probability of missing decreases with increasing average SNR of sensing channel? For a specified average SNR. A large false alarm rate will result in the decrease of probability of missing because of the decrease in threshold value of ED. Figure 1 shows variation in probability of missing with respect to distance between PU Tx and SU Tx for different transmit SNR values. In this case, we consider false alarm rate, $P_f = 0.01$ and path loss exponent $\alpha_1 = \alpha_2 = 2$. As shown, the probability of missing increases when secondary user is far from primary transmitter. It is also shown that for a fixed distance d_1.a higher transmit SNR can get a batter sensing performance i.e. a lower probability of missing. Because the received SNR is enhanced. Figure 1 presents the probability of missing as a function of path loss due to

IV. SIMULATION RESULTS AND DISCUSSIONS

In this section, we present and discuss the simulation results of the proposed transmit power control scheme. The simulations have been carried out in MATLAB. For simulation purpose, the parameters as shown in table -1 have been considered. We consider the situation where there are T antennas at SU1 observing independent Rayleigh fading with equal average SNRs i.e. Γs in the sensing channel. Furthermore, the ED is performed using the signals from the selected antenna to determine the presence or absence of the PU signals with false alarm rate

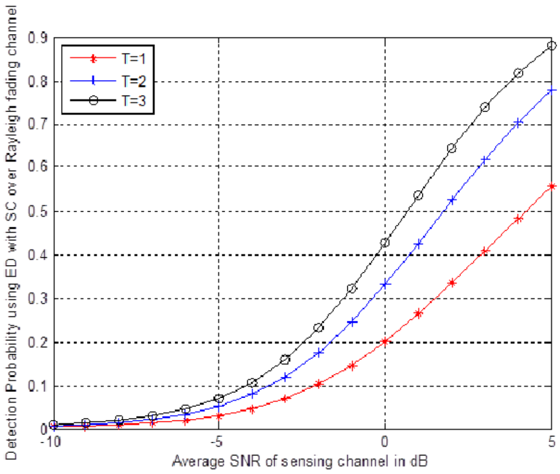

Figure 1: Detection probability using ED with SC in a Rayleigh fading channel

Pf = 0:001 and number of samples N_0 = 5. Figure 1 shows that the probability of detection increases with the increase in average SNR of the sensing channel. It also shows that the performance of the ED improves with SC i.e. the probability of detection becomes better as the number of antennas used at SU Tx is increased. By using the ED with SC at T = 3, we can improve the detection probability from 0.2 to 0.42 in a sensing The results are presented in figure 2. Which shows that the probability of missing decreases with increasing average SNR of sensing channel? For a specified average SNR. A large false alarm rate will result in the decrease of probability of missing because of the decrease in threshold value of ED. Figure 3, shows variation in probability of missing with respect to distance between PU Tx and SU Tx for different transmit SNR values. In this case, we consider false alarm rate, P_f = 0.01 and path loss exponent $\alpha_1 = \alpha_2 = 2$. As shown the probability of missing increases when secondary user is far from primary transmitter. It is also shown that for a fixed distance d_1.a higher transmits SNR can get a batter sensing performance i.e. a lower probability of missing. because the received SNR is enhanced. Figure 3 presents the probability of missing as a function of path loss due to distance for different values of path loss exponent, for the case of a single antenna at SU Tx. It is seen that the probability of missing increases with increased path loss due to distance between PU Tx and SU Tx. Also, for a particular path loss, channel of 0 dB SNR. larger path loss exponent will result into increased probability of missing. This is because of the fact that larger the path loss exponent worse is the wireless communication environment. In figure 4, we have plotted the probability of missing as a function of path loss due to distance, for different number of antennas at SU Tx, while keeping path loss exponent α_1 = 2. Result shows that when cognitive radio is experiencing heavy path loss from the PU Tx, the probability of missing is increased. Also, as is evident, for a particular path loss, the probability of missing can be reduced by employing more number of antennas at SU Tx. As shown in figure 5, the allowable transmit power of the SU transmitter can be increased when a heavy SNR loss occurs between the secondary transmitter and the primary receiver

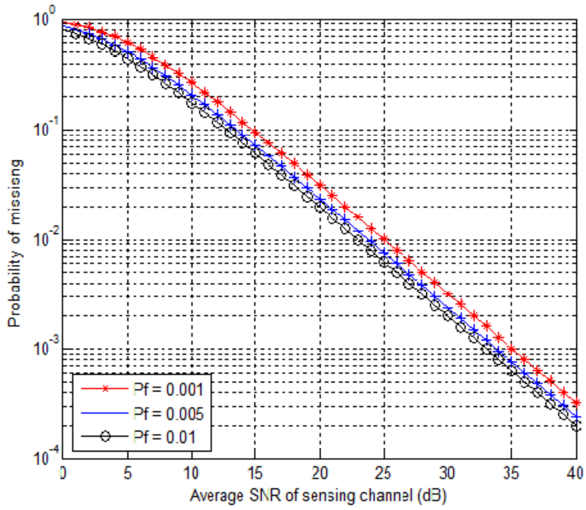

Figure 2: Probability of missing P_m versus average sensing SNR Γ_s for P_f = 0.001,0.005 and 0.01

