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Performance Analysis of NOMA System for 6G networks

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Abstract:
The fifth generation (5G) communications networks have already been deployed to investigate massive connectivity, ultra reliable low latency time communication and high data rates. 6G will continue what 5G started in shifting from connected people and things to connected intelligence. So, 6G technology will bring intelligence to all things like people, business and home, leading to a new horizon of innovations. NON-Orthogonal Multiple Access (NOMA) is considered as one of the key technologies for the next generation mobile communications (6G networks), which enables high spectral efficiency and massive connectivity. In this paper, performance Analysis of NOMA technique has been introduced. The bit error rate BER of NOMA technique has been measured and the effect of power allocation factor has been analyzed. The results show that the performance of NOMA is better than OMA technique. The results also show the extent of convergence between the results of the simulation and the mathematical model.

1. Introduction:

Multiple access technique refers to a technique that allows multiple users to share the same radio resources as a fundamental component of a cellular communication system. In cellular systems, the evolution in their multiple access schemes has been rapidly occurred. In particular, Time Division Multiple Access (TDMA), Frequency Division Multiple Access (FDMA), Code Division Multiple Access (CDMA), and Orthogonal Frequency Division Multiple Access (OFDMA) have been adopted for the cellular networks before 5G.

These techniques belong to the Orthogonal Multiple Access (OMA), where each user transmits or receives a user specific signal over an orthogonal radio resource unit in the time, frequency, code domains, or their combinations. OMA has been the initially choice for previous generations of cellular communications since it simplifies the transceiver design and reduces multiuser interference effects. However, the pool of radio resources restricts the system capacity in terms of the maximal number of active users. In contrast to OMA, Non-Orthogonal Multiple Access (NOMA) allows multiple users to share the same radio resources, improving connection densities and system capacity. As a special case of the NOMA technique, Multi-User Superposed Transmission (MUST) has been studied in LTE Release 13, mainly focusing on the downlink transmission (Y. Chen, et al. 2018).

In (J. A., Oviedo and H. R. Sadjadpour, 2018), the limits on the power allocation coefficients for each user under QoS rate constraints in downlink NOMA systems are derived. In (L. Shenhong, D. Mahsa, and S. Lambotharan, 2018), an efficient algorithm is proposed to obtain optimal control policies. Outage constrained power allocation in downlink multi-carrier NOMA system has been examined. An outage constrained optimization problem is formulated so as to minimize the transmit power. An efficient low complexity iterative algorithm is proposed to solve the optimization problem. In (J. Wang, *et al.* 2018), the authors analyze the outage performance for uplink NOMA systems over Rayleigh fading channels. The probability for each possible decoding order is derived based on the time-varying received power strength observations, where it has been shown that the dynamic ordered successive interference cancellation (SIC) scheme achieves better outage performance than the fixed SIC scheme.

In (G. Lv, *et al. 2018)*, the power allocation coefficients that allow successful decoding of each user's signal are derived, and found to be dependent only on the target rate and the total number of users. Joint subcarrier assignment and power allocation for weighted sum-rate maximization under transmit power constraint per user is considered. In (D. Zhai, *et al 2018)*, dynamic user scheduling and power control is considered.

A stochastic optimization problem with the objective to minimize the total power consumption subject is formulated, which is transformed into a series of deterministic optimization problems.

The reconfigurable intelligent surface (RIS) has been proposed to the benefits of low power consumption, low price, and high efficiency. The concept of RIS has been widely studied due to its potential to transform the unknown wireless channel into a pervasive network (Z. Luo and G. Huang, 2023)(T. Y. Kan, et al. 2023)(H. Liu, et al. 2022)(M. H. Shaikh, et al. 2022)(Z. Tang, et al. 2021). The rest of this paper is organized as follows: Section 2 introduces the research method; it also discusses the system model and the parameters of the system. Section 3 presents the simulation results and finally, the conclusion is drawn in Section 4.

