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IMPLEMENTATION AND PERFORMANCE EVALUATION OF NOMA TECHNIQUE VIA SIMULINK

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ABSTRACT

Non-Orthogonal Multiple Access (NOMA) is proposed for huge growth of 5th generation communication systems and beyond. It has the ability to benefit various applications, including future cellular networks like; Internet of Things (IoT), machine-to-machine (M2M) and device-to-device (D2D) communication. It is particularly suitable for scenarios with a high data traffic and large number of connected devices, as it offers efficient spectrum utilization and improved connectivity. In general, any Simulink software provide the researchers with the ability to evaluate various performance metrics of the system. NOMA system was implemented in this work via Matlab in his both (m. file) and (Simulink Block), and many cases were studied and evaluated. Where 2-users and 3-users cases are applied for different values of; user's distance from the base station, bandwidth, power allocation coefficients, modulation type and different noisy channels. The bit error rate (BER) versus two important parameters i.e. signal to noise ratio (SNR) and the transmitted power were measured and evaluated. Also fixed power allocation (FPA) and Dynamic power allocation (DPA) for the coefficients were implemented and tested for both cases; far and near user in DL–NOMA (down link). The enhancement value that achieved in outage probability for DPA over FPA is equal to 7.5 bps/Hz in far user case, while 6 bps/Hz is achieved in near user case.

KEYWORDS

Bit error rate (BER), Capacity and outage probability, Dynamic power allocation (DPA), Fixed power allocation (FPA), Non-orthogonal multiple access (NOMA) and Orthogonal multiple access (OMA).

1. INTRODUCTION

The scarcity of the spectrum and other obstacles has become a global issues, especially after massive growth of wireless communications, that's why the solution became an urgent matter. Multiple methods and procedures have been studied and applied to solve or mitigate these obstacles (Ammar O. Barznji et al., 2021). One of these methods is the Multiple Access technique, it can be divided into two categorize: OMA and NOMA. Where each multiple access technique has its advantage and is suitable for different scenarios (Chai, L. et al., 2023).

In Orthogonal Frequency Division Multiple Access (OFDMA), different users are assigned orthogonal subcarriers, which are non-overlapping in the frequency domain. Each user occupies a subset of subcarriers, and the signals can be easily separated at the receiver using fast Fourier transform (FFT). OFDMA is well-suited for high-capacity systems with diverse traffic requirements. It has been widely adopted in cellular networks, such as 4G LTE and 5G, due to its spectral efficiency, flexible resource allocation, and ability to handle high data rates. Code Division Multiple Access (CDMA), on the other hand, uses unique spreading codes to separate different user signals, allowing multiple users to share the same frequency band simultaneously. It is effective in environments with moderate user densities and a need for interference rejection. CDMA was extensively used in 3G systems like CDMA2000 and WCDMA (Mohamed H. et al., 2021) and (Ahmed R. K. et al., 2022). The two multiple access mentioned above are OMA technique type.

NOMA, does not rely on orthogonality and allows for non-overlapping user signals by using power domain multiplexing. Where it is particularly beneficial in scenarios with limited spectrum resources and large number of users. NOMA is considered a promising technique for future wireless systems, including 5G and beyond, as it offers higher capacity, improved connectivity, and better support for massive connectivity scenarios (Omer M. et al., 2022) and (Khoung Ho. Van 2024). Unlike OMA, which allocates orthogonal resources to different users, NOMA gives permission to multiple users to share the same time-frequency resource non-orthogonally. It enables flexible power allocation, which can be used to prioritize certain users or differentiate services based on quality-of-service requirements. Users with poor channel conditions or higher quality-of-service demands can be assigned higher power levels, ensuring reliable and high-quality communication for those users. It has been considered as a potential technology for future wireless communication systems. It is expected to play a crucial role in supporting the increasing demand for high-capacity and low-latency services in wireless networks (Saito Y. et al., 2013) and (Ding, Z. et al., 2017).

NOMA users are separated in the power domain rather than the time or frequency domain. This type of multiplexing allows for overlapping transmissions, as the receiver can decode the signals based on their power levels. So, multiple users are allocated the same time-frequency resource but with different power levels. Then the signals from different users are superimposed at the receiver, which employs advanced signal processing techniques called; Successive Interference Cancellation (SIC) as in Fig. 1 to separate and decode the individual user signals. SIC involves decoding the signal with the highest power level first and subtracting its contribution from the received signal to decode the next signal with a lower power level. This process continues until all user signals are decoded (Ding, Z. et al., 2020) and (Liu, C. et al., 2023).

