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Error Mitigation in Noma for Underlay CR Networks with Imperfect Successive Interference Cancellation

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ABSTRACT- This study examines the outage probability in a partial relay selection relaying network, an underlay cognitive radio (CR) network, and a non-orthogonal multiple access (NOMA) system. NOMA, which consists of K half-duplex Decode and Forward (DF) relays, is used in the secondary network. These relays are used to enable data transmission to secondary users (SUs) from the secondary base station (SBS). By establishing mathematical formulations, it is feasible to quantify the outage probability that SUs experience while accounting for imperfect successive interference cancellation (i-SIC). The paper also addresses optimum power allocation (OPA) at the SBS, which maximizes the throughput delay in the CR-NOMA system while accounting for the relay of choice independently. The work not only gives mathematical formulas for OPA components but also discusses why these aspects are important for throughput delay improvement. The study highlights how crucial power distribution and relay selection are to enhancing secondary network performance.

Keywords: Relay aided NOMA, cognitive radio, Outage Probability, Partial relay selection, imperfect successive interference cancellation, optimal power allocation.

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1. INTRODUCTION

The novelty in communication networks is to use a developed CRNOMA scheme, because it can be implemented as a simple add-on One of the most reliable technologies pertaining to 5G network has taken to be non-orthogonal multiple access (NOMA). It is having the capability for improving spectrum efficiency and overcome the limited user capacity by supporting more users than the available orthogonal resources. [1]. This paper conducts a thorough examination of the cutting-edge CR-based NOMA network architecture, elucidating its fundamental characteristics, merits, and hurdles [2] High spectral efficiency and large connection requirements need the use of new communication techniques, which are motivated by an exponential rise of mobile devices and the quick expansion of wideband wireless services. It is anticipated that CR and NOMA will play a significant role in fifth generation wireless networks. The potential for increasing system capacity and improving spectral efficiency through an integration of NOMA approaches into CRNs is enormous. However, employing NOMA causes substantial interference, which presents several technological hurdles. Numerous attempts have been made to make it easier for CRNs to use NOMA and to look at how well [3,4,5] NOMA facilitates the multiplexing of several users over a single resource, with each user being assigned varying power based on their service quality. This study delves into analyzing the throughput of a cognitive radio (CR) system adopting non-orthogonal multiple access (NOMA) techniques, enhanced by the presence of multiple unmanned aerial vehicles (UAVs) serving as relays. The investigation extends to considering both system performance metrics and security constraints [6]. High power coefficients are allocated to weak channel gain and low power coefficients are low power coefficients are allocated to strong channel gain [7]. In NOMA one slot can be used by more than one user so interference will be high as well as so requirement has to remove the interference at the receiver so complexity will be very high. Basically, the biggest challenge is to allocate power for every user in downlink because distance of each user is different from station [8]. Base station has to decide how much power is to be given to user1, user2 etc. Looking at the distance of user from base station will decide the channel gain then allocate the power to each user after that performs the coding. At receiver will combine all coding called superposition coding [9]. A well-established technique for enhancing the capacity and reliability of wireless network is cooperative relaying [10-11]. Cooperative NOMA has been proposed for enhancing reliability of weak user and coverage of the network, it also improves the diversity with throughput of the system [12]. CR-NOMA data in recent studies has been presented in *table1*.

Table 1: CR-NOMA data in recent studies

Ref.	Authors	Techniques and descriptions	Observation	Year
3	Wang.Xin et al.	A NOMA system with Simultaneous Wireless Information and Power Transfer (SWIPT) for CR network is used. A Dinkelbach algorithm method was used.	The poor channel performance is not considered.	2019
29	Lina Bariah et al.	Developed a precise estimation for the pairwise error probability (PEP) of secondary users utilizing imperfect successive interference cancellation (SIC).	Future work will focus on power allocation, user clustering, green communication	2019
20	K. Chitti, et.al	Explored the fundamental principle of NOMA, the core concept of cognitive radio, the methodology for spectrum sharing, and outlined the benefits and obstacles associated with NOMA and cognitive radio spectrum sharing.	Additional research, implementation, and analysis are required to address the numerous challenges and complexities associated with integrating NOMA with CR.	2020
30	Dinh-Thuan Do et al.	Relay strategy is used in CR-D2D NOMA network	The proposed work is for two users. This can be extended to multiple users	2019
32	T. Balachander	cooperative spectrum sensing (CSS) in Cognitive Radio Network (CRN) using MIMO NOMA technology is implemented also increase the ergodic capacity of secondary user.	Consider only perfect successive interference cancellation at receiver	2021

