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Effect of ModulationTechniques and Various Input Signals on Non-Orthogonal Multiple Access (NOMA) for Wireless Communication System

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Abstract: Non-Orthogonal Multiple Access (NOMA) is one of the good applicants for fifth generation wireless system. This access technique ensuresbandwidth efficiency than the Orthogonal Frequency Division Multiple Access (OFDMA). All the users in NOMA use the same time and frequency resources which results in improved spectral efficiency but power is different for all users. Hence NOMA is a power domain multiplexing scheme and its prospect for next generation wireless communication is need to be explored.BER performance of NOMA under various conditions has been studied in this paper. Performance comparison has been done with OFDMA to observe the effectiveness for particular environment. From the simulation results, it is observed that NOMA shows competent result for different modulation techniques and various types of input signals. Around 2% BER performance variation is observed from the figures under different modulation schemes for different types of input signals which is consistent.

Keywords: *NOMA; OFDM; SNR; BER; QAM; BPSK*

Introduction: Wireless communication system needs more efficient use of the spectrum available for the system because the spectrum or bandwidth is limited in a wireless communication system but the traffic over wireless communication system are increasing day by day[14]. Many new communication systems are there such as device-to-device communication, ultra densification, millimeter wave communication and novel multiple access schemes under the umbrella of fifth generation (5G) networks [9].Obviously, the generationis expected to have higher data rates, high spectralefficiency. Achieving this data rate needscareful selection of modulation schemes and multiple access techniquesthat are available for 5G.Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA), OFDMA are used in previous communication system [12].NOMA is new of them. Now it is important to find out the performance of this system in the mobile radiochannel and how it is better than the other techniques. Also it is necessary to explore which modulation technique and encoding technique [6, 8] work better for NOMA. Many modulation techniques like Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK), and Quadrature Amplitude Modulation (QAM) are used in communication system [13].It is needed to focus on finding the benefit and drawback of these systems. The implementation of these modulation techniques in the wireless communication is clearly discussed in many literatures [10-11].

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In this paper, extensive studyand investigation on the effect of several modulationtechniquesfor measuring the performance of OFDMA and NOMA system has been targeted. The effect of different input signals such as synthetic data and textare targeted to explore for OFDMA and NOMAbased wireless communication.There have some limitations of transmission channels in wireless channel betweenreceiver and transmitter. The transmitted signals arriveat receiver with different power and time delay due to thereflection, diffraction and scattering effects. TheBER (Bit Error Rate) of the wireless channel isrelatively high. During data transmission and storage operations, performance criterion is commonly determined by BER which is simply the ratio of erroneous bit to the total bits. Therefore BER performance is targeted to study for OFDMA and NOMA based wireless communication system. Simulation based study on the capacity of NOMA and OFDMA is focused for service-oriented wireless communication.

Basic Concept of NOMA: In the transmission section of NOMA, the one user data is superimposed with other user data.The equation of NOMA transmission section is represent as

$$y(t) = h_1\left(\sqrt{p_1}x_1(t) + \sqrt{p_2}x_2(t)\right) + N_{0,1} \qquad \text{eq. 1}$$

For simplicity, in equation eq.1 we have considered two users. User 1 data is X_1 and User 2 data is X_2. NOMA symbol after super positioning X_1(t)+X_2(t), is transmitted[1-5]. The signal $y(t)$is received by two users. All users decode their transmitted signalsin conventional NOMA.To overcome the interference, Successive Interference Cancellation (SIC) technique has been introduced as of paper [7].

Basic Concept of OFDMA: The equation of OFDMA transmission section is represented as

$$y(t) = x_1F_1(t) + x_2F_2(t) + N_{0,1} \qquad \text{eq. 2}$$

In equation eq.2 we have considered two users for simplicity. User 1 data is X_1 and User 2 data is X_2. The individual data is multiplexed with the subcarrier frequency. The subcarrier frequency is achieved by dividing the total frequency or bandwidth according to users[10-12]. Here we have considered total frequency F which is divided by two. $F_1$is a frequency of User 1 and $F_2$is a frequency of User 2. Here individual user data is multiplexed with individual frequency that why it is less possibility to interference a user data with other user data.

Resource Allocation for OFDMA and NOMA: The total transmit bandwidth is used by NOMA. Base station transmits the signal to different usersusing the same frequency but power is different. The users are multiplexed the transmitted signal in power domain. At the receiver section, the users candecode their transmitted signal based on their channel gain. On the other hand, the total transmit bandwidth is not used by OFDMA like NOMA. Here the total bandwidth is divided according to users but power is same for all users. Base station transmits the signal to different users using the different frequency but power is same. The users are multiplexedwith the transmitted signal in frequency domain. For simplicity we have considered 3 users and showed the figure about NOMA and OFDMA in Fig.1.

