Using NOMA Scheme for the Management of Interference and the Improvement of Performance in 5G Networks

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***Abstract*—The new generation of 5G networks, compared to 4G networks, is a very important example of change in achieving very high frequencies in the carrier with huge bandwidth, high densities with a huge number of antennas and improved quality of services, making effective interference management necessary. In this paper, we present the contribution of the Non-Orthogonal Multiple Access (NOMA) scheme to improving the performance of 5G networks. We refer to the technique of sequential interference cancellation applied to some NOMA formats, compare NOMA and Orthogonal Multiple Access (OMA) formats in terms of the capabilities they offer users and NOMA's significant contribution to Multiple-Input Multiple-Output (MIMO) technology and compare three basic NOMA formats in three different resource and user reporting scenarios. Finally, we present the results of the simulations of the above comparisons and analyze the contribution of each scheme to the improvement of the system performance.**

Keywords—*5G, MIMO, NOMA, OMA, SIC, interference*

I. Introduction

With the development of technology in the field of telecommunications and the introduction of innovative ideas aimed at increasing the speed of information transmission, the simultaneous service of a large number of users, reliability and scalability, we observe a number of factors that influence the achievement of these goals. Interference in the telecommunications sector is one of these factors as it causes serious damage to the availability and reliability of a system and in the case of multiple network levels we can divide them into two categories. The first category includes the interferences observed between the various elements of a network belonging to the same layer and the second category includes the interferences that occur between the different layer layers of the network [1]. The most basic types of interference are co-channel interference (CCI), adjacent channel interference (ACI), self-interference (Self-Interference or SI), multi-access interference, inter-symbol interference (ISI), electromagnetic interference (EMI), inter-carrier interference (ICI) and common-mode interference (CMI) [2]-[5].

Non-Orthogonal Multiple Access (NOMA) is one of the most basic elements for fifth generation cellular networks. Using this method and all the schemes it includes, improves the spectral performance and the mass connectivity of the various users in the system is provided through the non-orthogonal distribution of resources in the system [6]. The application of NOMA in cellular networks requires high computing power for the implementation of real-time power distribution but also for the support of successive interference cancellation algorithms. Within NOMA, the supercharger encoding is applied to the transmitter in order to separate the network users, both on the downlink channels and the corresponding uplink channels, by Successive Interference Cancellation (SIC) on the receiver. With the continuous development of 5G networks and the services they offer, the computing power of both the various access points and the mobile devices connected to these networks is expected to increase sufficiently for the best possible execution of the various algorithms used in NOMA [7].

The authors [8] refer to a unified NOMA model for both downlink and uplink transmission, as well as Multiple Input Multiple Output (MIMO) collaborative communication scenarios. They also compare the performance of Orthogonal Multiple Access (OMA) and NOMA networks. The authors [9] examine the application of different MIMO methods to NOMA systems, simultaneously propose a new design of pre-coding and detection registers for MIMO - NOMA, and analyze its performance in a fixed set of power distribution scripts compare three prominent NOMA schemes, the Pattern-Division Multiple Access (PDMA), the Sparse Code Multiple Access (SCMA) and the Multi-User Shared Access (MUSA) scheme in cases of two different receiver types, with multi-user Ordered Successive Interference Cancellation (OSIC) detection and multi-user Message Passing Algorithm (MPA) detection. The authors of [10] also discuss the comparison of the three before mentioned NOMA designs in standard Rayleigh fading channels.

In this paper, we first look at the NOMA scheme and compare it to the OMA scheme in terms of their performance and the capability they offer across the network, we will further analyze the technique of SIC by the receiver, we will refer to the contribution of the NOMA scheme to MIMO downlink (DL) technology and finally we will compare basic NOMA schemes in a downlink system, one cell, which includes a base station, and all independent users have a transmission antenna. The schemes we will compare are SCMA, PDMA and MUSA. The PDMA and MUSA schemes use the well-known SIC technique, the MUSA and PDMA schemes contain the Quadrature Phase Shift Keying (QPSK) format and the SCMA and PDMA schemes contain the MPA algorithm. The comparisons of the three NOMA programs were performed in three different scenarios, underload, full load and overload.

The rest of this work is organized as follows. In section II we refer to the system model we used to compare OMA and NOMA schemes, then we list the system model we used to compare OMA and NOMA for their contribution to MIMO

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technology and then we present the basic features of PDMA schemes , SCMA and MUSA respectively. In section III we analyze the results of the simulations we performed from the application of system models with the appropriate parameters. Finally, in section IV we summarize our conclusions for this work and provide some information for future work.

