



## BER Performance for Downlink NOMA

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### Abstract

Non-Orthogonal Multiple Access (NOMA) is a possible multiple access option for the coming generation of wireless communications that has a higher SE and takes advantage of network resource reuse. As a result, academic and industry researchers have recently looked into the error performance and capacity of NOMA schemes. Because of the non-orthogonal nature of NOMA technique, the main disadvantage is users' interference, which is normally mitigated using interference cancellation techniques such as Successive Interference Cancellation (SIC) at the receivers. In this paper, we investigate the performance of NOMA and the power allocation strategy utilized on BER. We used BASK modulation with Rayleigh fading channel and AWGN channel. The numerical results show that NOMA works well in equal and different distances between users.

**Keywords:** NOMA, BER, ASK modulation, SNR, AWGN, Rayleigh fading

**الخلاصة:** NOMA هو خيار وصول متعدد مثالي للجبل القادم من الاتصالات اللاسلكية التي تحتوي على كفاءة طيفية أعلى و تتمتع بميزة إعادة استخدام مصادر الشبكة. لذلك نظر الباحثون الأكاديميون والصناعيون مؤخرا في أداء BER و قدرة أنظمة NOMA. بسبب الطبيعة غير المتعامدة لتقنية NOMA، فإن المشكلة الرئيسية هي تداخل المستخدمين والتي يتم تخفيفها عادة باستخدام تقنيات إلغاء التداخل مثل SIC في جانب المستلم. في هذا البحث، تحققنا من أداء NOMA واستراتيجية تخصيص الطاقة على BER. استخدمنا تضمين BASK مع قنوات Rayleigh و AWGN. النتائج العددية توضح ان NOMA يعمل بشكل جيد سواء كانت المسافات بين المستخدمين متساوية أو مختلفة.

## 1. INTRODUCTION

It is critical to have high-performance transmission and receiving systems. Attenuation, distortion, and noise from signal transmission must be avoided as much as possible for excellent performance. As a result, reliable measurements of the transmitting and receiving signals are required. The transmission quality and reliability of the received signal can be affected by factors, coding, features, and some digital modulation systems. Wireless technology differs from the wired version in that it offers various benefits, including mobility, increased productivity, lower costs, ease of installation, and scalability [1]. However, due to reflection, diffraction, and scattering effects, there are some restrictions and disadvantages of various transmission channels in the wireless medium between receiver and transmitter where transmitted signals arrive at the receiver with varying power and time delay. Besides that, the Bit Error Rate (BER) value of the wireless medium is relatively high. These flaws can hurt the performance of wireless data transfer. As a result, in many applications, error control is required.

The modulation techniques used to modify a carrier wave by discrete signals are referred to as digital modulation. High carrier frequencies are employed in digital modulation to allow signals to be transmitted over long distances using existing long-distance communication systems like radio channels [2]. The received demodulated signal is not adversely affected by noise in the channel. On the other hand, the demodulated signal is distorted if an analogue signal contains noise. Future radio access networks, known as 5G, will offer applications with an extremely high rate, ultra-low latency, large connections, and great mobility [3][4].

Non-Orthogonal Multiple Access (NOMA) is highly suggested and explored by researchers in an attempt to reach these goals. By allowing users to share the same radio resources, NOMA achieves excellent spectrum efficiency and enables dense networks [5]. Multiple users are served by traditional Orthogonal Multiple Excess (OMA) schemes by assigning them to distinct radio resources, such as frequency and time. In contrast to OMA, NOMA splits users into power domains to serve numerous User Equipment (UE) on the same resource blocks at the same time. The NOMA principle is focused on superposition coding at the transmitter and successive interference canceller at the receiver [6][7]. Figure 1 displays the details of how digital communication systems work.

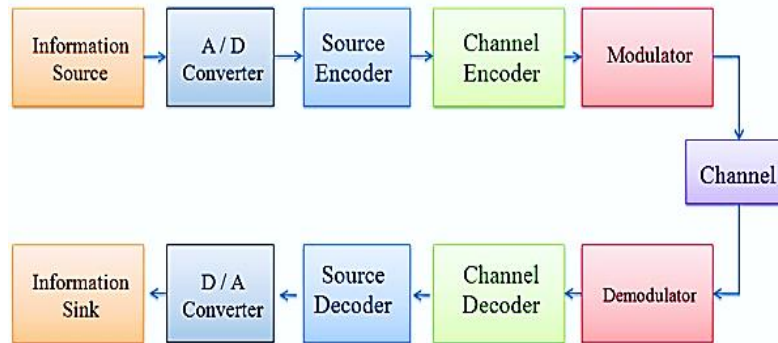


Figure1. Block diagram of a digital communication system [8].

