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Dynamic Power Allocation as a Way of Improving the Performance of Users in Non-Orthogonal Multiple Access (NOMA) for 5G Communications

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Abstract:-In this work the performance of the downlink non-orthogonal multiple access (NOMA) technique is investigated for two users, that is, cell centre user (user c) and cell edge user (user e). The performance of these users is highly dependent on the power split among the data flows and the associated power allocation (PA) problem. In this research we propose a power allocation scheme that ensures fairness for the downlink users ensuring improved quality of service (QoS). The system is analysed based on outage probability which is dependent on the channel state information (CSI) and is compared to the fixed power allocation scheme. The simulation results demonstrate the improvement in performance of the users when dynamic allocation is used as compared to the fixed power allocation scheme.

***Keywords**:- NOMA, 5G, Power allocation, Outage probability*

I. INTRODUCTION

Non-orthogonal multiple access (NOMA) scheme has received significant attention for fifth generation (5G) cellular networks in the recent years [1], [2]. NOMA can support multiple users within a single resource and thus can improve user and overall system throughput. It can be realised via power domain, code domain and other domains. NOMA offers a lot of advantages as compared to the conventional orthogonal multiple access (OMA) which has been used in the past generations, such as the fourth generation (4G). The conventional OMA technology is limited by orthogonal resources and it is difficult to meet the need of the increasing user number. In NOMA systems, Base Stations (BSs) transmit signals via superposition coding at the same time, frequencyand code but with different power levels relying on successive interference cancellation (SIC) performed at the receivers [3], [4]: therefore NOMA provides higher spectral efficiency, massive connectivity and low latency as compared to OMA[5]. The users with good channel conditions are called strong users and the others are called weak users. The weak users are allocated with more power whereas strong users are allocated with less power for the purpose of improving the user fairness. Weak users decode their own messages by treating the strong users' messages as noise. On the other hand, strong users implement SIC technique to decode their own messages by removing the weak users' messages from the received signal[6]. User fairness can be supported by appropriate allocation of power coefficients at the base station. Fig. 1 shows a two user NOMA downlinksystem.

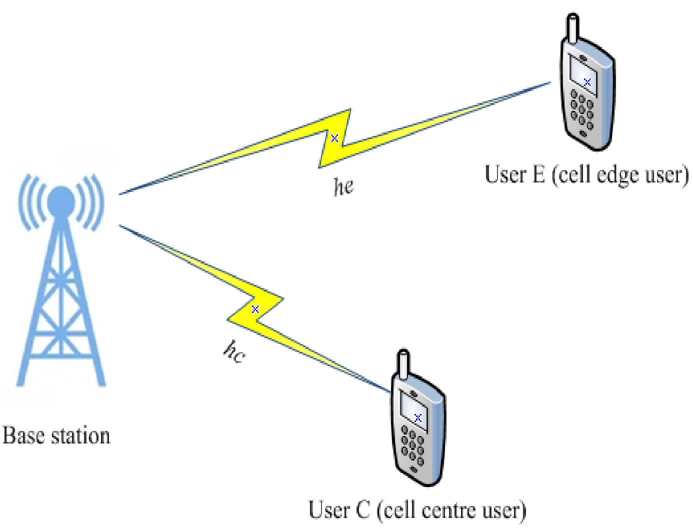

Fig. 1: An example of two user NOMA downlink system

II. RELATED WORKS

User fairness is a very important performance metric of NOMA and has significantly received attention in the recent years. NOMA raises a critical user fairness issue between cell centre and cell edge users. Fairness can be supported through appropriate power allocation of the superimposed transmitted data flows The user fairness issues of NOMA are discussed in [4] with instantaneous or statistical CSI at the base stationand they formulated algorithms that yield the optimal solution in both cases considered. The power allocation for NOMA based on proportional fairness scheduling is studied for both max-sum-rate and max-min-rate in [7]. A new definition of fairness which is purely based on information theoretic grounds in the power domain NOMA wasstudied in[6]. A reversed relay assisted NOMA considering user fairness was studied in[8]and the considered model analyzed in terms of all key performance indicators (KPIs) like ergodic capacity, outage probability, and bit error rate with a more accurate imperfect SIC model and imperfect CSI. Overall the above studies show that NOMA can improve the user fairness in terms of outage probability performance compared to OMA, however they do not employ the dynamic power allocation but instead use fixed power allocation which allocates power to the users utilizing a fixed ratio based on their positions in the channel ordering. Thus the writers in [9] studied the performance improvement for a cell – edge user in a two user noma system by proposing two cooperativerelaying schemes but this introduces a performance loss for the cell center user.

The main novelty of this paper is to analyze NOMA system in terms of user fairness betweencell center and cell edge users using proposed dynamic power allocation scheme (proposed DPA) which is. Then based on this proposed power allocation scheme the system is further analyzed under the outage probability.