A number of writers have been examined an effectiveness for CR networks and NOMA systems in the literature. The authors in [8], [9] study MIMO and NOMA techniques whereas [13], [14] studied millimeter-wave NOMA systems. Additionally, relay systems [15]–[16] and cognitive radio (CR) networks [17] were also implemented with NOMA. Power allocation is one of the major concerns in NOMA, Ineffective power distribution has the potential to greatly increase interference, which lowers user-end data recovery. The power allocation applications in NOMA systems are covered in this study. [18]. A writer in this paper derives the minimal quality of system restrictions on Power Allocation Coefficients for each user. They show that there is a basic set of power allocation coefficients that renders the probability non-zero for requirement of minimum QOS rate R_o [19]. In [20-21] The spatial modulation (SM) that improves spectral efficiency employing a detector for maximum likelihood (ML). It easily manages several CEUs or several CCUs.SM is a modulation method that uses antennas as its indexes to send data. This paper [22] proposed a new type of downlink non-orthogonal multiple access assisted multiple input multiple output system with finite alphabet inputs, where the system's possible spectral efficiency is characterized by mutual information. In order to offer an estimate of the simulated MI, they also suggest a computationally efficient bottom bound. In [23] the authors have shown a method for alternating between spatial modulation with NOMA for same channel gain and power of different users, Results of the simulation indicate that higher spectral efficiency is possible. And authors of [24] studied that Software defined radio (SDR) is the radio communication technology that comes before cognitive radio. The three cognitive radio approaches are Interweave, Overlay, and Underlay. Both the primary non-cognitive radio user and the secondary cognitive radio user can broadcast concurrently using underlay and overlay techniques. It is not feasible to transmit simultaneously using the interweave approach. In [25-28] authors described nonlinear equations, energy efficiency by optimal fusion rule, iterative search algorithm for maximization of energy efficiency with different design parameters.

2. SYSTEM AND CHANNEL MODEL

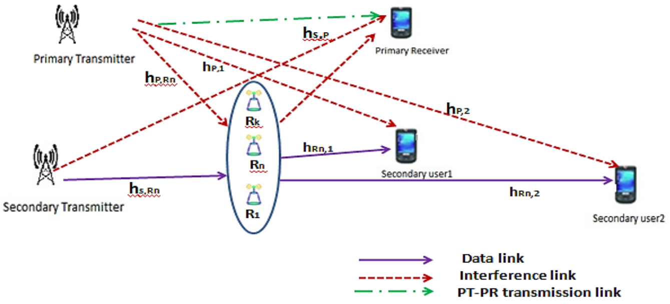

Figure 1. Cognitive Radio Network based on NOMA with primary and secondary transmitters

Here *figure1* shows an underlay CR-NOMA system including secondary network, primary network and relays. There are using one of the K DF HD relays for support. $\{R_k\}$ where k = 1,2,3… K. Using the PRS approach, the relay Rn that facilitates communication between SBS and SUs is chosen. The principal transmitter (PT)-primary receiver (PR) pair makes up primary network, which uses the licensed spectrum [4-6]. As the result, this study has been taken into consideration a two-user scenario. Assuming that the connections linking nodes *i* and *j* correspond to the fading channel coefficients $\{h_{i,j}\}$.It anticipates separate block Rayleigh fading in every connection. As a result, $E[\|h_{i,j}|^2] = \lambda ij$

and a channel power gains $\|h_{i,j}|^2$ exhibit exponential PDFs. It is assumed that the AWGN variance at every receiver of networks is σ^2. An R_n relay with a highest channel gain to the Secondary base station has been chosen for communication from the SBS to SU's under PRS system under consideration. In representation, this is in papers [29-31]:

$$R_n=\arg \max_{k=1\ldots K} |hs, Rk|^2$$

Here K relays are closer as compared to SBS. Since the fading through SBS-Rk connections is assumed to be independent, the exponential random variables $|h_S,R_k|^2$. One may obtain the CDF of $|h_S,R_n|^2$ as [31].

$$F_{|hS,Rn|^2}(x) = \Pr\left(\max_{k=1,2,3,\ldots K}|h_S, R_k|^2 \le x \right) \quad (1)b$$

$$=\prod_{k=1}^{K} \Pr(|h_S,R_k|^2 \le x) = \left(1-e^{-x/\lambda_0} \right)^K \quad (1)c$$

$$= 1- \sum_{i=1}^{K}(-1)^{i-1\,K} C_i\, e^{-ix/\lambda_0} \quad (1)d$$

the PDF of $|h_S,R_n|^2$ is provided by [31]:

$$f_{|hS,Rn|^2}(x) = \sum_{i=1}^{K}(-1)^{i-1\,K} C_i \frac{i}{\lambda_0} e^{-ix/\lambda_0}$$

Consequently, P_S and P_R will be chosen as [17,31]

$$P_S = \min \left(P_{S,max}, \frac{Ith}{|h_{S,P}|^2} \right) \quad (2)a$$

$$P_R = \min \left(P_{R,max}, \frac{Ith}{|h_{Rn,P}|^2} \right) \quad (2)b$$

Let $s_1(t)$ and $s_2(t)$ represent the message signals at time t that are meant for SU_1 and SU_2, respectively. By assigning different power levels to SU1 and SU2, and power allocation coefficients are α_1 and α_2 along with power allotted equal to $\alpha_1 Ps$ and $\alpha_2 Ps$.

