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Performance Evaluation of Downlink MIMO-NOMA Achievable Sum Rate, Outage Probability, and Energy Efficiency

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Abstract-* The introduction of multiple antennas at the transmit and receive ends respectively with non-orthogonal multiple access (NOMA) will give rise to wireless communication system that leverages the spatial multiplexing configuration of the MIMO scheme that would be able to multiply the spectral efficiency gain and as such improve system performance. In this paper, the performance of downlink MIMO-NOMA system is evaluated in terms of achievable sum rate, outage probability, and energy efficiency. An outage probability performance evaluation conducted revealed that the farther a user is from the base station (BS), the greater the chances of being dropped out from communication link. Thus, the simulation result in terms of far and near user revealed that the far user with outage probability of 1.2 × 10-5 has the highest chance or probability of being out of service in the network compared to the near user with outage probability of 4 × 10-6. The simulated achievable sum rate of the considered system was 43.33 bps/Hz. The EE against SE analysis revealed that the system achieved better maximum values (EE = 568872 b/J and SE = 11.1878 bps/Hz) than orthogonal frequency division multiple access (OFDMA) that yielded EE = 420118 b/J and SE = s 8.40236 bps/Hz. Finally, to ascertain the advantage of the considered downlink MIMO-NOMA with three users over the arrangement with two users, achievable sum rates of both were compared and the simulated results revealed improvement over the previous scheme with two users. It suffices to say that the considered multiuser NOMA with three users outperformed the previous system in literature with two users and thus will be more preferable for improved 5G application. However, further study should be conduct with a greater number of antennas to large scale capacity to achieve greater sophisticated MIMO-NOMA system.

***Keywords:* Achievable Sum Rate, Downlink System, MIMO-NOMA, Outage Probability, Spectral Efficiency**

I. INTRODUCTION

Multiple input multiple output (MIMO) system is used to advantage in facilitating the transmit and receive of signal as it moves through different paths between transmitter and receiver (Muoghalu *et al.*, 2023). MIMO is widely considered as one of the technologies to address the issue increasing rate of data transfer demand (Achebe & Muoghalu, 2025). MIMO application offers reliable link and improves wireless data transfer capacity (Achebe and Muoghalu, 2023; Achebe & Okwueze, 2023). Some techniques such as adaptive equalization to improve signal quality in multipath terrain (Osuagwu *et al.*, 2025). MIMO has been implemented with different multiple access schemes such as orthogonal frequency division multiple access (OFDMA) and non-orthogonal multiple access (NOMA).

In contrast to conventional multiple access schemes such as orthogonal multiple access (OMA) and orthogonal frequency division multiple access (OFDMA), NOMA is seen as promising method to solve these challenges for 5G and next generation wireless network because it offers improved user fairness, limited number of connected users, latency, and robustness Therefore, this paper attempts to implement downlink MIMO-NOMA using multiple antennas at transmitter and with more receive antennas with increased number of users to potentially improve spectral efficiency (SE), user rate, and energy efficiency (EE) of wireless Multiple Input Multiple Output (MIMO) system,

Downlink transmissions and the basic principle of NOMA in such system has been covered in literature.

Power domain multiplexing of users at the base stations and signal interference cancellation (SIC)-based signal reception at the terminals of user equipment was proposed by Saito *et al*. (2013). Different aspect of NOMA systems, including combination with MIMO technique, power allocation to multiuser and scheduling schemes for user, propagation of error in SIC, and collective benefit of the system has been presented (Benjebbour *et al.*, 2013). In terms of overall system's throughput and each user's throughput, simulation analysis at system level and sink-level demonstrated obvious advantage of NOMA over OMA (Benjebbour *et al.*, 2013). NOMA system with two users test-platform was presented in Benjebbour *et al.* (2015). In the study, 5.4 MHz bandwidth setting for NOMA users was considered in carrying out experiments and the outcomes were compared to two OMA users with each having 2.7 MHz transmission bandwidth.

Static power allocation was considered for two users in closed-form evaluations for ergodic sum-rate and outage probability, including investigation of user pairing impact (Ding *et al*., 2014). Among the NOMA users, transmission powers were statically allocated considering fixed and opportunistic user pairing. Taking into account perfect CSI feedback together with average CSI feedback, power allocation impact downlink NOMA fairness was evaluated (Timotheou & Krikidis, 2015). The idea of pairing of weak channel users with strong channel users was advocated for cooperative data transmission in cooperative NOMA system (Ding *et al.*, 2015).

In recent times, significant interest has been demonstrated in NOMA's application in multiuser MIMO technology. (Muoghalu *et al,* 2026) evaluated how using multiple antennas enhances Non-Orthogonal Multiple Access (NOMA) for 5G and next-generation wireless networks. It analyzed how combining these technologies overcomes traditional limitations, achieving higher spectral efficiency and better connectivity. With two transmit antennas at base station and single antenna user equipment (UEs), a random beamforming was employed for MIMO-NOMA system of 2-user configuration, in a fundamental study involving the integration of MIMO and NOMA in downlink transmission (Benjebbour *et al*., 2013). At the transmitter, fixed power allocation method was used. Conversely, at the receiver of UE, interference cancellation method was performed in two-stage. Interference rejection combining (IRC) was used in the first stage to solve the problem inter-beam/inter-cluster interference. For the second stage, SIC was used to cancel intra-bean/intra-cluster interference.

