A LEARNHEURISTIC FRAMEWORK FOR PERFORMANCE ENHANCEMENT IN HCCRN

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Abstract- With the growing need for wireless data, researchers are looking at Cognitive Radio (CR) and collaboration between devices (cooperative techniques) to make better use of the available radio spectrum. For correct detection of spectrum availability, it is essential to avoid false detection of troublesome users. A certain number of bits must be included in transmission signals to avoid such threats which results in reduction of energy efficiency. HCCRN system for downlink in underlay mode is considered. When the signal strength isn't strong enough compared to interference [measured by signal to inference ratio (SIR)], a user experiences an outage (loses connection). We can determine outage probability after characterizing the interference to signal power ratio. This research focuses on how these outages happen based on the random placement of users and the unpredictable nature of signal strength in wireless environments. Different subcarriers are required to satisfy the requirement of a data rate that depends on the experienced SIR. Outage probability analysis is done here for the HCCRN considering the effect of noise in the Rayleigh faded channel with machine learning based metaheuristic algorithm.
Keywords: Outage Probability, Hybrid cooperative cognitive radio network, SVM-RDA, signal to interference ratio

I. INTRODUCTION

With the wide application of wireless devices in day-to-day real-time applications results in the scarcity of the spectrum. Various technologies have been suggested to utilize resources effectively with CR and Cooperative communication to meet the challenging requirements of radio resources. Resource allocation is a technique to make use of resources dynamically while taking into consideration the channel interference and fluctuations in wireless networks [1]. This approach allows devices to find and use unused parts of the radio spectrum, which improves overall spectrum utilization [2, 3]. Cooperative communication improves capacity, speed, throughput, transmission coverage area performance, reduces energy consumption, and extends network lifetime [4]. The effect of interference and noise on outage probability in hybrid cooperative CR network (HCCRN) for uplink is analyzed to observe if PU's operating frequencies to the primary base station (PBS) and SU to SBS are the same [5].
The spectrum is a sparse resource that must be utilized intelligently. The idea is to use a licensed and unlicensed spectrum simultaneously in wireless networks called a hybrid cooperative CR network (HCCRN) to optimize a limited available spectrum. Local coverage of communication is done by cognitive relay with cognitive Radio relay (RR) and it communicates with BS using licensed RR. Thus, it works in full-duplex mode proving to be excellent than conventional relays. On the other hand, local coverage is done through licensed RR and back-haul communication done through cognitive RR. A hybrid scenario is used to efficiently use spectrum where primary and secondary users are combined in underlay mode. The Relay is included in the model for range extension and capacity improvement [6].
Xin-She Yang's stochastic optimization method may be divided into heuristic and metaheuristic classes. Heuristic algorithms search using expert knowledge and experience. These algorithms employ trial and error to obtain the objective function's optimal value in a reasonable time, but they may not yield the optimum global value [7]. The "metaheuristic algorithm" has several advantages that can alter itself to generate optimized versions, possibility of hybridization within these algorithms, and the fact that these algorithms are adaptable against environmental and dynamic changes. ML algorithms are based on math and logic programs. Also, adjust the parameters inside the algorithms to achieve better classification with numerous data. A change in humans for data processing through learning, the programs also changing for data processing over time [8-9].

Section 2 discuss about Literature review. Section 3 discuss about proposed model, mathematical analysis and proposed algorithm. Section 4 discuss about result and discussion and section 5 is conclusion and future scope.