## 2. RELATED WORK

In [9] researchers presented the NOMA for future cellular networks and showed its potential in terms of capacity and user-fairness possibilities in comparison to OMA schemes. Due to this potential, NOMA has been extensively studied in terms of outage performance [10][11], power allocation [12][13], user clustering [14][13][15], and system capacity [16][17]. The Shannon capacity theorem is used in most of these papers. The authors of [18] found that the outage likelihood of NOMA systems is strongly influenced by the desired data rates and the power allocated to each user. In [10] the authors studied the outage probability and sum rate of various power allocation scenarios, taking into account both instantaneous gain and average channel gain. The authors of [19] investigate a NOMA-based downlink Amplify-and-Forward (AF) relaying network in the presence of Nakagami-m fading. This work's contribution is to investigate the BER performance of various numbers of UEs in a downlink NOMA system over various fading channels with different modulation schemes while considering perfect Successive Interference Cancellation (SIC), which is very important, to obtain some informative results about each individual user's Quality of Service (QoS). The simulation results are presented in terms of BER performance for all UE receivers. In [20], the BER performance of downlink NOMA is examined using simulations with perfect and imperfect SIC, but no analytical derivation and results are provided.

## 3. THEORETICAL DESCRIPTION

### 3.1. Amplitude Shift Keying (ASK)

ASK is a type of Amplitude Modulation that uses binary data (1 or 0) to express amplitude variations in a carrier wave. On-Off Keying (OOK) is another name for amplitude shift keying. It's the most basic method of digital modulation. An analogue carrier signal's amplitude changes according to the bit stream (modulating signal), with remaining the frequency and phase constant [21]. Any modulated communication contains a high-frequency carrier. In the case of ASK modulated the binary signal produces a zero value for low input and the carrier output for high input. ASK can be stated in the following way [21]:

$$S(t) = d.n.Cos2\pi f_c t \quad 0 \leq t \leq T \quad (1)$$

where  $f_c$  is the carrier frequency,  $n$  constant,  $d$  is the binary data which is either 0 or 1, and  $T$  is the data bit time duration.

### 3.2.Bit Error Rate

It is the ratio of the number of received bits containing errors to the total number of transmitted bits of a data stream, over a certain time. In a digital transmission is defined as BER. The equation of BER as indicated in [22]:

$$BER = \frac{\text{Received erroneous bits}}{\text{total number of bits}} \quad (2)$$

### 3.3.Signal to Noise Ratio

The ratio of desired signal power to the noise power in a wave is known as the signal to noise ratio [23]. It's a metric for comparing the strength of the desired signal to the strength of background noise. It's could be represented on a logarithmic scale (dB).

$$SNR = \frac{\text{Signal Power}}{\text{Noise Power}} \quad (3)$$

## 4. CHANNEL ENVIRONMENT

### 4.1.Additive Noise

Additive White Gaussian Noise (AWGN) is a major and mostly acceptable noise model, which resembles many procedures gotten in nature. It has a constant power spectral density through the entire frequency range. When a transmitted signal passes across a channel, it is affected by AWGN [24]. A channel that only adds AWGN to a transmitted signal and nothing else, which is called an AWGN channel. It's unrelated to fading or any other system factors. Noise limits high data rate transmission over an AWGN. It can be represented by a mathematical equation in the received signal [24]:

$$Y(t) = X(t) + N(t) \quad (4)$$

where  $Y(t)$  is the received signal,  $X(t)$  is the transmitted signal, and  $N(t)$  is AWGN, its values are identically distributed and statistically independent of each other at any two points in time.

### 4.2.Rayleigh Fading

Rayleigh fading is a related model when there are multiple objects and conspicuous topographical characteristics in the environment that reflect, diffract, and scatter the transmitted signal before it reaches the receiver.

