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Downlink NOMA Networks in the Presence of Imperfect SIC: Receiver Design and Performance Analysis

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Abstract
The aim of this paper is investigating the performance of downlink NOMA using imperfect successive interference cancellation (SIC) conditions. The purpose is to provide a more realistic analysis of SIC in downlink NOMA rather than considering the perfect SIC conditions by adding noise while transmitting the signal. Simulation was done and the result is provided in terms of Bit Error Rate (BER) at the receiver end.
Keywords: *NOMA, Bit Error rate, Multiple access, Successive interference cancellation.*

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I. INTRODUCTION

The 5th generation (5G) and beyond technologies require lower latency, energy, cost, network capacity, high data rates and throughput. According to survey conducted by Cisco, user devices are anticipate to exceed the number of users by 2018, meaning that users will have multiple devices to access on a time.

To copy with the increasing demand of high bandwidth and capacity, the 3rd Generation Partnership Group (3GPP) has specified many solutions for the 3.9 and 4th generation (4G) mobile communication systems like the Long-Term Evolution (LTE) and LTE-Advanced. One of these solutions is the use of orthogonal multiple access (OMA) techniques to achieve good system-level throughput.

However, with the increasing volume of mobile traffic and inclusion of technologies like Internet of Things (IOT) researchers are now working for the further evolution of 4G towards 5th generation (5G) mobile communication systems and beyond (future radio access (FRA)).

1.1NOMA

To go beyond 5G and further enhance the radio access technologies, researchers are exploring possibilities of Non- orthogonality of this scheme allows protrude of the signals from different UEs to form a single transmit signal by exploiting the power domain.

In easy words, transmit information of multiple UEs is superposed, in the power domain, by non-orthogonally multiplexing it over the same signal. This gives a new idea for isolating the signal information from the multiple users UES and giving them access to a base station (BS). To use NOMA successfully it must be used together with advanced transmission/ reception technique, e.g., successive interference cancellation (SIC).

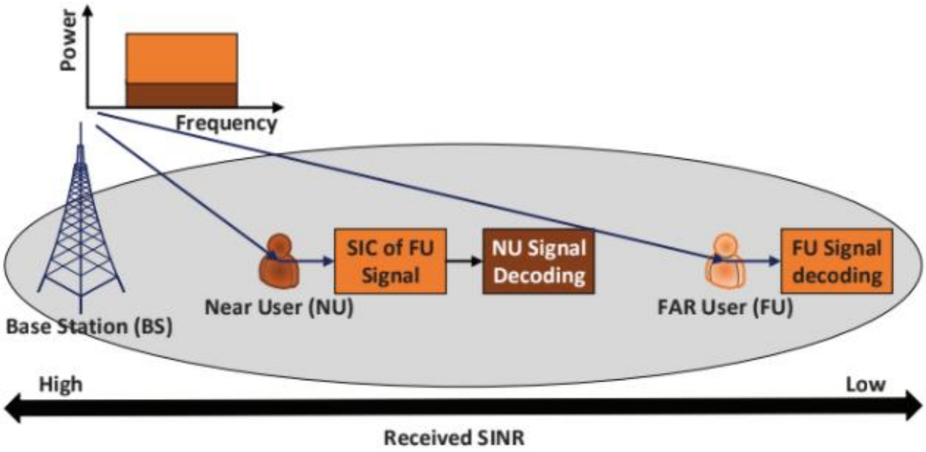

Fig. 1. Downlink NOMA with SIC

1.2 SIC

In this work we have used SIC at the receiver side to segregate or retrieve the user's information at the UE receiver. In SIC, the UE receiver is able to receive two or more signals simultaneously. The stronger signal is decoded and subtracted from the combined signal, then the weaker one is extracted from the residue i.e. the users with weaker channel is extracted by users with stronger channel gain.

To perform SIC in downlink NOMA, it is important to know that which UE will perform SIC, known as order of decrypting. Briefly, this order is determined by the increasing channel gain of UEs from a respective BS. Based on this order, the UE that has high channel gain, known as near user (NU), decodes the signal of the low channel gain users, known as far users (FUs). Once the signal is decoded then near user discards the unwanted signal information using SIC. Imperfect conditions mean that the signal information of FU at NU is distorted using the effects of AWGN, which appears to be a more realistic scenario.

The contribution of this work is to provide the under the imperfect conditions, hence providing a more realistic analysis as compared to the idea conditions of SIC. The simulation results are provided in terms of bit error rate (BER) performance of the UE receiver for both NU and FU.

II. SYSTEM MODEL

In this part we explain the system model. The block diagram of system model is shown below.