A 2-user conventional MIMO-NOMA downlink system with multiuser zero forcing-beamforming considering cluster-heads' channel information was examined by Kim *et al.* (2013). The users were grouped into cluster according to correlations and differences of their channel gains with cluster head's channel gain. The evaluation of the system was conducted at extremely correlated user cluster condition. However, different user equipment's radio channels can be uncorrelated in practice. Ugwu *et al.* (2026) presented performance enhancement of non-orthogonal multiple access (NOMA) network for 5G network application with a developed model for multiuser NOMA system.

In a downlink MIMO-NOMA where the number of transmit antennas at base station equal the number of each antenna at the receiver of each UE, outage probabilities of users in a cluster was analysed (Ding *et al*., 2016). The model was simulated by implementing fixed power allocation schemes for each MIMO-NOMA cluster with up to 3 antennas at the receiver of user equipment and the base station. With equal number of antennas at base station and at each user equipment, power allocation scheme for 2-user downlink MIMO-NOMA cluster was presented in Sun *et al.* (2015). The authors proposed optimal and suboptimal solutions for a formulated non-convex power allocation problem in 2-user MIMO-NOMA.

In this paper, a downlink MIMO-NOMA with 3-user is considered. The study aims at evaluating critical parameters of MIMO-NOMA wireless system such as achievable sum rate, outage probability, and energy efficiency.

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II. METHODOLOGY

MIMO-NOMA Block Diagram Modelling

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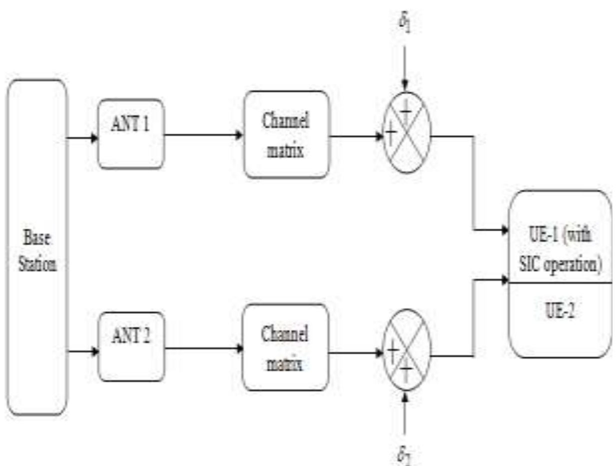

Figure 1: MIMO-NOMA system configuration (Mbachu and Ibe, 2024)

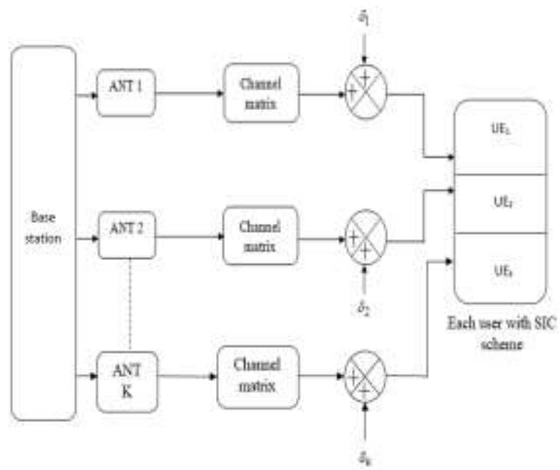

Figure 2: Designed MIMO-NOMA system configuration

Mathematical Description of Performance Parameters

SNR and Sum Rate

The mathematical description of the system performance starts by defining the transmitted signal by BS as follows:

$$x(t) = \sqrt{\alpha_1 P_T x_1(t)} + \sqrt{\alpha_2 P_T x_2(t)} + \cdots + \sqrt{\alpha_k P_T x_k(t)} \quad (1)$$

Or simply as:

$$x(t) = \sum_{k=1}^{K} \sqrt{\alpha_k P_T x_k(t)} \quad (2)$$

where $x_k(t)$ is the transmitted signal to kth user, P_T is the transmission power from the BS (i.e. the total available power at the BS in one symbol period), and $\alpha_k$is the power allocation coefficient for kth user. Thus, the power allocated to each kth user, UE_k is given by Kizilirmak (2016):

$$P_k = \alpha_k P_T \quad (3)$$

Power allocation is carried out according to the users' (UEs) distance from the BS. In this work, the power allocation is carried out by allocating the highest power to UE_1, which is considered the farthest user equipment and the closest user is UE_k, which is allocated the least power (in this case k = 3, since there are 3 users). Therefore, signal at kth user equipment is given by:

$$y_k(t) = h_k x(t) + \sigma_k(t) \quad (4)$$

where h_k is the channel factor for the link between the BS and UE_k, and $\sigma_k(t)$ represents the AWGN at UE_k.

