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Performance Assessment of MIMO-NOMA System with Simultaneously Different Data Transmission for the Next Generation Wireless Communications

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Abstract In this paper, we have analyzed the performance of downlink multiuser six generation (6G) and beyond 5G (B5G) with concurrently different data transmission compatible MIMO-NOMA wireless communication system. The proposed simulated system has been implemented incorporating ML decoding based QR channel decomposition aided successive interference cancellation (SIC) scheme signal detection, convolutional channel coding, BPSK, and QAM digital modulation schemes. Two different types of messages are transmitted simultaneously from the base station (BS) through a 2×2 MIMO channel for two different users. The image data is transmitted for user one and synthetic data is used for the other user. By observing the simulation results, we can say that the system provides acceptable performance under AWGN and Rayleigh fading channels. To improve the performance, we have properly assigned power to the users, and accurately maintained the signal's phase difference between the users. With the increase of the signal-to-noise ratio (SNR) the bit error rate (BER) has degraded adequately which indicates the system is very robust and efficient for the transmission of different data concurrently and suitable for the next generation of wireless communications.

Keywords MIMO, NOMA, 5G, Beyond 5G, SIC, AWGN, BPSK, 4-QAM, 16-QAM, SNR, BER, MUD

1. Introduction

The rapid use of mobile communications has been increased last decade in both academic and industrial communities which motivates the research activities to design the next generation wireless networks that can introduce significant improvements in large coverage and user requirements [1]. It is an important role to determine the performance of mobile communication systems for next-generation wireless networks which utilize highly spectral-efficient multiple access techniques. Based on the way the resources are allocated to the users the multiple access techniques can be classified into orthogonal and non-orthogonal [2]. In the approach of Orthogonal Multiple Access (OMA) techniques, the users of each cell are assigned the resources exclusively and there is no interference between users, therefore, low-complexity detection approaches can be carried out in the receiver to recover the transmitted signals. The Long Term Evolution (LTE) and LTE-Advanced have been using in current mobile communication systems [3]. In LTE systems, OMA techniques such as Orthogonal Frequency Division Multiple Access (OFDMA) and Single Carrier Frequency Division Multiple Access (SC-FDMA) have been used. On the other hand, all the users can use whole allocated resources in Non-Orthogonal Multiple Access (NOMA) techniques simultaneously that's why there has inter-user interference. Therefore, extra complex Multi-User Detection (MUD) techniques are required to retrieve the user's transmitted signals at the receiver end. It is known that orthogonal multiple access transmission systems are appropriate for downlink to achieve the maximum number of users' sum-rate [4]. Additionally, MUD techniques are more complex to implement at the user end for the inadequate processing power. OMA cannot attain the system upper bound for this reason it is not an ideal solution in terms of spectral efficiency to uplink [5]. When multiple users are considered in the MIMO-NOMA systems there will be a noticeable issue with inter-user interference cancellation [6]. Consequently, NOMA multiple access technique have the challenge to be implemented in the next generation of

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wireless networks to develop the maximum use of system spectral efficiency, The crucial advantage of NOMA is to share each resource element (in frequency or time domain) to all the users, and the power allocated to all users through iterative water-filling [7]. The number of users that share each subcarrier in the optimal NOMA scheme makes the MUD very complex at the receiver end. Therefore, other techniques that allow NOMA (such as Successive Interference Cancelation (SIC), Interleave Division Multiple Access (IDMA) [8], Low Density Spreading (LDS) [9], and Low Density Parity Check Code (LDPC) etc.) add redundancy via coding/spreading to help the users split-up at the receiver.

