Analysis of NOMA's Performance Evolution and Throughput in Cognitive Radio Network

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ABSTRACT

The spectral 5G Non-Orthogonal Multiple Access (NOMA) network's performance is influenced by power factor.In this instance, the spectral improvement ishandled by Cognitive Radio (CR). The CR in the NOMA secondary network is examined in this article. We are examining the secondary network's transmission signal quality for the remote NOMA user. The NOMA is worked with the power location scheme. The far NOMA user receives a higher power allocation, whereas the weak user receives a lower power allocation.We first use the Successive Interference Cancellation (SIC), a technique based on the SNR of each user, to calculate the SNR and outage probability for each user. The obtained simulation results give the comparison between the derived values i.e. theoretical values then we can decide the performance factors like rate and likelihood of an outage for remote NOMA users in the secondary network.

Index terms: NOMA, Cognitive Radio, SIC, Outage Probability, SNR Values

1. Introduction

When multiple users are served at the same time or frequency, but with varying powers, for fifth generation (5G) mobile networks, a spectrally effective multiple access technique called NOMA is starting to take off. Uplink transmissions, coordinated systems, and wireless power transfer networks are just a few of the most recent uses of NOMA.The spectrally efficient multiple access technique known as NOMA is becoming more popular for fifth generation (5G) mobile networks[1]. Cognitive radio (CR), on the other hand, has been recognised as a promising strategy to increase spectral efficiency [2]. Various wireless network layout frameworks based on this innovative new technology are covered, along with capacity limits and related transmission methods. The two concepts are combined by defining a cognitive radio as an intelligent wireless communication device that uses side information about its environment to optimise spectrum utilisation. [3]Take into account the latter scenario, also refers to as the spectrum sharing, and investigate the best power distribution techniques to realise the ergodic and outage capacities of the SU fading channels under different power constraints and fading channel models. It addressed the issue of the best robust transmitter design for the secure MISO CRN, where the SU-Tx only has knowledge of the equivalent ambiguity sets and does not have ideal CSI of every channel in the system [4]. For secure communication, we recommend employing cooperative jamming at the physical (PHY) layer. To block the eavesdropper without interfering with the legitimate receivers, some SUs are used in cooperative jamming as helpers to send jamming signals[5]. The confidential rate and transmission scheme used by the primary user must remain unaltered for the secondary user to be able to send his own signals [6].The efficiencyof the Amplify-and-Forward (AF) and Decode-and-Forward (DF) schemes is compared in the hybrid time switching-based and power splitting-based relaying protocol (PSRP) when channel state information (CSI) is inadequate [7]. Throughput that can be achieved for the two communication modes of right away transmission and delay-constrained transmission. Additionally, the best policies for allocating collected power are investigated for these gearbox modes [8]. An analytical expression of the throughput that can be achieved for both instantaneous and delay-constrained transmission in two different communication modes. Additionally, for these transmission modes, the best policies for allocating harvested power are investigated [9].We consider the case of SWIPT-enabled full duplex transmission. We jointly designed the optimal transmit power of FD-A and FD-B, as well as the PS ratio at FD-B, with the goal of maximising the energy captured by FD-B [10]. The functionality of the secondary networks when affected by hardware flaws and co-channel interference from the primary networks[11,12]. The new system model takes into account how the wireless network is impacted through energy harvesting fractions and derives analytical expressions for outage probability and ergodic rate for the information spread link.In order to achieve the best outage and ergodic capacity performance, it showed that NOMA users can choose the best power distribution strategy[13]. The effect of ICI and we adopt more practical parameters to evaluate the optimal power splitting co-efficient regarding energy harvesting system performance analysis.[14]NOMA all depends on the power allocation scheme to the users. The data rate affects the system's performance. The M-SRBOA (Multi-Objective Sum Rate Butterfly Optimization Algorithm) improves the data rate and outage probability of the far NOMA users. [15] NOMA gives better results when compared to conventional OMA schemes. In this NOMA when identifies the different users and assigns the outage probability value as 1, this makes to improve the performance factor like the sum rate of the far NOMA user.As of right now, the NOMA approach 5G in the cellular network delivers QoS in terms of ergotic data rate and enhanced spectral efficiency [16, 17].When multiple users are active and the NOMA provides lots of opportunities for transmission, the system increases interference [18].Utilising superposition coding and SIC, the affected broadcast channels' channel capacity is increased [19].The primary goal of the NOMA is to allow multiple users to share a single resource block, like a subcarrier or time slot [20].

