PERFORMANCE ANALYSIS OF NOMA IN RAYLEIGH AND NAKAGAMI FADING CHANNEL

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ABSTRACT

Cellular connectivity is expanding rapidly in the modern world. The multiple access strategy is one of the highly used methods for allocating the range of users in cellular network. Spectrum allocation is a crucial element to take into account since cellular communication is becoming more and more popular. NOMA is a channel access mechanism used in 5G mobile communication. It is also known as non-orthogonal multiple access. NOMA is a potential strategy for enhancing spectral efficiency and sum rate. Using the NOMA method, we evaluated the BER versus transmitted power of two users in rayleigh and nakagami fading channels. In this NOMA setup, a single antenna is shared by two users. Two users can accept the same frequency using 5G NOMA technology, but at different power levels. The results of the MATLAB simulation show that the two user NOMA in the Nakagami channel performs better than the Rayleigh channel in terms of Bit Error Rate vs. Transmitted Power.

KEYWORDS

NOMA, Rayleigh, Nakagami Fading, BER, Transmitted Power and Probability Density Function.

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1. INTRODUCTION

One of the crucial requirements for 5th generation mobile systems is expanded data networks. The development in this field aims to boost system throughput and capacity. This is a must-have requirement given the rapid increase in mobile traffic that has just occurred. The network's increasing traffic should be able to be handled by the multiple access strategy that is suggested Aditi Agrawal et al. [2022] M. W. Baidas et al. [2018]. Early versions of multiple access strategies distributed users and resources in an orthogonal way. But, in 5G, NOMA has been the centre of study. A mechanism called as NOMA is used to make sure that there is equity in the deployment of forthcoming radio access resources. The fifth generation must offer high connectivity, dependability, and low latency, therefore this is necessary. In this type of design, NOMA surpasses OMA by roughly 30% B. Kim et al. [2019. Superposition coding is used by the base station (BS) to broadcast in NOMA, while SIC is used to decode the signals. Combining this SIC with an interference cancellation combining receiver will boost capacity A. Benjebbour et al.[2013]. Non-orthogonal multiple access may be divided into 2 categories which are the domains of code and power C. Hsiung et al. [2019]. In NOMA domain, users having poor channel conditions receive high power, while users having acceptable channel conditions receive low power. While the less powerful user performs SIC, the more powerful user directly decodes their own signal in the receiver. Because users may communicate in both good and bad channel conditions, NOMA is more democratic than OMA P. N. Thakre et al. [2022]. In comparison to other orthogonal users, the throughput of cell edge users improves owing to the intra beam SIC's removal of interference D. K. Hendraningrat et al. [2020].

When fifth-generation systems connect large devices, improving spectrum allocation is essential. NOMA helps to improve spectrum utilization. In this study, the simulation results of BER vs transmitted power in two different fading channels are shown. This article has the advantage of illustrating the BER of a system employing NOMA in two fading channels. To enhance the spectral efficiency in 5-G communications, NOMA has been proposed. Spectrum distribution becomes significant in a number of methods as user numbers increase A. Benjebbour et al. [2013]. In order to improve a network's overall rate, outage probability, and ergodic capacity, multiple access approaches are deployed. The importance of power allocation in network performance also increases along with the number of users K. Wang et al. [2019] K. Higuchi et al. [2015] Y. Kishiyama et al. [2012] Harada et al. [2014] Prasheel Thakre et al. [2022] Y. Saito et al. [2013]. Performance is assessed using the users' BER calculations. Since the performance is usually acceptable, power domain NOMA is properly assessed. Performance will be better with the distribution to NOMA users than with regular OMA. Applications, like visible light communications, are also where NOMA is most commonly employed. The most frequent issue with VLC is blockages; the dynamic user pairing strategy helps with distribution of resource, which right away enhances the performance of the system Z. Xiao et al. [2019] Y. Yin at al. [2019] . Combining user pairing with power allocation, the fractional transmit power that results in low performance is used for resource allocation Y. Yin at al. [2019]. BER vs SNR of two users was compared for various fading channels using NOMA approach and it was found that Nakagami channel performs considerably better when compared to the Rayleigh and Rician channel in BER vs SNR but transmit power isn’t considered for the different channels K. Higuchi et al. [2015]. Moreover, comparison of NOMA against OMA networks conveys that NOMA outperforms OMA and provide better spectral efficiency and user fairness (C. Hsiung et al. [2019]. Closed-form expressions of BER at near and far users of the considered downlink NOMA are calculated in the presence of SIC over Nakagami fading channel A. Benjebbour et al. [2013]. The equations for average SNR, achievable rate, and outage probability show that network users' ordered channel gains are equal to their diversity orders M. W. Baidas et al. [2018]. NOMA has developed independently in every aspect of wireless communication. Whenever there is a rise in users, the allocation of resources is also considered to account for the effectiveness of the system.