2. LITERATURE REVIEW

An underlay cognitive network with Rayleigh fading channel is considered for analysis of CSI dependent and fault-tolerant strategies. The precise cumulative distribution function (CDF) of the received SNR over each hop is provided to determine the closed-form equation for the outage probability for a transmission rate. Xiao et al. has proposed a power allocation method to optimize the hybrid DF cooperative transmission for multisource multi-relay intelligent transport system (ITS) networks as a means to minimize the total power consumption while reducing outage probability [10]. Closed-form outage probability equations are derived and an energy-efficient relay selection technique is presented to create an optimal relay group. Exact outage probability and ergodic capacity are derived by Duong et al. for CRN where both diversity and coding gains are calculated over independent but non-identically distributed fading [11].
Primary characteristics of the hybrid cooperative Gaussian relay channel (HCGRC) are investigated meticulously by K Xue et al. in regards to capacity, SE and EE [12]. The optimal resource allocation plan is derived and the effects of CR spectrum reliability and relay position on the performance parameters are discussed. Authors have derived the optimal power-bandwidth allocation methods for the cognitive relay to enhance SE, EE and capacity in HCGRC system [13].
Ding et al. suggested two types of low complexity and energy-efficient strategies for uplink cognitive cellular networks [14]. A heuristic resource allocation algorithm is presented to

optimize the Energy Efficiency- Spectrum Efficiency (EE-SE) trade-off concentrating on the medium and high SE [15]. Chamkhia et al. have considered an underlay cognitive network based on OFDM presented new sub-channel selection methods that alter either the sequential order of the best subchannel to boost the system performances or the transmission power [16]. A two-hop DF relayed CR-NOMA (non-orthogonal multiple access) networks over Nakagami-m fading channels is considered by Nauryzbayev et al. [17].

3. PROPOSED SYSTEM

3.1 System Model

The proposed system is a hybrid cooperative CR network cognitive user (CU) , base station (BS), and CR. Primary advantage of utilizing cognitive relay is to achieve enhancement of capacity and range extension. Model considered in Figure 1 is a Rayleigh faded interference model [18]. The full-duplex mode of communication could be feasible under the assumption that BS and Cr operate on separate frequencies without any interference between them. Transmission between SU and BS takes place with power PUB over the bandwidth WUB and between SU and Cr takes place with power PUR over bandwidth WUR in primary band [19].

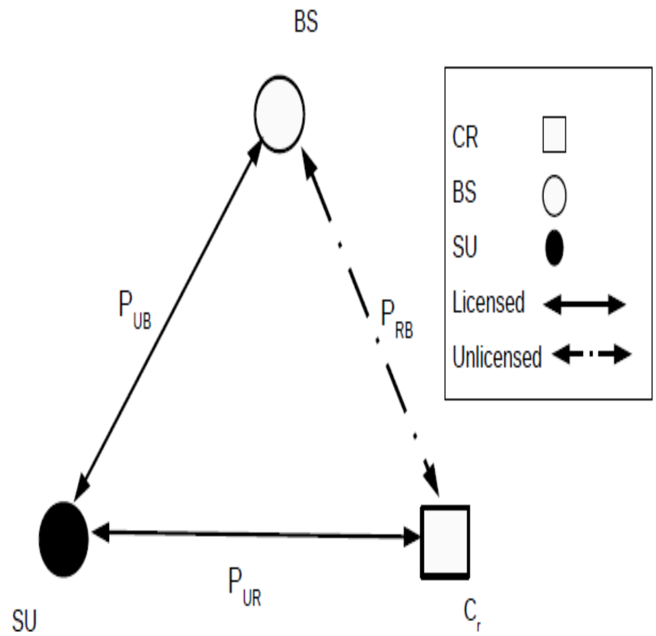


Figure 1. Hybrid Cooperative Relay Network [22]

3.2 Mathematical Analysis

Similar to the concept of SIR, a user is considered to be in an outage state if SNR on a connection fall below a certain level τ_{th}. Outage probability is given by equation (1) for the transmission between SU and BS over a licensed band [20].

$$P_{out} = P_r[\tau_{UB} \leq \tau_{th} \quad (1)$$

The system will lead to outage even if any one of the links fails [21].

$$P_{out} = P_r[\tau_{min} = \min(\tau_{UR}, \tau_{RB}) \leq \tau_{th} \quad (2)$$

PUB, PUR and PRB are the allocated values of powers over respective links chosen to reduce the probability of outage. It is a dual-hop system with one of the hops between users to relay and the other between relay to BS.