2. Literature Review

Most common multiple access techniques such as Orthogonal Frequency Division Multiple Access (OFDMA) as well as other orthogonal multiple access techniques have a major issue to achieve the system capacity boundary in the uplink system according to the individuality in resource allocation. This issue is more familiar when fairness surrounding all users is considered in the multiple access system. NOMA technique can pointedly improve the system performance in terms of simultaneously accessing the multiple numbers of users, spectral efficiency, and fairness compared to OFDMA [10]. The new concept of Non-orthogonal Multiple Access (NOMA) has been recommended to increase multiple access of the total number of users than the number of available orthogonal time-domain, frequency-domain, or code-domain resources. The general concept of NOMA is to allow sharing of the non-orthogonal resource among the users at the ultimate cost of increased receiver complexity, which is a vital challenge for a researcher in separating the non-orthogonal signals. In recent times, several NOMA solutions have been investigated to solve the complex received data separation of all users [11]–[15], which can be divided into two main categories, one approach is power-domain NOMA [16] and another is code-domain NOMA [17]–[19]. Power domain NOMA has been used in this paper. NOMA scheme has significant consideration for next-generation wireless communication systems because of its distinctive features such as maximum use of spectral efficiency, improving the coverage area, low latency, enormous connectivity, fairness, and high-speed data rate, etc. NOMA can be a suitable multiple access candidate scheme due to these multiple advantages for future massive machine type communication (m-MTC) and mobile communication to be worked and delivered by 5G and next generation networks [20]. There are several additional NOMA schemes have also been proposed in the research works [21], [22], and [23]. Similar works like NOMA investigated in literature [24] named Pattern Division Multiple Access (PDMA), Power-Domain NOMA (PD-NOMA), and Sparse Code Multiple Access (SCMA) have been introduced in papers [25] and [26] consecutively. In this paper, we have modelled a system that can transmit two different data at a time for user#1 and user#2. We have used text messages for user#1 and synthetic data for user#2. By using NOMA multiple access scheme two different data have been transmitted over the AWGN channel and recover the original data at the receiver end. Finally, we have plotted some figures to represent the BER performance with the SNR of the proposed system.

3. Background

The principle of NOMA is to assign different power coefficients for different users at both downlink and uplink systems and employed Successive Interference Cancelation (SIC) operation. SIC process is performed both in the receiver side in downlink NOMA system and in the transmitter in uplink NOMA system [27]. The basic operation of NOMA is to decide the number of pair users (i.e User#1 and User#2) to be multiplexed over single individual sub-channel and the power to be allocated to pair users according to their channel conditions [28]. NOMA system have suggested to select the paired of users in a single sub-channel with distinctive channel conditions such that the user of bad channel conditions multiplex with the user of good channel conditions.

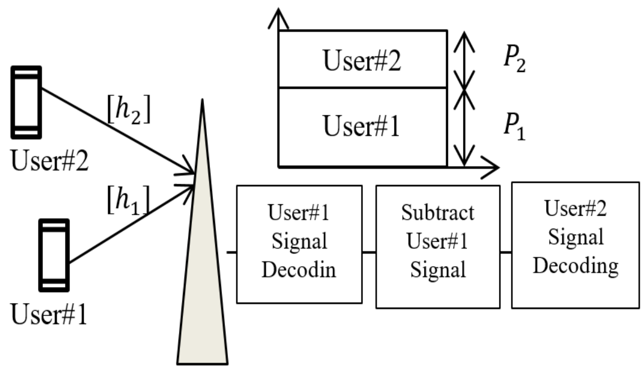

Figure 1. Uplink Non-Orthogonal multiple access

Figure 1 shows NOMA uplink system where two users are multiplexed together. User#1 denotes good channel condition while User#2 denotes poor channel condition. In NOMA systems, Base Station (BS) in uplink decodes User#1 signal first and then subtracts User#1 signal from the superimposed signal to decode the User#2 signal [29]. The received signal at the BS is represented as:

$$y = \sqrt{P_1}|h_1|S_1 + \sqrt{P_2}|h_2|S_2 + v \qquad (1)$$

Here, for User#1, P_1 indicates transmission power, $|h_1|$ denotes channel condition between User#1 and BS, and S_1 indicates the transmitted message signal of User#1. On the other hand, for User#2 P_2 indicates the transmitted power. $|h_2|$ denotes the channel condition between User#2 and BS and S_2 is the signal of User#2 message. The term v represents Additive White Gaussian Noise (AWGN) in addition to inter-cell interference with spectral density N_0 [30]. Figure 2 depicts downlink NOMA system, suppose two users (i.e. User#1 is the near user with good channel condition and User#2 is the far user with bad channel condition), one sub-channel and h_2 which indicates channel coefficient of User#2 as the weak user and h_1 implies channel coefficient of User#1 as the strong user. Assuming User#1 channel condition is better than User#2 which express as $(h_1 > h_2)$. SIC technique is applied to User#1 which is assigned a low power level to decode User#2 signal and then remove it to be able to decode its signal at the end [31]. On the other hand, there does not need to perform SIC technique on User#2 because it assigned a high power level and only need to decode User#2 signal through treating User#1 signal as interference. The transmitted signal S_1 for User#1 and S_2 for User#2 and power allocation P_1 and P_2 given as $P_1 < P_2$. Transmitted superimposed signal by BS is expressed as:

$$x = \sqrt{P_1}S_1 + \sqrt{P_2}S_2 \tag{2}$$

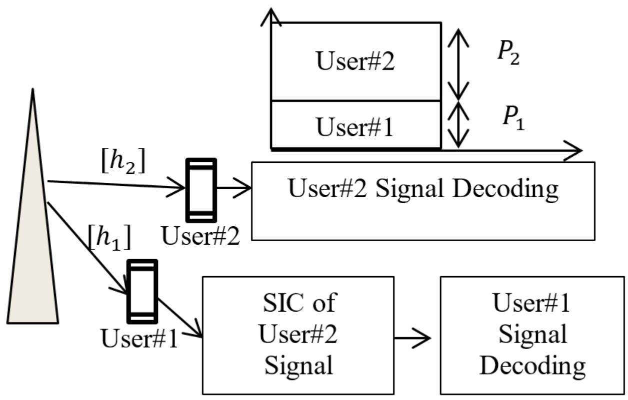

Figure 2. Downlink Non-Orthogonal multiple access

The received signal at User#1 and User#2 side indicated by y_i is expressed as:

$$y_i = |h_i|x + v_i \tag{3}$$

Using Shannon's capacity formula the data rates of User#1 and User#2 for NOMA are expressed as:

$$R_{UE1} = B\log_2(1 + \frac{P_1|h_1|}{N_0}) \tag{4}$$

$$R_{UE2} = B\log_2(1 + \frac{P_2|h_2|}{N_0}) \tag{5}$$

Here, R_{UE1} represents as the data rate of User#1 and R_{UE2} indicates as the data rates of User#2 and the total bandwidth of channel is B. Therefore, the summation of data rate of two users is the capacity of downlink NOMA represents as:

$$R_{Total\ (NOMA)} = R_{UE1} + R_{UE2} \tag{6}$$

In contrast, orthogonal multiple access system uses in OFDMA policy. In two users OFDMA strategy, the total bandwidth B is divided by User#1 and User#2 in half. So the data rates are achieved by two individual users given as follows:

$$R_{UE1(OMA)} = \frac{B}{2}\log_2(1 + \frac{P_1|h_1|}{N_0}) \tag{7}$$

$$R_{UE2(OMA)} = \frac{B}{2}\log_2(1 + \frac{P_2|h_2|}{N_0}) \tag{8}$$

Here, $R_{UE1(OMA)}$ represents as the data rate of User#1 and $R_{UE2(OMA)}$ indicates as the data rates of User#2 and total bandwidth of channel B is divided by two. Therefore, the summation of data rate of two users' is the capacity of downlink OMA represents as:

$$R_{Total\ (OMA)} = R_{UE1(OMA)} + R_{UE2(OMA)} \tag{9}$$

4. Downlink NOMA

The BS transmits a message signal to User#1 and User#2 over the same sub-channel. In the NOMA system, the message signal of User#1 superimposed with User#2 signals multiplexed over a similar sub-channel. In general, the message signal of User#i (i is a multiple numbers of users) superimposed with other users' signals multiplexed over a similar sub-channel. The BS transmits the superimposed signal to users using the same sub-channel. By using the SIC technique the receivers decode the originally transmitted signals iteratively where strong users (good channel condition users) demultiplex other signals to retrieve its signal in the end. On the other hand, the weak users (bad channel condition users) decode their signal directly treating other users' signals as interference. SIC technique works based on different power allocations for individual users which are determined by the BS. In NOMA systems, the same type of message signal of two users is multiplexed over the same sub-channel shown in maximum research articles. Basically, the number of users who can share an individual sub-channel is not bounded to two users. It is possible to pair two or more users carefully by using superimpose system among a list of available users in the system. The basic condition to pair more than two users is a user with poor channel conditions (weak user) is chosen to be paired with a user with high channel conditions (strong user). The same types of message signals of user pairing are studied widely in different approaches proposed throughout a large number of researches. In this paper, different types of message signals for two users User#1 and User#2 pairing schemes are investigated to attain a clear understanding of the effect of different message signal pairing on the performance. The most straightforward approach is that message signals of pair users have selected the same type. It is simple yet inefficient to check the performance of NOMA when the different users send different types of message signals. In NOMA, the message signal of one user is superimposed on the other users' message signal. Therefore, it's decode system is more complex but in many approaches, the researchers show the better BER per performance against SNR when they have used same types of the transmitted signal [32]. In the OFDMA system, the individual user can send different types of messages as their requirement through an individual sub-channel. On the other hand, the NOMA decode system will be more complex when the users multiplex their different types of messages signal. In this paper, we have transmitted two different type's message signals simultaneously to the two different users called User#1 and User#2. The image message signal is used for User#1 and the synthetic message signal is used for User#2. Firstly, two different data of users have multiplexed. Secondly, decode the two different data successfully in the receiving end and finally plot BER against SNR. From our simulation results, we have shown that the NOMA also gives better performance when the multiple users send multiple types of message signals concurrently.

5. System Model

The wireless communication system model of multiuser downlink MIMO NOMA represents in figure 3. The figure shows the summary of our system model which is implemented in the result and discussion section. In this system, we have considered two users who are expecting to receive two different types of message signals. User#1 receive gray image of identical size (height: 182 pixels and width: 186 pixels) and User#2 receive synthetic message signal. The message signal (gray image) of User#1 which is converted into its respective two Black and White components with each component 182 × 186 pixels in size. The pixel integer values are converted into 8 bits in binary form. On the other hand, the message signal of User#2 receives directly the synthetic data (the random binary bit whose size is 182*186*8). The scrambled binary data of user#1 and User#2 are channel encoded by a convolutional scheme, interleaved, and subsequently converted their message binary bits into digitally modulated complex signals using BPSK, QPSK, DQPSK, 4-QAM, and 16-QAM [33]. The modulated symbols in digital form are allocated assigned power and then send into the spatial multiplexing encoder section finally, the generated signal is transmitted from the transmitting antenna. The transmitted signal is changed when it passes through the wireless noisy channel. For this reason, in receiving section of each user, the signal is detected and adulterated with AWGN noise. The noise-contaminated signals are treated layer-wise and interference terms are removed to retrieve original signals using ML decoding-based QR channel decomposition aided SIC scheme. The retrieve signals are provided into a spatial multiplexing decoder. After that, the decoded signals are digitally demodulated, de-interleaved and channel decoded to regain the transmitted binary bit stream. Finally, the decoded binary data of User#1 are descrambled and converted into pixel integers and get back to recover the transmitted gray image. The retrieved binary data of User#2 no need to convert because we have sent random binary data for it.