The values of $\alpha_1 < \alpha_2$ and $\sum_{i=1}^{2} \alpha i = 1$ indicate that the distant user SU_2 at SBS is assigned a greater power.

$$s(t)= \sqrt{\alpha_1 P_S s_1(t)} + \sqrt{\alpha_2 P_S s_2(t)} \quad (3)$$

The signal received is

$$yR_n(t) = h_{S,Rn}\sqrt{\alpha_1 P_S s_1(t)} + |h_{S,Rn}|\sqrt{\alpha_2 P_S s_2(t)} + |h_{P,Rn}|\sqrt{P_p s_p(t)} + w_{Rn}(t) \quad (4)$$

Let equivalent SINRs are $\boldsymbol{\Gamma}_{Rn,s2}$, $\boldsymbol{\Gamma}_{Rn,s1}$ respectively, which are given by

$$\boldsymbol{\Gamma}_{Rn,s2} = \frac{\alpha_2 P_S |h_{S,Rn|}^2}{\alpha_1 P_S |h_{S,Rn|}^2 + P_p |h_{P,Rn|}^2 + \sigma^2} \quad (5)$$

$$\boldsymbol{\Gamma}_{Rn,s1} = \frac{\alpha_1 P_S |h_{S,Rn|}^2}{\beta\alpha_2 P_S |h_{S,Rn|}^2 + P_p |h_{P,Rn|}^2 + \sigma^2} \quad (6)$$

The residual interference at R_n caused by i-SIC is denoted by a term $\beta\alpha_2 P_S |h_{S,Rn|}^2$ and the i-SIC factor is represented by β ($0 \le \beta < 1$). The value of $sR_n(t)$ is provided by

$$\mathbf{s}_{Rn}(t) = \sqrt{\alpha_1 P_R s_1(t)} + \sqrt{\alpha_2 P_R s_2(t)} \quad (7)$$

where the power allocation factor at R_n is denoted by α_i.$y_1(t)$ is received signal at SU_1 with $y_2(t)$ at SU_2 given as

$$\mathbf{y}_1(t) = \left(\sqrt{\alpha_1 P_R s_1(t)} + \sqrt{\alpha_2 P_R s_2(t)}\right) h_{Rn,1} + h_{P,1}\sqrt{P_p s_p(t)} + w_1(t)$$

$$\mathbf{y}_2(t) = \left(\sqrt{\alpha_1 P_R s_1(t)} + \sqrt{\alpha_2 P_R s_2(t)}\right) h_{Rn,2} + h_{P,2}\sqrt{P_p s_p(t)} + w_2(t) \quad (9)$$

Now, the distant user SU_2 uses $y_2(t)$ and the associated SINR to immediately decode its symbol, s_2.

$$\boldsymbol{\Gamma}_{2,s2} = \frac{\alpha_2 P_R |h_{Rn,2|}^2}{\alpha_1 P_R |h_{Rn,2|}^2 + P_p |h_{P,2|}^2 + \sigma^2} \quad (10)$$

For near user SU_1, SINRs are given by

$$\boldsymbol{\Gamma}_{1,s2} = \frac{\alpha_2 P_R |hR_{n,1|}^2}{\alpha_1 P_R |h_{R_{n,1}}|^2 + P_p |h_{P,1}|^2 + \sigma^2} \quad (11)$$

$$\boldsymbol{\Gamma}_{1,s1} = \frac{\alpha_1 P_R |h_{R_{n,1|}}^2}{\varsigma\, \alpha_2 P_R |h_{R_{n,1}}|^2 + P_p |h_{P,1}|^2 + \sigma^2} \quad (12)$$

3. ANALYSIS OF OUTAGE PROBABILITY

Let SU1 and SU2 goal rates be denoted by r_1 and r_2, respectively, (bits per channel use-bpcu). Attained rates are half since a communication from SBS to SU's requires two separate time periods to be completed. For the effective decoding of s_1 and s_2,

the target SINRs are therefore provided by $u_1^{HD} = 2^{2r_1}-1$ and $u_2^{HD} = 2^{2r_2}-1$

3.1 Explanation of Outage Probability for near User SU₁

The OP that SU_1 encountered in the CR-NOMA network under consideration (P_{out};1) is.

$$P_{out,1} = 1-\Pr\left\{\Gamma_{Rn,s2} \ge u_2^{HD}, \Gamma_{Rn,s1} \ge u_1^{HD}, \Gamma_{1,s2} \ge u_2^{HD}, \Gamma_{1,s1} \ge u_1^{HD}\right\} \quad (13)$$

Putting the SINR expressions (5)-(6) and (11)-(12) in (13).

$$\mathbf{P}_{out,1} = 1-\Pr\left\{\left|h_{SR_n}\right|^2 \ge \frac{u_2^{HD}\left(P_p |h_{PR_n}|^2+\sigma^2\right)}{P_S(\alpha_2-\alpha_1 u_2^{HD})}, \left|h_{SR_n}\right|^2 \ge \frac{u_1^{HD}\left(P_p |h_{PR_n}|^2+\sigma^2\right)}{P_S(\alpha_1-\beta\alpha_2 u_1^{HD})}, \left|h_{R_{n,1}}\right|^2 \ge \frac{u_2^{HD}\left(P_p |h_{P,1}|^2+\sigma^2\right)}{P_R(\alpha_2-\alpha_1 u_2^{HD})}, \left|h_{R_{n,1}}\right|^2 \ge \frac{u_1^{HD}\left(P_p |h_{P,1}|^2+\sigma^2\right)}{P_R(\alpha_1-\alpha_2\varsigma u_1^{HD})}\right\} \quad (15)a$$

$$= 1-\Pr\left\{\left|h_{SR_n}\right|^2 \ge \frac{\phi_0}{P_S}\left(P_p |h_{P,R_n}|^2 + \sigma^2\right) \times \Pr\left|h_{R_{n,1}}\right|^2 \ge \frac{\phi_1}{P_R}\left(P_p |h_{P,1}|^2 + \sigma^2\right)\right. \quad (15)b$$

