A Two-step User Centric Clustering Approach for Non-Orthogonal Multiple Access in Dense Networks

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Abstract

Non-orthogonal multiple access (NOMA) provides the higher spectrum efficiency by allowing multiple users to share the same spectrum resource. Since mobile operators need to fulfill the users demand, more and more base stations are deployed densely. With the help of Coordinated Multipoint Transmission (CoMP), a base station can transform the interfering signals from the other base station to a useful signal by coordinating with each other. When NOMA is considered in CoMP environment, there will be two types of clustering; one is base station clustering for CoMP and the other is user clustering for NOMA. In this paper, a two-step user centric clustering algorithm is proposed where base stations are clustered for every cell edge users and NOMA clustering is defined in each cell later. Then, simulation is performed to show that how different threshold parameters affect the user association to base stations.

1. Introduction

Non-orthogonal Multiple Access (NOMA) has been a promising solution for higher spectrum efficiency and multi-connectivity of users. It has been standardized in 3GPP under the name of Multiuser Superposition Transmission (MUST). Since an increasing number of base stations is deployed to meet the growing user demand, networks have become very dense in certain areas. Coordinated Multi-Point Transmission (CoMP) allows us to connect multiple base stations as in Cloud Radio Access Networks (C-RAN) where a user can connect to multiple remote radio heads (RRH).

The concept and some shortcomings of NOMA are discussed in [1]. Authors in [2] discussed the challenges of NOMA and the future of NOMA coexisting with other technology. A few papers have been focused on NOMA in multi-cell environment. [3] focused on NOMA in heterogeneous networks but their interest is Multimedia Broadcast Multicast Service (MBMS). [4] proposed a grouping and cooperating among access points for NOMA with ultra-dense networks. But, in their paper, NOMA is in terms of access points which means signals from multiple access points are multiplexed on a power domain and send to a user. [5] proposed a base station clustering algorithm which takes the load balancing into account but authors defined a maximum number of users for each base station as a load balancing parameter.

In this paper, a two-step user centric clustering algorithm is proposed. User centric base station clustering is performed first for every cell edge user. The number of base stations participating in the coordination should be limited to prevent the overhead of message exchange. Thus, in this paper, only the cell edge users can utilize the CoMP with limited number of base stations to prevent this overhead. The next issue is to balance the load among base stations. To point this out, we define a threshold which takes both the received power and number of users connected to a base station into account. For NOMA clustering, we propose a random clustering with a threshold. The goal of our proposal is to reduce the message exchange while trying to balance the load between base stations.

2. System Model

A NOMA network with densely deployed base stations is considered.

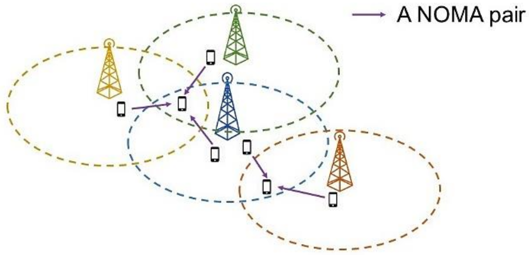

Figure 1. A NOMA network with Coordinated Transmission

Users are split into two groups, high channel gain users and low channel gain users. To prevent the overhead of message exchange, only low channel gain users are allowed to connect to multiple base stations which means they can be part of multiple NOMA clusters. The other reason why we divide the users into two groups is due to the complexity of Successive Interference Cancellation (SIC) in NOMA. Bandwidth and power are uniformly allocated to NOMA clusters.

3. Problem Formulation

The whole problem formulation is presented below.

$$\max \sum_i \sum_j \alpha_{ij}\, \omega \quad \log_2(1 + SINR_{ij})$$

s.t.

$$\sum_j \alpha_{ij} \quad \mathbb{I}(g_{ij} \le \delta) \le B$$

$$\sum_j \alpha_{ij} \quad \mathbb{I}(g_{ij} > \delta) \le 1$$

$$\sum_i \sum_k \alpha_{ij}\beta_{ik} + \alpha_{kj}\beta_{ik} \quad \le 2$$

$$\alpha_{ij} \in \{0,1\}, \beta_{ik} \in \{0,1\}$$

$$SINR_{ij} = \frac{p_l g_{ij}}{p_h g_{kj} + n_0} \text{ where } g_{ij} \le \delta$$

$$g_{kj} = \sum_m \alpha_{im}\beta_{mj} g_{mj}$$

$$SINR_{ij} = \frac{p_h g_{ij}}{n_0} \text{ where } g_{ij} > \delta$$

The objective is to maximize the sum rate of all users. α_{ij} is the user i-base station j association variable. β_{ik} is NOMA clustering variable whether user i is in the same cluster with user k or not. $\mathbb{I}(g_{ij} \le \delta)$ is the indicator function. The first constraint is for the messaging overhead where it limits the number of coordinating base station to B. So, it is associated to low channel gain users. The second constraint is for high channel gain users that they can only connect to one base station. The third constraint is for NOMA cluster where only two users are allowed in one cluster. This problem is combinatorial so we propose a user-centric clustering approach in next section. p_h and p_l are fixed power allocated to high channel gain users and low channel gain users.

