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IMPLEMENTATION OF TWO-WAY AF RELAY CRN AND ITS PERFORMANCE EVALUATION USING OUTAGE PROBABILITY

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***Abstract*-In study of orthogonal-frequency division-multiplexing to examine cognitive two-way relays network with imperfect spectrum sensing, we propose a joint resource allocation algorithm to increase total transmission rate of secondary users (SUs) under maximal transmit power constraints and interference temperature constraints. To answer this joint optimization problem, we implement the discrete searching approach, Lagrange dual decomposition method, and the Hungarian algorithm to obtain the subcarrier pairing matrix, best optimal power allocation and relay selection matrix. By the study of system performance and comparing the algorithm with perfect spectrum sensing the advantage of this algorithm with imperfect spectrum sensing is proved. The results also show the algorithm can protect primary user (PU) while SUs and relays opportunistically enter the spectrum occupied by PU.BER Performance analysis by using Outage Probability.**

In this study, in an cognitive two-way AF relay network based on OFDM to increase total transmission rate of the secondary system under the imperfect spectrum sensing a joint RA algorithm is proposed where time-division half-duplex relays are taken to assist exchange of message between SUs.

***KEYWORDS*: Cognitive Radio Network, Two Way Amplify Forward relay, OFDM, Power Allocation, Relay Selection, Outage Probability.**

I. INTRODUCTION

For ten years there is a rapid development in wireless communication. In telecommunication engineering the wireless communications have grown into the biggest sectors in 21st century. For the growth of business and marketing from 1990's to 21stcentury it is the most promising technology which has been evolved. The most attractive feature in wireless communications is mobility and portability. The user can also carry and handle the devices easily these features also have attracted the users. As every user cannot use this wireless technology however many of the residents were being able to access when Bell Laboratories have introduced cellular concept in 1960's and 1970's. In wireless communication day by day the demand for high data rates, Internet accessing and high reliability are tremendously increased along with the voice communication for the multimedia exchange. 3G technology has been introduced as the demand of high-speed data and voice transmissions, Internet accessing and high reliability was increased by investing huge amount where it supports the data rate upto 2Mbps for transmitting burst data. To meet the requirements like transmission of high-quality multimedia like HD videos or audios and like online shopping it needs to satisfy 100Mbps to 1 Gbps bit rates, a new technology in wireless environment like broad band wireless communications have to be adopted.

In recent years, 5G communications and CRN with RA as a important technique has attracted a lot of attention. 4G and 5G communications are used as they have the advantage of lower interference from orthogonal subcarriers (or channels), higher utilization of spectrum and uses orthogonal frequency-division-multiplexing (OFDM) modulation. The scenarios of multicarrier communication from OFDM technique is applied to cognitive relay networks which resulted in the growth of high data rate wireless communications and the radio spectrum is becoming overcrowded and scarce. The use of spectrum as efficiently as possible is very important under these circumstances. Cognitive radio (CR) is a technique that allows the radio spectrum to be utilized efficiently by two classes of users with two levels of priority: primary and secondary users. In CR networks, the radio spectrum is used by the secondary users by using one of the following strategies: interweave, underlay and overlay. Resource allocation (RA) techniques for wireless communications face not only sustainable developments but also significant challenges with the rapid increase in number of wireless users and various devices. The efficient use radio spectrum resources is one of the difficult challenge. Cognitive radio (CR) technology has the ability to efficiently improve the spectrum utilization. In CR networks (CRNs), there are three spectrum sharing models: interweave, underlay, overlay and hybrid. In the process of development of CRN's, to achieve better performance, power allocation technology plays an important role.

From the viewpoint of information theory to survive with fading and time-varying characteristic of the wireless channels the view of relay networks is presented. By the several standards of classification, relay networks frequently have various kinds of classification: amplify-and-forward (AF) and decode-and-forward (DF) relay networks based on the various forward protocols, one-way and two-way relay networks depending on the various duplex modes, two hop and multi-hop relay networks by depending on the number of hops, and single relay networks and multi-relay networks relying on the number of relays in the networks. Because of the advantages of high-reliability and wide-range of communication, for achieving better performance the relay techniques have been introduced to CRNs.

SCOPE OF THE PROJECT

In this study, an OFDM-based cognitive two-way AF relay network under imperfect spectrum sensing, a joint RA algorithm is proposed to increase the total transmission rate of the secondary system, where time-division half-duplex relays are considered to assist exchange of message between SUs.

II. METHODOLOGY

This paper discusses, the study of cognitive two-way AF relay network which is based on OFDM by using joint RA algorithm with imperfect spectrum sensing is proposed for the secondary system to increase the total transmission rate, by considering time-division half-duplex relays to help the exchange of message between SUs.

The problem of Power optimization is solved by Lagrange dual decomposition method by updating Lagrange multipliers with the sub-gradient approach.
By operating SUs' transmitters and relays' transmitters separately for the power allocation by discrete searching method makes the algorithm extra practical and flexible. To reduce the complexity and obtain the best solution for the subcarrier pairing, Hungarian algorithm is introduced.
By considering PU in two time slots which is demanded by the interference temperature (IT) constraints, with imperfect spectrum sensing the proposed algorithm improves the rate of transmission of SUs and also gives protection for PU when SUs and relays utilize the spectrum of PU with tolerable threshold limited by IT constraints.
In proposed model, we combinedly optimize the two levels which are relay selection and spectrum allocation for answering the problem of spectrum sharing so that under minimal QoS i.e quality of service for primary networks the maximum achievable rate in the secondary network is satisfied.

System Model

In this paper, consider a two-way AF CRN which is based on OFDM where the licensed spectrum of PU is shared by a secondary network with multi-relay for helping the SU's in the communication, as shown in Fig.4.1. Consider SU1 and SU2, are two SU's in a network, i.e., the SU set S={1,2} which exchange the messages with the help of K relays, one pair of PU, and each user operating with time-division half duplex mode with single antenna is equipped.

The Primary User, PU-T and PU-D are represented as transmitter and receiver, respectively and the relays are represented as RS-1, RS-2, ... , RS-k, ... , RS-K, respectively, that is, the relay set K = {1; 2;...; k; .... ;K}. OFDM modulation mode is used by the two PU network and two-way CR relay network. The total bandwidth is separated into Nsubcarriers is assumed, N = {1; 2; · · · ; n; · · · ;N}is defined as the set of all subcarriers. The SUs can access M vacant subcarriers which is given by the set Nv= {1; 2; ....; m;....;M}.The PU occupied the L associated subcarriers which is given by the set No={1; 2; ....l;....;L}, and M + L = N, ∀i; j; q ∈ Nv. To decrease the mutual interference between sub channels (i.e., inter-channel interference (ICI)) all the subcarriers are supposed to be orthogonal to each other and each subcarrier undergo flat fading to remove inter-symbol interference (ISI).

