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BER-performance evaluation for 5G-PD-NOMA system in multipath communication channels

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ABSTRACT

In this paper, a bit error rate (BER) performance is evaluated for power domain non-orthogonal multiple access (PD-NOMA) system. The performance test is examined considering; additive white gaussian noise (AWGN), flat and long-term evolution (LTE)-multipath selective channels such as; pedestrian channel model (EPA), vehicular channel model (EVA), and typical urban model (ETU). The proposed system considering two user equipment's (UE1 and UE2) with a single base station (BS) for downlink channel. Two different powers were allocated to each user according to their positions from the BS. The superposition coding process is performed with successive-interference-cancelation (SIC) at both transmitter/receiver sides respectively to distinguish the desired received signal. The performance evaluations proves that the degree of power allocated to each user plays a significant rule in frequency selection environments. UE1 has a better BER performance than UE 2 by about 9 dB in EPA, 6 dB in EVA, and 7 dB in ETU environments respectively at a BER of 10^{-3}. However, in flat fading environment, the distance for each user represents a significant factor affecting the BER performance, where, UE 2 has a better BER performance than UE 1 by about 10 dB at a BER of 10^{-3}.

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1. INTRODUCTION

In recent mobile communication generations, orthogonal multiple access (OMA) schemes fails to provide high quality-of-service (QoS) to all users connected to the network due to multi-channel conditions, were a rich channel condition having the higher priority on the other one [1]–[5]. In 5th generation networks, this problem has been solved when non-orthogonal multiple access (NOMA) scheme was introduced to meet the high radio access demand. In NOMA communication system, high computation power is needed in order to implement power allocation and successive-interference-cancelation (SIC) at both transmitter/receiver sides respectively [6]–[14]. There are many benefits were introduced as a result of implementing NOMA technology in 5G networks such as; minimum latency communication with throughput improvement, good reliability with extremely massive connectivity [15]–[18]. NOMA technology was introduced with to approaches; power domain (PD) and coding domain (CD) [19]. In power domain NOMA system, multi-user communication is achieved using multiplexing in power domain unlike the second approach where multi-user communication is handled by implementing multiplexing in code domain such as in code division multiple access (CDMA) systems [20]–[23]. By using these two approaches, NOMA can serve multiple users sharing the same spectrum resources and avoiding user interference [24]–[26]. The power domain downlink NOMA system exploits channel gain differences between multiple users to provide them with the required service at the same time by using superposition coding and SIC at both transmitter and receiver sides [27]–[31].

Kucur *et al.* [6] introduced a simple tutorial of NOMA technology in 5G networks. They introduce a unified formal description for uplink and downlink NOMA along with cooperative communication scenario-based multiple-inpute/multiple output (MIMO) concepts. Their work was formalized to compare OMA system performance versus NOMA system performance in a simple comparison study.

The implementation of time diversity based NOMA (TD-NOMA) system using 5G technique based applications was discussed in [7] in order to improve system's bit error rate (BER) performance. This suggestion was implemented based binary phase shift keying (BPSK), and quadrature phase shift keying (QPSK) modulation schemes. The test results of the proposed technology shows that its BER performance outperforms the tests of traditional methods by reducing the fading channel effects on the transmitted data.

Mahmood *et al.* [15], Hassan *et al.* [23], and Kumar *et al.* [25] a power domain NOMA system is tested. The BER performance is evaluated on Stanford University Interim (SUI) fading channel models considering a various number of users per-cluster in suburban environments. Test results shows that as the number of users per-cluster increased, the BER performance will be degraded.

Many researchers discussed the applicant of channel coding receiver's design techniques for NOMA systems [19]-[23]. The tests are examined and evaluated as a BER performances in fading channels in addition to additive white gaussian noise (AWGN) channel. The tests shows that the system gained a good BER performance as compared to the performance tests without channel coding.

For the purpose of evaluation of downlink NOMA system performance in fading channels, a BER performance in Nakagami-m fading channel was presented in [32] considering QPSK modulation technique. Performance tests shows that the simulation results are matched the theoretical one with an optimum power allocation. A different communication channels with different modulation schemes are considered in [33] order to evaluate the BER performance of downlink NOMA system with a different number of user's at the receiver side. The tests consider AWGN, Rayleigh fading, and Rician fading channel effects, which produces insightful results for the QoS for individual users. Another test considering both Rayleigh and Rician with Nakagami-m fading channel effects was proposed in [34] for downlink NOMA system of 2-users. The test simulates the variations of system's BER based BPSK modulation scheme.