For simplification assume first part is A_0 and second part is A_1.

$$= 1- A_0 A_1 \quad (15)c$$

Now finding the values of A_0 and A_1

$$A_0 = \Pr\left\{\left|h_{SR_n}\right|^2 \ge \frac{\phi_0}{P_{S,max}}\left(P_p |h_{PR_n}|^2 + \sigma^2\right), P_{S,max} < \frac{Ith}{|h_{S,P}|^2}\right\} + \Pr\left\{\left|h_{SR_n}\right|^2 \ge \frac{\phi_0}{I_{th}}\left(|h_{S,P}|^2 P_p |h_{PR_n}|^2 + \sigma^2\right), P_{S,max} > \frac{Ith}{|h_{S,P}|^2}\right\} \quad (16)$$

For simplification assume first part is A_{00} and second part is A_{01}

$$A_{00} = \Pr\left\{\left|h_{SR_n}\right|^2 \ge \frac{\phi_0}{P_{S,max}}\left(P_p |h_{PR_n}|^2 + \sigma^2\right)\right\} \times \Pr\left\{|h_{S,P}|^2 < \frac{Ith}{P_{S,max}}\right\} \quad (17)a$$

Let $\lambda_{S,P}$ and $\lambda_{P,Rn}$ are the mean values of $|h_{S,P}|^2$ $|h_{P,Rn}|^2$ so A_{00} becomes

$$A_{00} = \sum_{i=1}^{K}(-1)^{i-1\,K} C_i \int_{y=0}^{\infty} e^{-\frac{i\phi_0(P_p y+\sigma^2)}{P_{S,max}\lambda_0}} |h_{P,R_n}|^2(y)dy \times 1 - e^{-\frac{I_{th}}{P_{S,max}\lambda_{S,P}}} \quad (17)b$$

$$=\left(1-e^{-\frac{I_{th}}{P_{S,\max}\lambda_{S,P}}}\right)\times\sum_{i=1}^{K}(-1)^{i-1}\,{}^{K}C_i\times\int_{y=0}^{\infty}e^{-\frac{i\phi_0(P_p y+\sigma^2)}{P_{S,\max}\lambda_0}}\frac{1}{\lambda_{P,Rn}}e^{-\frac{y}{\lambda_{P,Rn}}}dy$$

(17)c

Simplify it, So A_{00} is

$$A_{00}=\left(1-e^{-\frac{I_{th}}{P_{S,\max}\lambda_{S,P}}}\right)\times\sum_{i=1}^{K}(-1)^{i-1}\,{}^{K}C_i\times e^{-\frac{i\phi_0\sigma^2)}{P_{S,\max}\lambda_0}}\left(\frac{P_{S,max}\lambda_0}{i\phi_0 P_p\lambda_{P,Rn}+P_{S,\max}\lambda_0}\right)$$

(17)d

$$\mathbf{P}_{out,1}=1-\Big[\!\!\Big[\left(1-e^{-\frac{I_{th}}{P_{S,\max}\lambda_{S,P}}}\right)\times\sum_{i=1}^{K}(-1)^{i-1}$$

$${}^{K}C_i\,e^{-\frac{i_{\phi_0}\sigma^2}{P_{S,\max}\lambda_0}}\left(\frac{P_{S,max}\lambda_0}{i\phi_0 P_p\lambda_{P,Rn}+P_{S,\max}\lambda_0}+\right)-\sum_{i=1}^{K}(-1)^{i-1}\,{}^{K}C_i$$

$$\times\frac{Ith\ \lambda_0}{\lambda_{S,P}\lambda_{P,Rn}i\phi_0P_p}e^{\frac{I_{th}\lambda_0}{i\phi_0P_p\lambda_P R_n}\left(\frac{i_{\phi_0}\sigma^2}{I_{th}\lambda_0}+\frac{1}{\lambda_{S,P}}\right)}\ \mathrm{Ei}$$

$$\left(-\left(\frac{i_{\phi_0}\sigma^2}{I_{th}\lambda_0}+\frac{1}{\lambda_{SP.}}\right)\frac{Ith}{P_{S,max}}-\left(\frac{i_{\phi_0}\sigma^2}{I_{th}\lambda_0}+\frac{1}{\lambda_{SP.}}\right)\frac{I_{th}\lambda_0}{i\phi_0P_p\lambda_P R_n}\right).]$$