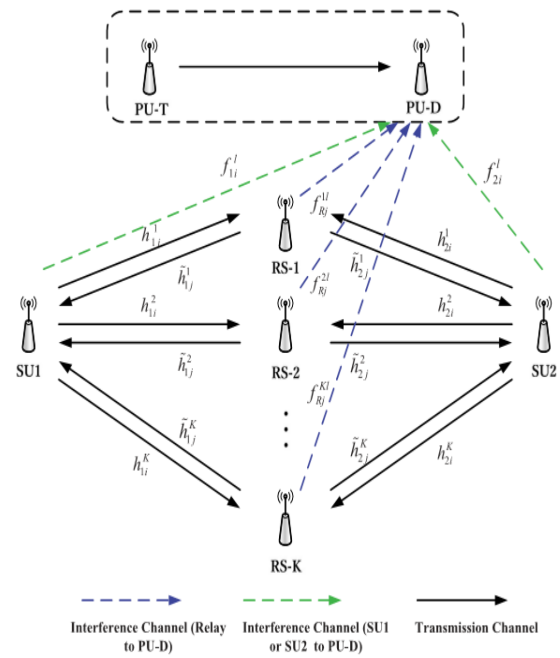

Figure 1: System model

In addition, in cognitive relay network a central control unit is added so that the complete status information of the system is collected and analyzed. The global information to users is broadcasted by the unit, e.g., IT level and channel gains [20]. The other related symbol explanations are given in 4.2. In this CRN system, the two-way AF mode [4] based on the possibilities a relaying selection protocol is used. The direct communications in between two SUs are not considered because of the poor channel statement and large distance. The whole transmission is classified into two phases: In the MA phase on the subcarrier i, the mixed signal from SUs is received by the selected relay, i.e., RS-k, simultaneously and then its amplified and in the BC phase on the subcarrier j, to complete the exchange of message the received signals are broadcasted to SUs . For a selected relay, (i,j) represent the subcarrier *i* in the MA phase is same as the subcarrier j in the BC phase correspondingly, the sub carrier pairing criteria between two phases is utilized, as shown in Fig.1.

SECONDARY NETWORK RATE ANALYSIS

A secondary network with MA and BC phases by a two-way AF relay strategy with the time period and no direction communication between SUs is studied. Consider that each subcarrier pair is allotted with one relay in order to avoid inter relay interference, but one relay can be allowed to be chosen by multiple subcarrier pairs. Now, the complete process of exchange of signals can be given as follows:

P_{1i}^{k} SU1's Transmit Power on ith subcarrier for the k^{th} relay
P_{2i}^{k} SU2's Transmit Power on ith subcarrier for the k^{th} relay
P_{Rj}^{k} k^{th} relay's transmit power on jth the subcarrier
h_{1i}^{k} SU1's Channel gain on ith subcarrier to the k^{th} relay
h_{2i}^{k} SU1's Channel gain on ith subcarrier to the k^{th} relay
h_{1j}^{k} k^{th} relay's Channel gain on jth the subcarrier to the SU1
h_{2j}^{k} k^{th} relay's Channel gain on jth the subcarrier to the SU2
f_{1i}^{l} SU1's channel gain with Interference on the ith subcarrier to PU on the lth subcarrier
f_{2i}^{l} SU2's channel gain with Interference on the ith subcarrier to PU on the lth subcarrier
f_{Rj}^{kl} Kth relay's channel gain with Interference on the ith subcarrier to PU on the lth subcarrier

MA phase

In the MA phase, on the allocated subcarriers, SU1 and SU2 signals are transmitted at the same time to the selected relay. For example, at the selected relay the signal received (i.e., the k^{th}relay) on the ith subcarrier is

$$y_i^k = \sqrt{P_{1i}^k h_{1i}^k x_{1i}^k} + \sqrt{P_{2i}^k h_{2i}^k x_{2i}^k} + \theta_i^k \qquad (1)$$

Where the unit power symbols is denoted by $x_{1i}^k$and x_{2i}^k, which is transmitted by SU1 and SU2 on ith subcarrier, respectively. And assume that $E[|x^k_{1i}|^2] = E[|x^k_{2i}|^2]=1$, where $|\cdot|$ indicates the definite value of a complex number and $E[\cdot]$ represent the expectation operator[11]. The additive white Gaussian noise (AWGN) [3] on the ith subcarrierat the k^{th} relay is given by θ^k_i.

BC phase

The signal is amplified and broadcasted to SUs by the selected relay RS-k after receiving the signal from SUs, with the amplification factor$|\mu_j^k| = \frac{1}{\sqrt{P_{1i}^k|h_{1i}^k|^2+P_{1i}^k|h_{1i}^k|^2+\sigma^2}}$on the jth subcarrier in BC phase, where the AWGN thermal noise power is denoted by σ^2 and it is the similar for other receivers in this CRN system.

$$y_{1j}^k = \mu_j^k\sqrt{P_{Rj}^k}\sqrt{P_{1i}^k h_{1j}^k h_{1i}^k x_{1i}^k} + \mu_j^k\sqrt{P_{2i}^k h_{1j}^k h_{2i}^k x_{2i}^k} + \mu_j^k\sqrt{P_{Rj}^k}\, h_{1j}^k \theta_i^k + \theta_{1j} \qquad (2)$$

$$y_{2j}^k = \mu_j^k\sqrt{P_{Rj}^k}\sqrt{P_{2i}^k h_{2j}^k h_{2i}^k x_{2i}^k} + \mu_j^k\sqrt{P_{1i}^k h_{2j}^k h_{1i}^k x_{1i}^k} + \mu_j^k\sqrt{P_{Rj}^k}\, h_{2j}^k \theta_i^k + \theta_{2j} \qquad (3)$$

Where at SU1 and SU2 on the jth subcarrier the broadcasted signals received by RS-k is given as $y_{1j}^k$and y_{2j}^k, respectively. The AWGN at SU1 and SU2 are θ_{1j} and θ_{2j} [3] on the j subcarrier. In the procedure of modelling of wireless channel, the exact CSI is taken into account by channel estimation algorithms, and each other's precise channel gains of SU's can be known. Thus, self-interference [11] can be easily removed as the first unit in (2) and the first element in (3) which are known. Then, at SU1and SU2 along RS-k over the subcarrier pair (i,j) the equivalent signal-and-noise ratio (SNR) can be specified as follows [11]

$$\gamma_1^{i,j,k} = \frac{P_{2i}^k P_{Rj}^k |h_{2i}^k|^2 |h_{1j}^k|^2 |\mu_j^k|^2}{P_{Rj}^k |h_{1i}^k|^2 |\mu_j^k|^2 \sigma^2 + \sigma^2} \qquad (4)$$

$$\gamma_2^{i,j,k} = \frac{P_{1i}^k P_{Rj}^k |h_{1i}^k|^2 |h_{2j}^k|^2 |\mu_j^k|^2}{P_{Rj}^k |h_{2j}^k|^2 |\mu_j^k|^2 \sigma^2 + \sigma^2} \qquad (5)$$