A two-way relay channel is considered in [35] for cooperative relaying nonorthogonal multiple access (CR-NOMA) system where power-splitting relaying (PSR) and time-switching relaying (TSR) protocols are employeed between users. The author first derives system outage probability and throughput with many other performance metrics in order to evaluate behaviour in different measurmants conditions. Other tests considering the evaluation of the impact of transmit antenna selection on NOMA system ergodig capacity where proposed in [36]. The test also concidering both channel state information (CSI) and SIC problems. Over the test simulations, it confirmed the performance superiority of the proposed schemes. In addition, imperfect CSI and SIC are extremely degraded the system performance, which is useful for engineering practice.

This paper is prepared and organized to describe the traced methodology and define system model considered in simulations in section 2. Section 3 defines the important system parameters and channels considered in simulations. Finally, a conclusion remarks are evaluated in section 4.

2. METHOD AND SYSTEM MODEL

In downlink PD-NOMA system with single base (BS) and multiple user's equipment's (UE) of Figure 1, the BS superposes multiple signals using the same spectrum resource to be received by all end users with the interference caused by other signals of other users. At each UE end, the final desired signal can be extracted using SIC at receiver to decode and subtract the highest interfered signal from the previously superposes one. The allocation of different power levels for the superposed signals is very important to distinguish each signal and to perform a correct SIC at each UE end since all UEs receives the interfered and the desired signals together.

The system is modeled with two antenna BS and two users with different allocated powers α_i from the total transmission power α. The user with the highest allocated power α_1 is the strong one, while the other one is the weak one with power α_2. Each user is distant from the BS by d_i, where, user1 is modeled as the farthest one at distance d_1 and user 2 is the nearest one at distance d_2. In the proposed system of Figure 2, the transmitted signals from user 1 and/ or user 2 is first modulated using BPSK modulation technique to produce x_1 and x_1 respectively.

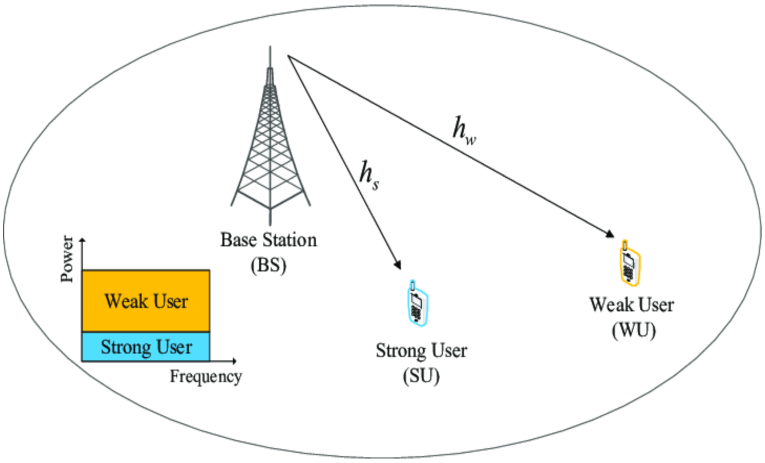


Figure 1. Downlink NOMA system

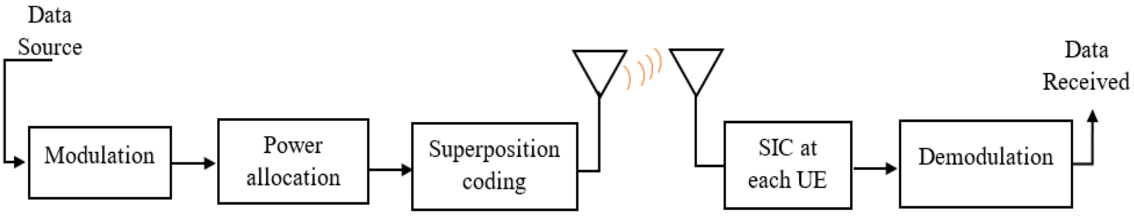


Figure 2. Proposed system model

For each user, the modulated signal is gained with the allocated power coefficient in order to differentiate it from the other transmitted signals, and hence T_1 and T_2 are generated respectively by:

$$T_1 = \sqrt{\alpha_1}\, x_1 \tag{1}$$

$$T_2 = \sqrt{\alpha_2}\, x_2 \tag{2}$$

According to the principle of signal transmission-based PD-NOMA system, the transmitted signals must be superimposed first to generate the final signal to be transmitted by:

$$T = T_1 + T_2 \tag{3}$$

In the proposed simulations, the transmission links from each BS antenna to each UE end is treated considering single-input/single-output (SISO) system and exhibits the same channel conditions H which is differentiated by a strong path h_s and weak path h_w due to its effect on the previously gained signals. At the downlink system, the received signals at UE1 and UE2 are given by:

$$y_1 = TH + n_1 \tag{4}$$

$$y_2 = TH + n_2 \tag{5}$$

Where, n represents the Gaussian noise coefficient.

Since multi-user signal transmission is performed simultaneously on the same carrier frequency using NOMA system, it is important to implement an inter-user interference cancelation algorithm at each user end so as to extract the desired signal. Hence, for UE1's desired signal x_1, it is directly decoded (BPSK demodulation) since user 1 allocated higher power coefficient than user 2. For UE2, the received signal y_2 is directly demodulated first to obtain x_1 from y_2. Remodulate the demodulated signal x_1 to produce x_1' using:

$$x_1' = 2x_1 - 1 \tag{6}$$

The estimated signal x_1' is multiplied by the power coefficient allocated to UE1 to produce S:

$$S = \sqrt{\alpha_1} x_1' \tag{7}$$

Finally, the result is subtracted from the received signal y_2 to estimate $\hat{x}_2$:

$$\hat{x}_2 = y2 - S \tag{8}$$

Do BPSK demodulation to the reminder of the subtraction process in order to retrieve the desired signal x_2.

3. SIMULATION TESTS AND RESULTS

Different wireless channel environments are considered in the proposed simulations; additive noise (AWGN) with flat and frequency selective fading channels. In AWGN channel, a white gaussian noise which has a constant power spectral density (PSD) along the channel bandwidth is added to the transmitted signal, where they are independent of each other as shown in (9).

$$y_i = T + n_i \tag{9}$$

Data transmission in the presence of flat fading effects is affected by channel attenuation due to two independent gaussian random variables $h_{1,i}$ and $h_{2,i}$ and their phase θ_i. It occurs when the fading channel coherence's bandwidth is large compared to the bandwidth of the transmitted signal [37]. The propagated signal is treated and multiplied by a single path of a complex value a_i as (10) and (11).

$$a_i = \sqrt{{d_i}^{p_i}} \times (h_{1,i} + h_{2,i}) \tag{10}$$

$$a_i = |a_i|.e^{j\theta_i} \tag{11}$$

Where; $|a_i|$ is the magnitude of the complex valued samples of $h_{1,i}$ and $h_{2,i}$ multiplied by the distance with the effective path loss p_i.

$$\theta_i = \tan^{-1}\frac{h_{2,i}}{h_{1,i}} \tag{12}$$

Figure 3 represents the implementation procedure of the proposed system. It begins with parameters intializations to determine the number of users contacted in the communication process with the required power allocation for each user, the modulation scheme used in simulations, the supper postions coding operation and the wireless channel gain and delay parameters.