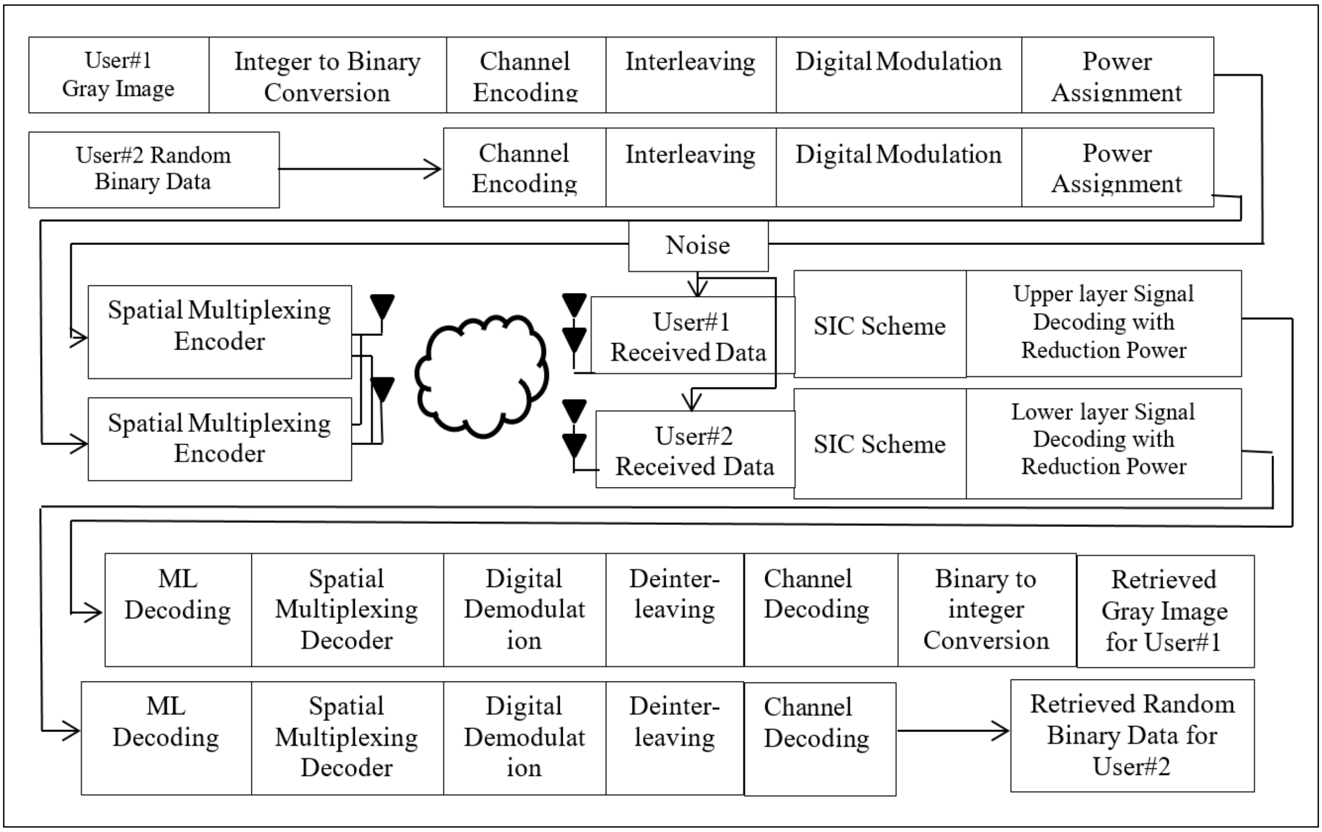

Figure 3. Block diagram of MIMO NOMA wireless communication system

6. Result and Discussion

The system performance evaluation of multiuser with different data types downlink MIMO NOMA wireless communication is shown in this section. Our simulation results have been presented using MATLAB R2014a to clarify the significant change of various types of channel coding and digital modulation techniques on system performance in terms of bit error rate (BER). In the whole processing work, it is considered that at the receiver end the channel state information (CSI) of the fading channel is available with unchanged fading. Which parameters are used in our system to evaluate the system performance are shown in Table 1.

Table 1. Summary of the Simulated System Parameters

Sl	Parameters	Types
1	Data type	Gray image and Binary bit
2	Image size (For User#1)	(182 x 186) pixels
3	Random Binary data (For User#2)	(182x186x8) bits
4	No. of user	2
5	Antenna configuration	2 x 2 MIMO Channel
6	Channel coding	½ -rated Convolutional
7	Digital modulation	BPSK, QPSK, DQPSK, 16-QAM and 4-QAM
8	Signal detection technique	ML decoding based QR channel factorization aided SIC scheme
9	SNR	0 to15 dB
10	Channel	AWGN and Rayleigh
11	Noise Type	Gaussian

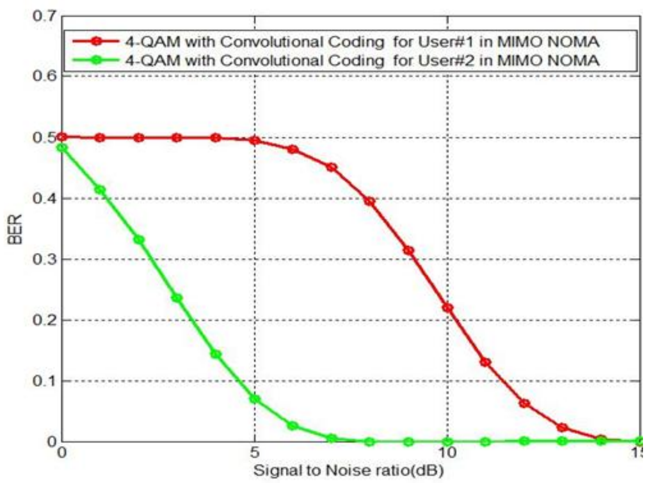

Figure 4. BER performance of Convolutional channel encoded MIMO NOMA communication system with 4-QAM digital modulation scheme for image and binary data transmission