II. System Model

A. System model for OMA and NOMA

We refer to a downlink communication with a base station and various users, number N. Suppose that c_i refers to the base station channel for the i^{th} user and $c_1, c_2, c_3, \dots, c_N$ in total the N user channels . Suppose user 1 with c1 is the most powerless user because he is the farthest from the base station, user 2 is relatively close to user 1 approaching the base station and therefore user N is closest to the base station. and at the same time the most powerful user. Therefore, the conditions of the users' communication channels are reported as follows: $|c_1|^2 < |c_2|^2 < \dots < |c_N|^2$.

1) NOMA model: Suppose that $m_1, m_2, \dots, m_N$ are the messages that will be transmitted to the various users. The base station will apply overlay encoding to the specific messages and transmit the following NOMA signal to the communication channel:

$$m_{NOMA} = \sqrt{P}(\sqrt{a_1}m_1 + \sqrt{a_2}m_2 + \dots + \sqrt{a_N}m_N) \quad (1)$$

where P refers to the total transmission power and $\alpha_1, \alpha_2, \dots, \alpha_N$ refer to the power distribution coefficients. Once the channels are classified as $|c_1|^2 < |c_2|^2 < \dots < |c_N|^2$, the power distribution coefficients should be classified as follows $\alpha_1 > \alpha_2 > \dots > \alpha_N$. Equation (1) can also be formulated as follows $m_{NOMA} = \sqrt{P}\sum_{i=1}^{N}\sqrt{a_1}m_i$ while the signal received by the i[th] user is $s_{i,NOMA} = m_{NOMA}c_i + w_i$, where w_i is the additional white noise Gauss (AWGN) with zero mean and variance equal to σ^2. By replacing it with (1), we have:

$$s_{i,NOMA} = \sqrt{P}(\sqrt{a_1}m_1 + \sqrt{a_2}m_2 + \dots + \sqrt{a_N}m_N)c_i + w_i \quad (2)$$

According to (2) we can mention that for user 1 who is also the farthest from the base station that from $s_{1,NOMA}$ the term $\sqrt{\alpha_2}m_2 + \dots + \sqrt{\alpha_N}m_N$ is the interpolation while the initial term, in parentheses, is desirable and dominant in the signal. Next, we need to mention the general decoding rule for user 1, who has been assigned the highest amount of power and this results in the dominance of the message, intended for him, over the total signal received. So, because of this, it simply applies decoding and treats the messages of other users as interference. Therefore, the SINR for decoding user signal 1 is expressed as $SINR_{1,NOMA} = \frac{a_1P|c_1|^2}{a_2P|c_2|^2 + a_3P|c_3|^2 + \dots + a_NP|c_N|^2 + \sigma^2}$. According to the signal received by user 2, the first term $\sqrt{\alpha_1}m_1$ is the dominant but undesirable part of the received signal, the second term in parentheses $\sqrt{\alpha_2}m_2$ is the desired part of the signal, and the rest of the parentheses is the interpolation. Once user 1 has the highest power, his message will dominate the signal received by all other users. So first user 2 has to immediately decode the message from user 1 and then execute the SIC to separate it from $s_{2,NOMA}$ and if the SIC application is perfect, the resulting signal will be $s'_{2,NOMA} = \sqrt{P}(\sqrt{\alpha_2}m_2 + \dots \sqrt{\alpha_N}m_N)c_2 + w_2$ after the implementation of SIC the message $\sqrt{\alpha_2}m_2$ of user 2 is the dominant term and now has the ability to directly decode his message from $s'_{2,NOMA}$ while the rest of the messages of the various users are treated as interference. Therefore, the SINR for encoding user signal 2 is expressed by the following formula $SINR_{2,NOMA} = \frac{a_2P|c_2|^2}{a_3P|c_3|^2 + \dots + a_NP|c_N|^2 + \sigma^2}$. A similar procedure can be applied to other users. For example, for user 3, it will first decode user's message 1, then apply SIC to neutralize it, then decode user 2's signal and re-apply SIC to neutralize it, and finally decode its own beneficial and dominant brand. Therefore, the most common type of SINR for decoding each user's signal is $SINR_{i,NOMA} = \frac{a_iP|c_i|^2}{a_{i+1}P|c_{i+1}|^2 + \dots + a_NP|c_N|^2 + \sigma^2}$ while the achievable percentage for each different user can be expressed as $R_{i,NOMA} = \log(1 + SINR_{i,NOMA})$ and the sum of all NOMA users is expressed as $R_{NOMA} = \sum_{i=1}^{N} R_{i,NOMA}$.