$$\times\Big[\left(1-e^{-\frac{I_{th}}{P_{R,\max}\lambda R_n{}^{P}}}\right)e^{-\frac{\phi_1\sigma^2}{P_{R,\max}\lambda_{Rn,1}}}\times\frac{P_{R,max}\lambda_{Rn,1}}{\phi_1P_p\lambda_{P,1}+P_{R,max}\lambda_{Rn,1}}-$$

$$\frac{Ith\ \lambda_{R_{n,1}}}{\lambda_{Rn,P}\lambda_{P,1}\phi_1P_p}e^{\frac{I_{th}\lambda_{Rn,1}}{\phi_1P_p\lambda_{P,1}.}\left(\frac{\phi_1\sigma^2}{I_{th}\lambda_{Rn,1}}+\frac{1}{\lambda_{Rn,P}}\right)}\times\mathrm{Ei}\Bigg(-\bigg(\frac{\phi_1\sigma^2}{I_{th}\lambda_{Rn,1}}+$$

$$\frac{1}{\lambda_{Rn,P}}\bigg)\frac{Ith}{P_{R,max}}-\left(\frac{\phi_1\sigma^2}{I_{th}\lambda_{Rn,1}}+\frac{1}{\lambda_{Rn,P}}\right)\Bigg)\frac{I_{th}\lambda_{Rn,1}}{\phi_1P_p\lambda_{P,1}.}\Big]\!\!\Big]$$

(17)e

Now for finding the A_{01} for *equation (16)*, assuming

$|h_{PR_n}|^2=Y$, $|h_{S,P}|^2=Z$, putting the value of $|h_{SR_n}|^2$

$$A_{01}=\sum_{i=1}^{K}(-1)^{i-1}\,{}^{K}C_i\int_{y=0}^{\infty}\int_{z=\frac{I_{th}}{P_{S,max}}}^{\infty}\times e^{-\frac{i\phi_0}{I_{th}\lambda_0}z\ (P_p y+\sigma^2)}f|h_{S,P}|^2(z)\ \ f|h_{PR_n}|^2(y)\,dz\,dy$$

(18a)

$$\sum_{i=1}^{K}(-1)^{i-1}\,{}^{K}C_i\ \frac{1}{\lambda_{,P,Rn}\lambda_{S,P}}\int_{y=0}^{\infty}\int_{z=\frac{I_{th}}{P_{S,max}}}^{\infty}\times e^{-\frac{i\phi_0}{I_{th}\lambda_0}z\ (P_p y+\sigma^2)}e^{-\frac{z}{\lambda_{S,P}}\times}\ e^{-\left(\frac{y}{\lambda_{P,Rn}\ dzdy}\right)}\quad (18b)$$

$$A_{01}=\sum_{i=1}^{K}(-1)^{i-1}\,{}^{K}C_i\ \frac{I_{th}\lambda_0}{i\phi_0\lambda_{S,P}P_p\lambda_{P,Rn,}}\times e^{\frac{I_{th}\lambda_0}{i\phi_0P_p\lambda_{P,Rn}}\left(\frac{i\phi_0\sigma^2}{I_{th}\lambda_0}+\frac{1}{\lambda_{S,P}}\right)}\times\mathrm{Ei}\Bigg(-\bigg(\frac{i\phi_0\sigma^2}{I_{th}\lambda_0}+\frac{1}{\lambda_{S,P}}\bigg)\frac{I_{th}}{P_{S,max}}-\left(\frac{i\phi_0\sigma^2}{I_{th}\lambda_0}+\frac{1}{\lambda_{S,P}}\right)\frac{I_{th}\lambda_0}{i\phi_0P_p\lambda_{P,Rn}}\Bigg)\quad (18c)$$

From *equation (15)c*, we can find out A_1 with the help of *equation (2)*

$$A_1=\Pr\left\{|h_{R_{n,1}}|^2\geq\frac{\phi_1}{P_{R,max}}\left(P_p|h_{P,1}|^2+\sigma^2\right)\right\}\times P_{R,max}<\frac{Ith}{|h_{R_{n,P}}|^2}\Bigg\}+$$

$$\Pr\left\{|h_{R_{n,1}}|^2\geq\frac{\phi_1}{Ith}\left(P_p|h_{P,1}|^2+\sigma^2\right)\right\}|h_{R_{n,P}}|^2\quad P_{R,max}>\frac{Ith}{|h_{R_{n,P}}|^2}\Bigg\}$$

(19)

Here first term assumes A_{10} and second term is $A_{11.}$ As it founds A_{00} and A_{01} similarly A_{10} and A_{11} can be find out

$$A_{10}=\left(1-e^{-\frac{I_{th}}{P_{R,\max}\lambda_{Rn,P}}}\right)\times e^{-\frac{\phi_1\sigma^2}{P_{R,\max}\lambda_{Rn,1}}}\times\left(\frac{P_{R,max}\lambda_{Rn,1}}{\phi_1P_p\lambda_{P,1}+P_{R,\max}\lambda_{Rn,1}}\right)\quad (20)$$

$$A_{11}=-\frac{I_{th}\lambda_{Rn,1}}{\phi_1\lambda_{Rn,P}P_p\lambda_{P,1}}\times e^{\frac{I_{th}\lambda_{Rn,1}}{\phi_1P_p\lambda_{P,1}}\left(\frac{\phi_1\sigma^2}{I_{th}\lambda_{Rn,1}}+\frac{1}{\lambda_{Rn,P}}\right)}\times\mathrm{Ei}$$

$$\left(-\left(\frac{\phi_1\sigma^2}{I_{th}\lambda_{Rn,1}}+\frac{1}{\lambda_{Rn,P}}\right)\frac{I_{th}}{P_{R,max}}-\left(\frac{\phi_1\sigma^2}{I_{th}\lambda_{Rn,1}}+\frac{1}{\lambda_{Rn,P}}\right)\frac{I_{th}\lambda_{Rn,1}}{\phi_1P_p\lambda_{P,1}}\right)$$