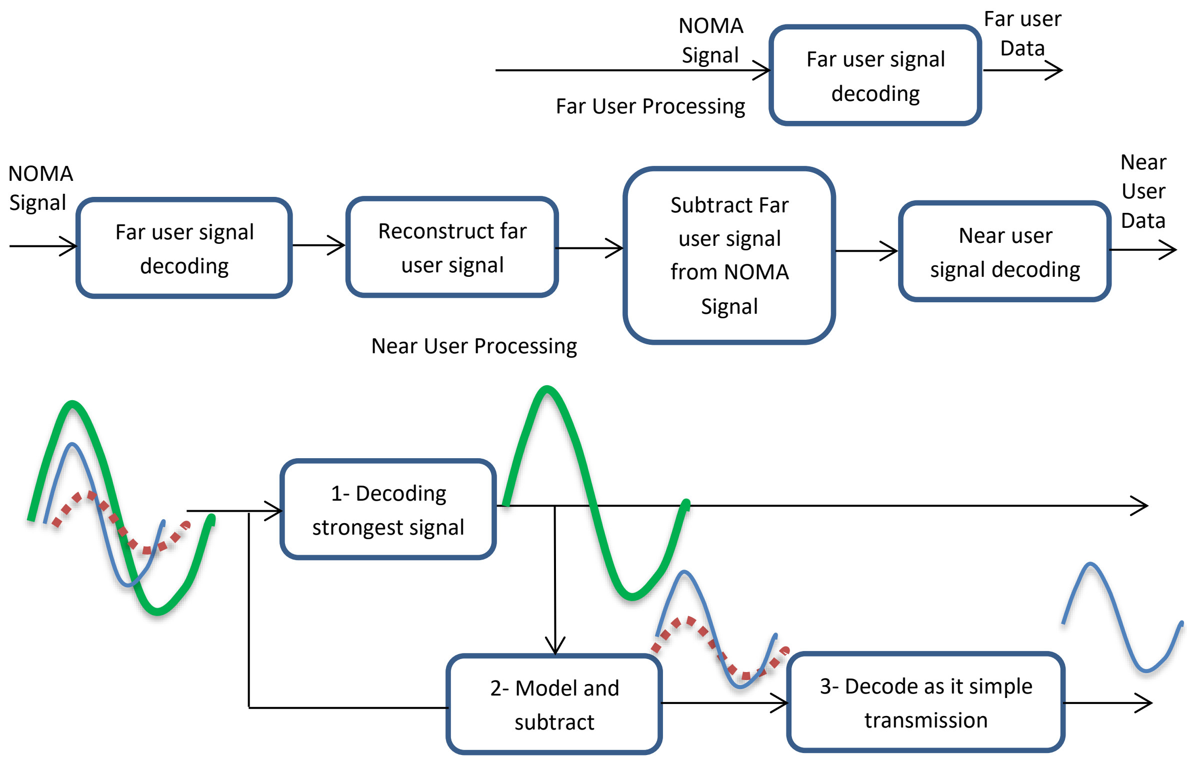


Fig. 1. Successive interference cancelation (SIC)

The main contribution of this paper is to implement NOMA system via Matlab Simulink and applying two types of noisy channel; Additive White Gaussian Noise (AWGN) and Rayleigh Fading channel, then evaluating the system performance through study and analyze the following:

- BER vs. SNR, then vs. transmit power. This is done through changing the users distances, the bandwidth and the channel type for 2 users case, then repeated for 3 users.
- Applying a dynamic power allocation (DPA) for the coefficients in downlink (DL) DL-NOMA to prove the enhancement over fixed power allocation (FPA) for far and near user cases.

The rest of this paper is organized as follows; section 2 is the related work and section 3 goes through NOMA characterization and theory. Section 4 is the capacity comparison between OMA & NOMA. Section 5 explaining the effect of DPA on the system capacity. Section 6 about Matlab representation of NOMA system and the results, it deals with implementing and analyzing 2-users then 3-users NOMA system applying two types of channels; AWGN channel and Rayleigh fading channel. Also DPA and FPA cases are examined in the same section. Finally the conclusion and the future work are discussed at the last section.