Now, considering the farthest user first since the signal it will decode first is its own signal because compared with other equipment, it is the one allocated the most power (Kizilirmak, 2016). Given that the other UEs signals will act as interference to the UE_k signal, its SNR is given by:

$$SNR_k = \frac{P_k h_k^2}{n_0 W + \sum_{i=1}^{k-1} P_i h_k^2} \quad (5)$$

where SNR_k is the kth user SNR, n_0 is the noise density, and W is bandwidth of the transmission. Similarly, assuming perfect cancellation, the SNR for the nearest user equipment, UE_1 is given by Kizilirmak (2016):

$$SNR_1 = \frac{P_1 h_1^2}{n_0 W} \quad (6)$$

The throughput in bps of system when NOMA is used for each kth user is given by Kizilirmak (2016):

$$R_k = W log_2 \left[1 + \frac{P_k h_k^2}{n_0 W + \sum_{i=1}^{k-1} P_i h_k^2}\right]$$
(7)

where $W_k = \frac{W}{K}$. The sum capacity (or rate) and the fairness index for both NOMA.

Outage Probability

Each UE instantaneous signal to noise ratios reduces below the specified value when outage occurs. The outage probability can be used to determine the scope of NOMA, and measures the quality of service (QoS) of the user (Suprith & Ahmed, 2022). The outage probability of kth user UE_K can be defined by Li *et al.* (2019):

$$\begin{aligned} P_K^{out} &= P(\log(1+r_{1\to k}) < R_{k+1} or \log(1+r_1) < R_1) \\ &= 1 - P(\log(1+r_{1\to k}) \geq R_k) P(\log(1+r_1) \geq R_1) \end{aligned} \quad (8)$$

where $r_{1\to k}$ is the information intended for UE-k obtained by UE-1, and R_1, R_k are the target rates of UE-1 and UE-k.

Energy and Spectral Efficiencies

The power consumption at the transmitter can defined as the sum of the signal power and power the power consumed by the circuits, which is usually the power amplifiers. Therefore, for the downlink system, the overall used at BS can be defined by:

$$P_t = P_T + P_{circuit} \quad (9)$$

where P_t is the sum of the power consumed at the BS, and $P_{circuit}$ is the power consumed by the circuitry of the transmitter.

The energy efficiency (EE) of the system can be described as the ratio of the sum rate to the sum of the power consumed at the base station (Xiong *et al.,* 2011):

$$EE = \frac{R_T}{P_{total}} \text{ in bits/Joule} \quad (10)$$

On the other hand, the spectral efficiency SE is defined in Equation (11) and the relationship between it and EE is given in Equation (12).

$$SE = \frac{R_T}{W} \text{ in bps/Hz} \quad (11)$$

$$E = \boldsymbol{SE} \frac{\boldsymbol{W}}{\boldsymbol{P_{total}}} \quad (12)$$

Simulation Parameters

The system's parameters for simulation in MATLAB are presented in Table 1.

Table 1 Simulation parameters

Definition	Value
Average channel gain of UE-1	h1 = -160 dB
Average channel gain of UE-2	h2 = -140 dB
Average channel gain of UE-3	h3 = -120 dB
Power allocation coefficients	$\boldsymbol{\alpha_k = 0:0.01:1}$
Transmission power of single antenna	1 W
Channel state information (CSI)	Perfectly known at receiver (assumed)
Channel	Rayleigh fading
Distance of users from BS	Varied
Power consumed by circuitry	100 W

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Noise density	-150dbW/Hz
System bandwidth	5 MHz
Number of symbols	32

III. RESULTS AND DISCUSSION

Achievable Sum Rate Analysis

The achievable sum rate of the MIMO-NOMA is evaluated in this section for the downlink communication between the BS and each of the users. Figure 3 shows the result of the achievable sum rate of the MIMO-NOMA system for the BS communication with three users' arrangement. The distance from the far user to near user to the BS is: 100, 60, and 40 m, respectively.

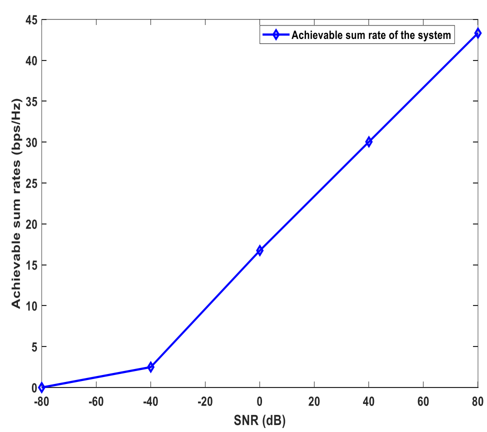

Figure 3: Simulated curve of achievable sum rate

The simulated achievable sum rate shown in in Figure 3 is the overall data transfer rate or capacity of the MIMO-NOMA downlink system considered in this work. From the simulated waveform, it can be seen that the achievable sum rate increases as the transmit signal power or SNR in dB increases. Thus, the achievable sum rate at SNR = 80 dB was 43.33 bps/Hz.

Figure 4 shows the simulated waveform of the achievable sum rate for the individual user's equipment, i.e. UE-1, UE-2, and UE-3.

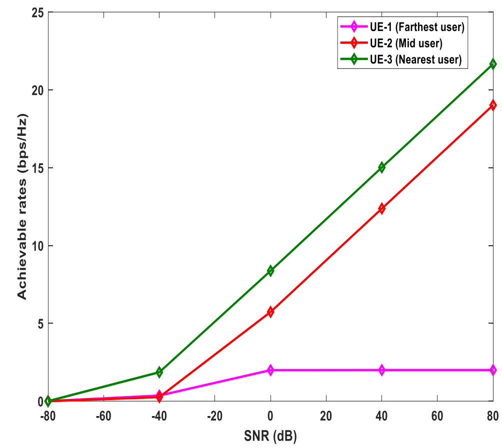

Figure 4: Simulated achievable sum rate of each user's equipment

The simulated curves of the achievable sum rate for each user follows similar trend as with overall achievable sum rate of the system, which increases as the signal strength increases. The farthest user (UE-1) achieved the least sum rate compared with other users. The simulation revealed achievable sum rate of 2 bps/Hz, 19.02 bps/Hz, and 21.66 bps/Hz at SNR = 80 dB for UE-1, UE-2, and UE-3, respectively.

