BER Performance of NOMA Downlink for AWGN and Rayleigh Fading Channels in (SIC)

Mohamed Hassan[1,*], Manwinder Singh[2] and Khalid Hamid[3]

[1]Dept. of Wireless Communication, Lovely Professional University – India, mhbe4321@gmail.com
[2]Dept. of Wireless Communication, Lovely Professional University – India, manwinder.25231@lpu.co.in
[3]Dept. of Electronics and Communication, University of Science & Technology – Sudan, khalid.bilal@ust.edu.sd

Abstract

Non-orthogonal multiple access (NOMA) is a great option for an upcoming radio access network due to its ability to provide enormous connections and high spectral efficiency. However, NOMA's primary issue is the error with successive interference cancellation (SIC). This paper aims to examine bit error rate (BER) downlink (DL) NOMA power domain (PD) for various SNR levels in additive white Gaussian noise (AWGN) as well as in Rayleigh fading channels utilizing Quadrature Phase Shift Keying (QPSK) for three different scenarios, to clearly differentiate the more effect of distance, bandwidth (BW), and power location coefficients factors using the MATLAB simulation software program. The BER versus SNR results were obtained in terms of charts for different BWs, distances, and power location coefficients. According to the findings, the BW parameter has the strongest effect on BER DL NOMA PD when compared to the distance, and power location coefficient parameters.

1. Introduction

Designing radio access technology for mobile cellular communications is a key element in improving system capacity more efficiently [1]-[2]-[3]. It can be divided into two main divisions, the first is orthogonal multiple access (OMA), which is a logical approach to achieving excellent system-level transmission efficiency by simplifying packet domain services receiver design [4]. It typically contains several access systems such as frequency division multiple access (FDMA), time division multiple access (TDMA), code division multiple access (CDMA), and orthogonal frequency division multiple access (OFDMA), which allow many users to concurrently access and share system resources [5]-[6]. Although more future designs are needed to reduce intracellular and/or intracellular interference to improve the efficiency of the spectrum in the future.

The second type is non-orthogonal multiple access (NOMA). Multi-user capacity can be achieved by NOMA by separating times or rates. The key aspect of the NOMA is that More users are provided by the number of orthogonal resources [7]. For the NOMA (1) NOMA power domain (PD) and (2) NOMA code domain, two main categories are available. The first category is utilized in the same frequency resource or time by many users with varying power transfers, A sparse codebook with the data matched on the codebook design for every user for the second category [8]. The capacity of future systems must therefore be greatly improved to address traffic volume growth. The supply of larger system capacity is particularly critical for 5G networks [9].

Although this technology offers many advantages, the problem of interference is a major challenge that must be addressed, and good solutions discovered. One such technique is successive interference cancellation (SIC) that is used [10]-[11]-[12]-[13]-[14].

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*Corresponding author. Email: mhbe4321@gmail.com

In [15] developed closed expressions of the BER rate at the near user ($U1$) and remote user ($U2$) of the examined DL-NOMA system and compared them to OMA plots, however, the distances and BWs factors and their effect on BER were not taken into account. The accuracy of the BER rate computed in a closed form for BPSK modulation in the perfect and deficient SIC states for the DL NOMA network was explored using the AWGN and Rayleigh fading channels. Nevertheless, characteristics that influence the BER, such as distance and power location coefficients, were not included in [16].

The goals of this paper are to study and analyse BER performance against SNR for different distances, BWs and power location coefficients for DL NOMA PD. The following are some of the most important contributions:
A DL NOMA over the Rayleigh Fading channel with three different BW has been proposed and investigated.
The impact of changing BWs, distances, and the power location coefficients for BER performance is explored with various scenarios.

The remainder of this paper is organized as follows. The 2nd section is related work. In 3rd section system model, it was divided into three scenarios, the first scenario involves 3 users, and the second and the third scenario comprise one user changing the conditions for study. The 4th section simulation. The 5th section result and discussions. Finally, the 6th Section concludes the paper.

