International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 11 Issue 4 ǁ April 2023 ǁ PP. 90-96

Improving Spectral and Power Efficiency Using Noma and Massive Mimo In 5g

Chelikani Satya Sai Sri Pranav,
Muskan Aryan, Pagadala venkata Shrihari
Mr. K.V. SATYA KUMAR
ECE Department ,GITAM School of Technology, Visakhapatnam

ABSTRACT
This paper presents a novel approach to improving spectral and power efficiency in 5G networks by combining Non-Orthogonal Multiple Access (NOMA) and Massive Multiple Input Multiple Output (MIMO) technologies. NOMA enables multiple users to share the same time-frequency resources by using different power levels and decoding orders, which can significantly increase spectral efficiency. On the other hand, Massive MIMO utilizes a large number of antennas at the base station to improve power efficiency by exploiting spatial diversity and multiplexing gain. By combining these two technologies, we propose a NOMA-Massive MIMO scheme that can achieve both spectral and power efficiency gains. We also provide a mathematical analysis of the proposed scheme and show that it outperforms conventional orthogonal multiple access schemes in terms of spectral and power efficiency. Finally, we present simulation results to validate the performance of the proposed scheme in practical scenarios. Our results demonstrate that the NOMA-Massive MIMO scheme can provide significant improvements in both spectral and power efficiency in 5G networks, making it a promising technology for future wireless communications.
Keywords: *SIC, Zero-Forcing, Massive Multiple Input Multiple Output (MIMO),Non Orthogonal Multiple Axis (NOMA),Successive Interference Cancellation (SIC),Zero-forcing (ZF)*

Date of Submission: 20-03-2023 Date of acceptance: 04-04-2023

I. INTRODUCTION

The explosive growth in mobile data traffic has motivated the development of fifth-generation (5G) wireless networks, which aim to provide higher data rates, lower latency, and better coverage than previous generations of wireless networks. To achieve these goals, 5G networks rely on advanced technologies such as Non-Orthogonal Multiple Access (NOMA) and Massive Multiple Input Multiple Output (MIMO). NOMA allows multiple users to share the same time-frequency resources by assigning different power levels and decoding orders to each user. This can significantly increase the spectral efficiency of the system. On the other hand, Massive MIMO utilizes a large number of antennas at the base station to exploit spatial diversity and multiplexing gain, thereby improving the power efficiency of the system.

While NOMA and Massive MIMO are promising technologies, they also introduce new challenges, such as multiuser interference and high computational complexity. To address these challenges, various schemes have been proposed that combine NOMA and Massive MIMO with other techniques such as successive interference cancellation (SIC) and zero forcing (ZF). These schemes aim to improve the spectral and power efficiency of the system while mitigating the interference caused by NOMA.

This paper proposes a new scheme that integrates NOMA, Massive MIMO, SIC, and ZF to achieve even higher spectral and power efficiency in 5G networks. We provide an analytical and simulation-based evaluation of the proposed scheme and compare it with conventional NOMA-Massive MIMO schemes. Our results show that the proposed scheme can significantly improve the sum rate and energy efficiency of the system while maintaining a high level of spectral efficiency. Overall, the proposed scheme has the potential to address some of the key challenges facing 5G networks and enable the development of more efficient and reliable wireless communication systems.

II. MATERIALS AND METHODS

2.1.Massive Multiple Input Multiple Output (MIMO)

Massive MIMO is a wireless communication method that utilises a sizable number of base station antennas to simultaneously interact with a sizable number of user devices. Massive MIMO uses hundreds or even thousands of antennas to increase the number of spatial degrees of freedom, which enhances the capacity and quality of wireless communication. This is in contrast to traditional MIMO, which uses a limited number of antennas at the base station.