2. Cognitive Radio System Model

A transceiver can strategically identify which modes of communication are in use and which ones are not in cognitive radio (CR), a form of wireless communication. The transceiver then right away switches to open channels, avoiding busy ones. These features aid in the radio frequency (RF) spectrum optimal use. It reduces user interference overall. In addition, it increases spectrum efficiency and improves users' quality of service (QoS) by avoiding used channels.

This Cognitive Radio consists of an amplifier and a forward network of wireless sensors at the secondary side. It consists of Source (S) and that's in contact with the two destinations D1 and D2 and the Relay (R) is intermediate. The figure. 1 one shows that the source can serve the two far devices. The complete setup is in a wireless mobile network. Even though there is no mobile network available between the two locations, it is still possible to use the relay between the source and destination.Here PD1 is the near user; SD2 is the far user the distances between the relay destination (D1) and destination (D2) respectively.

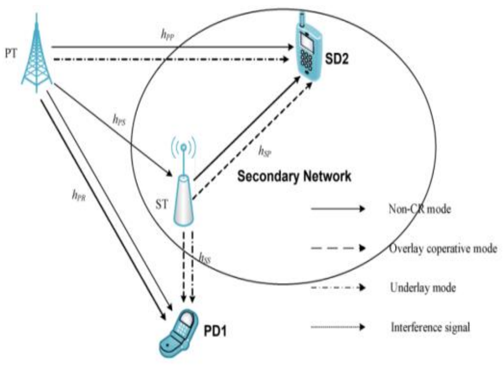

Figure 1: CR based NOMA Network

The NOMA work depends on the power factor. Since the CR is present in between the destination and the source.The time power-based relaying energy harvesting protocol is existed. The PS is the power from the source, a_1 and $a_2$the power distribution quantity for the symbols X1, X2 respectively, Xs is the combined signal. Hence the Xs can be the combination of X1 and X2 of the power distributioni.eXs= $a_1X_1+a_2X_2$. Here the gains in the communication channel between the nodeshs~CN(0,Ω1). Two channels' average gains to D1 and D2 are assumed to be equalh_{D1}, h_{D2}~CN(0,Ω2). The path loss factor in this case is'm'.

It is possible to represent the signal that the relay receives as

$$y_R = \frac{1}{\sqrt{d^m}}\sqrt{(1-\beta)P_{S}}\,h_S\,(a_1x_1 + a_2x_2) + \sqrt{(1-\beta)}n_R^A + n_R^C (1)$$

Here, n_R^A represents the antenna noise and n_R^C is the AWGN noise signal. The factor G represents the amplified signal and it can be represented as below

$$G=\frac{1}{\sqrt{(1-\beta)P_S\ |h_S|^2\,d^{-m}+(1-\beta)\,\sigma_n^2A+\sigma_n^2C}}(2)$$

When the signal is transmitted from the P_R power it reaches to the secondary network relay. Since the user D1 is far away from relay the total power which it is received at user one D1 can be represented as

$$y_{D1} = \frac{\sqrt{P_R h_D G}}{\sqrt{d_1^m}}y_R + n_D^A + n_D^C (3)$$

Where, n_D^A *and* $n_D^C$are AWGN at the destination D1. By using (1), (2) and (3) the y_{D1} can be expressed as

$$y_{D1} = \frac{\sqrt{(1-\beta)P_R P_S h_S h_{D1}(a_1\,x_1+a_2x_2)}}{\sqrt{(1-\beta)\,P_S|h_S|^2d_1^m+d^m\,d_1^m\,\sigma_{nR}^2}} + \frac{\sqrt{P_R}d^m\,h_{D1}n_R}{\sqrt{(1-\beta)P_S|h_S|^2d_1^m+d^m\,d_1^m\,\sigma_{nR}^2}}(4)$$