2. Related Work

The author examined the performance of DL NOMA systems, particularly BER on Nakagami-m flat-fading channels. In different situations and scenarios, the exact BER of downlink NOMA systems is calculated considering the SIC in [20]. The author examines the performance of DL NOMA networks in the [16] binary shift phase of the key BER modulation. For every user, the precise BER equation is determined by the AWGN and Rayleigh fading channels in a closed-form in perfect and imperfect SIC situations. Author in [17], the highest BER was mathematically rated in a NOMA user system with a combined maximum probability detector in a multi-antenna base station. The author mention that the most significant disadvantage of NOMA is the error during SIC is carried out due to the inter-user interferences [18]. They obtain closed-form exact BER expressions for DL NOMA over Nakagami-m fading channels in which SIC errors are present. The performance of a Visible Light Communication (VLC) system NOMA-enabled is studied utilizing various modulation methods. A bit-decision axis and signal space-based analytical framework are provided to achieve the closed-form BER expressions for NOMA-enabled VLC systems in [19]. The author examines jointly in [21] the symbolic error rate (SER) and considers the DL / UL transmission, the number of information streams and

canal coding BER. The resultant SER and BER are represented in closed form, which helps assess transmission performance effectively.

3. System Model

The paper works separated into three scenarios of models. However, the same methodology is used as explained in the block diagram shown in figure 1.
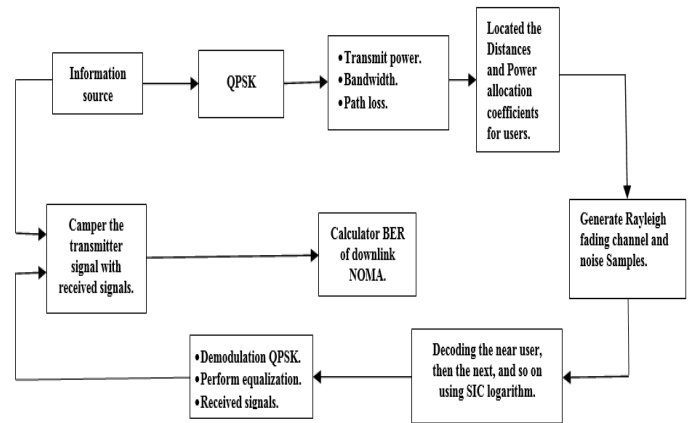

Figure 1. Block diagram for steps of downlink NOMA and calculate the BER

3.1. The First Scenario

Assume a wireless network comprising three NOMA users, as illustrated in figure 2, users ($U1$, $U2$, and $U3$). Let $d1$, $d2$, and $d3$ signify their respective Base Station (BS) distances, thus $d1 > d2 > d3$. According to distances, $U1$ is the weak/far and $U3$ is the strong/ near user for BS. Let $h1$, $h2$, and $h3$ indicate $|h_1|^2 < |h_2|^2 < |h_3|^2$ the Rayleigh fading coefficients that they match, (The channels are arranged this way because $h_i \propto 1/d_i$). Their relative power coefficients are indicated in α_1, α_2, and α_3. By the principles of NOMA PD, the weaker user should have more power and less power should be provided to the stronger user. The power coefficients must thus be adjusted accordingly as $\alpha_1 > \alpha_2 > \alpha_3$. We use a set of power coefficients in this paper for simplicity. Several dynamic power coefficient strategies are available to improve efficiency. Let x_1, x_2, and x_3 list the quadrature phase-shift keying (QPSK) formed messages to transmit to $U1$, $U2$, and $U3$ the base stations. Then the encoded overlay signal from the base station is provided

$$x = \sqrt{p}\left(\sqrt{\alpha_1}x_1 + \sqrt{\alpha_2}x_2 + \sqrt{\alpha_3}x_3\right).$$