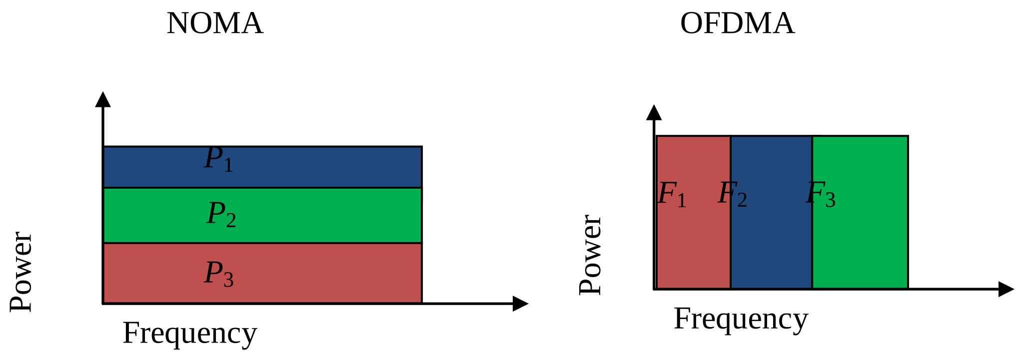

Fig.1. Resource allocation for NOMA and OFDMA.

In Fig.1 the total power of NOMA system is divided among the users. P_1, P_2, P_3 are the power of individual users which is needed to be different for different users. On the other hand, the total bandwidth is divided among the users. F_1, F_2, F_3 are the frequency of individual users which is divided according to the total users. The frequency is allocated as F_1, F_2, F_3 but power P is same for each user.

Different modulation technique for NOMA and OFDMA:

Quadrature Amplitude Modulation (QAM): In PSK modulation, the amplitude of the transmitted signal was constrained to remain constant, thereby yielding a circular constellation. By allowing the amplitude to vary with the phase, a new modulation scheme called QAM is obtained. The constellation consists of a square lattice of signal points. The general form of an M-ary QAM signal can be defined as

$$S_i(t) = \sqrt{\frac{2E_{min}}{T_s}}\, a_i \cos(2\pi f_c t) - \sqrt{\frac{2E_{min}}{T_s}}\, b_i \sin(2\pi f_c t);\quad 0 \le t \le T,\ i = 1, 2, \ldots, M \qquad \text{eq.3}$$

Where E_{min} is the energy of the signal with the lowest amplitude, a_i and b_i are a pair of independent integers chosen according to the location of the particular signal point. It is to be noted here that M-ary QAM does not have constant energy per symbol, nor does it have constant distance between possible symbol states. The reason is that particular values of $S_i(t)$ will be detected with higherprobability than others. If rectangular pulse shapes are assumed, the signal $S_i(t)$ may be expanded in pair of basis functions defined as

$$\phi_1(t) = \sqrt{\frac{2}{T_s}}\cos(2\pi f_c t);\quad 0 \le t \le T_s \qquad \text{eq. 4}$$

$$\phi_2(t) = \sqrt{\frac{2}{T_s}}\sin(2\pi f_c t);\quad 0 \le t \le T_s \qquad \text{eq. 5}$$

The co-ordinate of the i^{th} message point are $a_i\sqrt{E_{min}}$ and $b_i\sqrt{E_{min}}$, where (a_i, b_i) is an element of the L by L matrix given by

$$\{a_i, b_i\} = \begin{bmatrix} (-L+1, L-1) & (-L+3, L-1) & \ldots & (L-1, L-1) \\ (-L+1, L-3) & (-L+3, L-3) & \ldots & (L-1, L-3) \\ . & . & . & . \\ . & . & . & . \\ (-L+1, -L+1) & (-L+3, -L+1) & \ldots & (L-1, -L+1) \end{bmatrix}$$

where, $L = \sqrt{M}$. eq. 6

Binary Phase Shift Keying (BPSK): Binary Phase Shift Keying (BPSK) (also sometimes called PRK, phase reversal keying, or 2PSK) is the simplest form of Phase Shift Keying (PSK). It uses two phases which are separated by 180° and so can also be termed 2-PSK [13]. It does not particularly matter exactly where the constellation points are positioned, and in this figure they are shown on the real axis, at 0° and

180°. This modulation is the most robust of all the PSKs since it takes the highest level of noise or distortion to make the demodulator reach an incorrect decision. It is, however, only able to modulate at 1 bit/symbol and so is unsuitable for high data-rate applications.