$$P_{out} = 1 - P_r[(\tau_{UR} \geq \tau_{th})(\tau_{RB} \geq \tau_{th})] \quad (3)$$

Considering single relay, equations for SNR over the link are

$$\tau_{UR} = \frac{P_{UR}F_{UR}}{NW_{UR}} \quad \text{and} \quad \tau_{RB} = \frac{P_{RB}F_{RB}}{NW_{RB}}$$

$$P_r[(\tau_{UR} \geq \tau_{th})] = P_r[\frac{P_{UR}F_{UR}}{NW_{UR}} \geq \tau_{th}] \quad (4)$$

$$P_r[(\tau_{UR} \geq \tau_{th})] = P_r[\frac{\tau_{th}NW_{UR}}{P_{UR}} < F_{UR}] \quad (5)$$

Rayleigh fading channel has an exponential distribution. So

$$P_r[(\tau_{UR} \geq \tau_{th})] = \int_{\infty}^{\infty} \exp(-\lambda) d\lambda = \exp(x) \quad (6)$$

Where $\quad x = \frac{\tau_{th}NW_{UR}}{P_{UR}} \quad (7)$

$$P_{out} = 1 - \exp[(-\frac{\tau_{th}NW_{UR}}{P_{UR}})(-\frac{\tau_{th}NW_{RB}}{P_{RB}})] \quad (8)$$

$$P_{out} = 1 - \exp[-\tau_{th}N(\frac{W_{UR}}{P_{UR}} + \frac{W_{RB}}{P_{RB}})] \quad (9)$$

The Outage probability P_{out} can be minimized through maximizing the following terms

$$\exp[-\tau_{th}N(\frac{W_{UR}}{P_{UR}} + \frac{W_{RB}}{P_{RB}})] \quad (10)$$

$$\max\left[-\tau_{th}N\left(\frac{W_{UR}}{P_{UR}}+\frac{W_{RB}}{P_{RB}}\right)\right] \quad (11)$$

subject to $P_{UR} + P_{RB} = P_{UB}$. The modified objective function J is written by employing Lagrange's multiplier maximization technique.

$$J = \; -\tau_{th}N\left(\frac{W_{UR}}{P_{UR}}+\frac{W_{RB}}{P_{RB}}\right) - \wedge(P_{UR} + P_{RB} - P_{UB}) \quad (12)$$

Where $\wedge$ is Lagrange's multiplier. Taking derivative of J w.r.t. P_{UR} and P_{RB} and equating it to zero.

$$\frac{dJ}{dP_{UR}} = -\tau_{th}NW_{UR}logP_{UR} - \wedge = 0 \quad (13)$$

$$\frac{dJ}{dP_{RB}} = -\tau_{th}NW_{RB}logP_{RB} - \wedge = 0 \quad (14)$$

Let's assume normalized bandwidth $W_{UR}= W_{RB}=1$

Solving Equation 13 and 14, we get $\log P_{UR} + \log P_{RB} = 0$. Solving further and substituting $P_{UR} + P_{RB} = P_{UB}$ condition the solution in quadratic form is received.

$$P_{out} = 1 - \exp\left[-\tau_{th}N\left(\frac{4}{P_{UB}\pm\sqrt{P_{UB}^2-4}}\right)\right] \quad (15)$$

Outage probability is calculated by examine the direct transmission scheme among users and BS and compared with dual hope scheme.

3.3 Support Vector Machine- Red Deer Algorithm (SVM-RDA)

1. Start
2. Input position of BS, SU, Cr, Rayleigh fading coefficients, noise power density, and transmit power.
3. Calculating the probability of a direct connection (between user and base station) experiencing an outage based on various factors like noise levels, transmission power, and user location.
4. *Initialize* constraints of SVM like weight and bias vector (training).
5. Weight vector is arbitrarily restructured and it can't able to sense spectrum availability precisely.
6. *Initialize* Red Deer populace (weight vectors)
7. Calculate fitness and sort them according to fitness and form hinds and male Red Deers.
8. Apply Lagrange's multiplier maximization and assume normalized bandwidth, WUR = WRB = 1
9. Calculate outage probability for a relayed link of a user to relay and relay to BS link for different noise power density, transmit power and threshold SNR.
10. Calculate overall outage probability from equation 15.
11. Stop

Figure 2 describe about SVM- RDA algorithm.

