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Sensing Based Spectrum Sharing Using Optimal Power Allocation Scheme in Cognitive Radio Network

Soniya S.Christani[1], Jigneshkumar N. Patel[2]

PG Student, Department of ECE, Sardar Vallabhbhai Patel Institute of Technology, Vasad, India[1]

Assistant Professor, Department of ECE, Sardar Vallabhbhai Patel Institute of Technology, Vasad, India[2]

ABSTRACT: In this paper, we consider a new spectrum sharing model called sensing based spectrum sharing for cognitive radio network. In our proposed system model, which consists of two steps: In the first step, the secondary user (SU) listens to the spectrum allocated to the primary user (PU) to detect the state of the PU; in the second step, the SU adapts its transit power based on the sensing results. If the PU is inactive, the SU allocates the transmit power based on its own benefit. However, if the PU is active, the interference power constraint is obligatory to protect the PU. Finally, numerical results are presented to validate the proposed studies. It is shown that the SU can achieve a significant capacity gain under the proposed model.

KEYWORDS: Detection Probability, False Alarm Probability, Cooperative Spectrum Sensing, Detection Threshold, Optimal Power Control.

I. INTRODUCTION

Cognitive Radio(CR) is one kind of intelligent wireless device, which is able to adjust its transmission parameters, such as transmit power and transmission frequency band, based on the environment [3]. In a CRN, ordinary wireless devices are referred to as primary users (PUs), and CRs are referred to as secondary users (SUs). Conventionally, a CRN can be formed by allowing either the SUs to opportunistically operate in the frequency bands originally allocated to the PUs when the PUs are inactive or the SUs to coexist with the PUs, as long as the quality of service of the PUs is not degraded to an unacceptable level by the interference from the SUs. The previous transmission technique is known as opportunistic spectrum access, and the later transmission model is known as spectrum sharing. As a promising spectrum sharing scheme, sensing-based spectrum sharing not only improves the throughput of the secondary network but also guarantees the QoS of the primary network. Sensing-based spectrum sharing[5] combines the benefits of both spectrum overlay and spectrum underlay to improve the throughput of the SU, without generating harmful interference to the PU.

In this paper, we propose a new transmission model referred to as sensing-based spectrum sharing. In this model, the SU first senses the frequency band allocated to the PU to detect the state of the PU and then adapts its transmit power according to the detection result. If the PU is inactive, the SU allocates the transmit power based on its own benefit to achieve a higher transmission rate. If the PU is active, the SU transmits with a lower power to avoid causing harmful interference to the PU. This is different from either opportunistic spectrum access or spectrum sharing. In the opportunistic spectrum access [4], the SU transmits only when it detects spectrum holes [3], which are the time duration that the PU is not transmitting over the band. In the spectrum-sharing model[6], the SU can transmit at any time without having to detect whether the PU is active or not. However, it has to restrict its transmit power to not cause harmful interference to the PU during the whole transmission process.

The rest of this paper is organized as follows: The sensing-based spectrum-sharing system model briefly introduced in Section II. In section III optimal power allocation scheme discuss. The numerical results are given in Section IV. Finally, Section V concludes this paper.

II. SYSTEM MODEL

A proposed system model consists of (i) a PU and (ii) a cognitive radio network(CRN), which is shown in figure 1. In our proposed model, a CRN consist of M no. of nodes, i.e. a secondary source(SS); secondary relay(SR); secondary destination(SD) pairs.