The comparison of the MIMO-NOMA system with three users against the MIMO-NOMA with two users is carried out in terms of the achievable sum rate achieved by both systems. The simulated achievable sum rate with three users and two users are shown in Figure 5.

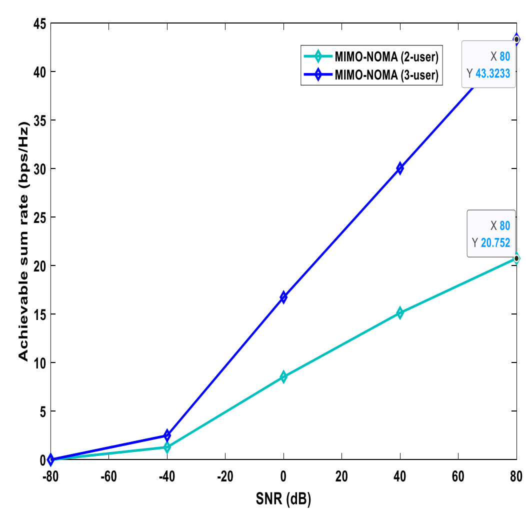

Figure 5: Achievable sum rate comparison for two-user and 3-user MIMO-NOMA systems

The simulated achievable sum rate curves for two-user and three-user MIMO-NOMA systems shown in Figure 5 revealed that as more channels is created due to the inclusion another user to the network, the rate of that transmission is increased. This conforms to the basic theory of multiuser multi-antenna system wherein the capacity of the wireless communication is increased by multiple channels. Thus, it can be observed that the three users MIMO-NOMA downlink system offered better achievable sum rate of 43.3233 bps/Hz compared with two users MIMO-NOMA of achievable sum rate of 20.752 bps/Hz. With this comparison analysis, it suffices to say that the three users MIMO-NOMA is an improvement of two users MIMO-NOMA.

Outage Probability Analysis

The outage probability of the MIMO-NOMA is evaluated in this section in terms of the downlink communication between the BS with farthest and Nearest users (which will be simply called far and near users), i.e. UE-1 and UE-3, respectively. The simulated outage probability curves of far and near users are shown in Figure 6.

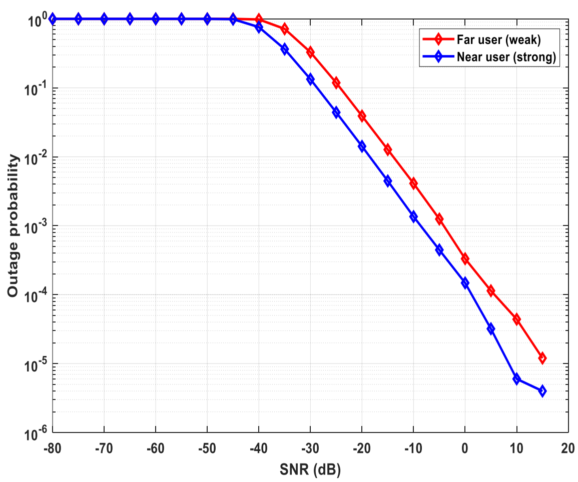

Figure 6: Individual User's outage probability

The simulated outage probability performances of the far and near users shown in Figure 6 reveal that the near user (UE-3) has better chance of lasting in the network with quality or strongest signal reception than the far user (UE-1). From the simulated waveforms, the outage probabilities of far user (considered as user with weak signal) and that of the near user (strong signal user) are 1.2×10^{-5} and 4×10^{-6}, respectively. Thus, from the magnitude of their outage probabilities, it suffices to say that the far user has the highest chance or probability of being out of service in the network compared to the far user. This means that near user has better quality of service (QoS) than the far user.

Energy Efficiency

The energy efficiency of the system is evaluated in this case against spectral efficiency as shown in Figure 7. The setup for the evaluation of the system's energy efficiency (EE) against spectral efficiency (SE) is as follows. The bandwidth of the system is taken as 5 MHz. Each user's average channel gain is -160 dB (for UE-1), -140 dB (for UE-2), and -120 dB (for UE-3), respectively. The noise density is -150 dBW/Hz. The static power consumption of the circuit taken as 100 W. The energy efficiency of the system is evaluated in this case against spectral efficiency is shown in Figure 7. Further analysis was conducted by comparing the energy efficiency against spectral efficiency of the NOMA system with that of OFDMA as shown in Figure 8.