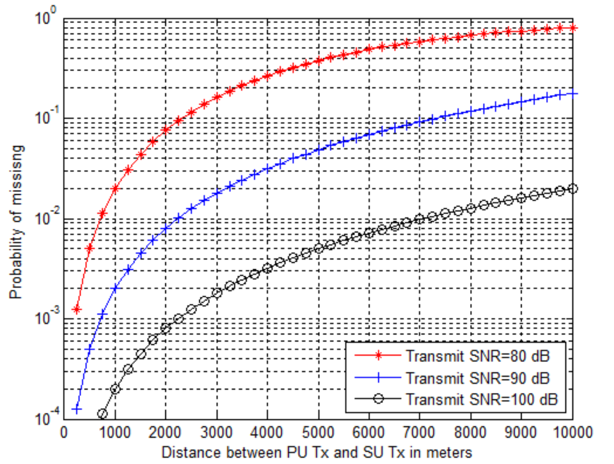

Figure 3: probability of missing P_m versus distance d_1, between PU Tx and SU Tx for different transmit SNR i.e. Γ_s= 80, 90 and 100dB.

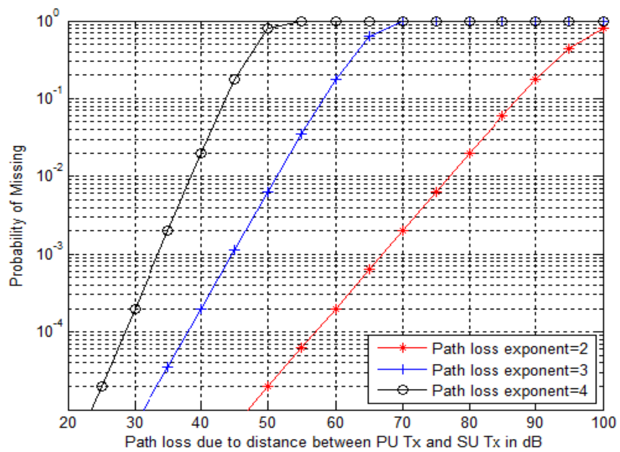

Figure 4: Probability of missing Pm versus path loss due to distance d1 for different values of path loss exponent between PU Tx and SU Tx.

distance for different values of path loss exponent, for the case of a single antenna at SU Tx. It is seen that the probability of missing increases with increased path loss due to distance between PU Tx and SU Tx. Also, for a particular path loss, a larger path loss exponent will result into increased probability of missing. This is because of the fact that larger the path loss exponent, worse is the wireless communication environment. probability of missing can be reduced by employing more number of antennas at SU Tx.the allowable transmit power of the SU transmitter can be increased when a heavy SNR loss occurs between the secondary transmitter and the primary receiver. This is reasonable because the interference power that the cognitive radio inflicts on the primary receiver is reduced by the large path loss

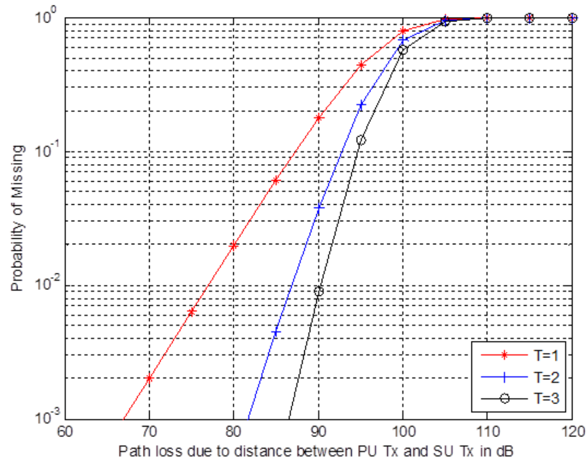

Figure 5: Probability of missing Pm versus path loss due to distance d1 for different number of antennas.

By employing more number of antennas at SU Tx. It is also obvious that better the probability of detection more accurate will be our power control scheme. In this proposed work, we considered the situation where primary user (PU) shares spectrum with secondary user (SU) i.e. cognitive radio. We have proposed a distance based efficient transmit power control scheme which calculates maximum allowable transmit power at SU transmitter while guaranteeing decodable signal of PU transmitter at PU receiver in presence of cognitive radio. In order to calculate desired distance we have also derived a mathematical model for probability of detection in terms of distance between PU transmitter and SU transmitter which includes the location information of primary user indirectly. This scheme has shown that we can achieve better sensing performance by employing more number of antennas at SU Tx. Because of better sensing performance, we can exercise more accurate control on transmit power of SU Tx. Here, though, we considered worst case scenario where PU Rx is at shortest distance to SU Tx; however, the proposed scheme is equally applicable to maintain a quality-of-service for the PU by limiting the interference generated by SU Tx, at any location.

V. CONCLUSION

Cognitive radio has emerged as a promising technology to overcome the spectrum scarcity problem by dynamic spectrum access. CRs are fully acquainted with their operating environment, available frequency spectrum, and based on this information, adapts its way of communication with minimum interference at PU while guaranteeing an acceptable level of aggregate interference at the PU receivers. However, there are number of research challenges which need to be address in the implementation of cognitive radio network. The main focus of this research work is take up one of the most critical design challenge in cognitive radio system, by establishing a balance between transmit power level and interference constraint. In this research work, the performance analysis of three existing power control schemes in cognitive radio system have been carried out. The simulation results of the existing fixed and adaptive power control schemes have been verified. Then, a new and an efficient transmit power control scheme in cognitive radio system with multiple antennas has been proposed to overcome the problem of interference at PU Rx.

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