The figure 4 shows the BER values of User#1 and User#2 by using of convolutional channel coding schemes with 4-QAM digital modulation technique. It is clear in figure 4 that the performance of User#2 is better than the User#1 aspect of BER values. The User#1 in case of LDPC channel coding BER values decrease slowly with increase in signal to noise ratio (SNR) values(0 dB to 15 dB). For User #1 SNR value of 6 dB, the estimated BER values are 0.4981 in case of convolutional channel coding with 4-QAM digital modulation. On the other hand, in case of User #2 for 6dB SNR value, the estimated BER value is 0.0499. The estimated system performance for User #2 is better than the User #1 as comparatively more power and binary data was assigned to User #2. Although the BER performance of User#2 is good compare with User#1 but it does not impose more effect to get desire result in our system for User#1.

Figure 5. Transmitted image of User#1 over AWGN channel with the 4-QAM modulation scheme

Figure 5 indicates that the transmitted image of User#1 is almost the same as the received image. Some noise has been added to the original image but it is almost clear to identify the user. The synthetic binary data of User#2 receive a minimum number of bit errors which is shown in figure 4. So, the received bit of User#2 is similar to the transmitted bit.

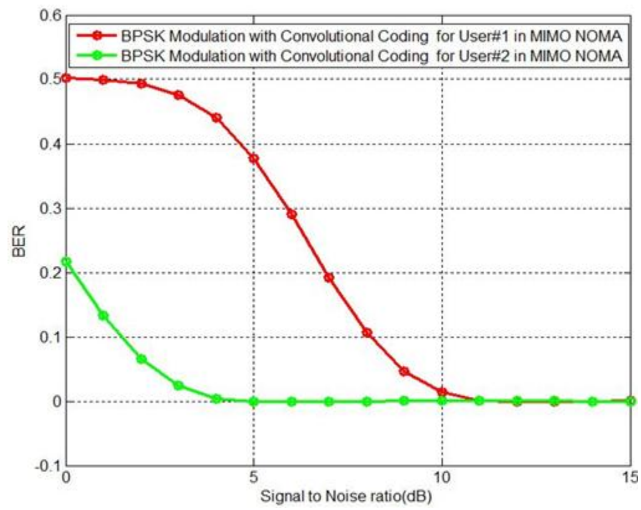

Figure 6. BER performance of Convolutional channel encoded MIMO NOMA wireless communication system with BPSK digital modulation scheme for image and data transmission

It is seen from figure 6 that the estimated BER values to SNR (0-15 dB) for both users are almost similar in convolutional channel coding and BPSK modulation. Under the assumption of an SNR value of 10 dB in the case of User#1, the estimated BER values are 0.2506 in convolutional channel coding schemes with BPSK digital modulation. In the case of User #2 for an identical SNR value, the estimated BER value is 0.05023 at the same SNR value as User#1. The performance of BPSK and 4-QAM modulation is almost similar in the case of User #2 in comparison to User #1 with their different data.

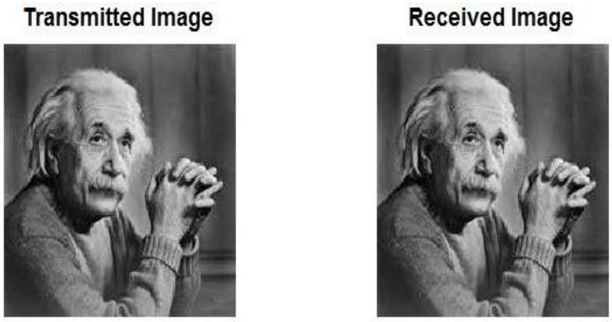

Figure 7. Transmitted image of User#1 over AWGN channel with the BPSK modulation scheme

In BPSK modulation technique has given a similar performance as like 4-QAM modulation technique shown in figure 6. The transmitted image of User#1 is almost the same as the received image for the BPSK modulation technique which is shown in figure 7. Some noise has been added to the original gray image but it is almost clear to identify the user. The synthetic binary data of User#2 has been received the minimum number of bit error.