2. NOMA SYSTEM MODEL

We consider Non-Orthogonal Multiple Access Scheme. Here, the BS superimposes the information waveforms for its serviced users. Each user equipment employs Successive Interference Cancellation to detect their own signals.

In a NOMA system with two users , suppose User 1 is a faraway user with a weak signal and User 2 is a close user with a good signal.

The BS serves both users on the same frequency spectrum. h_1 and h_2 be the channels of far user and near user respectively. The base station's signal can be described as follows:

$$x = \sqrt{P}(\sqrt{\alpha_1}x_1 + \sqrt{\alpha_2}x_2)$$

where, P is the transmitted power, α is fractional coefficient of total power such that $\alpha_1 > \alpha_2, \alpha_1+\alpha_2=1$

At the User 1, the received vector is expressed as:

$$y_1 = h_1\sqrt{P}(\sqrt{\alpha_1}x_1 + \sqrt{\alpha_2}x_2) + w_1 \tag{2}$$

or,

$$y_1 = \underbrace{h_1\sqrt{P}\sqrt{\alpha_1}x_1}_{} + \underbrace{h_2\sqrt{P}\sqrt{\alpha_2}x_2}_{} + \underbrace{w_1}_{} \tag{3}$$

Desired dominating Interference low power Noise

Now, direct decoding is performed to estimate x_1

The SINR for decoding the 1st (far) user signal is given by:

$$\gamma_1 = \frac{\alpha_1 P\left|h_1\right|^2}{\alpha_2 P\left|h_1\right|^2 + \sigma^2} \tag{4}$$

The achievable rate(bps/Hz) of the User 1 is given as:

$$R_1 = \log_2\left(1 + \frac{\alpha_1 P\left|h_1\right|^2}{\alpha_2 P\left|h_1\right|^2 + \sigma^2}\right) \tag{5}$$

For User 2, the received vector is given as:

$$y_2 = \underbrace{h_2\sqrt{P}\sqrt{\alpha_1}x_1}_{} + h_2\sqrt{P}\sqrt{\alpha_2}x_2 \underbrace{+}_{} w_2 \tag{6}$$

Interference dominating Desired low power Noise

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Firstly, direct decoding for the x1 signal, then the concept of the SIC is applied as:

$$y_2' = h_2\sqrt{P}\sqrt{\alpha_1}x_1 + h_2\sqrt{P}\sqrt{\alpha_2}x_2 + w_2 - h_2\sqrt{P}\sqrt{\alpha_1}\hat{x}_1 \tag{7}$$

Now, direct decoding for the near user signal x2.