2. RELATED WORK

NOMA has been a subject of extensive research in the field of wireless communication systems. Numerous researchers have investigated and proposed various techniques and algorithms related to NOMA. Here there are a few examples of previous research works in this regard (Saito Y. et al., 2013) revealed the capabilities of NOMA for upcoming cellular networks. They verified that the performance of NOMA is better than OMA in terms of capacity and user fairness. Since then, researchers around the world have begun to explore how to turn the NOMA concept into next-generation radio access technology. (Wenjia Liu et al., 2018) studied the uplink NOMA case and tried to enhance it through the requirements of high reliability and massive connectivity. Also they went through proposing multi-level received power so that SIC become more better. In (Assaf T. et al., 2019) they examined the BER of DL-NOMA on different situations, channels and scenarios, particularly Nakagami-m flat-fading channels. They calculated the exact BER and the effect of SIC at the receiver side. In (Jain M. et.al., 2020) they studied a DL-NOMA system in the presence of SIC error over Rayleigh fading channels. They derived the exact closed-form expressions of BER at the users and compared the results with conventional OMA. The Master Degree thesis of (Rahul Ch. E. and Viswakanth R. G., 2021) analyzed the performance metrics of a power domain NOMA system. They assume that the near user behaves as full duplex relaying because he forward the signal to far user under effect of Nakagami-m fading. To show the effect of system parameters, they measured the outage probability and assessing using full duplex mode, the performance of the NOMA system. In (Kardes A. and Tansal G., 2021) they derived an equations related symbol error rate (SER), channel capacity and outage probability for a DL-NOMA system over generalized-K fading channels with an arbitrary number of users. Also they analysed the relationship between power density function (PDF) and signal to interference noise ratio (SINR) coefficients. In (Han W. et.al., 2021) they studied the SER and BER for both downlink/uplink transmission, the information streams, and the channel coding. They proved that there is no propagation error or accumulation error when SIC is used in decoding side, which is the major drawback of any NOMA systems. In (Anju V. K. and Sumitra N. M., 2021) they proposed a detection algorithm that enhancing the capacity of multiple users, they called it (Whale Rank Successive Interference Cancellation (WRSIC)). This algorithm used in multiple input multiple output (MIMO) - NOMA to minimize the interference and maximize the channel capacity. In (Arsla K. et al., 2021) they presented a NOMA simulator and studied the performance for two and more than two users. They applied the design for link-level and system-level using a single cell, multi cells scenarios and multi-carrier NOMA. For the baseline of NOMA simulator, they used Long-term evolution (LTE). The performance of the system was assisted by analyzing and measuring the bit error rate (BER), spectral efficiency and throughput. (Mohamed H. et al., 2022) in their paper, they examined BER in DL-NOMA power domain for various SNR levels in AWGN channel and QPSK modulation. They used Matlab simulation to differentiate the effect of distance, bandwidth. Also they examined the scenario of fixed power location coefficients only without showing the effect of adaptive case. Also other type of channels are not tested in their work. In (Charan K. R. et al., 2023) they presented the Simulink implementation of NOMA over AWGN, Rayleigh and Rician fading channel. Where the assessment of the system is done through values tabulated for BER vs. SNR without plotting the relationship to clarify the design. Also they didn't deal with adaptive power allocation for different users distances.

3. NOMA CHARACTERIZATION AND THEORY

For DL-NOMA concepts, consider user1 (U_1) is near to the base station (BS) while user2 (U_2) is far away as in Fig. 2. It is well known in this concept that using superposition coding (SC) at the transmitter side, and SIC at the user end (Jinyuan Gu et al., 2024). BS will assigned low power to U_1 having channel gain h_1, and high power to U_2 having channel gain h_2, such that $|h_1|^2 > |h_2|^2$ (Ameer H. Ali and Saad S. Hreshee, 2023), (Kara, F. and Kaya H., 2018) and (Saito, Y., 2013).

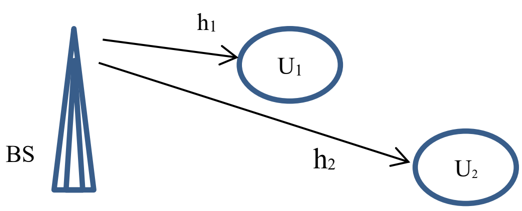


Fig. 2. Basic DL-NOMA system

$$y_1 = h_1 p x_1 + n_1 \quad (1)$$

$$y_2 = h_2 p x_2 + n_2 \quad (2)$$

Eq.1, 2 are like TDMA case, where: (x) is the message signal, (n) is the noise and (p) is the entire power given to each user. But for DL-NOMA case the power allocated is:

$$p_1 + p_2 = p \tag{3}$$

Let |h1| > |h2| because of h2 is the worst channel, so more power should be given to him, i.e. p2 > p1

$$y_2 = h_2\,(p_1 x_1 + p_2 x_2) + n_2 \tag{4}$$

$$= h_2\, p_2 x_2 + h_2\, p_1 x_1 + n_2 \tag{5}$$

Because of the term (p1 x1) having a small value, all the second term (h2 p1 x1) is also small and look like a noise when adding to n2, then it can be detected as direct detection. Also:

$$y_1 = h_1\, p_1 x_1 + h_1\, p_2 x_2 + n_1 \tag{6}$$

In Eq. 6, the second term (h1 p2 x2) having a large amount and cannot treated as a noise, so we can detect and decode this term using SIC. Also this means that the detection process estimate the value of x as x^, so:

$$y_1 = h_1\, p_1 x_1 + h_1\, p_2 x_2 + n_1 - h_1\, p_2 \hat{x_2} \tag{7}$$

While the term: $y_1 = h_1\, p_1 x_1 + n_1$ is look like the term of TDMA in Eq. 1

4. CAPACITY COMPARISON BETWEEN OMA & NOMA

The performance is measured be Shannon channel capacity (Kara F. and Kaya H., 2018), (Saito Y. et al., 24th IEEE, 2013) and (Saito Y. et al., 77th IEEE, 2013):

$$C = W\, log_2\,(1 + SNR)\; bits/\sec \tag{8}$$

This is the achievable capacity or (theoretical limit), where *W* is the bandwidth and has a higher impact on capacity equation than SNR, from Eq. (8) we will try to prove that NOMA is more benefit than OMA.