2) OMA model: Regarding normal transmission within OMA, we refer to the Time Division Multiple Access (TDMA) scheme. According to the specific scheme, N slots are required to serve N users. During the first slot the signal of user 1 is transmitted, during the second slot the signal of user 2 is transmitted and accordingly the specific process continues up to user N. By providing the same duration of all slots, during the i[th] slot the i[th] signal is transmitted to the i-th user. Then, the transmission signal is expressed by the following formula: $m_{i,OMA} = \sqrt{P}m_i$. Comparing equations (1) and (6), we notice that NOMA has a significant advantage over OMA and this concerns the possibility of simultaneous transmission with controlled interference. In contrast, with OMA, users receive the signal without interference. The received signal in the i[th] user is expressed as follows: $s_{i,OMA} = \sqrt{P}m_ic_i + w_i$ while the SNR of the i[th] OMA user is expressed as follows: $SNR_{i,NOMA} = \frac{P|c_i|^2}{\sigma^2}$, also the possible percentage of the i[th] user OMA is given by the formula $R_{i,OMA} = \frac{1}{N}log(1 + SNR_{i,OMA})$ and finally the sum of the OMA is expressed as $R_{OMA} = \sum_{i=1}^{N} R_{i,OMA}$.

B. System Model for MIMO-OMA and MIMO-NOMA

First, we refer to a MIMO 2x1 downlink system. Suppose d1 and d2 refer to the distance of user 1 (UE1) and user 2 (UE2) respectively from the transmitter MIMO base station. Assume that UE1 is the weak user and UE2 is the strong one, so it will hold that distance d1 will be greater than distance d2. The MIMO scheme provides the possibility of increasing the achievable transmission rate through spatial multiplexing but also reducing the digital error ratio (BER) through the gain of differentiation. In this scenario we will use MIMO to achieve the gain of differentiation, therefore we will assume that antennas 1 and 2 transmit the same information. Suppose that m_1 and m_2 refer to the messages/information intended for UE1 and UE2 users respectively and $c_{r,t}$ the Rayleigh interrupt channel between the t^{th} antenna and the r^{th} receiver.

1) Transmission Signal: The signal transmitted by both transmitting antennas of the base station is expressed as $m = \sqrt{P}(\sqrt{a_1}m_1 + \sqrt{a_2}m_2)$ where α_1 and α_2 are the power distribution coefficients from the NOMA scheme and if it has been reported that user UE1 is the powerless user, then $\alpha_1 > \alpha_2$.

2) Signal Received: The signal m is transmitted in parallel by both transmission antennas, so the received signal to the user UE1 is expressed as:

$$s_1 = mc_{11} + mc_{12} + n_1 = m(c_{11} + c_{12}) + n_1 \quad (3)$$

and the corresponding received signal to the user UE2 is expressed as:

$$s_2 = mc_{21} + mc_{22} + n_2 = m(c_{21} + c_{22}) + n_2 \quad (4)$$

where n_1 and n_2 are samples of additional white Gaussian noise (AWGN) with zero mean and variance equal to σ^2.

3) Decoding in UE1: The UE1 user must decode m_1 from s_1. Since UE1 is the powerless user the signal of m_1 shows higher power and it holds that α_1 is greater than α_2. So the term m_2 can be treated as an interference and the user UE1 has the ability to directly decode m_1 from s_1. Substituting m in (3), we will have the following $s_1 = \sqrt{P}(\sqrt{a_1}m_1 + \sqrt{a_2}m_2)(c_{11} + c_{12}) + n_1$and extending the specific relation the factor $\sqrt{P}\sqrt{a_1}m_1(c_{11} + c_{12})$ is the desired part of the signal. The SINR for decoding m_1 by UE1 is expressed as $SINR_1 = \frac{Pa_1|c_{11}+c_{12}|^2}{Pa_2|c_{11}+c_{12}|^2+\sigma^2}$ and the achievable transmission rate will be as $R_1 = log(1 + SINR_1)$.