Energy scavenging phase E_h^{TPSR} between the relay and the signal further carried (1-α)Tbe power at relay can be represented as

$$P_R = \frac{E_h^{TPSR}}{(1-\alpha)} = \eta\left(\frac{P_S|h_S|^2}{d^m}\right)\frac{\alpha\beta}{(1-\alpha)}(5)$$

Substituting P_R in equation (4), we get

$$y_{D1} = \frac{\sqrt{\eta(P_S|h_S|^2d_1^m)}\alpha\beta\ (1-\beta)P_S h_S h_{D1}x_S}{\sqrt{d^m\,d_1^m(1-\alpha)}\sqrt{(1-\beta)P_S|h_S|^2d_1^m+d^m\,\sigma_{nR}^2}}\}\text{SIGNAL}$$

$$+\frac{\sqrt{\eta}(P_S|h_S|^2d_1^m)\,\alpha\beta\,d^m\,h_{D1}n_R}{\sqrt{d_1^m(1-\alpha)}\sqrt{(1-\beta)P_S|h_S|^2d_1^m+d^m\,\sigma_{nR}^2}} + n_{D1}\}\ \text{NOISE}\ (6)$$

3. Outage Probability And Throughput Analysis

Calculate the SNR value first, and then carry out the throughput and outage probability analysis.The likelihood that the threshold value will occur can be expressed as

$$I_{RD} = \frac{1}{2}\log_2(1 + SNR_D) \quad (7)$$

The SNR value can finally be calculated as

$$SNR_D = \frac{E\{|Signal|^2\}}{E\{|Noise|^2\}} \quad (8)$$

The NOMA fundamentals state that successive interference cancellation (SIC) will be used to enable user-level decoding for each user in a separate group. Furthermore, conventional OMA and distinct superimposed symbols can be used to lessen inter-user interference. While SIC is set up at destination D2 to help with signal detection there, the considered user at destination D1 initially interprets D2's signal as noise in order to detect its own signal. It is common knowledge that providing users with better channel conditions with more transmit power and providing users with worse channel conditions with less transmit power enables a stable trade-off between system throughput and user fairness. The coding order is determined by the QoS requirement in NOMA.

We also assume, without sacrificing generality, the users power allocation coefficients are organised as $a_1^2 > a_2^2$. To keep NOMA systems performing at their best, the NOMA-strong user (i.e., D1) typically receives less power than the NOMA weak user (i.e., D2). As a result, a specific SNR for detecting the D1 signal at D1 can be obtained.

$$SNR_{D1,x1} = \frac{\eta\alpha\beta\,(1-\beta)P_S|h_S|^2\,|h_{D1}|^2a_1^2}{\eta\alpha\beta\,(1-\beta)P_S|h_S|^2|h_{D1}|^2a_2^2 + \eta\alpha\beta\,d^m|h_{D1}|^2\sigma_{nR}^2 + Q_1\frac{(1-\alpha)d^m d_1^m\sigma_{nR}^2\sigma_{nR}^2}{P_S|h_S|^2}} \quad (9)$$

For detecting symbols x1 at the destination D1, the received SNR can therefore be roughly expressed as:

$$SNR_{D1,x1} \approx \frac{\eta\alpha\beta\,(1-\beta)P_S|h_S|^2{h_{D1}}^2a_1^2}{\eta\alpha\beta\,d^m|h_{D1}|^2\sigma_{nR}^2 + \eta\alpha\beta\,(1-\beta)P_S|h_S|^2|h_{D1}|^2a_2^2 + Q_1} \quad (10)$$

