Ant-Colony Optimization for 5G NOMA User Grouping

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Abstract — **Non-orthogonal multiple access (NOMA) is essential for 5G networks in achieving improved fairness and throughput. Scheduling the massive number of users on NOMA systems and wireless networks lead to a rise in the computational loads, which can be reduced using heuristic algorithms. This paper proposes ant-colony optimization (ACO) for user grouping in NOMA systems for 5G networks. The number of resource blocks is increased from one up to twenty to reflect the increase in the number antennas in the large antenna systems. It is observed that the mean throughput of the proposed scheme is improved, and the average mean square error per user is reduced as opposed to the existing schemes.**

Index Terms — Ant-colony optimization, Large antenna,Non-orthogonal multiple access.

I. INTRODUCTION

Recently, non-orthogonal multiple access (NOMA) is an essential mechanism for configuring the user access of the resource blocks (RB) available in cellular networks for multiple users in one RB. For the current cellular network generation 5G, NOMA plays an important role to achieve heterogeneous requirements on the large antenna connectivity and increase the throughput [1]. To maximize the capacity in serving the users, large number of antennas can be employed in the radio cells that will lead to higher data rates for the users.

The scheduling operation to group this increasing number of users in NOMA systems must be taken into consideration as the required computational complexity for grouping the users will increase. As reported in [2], the rise in the computational complexity in grouping a huge number of users is worth to be addressed using heuristic scheduling models such ACO model. ACO is more useful for developing discrete-based optimization such as user grouping in a 5G NOMA systems by integrating with interference mitigation to improve the performance [3].

II. LITERATURE REVIEW

NOMA has become the possible candidate for the future 5G cellular networks due to its low latency and system throughput [2]. Although NOMA has relatively high spectral efficiency, it is vulnerable to interference from the sharing users [4]. NOMA offers high bandwidth to improve the network capacity by designing a required channel state information at the transmitter because of the huge number of simultaneous signal transmissions [5-6].

Several mechanisms are suggested for the development of user groups, such as round robin [7]. As such mechanisms continue to demand substantially higher computational loads as the number of users rises, new computationally lower strategies have been suggested to classify user groups, like the heuristic models based on artificial intelligence methods such as particle swarm optimization (PSO) and ACO [8]. PSO has been implemented to schedule the users through various sub-channels in NOMA. Also, PSO has been utilized to assign the power to every band to increase the overall network throughput as discussed in [9].

ACO imitates ants rummaging behavior for natural source food [10] and has an intrinsic parallel and constructive feedback system that allows it desirable to find user multiple antennas in NOMA [11]. This approach has been implemented in high speed cellular networks prior to 5G [12]. It can be integrated with other models, thus enhancing the performance for both schemes [13-14]. To conclude, this paper provides the following contributions:

- A NOMA system design with large numbers of antennas at the transmitting and receiving ends for 5G.
- Comparative study of the ACO performance against other algorithms for user grouping over high speed cellular networks in throughput improvement.

This paper is organized as follows. The 5G NOMA system model is presented in Section III, in which all essential parameters and equations are described. In addition, the proposed user grouping approach which is based on the ant-colony optimization is also explained under Subsection III-A. Subsequently, the results are produced and shown in Section IV where the proposed user grouping approach, ACO, is compared with other conventional methods. Finally, the paper is concluded in Section V.

III. 5G NOMA SYSTEM MODEL

A NOMA system for high-speed cellular networks such as 5G is considered in the downlink direction. A total of N_{user} users are deemed to be uniformly located in a number of sites in the radio cells. All users are separated and grouped into N_g groups with N_r receiving antennas and N_t transmitting antennas. The system consists of a cell network with N_{site} sites, and each has a cell with three sectors, where every sector is defined as $A(i,j)$, for $i \in [1, N_{site}]$ and $j \in [1,3]$. It is assumed that the networks have uniformly distributed users in the sector and a completely loaded network wherein the frequency resources assigned to all sectors are utilized in all sites. The mean power received over resource block r is represented as follows:

$$P_{i,j,u,r} = P_u G_{PL}(i,u)\, c_{i,u} G_A(i,j,u) f_{i,j,u,r} \quad (1)$$

The average transmission power is $P_u = a_u P_t$, which is considered to be distributed equally to each resource block, with P_t and a_u as the total power and the power ratio respectively, $C_{i,u}$ and $G_{PL}(i,u)$ represent the shadow fading and path gain between site I and user u, given the sites shadowing impact is entirely associated and the antenna gain between the user and sector $A(i,j)$ is expressed as $G_A(i,j,u)$. The small-scale fading, $f_{i,j,u,r}$, is assumed for resource block RB between the user and sector $A(i,j)$.