Result and Discussion: In this section, a series of simulation results using MATLAB are presented to illustrate the significant impact of various types of input signals and modulation techniques on NOMA and OFDMA Wireless Communication system performance in terms of BER. The multiplexed NOMA and OFDMA scheme based multiuser (2-user) wireless communication system simulation model is simulated with convolutional channel coding and two types of input signals, random synthetic data and text dataare used. Twotypes of modulation techniques 4-QAM and BPSK have been used to study BER performance of NOMA and OFDMA based wireless communication system. The implemented model needs to be as realistic as possible in order to get reliable results. It is ought to be mentioned here that the real communication systems are very much complicated, generally the simulations are made on the basis of some assumptions to simplify the communication systems concerned.

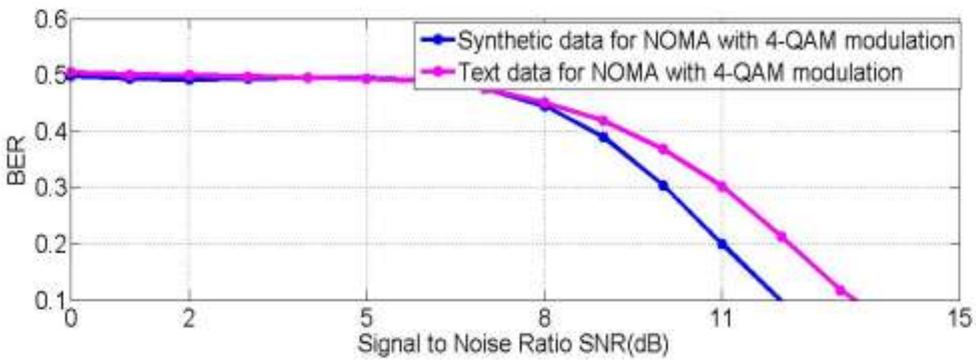

Fig.2. BER performance of NOMA for random synthetic data and text data with 4-QAM modulation

The BER performances of the NOMA wireless communication system in case of user 1 and user 2 under implementation of AWGN channel and 4-QAM digital modulation schemes are presented graphically in fig.2. The estimated BER values are almost stable for synthetic data and text data with different values of SNR ranging from 0 dB to 15dB.From the figure it is observed that NOMA is consistent with different types of input signal under 4-QAM modulation schemeas it shows around 2% variation only for these two types of input data.

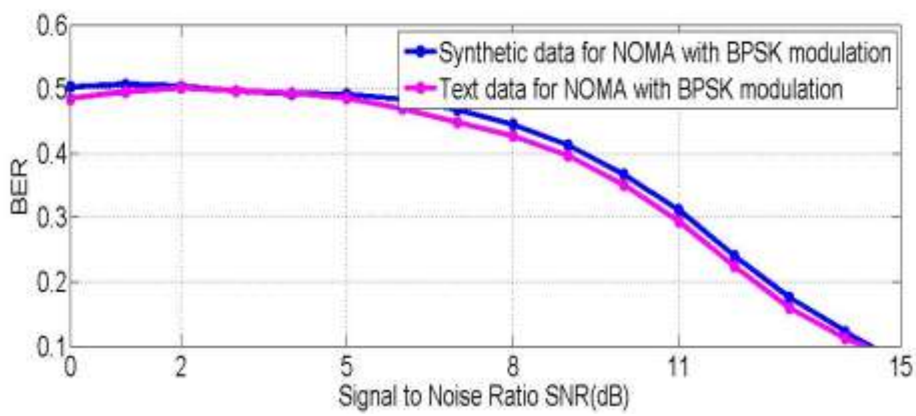

Fig.3. BER performance of NOMA for synthetic and text data with BPSK modulation

The BER performances of the NOMA wireless communication system in case of user 1 and user 2 under implementation of AWGN channel and BPSK digital modulation schemes are presented graphically in fig.3. The estimated BER values are almost stable for synthetic data and text data with different values of SNR ranging from 0 dB to 15dB.From the figure it is observed that NOMA is consistent with different types of input signal under BPSK modulation schemeas it shows around 1% variation only for these two types of input data.