Where,$|\mu_j^{k^2}| = \frac{1}{P_{1i}^k|h_{1i}^k|^2+P_{2i}^k|h_{2i}^k|^2+\sigma^2}$.To calculate the formulas, by dividing (4) and (5) with $|\mu^k_j|^2\sigma^4$, respectively. Then, (4) and (5) can be correspondingly rewritten as

$$\gamma_1^{i,j,k} = \frac{P_{2i}^k P_{Rj}^k H_{2i}^k H_{1j}^k}{P_{Rj}^k H_{1j}^k + P_{1i}^k H_{1i}^k + P_{2i}^k H_{2i}^k + 1} \qquad (6)$$

$$\gamma_2^{i,j,k} = \frac{P_{1i}^k P_{Rj}^k H_{1i}^k H_{2j}^k}{P_{Rj}^k H_{2j}^k + P_{1j}^k H_{1i}^k + P_{2i}^k H_{2i}^k + 1} \qquad (7)$$

Where, $H_{2i}^k = |h_{2j}^k|^2/\sigma^2$ and $H_{1i}^k = |h_{1i}^k|^2/\sigma^2$

Therefore, by the help of the two-way relay RS-k the rate of transmission of SUs (i.e., SU1 and SU2) on the matched subcarrier pair $(i; j)$ can be given as [11]

$$R_{AF}^{i,j,k} = \frac{1}{2}\log_2\left(1+\gamma_1^{i,j,k}\right) + \frac{1}{2}\log_2\left(1+\gamma_1^{i,j,k}\right) \qquad (8)$$

To complete the exchange of message between SU's the two orthogonal time slots were required which is denoted by the multipliers (i.e., two 1/2).

INTERFERENCE MODE

Because of the characteristics of CRNs, to give protection for PU's communication when SUs is allocated with frequency spectrum the IT limitations of PU must be considered. In two time-slots the interference to the PU are discussed as the relays are in half-duplex mode.

Perfect spectrum sensing

In this case, consider that SUs do not work with PU on the same subcarrier. In other words, when the frequency bands are accessed which are allowed by PU, then SUs can absolutely detect state of spectrum then avoid collision. Thus, in the 1st time slotI_1^i is the SUs interference power on ith the subcarrier to PU-D, and in the 2nd time slot I_2^i is the relays interference power on jth subcarrier at PU-D, can be given by

$$I_1^i = \sum_{k\in K}\left(P_{li}^k \sum_{l\in N_o}|f_{1i}^l|^2 + P_{2i}^k \sum_{l\in N_o}|f_{2i}^l|^2\right) \qquad (9)$$

$$I_2^i = \sum_{k\in K}\left(P_{Rj}^k \sum_{l\in N_o}|f_{Rj}^{kl}|^2\right) \qquad (10)$$

As a result, in two timeslots the power constraints with interference can be given by

$$I_1 = \sum_{i\in N_v}\sum_{k\in K}\left(P_{li}^k \sum_{l\in N_o}|f_{1i}^l|^2 + P_{2i}^k \sum_{l\in N_o}|f_{2i}^l|^2 \leq I^{th}\right. \qquad (11)$$

$$I_2 = \sum_{j\in N_v}\sum_{k\in K}\left(P_{Rj}^k \sum_{l\in N_o}|f_{Rj}^{kl}|^2 \leq I^{th}\right. \qquad (12)$$

Where, $I^{th}$is the IT threshold described by PU.

Imperfect spectrum sensing

In this case, the method of formulating the interference model with imperfect spectrum sensing is considered. The effect of the imperfect spectrum sensing in mathematical expression is mostly on detection probability. Let the subcarrier with PU active and inactive is represented as O_m and V_m, the results of detection of the subcarrier m which is occupied and unoccupied by PU, is given as $\hat{O}_m$ and $\hat{V}_m$, respectively. Thus, Q_m= Pr{O_m} or 1−Q_m= Pr{V_m} can be denoted as the probability of active or inactive of PU on the *m* subcarrier, Q^{md}_m= Pr{ $\hat{V}_m|O_m$} and Q^{fa}_m=Pr{$\hat{O}_m|V_m$} the probability of false detection and incorrect-alarm probability on the subcarrier *m* respectively, where probability operator are denoted by Pr{O_m} + Pr{V_m} = 1and Pr{O_m| $\hat{V}_m$} + Pr{V_m| $\hat{V}_m$} = 1, and Pr{ ·} [24].

In this, the imperfect spectrum sensing will effect the communication to both PU and SU for cognitive relay network which is based on OFDM:

- From miss-detection of sensing errors, the co-channel interference to PU would make the SU utilize the spectrum used by PU, the communication of SUs will get affected by the interference from PU-T, and it will also give harmful interference to PU.
- The wastage of spectrum hole will degrade the performance of SUs, for example, SU's the transmission capacity, would make empty frequency band since incorrect-alarm sensing errors which is identified as the utilized one by PU.

According to the Bayes theorem, to describe the effects on CRNs by the imperfect spectrum sensing [24], 2 conditional probabilities of detection are expressed as

$$P_r\{O_m|\tilde{V}_m\} = \frac{P_r\{v_m|O_m\}P_r\{O_m\}}{P_r\{\tilde{V}_m|O_m\}P_r\{O_m\}+P_r\{\tilde{V}_m|v_m\}P_r\{v_m\}} \quad (13)$$

$$P_r\{O_m|\hat{O}_m\} = \frac{P_r\{\hat{O}_m|O_m\}P_r\{O_m\}}{P_r\{\hat{O}_m|O_m\}P_r\{O_m\}+P_r\{\hat{O}_m|v_m\}P_r\{v_m\}} \quad (14)$$

Let β_m= Pr{$O_m|\hat{V}_m$} and α_m= Pr{$O_m|\hat{O}_m$}, then

$$\beta_m = \frac{Q_m^{md}Q_m}{Q_m^{md}Q_m+(1-Q_m^{fa})(1-Q_m)} \quad (15)$$

$$\alpha_m = \frac{(1-Q_m^{md})Q_m}{(1-Q_m^{md})Q_m+Q_m^{fa}(1-Q_m)} \quad (16)$$

Where the miss detection with conditional probability is denoted by β_m which actually is PU occupies $m\in Nv$ subcarrier, but the secondary network find it as empty based on sensing information; the conditional probability that the subcarrier $m \in No$ is practically treated as used by PU and busy is represented by α_m. Similarly, as case1 (i.e., with perfect spectrum sensing the interference model), consider the process of evaluating the interference model with imperfect spectrum sensing.