For the case of no bandwidth sharing, which is called the Orthogonal Multiple-Access OMA, the signal-to-interference-and-noise-ratio (SNIR) is represented as $\gamma_{u,r}^{1,1}$, defined as follows:

$$\gamma_{u,r}^{1,1} = \frac{P_{1,1,u,r}}{\sum_{i=1}^{N_S} \sum_{j=1}^{3} P_{i,j,u,r} - P_{1,1,u,r}} \quad (2)$$

Without loss of generality, when one resource block is assigned for user 1 and user 2, it is assumed that the SINR of user 1 is higher than SINR of user 2 $\gamma_{u1,r}^{1,1} > \gamma_{u2,r}^{1,1}$, with a power amount of aP_t to user 1 and $(1-a)P_t$ to user 2, where $0 < a < 0.5$. Therefore, $\gamma_{u2,r}^{1,1}$
is the SINR for user 2, calculated as:

$$\gamma_{u_2,r}^{1,1} = \frac{P_{1.1.u_2,r}}{\sum_{i=1}^{N_S} \sum_{j=1}^{3} P_{i,j,u_2,r} - P_{1,1,u_2,r} + P_{1,1,u_1,r}} \quad (3)$$

where the SINR value for user 1 is expressed as:

$$\gamma_{u_1,r}^{1,1} = \frac{P_{1,1,u_1,r}}{\sum_{i=1}^{N_S} \sum_{j=1}^{3} P_{i,j,u_1,r} - P_{1,1,u_1,r}} \quad (4)$$

To evaluate the SINR $\gamma_{u2,r}^{1,1}$ while decoding the obtained signal for user 1, the procedure of the SIC is performed to eliminate the interference generated by second user. The model for 5G NOMA with large numbers of antennas at both the receiver and the transmitter is considered.

The aim is to maximize the throughput for each group, in which there are two users per group sharing the same resource block. The throughput for two users in each group is expressed as:

$$R_{t,u,g} = \sum_{i=1}^{N_{ug}} \gamma_{u_n,r}^{c,S} \quad (5)$$

where N_{ug} is the number of users in each group with one cell and one site. In the following section, ACO is designed for large antenna systems to group users and select the best pair and compare to other schemes.

A. Ant-Colony Optimiztation (ACO) Model

In order to run the NOMA system with relatively large numbers of antennas, for grouping the users in pairs based on the available resource block, ACO is implemented. The purpose of ACO is to develop an acceptable solution for a complex problem, based on the performance of ants when hunting for their foods. ACO is able to integrate with other algorithms to be studied and improved its performance and the other schemes. The ACO is started with a number of ants N_{ant}, the number at receiving antennas N_r, the number of users N_{user}, the users` number in each group N_u and the group number, which is calculated as [10]:

$$N_{ug} = \frac{N_{user}}{N_u} \quad (6)$$

One of the main parameters measured in this model is the SINR for each user allocated with the same bandwidth. The number of nodes and stages are set to be the number of ants N_{ant}, based on the pheromone value and the heuristic data which the ants will determine as the next step to the nodes.

When the throughput for each group reaches to the optimal value $R_{t,u,g}$ of the objective function, the evaporation rate, the pheromone value and the probability will change until the next iteration is completed. The algorithm is stopped when the convergence condition is achieved, or the maximum number of iterations is reached. In [15], user grouping that requires high-speed network access [16-17] is suggested that it should really be implemented with low complexity.