The BER performances of the OFDMA wireless communication system in case of user 1 and user 2 under implementation of AWGN channel and 4-QAM digital modulation schemes are presented graphically in fig.4. The estimated BER values are almost stable for synthetic data and text data with different values of SNR ranging from 0 dB to 15dB. From the figure it is observed that OFDMA is also consistent with different types of input signal under 4-QAM modulation schemeas itshows around 2% variation only for these two types of input data.

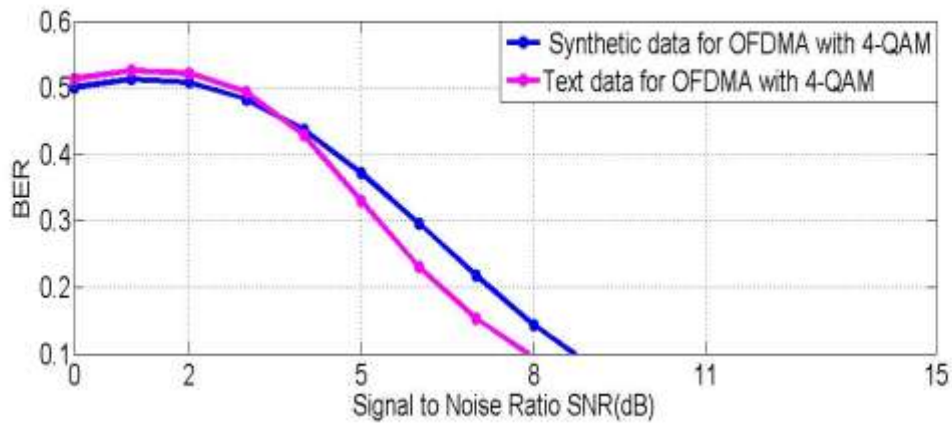

Fig.4. BER performance of OFDMA for synthetic and text data with 4-QAMmodulation

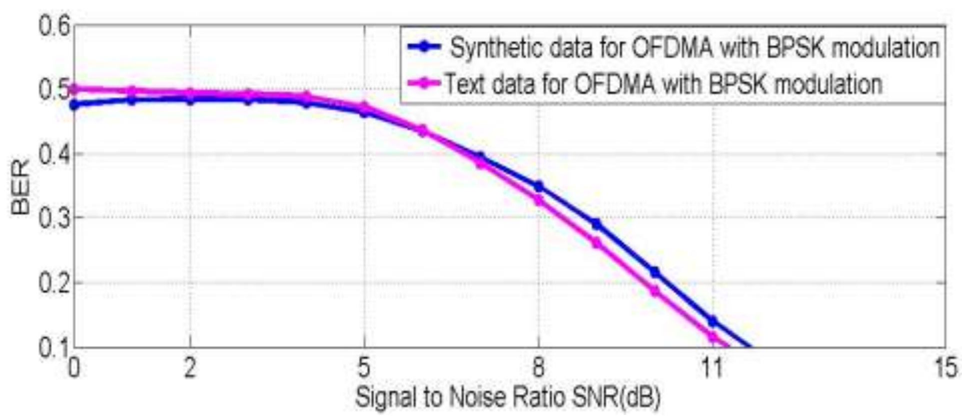

Fig.5. BER performance of OFDMA for synthetic and text data with BPSK modulation

The BER performances of the OFDMA wireless communication system in case of user 1 and user 2 under implementation of AWGN channel and BPSK digital modulation schemes are presented graphically in fig.5. The estimated BER values are almost stable for synthetic data and text data with different values of SNR ranging from 0 dB to 15dB.From the figure it is observed that OFDMA is consistent with different types of input signals under BPSK modulation schemeas itshows around 1% variation only for these two types of input data.

The BER performances of the OFDMA and NOMA wireless communication system in case of user 1 and user 2 under implementation of AWGN channel and 4-QAM digital modulation schemes are presented graphically in fig.6. The estimated BER values are almost stable for synthetic data and text data for NOMA and OFDMAwith different values of SNR ranging from 0 dB to 15 dB but if we consider different between NOMA and OFDMA then it show that OFDMA provide better BER than NOMA. The input data types do not effect on OFDMA and NOMA.