The received signal at the ith user is delivered through, $y_i = h_i x + n_i$, where n_i denotes AWGN at the receiver of U_i.
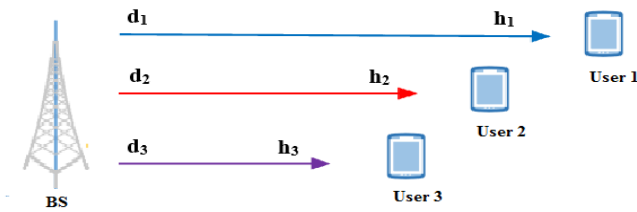

Figure 2. Wireless network NOMA PD with 3 users

where 3 users are $U1$, $U2$, and $U3$, their respective BS distances are indicated by $d1$, $d2$, and $d3$, and their respective Rayleigh fading coefficients are indicated by h_1, h_2, and h_3.

SIC Decoding Procedure
Figure .3 shows a technique of work (SIC), as the farthest user receives and decodes message directly without using (SIC) technics, but the closest users need to use (SIC), to decode and remove data of other users.
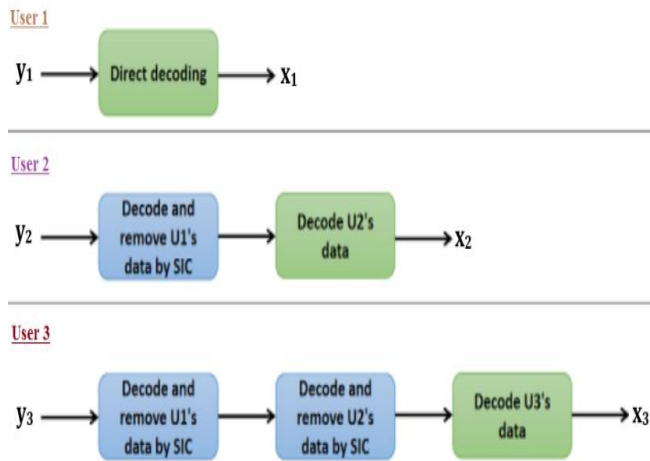
Figure 3. The working method of (SIC)

as $U1$ is assigned the highest power, it directly decodes y_1, which interferes with the $2^{nd} U$ and $3^{rd} U$ signals. The attainable first-rate is, given by as in [22] – [23].

$$R_1 = \log_2\left(1 + \frac{\alpha_1 P |h_1|^2}{\alpha_2 P |h_1|^2 + \alpha_3 P |h_1|^2 + \sigma^2}\right) \quad (1)$$

which can be simplified further as,

$$R_1 = \log_2\left(1 + \frac{\alpha_1 P |h_1|^2}{(\alpha_2 + \alpha_3) P |h_1|^2 + \sigma^2}\right) \quad (2)$$

Make one important note from the above equation, since the denominator is $\alpha_2 + \alpha_3$, the need now is α_1 to satisfy $\alpha_1 > \alpha_2 + \alpha_3$. The transmitted signal x, and the received signal, y_1, then dominate the power $U1$.

Next, let's write the equation for the rate of $U2$. First, To remove $U1's$ data and regard $U3$ it as interference, as $\alpha_2 < \alpha_1$, and $\alpha_2 > \alpha_3$, $U2$ must perform (SIC). The achieved rate is $U2$ after the deletion of $U1$ data by SIC.

$$R_2 = \log_2\left(1 + \frac{\alpha_2 P |h_2|^2}{\alpha_3 P |h_2|^2 + \sigma^2}\right) \quad (3)$$

To fulfil α_2, $\alpha_2 > \alpha_3$, as the α_3 is in the overlapping term of the denominator.