For the OMA case:

$$SNR_{near} = \frac{P_{near}}{noise} \quad and \quad SNR_{far} = \frac{P_{far}}{noise} \tag{9}$$

For the NOMA case: near-user can cancel the far-user signal, so;

$$SNR_{near} = \frac{P_{near}}{noise} \tag{10}$$

While NOMA far-user can't cancel the near-user signal, so;

$$SNR_{near} = \frac{P_{far}}{P_{near} + noise} \tag{11}$$

$$C_{OMA} = \frac{W}{2}\log_2\left(1 + \frac{P_{near}}{noise}\right) + \frac{W}{2}\log_2\left(1 + \frac{P_{far}}{noise}\right)\; bits/\sec \tag{12}$$

$$C_{NOMA} = W\,\log_2\left(1 + \frac{P_{near}}{noise}\right) + W\log_2\left(1 + \frac{P_{far}}{P_{near} + noise}\right)\; bits/sec \tag{13}$$

It is clearly seen from Eq. 13 and Fig. 3 that the capacity of NOMA is greater than OMA because it depends on (*W*) i.e full bandwidth and not half (*w/2*).

$$P_{far} + P_{near} = P_{total} = constant \quad (14)$$

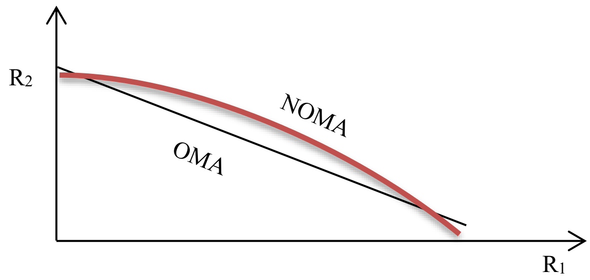


Fig. 3. The rate or the capacity of NOMA vs. OMA

5. DYNAMIC POWER ALLOCATION IN NOMA

In all the previous designed cases, it's clear that the value of power allocated to the user (a_i), has a direct relationship with the BER. Also their values are fixed at the design Fixed Power Allocation (FPA) and didn't changed. But some researchers (Kara F. and Kaya H. 2018) and (Yang Z. 2017) were tried to do some enhancements in energy efficiency, capacity, and other parameters through using Dynamic Power Allocation (DPA) based on the values of CSI. This happens by giving the priority to the far/weak user and providing him high power, so that he can achieves his goal, while the remaining value of power is allocated to the near user. The derivation of the power allocation coefficients a_f and a_n for far and near users respectively, can be derived as follows (website):

$$a_f + a_n = 1 \quad (15)$$

where: $a_f > a_n$

let C_t denote the target capacity of far user (C_f) and a_f should be chosen, so: $C_f \geq C_t$, and the noise power is σ^2; Assuming: $C_f = C_t$,

$$log_2\left(1 + \frac{|h_f|^2 \ Pa_f}{|h_f|^2 \ Pa_n + \sigma^2}\right) = C_t \quad (16)$$

By taking ($\log^{-1}$) for both sides;

$$\frac{|h_f|^2 \ Pa_f}{|h_f|^2 \ Pa_n + \sigma^2} = 2^{C_t} - 1 \quad (17)$$

Assuming: $$€ = 2^{C_t} - 1 \quad (18)$$

where € is the target SINR for the far user who has target capacity C_t

$$\frac{|h_f|^2 \ Pa_f}{|h_f|^2 \ Pa_n + \sigma^2} = € \quad (19)$$

Then; $$|h_f|^2 \ Pa_f = € \, |h_f|^2 \ Pa_n + € \, \sigma^2 \quad (20)$$

Substituting in Eq. 15, then:

$$|h_f|^2 \ \text{P}a_f = € \, |h_f|^2 \ \text{P} \, (1 - a_f) + € \, \sigma^2 \tag{21}$$

After some simplifications the equation will be:

$$\text{a}_\text{f} = \frac{€ \, (\, |\text{h}_\text{f}|^2 \ \text{P} + \sigma^2)}{|\text{h}_\text{f}|^2 \ \text{P}(1+€\,)} \tag{22}$$

We don't want a_f exceeding the value of 1, so let the limit be:

$$a_f = \min\left(1, \frac{€ \left(|h_f|^2 \, P + \sigma^2 \right)}{|h_f|^2 \ P(1 + €\,)}\right) \tag{23}$$

Then we can easily calculate a_n from Eq. (23) because; $a_n = 1 - a_f$

6. MATLAB IMPLEMENTATION OF NOMA SYSTEM AND THE RESULTS

Number of simulation systems were implemented and tested. This done through changing the number of users, the distances, the noisy channel and the values of the power allocated to each user depending on how far or close to BS. They can be classified as follows:

6.1. Two DL-NOMA Users applying AWGN Channel

A 2 DL-NOMA users is simulated using Matlab with AWGN channel and without applying a path loss to keep a simple design as shown in Fig. 4. The assumption here is that; two users U_1 and U_2 are located at equal distances from the BS using BPSK modulation for both users, where BS is at the cell centre. x_1 is the data to be sent to U_1 and x_2 is the data to be sent to $U2$.