The SINR for decoding far user's signal at near user is given by:

$$\gamma_{1,2} = \frac{\alpha_1 P\left|h_2\right|^2}{\alpha_2 P\left|h_2\right|^2 + \sigma^2} \tag{8}$$

Hence the achievable rate(bps/Hz) will be:

$$R_{1,2} = \log_2\left(1 + \frac{\alpha_1 P\left|h_2\right|^2}{\alpha_2 P\left|h_2\right|^2 + \sigma^2}\right) \tag{9}$$

After the far user's signal has been cancelled, the near user's SINR for decoding its own signal is:

$$\gamma_2 = \frac{\alpha_2 P\left|h_2\right|^2}{\sigma^2} \tag{10}$$

The corresponding achievable rate(bps/Hz) is given as:

$$R_2 = \log_2\left(1 + \frac{\alpha_2 P\left|h_2\right|^2}{\sigma^2}\right) \tag{11}$$

The three types of NOMA schemes that are now being employed in the broad spectrum are PD-NOMA, waveform domain NOMA, and CD-NOMA, according to the survey and resources that are currently accessible. The focus of most NOMA research is PD-NOMA, which necessitates a substantial power differential between the signals allocated to various users. At the transmitter's side of a PD-NOMA system, superposition coding (SC) is used to create the signals of numerous users on each subcarrier, which are dispersed over several users (In SC, although sharing the same time-frequency-code resources, each user has their own power level. Each user's power level is determined by the channel gain value; those with lower channel gain values receive greater power levels, and vice versa. At the receiver side, the SIC approach is used to filter out extra user signals that interfere with that band.

In terms of spectrum efficiency, NOMA's SIC method outperforms OMA. Between users 1 and 2, the power is split. The power distribution to users has a considerable impact on the throughput of users in the NOMA domain. The fairness of the users' Power allocation largely determines throughput.

3. FADING CHANNELS

During wireless propagation, fading refers to the degradation of the transmitted signal power caused by a variety of factors. These variables include geographic location, time, radio frequency, and atmospheric conditions like rainfall and lightning. There are different types of fading channels and they are Rayleigh, Rician, Nakagami, Weibull fading channel, etc.

In this paper two fading channels Rayleigh and Nakagami are considered. Only NLOS components between the transmitter and receiver are modelled in the Rayleigh. It is assumed that there is an absence of Line-Of-Sight route between the transmitter and receiver. When multipath scattering occurs with relatively high delay time spans and various groups of reflected waves, Nakagami fading takes place. Table 1 shows a comparative study of Rayleigh and Nakagami fading channels taking few key parameters into consideration.

Table I. Comparison between rayleigh and nakagami fading channel.

Parameters	Rayleigh fading channel	Nakagami fading channel
SNR	For 1000 samples, SNR=0.9	For 1000 samples, SNR=0.35
Power Consumption	More power consumption	Less power consumption
BER vs SNR	BER vs SNR values for Rayleigh are lower as compared to Nakagami	BER vs SNR values for Nakagami are higher as compared to Rayleigh

4. PERFORMANCE OF NOMA IN RAYLEIGH AND NAKAGAMI FADING CHANNEL

From Fig. 1, we can infer that for a two user NOMA to maintain user fairness, the system has given the distant user more power and the close user less. Secondly, we conclude that as power increases, the BER for both users decreases. Also, at a particular value of transmit power, BER value for user who is located distantly from the base station is more compared to user nearer.

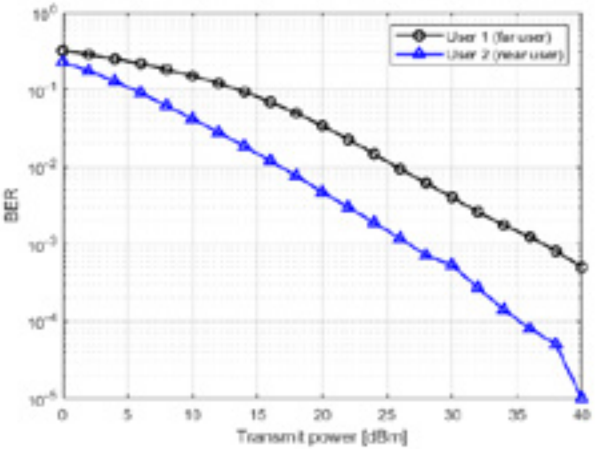

Fig. 1. BER vs Transmitted power graph for rayleigh channel.