Uplink spectral efficiency bounds,

$$\mathrm{SE}_{j,k,UL}^{ub} = \frac{\tau_u}{\tau_c} \mathrm{E}\left[\log_2\left(1 + \frac{p_{j,k}\,|d_{j,k}^H h_{j,k,j}|^2}{\sum_{l=1}^{L}\sum_{i=1}^{K_l} p_{l,i}\,|d_{j,k}^H h_{l,i,j}|^2 + \sigma_{UL}^2 ||d_{j,k}||^2}\right)\right]$$

Downlink spectral efficiency bounds,

$$\mathrm{SE}_{j,k,DL}^{ub} = \frac{\tau_d}{\tau_c} \mathrm{E}\left[\log_2\left(1 + \frac{\rho_{j,k}\,|h_{j,k,j}^H q_{j,k}|^2}{\sum_{l=1}^{L}\sum_{i=1}^{K_l} \rho_{l,i}\,|h_{j,k,l}^H q_{l,i}|^2 + \sigma_{DL}^2}\right)\right]$$

2.2.Non Orthogonal Multiple Axis (NOMA)

By allocating alternative power levels and decoding orders, the NOMA multiple access technique enables numerous users to share the same frequency band and time slot. Each user is given a separate sub-channel in traditional orthogonal multiple access (OMA) systems, which divide the available bandwidth into orthogonal sub-channels. Contrarily, NOMA enables several users to share a single sub-channel by superimposing signals of various intensities. The basic concept behind NOMA is to use the power domain rather than the frequency or time domain to distinguish users.

The corresponding achievable data rate for NOMA is,

$$R = log_2(1+\gamma) = log_2(1 + \frac{|h|^2 P\alpha}{\alpha^2})$$

2.3. Successive Interference Cancellation (SIC)

A signal processing technique called successive interference cancellation (SIC) is used in communication systems to reduce interference brought on by several users transmitting on the same frequency band. In SIC, the strongest user's signal is first identified and decoded by the receiver, and it is then subtracted from the received signal to eliminate its contribution to the overall interference. When all users have been decoded and the interference has been eliminated, the receiver repeats this process for the remaining users in decreasing order of signal intensity.

When several users share the same time and frequency resources in non-orthogonal multiple access (NOMA) systems, SIC is very helpful. In NOMA, users are given varied power levels depending on the channel conditions and transmit at the same time and frequency. At the receiver, SIC is then used to separate the signals from various users. The process is repeated for the remaining users in order of decreasing channel strength after the receiver has first decoded the signal of the user with the strongest channel condition and removed it from the total received signal.

2.4. Zero-forcing (ZF)

The zero-forcing (ZF) method is one way to increase the number of pilots without lowering the data rate. The ZF approach entails employing only a portion of the antennas for pilot transmission and the remaining antennas for data transfer. This permits the transmission of more pilots without affecting the amount of bandwidth available for data transfer. The data transmission matrix and the pilot transmission matrix in the ZF approach are intended to be orthogonal. This guarantees that the pilot broadcast does not impede the data transmission and that the accuracy of the channel estimation is not jeopardised. The pilot transmission matrix is made to only transmit pilots on a portion of the antennas, while the remaining antennas send data.

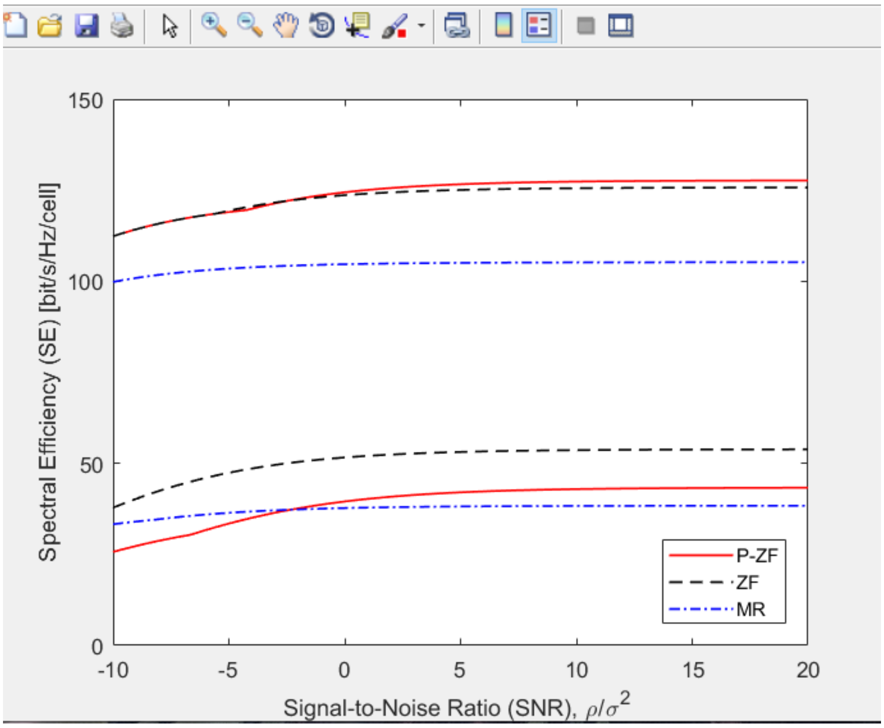
2.5. Signal-Noise Ratio (SNR)