When there are several reflection paths and no Line-of-Sight (LoS) communication between the transmitter and the receiver, the received signal's envelope statistically describes a Rayleigh Probability Density Function (PDF), which is represented as [25]:

$$P(r) = \begin{cases} \frac{r}{\sigma^2} \exp\left(-\frac{r^2}{2\sigma^2}\right) & \text{for } r \geq 0 \\ 0 & \text{otherwise} \end{cases} \quad (5)$$

where  $r$  is envelope amplitude of the received signal, and  $2\sigma^2$  the mean pre-detection power of the multipath signal.

## 5. SYSTEM MODEL

BER is a key metric for evaluating the performance of systems that transfer digital information from one point to another. There is a possibility that errors will be introduced into the system when data is transmitted across a data link [22]. As a result, it's essential to evaluate the system's performance using BER. The exact expressions of BER are analyzed for DL NOMA. First, Near User (NU) detects Far User (FU) symbols and detects his own symbols after removing detected FU symbols with SIC. The decoding process in the FU, however, is carried out by claiming that the NU is noise. Therefore, through the received superposition-coded symbols, the FU decides his own symbols directly. This decision is based on the detection of maximum likelihood. The amount of the error probabilities of all conceivable symbols (various points in the constellations) multiplied by the prior possibility of that symbol is the maximum likelihood detector error probability. The choice of a symbol is determined by the

area where the signal is received. The decision limit is dependent upon whether the in-phase component of the received data is greater, lower, or equal to zero when ASK modulation is used. The received signal constellation at users is shown in Figure 2.

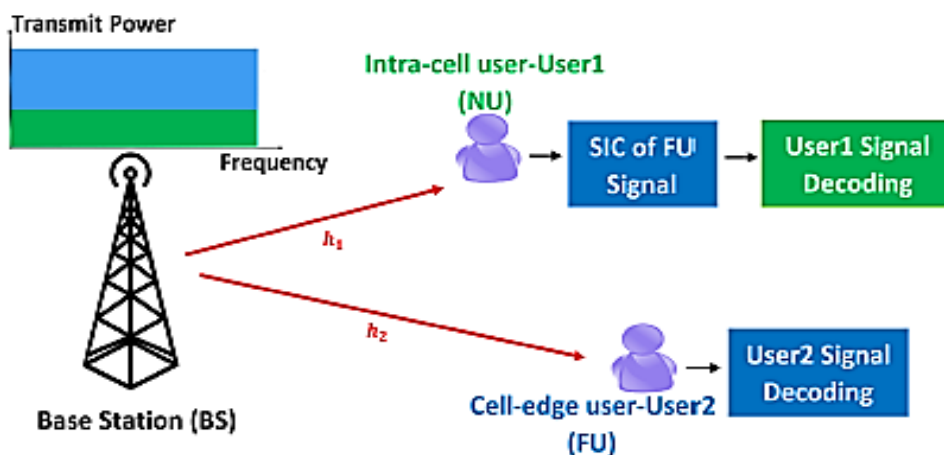


Figure 2. DL-NOMA schemes [26].

Rappaport in 2002 introduced BER expression as:

$$BER = \int_0^{\infty} P_b \langle E/r \rangle \langle P_r \rangle d_r \tag{6}$$

where  $P_b \langle E/r \rangle$  refers to the conditional error probability and  $\langle P_r \rangle$  refers to the PDF of the SNR.

The BER vs SNR with the consideration of AWGN channel and BER vs the transmitted power with Rayleigh fading model of a two users NOMA network is expressed to understand the concept of NOMA.

Rayleigh fading model can be used when there is no LoS path between the transmitter and the receiver i.e. all multipath components experience small-scale fading effects like reflection, diffraction, and scattering, etc.

AWGN is used to keep things simple, so that the focus will be on the essential parts of NOMA implementation.

## 6. NUMERICAL RESULTS

### 6.1. BER with Transmit Power

The Base Station (BS) carries two separate messages M1 to FU device one (User1) and M2 to NU device two (User2). The power allocation strategy utilized also has a substantial influence on the BER performance. For User1 and User2, the power allocation factors are equal to 1. In NOMA to boost user fairness, extra power is assumed to the FU but a smaller amount of power is given to the NU. Let  $h_1$  and  $h_2$  represent the channels from the BS to the NU and the FU separately.