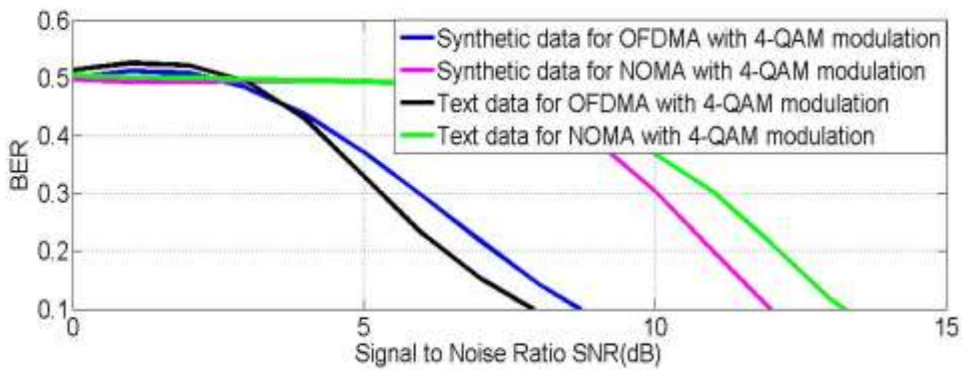

Fig.6. BER performance of OFDMA and NOMA for synthetic and text data with 4-QAM modulation

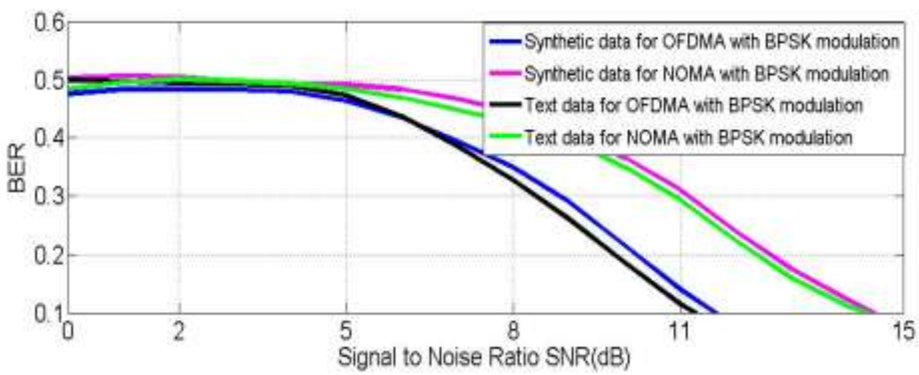

Fig.7. BER performance of OFDMA and NOMA for synthetic and text data with BPSK modulation

The BER performances of the OFDMA and NOMA wireless communication system in case of user 1 and user 2 under implementation of AWGN channel and 4-QAM digital modulation schemes are presented graphically in figure fig.7. The estimated BER values are almost stable for synthetic data and text data for NOMA and OFDMA with different values of SNR ranging from 0 dB to 15dB.The BER performance only effect for accessing technique not input data.

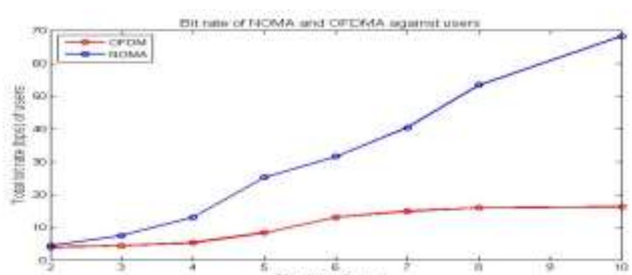

Fig. 8. Comparison of total bit rate of users (capacity) between OFDMA and NOMA scheme at a typical bandwidth and transmitting power.

Fig.8 shows the capacity comparison between NOMA and OFDMA. From the figure it is clearly depicted that the sum rate is always higher for the case of NOMA scheme relative to OFDMA and total bit rate of NOMA users increases rapidly as compared to OFDMA users. From the figure, it is observed that the capacity of NOMA increases rapidly when the number of users is higher. Total bit rate of users is around 18 bps for OFDMA and 78 for NOMA for 10 users case which is a very significant improvement for wireless communication system.

Conclusions: The BER is essential for describing the performance of access technique. In this paper, we have analyzed the BER performance of OFDMA and NOMA scheme under different types of data and modulation techniques for future wireless communication system. We have tried to show that the NOMA provides similar BER performance with other multiple access technique like OFDMA for selecting access technique in next generation. There is around 2% BER performance variation for different types of input signals for NOMA which is consistent with OFDMA. From the simulation result it is also observed that NOMA provides more capacity for multiple users than OFDMA which is very crucial for service-oriented next generation communication system. With proper choice of modulation scheme and other parameters, NOMA shows good result with significant capacity for handling higher data rate for future communication. However, the overall BER performance is not that much satisfactory. Our future target is to accomplish an effective BER minimization technique for NOMA based wireless communication system.

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