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# Game Theoretic Power Allocation in user Pairs for NOMA in 5G Systems

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***Abstract*—***One of the primary enabling candidates for fifth generation (5G) systems is thought to be non-orthogonal multiple access (NOMA). The power allocation has a significant impact on how well these systems perform. The issue of power allocation (PA) in a downlink cellular NOMA network is discussed in this research. Through a random method, users with weak channel conditions are paired with users with strong channel conditions. It has been suggested that user pairs compete for the transmit power that the base station (BS) is selling in an auction game. Additionally, each user pair iteratively bids in order to maximize their own utility. A theoretical demonstration of the existence of a unique Nash equilibrium (NE) has been made.*

***Keywords:*—***5G, NOMA, user paining, auction, Nash equilibrium, power allocation*

## 1. INTRODUCTION

Researchers have recently become interested in non-orthogonal multiple access (NOMA) as a possible solution for next-generation wireless networks [1, 2]. Orthogonal multiple access (OMA) approaches, which use the power domain to serve several customers simultaneously in the time and frequency domain, are fundamentally different from NOMA [3]. This is accomplished by using successive interference cancellation (SIC) at the receiver side and superposition coding at the transmitter side, respectively [4]. Compared to OMA, NOMA ramps up the number of consumers being serviced and greatly increases the system's spectral efficiency.

The power allocation (PA) has a significant impact on the NOMA systems' overall performance. The goal of an effective PA is to reduce user interference. Timotheou et al. [1] examined the optimal PA problem in NOMA from the perspective of downlink users' fairness. In order to maximize the cumulative capacity in a two-user NOMA system, Wang et al. [2] developed an optimization problem for PA. In a downlink NOMA network, Di et al. [4] tackled the PA and user scheduling problem with the goal of optimizing weighted total sum-rate while maintaining user fairness. The power control issue for a multi-cell NOMA network's downlink was examined by Fu et al. [5], who also suggested a distributed approach for minimizing power usage.

Game theory is a powerful bag of tools that is quite effective in analyzing the strategic decision making processes in an interactive multi-user system [6, 7]. In [3, 8], the authors proposed PA schemes based on Stackelberg game in cellular NOMA networks. In [9], the authors employed auction theory to address PA problem in downlink cellular NOMA networks where all the users were served simultaneously. However, it makes the technique practically infeasible as the user with the best channel conditions will have to decode the rest 99 users' signal for a 100-user NOMA system [10]. Hence, in the proposed PA scheme, user pairing is done where each pair is allocated a different subband (SB) for transmission. This not only decreases the computational complexity at the receiver end but also manages the interference experienced by the user. To the best of the authors' knowledge, this is the first work to employ auction theory to address the problem of PA in user pairs in a downlink cellular NOMA network.

The infrastructure aims to sell its transmission power, while each user pair participates as a player, bidding to maximize their utility. In this setup, a user with favorable channel conditions (referred to as a strong user) is randomly paired with a user experiencing poor channel conditions (referred to as a weak user), and both are assigned a sub-band (SB) simultaneously. Additionally, we mathematically demonstrate the convergence of the game to a unique Nash equilibrium (NE). The proposed auction-based game outperforms the existing algorithms in [8] and [9] in terms of the average sum rate of users.The remainder of this paper is structured as follows. Section II presents the system model. Section III describes the proposed auction game and analyzes its convergence. The performance of the proposed scheme is examined in Section IV. Section V concludes the paper.

## 2. SYSTEM MODEL

Consider a downlink cellular system which comprises of a BS and a set of $2M$ available users denoted by $\mathcal{M} = \{1,2,\dots,2M\}$. The total bandwidth of the system $B$ is equally divided into $K$, $K \geq M$ SBs of bandwidth $B/K$.Each user pair is assignedone SB. For notational simplicity, we assume that $K = M$ and each $m$th user pair, $\forall\, 1 \leq m \leq M$, is multiplexed on the $m$th SB. $P_m$ denotes the power allocated to the $m$th SB. The channel fading coefficient between the BS and the $j$th user in the $m$th SB is denoted as $h_{j,m}$.In NOMA, BS uses superposition coding at the receiver end to serve several users simultaneously. For $m$th user pair, the superposition coded signal transmitted by the BS is given by

$$x_m = \sqrt{P_m}\sum_{j=1}^{2}\sqrt{\alpha_{j,m}}x_{j,m} \qquad \text{....................(1)}$$

where $x_{j,m}$ represe $x_{j,m}$ nts the message sent by the BS to thet $j$ h usera $j$ n $\alpha_{j,m}$ denotes $\alpha_{j,m}$ the power allocation coefficient of tht $j$ h user $j$ such that.

$$\sum_{j=1}^{2}\alpha_{j,m} = 1 \qquad \text{.................................(2)}$$

## 3. PROPOSED PA SCHEME

In the proposed power allocation (PA) scheme, a strong user is paired with a weak user to form a NOMA pair. The user pairing mechanism leverages the difference in channel gains among users to enhance the system's achievable throughput. The achievable data rate for the strong user on the mmmth sub-band (SB), as defined in equation (6), depends on the power allocation coefficient α1,m\alpha_{1,m}α1,m and the channel fading coefficient ∣h1,k∣|h_{1,k}|∣h1,k∣. It remains unaffected by interference from the weak user within the same SB. Although the NOMA protocol allocates less power to users with higher channel fading coefficients, the achievable data rate can still be improved by selecting users with sufficiently high channel gains, thereby minimizing the impact of allocated power on the achievable data rate. Consequently, distributing strong users across different SBs is preferable to maximize overall system throughput. Additionally, pairing a weak user with a strong user enhances the weak user's achievable data rate, as the NOMA protocol assigns higher power to users with lower channel fading coefficients.

## 4. SIMULATION RESULTS AND DISCUSSION

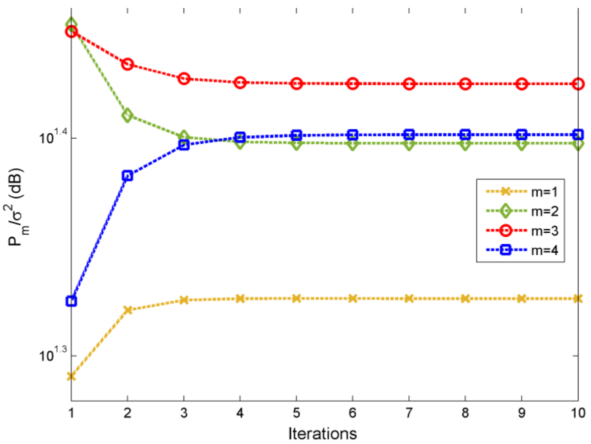


*Figure 1: The convergence performance of the proposed PA scheme for* $M = 4$ .

## 5. CONCLUSION

PA is a crucial and critical issue for NOMA in 5G networks. In this paper, we propose an auction game based PA scheme for downlink cellular NOMA in 5G systems. We model the BS as an auctioneer which needs to sell its transmit power. Users are paired through a random mechanism in such a manner that each pair consists of a strong and a weak user.

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