4) Decoding in UE2: The UE2 user must decode m_2 from s_2. Since UE2 is the strong user the signal of m_2 has less power and s_2 will be dominated by the power of the term m_1. So, first the UE2 user will apply direct decoding to s_2 to bind m_1, then SIC will be applied to remove m_1 and finally m_2 will be decoded. By substituting m in (4), we will have $s_2 = \sqrt{P}\sqrt{a_1}m_1(c_{21} + c_{22}) + \sqrt{P}\sqrt{a_2}m_2(c_{21} + c_{22}) + n_2$ in which the first factor is the dominant but unwanted part of the signal, which will then be removed by applying SIC while the second term is the desired part of the total signal. The SINR to user UE1 for direct decoding of m_1 is expressed as $SINR_{12} = \frac{Pa_1|c_{21}+c_{22}|^2}{Pa_2|c_{21}+c_{22}|^2+\sigma^2}$, after the application of SIC the first term will be removed and the signal that will remain will be $s'_2 = \sqrt{P}\sqrt{a_2}m_2(c_{21} + c_{22}) + n_2$, from which the first term is the desired one and now the SNR of UE2 with the decoding of its signal is expressed as $SNR_2 = \frac{Pa_2|c_{21}+c_{22}|^2}{\sigma^2}$ and finally the feasible rates in the UE2 user regarding the decoding of m_1 and m_2 are expressed as $R_{12} = log(1 + SINR_{12})$and $R_2 = log(1 + SNR_2)$.

5) Model of MIMO-OMA: In order to present the effectiveness of the MIMO-NOMA network, we will use the MIMO-OMA network as a reference point. Suppose that the process of transmitting messages takes place in two equal time slots, in the first time slot the two antennas transmit to UE1 while in the second time slot the two antennas transmit to UE2. In the first slot the signal transmitted to UE1 is referred to as Px_1 and the signal received by UE1 is expressed as$s_{1,OMA} = \sqrt{P}m_1(c_{11} + c_{12}) + n_1$ and in the second slot the signal transmitted to UE2 is referred to as Px_2 and the signal received by UE2 is expressed as $s_{2,OMA} = \sqrt{P}m_2(c_{21} + c_{22}) + n_1$, the SNR in UE1 and UE2 are expressed as $SNR_{1,OMA} = \frac{P|c_{11}+c_{12}|^2}{\sigma^2}$ and $SNR_{2,OMA} = \frac{P|c_{21}+c_{22}|^2}{\sigma^2}$ respectively. Thus, the possible transmission rates of the MIMO-OMA network for UE1 and UE2 users are expressed as $R_{1,OMA} = \frac{1}{2}log(1 + SNR_{1,OMA})$ and $R_{2,OMA} = \frac{1}{2}log(1 + SNR_{2,OMA})$respectively. We use the term 1/2 because for the communication of each user only half of the slot was used, compared to the MIMO-NOMA network, in which the whole slot is used for the parallel transmission to both users.

C. System model for MUSA, SCMA and PDMA

1) MUSA(Multi-User Shared Access) Model: Suppose that one user, out of all U_M users, transmits one symbol at a time and there are N_M sub-carriers, then there will be an overload case where N_M is greater than U_M and an overload case when N_M is less than U_M. Therefore, the signal received in the n subcarrier will be expressed as $y_n = \sum_u^{U_M} g_{n,u}a_{n,u}x_u + w_n$, where $g_{n,u}$ is the gain of the user attenuation channel u in the n subcarrier, $\alpha_{n,u}$ is the n element of its propagation sequence a_u of user u and w_n is the complex Gaussian noise distribution, with zero mean and variance equal to σ^2, in the subcarrier n. The signal received from all the carriers can be combined as$y = [y_1, y_2, \ldots, y_{N_M}]^T$, the transmitted signals and the noise elements can be combined as $x = [x_1, x_2, \ldots, x_{U_M}]^T$ and $w = [w_1, w_2, \ldots, w_{N_M}]^T$, respectively. Thus the received signal y can be expressed as $y = Hx + w$, where H is the register of a channel of size N_M x U_M with the elements of $h_{n,u}$ in the row n and in the column u given as$h_{n,u} = g_{n,u}a_{n,u}$.