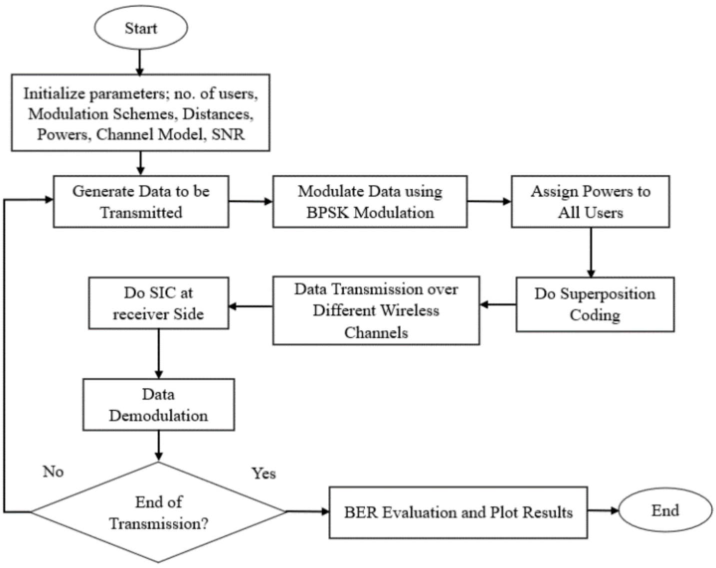


Figure 3. Proposed system flowchart

In the proposed simulations, both the magnitude and phase are supposed to be acknowledged at the destenation. Alternatively, when the transmitted signal bandwidth is large as compared to the channel's coherence bandwidth, the transmitted signal will examine the frequency selectivity effects. Hence, different magnitude and phase shifts will affect different frequency components of the transmitted signal. Unlike flat fading, the received signal in multipath fading channel consists of receiving signal via multiple paths having different delays and attenuations. Tables 1 to 3 show different channel delay and gain parameters are considered in simulations to represents different channel delay spread effects, which are; extended pedestrian (EPA), vehicular (EVA), and typical urban (ETU) models respectively.

Table 1. EPA delay profile

Path delay (ns)	Path gain (dB)
0	0.0
30	-1.0
70	-2.0
90	-3.0
110	-8.0
190	-17.2
410	-20.8

Table 2. EVA delay profile

Path delay (ns)	Path gain (dB)
0	0.0
30	-1.5
150	-1.4
310	-3.6
370	-0.6
710	-9.1
1090	-7.0
1730	-12.0
2510	-16.9

Table 3. ETU delay profile

Path delay (ns)	Path gain (dB)
0	-1.0
50	-1.0
120	-1.0
200	0.0
230	0.0
500	0.0
1600	-3.0
2300	-5.0
5000	-7.0

Following the structured flowchart of Figure 3, the simulation tests of the suggested 2 UE-NOMA-system is listed and discussed in the following figures. The test results of Figure 4 of the proposed simulations over AWGN channel shows that there is a slightly difference between the BER performance of UE 1 and UE 2 at low signal-to-noise ratio (SNR) values. However, in Figure 5, same system parameters are tested over a flat fading channel were user 2 has a better performance as compared to user 1 since user 2 is nearest than user 1 to the BS examining the same channel effects. The test shows that the error rate performance of user 2 outperform error rate tests of user 1 by about 10 dB for a BER of 10^{-3}. The simulation test of Figures 6(a) to (c) evaluates the error performance of the proposed system over different selective fading channel environments. By considering the EPA channel model of Table 1, the tests of Figure 6(a) shows that, the BER performance of user 1 is better as compared to that of user 2 by about 9 dB at a BER of 10^{-3}. In Figure 6(b), by considering EVA channel environment, the performance gain of user 1 is by about 5.5 dB as compared to user 2. However, the tests of Figure 6(c) of the proposed simulations over ETU channel environments shows that user's 1 performances outperform user's 2 performance by about 7.6 dB at 10^{-3} BER.

