Users Clustering and Power Allocation in Non-Orthogonal Multiple Access Systems : A Heuristic Approach

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Abstract

Users clustering and power allocation problems are two-key confronting issues in non-orthogonal multiple access (NOMA) systems. Users in the same group access the same channel where they are multiplexed in power domain. As more than one users share the same channel, they gain the intra-cluster interference. In this paper, a heuristic clustering algorithm is introduced to lessen the interference between users. Moreover, a power allocation problem is developed as an optimization problem where intra-cluster interference is reduced by guaranteeing the quality of service (QoS) of users. This problem is answered by a heuristic power allocation algorithm. Then, simulation is implemented to present that the proposed clustering surpasses the random clustering of users.

1. Introduction

In orthogonal multiple access systems (OMA), resources (frequencies or times) allocation is isolated between users. There will be no interference for users as they are using the orthogonally divided resources. Then, non-orthogonal multiple access (NOMA) is introduced. NOMA allows much more devices than OMA to access the networks by granting them to share the same frequency resources. As many Internet of Things (IoT) devices are connected to networks, NOMA is a promising technique.

The basic idea of NOMA and issues were discussed in [1]. [2] also surveyed about problems and trends in NOMA. The two most critical issues in NOMA are users grouping and power allocation. Channel allocation which is also user grouping and power allocation were jointly optimized in [3]. User pairing algorithms were proposed in [4]. [5] solved the user clustering and power allocation problem where the closed form for power allocation of the specific number of users in group was derived. The limitation of these papers is that whenever a new user comes, user clustering has to be performed all over again.

In this paper, a heuristic user clustering algorithm is introduced where centroids of the clusters are switched every time a user is clustered. The idea behind this to prevent the clustering of very similar users. In addition, clustering do not need to be calculated again whenever a new user joins or a user leaves the network. After solving the users clustering problem, power allocation needs to be performed within the cluster. The objective of the proposed power allocation algorithm is to minimize the interference while maintaining the data rate requirement of users.

2. System Model

A single cell downlink NOMA network with a set of k channels is considered. There is no inter-channel interference between channels. Users are packed into k groups. As the users in the same group share the same channel, they experience the intra-cluster interference as shown in fig.1.

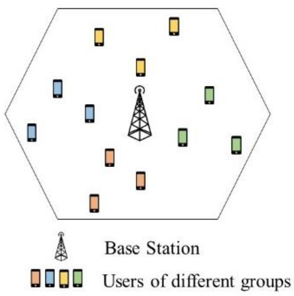

Fig. 1. NOMA system with one MBS, 4 channels

The fundamental of NOMA using successive interference cancellation (SIC) is shown in fig. 2. UE1 who has the highest channel can decode the signals of UE3 and cancel out UE3 signals then decode UE2 signals and cancel them. Finally, it can decode the signal for itself. So, UE1 will not suffer interference. UE2 is not able to decode the signal of UE1 so it will take the signals as interference. In case of UE3, as the channel gains of UE2 and UE1 are higher than its channel gain, it cannot figure out them. Therefore, it will assume both signals as interference.

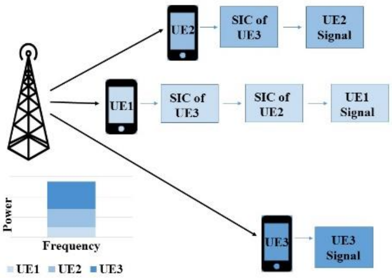

Fig. 2. Basics of NOMA

Power needs to be allocated to the interference experienced users more so as to be able to decode their own signals. So, users clustering plays the critical role in grouping the users with different channel gains.

3. Users Clustering

The important problem in clustering is how to define the centroid of the clusters and determine the distance function of users [6]. The distance between two users is the difference of their channel gains. If the difference is high, these users will be grouped in the same cluster. The centroid has to be carefully chosen to maintain the different users in the cluster. For this problem, we replace the centroid whenever a user comes in. The algorithm is expressed below.

Heuristic Users Clustering Algorithm

1: Input : channel gains of users
2: Output : clusters of users
3: sort the channel gains of users $g_1 \le g_2 \le \cdots \le g_k \le \cdots \le g_N$
4: assign k channels to k lowest channel gains users $\in \mathcal{U}_k$
5: **for all users** $\boldsymbol{i \notin \mathcal{U}_k}$ **do**
6: cluster index ← $\arg\max_k\{|g_i - g_k|\}$
7: cluster [cluster index] ← i
8: centroid [cluster index] ← i
9: **end for**

4. Power Allocation

The power allocation problem is as follows for each cluster.

$$\min_{p_i} \sum_{i\in I}\sum_{j\in J:j<i} p_j\, g_i$$

s.t.