Finally, deleting data from y_3 both $U1$, and $U2$, $U3$ ($\alpha_3 < \alpha_1$, $\alpha_3 < \alpha_2$) needs to execute two SIC functions. Because α_1 prevails y_3, it must first be deleted. The α_2 term must be deleted after that. The attainable rate is

$$R_3 = \log_2\left(1 + \frac{\alpha_3 P |h_3|^2}{\sigma^2}\right) \quad (4)$$

3.2. The Second Scenario

We consider a wireless network consisting of one user NOMA PD as shown in figure 4. $U1$ moves from $d1$ to $d2$ and finally to $d3$ signify the respective BS distances, thus $d1 > d2 > d3$. Consider that the power coefficient (α) is constant. The corresponding Rayleigh fading coefficients are denoted by (h).
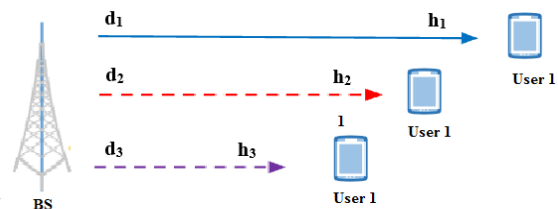
Figure 4. Wireless network consisting of one user NOMA with different distance

3.3. The Third Scenario

Consider a wireless network consisting of one user NOMA PD as shown in figure 5. The change in these times will be in the BW the distance factor (d), and power coefficients (α) are constant.
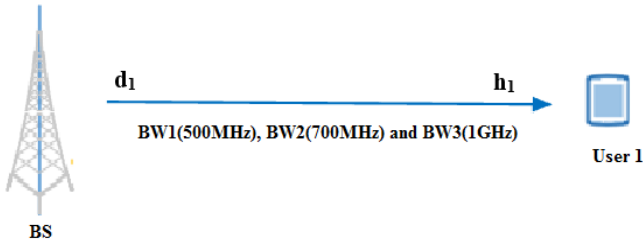

Figure 5. Wireless network consisting of one user NOMA with different bandwidths

4. Simulation Model

Firstly, let's specify our simulation settings shown in table (1) for three situations in the first scenario. Set path loss exponent (η) equals four. Generate Rayleigh fading h_1, h_2, $and\ h_3$ for every user. The number of bits that will be transferred in this case is N. Since utilizing QPSK modulation, each symbol has two bits. Therefore, the $N/2$ symbols are sent. For each symbol, create a fading Rayleigh coefficient. In addition, $d^{-\eta i}$ is the h_i variance, and is medium to zero.

Table 1. Parameters utilized for the first scenario

Table column heading	Parameters	User1	User2	User3
		d1	d2	d3
Distance (m) from BS		1000	500	100
Power Coefficients		α_1 0.8	α_2 0.15	α_3 0.05
Band Width		BW1 BW2 BW3	10^5 10^6 10^7	

Table 2. Parameters utilized for the second scenario

Table column heading	Parameters	One user		
		d1	d2	d3
Distance (m) from BS		2000	1500	1250
Power Coefficients (α)		0.4		
Band Width (BW)		100 KHZ		

Table 3. Parameters utilized for the third scenario

| Table column heading	Parameters	One user		
		BW1	BW2	BW3
Band Width (BW) KHz		500	700	1000
Power Coefficients (α)		0.75		
Distance (m) from BS		950		

Set the noise power quantity, consider a BW and the thermal noise power, kTB, and noise power in $log_{10}(kT) = -174$ dBm with the BW of 1 Hz. The noise power will thus be $-174 + log_{10}(BW\ MHz)$, with the noise strength computed in the last stage, let the three users utilized n_i to produce noise samples. The n_i has a mean zero and variance σ^2. Generate random user message bits and modulation and demodulation of QPSK. Creates the NOMA signal by superposition coding. Carry out the SIC to delete our estimate of the data or any user.
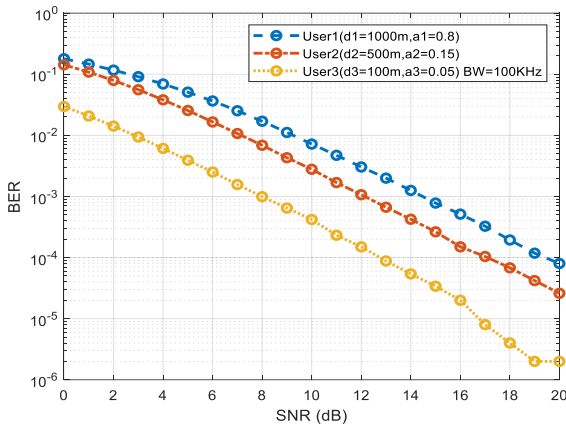
5. Result and Discussions