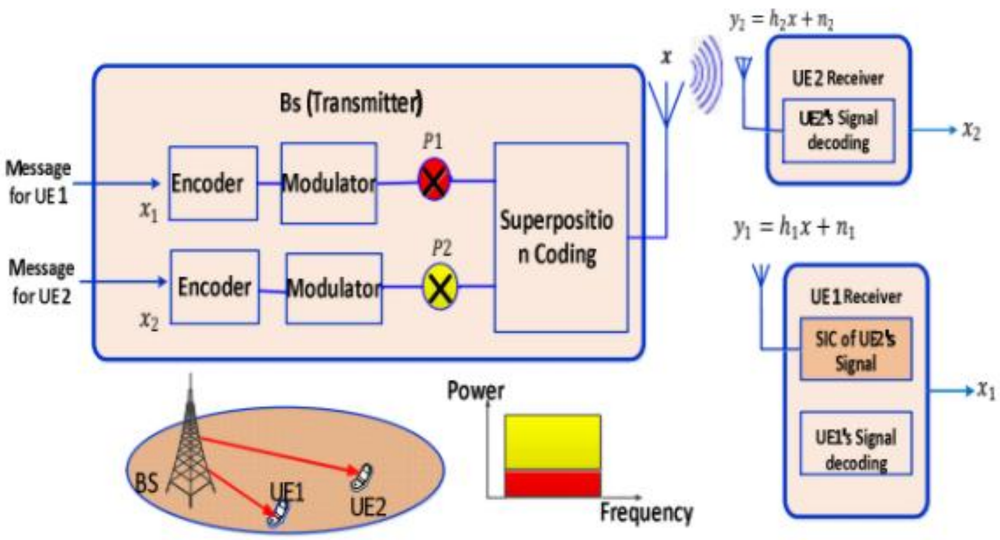

Fig.2 System model of NOMA with one base station and two users

Here we consider that a BS transmits a signal for i user with transmission power Pi. Then the transmitted signal is

$$s=\sum_{i=1}^{N} Si\sqrt{Pi} \quad (1)$$

Si are superposition coded signal of the i users and i[1,..,N]. For our case we have considered that N=2 where i=1 is high gain user and i=2 is low gain user.

The received signal for the i users is

$$Xi=hi \times s + ni$$

$$Xi=hi \times (\sum_{i=1}^{N} Si\sqrt{Pi}) + ni \quad (2)$$

hi is channel response from BS to the i user, ni is AWGN. Transmission power Pi is given below

$$Pi=\frac{\alpha i\times Pbs}{Nsb} \quad (3)$$

αi means power assignment ratio of the i user, Pbs is transmission power of the serving BS ,Nsb is the number of sub-bands in the system. The power assignment ratio αi-can take any value. In downlink NOMA, the SIC is implemented at the user receiver, so it is important for decoding the received signal. This is determined in the order of the increasing channel gain normalized by noise, |hj|^2/N0,j. .

Based on this, any user with high channel gain can correctly decode the signals of the users appearing before that user in the order. If we consider that there is some UE-a with high channel gain in the total j UEs then, in easier terms, UE-a can decode the signals of the UEs whose , |hj|^2/N0,j is lower than |ha|^2/N0,j In this case the desired signal at UE-a will be given as:

$$ya = ha \times sa\sqrt{Pa} + ha \times (\sum_{i=a+1}^{N} Si\sqrt{Pi}) + nj \quad (4)$$

$$y1 = h1 \times s1\sqrt{P1} \quad + \quad h2 \times s2\sqrt{P2} \quad + nj \quad (5)$$

2.1 Imperfect SIC Receiver

Here considered that near user does not have perfect knowledge of the far user signal information. So assumed that the interference from the far users cannot be perfectly removed at the near user. This is achieved by distorting the signal information of all far users at the near user by adding the effects of AWGN, therefore creating a more realistic scenario than the perfect SIC.

$$sj = hj \times \left(\sum_{i=a+1}^{N} Si\sqrt{Pi}\right) + nj \quad (6)$$

$$Sa =[\frac{ya-sj}{\sqrt{Pa}}] \quad (7)$$

$$S2= h2 \times s2\sqrt{P2} +n2 \quad (8)$$

$$S1=[\frac{y1-s2}{\sqrt{P1}}] \quad (9)$$

III. SIMULATION

3.1ASSUMPTIONS

Here are the assumptions we are going to make:

1. Let us do downlink transmission from base station (BS) to two users.
2. We are not using any path loss models and we assume that both users are located at equal distances from the BS.
3. We are assuming an AWGN channel
4. We are going to use BPSK modulation for both users
5. Since we are using BPSK, we are going to consider only the in-phase/real component of complex AWGN

3.2 IMPLEMENTATION IN MATLAB

The steps we use in matlab is as follows

- Generate random binary data for user 1 and user 2
- Do BPSK modulation to the above generated data.
- Do superpostion coding
- Add AWGN
- For user 1, perform direct BPSK demodulation of y_1 to get x_1.
- For user 2, first perform direct BPSK demodulation of y_2 to get x_1.