(21)

In *(15)c*, substituting *(17)d*, *(18)c*, *(20)*, and *(21)* yields *(14)*. It is evident from *(15)a* that $0 < P_{out,1} < 1$ if and only if

$0<\alpha_1<\frac{1}{1+u_2^{HD}},\frac{\beta u_1^{HD}}{1+\beta u_1^{HD}}<\alpha_1<1, 0<\alpha_1<\frac{1}{1+u_2^{HD}}\frac{\varsigma u_1^{HD}}{1+\varsigma u_1^{HD}}<\alpha_1<1$, or else $\mathbf{P}_{out,1}$ can be unity.

If any of these requirements are not met, the probability component on the right-hand side of *equation (15)b* becomes 0.

3.2 Explanation of Outage Probability for far User SU₂

Similarly, Outage Probability of SU_2

$$\mathbf{P}_{out,2}=1-A_0B_0=(1-A_{00}+A_{01})(B_{00}+B_{01})$$

Now $\mathbf{P}_{out,2}$ can be find with the help of all equation. Here $0<\mathbf{P}_{out,2}<1$ if and only if

$0<\alpha_1<\frac{1}{1+u_2^{HD}},\frac{\beta u_1^{HD}}{1+\beta u_1^{HD}}<\alpha_1<1, 0<\alpha_1<\frac{1}{1+u_2^{HD}}$ or else $\mathbf{P}_{out,2}$ can be unity. If these conditions are not satisfied then probability can be unity.

4. PERFORMANCE EVALUATION RESULTS

The analytical and simulation findings for throughput and OP are presented in this section. The distances between the relays and the SBS are significantly greater than the distances between the relays, hence considering that relays are grouped somewhere in between SUs and SBS. The OP that SU1 and SU2 in the CR-NOMA network encounter against Pmax and their respective throughput against transmit power are displayed in *figures 2,3*.

Firstly, noted that SU2 experiences less outage probability than SU1, as its power allocation factor is less at the SBS and a chosen R_n relay. Additionally, SUs' OP is lower under the PRS scheme than under the RRS model. When the PRS scheme is used instead of the RRS scheme, An Outage Probability for SU_1 and SU_2 fall near 95% and 89%, correspondingly, with K = 3 and Pmax = 40dB.Additionally, under the PRS system, a greater value of K considerably enhances the OP performance of both SU_1 and SU_2.