Under imperfect spectrum sensing, in two time slots on the subcarriers *i*and *j*, consider the interference from SUs and relays, respectively, given as

$$\bar{I}_1{}^i = \sum_{k\in K}(P_{1i}^k(\sum_{l\in N_o} P_r\{O_l|\bar{O}_l\}|f_{1i}^l|^2 + \sum_{q\in N_v} P_r\{O_q|\tilde{V}_q\}|f_{1i}^q|^2))$$

$$\sum_{k\in K}(P_{2i}^k(\sum_{l\in N_o} P_r\{O_l|\bar{O}_l\}|f_{2i}^l|^2 + \sum_{q\in N_v} P_r\{O_q|\tilde{V}_q\}|f_{2i}^q|^2)) \quad (17)$$

$$\bar{I}_2{}^i = \sum_{k\in K}(P_{Rj}^k(\sum_{l\in N_o} P_r\{O_l|\bar{O}_l\}|f_{Rj}^{kl}|^2 + \sum_{q\in N_v} P_r\{O_q|\tilde{V}_q\}|f_{2i}^q|^2)) \quad (18)$$

Where the interference power is denoted by $\tilde{I}^i_1$ and $\tilde{I}^i_2$ from SU's (secondary users) and relays at PU-D with the subcarrier pair (i,j) in two time slots, respectively. The quantities $\tilde{F}_{1i}$and $\tilde{F}_{2i}$ are the interference factors for the subcarrier *i*, and $\tilde{F}^k_{Rj}$is the interference factor for the subcarrier *j*. By comparing with perfect spectrum sensing i.e case1, in two time slots the interference power constraints can be given as

$$\bar{I}_1 = \sum_{i\in N_v}\sum_{k\in K}(P_{li}^k\dot{F}_{1i} + P_{2i}^k\dot{F}_{2i} \le I^{th} \quad (19)$$

$$\bar{I}_2 = \sum_{j\in N_v}\sum_{k\in K}(P_{Rj}^k F_{Ri}{}^k) \le I^{th} \quad (20)$$

In addition, as imperfect spectrum sensing is considered, in practice the SU's transmission rate can be changed by power allocation. Therefore, the SU's transmission rate of SUs with assistance of the relay RS-k on the subcarrier pair (i,j) can be given as [25]

$$\hat{R}_{AF}^{i,j,k} = P_r\{V_i|\tilde{V}_i\}P_r\{V_j|\tilde{V}_j\}R_{AF}^{i,j,k} = (1-\beta_i)1-\beta_j)R_{AF}^{i,j,k} \quad (21)$$

Where Pr{V_i| $\hat{V}_i$} (Pr{V_j | $\hat{V}_j$}) represents the posterior conditional probability on that subcarrier *i* ,(*j*) is inactive practically and consider as empty by the secondary network.

PROBLEM FORMULATION

In this paper, in the process of RA the relay selection and subcarrier pairing schemes are choosen. We take

$$\Psi = \{\Psi_{i,j}^k\}M \times M \times K$$

subcarrier pairs and relay assignment matrix is denoted,

$$\Psi_{i,j}^k \epsilon\{0,1\}$$

for the *kth* relay the binary matching factor is given.

$$\Psi_{i,j}^k = 1$$

to RS-k the subcarrier pair ⟨*i; j*⟩ is allocated, otherwise

$$\Psi_{i,j}^k = 0$$

In subcarrier pairing term, is given as

$$\eta = \{\eta_{i,j}\}M \times M$$

denotes the subcarrier pairing matrix, where

$$\eta_{i,j}\epsilon\{0,1\}$$

In the MA phase with *ith*subcarrier and in BC phase with the j^{th}subcarrier are paired, then

$$\eta_{i,j} = 1, \text{otherwise}, \eta_{i,j} = 0$$

By the above introduction and discussion, the best solution with and without spectrum sensing errors is formulated.

Optimal problem based on perfect spectrum sensing

In this case, to increase the transmission rate of the secondary network we develop an optimization problem under several constraints: *C*2 and *C*3 represent the SUs and relays maximum transmit power constraints, respectively; *C*4and *C*5 denote the interference power constraints in two time slots which is limited by PU, respectively.

$$\textbf{OP1}\ \psi, \eta, P^{max} \sum_{i\in N_v}\sum_{j\in N_v}\sum_{k\in K}\Psi_{i,j}^k\eta_{i,j}\hat{R}_{AF}^{i,j,k}$$

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$$s.t\begin{cases} C1': \sum_{i\in N_v}\eta_{i,j}=1, \sum_{j\in N_v}\eta_{i,j}=1, \sum_{k\in K}\Psi_{i,j}^k=1, \forall_{i,j} \\ C2': \sum_{i\in N_v}\sum_{k\in K}P_{ai}^k \le P_a^{max}, \quad a\in\{1,2\} \\ C3': \sum_{j\in N_v}P_{R_j}^k \le P_{R_k}^{max}, \forall_k \end{cases}$$

$$\text{s.t}\begin{cases} C4': \sum_{i\in N_v}\sum_{k\in K}(P_{li}^k\sum_{l\in N_o}|f_{1i}^l|^2 + P_{2i}^k\sum_{l\in N_o}|f_{2i}^l|^2) \le I^{th} \\ C5': \sum_{j\in N_v}\sum_{k\in K}(P_{Rj}^k\sum_{l\in N_o}|f_{Rj}^{kl}|^2) \le I^{th} \end{cases} \quad (22)$$

Where, $P \triangleq \left(P_{1i}^k, P_{2i}^k, P_{R_j}^k\right)$ represent the SU1's, SU2's and the selected relay's RS-k transmit power RS- allocated on the subcarrier pair $\langle i;\ j\rangle$. $P^{max}{}_a(a\in\{1;\ 2\})$ and $P^{max}{}_{Rk}$ are the of SUs and the relay's RS-k maximum transmit power.

Optimal problem based on imperfect spectrum sensing

Under the case, similar to **OP1** the imperfect spectrum sensing is considered, for improving the performance of the cognitive two-way relay network the following optimization problem **OP2** is proposed. It is better to adapt to the complicated communication environment practically.

$$\textbf{OP2}\psi,\eta,P^{max}\sum_{i\in N_v}\sum_{j\in N_v}\sum_{k\in K}\Psi_{i,j}^k\eta_{i,j}\hat{R}_{AF}^{i,j,k}$$

$$s.t\begin{cases} C1': \sum_{i\in N_v}\eta_{i,j}=1, \sum_{j\in N_v}\eta_{i,j}=1, \sum_{k\in K}\Psi_{i,j}^k=1, \forall_{i,j} \\ C2': \sum_{i\in N_v}\sum_{k\in K}P_{ai}^k \le P_a^{max}, \quad a\in\{1,2\} \\ C3': \sum_{j\in N_v}P_{R_j}^k \le P_{R_k}^{max},, \forall_k \end{cases}$$

$$\text{S.t}\begin{cases} C4': \sum_{i\in N_v}\sum_{k\in K}(P_{li}^kF_{li}+P_{2i}^kF_{2i}) \le I^{th} \\ C5': \sum_{j\in N_v}\sum_{k\in K}(P_{Rj}^kF_{Ri}{}^k) \le I^{th} \end{cases} \quad (23)$$

where $C2'$ and $C3'$ denotes the maximum transmit power constraints; $C4'$ and $C5'$ represent the interference in two time slots from the secondary network to PU, which should be below the interference threshold so that relay and SUs can access the spectrum and communication of PU can be protected. By comparing **OP2** with **OP1**, we find that **OP2** can be converted to **OP1** when α_l= 1 and β_q= 0, $\forall l\in No$, $\forall q\in Nv$.