2) SCMA(Sparse Code Multiple Access) Model: In the SCMA scheme, each password-words of each individual user come from different password-books. In an uplink SCMA (UL) network with a number of US code-books equal to the number of users, each code-book contains a total of J sparse NS code-words. The phenomenon of code word rarity is the consequence of the existence of L of a plurality of non-zero elements relating to each code word of length N so that it holds that L << NS. Similar to the MUSA scheme, congestion occurs when NS is less than US while congestion in SCMA occurs when NS is greater than US. In the case where the signal will be transmitted by the user u using resources or subcarriers of size NS will be expressed as $x_u = [x_{1,u}, x_{2,u}, \ldots, x_{N_S,u}]^T$and the received signal in the subcarrier n can be expressed as $y_n = \sum_u^{U_S} h_{n,u}x_{n,u} + \eta_n$, where hn, u refers to the user channel gain u on subunit n and hn refers to a sample of a complex Gaussian distribution noise, with zero mean and variance equal to σ2, on subcarrier n. By combining the signal received from the set of carriers at the base station in vector format such as $y = [y_1, y_2, \ldots, y_{N_S}]^T$, received signal in the subcarrier can be formulated as $y = \sum_u^{U_S} H_u x_u + \eta$, where H_u=diag(h_u) and $h_u = [h_{1,u}, h_{2,u}, \ldots, h_{N_S,u}]^T$is the channel vector in terms of user u and the η is the complex Gaussian noise distribution, with zero mean and variance equal to $\sigma^2 I_{N_S}$ and the I_{N_S} is the identity matrix, size N_S x N_S. In the event that there are sparse passwords, with the use of which each individual user has to transmit his information to a small number of sub-carriers, the total number of active users will be higher than the total of the superimposed signals for each carrier. Therefore, the interference that develops between the large number of users will be significantly reduced and in this case equation (3) will be formulated as $y_n = \sum_{u\in\xi^{[n]}} h_{n,u}x_{n,u} + \eta_n$, where the $\xi^{[n]}$ is the set of users who have non-zero elements in the subcarrier n of their sparse passwords, which can be formulated as $\xi^{[n]} = [u: x_{n,u} \neq 0, u \in (1,2,\dots,U_S)]$.

3) PDMA(Pattern Division Multiple Access) Model: The multiplexing that takes place within the specific scheme can be applied in the field of code, in the spatial sector, in the power sector but also in any combination of these three sectors. In case the multiplexing is applied in the code field it is similar to the corresponding one in SCMA, in the case of the spatial configuration the PDMA configuration can be applied effectively in combination with a multi-antenna scheme and the different PDMA patterns are selected for provide different diversity commands in terms of transmission. Finally, in the case of the application of multiplexing in the power sector, there is a need to carefully examine the power distribution under the overall power limitation. With a reference point of an uplink PDMA system with a number of users equal to U_P and a number of subcarriers equal to N_P, overload can occur when the number of U_P users is greater than the number of N_P subcarriers and congestion is achieved when the number of users U_P is smaller than the number of N_P subcarriers. The PDMA model of the code field is almost similar to the MUSA system. The symbols configured in the user u, x_u, are mapped by the code domain PDMA decoder, either to the available resources or to the subcomponents, which in turn generate PDMA x_u configuration vectors. These x_u configuration vectors of user u are bound by the propagation of the configuration symbol of that user, x_u according to the PDMA pattern d_u is expressed as $x_u = d_u x_u$ with $1 \leqslant u \leqslant U_p$, which is a N_Px1 binary vector containing "0" and "1" and this means that when the user data is mapped to the corresponding subcarriers, the non-zero elements of the user u spread sequence are equal to "1". The PDMA pattern of all U_P users corresponding to the results of the total N_P subcarriers in the matrix of the total PDMA pattern is expressed as $D_{N_P,U_P} = [d_1, d_2, \dots, d_{U_P}]$, which is the distribution sequence for PDMA and is similar to the MUSA system and can be expressed as $A_{N_M,U_M} = [\alpha_1, \alpha_2, \dots, \alpha_{U_M}]$ [11]. The total signal received from the set of subcarriers at the base station in vector form $y = [y_1, y_2, \dots, y_{N_P}]^T$ can be expressed as $y = \sum_{u}^{U_P} H_u x_u + \psi$, where ψ refers to noise and interference at the base station, $H_u = diag(h_u)$, $h_u = [h_{1,u}, h_{2,u}, \dots, h_{N_P,u}]^T$ is the vector of the channel for the user u and ψ is the Gaussian noise distribution, with zero mean and variance equal to $\sigma^2 I_{N_P}$ and can also be formulated as $y = H_{PDMA}x + \psi$, where $x = [x_1, x_2, \dots, x_{U_P}]^T$ and H_{PDMA} is the matrix of equivalent PDMA channel and can be expressed as the item-by-item output of both matrixes and the $H = [h_1, h_2, \dots, h_{U_P}]^T$.