2. Research Method:

NOMA is a promising multiple access technique for 6G networks, applying NOMA to meet the new 6G performance requirements has been proposed in (Y. Liu, et al 2022). According to the current-trend, the requirements of turning from the Internet of things (IoT) into intelligence and beyond fifth generation (B5G) will increase demands on the wireless spectrum that tends to accelerate the spectrum scarcity problem. During the last decade, academic research has focused on dynamic spectrum access to optimize scarce spectrum resources. NOMA is developed along with its promising applications regarding wireless access technique for the 6G era.

2.1 System Model

Power domain NOMA has the ability to accommodate several users simultaneously within the same OFDMA subcarrier, time slot, or spreading code, whereby multiple access is achieved through the allocation of distinct power levels to individual users based on their respective proximity to the base station. The basic system model of NOMA scenario is illustrated in Figure 1.

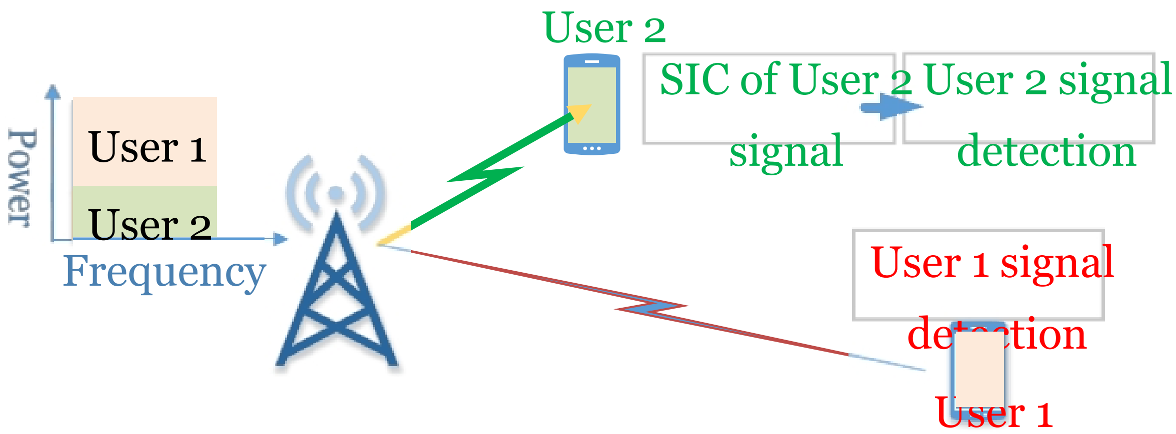

Figure 1: The System Model of NOMA Scenario

Downlink NOMA transmission employs the superposition coding technique at the transmitter for sending a combination of the signals and the SIC technique for interference cancelation, as shown in Figure 1.

2.2 Mathematical Model

Assuming that, the base station has two distinct messages x_1 to far user (user 1), and x_2 to near user (user 2). a1 and a2 are the power allocation factors for the far and the near user respectively. In NOMA, less power to the near user and more power is given to the far user. That is, $a_1 > a_2$.

$$a_1 + a_2 = 1 \qquad (1)$$

Let h_1 and h_2 denotes the channel from the base station to the near and the far user respectively.
The total **coded** NOMA signal (x) transmitted by the base station is:

$$x = \sqrt{P}\left(\sqrt{a_1 x_1} + \sqrt{a_2 x_2}\right) \qquad (2)$$

Where P is the total power transmitted.

The received signal at user 1 (far User) is:

$$y_1 = h_1 x + \omega_1 \qquad (3)$$

From Eq. 2 and 3,

$$y_1 = h_1 \sqrt{P}\sqrt{a_1}x_1 + h_1 \sqrt{P}\sqrt{a_2}x_2 + \omega_1 \qquad (4)$$

So, the SNR for user 1is:

$$SNR = \frac{|h_1|^2 \, P \, a_1}{|h_1|^2 \, P \, a_2 + \sigma^2} \qquad (5)$$

Similarity, the received signal at user 2 (near user) is:

$$y_2 = h_2 x + \omega_2 \qquad (6)$$

From Eq. 2 and 6,

$$y_2 = h_2 \sqrt{P}\sqrt{a_1}x_1 + h_2 \sqrt{P}\sqrt{a_2}x_2 + \omega_2 \qquad (7)$$

The far user must perform SIC before decoding his signal.
The BER was calculated by applying this technique to a communication system that uses BPSK with a Rayleigh model channel.