III. SYSTEM MODEL

We will consider a two user downlink NOMA system having a base station (BS), cell centre user (User C) and cell edge user (User E). All wireless links assumed to undergo Rayleigh fading with channel coefficients ordered as in [10]$|h_1|^2 \leq |h_2|^2 \leq \cdots \leq |h_m|^2$. If$|h_1|^2 \leq |h_2|^2$, then more power is assigned to user e and less power is assigned to user c. It is also assumed that the further away you move from the base station the signal strength diminishes and need for repeaters to boost the signal.

The composite signal having symbols of both users is transmitted from the BS as seen in figure 2, which represents the signal flow and process of obtaining the optimal power in the downlink NOMA system.

We assume the transmission power is P,S_i is the message for the users and then the transmitted signal from the base station can be written as:

$$x = \sum_{i=1}^{n} \sqrt{P\alpha_i} S_i \quad (1)$$

The received signal at user iis given by

$$y_i = h_i x + n_m \quad (2)$$

Where: h_i is the channel coefficient between BS and user i, $n_m$represents the Gaussian noise plus interference.

Following the principal of NOMA the rates for user e and c in downlink NOMA are given by:

$$R_e = \log_2\left(1 + \frac{\alpha_e |h_e|^2}{\alpha_e |h_e|^2 + \frac{1}{\rho}}\right) \quad (3)$$

$$R_c = \log_2(1 + \rho\alpha_c |h_c|^2) \quad (4)$$

respectively, where: $\rho =$ transmit SNR, α_e &α_c = power allocation coefficients for user e & user c, and$\alpha_e > \alpha_c$, $\alpha_e + \alpha_c = 1$.

In this paper we assume user c with better channel conditions as the strong user whereas user e with poor channel conditions can be regarded as a weak user, and assume that the target rate at user e is R_e^T which means.

$$R_e \geq R_e^T \quad (5)$$

Thus the proposed power allocation is derived by working out the equations given.

Note that this power allocation becomes a function of instantaneous channel gains meanwhile the fixed power allocation factors are constant and not changing with channel gains.

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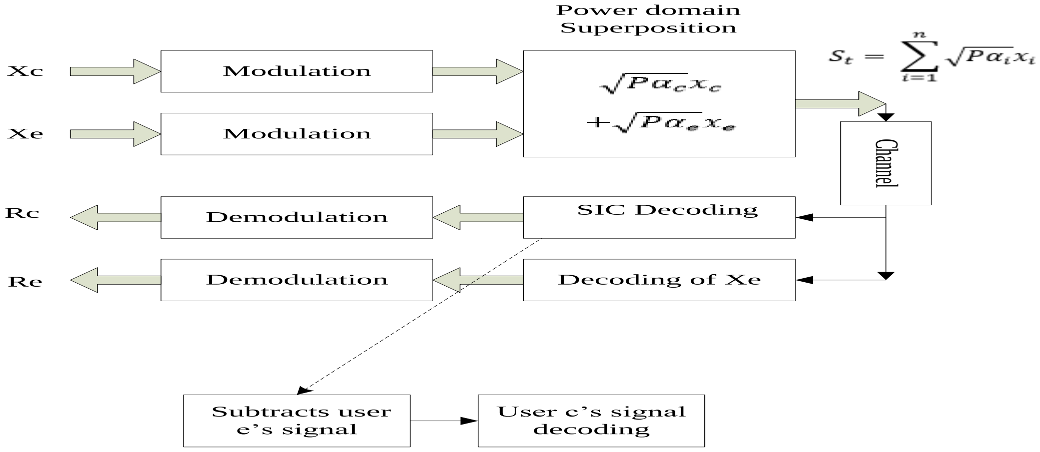

Fig. 2: Signal flow diagram of NOMA with SIC

A. *Performance analysis – Outage probability (OP)*

The system is analyzed based on outage probability in order to evaluate its performance. The outage probability of a communication channel can be defined as the probability that the SNR of a channel falls below a predefined target data rate[9]. Since NOMA allows users to share the same bandwidth and hence the data rate of each user must be within the limits of channel capacity. The decoding rate of data by a user should be high so that latency caused by SIC can be compensated. If the data rate of a user exceeds the Shannon's' rate, outage occurs, which leads to loss of data[11]. The generalized expression for probability of outage is given below:

$$P_c^D = 1 - \{R_{c\rightarrow e,D}^N > R_e, R_{c,D}^N > R_c\} \quad (6)$$

Where;

$$R_{c\rightarrow e,D}^N = \log_2\left(1 + \frac{\alpha_e \rho |h_c|^2}{\alpha_c \rho |h_c|^2 + 1}\right), R_{c,D}^N = \log_2(1 + \rho\alpha_c|h_c|^2)$$

and:

$$P_e^D = 1 - \{R_{e,D}^N > R_e\} \quad (7)$$

Where; $R_{e,D}^N = \log_2\left(1 + \frac{\alpha_e|h_e|^2}{\alpha_c|h_e|^2 + \frac{1}{\rho}}\right)$

IV. SIMULATION RESULTS AND DISCUSSION

In this section, we present the simulation results to illustrate the achievable performance of the proposed scheme. In our plots, unless otherwise stated, the distance between BS and both users is 10m and the path loss exponent $\epsilon = 6$. Fig. 3 and 4 we have results showing the comparison of outage probability of a two user Noma system. In figure 3, fixed power allocation is being used and$\alpha_e = 0.95, \alpha_c = 0.05$. The wireless channel is extremely dynamic in nature and fixed PA does not worry about the instantaneous channel conditions of users.