SNR, which stands for Signal-to-Noise Ratio, measures how strong the signal is in comparison to the background noise. It is described as the power difference between the noise and the signal. Since less noise interferes with the signal, the higher the SNR, the better the signal quality.By increasing the wireless communication system's signal-to-noise ratio (SNR), Massive MIMO primarily boosts spectral efficiency. The system's achievable data rate and the quality of the received signal are both significantly influenced by SNR. The system's ability to transmit data at higher bit rates with lower error rates and hence increase spectral efficiency depends on the SNR.

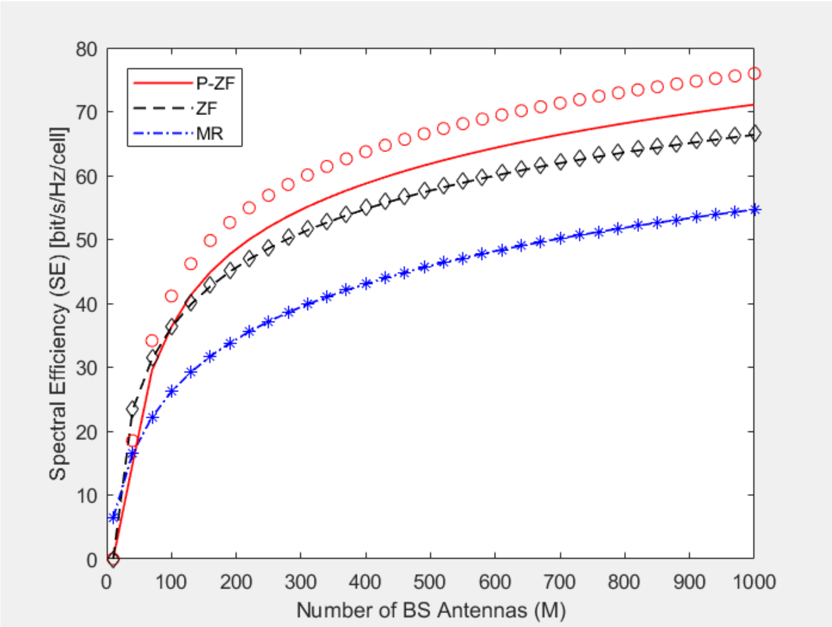
2.6. Outage Probability

Outage probability is a metric used to quantify the probability of a wireless communication system failing to meet a certain level of service, such as a minimum data rate or a certain level of signal quality.Massive MIMO and NOMA have the potential to reduce the likelihood of outages in wireless communication systems. The precise impact on the likelihood of an outage, however, depends on a number of variables, including the system parameters, channel conditions, and traffic patterns. As a result, field tests and simulations should be used to assess how well these technologies work in real-world scenarios.