JOINT RESOURCE ALLOCATION BASED ON DUAL DECOMPOSITION

By the above discussion, (23) a mixed-integer programming problem can be known, since the optimal solutions ($\psi*;\eta*;$P$*$) consist of two discrete variables $\Psi_{i,j}^{k\ *}$ and $\eta_{i,j}{}^*$ and continuous variable **P**$*$= ($Pk1i*$ $Pk2i*;PRj*$).By considering to [26] and [27], if it satisfies the time-sharing characteristic then the optimization problem has a zero duality gap. Thus, to solve **OP2,** the Lagrange dual decomposition method [28] is used to get the optimal solutions, in multicarrier networks the optimal resource non-convex problem (i.e.,**OP2**) with the duality gap can be ignored. The **OP2** with Lagrange function can be given as

$$\begin{aligned} \mathrm{L}(\psi,\eta,P,\lambda) = &\sum_{i\in N_v}\sum_{j\in N_v}\sum_{k\in K}\Psi_{i,j}^k\eta_{i,j}\hat{R}_{AF}^{i,j,k} \\ &-\sum_{a\in\{1,2\}}\lambda_{S_a}\left(\left(\sum_{i\in N_v}\sum_{k\in K}P_{ai}^k\right)-P_a^{max}\right) \\ &-\sum_{k\in K}\lambda_{R_k}\left(\left(\sum_{i\in N_v}P_{R_j}^k\right)-P_{R_k}^{max}\right) \\ &-\lambda_{I_1}\left(\left(\sum_{i\in N_v}\sum_{k\in K}P_{li}^kF_{li}+P_{2i}^kF_{2i})\right)-I^{th}\right)\right) \\ &-\lambda_{I_2}\left(\left(\sum_{i\in N_v}\sum_{k\in K}P_{Rj}^kF_{Ri}{}^k)\right)-I^{th}\right)\right) \end{aligned} \quad (24)$$

Where, $\lambda=[\lambda_{S_1},\lambda_{S_2},\lambda_{R_1},\dots\dots\lambda_{R_k},\lambda_{I_1},\lambda_{I_2}]_{1\times(K+4)}$ is the vector of Lagrange multipliers, in which all the elements are positive number. Thus, the **OP2** with dual function can be given as

$$\mathrm{D}(\lambda) \triangleq \max_{(\psi,\eta)\in\hat{J},P\in p} \mathrm{L}(\psi,\eta,P,\lambda)$$

$$\text{s.t}\sum_{i\in N_v}\eta_{i,j}=1, \sum_{j\in N_v}\eta_{i,j}=1, \sum_{k\in K}\Psi_{i,j}^k=1, \forall_{i,j} \quad (25)$$

Where, the set of all subcarrier pairings which are possible and the subcarrier pairs with relay matching is denoted by J= $\left\{(\psi,\eta)\,|\psi:\sum_{k\in K}\Psi_{i,j}^k=1,\ \ \eta\ :\ \sum_{i\in N_v}\sum_{j\in N_v}\eta_{i,j}=1\right\}$. P denotes all the set of discrete and adaptable power allocation of $P\triangleq(P_{1i}^k,P_{2i}^k,P_{R_j}^k)$ for the given matrixes $\varphi$and η, the definition in detail is

$$p(\psi,\eta)=\{P=\left(P_{1i}^k,P_{2i}^k,P_{R_j}^k\right)|\,P_{1i}^k\ge0, P_{2i}^k\ge0\ and\ P_{R_j}^k\ge 0\ \text{for}\Psi_{i,j}^k\eta_{i,j}=1$$
$$and\ P_{1i}^k=0, P_{2i}^k=0\ and\ P_{R_j}^k=0\ for\ \Psi_{i,j}^k\eta_{i,j}=0\}(26)$$

Then, the OP2 with dual optimization problem can be given by $\lambda^{min}D(\lambda)$s.t $\lambda\ge0$ (27)

POWER ALLOCATION ALGORITHM

The subcarrier pair and relay assignment is $\langle i;\ j;\ k\rangle$ is assumed, in order to optimize power allocation **P**' for dual variable vector λ' given then, the transmission power allocation with the dual function $D(\lambda)$ can be written as

$$\mathrm{D}_1(\lambda)=\max_{(\psi,\eta)\in\hat{J},P\in p}\left[\sum_{i\in N_v}\sum_{j\in N_v}\sum_{k\in K}W_{AF}^{i,j,k}+\sum_{a\in\{1,2\}}\lambda_{S_a}P_a^{max}\right.$$
$$\left.+\sum_{k\in K}\lambda_{R_k}P_{R_k}^{max}+(\lambda_{I_1}+\lambda_{I_2})I^{th}\right](28)$$

Where, $W_{AF}^{i,j,k} \triangleq \hat{R}_{AF}^{i,j,k} - \sum_{a\in\{1,2\}} \lambda_{S_a} P_{ai}^k - \lambda_{R_k} P_{R_j}^k - \lambda_{I_1}(P_{1i}^k F_{li} + P_{2i}^k F_{li}) - \lambda_{I_2} P_{R_j}^k F_{R_j}^k$. The first sub-problem can be given as

$$\text{SP1} \;\; P \triangleq (P_{1i}^k, P_{2i}^k, P_{R_j}^k)^{max} W_{AF}^{i,j,k}$$
$$\text{s.t } P_{1i}^k, P_{2i}^k, P_{R_j}^k \geq 0 \quad (29)$$

In multi carrier scene for cognitive two-way multi-relay network, there are different multicast users (relays and SUs) and also various channels (i.e., channels between users over all the subcarriers). In the outcome for different users the power allocation in (29) is individual from each other and to find transmit power of the secondary network in the closed-form solutions is difficult. Hence, to find individual values of transmission power, the searching method [10] [26] is used. In the searching algorithm, ρ is defined as the step size, then the numbers of searching can be derived for the temporary optimal power allocation $P' = (P_{1i}^{k\prime}, P_{2i}^{k\prime}, P_{Ri}^{k\prime})$ as $Y_k = P_{Rk}^{max}/\rho$ for the kth relay and $Y_a = P_a^{max}/\rho$, aϵ\{1,2\} for SUs. Thus, for the searching algorithm $O(Y_1Y_2Y_k)$ is the computational complexity and for finding the temporary optimal transmission power the computational complexity for all (i,j,k) assignments will be $\hat{O}(M^2 Y_1 Y_2 \sum_{k\in K} Y_k)$.

The algorithm given below is the power allocation algorithm.