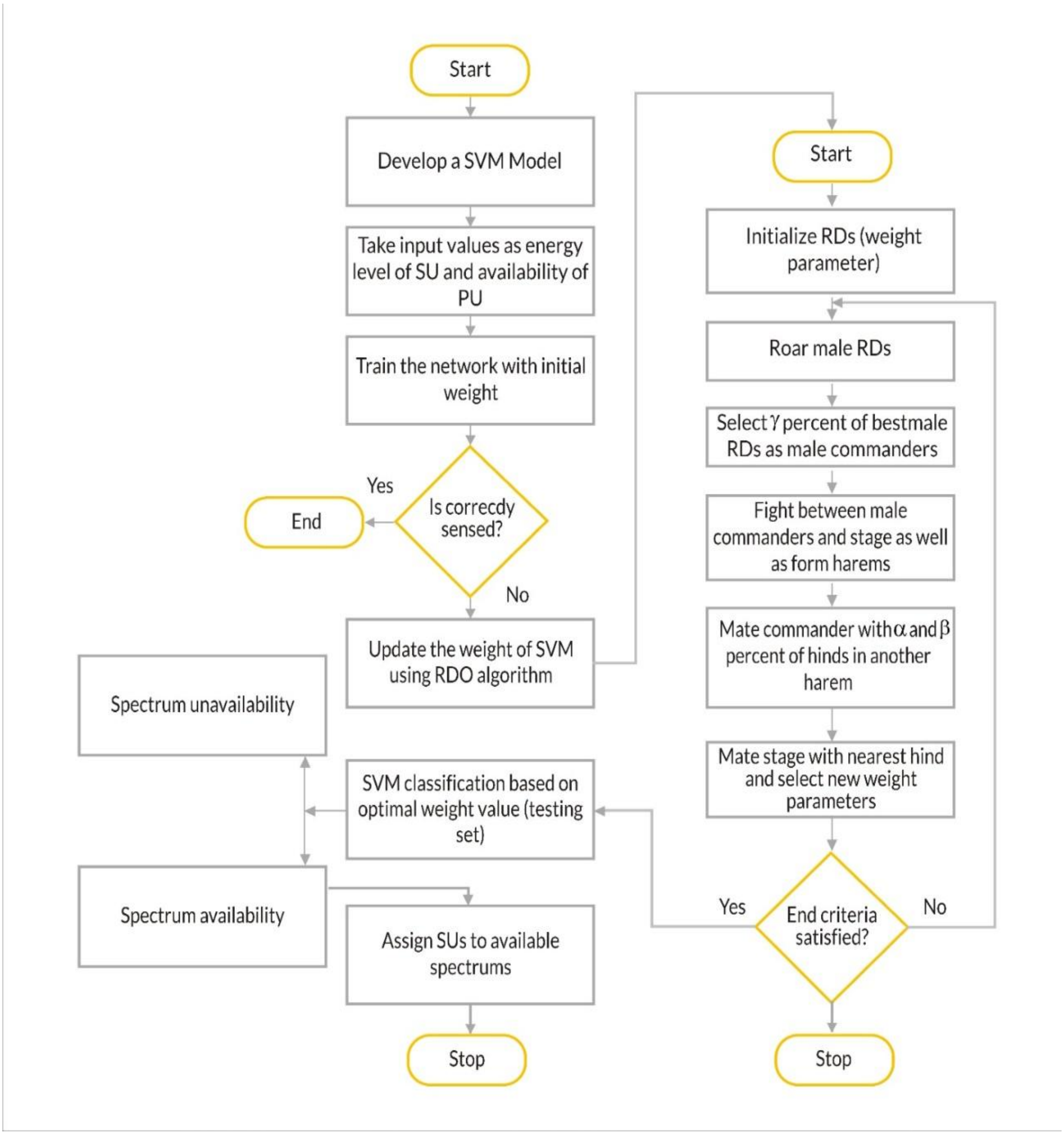


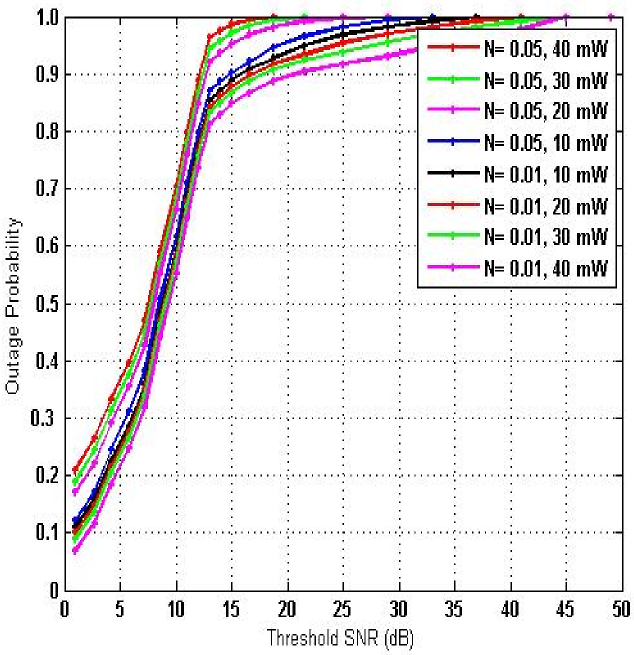
Figure 2 SVM-RDA [22]

4 RESULTS AND DISCUSSION

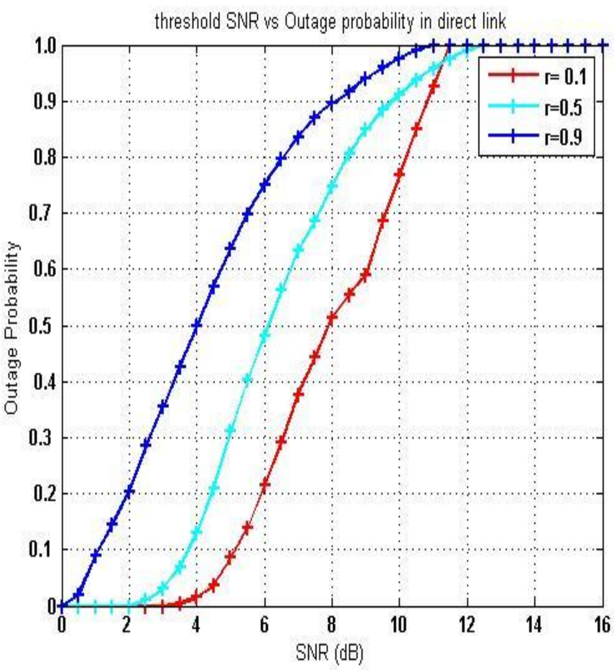
Figure 3 a show that there is an increase in the outage probability with an increase of noise level from N = 0.001 dB to 0.005 dB. For the lower transmit power, the outage probability is more. Result obtained indicates that at a higher value of threshold SNR, the probability of outage increases since link SNR will fall less than the threshold. Table 1 shows that there is a reduction in the outage probability from 0.32 to 0.1 for N=0.001 dB and 0.87 to 0.4 for N=0.005 dB for an increase in transmit power from 10 mW to 40 mW which indicates that an increase in transmit power reduces the outage probability.

The impact of threshold SNR on the outage probability for transmitting power of 40 mW is shown in Table 2. Outage probability increases from 0.02 to 0.64 with an increase in threshold SNR from 5 dB to 20 dB at a noise power density of 0.001 dB. We can observe an increase in the outage probability from 0.64 to 0.99 when noise power increases from 0.001 dB to

0.005 dB. Thus, the outage probability is affected by both threshold SNR and power density of noise.