IV. RESULTS AND ANALYSIS

A 5G NOMA system with considerably large number of antennas is considered to improve the throughput for users by using the ACO scheme to schedule the users. The proposed algorithm is compared with the existing conventional schemes namely, the Exhaustive Search (ES), Proportional Fairness Fixed Power-allocation (PFFP).

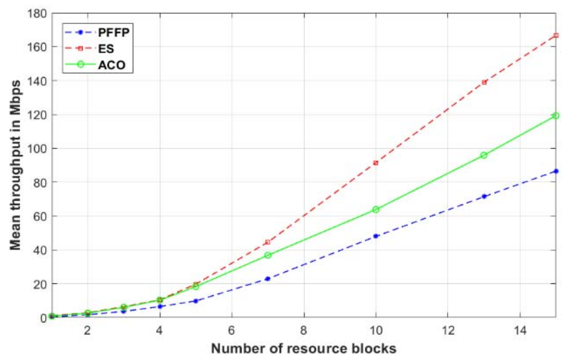

Fig. 1. The mean throughput Mbps with 15 resource blocks

Based on Fig. 1 the throughput for each user is influenced by several factors such as the number of resource blocks and total power. Firstly, the main throughput for each user is increased as the number of RB enhanced. The mean ACO performance is higher than PFFP, as the number of RB increases, the difference between these two mean performance increases. The ACO mean throughput is very close to the maximum result obtained by ES. In order to determine the highest mean throughput, all combinations of users are evaluated. In short, it is observed that the proposed ACO framework gives the best user grouping.

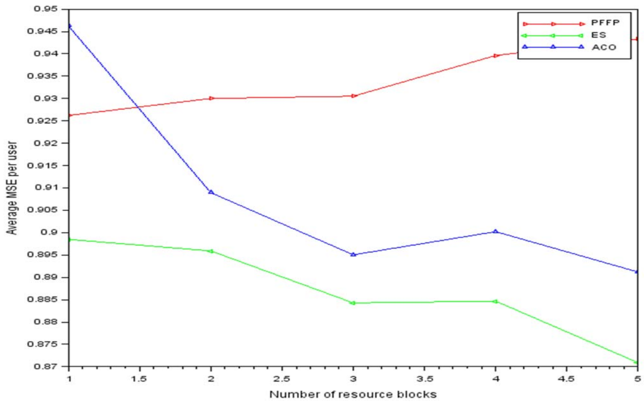

Fig. 2. The average mean square error per user

Fig. 2 shows the average mean square error recorded. It can be observed that the PFFP scheme has the highest average mean square error per user as compared with the rest. As for the proposed ACO scheme has produced lower average mean square error per user values as compared to that of PFFP scheme. It is also clear from this figure that the average mean square error of the proposed ACO scheme decreases to be closer to the lower bound set by the ES method as the number of resource blocks increases.

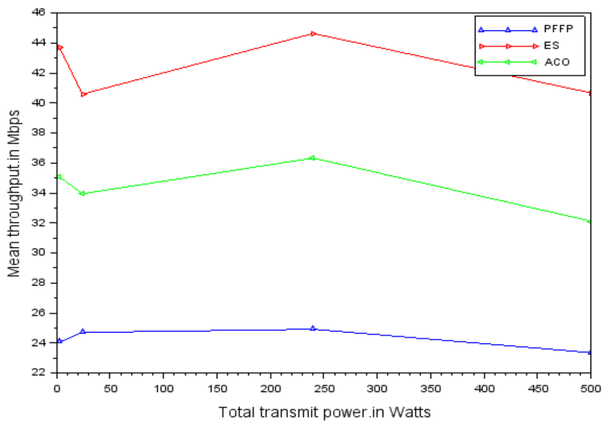

Fig. 3. The mean throughput in Mbps vs the total power in Watts

Fig. 3 shows the mean throughput of users associated to the total transmission power in watts, where the throughput of ACO is observed to be higher than that of PFFP, and close to the peak value of ES.

V. Conclusion

The proposed ACO is implemented for NOMA to group the users for enhancing the mean throughput and minimizing the computational complexity. Based on the analysis, the mean throughput of ACO is higher than that of the existing scheme and close to the peak value, where the throughput is influenced by several factors such as the number of resource blocks and the total transmit power.

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