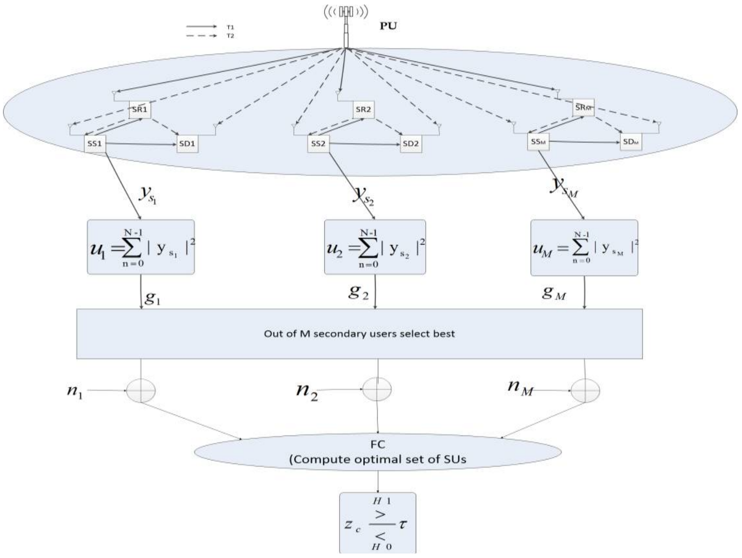

Figure. 1. Proposed System Model

Also cognitive radio network operate based on frame by frame. To improve performance in terms of secondary throughput and detection capabilities cooperative communication used. In cooperative communication, Amplify and Forward(AF) or Decode and Forward relaying used. In AF relaying, relay amplify the received signal from the source and retransmit it to the destination. As in AF relaying, each frame consist of two equal time slots T1 and T2. The frame structure of AF relaying is shown below figure.

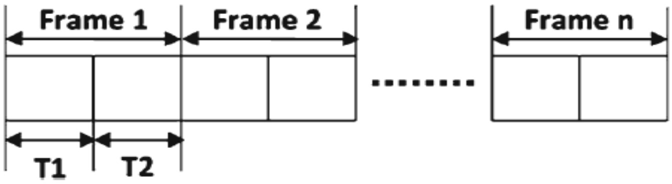

Figure. 2. Frame structure of AF Relaying

All the channels over the links for M no. of CRN, (PU–SR), (PU–SS), (PU–SD), (SS–SR), (SS–SD), (SR–SD) are modeled to be Rayleigh flat fading channels with coefficients hpr, hps, hpd, hsr, hsd, hrd respectively. Assume that the CRN operates in the first mode, since the second mode is just a modified version of the first one. In the first time slot $T1$, the SS will transmit data to both the SR and SD and in the same time the SR and SD will listen to the PU transmissions, as shown in Fig. 2.

The signal received by secondary user source is given by, the measurement model of the two hypotheses corresponding to absence or presence of the primary user at nth time instant sensed by the ith secondary user is given by :

$$y_{s_i}(n) = \lambda\sqrt{P_p}\,h_{s_i}x_p(n) + v_{s_i}\ , \ldots\ldots\ldots..(1)$$

Where, $y_{s_i}(n)$ is received signal by the ith secondary user denotes the primary user signal at time instant k with energy Es, distorted by the channel gains {hsi , where hsi =[h_i1; h_i2; ; ;h_iN]. P_p denotes the transmitted power from Primary user (PU) to secondary source(SS). Moreover v_{si} denotes noise signal vector such that $v_i \sim CN\ (0;\sigma_i^2)$ are additive white Gaussian noise (AWGN) with variances σ_i^2=[$\sigma_i 1^2$, $\sigma_i 2^2$,…, $\sigma_i N^2$]. λ defines the primary user present or absent i.e., if $\lambda = 1$ then PU is present or $\lambda = 0$ then PU is absent.

The received signals at the SR from the SS and the PU in T1 can be written as:

$$y_{rs_i}(n) = \lambda\sqrt{P_p}h_{rs_i}x_s(n) + v_{r_i}\ , \ldots\ldots\ldots..(2)$$

$$y_{rp_i}(n) = \lambda\sqrt{P_r}h_{pr_i}x_p(n) + v_{r_i}\ , \ldots\ldots\ldots..(3)$$

The combined received signal at the SR in T1 after applying EGC can be deduced as:

$$y_{r_i}(n) = \sqrt{P_s}h_{sr_i}x_s(n) + \lambda\sqrt{P_p}h_{pr_i}x_p(n) + v_{r_i}\ , \ldots\ldots\ldots..(4)$$