2.3 Simulation Parameters

For the performance of NOMA in term of BER, the scenario parameters are summarized in Table I.

Parameter	Value
Distances of near user from base station	1000 m
Distances of far user from base station	1500 m
Power allocation factors a_1	0.6, 0.7 and 0.8
Power allocation factors a_2	0.4, 0.3, and 0.2
Path loss exponent	4
Transmit power in dBm	0 to 50
Bandwidth	1 MHz
Modulation technique	BPSK
Channel Model	Rayleigh channel

3. Simulation Results:

In this section, the simulation results have been discussed. The comparison between the total base station capacity of NOMA and OMA techniques has been presented in subsection 3.1 and the performance analysis of NOMA has been discussed in subsection 3.2.

3.1 Comparison between NOMA and OMA capacity:

In this simulation, we verify that the performance of NOMA is better than that of OMA in terms of capacity. The total capacity of NOMA and OMA techniques has been shown in figure 2.

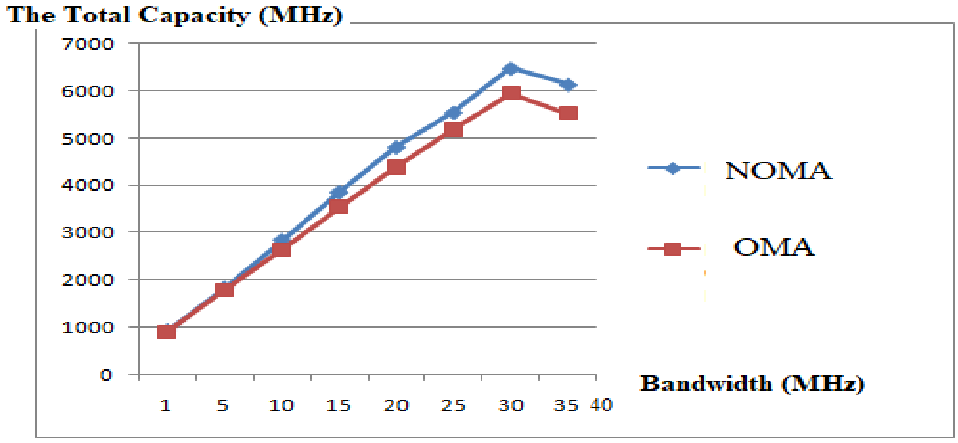

Figure 2: The Total Capacity of BS for NOMA and OMA

The results obtained at different values of bandwidth. Results show that the improvement rate increases with increasing band width. It can be observed that, the improvement percentages at the BW 30 and 35 MHz are 7% and 9% respectively.

3.2 BER of NOMA:

The analytical bit error rate (BER) expression for the non-orthogonal multiple access (NOMA) network is validated in this section through the simulation. Figure 3 illustrates the BER of the two user scenario as a function of transmit power for ideal successive interference cancellation.