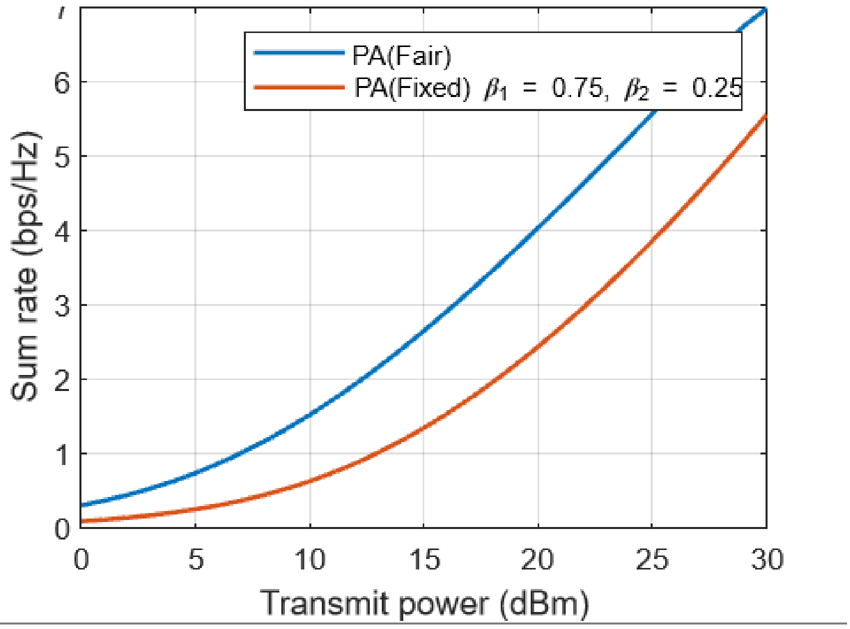
III. IMPLEMENTATION & EXPERIMENTAL RESULTS



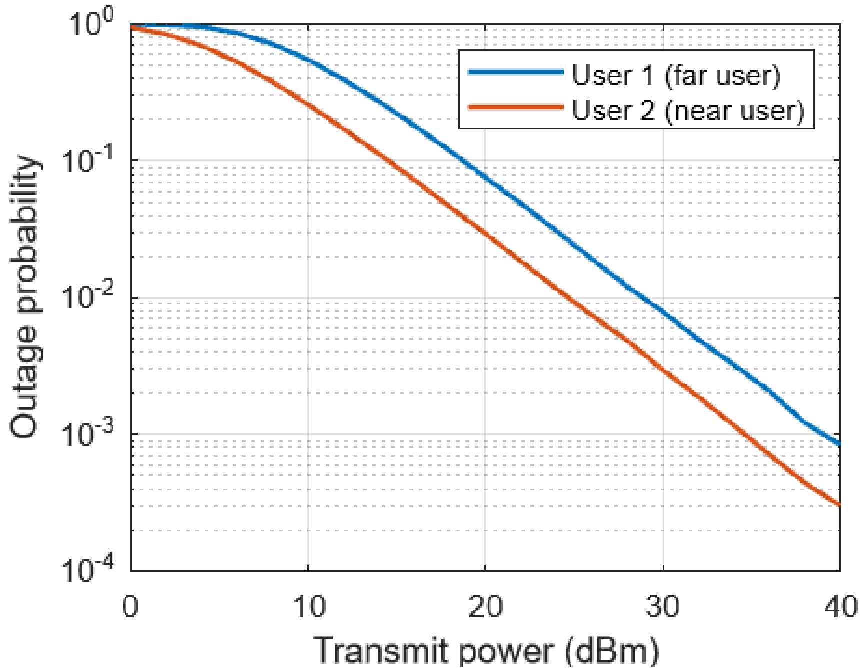
Impact of SNR variations on the SE.