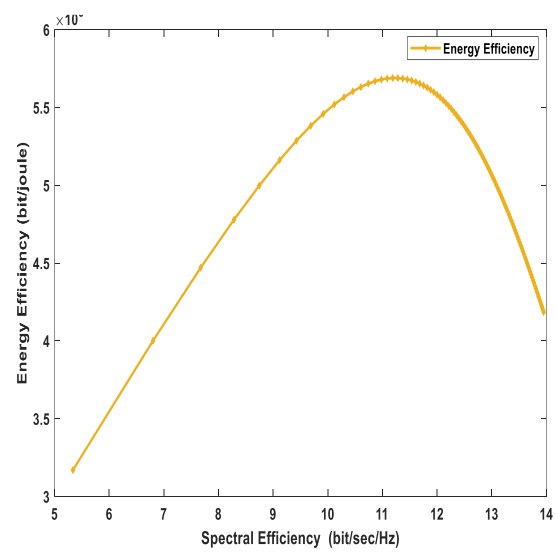

Figure 7: Energy efficiency against spectral efficiency of NOMA system

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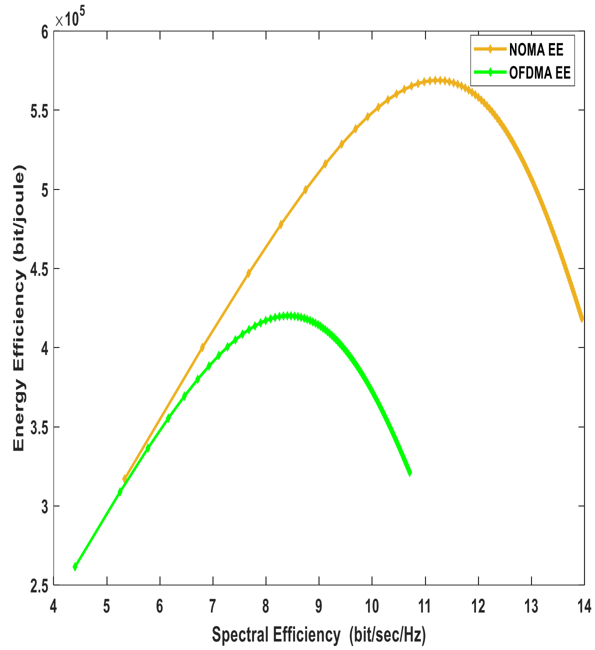

Figure 8: Comparison of energy efficiency against spectral efficiency for NOMA and OFDMA

As shown in the Figure 7, the obtained energy efficiency against spectral efficiency simulated curve revealed that the NOMA system achieved maximum energy of 568872 b/J when the spectral efficiency was 11.1878 bps/Hz. Further analysis was carried out to ascertain the effectiveness of NOMA over conventional OFDMA as show in Figure 8. The simulated curve revealed that the OFDMA system achieved maximum energy efficiency of 420118 b/J when spectral efficiency was 8.40236 bps/Hz. Generally, looking at both curves as shown in Figure 8, it can be seen that the energy efficiency increases as the spectral efficiency increases. However, energy efficiency reaches a maximum point and then begins to decline. Furthermore, a look at the curves, it is clear that the NOMA system outperformed the OFDMA.

IV. CONCLUSION

Analysis was carried out in terms of achievable sum rate to examine the rate of data communication between the BS and the various users. The results revealed that the sum rate of data transfer from the BS to the users was higher for the users nearer such that the nearest user achieved the most sum rate of 21.66 bps/Hz. The analysis of the system in terms of energy efficiency against spectral efficiency revealed that maximum energy of value 568872 b/J was achieved when the spectral efficiency was 11.1878 bps/Hz. Performance comparison plot of the three-user MIMO-NOMA and two-user MIMO-NOMA revealed that the present configuration offered better rate of data transfer than the previous downlink arrangement. Simulation in terms of outage probability considering only the nearest and farthest users revealed that a user nearer to the BS has the prospect of lasting longer in the network loop without dropping from the communication than far user. Thus, the simulated result revealed that the outage probability of near user is better than that of far user. The analysis of the system in terms of energy efficiency against spectral efficiency revealed that maximum energy of value 568872 b/J was achieved when the spectral efficiency was 11.1878 bps/Hz. A comparison with OFDMA of similar configuration revealed that the NOMA system offered better energy efficiency and spectral efficiency.

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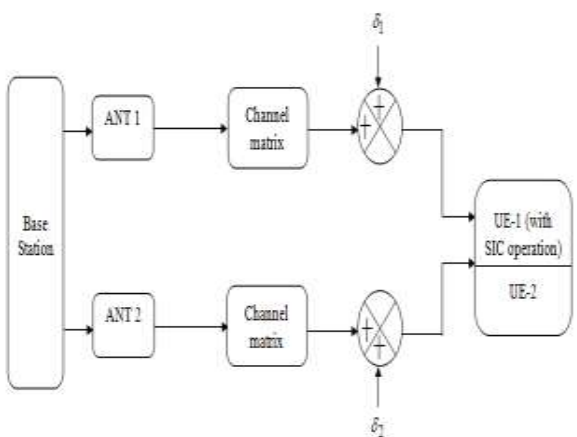
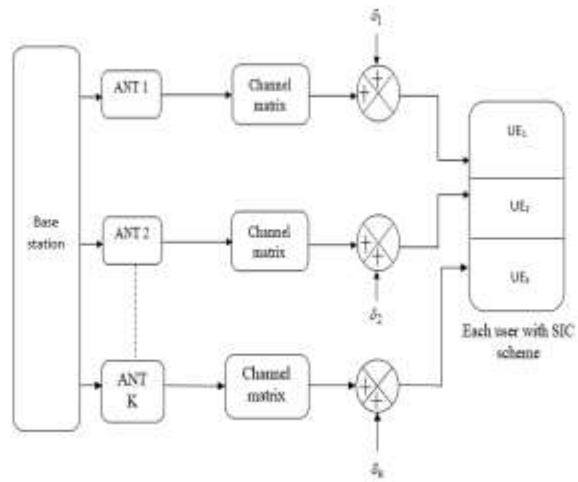