In the same manner, the combined received signal at the SD in the first time slot T1 can be written as:

$$y_{d_i}(n) = \sqrt{P_s}h_{sd_i}x_s(n) + \lambda\sqrt{P_p}h_{pd_i}x_p(n) + v_{d_i}\ , \ldots\ldots\ldots..(5)$$

In the second time slot T2, the combined received signal at the SR in T1 will be amplified and retransmitted to the SS and SD and at the same time the SS and SD will listen to the PU transmissions, as shown in Figure.8 The received signal at the SS in T2 can be written as,

$$y_{s_i}(n) = h_{sr_i}y_r(n) + \lambda\sqrt{P_p}h_{ps_i}x_p(n) + v_{s_i}\ , \ldots\ldots\ldots..(6)$$

As shown in Figure 8, each secondary user measures the energy u_i for (l = 1, 2,…, l_R) & (i = 1, 2,…, n_R) at detection interval of M samples given as follows:

$$u_{il} = \sum_{k=0}^{M-1}|y_{s_i}(n)|^2\ , \ldots\ldots\ldots..(7)$$

The measured energy ($u_i \triangleq [u_1,\ u_2,\ \ldots,\ u_i]$) recieved from l_R antennas are combined by equal gain combiner(EGC) using an equal gain α and output $\overline{ui}$ of EGC is transmitted to secondary user. Thus the observation $\overline{ui}$ received by each secondary user is given by :

$$\overline{ui} = \alpha\ u_i \quad ,\ldots\ldots\ldots..(8)$$

For a sufficiently large M, the central limit theorem implies that the decision statistic u_i approximately follows a Gaussian distribution under the two hypotheses H_1 : ($\lambda = 1$) and H_0 : ($\lambda = 0$). $x_p(n)T1$ and $x_p(n)T2$ are assumed to be CSCG random sequences, and $x_p(n)T1, x_p(n)T2$, u_r(n)T1, and u_d(n)T2 are pairwise independent. Then the mean and the variance of u_i under H_1 can be expressed as $\mu_i = N\ \mu_1$ and $\sum_1 = N\ \mu_2$ respectively, where, μ_1 = GpsPp +βGsr [$G_{pr}P_p+P_u$]+P_u. The mean and the variance of u_i under H_0 can be expressed as $\mu_0 = N\ \mu_0$ and $\sum 0 = N\mu_2$, respectively. where , $\mu_0 = \beta G_{sr}P_u + P_u$.

III. OPTIMAL POWER ALLOCATION

In this section, we formulate the optimization problem that maximizes the secondary users rate for CR networks without affecting the QoS of the PU. By optimizing the source selection, relay assignment and sharing of the available power budget P_T so that the probability of detection P_D is maintained above a minimum[18] threshold P_D^{th}. Initially K out of M nodes is randomly selected and an estimated power allocation is done. Then this set of selected CSs is matched against. The only the set is considered as a valid one and the next step is to follow optimal power allocation. The above process goes on for various combinations of K out of the M SU's. In our proposed system model, we assume that SS transmit power P_{s1} is higher when PU is detected to active otherwise SS transmit power P_{s2} lower when PU is sense to be absent. There are different possibilities of sensing results based on that power is allocated [18] as shown in table1.