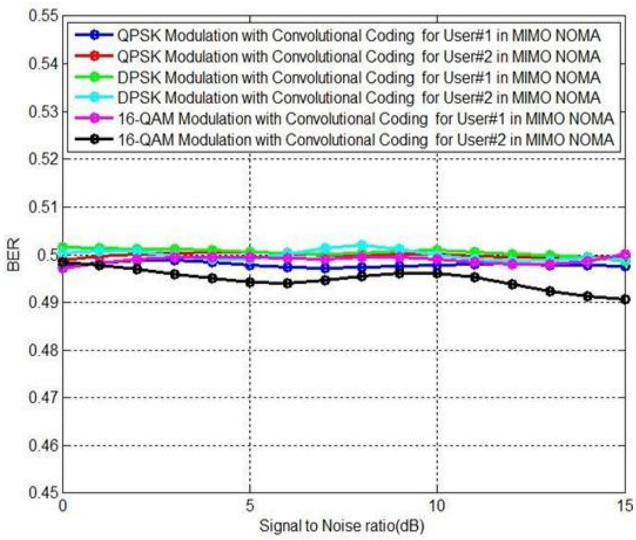

Figure 8. BER performance of Convolutional channel encoded MIMO NOMA system with 16-QAM, DPSK, and QPSK digital modulation scheme for image and data transmission

It is seen from figure 8 that the plot of BER values for both users are almost constant in convolutional channel coding. In the case of 16-QAM, DPSK, and QPSK modulation techniques it shows the same result. Under the assumption of an SNR value of 10 dB in the case of User#1, the estimated BER value is near 0.5026 for all modulation techniques in convolutional channel coding schemes. On the other hand, in the case of User #2 for an identical SNR value, the estimated BER value is also similar to the constant value like User#1 is 0.5023. So, the BER performance is the same in the case of User #2 compare with User #1 although the transmitted power of User#2 is higher than User#1.

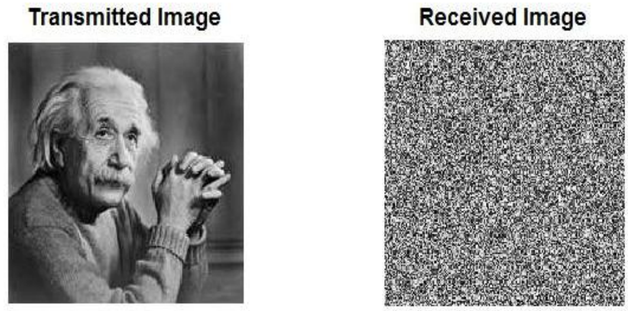

Figure 9. Transmitted image of User#1 over AWGN channel with 16-QAM, DPSK, and QPSK modulation schemes

The transmitted image of User#1 has not been back at the receiver side for the 16-QAM, DPSK, and QPSK modulation technique. Those types of modulation techniques are not given good results for User#2 also. More noise has been added to the original image and it is unclear to identify the user. The synthetic binary data of User#2 receive a maximum number of bit errors which is shown in figure 9.

7. Conclusions

In this paper, a comprehensive study has been undertaken on the performance evaluation of the MIMO NOMA wireless communication system for the transmission of different types of data to different users simultaneously. The simulation results of the proposed system confirm that it is possible to transmit different types of data for different users in the MIMO-NOMA wireless communication system which meets one of the major requirements of the next generation wireless communication system like B5G/ 6G. It is also noticeable from the simulation results that the BER performances are very much robust and satisfactory with BPSK and 4-QAM modulation techniques and conventional channel coding schemes. The simulation results of the proposed system also represent that power allocation among the users affect significantly the performance of the system, far user deserves more power than the near user for implementing NOMA. In the context of system performance, it can be concluded that NOMA is suitable for simultaneously different data transmission over the AWGN channel in a hostile fading environment.

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