Fig. 2 shows the Probability Density Function for Nakagami channel for different m values. From the literature survey, we infer that mu should be greater than 1 so that it corresponds to lesser fading than Rayleigh fading and omega is mostly taken 1.

mu=2 , w=1 and mu=5 and w=1 might be considered as the best values.

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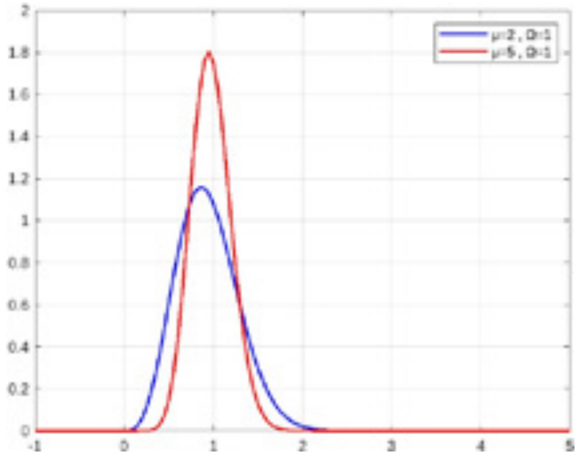

Fig. 2. PDF curve for nakagami-m channel for different values of mu and omega.

In Fig. 3, BER vs Transmit power has been plotted for Nakagami fading channel using different values of mu and omega as shown.

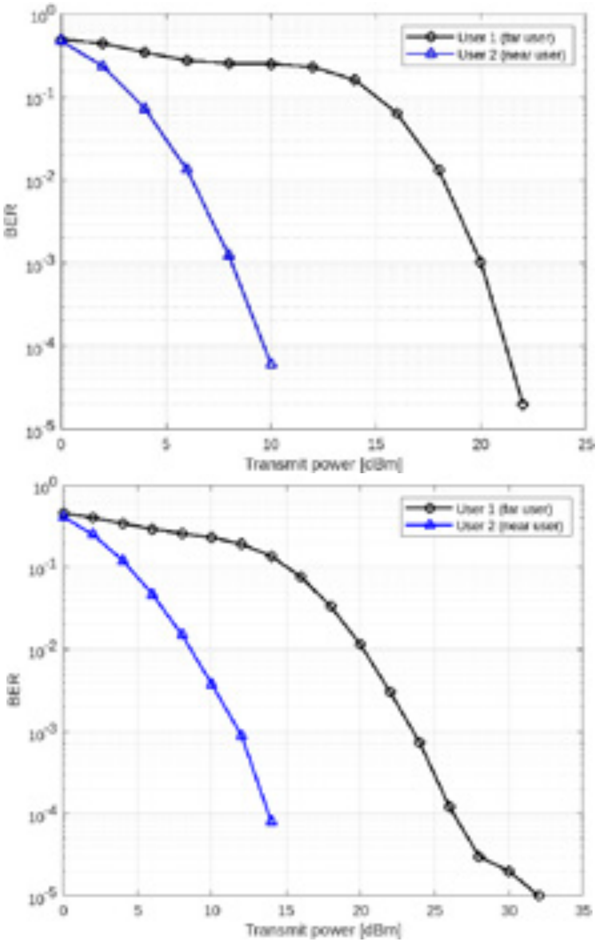

Fig. 3. BER vs Transmitted power graphs for nakagami channel (mu=5, omega=1) and (mu=2, omega=1).

5. CONCLUSION

NOMA is favored for 5G communications because it offers a strong connection, stability, and minimal latency. Large-scale networking is facilitated by this NOMA's improved spectrum efficiency. In this study, the performance analysis of two different fading channels—Rayleigh and Nakagami—for wireless NOMA communication is assessed. According to our research, when power increases in a Rayleigh fading channel, the bit error rate drops, greater power is distributed to far users while low power is distributed to nearby users, ensuring user fairness. Similar findings are obtained with Nakagami fading, although the BER performance is superior to that of Rayleigh fading. The Nakagami channel performs better than the Rayleigh channel in terms of Bit Error Rate. A rise in BER might be reduced by the employment of several coding techniques or differentiation strategies.

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