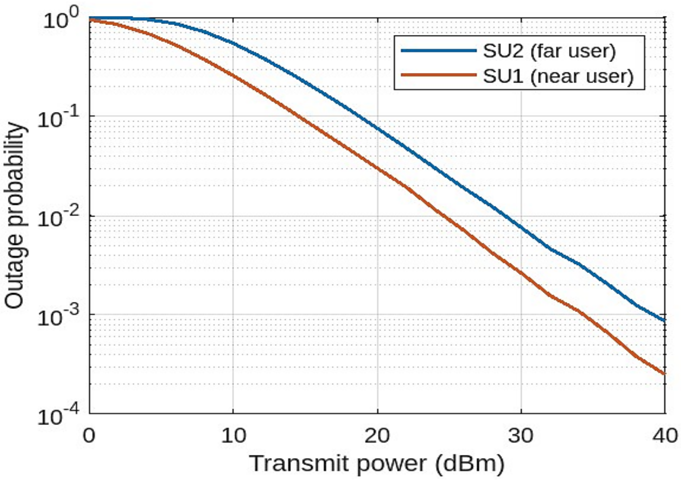

Figure 2. Outage Probability of SU1 and SU2 vs. transmit power

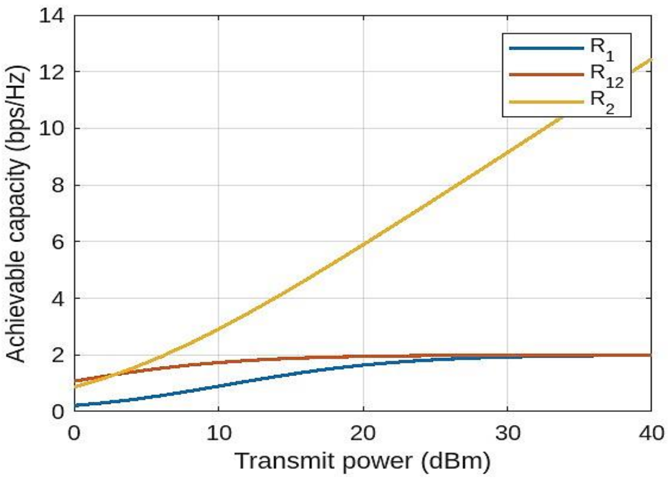

Figure 3. capacity of SU_1 and SU_2 vs. transmit power

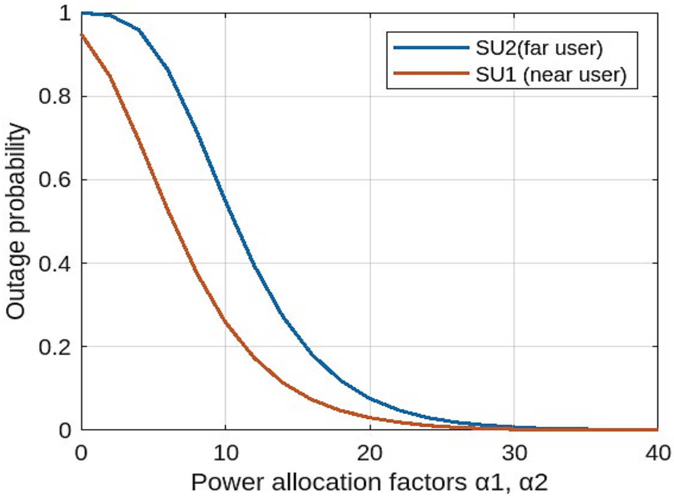

Figure 4. Outage probability of SU_1 and SU_2 vs. Power allocation factor

The secondary network's throughput results in the CR-NOMA system are displayed in *figure 4*. An OP for SU's is observed to decrease as Pmax is increased, provided that P_{max} is less than I_{th}. Result comparison with recent research has been shown in *table 2*.

Table 2. Result comparison with recent research

System model / method	**Parameters**	**Maximum EE (bits/ Hz/ Joule)**	**Remarks**
Wireless powered downlink and multiuser information uplink, Lagrangian multiplier approach [27]	Transmit power	2:55	Maximum EE is achieved for throughput R0, 0.5 bits/s/Hz
Massive MIMO for hybrid architectures based on phase shifters [13]	Number of base station antenna and SNR	0:054	Hybrid architecture of massive MIMO, Maximum EE is achieved at 300 BS and 20 dB SNR
EE maximization of Cooperative Cognitive radio in fading and non-fading environment [26]	Number of Secondary users, SNR	4:92	Maximum EE is achieved for koN rule in non-fading at throughput R0, 0.5 bits/s/Hz, SNR — 4 dB
Proposed: outage probability in a partial relay selection relaying network	secondary network, primary network and relays	4:97	Maximum EE is achieved with an Outage Probability for SU1 and SU2 fall near 95% and 89%, correspondingly, with K = 3 and Pmax = 40dB

5. CONCLUSION

In this work, Paper provides equations for the system throughput and outage probability of an underlay CR-NOMA network using the Partial Relay Selection (PRS) design. The SUs' experiences are considered. These formulations account for a number of important elements, such as tt is planned to broaden the scope of our analysis in the future by taking into account more elements and variables, which will help us better comprehend the functionality and performance of the system.

REFERENCES

[1] S. Antipolis,"Study on scenarios and requirements for next generation access technologies," 3GPP, France, Tech. Rep., vol. 38, no. 913, Jun. 2017

[2] Haythem et.al "Integration of Cognitive Radio Technology in NOMA-Based B5G Networks: State of the Art, Challenges, and Enabling Technologies", IEEE Access, 10.1109/ACCESS.2023.3242645, 06 February 2023.

[3]Wang, Xin; Na, Zhenyu; Lam, Kwok-Yan; Liu, Xin; Gao, Zihe; Li, Feng; Wang, Li"Energy efficiency optimization for NOMA based cognitive radio with energy harvesting" 2019, IEEE Access,139172-139180. doi:10.1109/ACCESS.2019.2940698.

[4] Z. Ding et.al, "Application of non-orthogonal multiple access in LTE and 5G networks," IEEE Commun. Mag., vol. 55, no. 2, pp. 185–191, Feb. 2017.

[5] L. Yu et.al "BER analysis of SCMA systems with code books based on star-QAM signaling constellations," IEEE Commun. Lett., vol. 21, no. 9, pp. 1925–1928, Sep. 2017.

[6] Viet-Hung Dang et.al "Throughput Optimization for Noma Energy Harvesting Cognitive Radio With Multi-UAV-Assisted Relaying Under Security Constraints" IEEE Transactions on Cognitive Communications and Networking (Volume: 9, Issue: 1, February 2023)

[7] Z. Ding, et.al, "A survey on non-orthogonal multiple access for 5G networks: Research challenges and future trends," IEEE J. Sel. Areas Commun., vol. 35, no. 10, pp. 2181–2195, Oct. 2017.

[8] Z. Ding, et.al, "A general MIMO framework for NOMA downlink and uplink transmission based on signal alignment,"IEEE Trans. Wireless Commun., vol. 15, no. 6, pp. 4438-4454, Jun. 2016.