Figure 1: MIMO-NOMA system configuration (Mbachu and Ibe, 2024)



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$$\boldsymbol{P_k = \alpha_k P_T} \quad (3)$$

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$$\boldsymbol{y_k(t) = h_k x(t) + \sigma_k(t)} \quad (4)$$

where $\boldsymbol{h_k}$ is the channel factor for the link between the BS and $\boldsymbol{UE_k}$, and $\boldsymbol{\sigma_k(t)}$ represents the AWGN at $\boldsymbol{UE_k}$.

Now, considering the farthest user first since the signal it will decode first is its own signal because compared with other equipment, it is the one allocated the most power (Kizilirmak, 2016). Given that the other UEs signals will act as interference to the $\boldsymbol{UE_k}$ signal, its SNR is given by:

$$\boldsymbol{SNR_k} = \frac{\boldsymbol{P_k h_k^2}}{\boldsymbol{n_0 W + \sum_{i=1}^{k-1} P_i h_k^2}} \quad (5)$$

where SNR_k is the kth user SNR, n_0 is the noise density, and W is bandwidth of the transmission. Similarly, assuming perfect cancellation, the SNR for the nearest user equipment, UE_1 is given by Kizilirmak (2016):

$$SNR_1 = \frac{P_1 h_1^2}{n_0 W} \quad (6)$$

The throughput in bps of system when NOMA is used for each kth user is given by Kizilirmak (2016):

$$R_k = W log_2 \left[1 + \frac{P_k h_k^2}{n_0 W + \sum_{i=1}^{k-1} P_i h_k^2}\right]$$

(7)

where $W_k = \frac{W}{K}$. The sum capacity (or rate) and the fairness index for both NOMA.

Outage Probability

Each UE instantaneous signal to noise ratios reduces below the specified value when outage occurs. The outage probability can be used to determine the scope of NOMA, and measures the quality of service (QoS) of the user (Suprith & Ahmed, 2022). The outage probability of kth user UE_K can be defined by Li *et al.* (2019):

$$\begin{aligned} P_K^{out} &= P(\log(1+r_{1\to k}) < R_{k+1} or \log(1+r_1) < R_1) \\ &= 1 - P(\log(1+r_{1\to k}) \geq R_k) P(\log(1+r_1) \geq R_1) \end{aligned}$$

(8)

where $r_{1\to k}$ is the information intended for UE-k obtained by UE-1, and R_1, R_k are the target rates of UE-1 and UE-k.

Energy and Spectral Efficiencies

The power consumption at the transmitter can defined as the sum of the signal power and power the power consumed by the circuits, which is usually the power amplifiers. Therefore, for the downlink system, the overall used at BS can be defined by:

$$P_t = P_T + P_{circuit} \quad (9)$$

where P_t is the sum of the power consumed at the BS, and $P_{circuit}$ is the power consumed by the circuitry of the transmitter.

The energy efficiency (EE) of the system can be described as the ratio of the sum rate to the sum of the power consumed at the base station (Xiong *et al.,* 2011):

$$EE = \frac{R_T}{P_{total}} \text{ in bits/Joule} \quad (10)$$

On the other hand, the spectral efficiency SE is defined in Equation (11) and the relationship between it and EE is given in Equation (12).

$$SE = \frac{R_T}{W} \text{ in bps/Hz} \quad (11)$$

$$E = SE \frac{W}{P_{total}} \quad (12)$$

Simulation Parameters

The system's parameters for simulation in MATLAB are presented in Table 1.

Table 1 Simulation parameters

Definition	Value
Average channel gain of UE-1	h1 = -160 dB
Average channel gain of UE-2	h2 = -140 dB
Average channel gain of UE-3	h3 = -120 dB
Power allocation coefficients	$\alpha_k = 0:0.01:1$
Transmission power of single antenna	1 W
Channel state information (CSI)	Perfectly known at receiver (assumed)
Channel	Rayleigh fading
Distance of users from BS	Varied
Power consumed by circuitry	100 W
Noise density	-150dbW/Hz
System bandwidth	5 MHz

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Number of symbols	32

VI. RESULTS AND DISCUSSION

Achievable Sum Rate Analysis

The achievable sum rate of the MIMO-NOMA is evaluated in this section for the downlink communication between the BS and each of the users. Figure 3 shows the result of the achievable sum rate of the MIMO-NOMA system for the BS communication with three users' arrangement. The distance from the far user to near user to the BS is: 100, 60, and 40 m, respectively.