PU's State	Sensing Results	Related Probability	Allocated Power	Related CSNR
Present(H_1)	H_1	P_D	P_{s2}	γ_4
Present(H_1)	H_0	P_M=1-P_D	P_{s1}	γ_2
Absent(H_0)	H_1	P_F	P_{s2}	γ_3
Absent(H_0)	H_0	1-P_F	P_{s1}	γ_1

Table1. Power Allocation based on Sensing Results

The secondary throughput[18] for selected nodes, can be written as,

$$R=0.5([(1-\alpha)(1-P_F)\log_2(1+\gamma_1)]+[\alpha(1-P_D)\log_2(1+\gamma_2)]+[(1-\alpha)P_F\log_2(1+\gamma_3)]+[\alpha P_D\log_2(1+\gamma_4)])\ldots\ldots\ldots(9)$$

Where,

$$\gamma_1 = \frac{G_{sd}P_{s1}}{P_u} + \frac{\beta G_{rd}P_{s1}G_{sr}}{\beta G_{rd}P_{u+}P_u}$$

$$\gamma_2 = \frac{G_{sd}P_{s1} + G_{pd}P_p}{P_u} + \frac{\beta G_{rd}P_{s1}G_{sr} + \beta G_{rd}P_pG_{pr} + G_{pd}P_p}{\beta G_{rd}P_{u+}P_u}$$

$$\gamma_3 = \frac{G_{sd}P_{s2}}{P_u} + \frac{\beta G_{rd}P_{s2}G_{sr}}{\beta G_{rd}P_{u+}P_u}$$

$$\gamma_4 = \frac{G_{sd}P_{s2} + G_{pd}P_p}{P_u} + \frac{\beta G_{rd}P_{s2}G_{sr} + \beta G_{rd}P_pG_{pr} + G_{pd}P_p}{\beta G_{rd}P_{u+}P_u}$$

P_{s1} and P_{s2} can be define as,

$$P_{s1} = \frac{P_{max1} - \beta(\alpha G_{pr}P_p + P_u}{1 + \beta G_{sr}} \ldots\ldots\ldots.(10)$$

$$P_{s2} = \frac{P_{max2} - \beta(\alpha G_{pr}P_p + P_u)}{1 + \beta G_{sr}} \ldots\ldots\ldots(11)$$

IV. SIMULATION RESULTS

In the simulation, simulation parameters are set as follows: N = 100, P_d' = 0.95, P_F' = 0.01, P_u = 0 dBW, and P_p = 0 dBW, α = 0.3 (means the (PU) is present for 30% of the time). The gains of the links between G_{sr}, G_{rd}, and G_{pr} are chosen to be −4 dB, and the gains of the links between G_{ps}, G_{sd}, are chosen to be −10 dB. Fig.3. shows that the results of probability of detection for chosen subset of SU versus relay amplification factor. From this figure, P_D increases of our proposed model when beta increase, which is compared with existing work[18]. Fig.4. Shows that the results of P_D versus different values of SNR(dB). From this figure, different values of SNR, P_D increases of our proposed model as compared to existing work[18]. In Fig.5 the secondary users throughput R versus relay amplification factor(β) are shown when power at 0 dBW. In Fig.6 the secondary users throughput R versus relay amplification factor(β) are shown when power at 10 dBW. From these figures, secondary users throughput increases of cognitive radio network.

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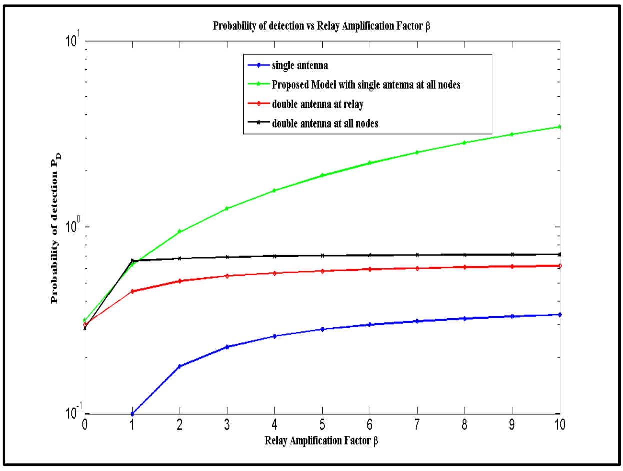