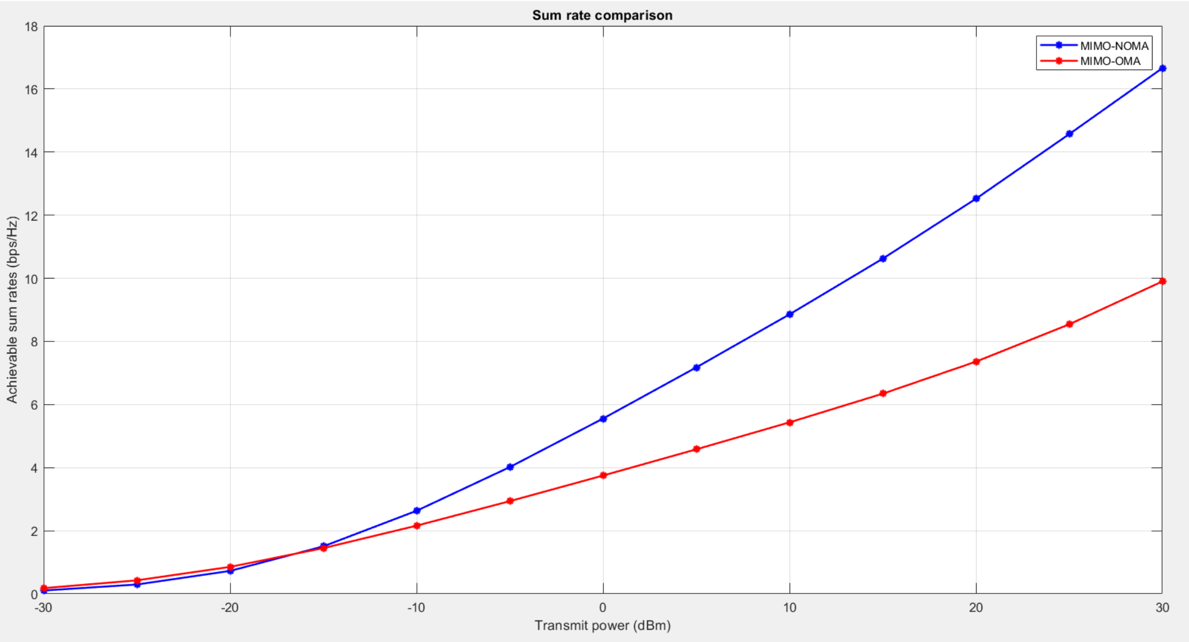
Increase in SE as the Number of Base antennas increase by using ZF



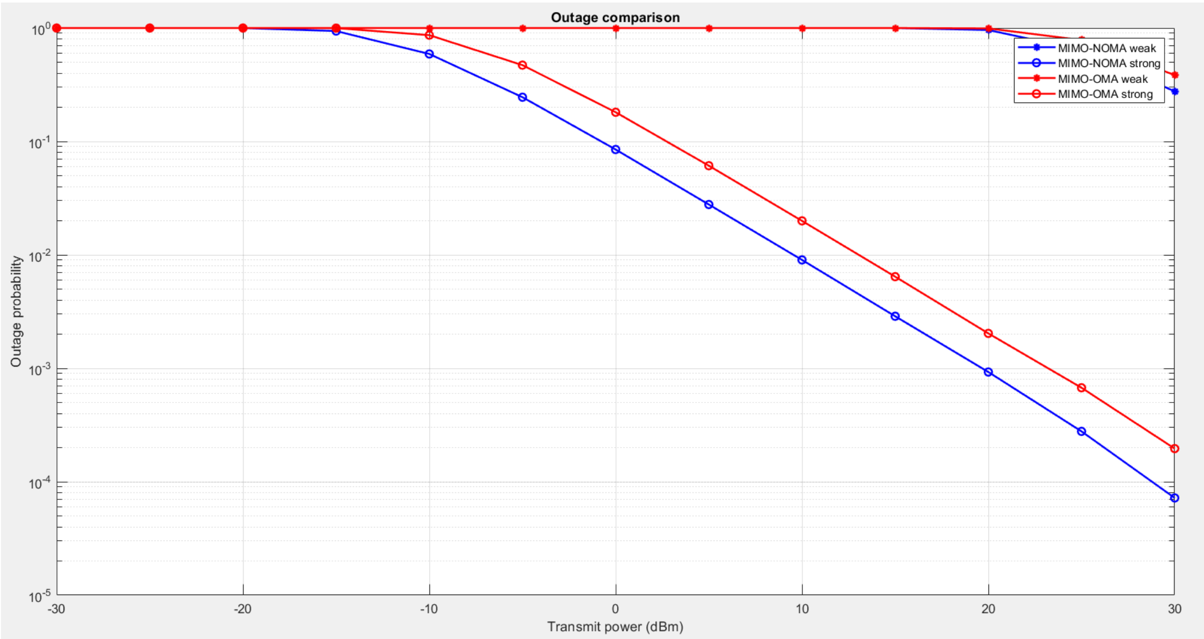
Sum rate vs transmit power of fixed and fair PA