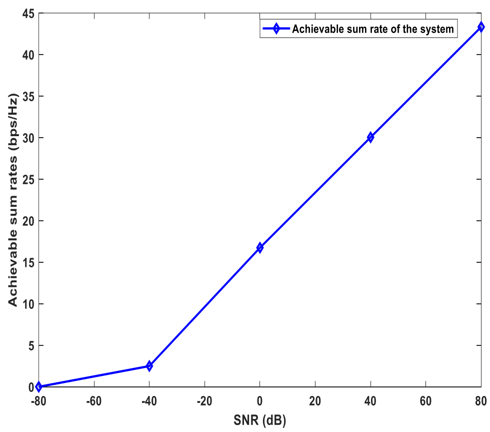

Figure 3: Simulated curve of achievable sum rate

The simulated achievable sum rate shown in in Figure 3 is the overall data transfer rate or capacity of the MIMO-NOMA downlink system considered in this work. From the simulated waveform, it can be seen that the achievable sum rate increases as the transmit signal power or SNR in dB increases. Thus, the achievable sum rate at SNR = 80 dB was 43.33 bps/Hz.

Figure 4 shows the simulated waveform of the achievable sum rate for the individual user's equipment, i.e. UE-1, UE-2, and UE-3.

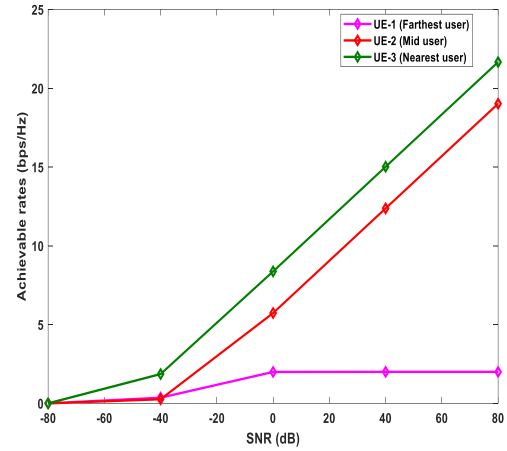

Figure 4: Simulated achievable sum rate of each user's equipment

The simulated curves of the achievable sum rate for each user follows similar trend as with overall achievable sum rate of the system, which increases as the signal strength increases. The farthest user (UE-1) achieved the least sum rate compared with other users. The simulation revealed achievable sum rate of 2 bps/Hz, 19.02 bps/Hz, and 21.66 bps/Hz at SNR = 80 dB for UE-1, UE-2, and UE-3, respectively.

The comparison of the MIMO-NOMA system with three users against the MIMO-NOMA with two users is carried out in terms of the achievable sum rate achieved by both systems. The simulated achievable sum rate with three users and two users are shown in Figure 5.

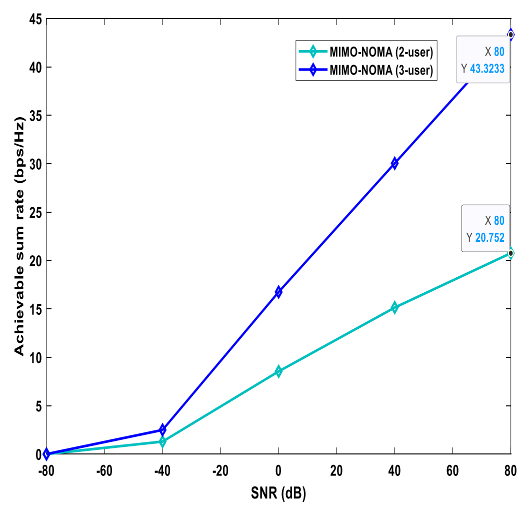

Figure 5: Achievable sum rate comparison for two-user and 3-user MIMO-NOMA systems

The simulated achievable sum rate curves for two-user and three-user MIMO-NOMA systems shown in Figure 5 revealed that as more channels is created due to the inclusion another user to the network, the rate of that transmission is increased. This conforms to the basic theory of multiuser multi-antenna system wherein the capacity of the wireless communication is increased by multiple channels. Thus, it can be observed that the three users MIMO-NOMA downlink system offered better achievable sum rate of 43.3233 bps/Hz compared with two users MIMO-NOMA of achievable sum rate of 20.752 bps/Hz. With this comparison analysis, it suffices to say that the three users MIMO-NOMA is an improvement of two users MIMO-NOMA.

Outage Probability Analysis

The outage probability of the MIMO-NOMA is evaluated in this section in terms of the downlink communication between the BS with farthest and Nearest users (which will be simply called far and near users), i.e. UE-1 and UE-3, respectively. The simulated outage probability curves of far and near users are shown in Figure 6.

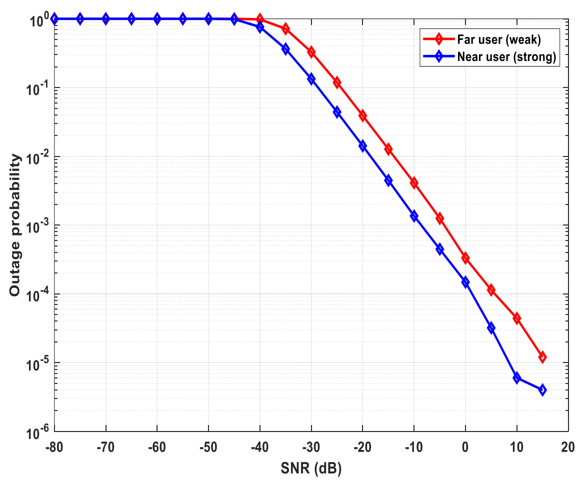

Figure 6: Individual User's outage probability

The simulated outage probability performances of the far and near users shown in Figure 6 reveal that the near user (UE-3) has better chance of lasting in the network with quality or strongest signal reception than the far user (UE-1). From the simulated waveforms, the outage probabilities of far user (considered as user with weak signal) and that of the near user (strong signal user) are 1.2×10^{-5} and 4×10^{-6}, respectively. Thus, from the magnitude of their outage probabilities, it suffices to say that the far user has the highest chance or probability of being out of service in the network compared to the far user. This means that near user has better quality of service (QoS) than the far user.