- Perform direct BPSK demodulation of rem to obtain x_2

IV. RESULT AND DISCUSSION

In the following, BER performance of the two users is shown with different power weights and different SNR values as mentioned in table below

Parameters	User 1	User 2
Power	0.75	0.25
SNR range	0:20	0:20
Noise	AWGN	AWGN
Modulation scheme	BPSK	BPSK

4.1 TABULATION 1

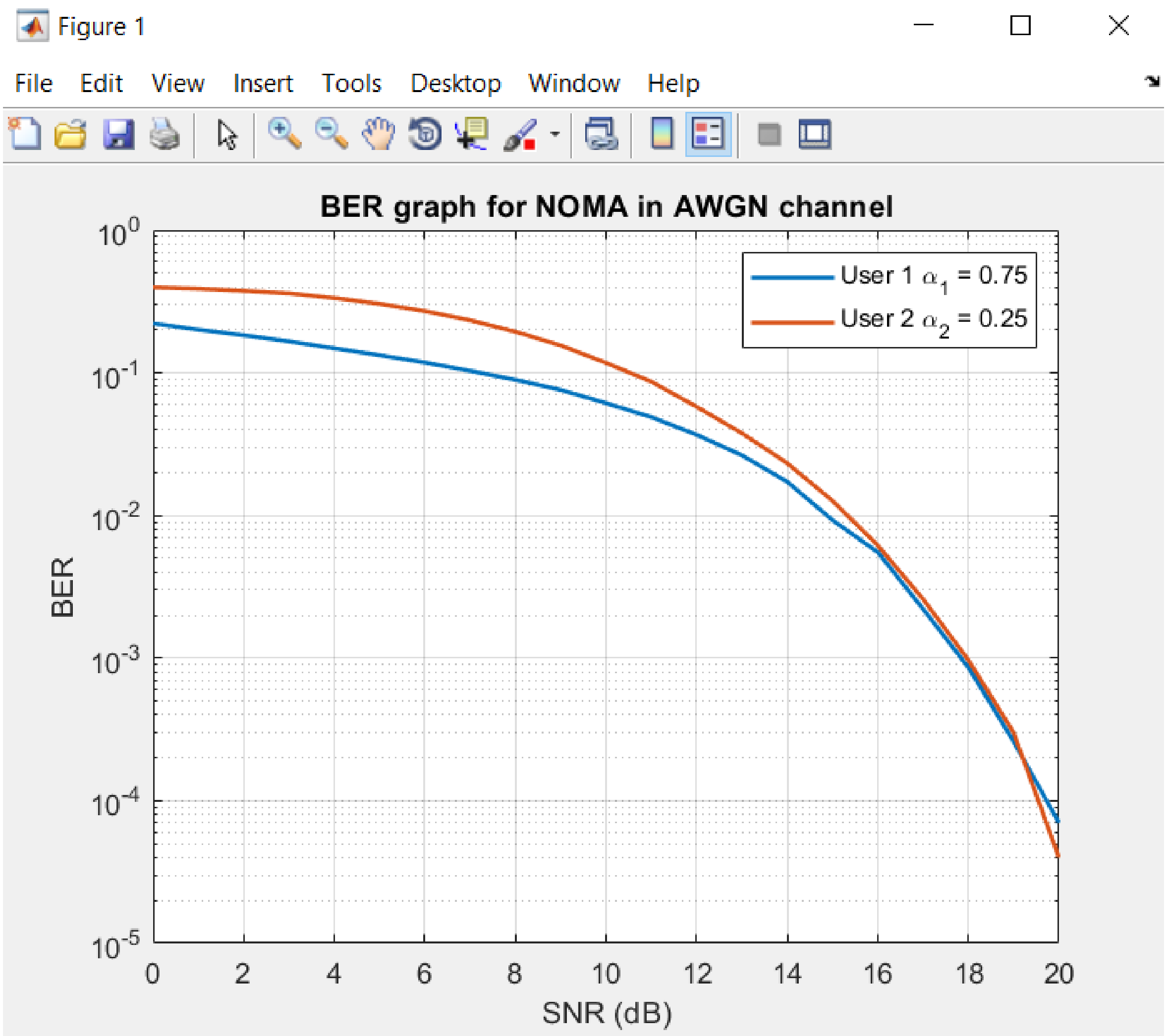

Fig.3 BER performance using imperfect SIC with a1=0.75 and a2=0.25

Parameters	User 1	User 2
Power	0.65	0.35
SNR range	0:50	0:50
Noise	AWGN	AWGN
Modulation scheme	BPSK	BPSK