(a) Outage Probability for different noise levels at various value of transmitted power



(b) Threshold SNR vs outage probability in direct link

Figure 3: Outage Probability

Table 1: Impact of noise and transmit power on the outage probability at threshold SNR=10 dB

Transmit Powe (mW)	Outage Probability at noise power = 0.001 dB	Outage probability at noise power= 0.005 dB
10	0.32	0.87
20	0.27	0.79
30	0.19	0.65
40	0.1	0.4

BS for transmitted power of 10 mW and noise power density of 0.001 dB. Outage

Table 2: Impact of threshold SNR on the outage probability for Transmit Power=40 mW

Threshold SNR	Outage probability at noise power= 0.001 dB	Outage probability at noise power= 0.005 dB
5	0.02	0.12
10	0.1	0.4
15	0.28	0.8
20	0.64	0.99

Table 3: Impact of distance on the outage probability at Threshold SNR= 5 dB

Distance (km)	Outage Probability
0.1	0.02
0.5	0.28
0.9	0.62

Figure 3 b shows the outage probability for users located at different distances from probability is higher for the users who are at a far distance from the BS as can be seen in Table 3 which indicates that the outage probability has increased to 0.62 at 0.9 km from 0.02 at 0.1 km. This scenario is for the direct link between the cognitive user and BS. Figure 3a is the comparative graph for the direct and relayed link showing the relation.

Table 4: Comparison of relayed and direct link on the outage probability for Transmit Power=20 mW

Threshold SNR (dB)	Outage Probability for relayed link	Outage Probability direct link