Table 1. parameters values of BER

Parameters	Value
Noise	AWGN
Bandwidth	1MHz
Chanel type	Rayleigh fading channel
Modulation	ASK
Power allocation	P1=0.78 , p2=0.22

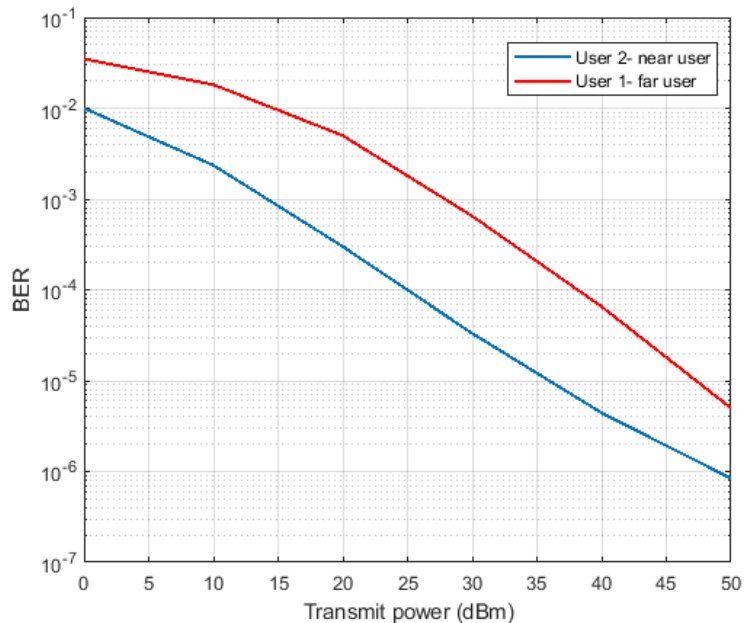


Figure 3. The influence of NOMA technique on BER.

Figure 3 illustrates the analytical and simulated BER performance for the scenario of two users,  $K= 2$  power coefficients and the power allocated for far user and near user is  $\gamma_1 = 0.78$  and  $\gamma_2 = 0.22$  respectively, with 1MHz bandwidth by using ASK modulation. From the above Figure, the FU has a higher BER than the NU because he suffers interference from the NU unlike user two that he is free from interference and has the lowermost BER. This proves that NOMA works as predictable.

### 6.2. BER with SNR

Simple downlink transmission from BS to two users NOMA system is simulated in this section by using MATLAB, The BER performance in presence of AWGN is shown, when the ASK modulation is used to generate modulated data stream for user information at the transmitter, assuming that both users are located at equal distances from the BS to see that NOMA works even under this assumption. It is clear from Figure 4 shown below, the User2 has a slightly higher BER than User1 especially when the SNR is low, which is due to the fact that User2 must perform the SIC. User 2 should first estimate User1's data from the Received (R) signal before the excusion of the decoding process . If this estimation is inexact, it will show up in the decoding of its special data because the inexact data will be subtracted from R. Another expression, User2 needs to decode both User1's data as well as its own data correctly. Any error in decoding User1's data or its own data will affect BER. That is why User2 faces a larger BER than User1.

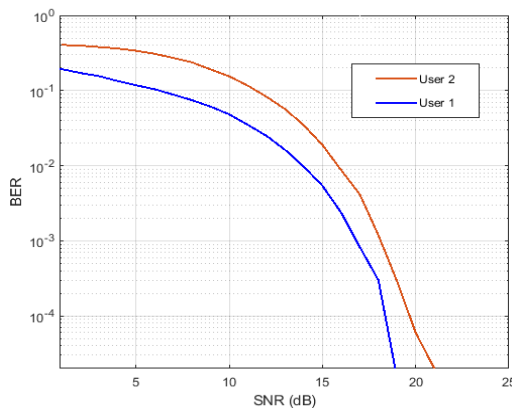


Figure 4. BER vs SNR for NOMA in AWGN channel.

## 7. CONCLUSION

The BER of a digital signal is a critical metric for determining the integrity of the information transmitted across the downlink NOMA system. In this paper, the BER performance of downlink NOMA with BASK transmission scheme has been evaluated. The BER vs SNR with AWGN channel and BER vs transmitted power with Rayleigh channel have been evaluated using Matlab. The simulation was carried out for two different scenarios, one with equal distances and the other with different distances to see the effect of the power allocation strategy on NOMA users. The results showed that NOMA provides acceptable fairness for users while keeping the interference low with agreeable BER.

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