Two cases were tested, the 1st is: the power allocation coefficient (PAC); $a_1 = 0.9$ given to U_1 and $a_2 = 0.1$ given to U_2. The 2nd case when $a_1 = 0.8$ and $a_2 = 0.2$. Table 1 and Fig. 5 clarify the relation between BER and SNR. It can be seen from them, that BER is decreased non-linearly when SNR is increased. Also U_1 have better performance than U_2 because of the large amount of power that allocated to him. There are slight deviation among the values for the two cases but the overall shapes are look like same.

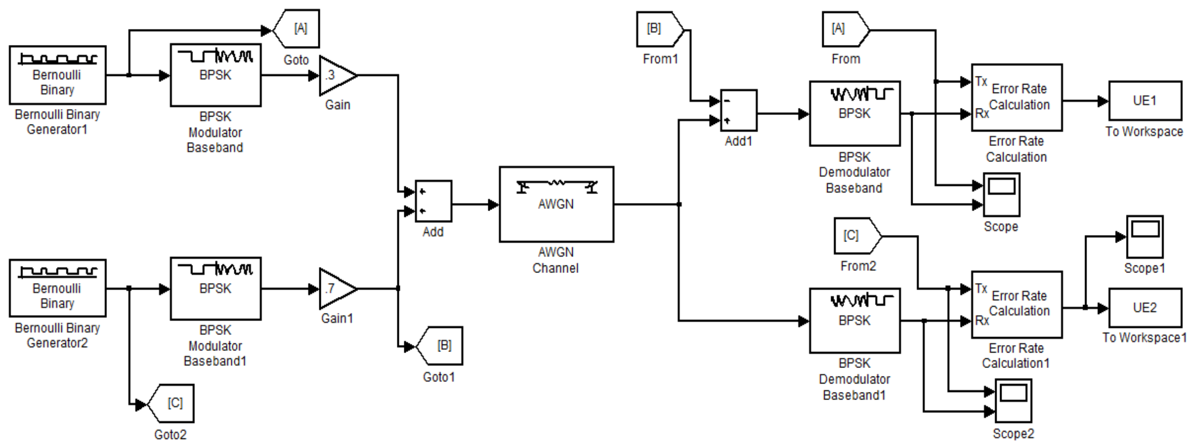


Fig. 4. Matlab Simulink block for 2 DL-NOMA users

Table 1. BER vs. SNR for 2 DL-NOMA users for different PAC and AWGN Channel

BER	**at $a_1 = 0.9$, $a_2 = 0.1$**		**at $a_1 = 0.8$, $a_2 = 0.2$**	
SNR dB	User 1	User 2	User 1	User 2
0	0.1855	0.4380	0.2078	0.4067
4	0.0901	0.3722	0.1266	0.3411
8	0.0285	0.2423	0.0635	0.1965
12	0.0030	0.1062	0.0192	0.0568
16	0.0000	0.0223	0.0013	0.0039
20	0.0000	0.0007	0.0000	0.0000

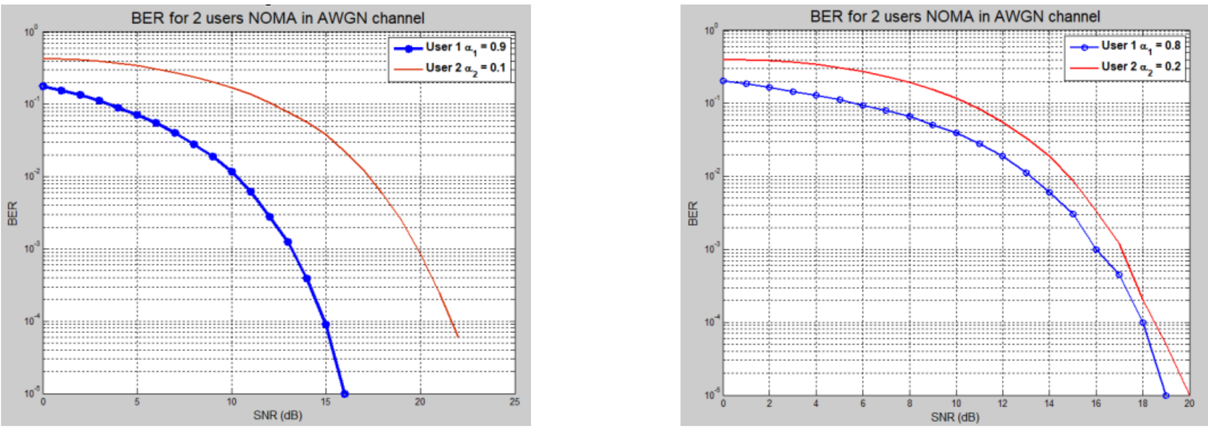


Fig. 5. BER vs. SNR for 2 DL-NOMA users with same distance from BS applying AWGN

6.2. Two DL-NOMA Users Applying Rayleigh Fading Channel

Considering the 2 users in this case are with different distances from the BS, where $d_1 > d_2$, i.e. U_1 is far and U_2 is near. Rayleigh fading channel is applied with path loss. Some parameters are assumed in the Simulink as follows:

$d_1 = 900$ m, $d_2 = 300$ m, , thermal noise power $N_o = kTB$.