It's crucial to remember that in D2, noise removal must come before decoding, in contrast to D1's decoding process. In this scenario, the signal from D1 is regarded as noise. Therefore, the received SNR for noise term x1 at D2 is as follows:

$$SNR_{D2,x1} \approx \frac{\eta\alpha\beta(1-\beta)P_S|h_S|^2{h_{D2}}^2a_1^2}{\eta\alpha\beta\,d_2^m|h_{D2}|^2a_2^2 + \eta\alpha\beta(1-\beta)P_S|h_S|^2|h_{D2}|^2a_2^2 + Q_1} \quad (11$$

Assuming NOMA, after SIC operation at destination D2, the receiving SNR for detecting x2 is given by:

$$SNR_{D2,x2} \approx \frac{\eta\alpha\beta\,(1-\beta)P_S|h_S|^2{h_{D2}}^2a_1^2}{\eta\alpha\beta\,d_2^m|h_{D2}|^2\sigma_{nR}^2 + (1-\alpha)(1-\beta)d^m d_2^m\sigma_{nD}^2} \quad (12)$$

4. Results and Discussions

The simulation result is carried out for the two NOMA users with the consideration of the Cognitive Radio network at the secondary side. The outage probability performance for the noise variance is shown in Figure 2.It is concluded that as SNR increases, the likelihood of an outage decreases.R2 = 1(bps/Hz) is better because it is having less outage probability. The dark mark on the line represents theoretical values, and the dark line represents the analytical results. From the above graph both the theoretical and practical values are matched.

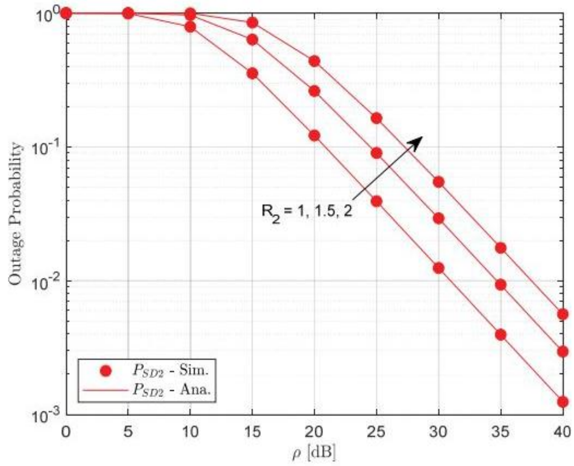

Figure 2: Outage probability versus SNR values.

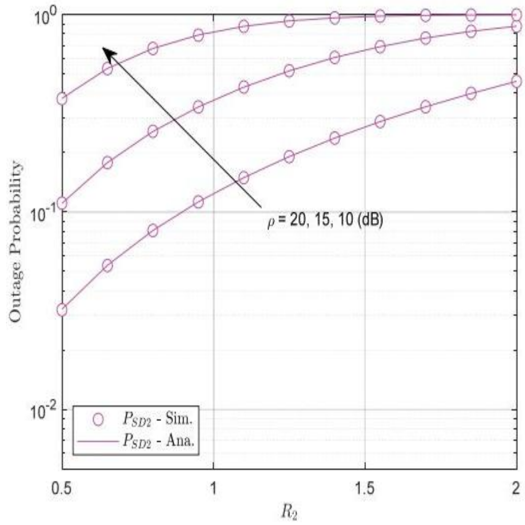

Figure 3: Outage Probability versus secondary network far user.

Figure 3 observes when we increase the target rate the bad will be the outage probability. The simulation result shows that using Cognitive Radio NOMA reduces the likelihood of an outage as SNR values are raised.