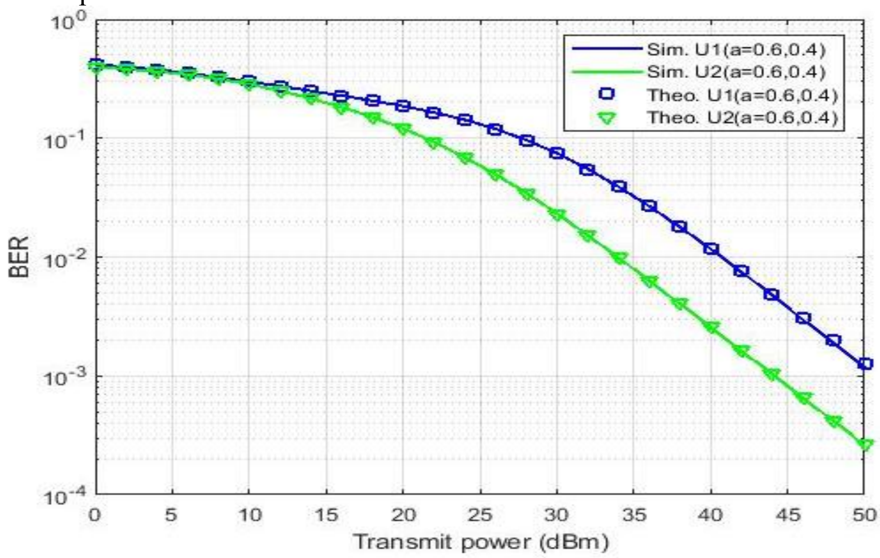

Figure 3: BER of NOMA at allocation factors (0.6 and 0.4)

The power allocation coefficients are selected 0.6 and 0.4 respectively. We observe that the simulation results exactly match with the corresponding theoretical results. Figure 4 illustrates the effect of changing power allocation factor on BER.

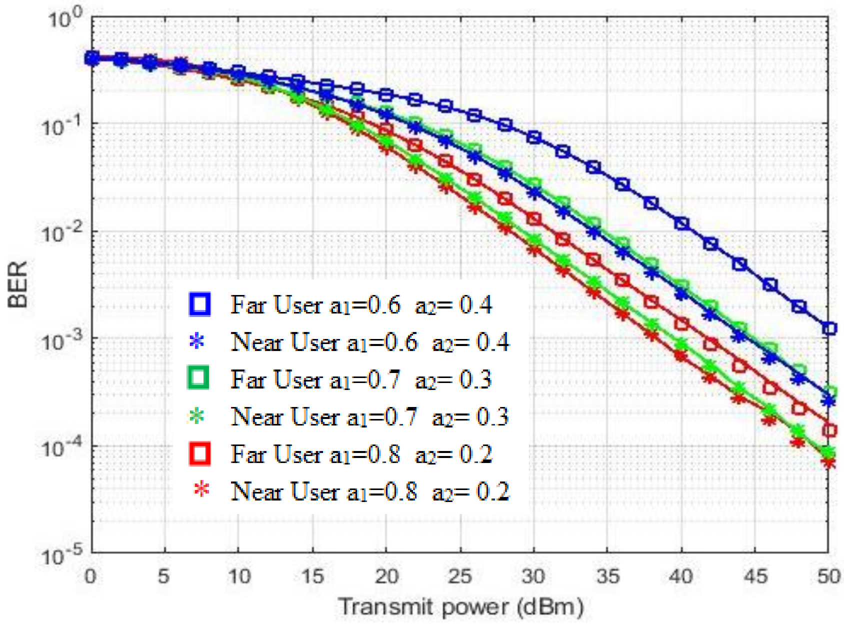

Figure 4: Effect of Power Allocation Factor in BER

As shown in figure 4, the BER values at the three different power allocation factors have a linear relationship with the theoretical curve from 0 to 50 dBm transmit power range. The lowest BER for near and far users achieves at a_1=0.8 and a_2=0.2. The results show that as the transmitted power increases, the error rate decreases. The system works better when the power allocation factor is increased.

4. Conclusions

In this paper, the bit error characteristics of the downlink NOMA network in the case of Rayleigh fading channels has been analyzed. The explicit expression for the BER has been determined analytically for BPSK modulation in scenarios with perfect successive interference cancellation (SIC). In the regime of high signal-to-noise ratio (SNR), the network's behavior can be described in terms of the total capacity and BER in the case of perfect SIC. This work can be extended by analyzing the performance of NOMA in the case of imperfect SIC. Optimization of power allocation factor in higher order modulation may be a good extension of this work.

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