Where:

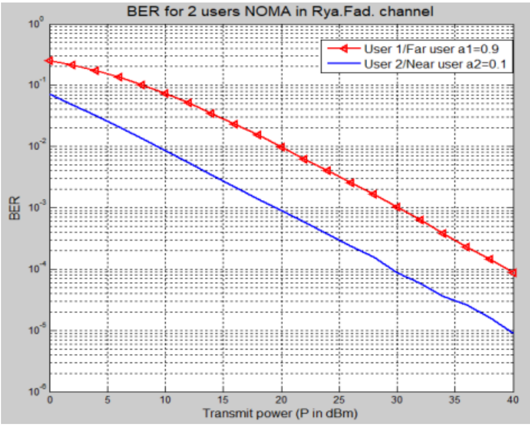
$k = 1.38\times10^{-23}$ J/K, temperature (T) = 300K and the bandwidth (B) = 1MHz.

Table 2 and Fig. 6 demonstrate the relationship between BER and the transmit power for two cases of PAC (0.9, 0.1) and (0.8, 0.2).

Table 2. BER vs. Transmit power for 2 DL-NOMA users for different PAC applying Rayleigh Fading Channel

BER	**at $a_1 = 0.9$, $a_2 = 0.1$**		**at $a_1 = 0.8$, $a_2 = 0.2$**	
Tr. Pw. dBm	User 1	User 2	User 1	User 2
0	0.2553	0.0716	0.2739	0.0504
8	0.1017	0.0133	0.1325	0.0086
16	0.0234	0.0022	0.0377	0.0014
24	0.0040	0.0004	0.0070	0.0002
32	0.0006	0.0001	0.0012	0.0000
40	0.0001	0.0000	0.0002	0.0000

The two cases showing similar change and the overall shapes behavior seems to be liner relationship. Where the BER decreased when the values of the transmit power increased. The results also show that U_2 is better in the performance and less BER than U_1, because the latter requires higher allocated power being the farthest from BS.



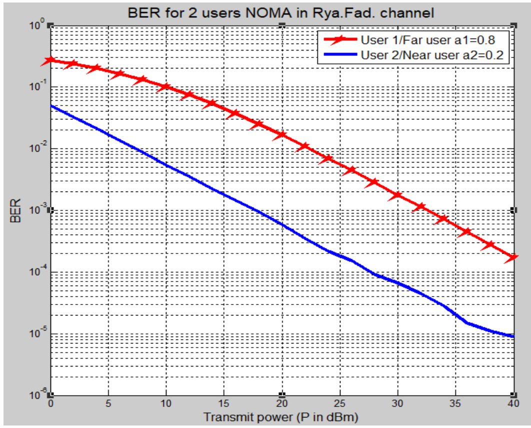


Fig. 6. BER vs. transmit power for two users with different distance from BS applying Rayleigh fading channel

6.3. BER Values of Three DL-NOMA Users with QPSK Modulation

Considering a NOMA system consists of three users (U_1, U_2, U_3) and their distances (d_1, d_2, d_3) are different, where; $d_1 > d_2 > d_3$ as in Fig. 7. Because of these distances, the weakest user is U_1 and the strongest user is U_3. Let h_1, h_2 and h_3 represent their corresponding Rayleigh fading coefficients such that; $|h_1|^2 < |h_2|^2 < |h_3|^2$. Assuming the PAC are: a_1, a_2 and a_3 respectively. So the strongest user must be allocated the least power while the weakest user must be allocated the most power as a principle of NOMA. Therefore, PAC must be ordered as: $a_1 > a_2 > a_3$.

The superposition coded signal transmitted by the BS is given by (Ashwaq Q. Hameed):

$$x = \sqrt{p}\ \left(\sqrt{a_1}\, x_1 + \sqrt{a_2}\, x_2 + \sqrt{a_3}\, x_3\right) \tag{24}$$

And the signal received at i^{th} user is given by;

$$y_i = h_i\, x + n_i \tag{25}$$

where n_i denotes AWGN at the receiver U_i.