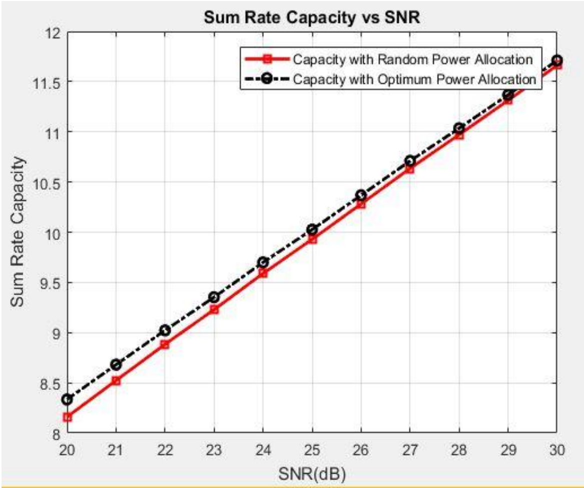

Figure 4. Sum rate calculation it respect to the SNR values

Figure 4 indicates the sum rate improvement when the SNR values increase. Thus using a relay at the secondary network improves the system performance by using optimal power allocation at the secondary network which improves the system performance ant throughput.

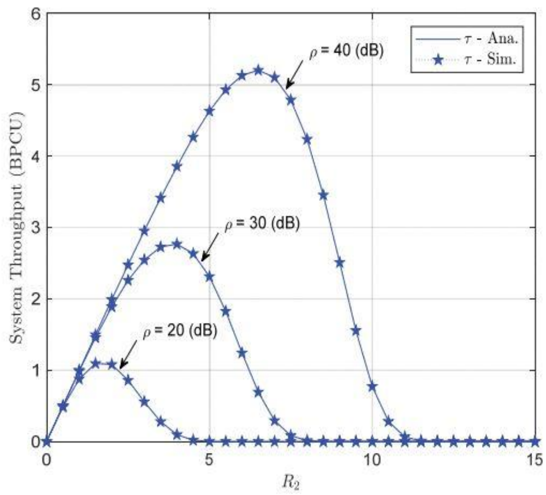

Figure 5: System throughput versus noise variance 20,30 and 40dB.

Figure 5 indicates the system throughput versus target rates. In this, the different noise variances to 20, 30, and 40 (dB) are plotted. Here higher performance factor i.e. 40 (dB) is obtained when using the CR-NOMA scheme. In the absence of CR-NOMA, less will be the throughput that we can conclude.Figure 6 indicates the lesser the outage probability for the user2 when increases the SNR significantly. Since using a cognitive radio at the secondary side the user2 theoretical value and the simulation values are matching that we can observe.

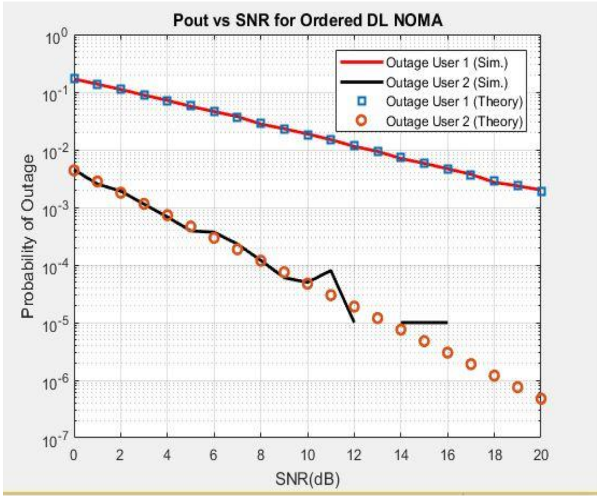

Figure 6: Outage Probability with respect to SNR values

5. Conclusions

When CR-NOMA is considered, the system throughput and the likelihood of an outage are examined. Here the performance is analyzed for the different target rates and different noise variance 20, 30, and 40 (dB) are plotted and analyzed. The above complete setup is analyzed for the NOMA-down link scenario. From the simulation result, it concludes that the outage probability decreases when we increase the SNR value. When CR-NOMA is utilised for the downlink NOMA network, the system's throughput in terms of more the sum rate calculation and less will be the outage probability. The end result allows for the faster achievement of high data rates and throughput. In the future, the relay input is analysed for uplink NOMA network scenario.

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