$$\omega \ \log_2(1+\tfrac{p_i g_i}{\sum_{j<i}p_j g_i + n_0}) \ \ge \ \gamma_i \qquad \forall i$$

$$\sum_{i\in I} p_i \le P_t$$

The objective is to minimize the interference within the cluster. ω is the channel bandwidth. The first constraint is QoS constraint and second is power budget constraint. Minimizing the interference will make the first constraint becomes equal to minimum QoS requirement. An example with two users is shown below.

$$\min_{p_1,p_2} p_1\, g_2$$

s.t.

$$\omega \ \log_2\left(1+\frac{p_1 g_1}{n_0}\right) \ \ge \ \gamma_1$$

$$\omega \ \log_2(1+\tfrac{p_2 g_2}{p_1 g_2 + n_0}) \ \ge \ \gamma_2$$

$$p_1 + p_2 \le p_t$$

Minimizing $p_1 g_2$ will make $\omega \ \log_2\left(1+\frac{p_1 g_1}{n_0}\right) = \gamma_1$. If there is more than one user whose channel gain is below user 2, the second constraint will also become equal. Here, both constraints are assumed to be equal to QoS requirement. So, we can derive the power as follows:

$$\omega \ \log_2\left(1+\frac{p_i g_i}{\sum_{j<i}p_j g_i + n_0}\right) = \gamma_i$$

$$p_i = \frac{2^{\gamma_i/\omega - 1}}{g_i}\left(\sum_{j<i}p_j g_i + n_0\right)$$

Heuristic Power Allocation Algorithm

1: Input : clusters of users
2: Output : power allocation to users
3: **for all clusters** $\boldsymbol{k}$ **do**
4: **for all users** $\boldsymbol{i} \in$ **cluster [k]**
5: calculate p_i as $p_i = \frac{2^{\gamma_i/\omega - 1}}{g_i}(\sum_{j<i}p_j g_i + n_0)$
6: **if** $\boldsymbol{\sum_{i\in I} p_i \le P_t}$ **then**
7: p_i is allocated to user i
8: **end if**
9: **end for**
10: **end for**

5. Evaluation

In evaluation, one MBS and 14 channels with 1.4 MHz are considered. Each channel has total transmit power 3.8 dbm. We use the power density thermal noise as -174dBm/Hz and the long distance path loss model. The minimum data rate requirement of users is uniformly distributed between 0.8 and 1 Mbps.

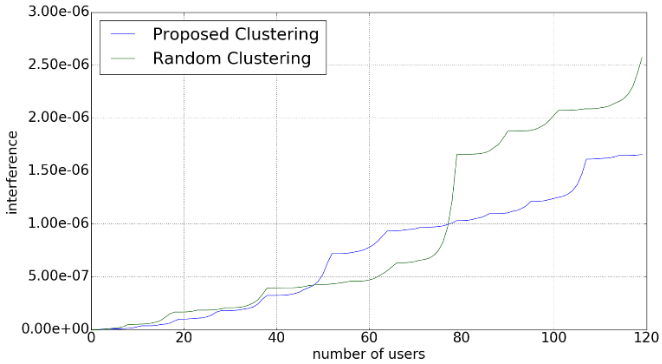

Fig. 3. Interference comparison

As in fig. 3, the difference between two approaches are not much up to 50 users. After that proposed clustering makes more interference compared to random grouping up to 78 users. But, as the number of users increases, the proposed clustering reduces much interference as compared to random one.

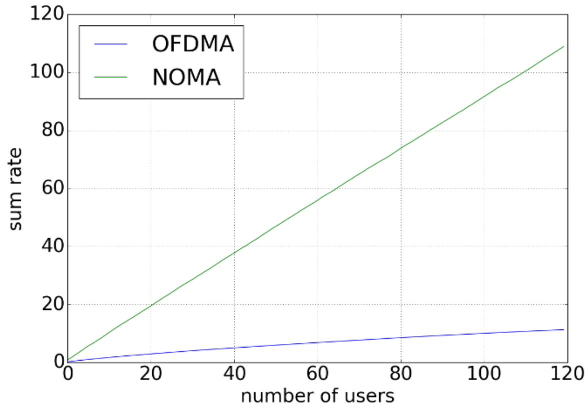

Fig. 4. Sum Rate comparison

Fig 4 shows how NOMA using proposed algorithms can outperform OFDMA. NOMA can achieve much higher data rate than OFDMA by allowing multiple users to share the same channel. This can be the promising technique as more and more devices are connected to the network.

6. Conclusion

In this paper, we proposed two algorithms which are the heuristic users clustering algorithm and power allocation algorithm for NOMA systems. The former one can work well with new users and also it does not need to be performed every time a new user comes into the system. Then, the proposed allocation algorithm minimizes the interference to users of all groups. At the same time, it ensures the minimum data rate requirements of users. The results show that the proposed clustering makes interference less than random clustering where interference is an important factor in NOMA.

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