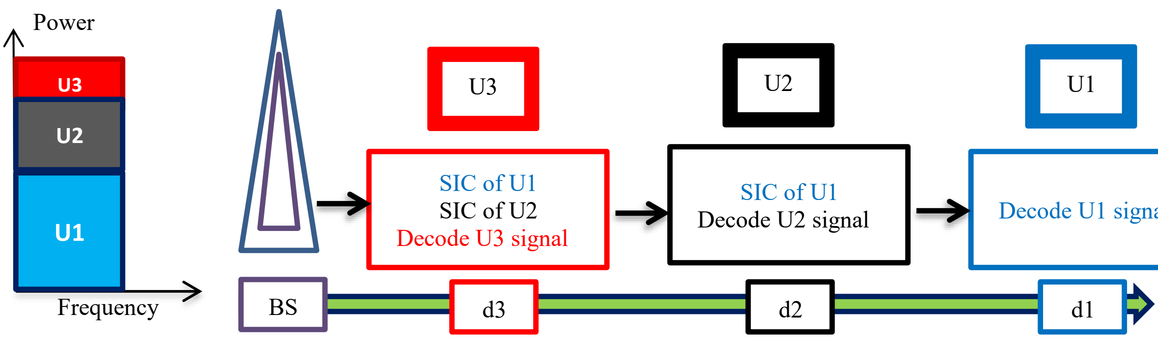


Fig. 7. 3 DL-NOMA users with SICs

Three cases were examined, the 1st case: d_1 = 600m and a_1 = 0.9, d_2 = 100m and a_2 = 0.08, finally d_3 = 10m and a_3 = 0.02. For the 2nd case: the distance were remain as 1st case but PAC changed to 0.75, 0.2 and 0.05 respectively. Finally for the 3rd case: PAC are same as 2nd case, but the distance changed to 700m, 200m and 50m respectively. Table 3 and Fig. 8, show that BER decreased when the transmit power increased.

Table 3. BER vs. Transmit power for 3 DL-NOMA users for different PAC and Distances

BER	$d_1 = 600m, a_1 = 0.9$ $d_2 = 100m, a_2 = 0.08$ $d_3 = 10m, a_3 = 0.02$			$d_1 = 600m, a_1 = 0.75$ $d_2 = 100m, a_2 = 0.2$ $d_3 = 10m, a_3 = 0.05$			$d_1 = 700m, a_1 = 0.75$ $d_2 = 200m, a_2 = 0.2$ $d_3 = 50m, a_3 = 0.05$		
Tr. Pw. dBm	U_1	U_2	U_3	U_1	U_2	U_3	U_1	U_2	U_3
0	0.173	0.005	0.0002	0.213	0.0035	0.0014	0.259	0.047	0.0176
8	0.052	0.0009	0.0001	0.101	0.0006	0.0003	0.133	0.0084	0.0032
16	0.0099	0.0002	0	0.034	0.0001	0.000	0.052	0.0013	0.0005
24	0.0015	0	0	0.0073	0	0	0.012	0.0002	0.0001
32	0.0002	0	0	0.0012	0	0	0.0021	0	0
40	0	0	0	0.0002	0	0	0.03	0	0