Algorithm 1: Power allocation (with Discrete Searching)

Input: Parameters λ', I^{th}, P_{Rk}^{max}, P_a^{max}, aϵ\{1,2\} for a given assignment (i,j,k)

Output: Optimal power allocation $P' = (P_{1i}^{k\prime}, P_{2i}^{k\prime}, P_{Ri}^{k\prime})$

Step 1 Initial calculation

/* each assignment (i,j,k) */
For each k ϵ {1.2……K},do
For each iϵ {1.2……M},do
For each j ϵ {1.2……M},do
/* Discrete Searching*/
For count 1= ρ: ρ: P_1^{max}, do
For count 2= ρ: ρ: P_2^{max}, do
For count 3= ρ: ρ: P_{Rk}^{max}
/* finding of maximum $W_{AF}^{i,j,k}$ */
Do max $W_{AF}^{i,j,k}$ s.t $P_{1i}^{k\prime}, P_{2i}^{k\prime}, P_{Ri}^{k\prime} \geq 0$
P $\Delta(P_{1i}^{k\prime}, P_{2i}^{k\prime}, P_{Ri}^{k\prime})$
/* finding optimal P' */
If $W_{AF}^{i,j,k} \leftarrow$ max $W_{AF}^{i,j,k}$
do $P' = (P_{1i}^{k\prime}, P_{2i}^{k\prime}, P_{Ri}^{k\prime})$
end end end end end end end

Step 2 Go to A**lgorithm 2: Relay Selection**

RELAY SELECTION ALGORITHM

By substituting into (28), the dual $P' = (P_{1i}^{k\prime}, P_{2i}^{k\prime}, P_{Ri}^{k\prime})$ function can be changed as

$$D_2(\lambda) = \max_{(\psi,\eta)\in \hat{J}} \left[\sum_{i\in N}\sum_{j\in N}\sum_{k\in K} \psi_{i,j}^k \eta_{i,j} V_{AF}^{i,j,k} + \sum_{a\in\{1,2\}} \lambda_{S_a} P_a^{max} + \sum_{k\in K} \lambda_{R_k} P_{R_k}^x + (\lambda_{I_1} + \lambda_{I_2}) I^{th}\right] \quad (30)$$

Where, $V_{AF}^{i,j,k} = W_{AF}^{i,j,k}|_{P=P'}$. Then, by solving the second sub-problem for the given subcarrier pairs (i, j) the best relay selection strategy can be obtained

$$\text{SP2} \;\; \Psi = \{\Psi_{i,j}^{k}\}^{max}_{M\times M\times K} V_{AF}^{i,j,k}$$
$$\text{s.t} \sum_{k\in K} \Psi_{i,j}^k = 1, \forall_{i,j} \quad (31)$$

As a result, the element $\psi^k_{i;j}$ satisfies temporary optimizing relay selection matrix ψ'

$$\Psi_{i,j}^{k\prime} = \begin{cases} 1, & K' = K'(i,j) = \arg max_k V_{AF}^{i,j,k}, \forall_{i,j} \\ & 0, \text{otherwise} \end{cases} \quad (32)$$

In this part, for optimal relay selection algorithm the computational complexity is $O(K)$ for the subcarrier pairs (i,j). In MA and BC phases, M^2 of possible combinations there are for subcarrier pairs. For the optimal relay assignment algorithm $O(KM^2)$ is the computational complexity. By Algorithm 2 for a given subcarrier pairs (i,j) the relay selection process can be given.

Algorithm2: Relay Selection

Input: Parameters λ', I^{th}, P' for a given assignment (i,j,k)

Output: Optimal power allocation $\Psi' = \{\Psi_{i,j}^k\} M\times M\times K$

Step 1 Initial calculation

/* each assignment (i,j,k) */
For each I ϵ {1.2……M},do
For each J ϵ {1.2……M},do
For each k ϵ {1.2……K},do
/* finding of maximum $V_{AF}^{i,j,k}$ */
Do max $V_{AF}^{i,j,k}$ s.t $\sum_{k\epsilon K} \Psi_{i,j}^k = 1, \forall_{i,j}$
$\Psi' = \{\Psi_{i,j}^k\}_{M\times M\times K}$
/* finding optimal Ψ' */
If $V_{AF}^{i,j,k} \leftarrow$ max $V_{AF}^{i,j,k}$
do $\Psi_{i,j}^k = 1, k' = k'_{(i,j)}$ = arg $max_k V_{AF}^{i,j,k}, \forall_{i,j}$
end end end end

Step 2 Go to A**lgorithm 3**

SUBCARRIER PAIRING ALGORITHM

By taking the above sub-sections A and B, and by substituting $\boldsymbol{\psi}$ into (30), the dual function $D_3(\lambda)$ achieved is,

$$D_3(\lambda) = \max_{\eta\in \hat{J}} \left[\sum_{i\in N}\sum_{j\in N} \eta_{i,j} Z_{AF}^{i,j} + \sum_{a\in\{1,2\}} \lambda_{S_a} P_a^{max} + \sum_{k\in K} \lambda_{R_k} P_{R_k}^x + (\lambda_{I_1} + \lambda_{I_2}) I^{th}\right] \quad (33)$$

and the best temporary optimal subcarrier pairing matrix can be achieved by solving the third sub-problem

$$\text{SP3} \;\; \eta = \{\eta_{i,j}^{max}\}_{M\times M} Z_{AF}^{i,j}$$
$$\text{s.t} \sum_{i\in N_v} \eta_{i,j} = 1 \; and \; \sum_{j\in N_v} \eta_{i,j} = 1, \forall_{i,j} \quad (34)$$

Where, $Z_{AF}^{i,j} = \arg \max V_{AF}^{i,j,k}, \forall (i,j)$. Because of the characteristic of linear assignment of **SP3**, the Hungarian algorithm [29] [30] is adopted with $O(M^3)$ which is the computational complexity, and Algorithm 3 which describes the detailed process is given below. As a result, solving **SP3**

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the subcarrier pairing matrix η' which optimize temporarily is determined.

Algorithm 3: Hungarian Algorithm for Subcarrier pairing

Input: Benefit Matrix $Z_{AF} = \{Z_{AF}^{i,j}\}, \forall_{i,j} \epsilon N_v$
Output: Optimal assignment$\eta' = \{\eta'_{i,j}\}_{M\times M}$
Step 1 Initial Reduction
For each iϵ {1.2……M},
/*row reduction */
Do $X_i = Z_{AF}^{i,j} - min_{\forall j} Z_{AF}^{i,j}$;
For each j ϵ {1.2……M},
/*column reduction */
Do $Y_i = Z_{AF}^{i,j} - (min_{\forall j} Z_{AF}^{i,j}) - X_i$;
/*Optimal check*/
Matching – count = or ≠ 0;
/*attempt at allocation */
Covering all zero elements inZ_{AF} in few lines as possible;
/*covering and lining*/
The count of covered lines nl;
/*scale of Z_{AF}*/
If nl = size(Z_{AF})
/*Optimal Subcarrier pairing */
Do$\eta' = Z_{AF}$
Else
finding the maximum elements z from uncovered elements;
/*reduction and addition*/
For each $Z_{AF}^{i,j}$ from uncovered elements
Do$Z_{AF}^{i,j}$--- z,
And at the intersections of lines the values are added;
End end end end
/* repeating */
Step 2 Go to **Sub-gradient algorithm**

OUTAGE PROBABILITY ANALYSIS

In this section, the performance of the spectrum sharing schemes is analyzed and the outage probabilities of the primary and secondary networks are taken which gives the rate of unsuccessful spectrum sharing.