5.1 First Scenario
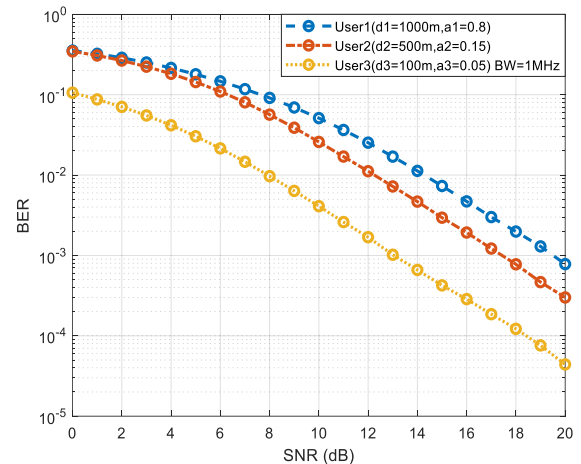
(a)
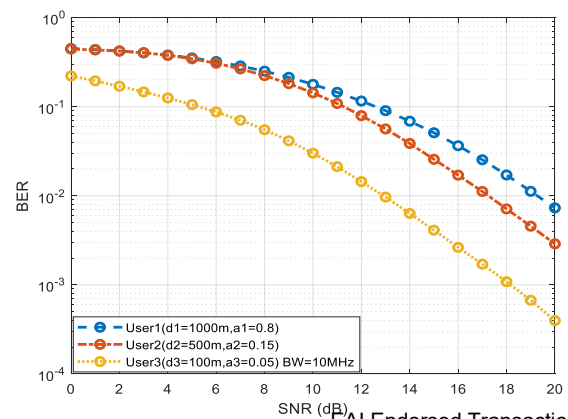
(b)

(c)

Figure 6. BER against SNR for different bandwidths, and distances for three users

Figure (6-a) shows the BER performance versus SNR at (100KHz) BW, the results show that the BER performance decrease as SNR increase and there is also a clear effect of distance and power coefficient. As the distance changed from (1 to 0.5) Km and the power coefficient changed from (0.8 to 0.15) the BER rate enhanced from user 2 to user 1 by (1.00E-04) and the distance changed from (500 to 100) m the and power coefficient changed from (0.15 to 0.05) the BER rate improved from user 3 to user 2 by (1.00E-03) for SNR of (18 dB). Hence the BER performance for user 3 is better than other users because user 3 is the nearest one. User 1 has the worst BER performance due to the interference from user 2 and user 3.

Based on increasing the bandwidth from 100 kHz to 1 MHz shown in Figure (6-b) for the same values of distance and power coefficient used in figure (6-a), find that the BER rate enhanced from user 2 to user1 by (12.00E-04) and the BER rate improved from user 3 to user 2 by (0.0007) for SNR of (18 dB). The results show that the performance of users 1 and 2 are close to each other until it reaches (4 dB) SNR and the BER performance has increased significantly.

Figure (6-c) shows the BER performance versus SNR at (10MHz) BW, the BER rate enhanced from user 2 to user1 by (1.00E-03) and the BER rate improved from user3 to user 2 by (6.00E-03) at SNR of (18 dB) with the same values of distance and power coefficient used in figure (6-a). The findings indicate BER performance for 1st user and 2nd user are closed to each other up to (8 dB) SNR, and there is a noticeable increase in the BER performance.