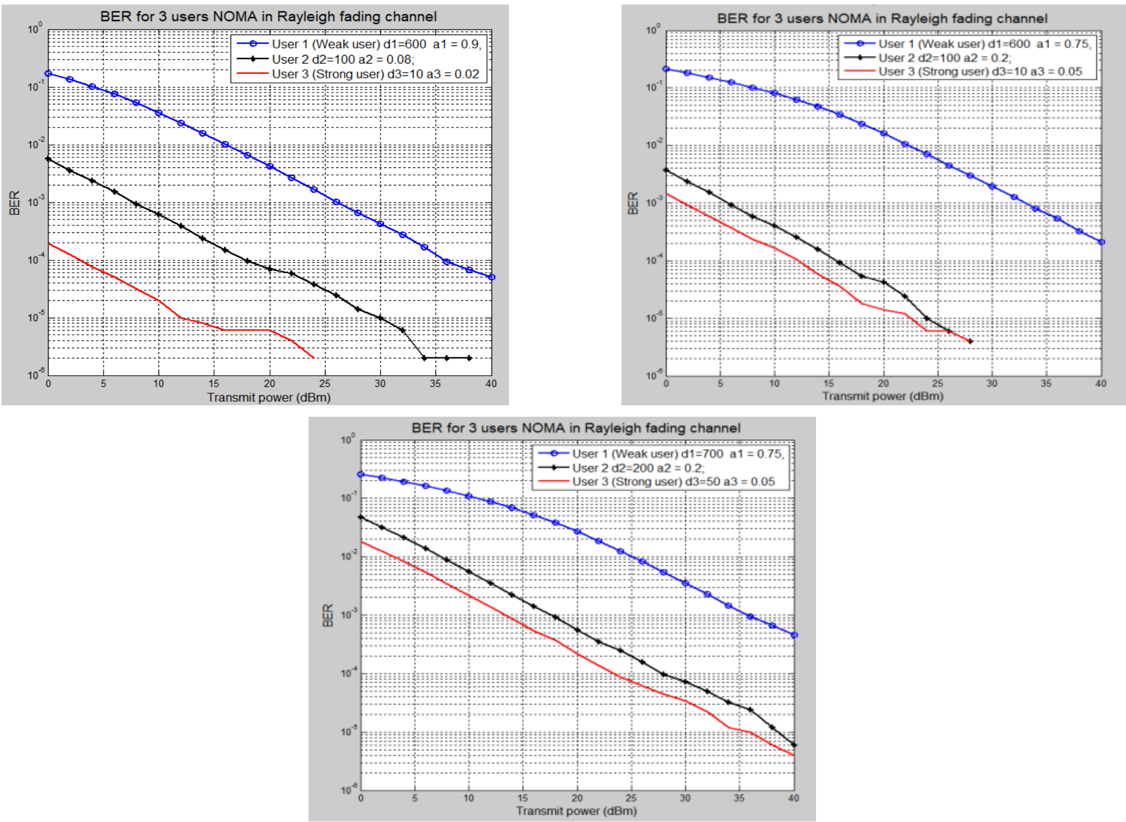


Fig. 8. BER vs. transmit power for three users with different distance from BS applying Rayleigh fading channel

Also U_1 in all the cases having the higher BER for same transmit power, because of interference with the other two users. While U_3 in all the cases having less BER because free from interference and its performance is the better one. In addition its seen that the overall performance of the 1st case is better than the other two cases.

6.4. Matlab Representation of NOMA Dynamic and Fix Power Allocation

Considering a NOMA system consists of two users. One of them is far away from BS while the second is near. Rayleigh fading channel is applied with path loss. The values assumed in this simulation are as follows:

Distance from BS to the far user (d_f) = 1100 m; Distance from BS to the near user (d_n) = 200 m; the total transmit power is fixed to 32 dBm, a_f = 0.85 and a_n = 0.15 as a FPA.

From Table 4. and Fig. 9 it can be seen that the performance of FPA is unsatisfactory and the outage probability reached rapidly the saturation (i.e. = 1) when C_t > 2.5 bps/Hz (exactly at 3 bps/Hz). Although the implementation of FPA is simple, but there is a decline in its performance. It doesn't use the instantaneous CSI, also doesn't take into account the target rate. While for DPA case; the value of a_n and a_f are adjusted depending on CSI and the target rate requirement, so that, the outage probability increases gradually for far user as his target rate requirement increases and reaches the saturation at 10.5 bps/Hz. So, the enhancement in using DPA is equal to; (10.5 – 3) = 7.5 bps/Hz. Return to the near user, the shape has quit sharp around Ct values 5 to 9 bps/Hz and then reach the saturation, (exactly at 9 bps/Hz). So, the enhancement for near user for the DPA case over FPA case is equal to; (9 – 3) = 6 bps/Hz.

Table 4. Outage probability vs. target rate (C_t) for FPA and DPA case.

Outage Probability	**at a_f = 0.85 a_n = 0.15**		**at Dyn. Pw. Allo. (DPA)**	
Target rate of Far user C_t bps/Hz	Far user – Near user FPA		Far user – Near user DPA	
0.5	0.0018	0.0000	0.0973	0.0025
2.0	0.0266	0.0001	0.2942	0.0117
3.5	1.0000	1.0000	0.3701	0.0381
5.0	1.0000	1.0000	0.3764	0.1154
6.5	1.0000	1.0000	0.5120	0.3357
8.0	1.0000	1.0000	0.6805	0.8182
9.5	1.0000	1.0000	0.9548	0.9998

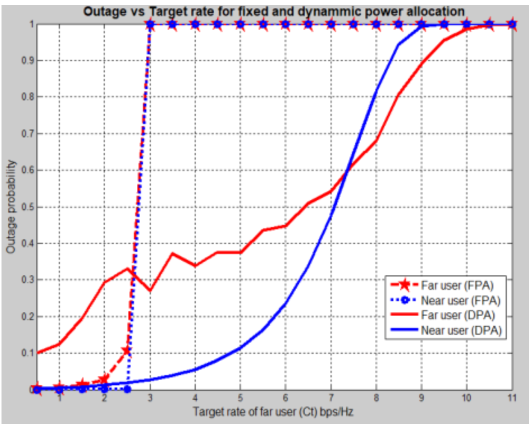


Fig. 9. Outage probability vs. target capacity (Ct) for FPA and DPA case

7. CONCLUSIONS AND THE FUTURE WORKS

The Simulink implementation of NOMA system and its performance evaluation have been examined in this work with multiple scenarios. This is done through changing: the number of users, their distances from base station, the channel type and finally applying fixed and dynamic power allocation coefficients. All that to check the behavior of the NOMA system through measuring BER vs. SNR then vs. the transmit power, also to check the outage probability vs. the capacity. For the AWGN channel and equal user's distance case, the behavior of the largest user's power is better because of his less BER. For Rayleigh fading channel and user_1 is far than user_2*,* the latter is better performance with less BER than user_1 because he needs less allocated power being the nearest to BS. The same things happened for three users case, i.e. the nearest user is less BER than the farthest one, because of the amount of the power allocated and the interference value. Finally in comparing between the DPA and FPA case, it's clear that the latter has worst performance and the outage probability reaches the saturation rapidly.

For a future work, the performance of the system can be checked by applying other types of channels, or by increasing the number of users to be more than 3,or by using other simulation software and comparing the results with this designed system.

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