D. MPA, SIC and MMSE Techniques

In each of the schemes mentioned above, the need arises for the effective detection of multiple users (MUD) in order to retrieve all the data of these multiple users. Regarding the MUSA scheme, the aforementioned need is met by applying the technique of sequential interference cancellation (SIC). In the case of the SCMA scheme, in which we encounter the sparse structure of the code-words, a message passing algorithm (MPA) is applied which contributes to the effective detection of user data acting as a receiver. While in the case of the PDMA scheme, either the combination of the MMSE filter and the SIC technique or the MPA algorithm have been proposed in order to retrieve the data of the various users. In this work the MPA algorithm is used in the SCMA and PDMA schemes, while in the MUSA scheme we apply the SIC technique in combination with the application of the MMSE filter to retrieve the data of the various network users.

During the detection process via the MMSE filter the rated signal is expressed as $\hat{x} = G_{MMSE}y$, where G_{MMSE} is the weight matrix of MMSE and is expressed as $G_{MMSE} = (\sigma_\eta^2 I + HH^H)^{-1}H^H$, where σ_η^2 is the noise variation and I refers to the identity matrix. Regarding the message passing algorithm (MPA), we mention that it is an iterative decoding algorithm aimed at the factorization of the universal multivariate function in the form of simpler local scope functions, which contain elements that are a subset of the variables. It is a specific factorization process with the required use of the factor graph. Variable nodes (users) consist of code words that are transmitted by U-number of users and the corresponding received signals to the N-number of subcarriers are referred as factor nodes (subcarriers).

III. Simulation Results

A. Simulation Result for OMA and NOMA

About the system model we used, the following figure shows the simulation results of the NOMA and OMA capacity comparison for a number of three users.

In Fig. 1 we observe that at low SNR the OMA scheme shows improved performance compared to the NOMA scheme and this is a consequence of the interference that develops in the context of the simultaneous transmission of signals by users in contrast to the OMA scheme in which users do not are confronted with these interferences. However, at higher SNR we observe that the NOMA scheme is clearly more efficient than the OMA scheme offering high capacity and using minimal resources. In this scenario, OMA's TDMA format needs three slots to complete the transmission of the three users' signals, in contrast to the NOMA format which uses only one slots to complete the total transmission. In this way, a critical reduction of transmission delays is achieved, which is particularly crucial for the next communication technologies.

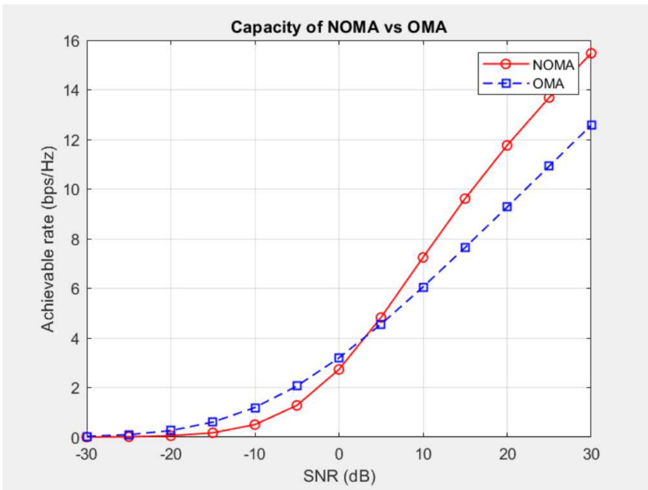

Fig. 1. OMA and NOMA performance comparison for three users.

TABLE I. DEFAULT PARAMETERS

Parameter	Setting
User Distances	d_1=5m, d_2=3m, d_3=2m
Exponential Path Loss	4
Power Distribution Factors	a_1=0.75, a_2= $(1-a_1)*a_1$, a_3= $(1-(a_1+a_2)*a_1)$
Bandwidth	1GHz

B. *Simulation Results for MIMO-OMA and MIMO-NOMA*

About the system model we used and we list the parameter table we used for the simulation of the comparison of the achievable sum rates of MIMO-NOMA and MIMO-OMA and the comparison of users' individual achievable rates.

TABLE II. DEFAULT PARAMETERS

Parameter	Setting
User Distances	d_1=700m, d_2=300m
Exponential Path Loss	4
Power Distribution Factors	a_1=0.8, a_2=0.2
Bandwidth	1MHz

The achievable sum rate of the MIMO-NOMA network is R_1+R_2 and the MIMO-OMA network is $R_{1,OMA}+R_{2,OMA}$.