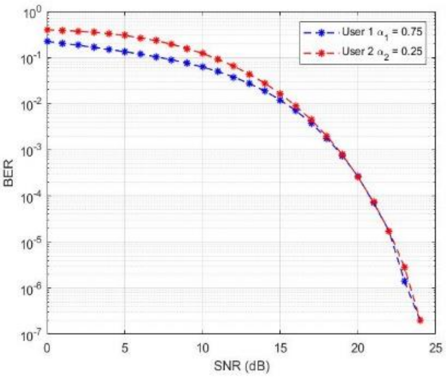


Figure 4. NOMA-BER system behavior in AWGN channel

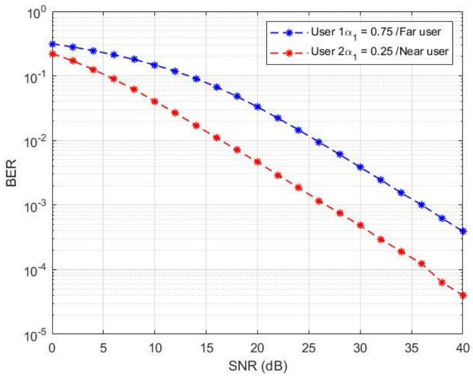
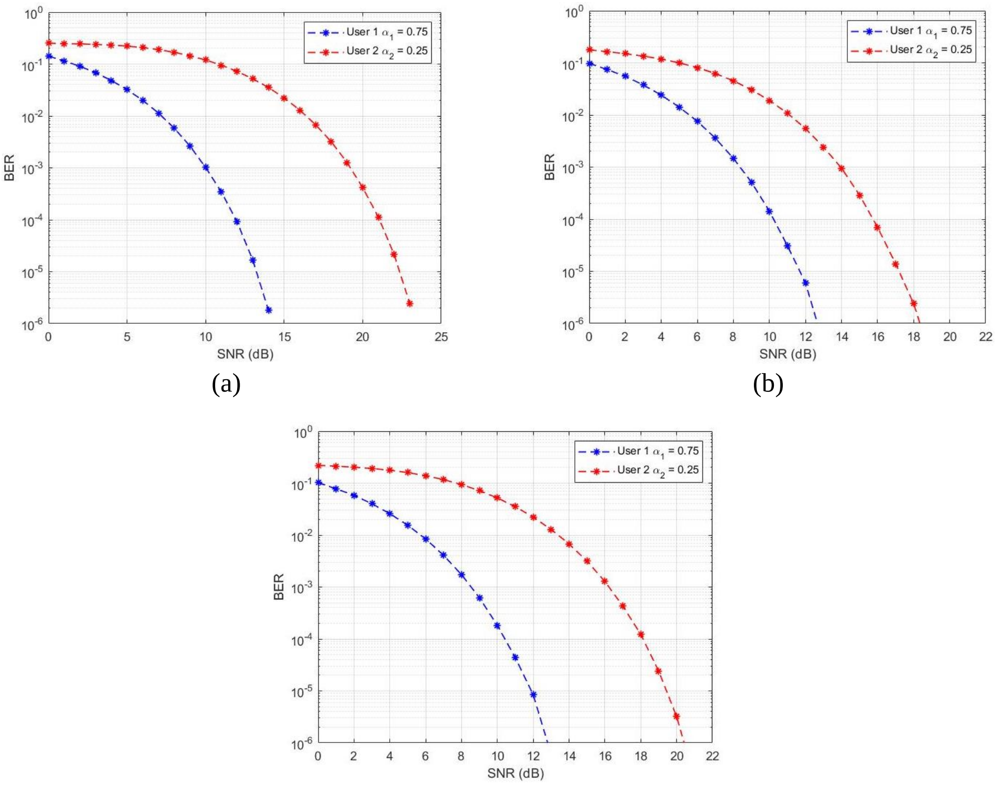


Figure 5. NOMA-BER system behavior in flat fading channel

As a final assessment of result, in AWGN channel, both of user 1 and user 2 has a good BER performance. Unlike fading channel testes, it is shown that there are some tests differences for each user's performance. In a flat fading environment, in spite of user 1 having a higher power allocation than user 2, user's 2 performance outperform of user 1 since it is the nearest one to the base station. In frequency selective fading channels, the performance test of user 1 outperforms BER performance of user 2 in different gain values. These differences are due to how much this channel affect the transmitted signal. As clearly shown in the above tests, as the channel become deep faded environment, the BER performance of both users degraded but it is still in an acceptable range.



(a) (b)

(c)

Figure 6. NOMA-BER system performance: (a) EPA fading channel, (b) EVA fading channel, and (c) ETU fading channel

4. CONCLUSION

In this paper, a PD-NOMA system is designed with 2 usrers having different power allocation on different distances. The BER performance for the proposed system is evaluated according to the presence of fading effects. The test results shows that the transmitted signals for each user is highly affected by channel enviroments. It is clearly that the user with higher peower allocation has a better performance than the other one in selective fading channels. As compared to flat fading channels, the nearest user to the BS gains a better performance than the farest one in spite of user 1 located higher power. As a future work, the proposed system can be simulated to evaluate BER performance in the presence of Doppler shifts.

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