10	0.59	0
20	0.98	0.02
30	1	0.19
40	1	0.85

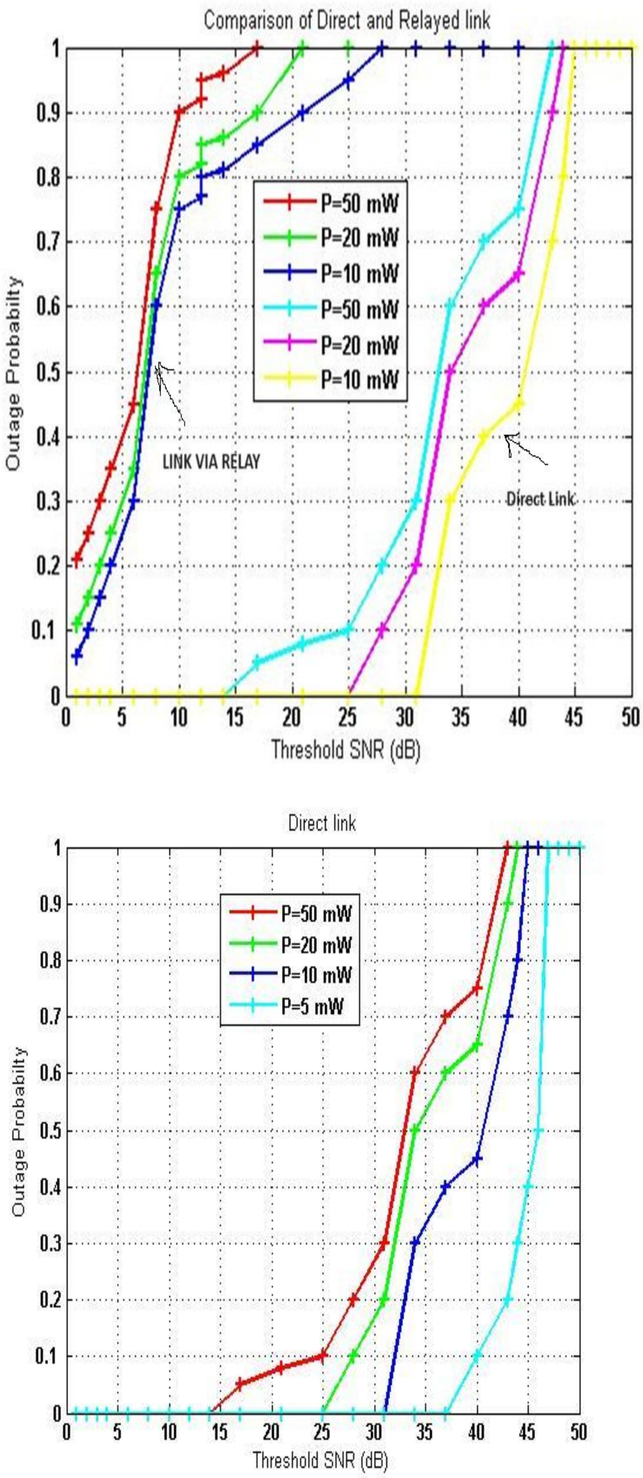


Figure 4: Outage probability versus threshold SNR for several values of transmit power

Figure 4 is graph between the outage probability and threshold SNR. The probability of outage is more in relayed links compared to direct links. The probability of outage is dependent on both the links in the relayed link. Thus the whole system will go into an outage if any one link fails. Despite having more outages, the relayed link can be employed for SUs to enhance the capacity of the system. At 20 mW of transmit power in Table 4, outage probability for a relayed link and direct link is compared for different values of threshold SNR. It can be observed that at 20 dB threshold SNR, the outage probability for the relayed link is 0.98 which is greater than the outage probability for the direct link which is 0.02.

Table 5: Impact of transmit power on the outage probability at N=0.004 dB

Transmit Power (mW)	Outage probability at Threshold SNR = 20 dB	Outage probability at Threshold SNR = 10 dB
5	0.07	0.02
10	0.04	0.01
15	0.03	0
20	0.02	0

Outage probability increases from 0.32 to 0.87 with increase in noise density 0.001 dB to 0.005 dB for 10 mW transmitted power and as transmit power increases from 10 mW to 40 mW the outage probability reduces from 0.32 dB to 0.1 dB for 0.001 dB noise density as can be seen from Table 1. At a higher value of threshold SNR of 20 dB in Table 2, the probability of outage increases to 0.64 at 0.001 dB noise density since link SNR will fall less than the threshold. User experiences more outages as he goes away from the BS as observed in Table 3. The probability of outage is more in relayed links than direct links since it depends on the links from users to relay and relay to BS. Thus, the whole system will go into an outage if any one link fails. Despite having more outages, the system can employ the relayed link for SUs to enhance the system's capacity. Outage probability performance can be improved as observed in Table 4 with the rise in transmit power.

5. CONCLUSION AND FUTURE SCOPE

Interference is the crucial parameter that creates an impact on the performance of any wireless communication system. It is essential to analyze the effect of interference and noise on the system in the uplink to understand the precautions to be taken to minimize the outage. In this research work Rayleigh fading channel is used for proposed HRCN. The model considered consists of a single relay with a Hybrid scenario where licensed radio and cognitive radio are combined to make optimum use of limited available spectrum called hybrid cooperative CR network (HCCRN). At a higher value of threshold SNR, the probability of outage increases since link. SNR will fall less than the threshold. Outage probability increases with noise density. Outage probability analysis of HCCRN in uplink- After the outage probability analysis is done for a hybrid scenario where primary and secondary users are combined; it is essential to do the uplink analysis considering interference and noise in the system. It has been found that more SINR is required to get a lesser outage probability for larger values of interference to noise power ratio. Higher transmit power can be utilized by SU as the interference power permitted to PU is increased. Thus, SINR attained will be high. Thus, the outage probability of SU improves.

The research work presented here can be extended in the following directions-

- In Hybrid Cooperative CRN, another parameter of QoS is blocking probability which can be analyzed for uplink and downlink. It is the probability that the user will be blocked the services due to the complete unavailability of the resources. Such a situation need not arise in wireless communication. To avoid it, certain techniques need to be studied and implemented.
- Mainly, the relays are used for capacity improvement and range extension. In future work, the analysis can be done for the optimum position of relay for promising results.

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