1) Primary Network: The primary network go through an state of outage if PU1 and PU2 cannot communicate with each other at a rate with the target rate greater than or equal to RP target. If there is no solution (15) this situation occurs. As said, the optimization problem (15) is not possible to do easily if $\min_{1<i<N} (\wedge\alpha^{TDBC}{}_i) > 1$, where $\wedge\alpha^{TDBC}{}_i$ is defined in (12).The probability can be calculated as

$$P_{out}^{P,TDBC} = \mathbb{P}\left(min_{1\le i\le N}\left(\acute{\alpha}_i{}^{TDBC}\right) \ge 1\right)$$
$$= \Pi_{i=1}^{N} \mathbb{P}\left(\acute{\alpha}_i{}^{TDBC} \ge 1\right)$$

$$\mathbb{P}\left(\acute{\alpha}_i{}^{TDBC} \ge 1\right) = \mathbb{P}(\min (R^{\wedge}{}_{PU1,SU_i}, R^{\wedge}{}_{PU2,SU_i}, R^{\wedge}{}_{SU_i,PU1} R^{\wedge}{}_{SU_i,PU2}) \le R^P_{target})$$
$$=1 - \Pi_{j=1}^{2}[\mathbb{P}\,(R^{\wedge}{}_{PU_j,SU_i} > R^P_{target})\ \mathbb{P}\,(R^{\wedge}{}_{SU_i,PU_j} > R^P_{target})]$$
$$\approx 1 - \Pi_{j=1}^{2}[\mathbb{P}\,(\frac{P_{PU_j}}{N_0}\|H_{PU_j,SU_i}\|_F^2 >)\mathbb{P}\,(\frac{\delta_i P_{SU_i}}{N_0}\|H_{SU_i,PU_j}\|_F^2 > \tau)$$

2) Secondary Network: If the target rate RS target the falls below achievable rate, the secondary network is in outage i.e.$\max_{1<i<N} R^S (SU_i;\ \wedge\alpha^{MABC}{}_i) <$ RS target. Following similar steps the we can calculate the outage probability as

$$P_{out}^{S,MABC} \approx \Pi_{i=1}^{N} \mathbb{P}\left(\acute{\alpha}_i{}^{MABC} \ge \lambda_i^{+}\right)$$

$$\mathbb{P}\left(\acute{\alpha}_i{}^{MABC} \ge \lambda_i^{+}\right) \approx 1 - F\begin{pmatrix}\mu_i\gamma'_{PU1,SU_i}\\ \delta_i\gamma'_{PU2,SU_i}\end{pmatrix} \times \prod_{j=1}^{2} \frac{\Gamma(M^2, \frac{\mu_i}{\gamma' SU_i}, PU_j)}{\Gamma(M^2)}$$

Whereμ_i and δ_i are given by

$$\mu_i = (2^{\frac{2}{M\lambda_i^{+}}R^P_{target}} - 1)\, M^2$$
$$\delta_i = (2^{\frac{4}{M\lambda_i^{+}}R^P_{target}} - 1)\, M^2$$

Substituting we obtain for the outage probability an approximate expression in closed form as

$$P_{out}^{S,MABC} \approx \Pi_{i=1}^{N}\left[1 - F\begin{pmatrix}\mu_i\gamma'_{PU1,SU_i}\\ \delta_i\gamma'_{PU2,SU_i}\end{pmatrix} \times \prod_{j=1}^{2} \frac{\Gamma(M^2, \frac{\mu_i}{\gamma' SU_i}, PU_j)}{\Gamma(M^2)}\right.$$

III RESULTS AND DISCUSSION

The results are obtained by using MATLAB for the existing and proposed work is presented. The working of the system can be easily understood and analyzed by the resulted graphs. Here the graphs show comparison ofSignal To Noise Ratio (SNR) and Bit Error Rate (BER) of proposed system with existing system.

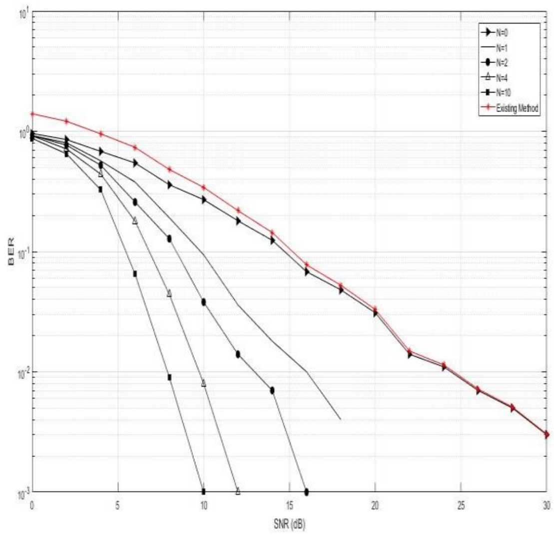

Fig 2 :SNR vs BER

The analysis in figure 2 shows the simulation results is for SNR vs BER for the N number of relays, which is basic for any communication system, which indicates that with change in SNR, BER must decrease, but here we are comparing with number of relays, and this shows that as the relays increases such that with highest number of relays the BER value is very Low in comparison. An existing system using AF with No relay system, the BER for existing system is on the higher value than compared with the Proposed system with No relay and with different relay values. The results are summarized in the below table 1.

BER	SNR	N NUM OF RELAYS
0.001	10	10
0.08	10	4
0.4	10	2
0.9	10	1
0.17	10	0
0.2	10	Existing system (two-way AF relay without power optimization)

Table 1: Shows the comparison of SNR Vs BER for N number of Relays.

From the above table 1, it can conclude that with increase in number of relays the BER value is very Low in comparison with SNR.

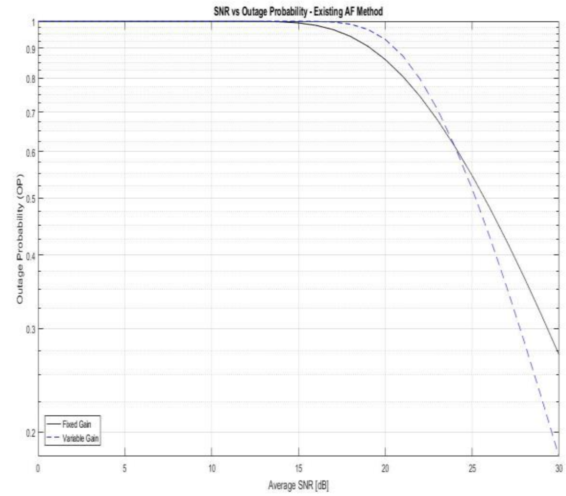

Fig 3: Outage Probability v/s Avg SNR for existing system.