5.2 Second Scenario
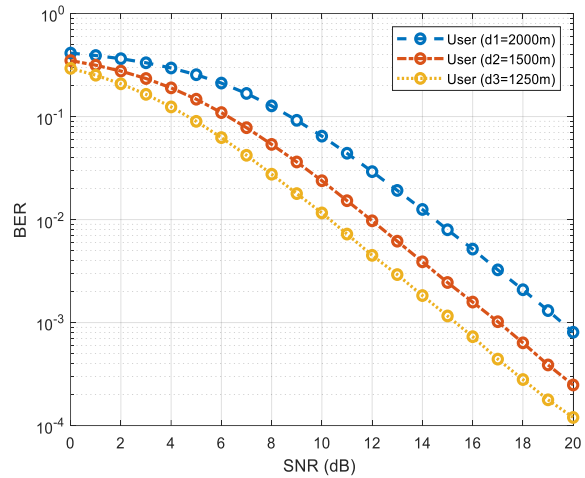
Figure 7. BER against SNR for one user with different distances

Figure.7 appears the BER performance for one user versus SNR at (100KHz) BW and (0.4) power coefficients for different distances. The effect of different distances appeared with increasing SNR. As the distance changed from (2 to 1.5) Km the BER rate improved by (6.00E-04) and the distance changed from (1.5 to 1.25) Km change the BER rate enhanced by (1.00E-04) at SNR of (20dB).

5.3 Third Scenario
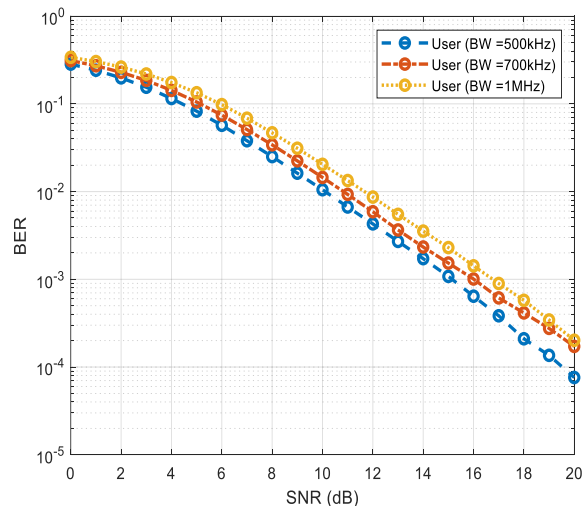
Figure 8. BER against SNR for one user with the different BW

This scenario studies the performance of a single user at the fixed distance of (950m), power coefficient of (0.75) and for different BW of (500, 700, 1000) KHz. As

BW changed from (700kHz to 500KHz) the BER rate improved by (1.00E-04) and BW changed from (1000 to 700) KHz the BER rate was enhanced by (3.00E-04) at SNR of 16dB. It becomes clear that as the BW increase the BER increase.

6. Conclusions

This paper has analyzed and explored the BER performance of DL NOMA PD against SNR for different scenarios with different BW, distances, and power location coefficients under AWGN and Rayleigh fading channels using QPSK with SIC. The findings indicate that the BER rate improved by (1.00E-04) at the BW of 100KHz, by (19.00E-04) at the BW of 1MHZ, and by (16.00E-03) at the BW of 10 MHZ and SNR of (18 dB) from user 3 to user1 for the first scenario. Hence the BER performance for user 3 is better than other users because user 3 is the nearest one. For the second scenario with one user and fixed BW and power coefficient with different distances. As distance changes from (2 to 1.25) Km, the BER rate is enhanced by (7.00E-04) at the SNR of (20 dB). For the third scenario with one user at the fixed distance and power coefficient with different BW. The BW Changed from (1000 to 500)KHz the BER rate improved by (4.00E-04) at the SNR of (16 dB). As the BW, distance, and power location coeffects rise, the BER increases. In comparison between BW, distance and power location coefficient factors, the BW parameter has the greatest influence on BER DL NOMA PD, according to the obtained results. Integration of NOMA with cognitive radio will be examined in future studies.

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