Energy Efficiency

The energy efficiency of the system is evaluated in this case against spectral efficiency as shown in Figure 7. The setup for the evaluation of the system's energy efficiency (EE) against spectral efficiency (SE) is as follows. The bandwidth of the system is taken as 5 MHz. Each user's average channel gain is -160 dB (for UE-1), -140 dB (for UE-2), and -120 dB (for UE-3), respectively. The noise density is -150 dBW/Hz. The static power consumption of the circuit taken as 100 W. The energy efficiency of the system is evaluated in this case against spectral efficiency is shown in Figure 7. Further analysis was conducted by comparing the energy efficiency against spectral efficiency of the NOMA system with that of OFDMA as shown in Figure 8.

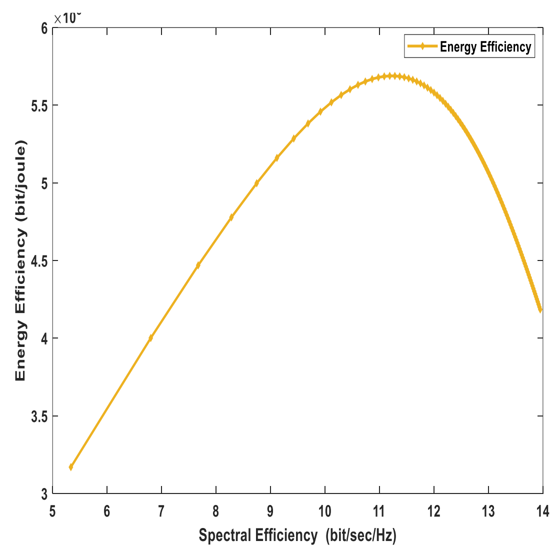

Figure 7: Energy efficiency against spectral efficiency of NOMA system

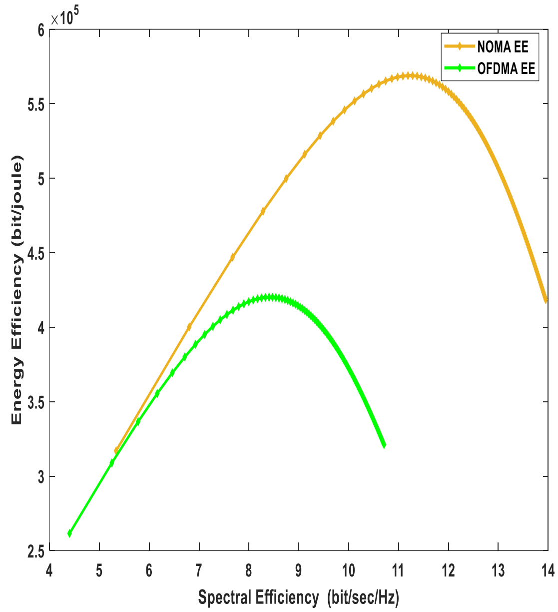

Figure 8: Comparison of energy efficiency against spectral efficiency for NOMA and OFDMA

As shown in the Figure 7, the obtained energy efficiency against spectral efficiency simulated curve revealed that the NOMA system achieved maximum energy of 568872 b/J when the spectral efficiency was 11.1878 bps/Hz. Further analysis was carried out to ascertain the effectiveness of NOMA over conventional OFDMA as show in Figure 8. The simulated curve revealed that the OFDMA system achieved maximum energy efficiency of 420118 b/J when spectral efficiency was 8.40236 bps/Hz. Generally, looking at both curves as shown in Figure 8, it can be seen that the energy efficiency increases as the spectral efficiency increases. However, energy efficiency reaches a maximum point and then begins to decline. Furthermore, a look at the curves, it is clear that the NOMA system outperformed the OFDMA.

VII. CONCLUSION

Analysis was carried out in terms of achievable sum rate to examine the rate of data communication between the BS and the various users. The results revealed that the sum rate of data transfer from the BS to the users was higher for the users nearer such that the nearest user achieved the most sum rate of 21.66 bps/Hz. The analysis of the system in terms of energy efficiency against spectral efficiency revealed that maximum energy of value 568872 b/J was achieved when the spectral efficiency was 11.1878 bps/Hz. Performance comparison plot of the three-user MIMO-NOMA and two-user MIMO-NOMA revealed that the present configuration offered better rate of data transfer than the previous downlink arrangement. Simulation in terms of outage probability considering only the nearest and farthest users revealed that a user nearer to the BS has the prospect of lasting longer in the network loop without dropping from the communication than far user. Thus, the simulated result revealed that the outage probability of near user is better than that of far user. The analysis of the system in terms of energy efficiency against spectral efficiency revealed that maximum energy of value 568872 b/J was achieved when the spectral efficiency was 11.1878 bps/Hz. A comparison with OFDMA of similar configuration revealed that the NOMA system offered better energy efficiency and spectral efficiency.

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