4. Two-step User Centric Clustering

To cluster the base stations for each low channel gain users, users are divided into two groups according to a threshold first. Then, each base station is assigned a user specific score which is the sum of normalized received power from a specific user and load balancing parameter. For the load balancing parameter, we define a received power threshold and take the number of users whose received power is greater than that threshold. The idea is to take the users who are closely located to a base station into account.

$$g_i = \max_j \{g_{ij}\} \quad \forall i$$

The channel gains are sorted as $g_1 \ge g_2 \ge \cdots \ge g_n$.

$$\delta = \frac{g_{n/2} + g_{\frac{n}{2}+1}}{2}$$

$$\gamma = \frac{p_{ij} - \min_{i,j} p_{ij}}{\max_{i,j} p_{ij} - \min_{i,j} p_{ij}} + \left(1 - \frac{n_j - \min_j n_j}{\max_j n_j - \min_j n_j}\right)$$

where n_j is the number of users whose received power from base station j is greater than a threshold.

$$\theta = \left| g_{n/2} - g_{\frac{n}{2}+1} \right|$$

Two-Step User Centric Clustering Algorithm

```
highUEs ← users [g_i > δ]
lowUEs ← users [g_i ≤ δ]
for each users in highUEs
    assign a BS with the maximum received power
end for
for each users in lowUEs
    assign a score γ to every base stations
    assign B base stations with maximum score
end for
for each base stations
    highUEs ← users [g_i > δ]
    lowUEs ← users [g_i ≤ δ]
    for each users i in lowUEs
        select a random user k where |g_i − g_k| > θ
    end for
end for
```

5. Simulation Results

In evaluation, base stations and users follow homogeneous Poisson Point Process where base station density is $0.87/m^2$ and user density is $8.75/m^2$. Power density thermal noise is -174dBm/Hz and the long distance path loss model is used. Fig. 2 shows the simulation setup used in the paper.

Fig. 2 shows the sum rate of all users with different received power threshold which plays an important role in deciding the load balancing parameter. Since the average received power is very low, most of the users join to a particular base station. Power allocation and bandwidth are shared among users in a base station, the rate they received is quite low. As we can see in fig. 3, most of the base stations have no connected users because users try to connect to the base station when load balancing parameter is low. When a threshold that is close to the maximum is chosen, load balancing parameter becomes high. Thus, users will connect to all base stations equally which can increase the sum rate of all users. As shown in fig. 4, most of the base stations have associated users because of the load balancing parameter. Even though the total load is not balanced among base stations a lot, most of the base stations have equal load.

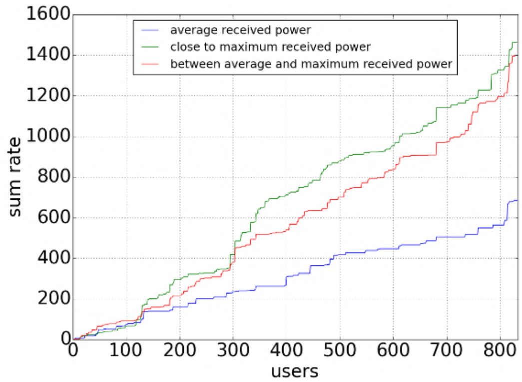

Figure 2. Comparison of sum rate over different received power thresholds

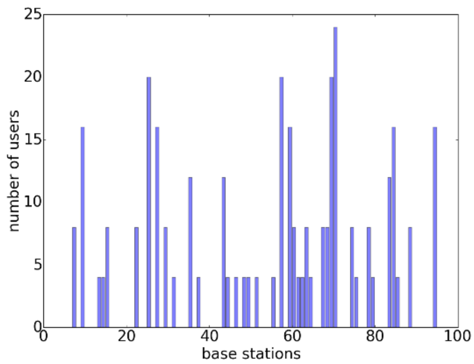

Figure 3. with average received power threshold

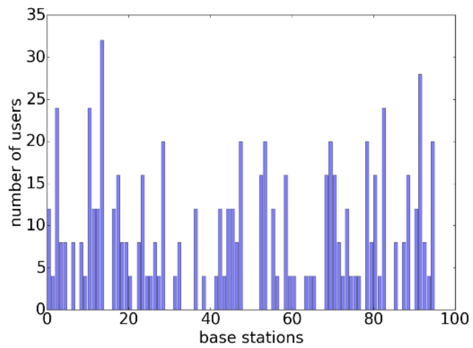

Figure 4. with a threshold which is between average and maximum received power threshold

6. Conclusion

In this paper, we proposed a two-step user centric clustering algorithm for base station clustering and NOMA users clustering. For base station clustering, we take the received power and the load balancing parameter into account. The load balancing parameter is determined by a received power threshold. For NOMA users clustering, a random clustering is performed with a threshold. Simulation results show that the received power threshold affects the user association.

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