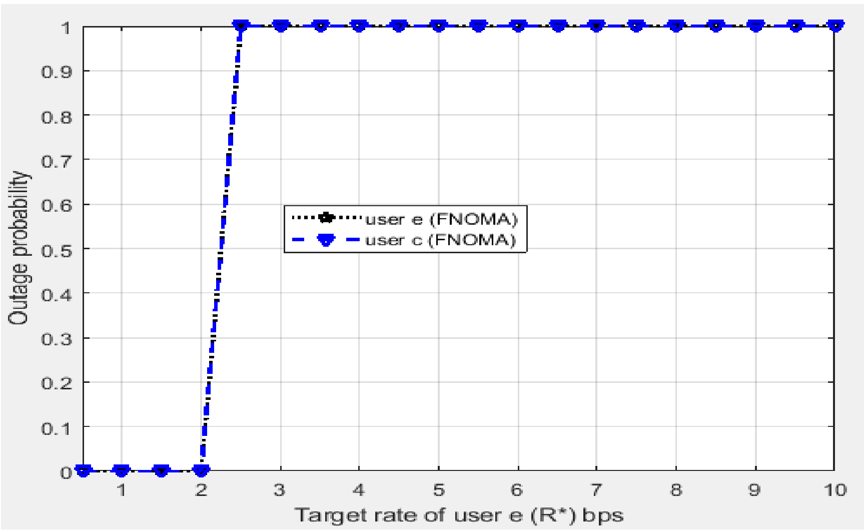

Fig. 3: OPs of user c and e as a function of R^* (bps) with the transmit SNR = 30dBm in FNOMA

Whenever the channel changes, the values of $\alpha_e \& \alpha_c$ are fixed and as the target rate (R^*)exceeds two, the receiver is always in outage. Thus it can be seen from fig. 3 that the fixed power allocation termed FNOMA is performing very poorly because it does not take into consideration the channel state information and the target rate requirements into account. The probability of the system failing is quite high all the time.

In fig. 4, the users are at the same distance of 10m from the BS. It can be seen that if we compare fig. 4 to fig. 3, there is an improvement in the performance of the system when the proposed dynamic power allocation (proposed DPA) is used and the rate of failure for user c is better as compared to that of user e, but both user e and user c in proposed DPA perform way better as compared to using fixed power allocation. It is worth noting that there's lower outage probability because $\alpha_e \& \alpha_c$ aredynamically adjusted based on target rate requirements and channel state information. Whenever the channel changes, the values of $\alpha_e \& \alpha_c$ are updated to meet the specifications reducing the rate of failure of the system.

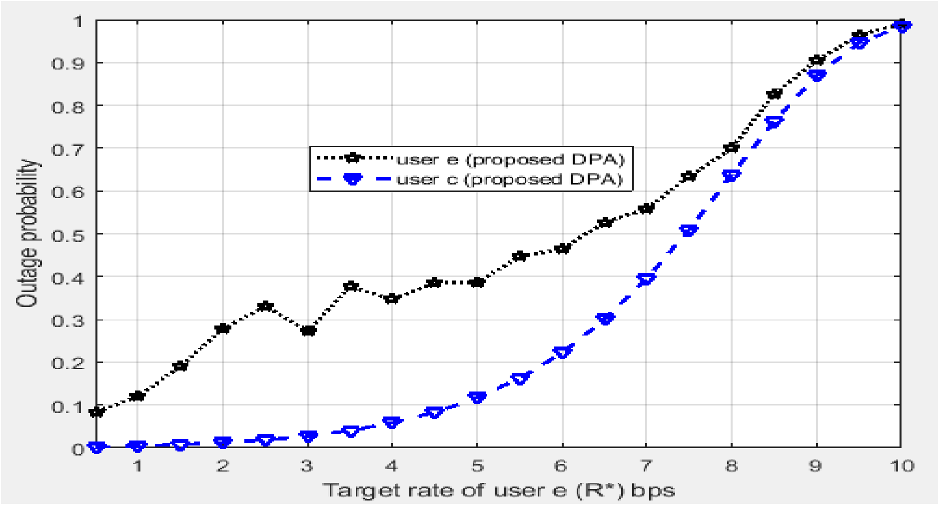

Fig. 4: OPs of user c and e as a function of R^* (bps) with the transmit SNR = 30dBm in DPA

V. CONCLUSION

In this research, we have studied performance improvement for users in a two user NOMA system. In particular we have proposedDPA where the power allocation coefficients are dynamically adjusted based on the state of the channel unlike fixed power allocation which always allocates more power to the cell edge user and the system performance analyzed based on outage probability. It is seen that the proposed DPA seems to be performing better than the fixed power allocation in terms of outage. The rate of failure when fixed power allocation is used is very high as compared to proposed DPA. The results can further be improved by employing other technologies like D2D, MIMO, cooperative relaying etc in collaboration with NOMA.

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