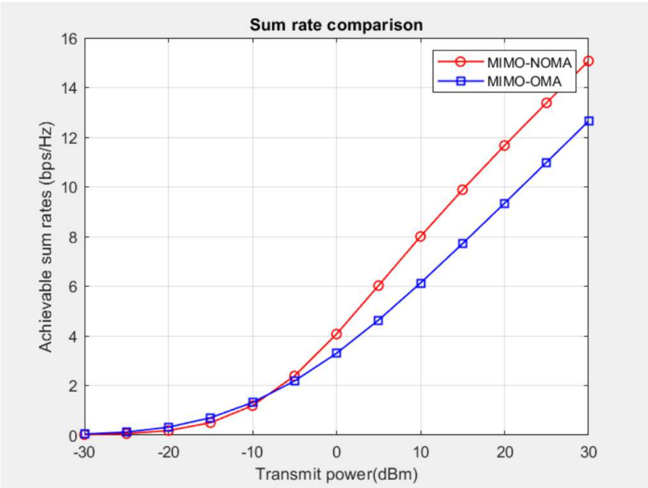

Fig. 2. Comparison of the achievable sum rates of MIMO-NOMA and MIMO-OMA.

In Fig. 2 we observe that MIMO-NOMA offers a higher sum rate than MIMO-OMA and this is due to the parallel service of users with the same frequency resource.

In Fig. 3 we observe that the weak user faces the issue of saturation at the possible rate after the transmission power of 10 dBm. This is due to the interference faced by the weak user and is expressed as saturation in its achievable rhythm. This issue will not be a problem if the required data rate of the weak user is less than the saturation limit. In OMA, on the other hand, this issue does not arise due to the absence of interference to the patient user via parallel transmission.

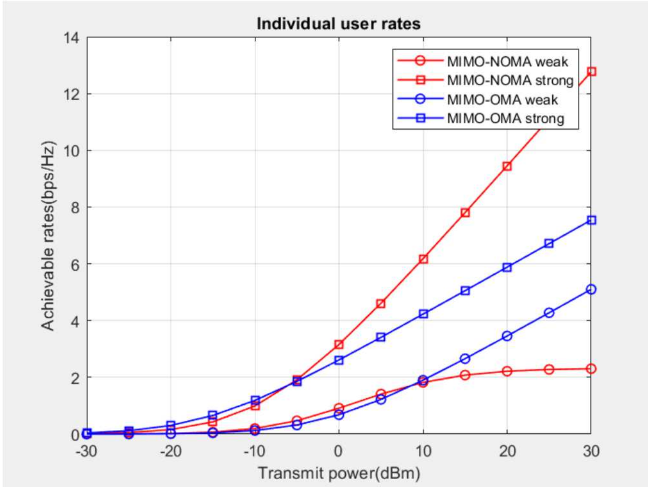

Fig. 3. Comparison of users' individual achievable rates.

C. *Simulation Results for the comparison of the three NOMA schemes, MUSA, SCMA and PDMA.*

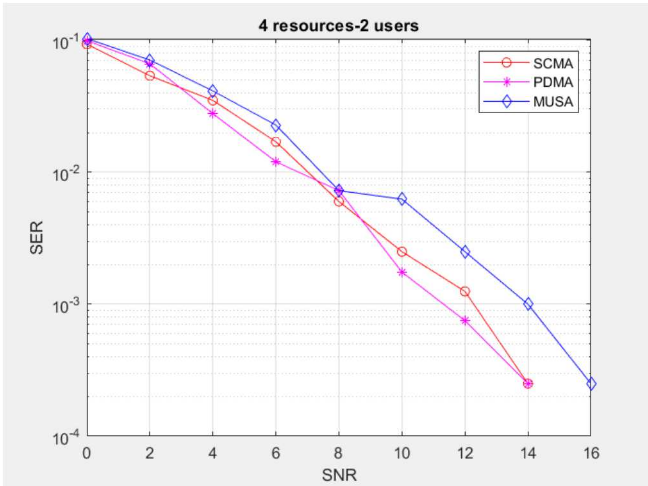

Fig. 4. Results of the SER to the SNR for comparing the three schemes in underloading scenario.

Fig. 4 shows the results of the simulation in which 4 available resources are used for 2 users in a underloading scenario and we observe that the PDMA scheme, which uses the same $D_{4,2}$ matrix with the SCMA scheme, provides much better performance relative to the MUSA scheme and slightly better compared to the SCMA scheme, which presents better results compared to the MUSA scheme.

Fig. 5 shows the results of the simulation in which 4 available resources are used for 4 users in a fully-load scenario and we observe that the PDMA and SCMA schemes, which use the same $D_{4,4}$ matrix, show similar results in their performances and clearly these specific performances are much better than those of the MUSA scheme.