In figure 3 the graph is being plotted to evaluate the Outage probability for Existing AF with the Relay system under conditions of Fixed and Variable Gain in the Channel. This graphs analyses as initial values of SNR has similar Probability for both the scenarios, but as the SNR increases the Variable Gain performs better than the Fixed gain, which represents that if the channel is able to adapt the changes happening in the data while travelling through the channel and the change the Overall Gain value then those systems results in better performance.

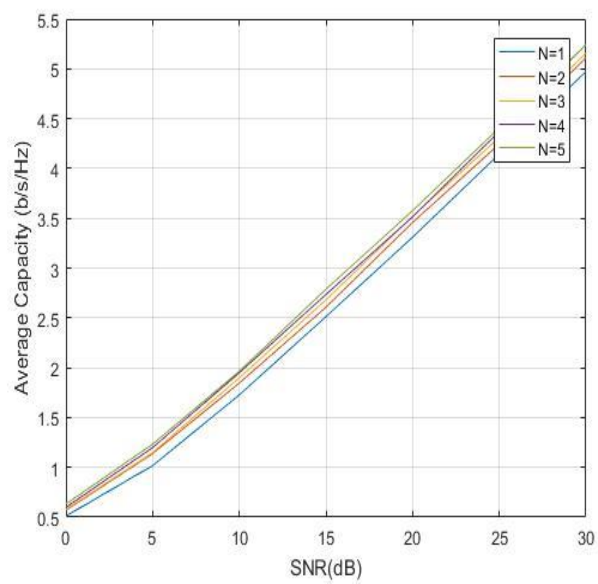

Fig 4: Avg Capacity vs SNR

From these results n figure 4 we can say that the simulation results for Average Capacity vs SNR for the N no. of relays the Average capacity increases as the no of relays increases and the rate of data of the system increases.

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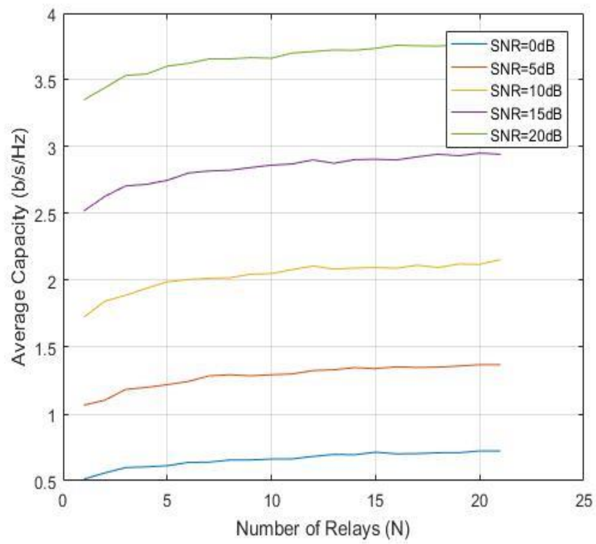

Fig 5: Average Capacity vs No of relays

Figure 5 shows the simulation results for Average Channel Capacity vs SNR for the N number of relays. It is observed that as the channel capacity changes with change in SNR, as the SNR increases the channel capacity increases.

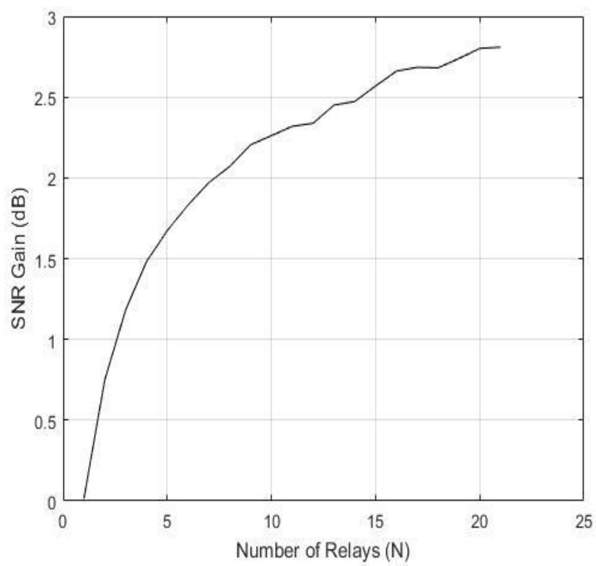

Fig 6 :SNR vs No of relays

The above figure 6 shows the simulation results for SNR vs No of relays. This is the plot which has the direct proportionality between the 2 parameters as one is dependent on other but increases exponentially with increase in Number of Relays and less errors are observed.

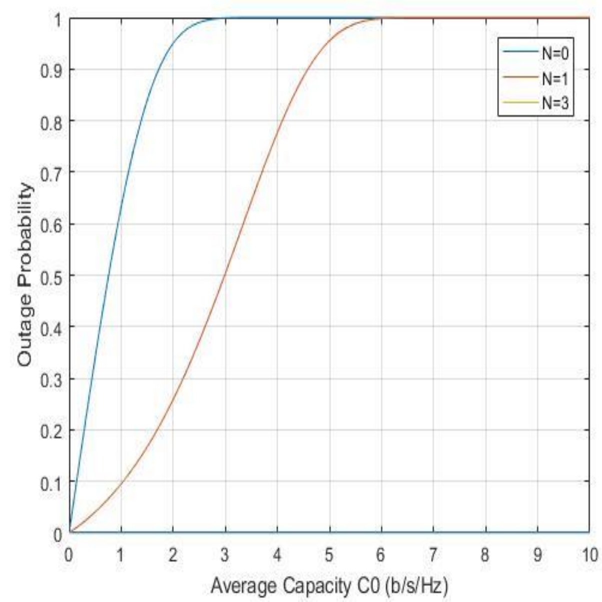

Fig 7: Outage Probability v/s Average Capacity

The results in the figure 7 show the Outage Probability v/s Average Capacity for the N number of relays. It is observed that with increase in capacity, the probability of data at the receiver also increases but its exponentially.

From these results it is observed that with the increase in number of relays the Bit Error Rate (BER) is reduced. The performance of the system by using outage probability is discussed along with the average capacity and SNR it is observed that the transmission rate of the system increased by observing the graphs.

IV. CONCLUSION

In CRNs unlike researches and previous work with the perfect spectrum sensing, in this paper the optimal resource allocation problem is given under the imperfect spectrum sensing, and a joint RA algorithm is proposed for the two-way AF cognitive relay network. In the proposed system different algorithms like Lagranges dual decomposition method, Hungarian algorithm, joint RA allocation algorithm is considered to increase the transmission rate of SUs with the IT constraints required by PU and to obtain the optimization technique for power allocation, relay selection and subcarrier pairing. The proposed algorithm via searching method transmit power is allocated the by using discrete value, by the Hungarian algorithm subcarrier pairing matrix is optimized, and the Lagrange multipliers updated by the and the best possible solution for power allocation is obtained. It is observed that the BER also decreased.

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