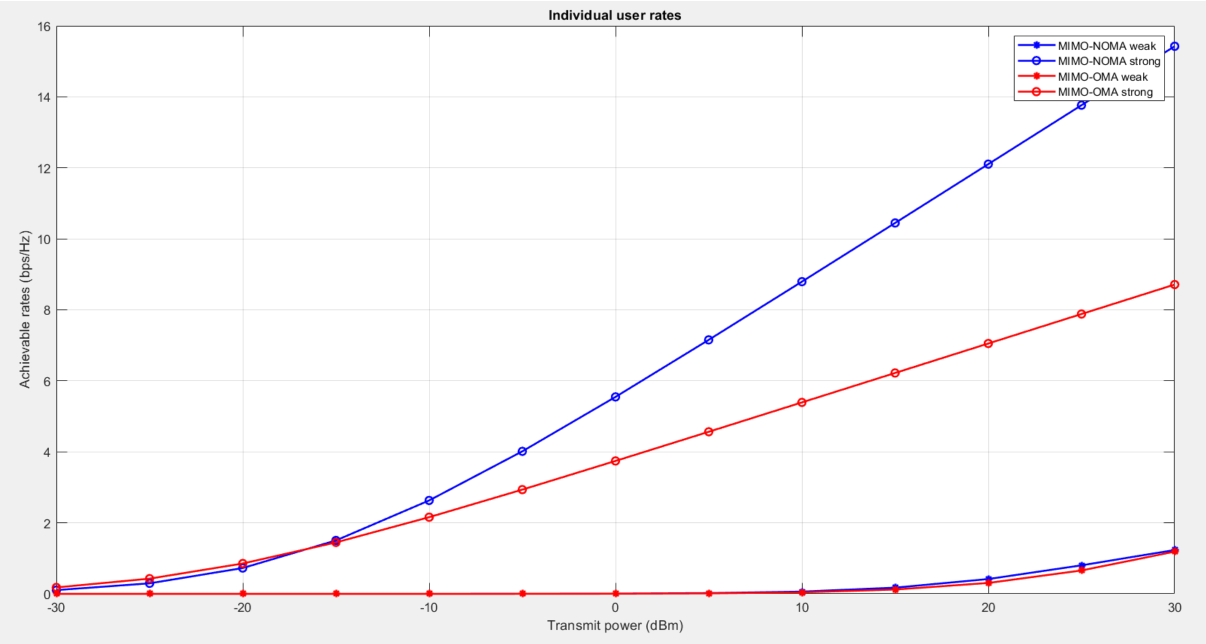
Outage Probability comparison between Farthest user and near user



Sum rate comparison Between MIMO-NOMA and MIMO-OMA



Outage comparison Between MIMO-NOMA and MIMO-OMA



Individual Data rates of MIMO-NOMA and MIMO-OMA

Achievable rate at user 1 is given by,

$$R_1 = log_2(1 + \gamma_1)$$

Where, γ_1 is SINR equation for user 1,

$$\gamma_1 = \frac{P\alpha_1|h_{11}+h_{12}|^2}{P\alpha_2|h_{11}+h_{12}|^2+\sigma^2}$$

Similarly for user 2,

Achievable rate at user 2 is given by,

$$R_2 = log_2(1 + \gamma_2)$$

Where, γ_2 is SINR equation for user 2,

$$\gamma_2 = \frac{P\alpha_2|h_{21}+h_{22}|^2}{\sigma^2}$$

IV. Conclusion

In this study, we looked at the gains that NOMA can offer in massive MIMO configurations with many antennas relative to the number of users and compared it to a conventional method from the massive MIMO literature. More specifically, we compare two non-orthogonal approaches—power-domain NOMA and mMIMO using ZF—instead of the traditional comparison between NOMA and OMA. Practically speaking, this contrast matters because BSs with numerous antennas are already being used in LTE networks and will become commonplace once 5G deployments get going. It's crucial to keep in mind that traditional mMIMO methods, which depend on beamforming to partly suppress inter-user interference and use spatial multiplexing to serve multiple users on the same time, frequency, and code resources, cannot be used today.

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