Figure 6 shows the results of the simulation which uses 4 available resources for 6 users in an overload scenario and we observe that the PDMA and SCMA schemes, which use the same table D4.6, the SCMA scheme shows the best performance results compared with the other two schemes, especially at higher SNRs. And the PDMA plan is presented as more effective compared to the MUSA plan. This is due to the significant effect of the propagation of SIC receiver errors on the overall performance of the system. Also, the percentage of overload factor is (U / N)*100% = (6/4) * 100% = 150%.

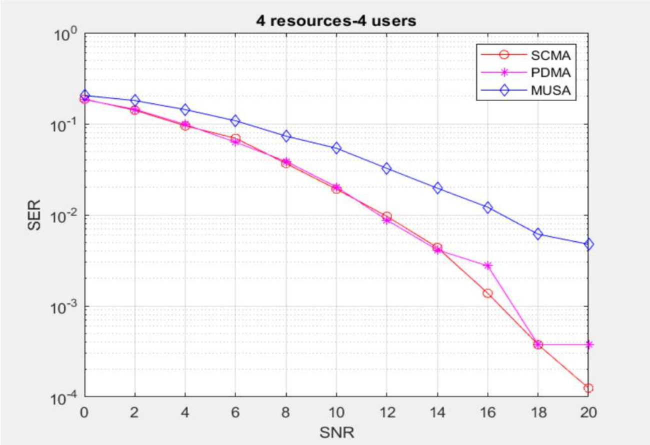

Fig. 5. Results of the SER to the SNR for comparing the three schemes in full-load scenario.

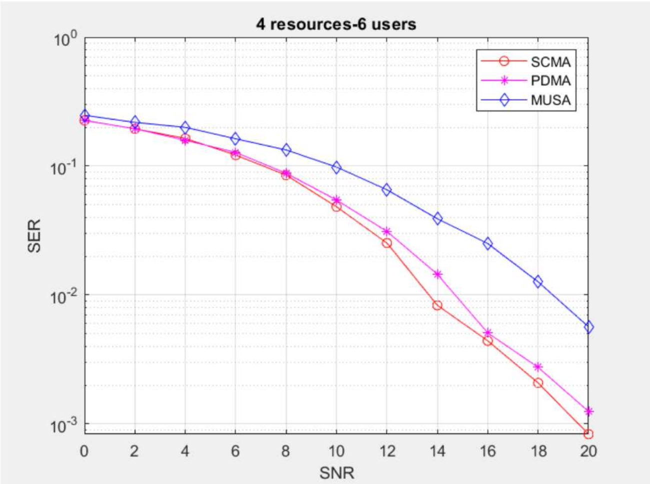

Fig. 6. Results of the SER to the SNR for comparing the three schemes in overload scenario.

Finally, taking into account the SER values in the above schemes, the performance of all three NOMA designs in the overload scenario is clearly better compared to the other two scenarios. This may be due to the smaller number of interferences developed in the underload scenarios, but also to the ability of the MUD techniques to retrieve the transmitted data more easily in the underload scenarios. The performance of SCMA is improved compared to other schemes, especially in the overload scenario, and this is a result of the beneficial effect of near-optimal sparse code configuration on improving system performance.

IV. Conclusion And Future Work

With the simulations we performed we noticed that SCMA as well as PDMA, show similar performance in the full-load scenario, PDMA is slightly better in the overload scenario, while in the overload scenario SCMA is best of all and this is due to the almost optimal design of sparse word codes in conjunction with the MPA algorithm. The MUSA scheme does not provide the appropriate results to improve network performance over the other two schemes in either of the three available scenarios, but it works much more efficiently in the congestion scenario, as do the PDMA and SCMA schemes.

To achieve the best possible performance for the NOMA system, non-orthogonal PDMA patterns, sparse SCMA code design, and low MUSA correlation spread sequences will need to be optimized in the near future. It is also necessary to strengthen the base station, during its operation as a receiver, with low complexity for the NOMA program, to extend the NOMA methods for their best possible application in 5G multi-cell configurations, to group the users more effectively with the application more specific selection criteria, to optimize the way resources are managed for 5G network users and to more effectively manage the messages received at the various base stations of each cellular network. The SIC method presents significant results in the management of interference but also particular complexity in its implementation. One of the techniques that shows improved efficiency and less complexity compared to the SIC method is the MIC (Multiple Interference Cancellation) technique as it optimizes the energy consumption of the overall system.

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