Fig.3. Probability of detection for chosen subset of SU's vs β

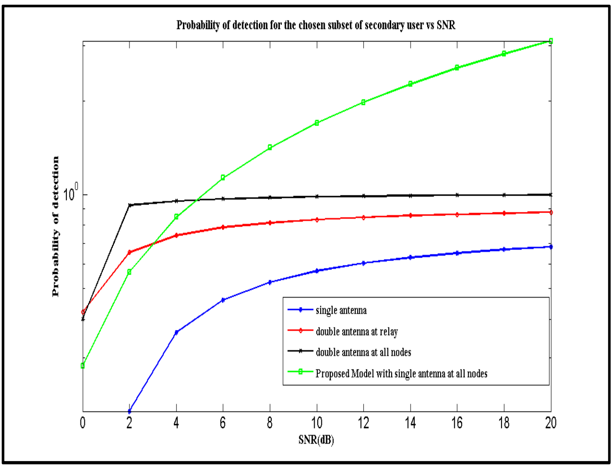

Fig.4. Probability of detection for chosen subset of SU's vs SNR(dB)

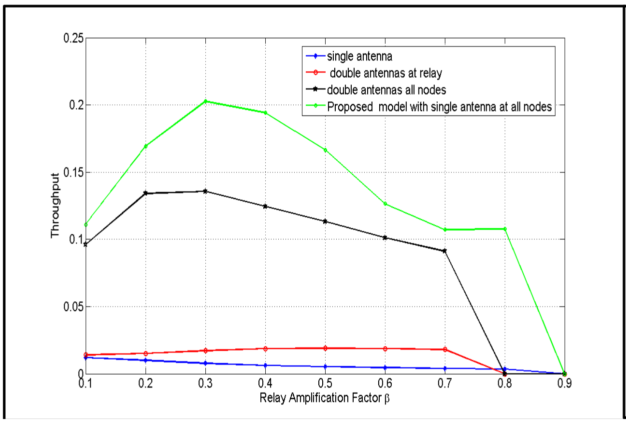

Fig. 5. Throughput vs β at P_{max}=0dBW

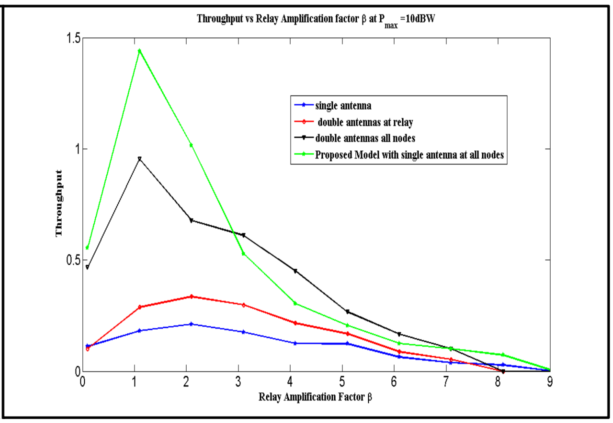

Fig. 6. Throughput vs β at P_{max}=10dBW

V. CONCLUSION AND FUTURE WORK

In this paper, we studied the problem of designing the optimal sensing capabilities and power allocation strategy that maximizes secondary users throughput of cognitive radio network. The power allocation is the function of the received signal energy by the secondary user. Finally, the simulation results have shown that the Secondary users can achieve a significant capacity gain under the proposed model, compared with the conventional spectrum sharing model. In future our work is extend using different fading channels..

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BIOGRAPHY

Soniya S. Christani has received her Bachelor degree in Electronics and Communication Engineering from Gujarat Technological University, Ahmedabad, India. Currently she is pursuing M.E (Communication system engineering) from Gujarat Technological University. Her area of interest include wireless communication, networking.

Mr. Jigneshkumar N. Patel has received the B.E. and M.E. degrees in Electronics & Communication Engineering from Dharamsinh Desai University (DDU), Nadiad, Gujarat, India, in 1997 and 1999, respectively. Since 1999, he is working as an Assistant Professor in SVIT, Vasad, Gujarat. His area of interests are Digital & Analog Communication, Digital Electronics.