4.2 TABULATION 2

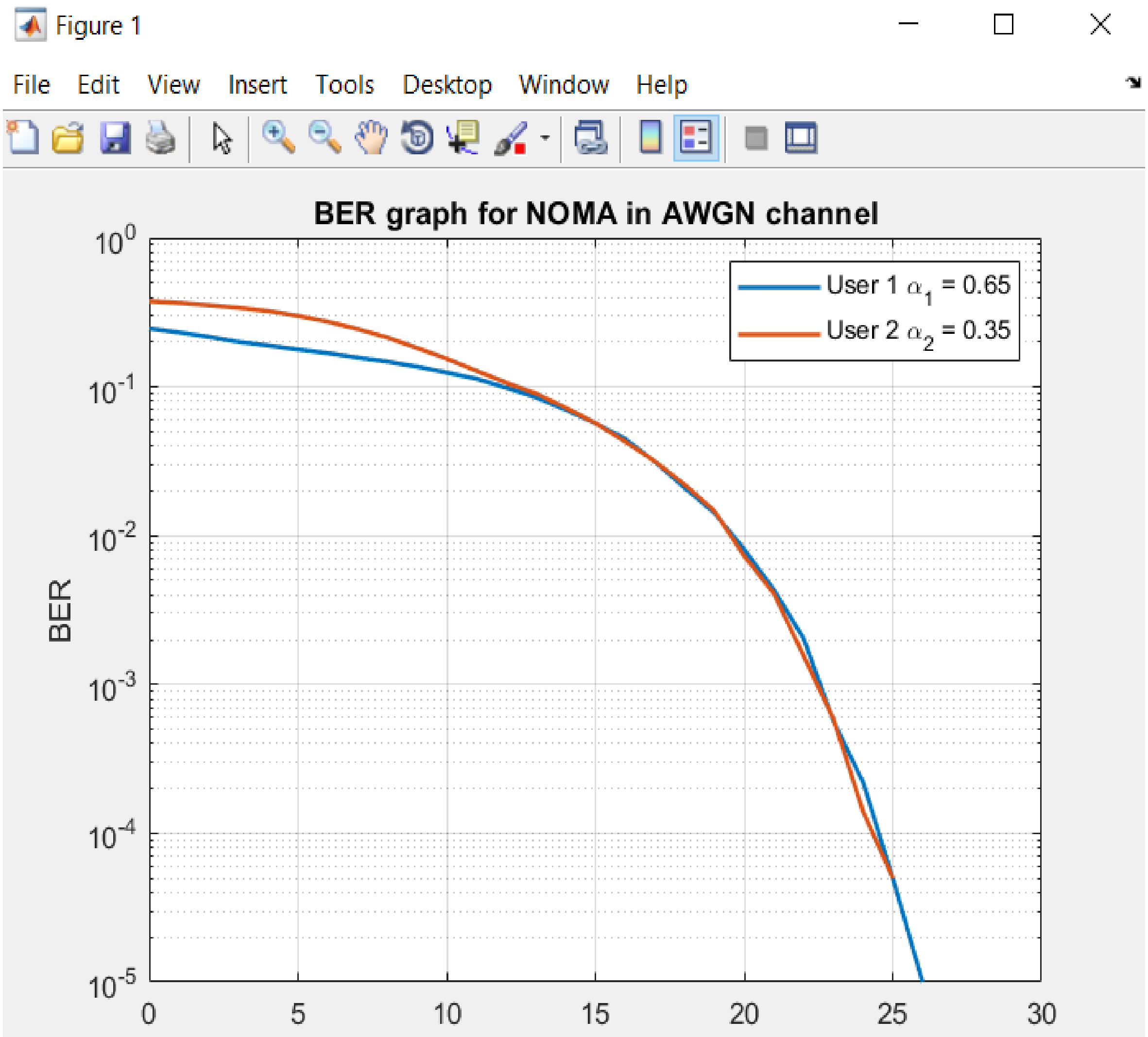

Fig.4 BER performance using imperfect SIC with a1=0.65 and a2=0.35

V. CONCLUSION

In this paper, an in-depth analysis of downlink power domain NOMA is discussed. Superposition coding is done at the transmitter side with power multiplexing and SIC is used at the receiver side. The analysis in this study is provided for multiple users but for simplicity two-user case is considered for the simulation purpose. From the results it can be seen that the overall analysis in this study gives more realistic approach than considering the ideal SIC conditions.

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