[9] Z. Yang, et.al, "The Impact of Power Allocation on Cooperative Non-orthogonal Multiple Access Networks With SWIPT," IEEE Trans. Wireless Commun., vol. 16, no. 7, pp. 4332- 4343, Jul. 2017.

[10] C. Hoymann, et.al, “Relaying operation in 3GPP LTE: challenges and solutions”, IEEE Com. Mag., vol. 50, no. 2, pp. 156-162, 2012.

[11] S. Y. Lien, et.al, “3GPP device-to device communications for beyond 4G cellular networks”, IEEE Commun. Mag., vol. 54, no. 3, pp. 29-35, Mar. 2016.

[12] Z. Ding, et.al, “Cooperative non-orthogonal multiple access in 5G systems”, IEEE Com.Let., vol.19, no. 8, pp. 1462–1465, Aug. 2015.

[13] Z. Ding, et.al, “NOMA Meets Finite Resolution Analog Beamforming in Massive MIMO and Millimeter-Wave Networks,” IEEE Commun. Lett., vol. 21, no. 8, pp. 1879-1882, Aug. 2017.

[14] Z. Ding, et.al, “Random beamforming in millimeterwave NOMA networks,” IEEE Access, vol. 5, pp. 7667-7681, Feb. 2017.

[15] G. Nauryzbayev, ey.al, “Performance of Cooperative Underlay CR-NOMA Networks over Nakagami-m Channels,” IEEE Int. Conf. Commun. Work. Kansas City, MO, USA, pp. 1-6, May 2018.

[16] X. Liang, Y. Wu, D. W. K. Ng, Y. Zuo, S. Jin and H. Zhu, “Outage performance for cooperative NOMA transmission with an AF relay,” IEEE Commun. Lett., vol. 21, no. 11, pp. 2428-2431, Nov. 2017.

[17] Y. Liu, et.al, “Nonorthogonal multiple access in large-scale underlay cognitive radio networks,” IEEE Trans. Veh. Technol., vol. 65, no. 12, pp. 10152-10157, Dec. 2016

[18] M. Basit Shahab, et.al “On the power allocation of Non-orthogonal Multiple Access for 5G wireless Networks”, 10.1109/ICOSST.2016.7838583, 2016 IEEE

[19] J.Oviedo; et.al “On the power allocation limits for downlink multi user NOMA with QOS” 10.1109/ICC.2018.8422366,

[20] K. Chitti, et.al “A survey of NOMA: Current status and open research challenges” 10.1109/OJCOMS.2020.2969899, 2020

[21] D. Hendraningrat, et.al “NOMA in downlink coordinated multipoint transmissions” Physical Communication, 2020

[22] X.Wang et.al “Spectral Efficiency analysis for downlink NOMA aided spatial modulation with finite alphabet inputs” 10.1109/TVT.2017.2737327 , IEEE 2017

[23] Jin Woo Kim; et.al “Selective Non orthogonal multiple access (NOMA) & Spatial modulation for improved spectral efficiency”. 10.1109/ISPACS.2015.7432833, IEEE 2015

[24] Qureshi, Faisal Fayyaz “A reliable and energy efficient cognitive radio multichannel MAC protocol for ad-hoc networks” University of Bedfordshire

[25] R. Vimala, et.al, “Oscillation of Nonlinear Neutral Delay Difference Equations of Fourth Order”, Mathematics, 2023, 11 (6), 1370, pp 1-13. https://doi.org/10.3390/math11061370

[26] M.Awasthi, et.al,“Energy Efficiency Maximization by Optimal Fusion Rule in Frequency-Flat-Fading Environment”, International Journal of Electronics and Communication(AEU), Elsevier, vol. 113,issue2020,

[27] Awasthi, M., et.al., “Optimal Sensing and Transmission of Energy Efficient Cognitive Radio Networks”,Wireless Personal Communication Springer, (2019), pp.1-12 https://doi.org/10.1007/s11277-019-06914-w.

[28] M. Awasthi, et.al, “Optimal Sensing, Fusion and Transmission with Primary User Protection for Energy-Efficient Cooperative Spectrum Sen sing in CRNs”,International Journal of Electronics and Communication (AEU), Elsevier, 2019,

[29]L. Bariah, S et.al “ Error Performance of NOMA-Based Cognitive Radio Networks with Partial Relay Selection and Interference Power Constraints” 2019, IEEE Transactions on Communication.

[30] Dinh-Thuan Do , et.al:” Outage Performance Improvement by Selected User in D2D Transmission and Implementation of Cognitive Radio-Assisted NOMA”, 2019 IEEE Sensors.

[31] Aswathi V, et.al, “Performance Analysis of NOMA-Based Underlay Cognitive Radio Networks with Partial Relay Selection” DOI 10.1109/TVT.2021.3071338, IEEE Transactions on Vehicular Technology, 2021

[32] T. Balachander, M. B. Mukesh Krishnan “Effcient Utilization of Cooperative Spectrum Sensing (CSS) in Cognitive Radio Network (CRN) Using Non-orthogonal Multiple Access (NOMA)”, Wireless Personal Communications 2021, https://doi.org/10.1007/s11277-021-087767.