Fuzzy Logic Based Multi-Criterion User Selection and Resource Allocation for Green Coordinated NOMA

Haiyong Zeng†, Xu Zhu*, Yufei Jiang†, Yan Zuo†, Zhongxiang Wei*, Tong Wang†

* Department of Electrical Engineering and Electronics, University of Liverpool, Liverpool, UK

† School of Electronic and Information Engineering, Harbin Institute of Technology, Shenzhen, China

Emails: zenghaiyong@stu.hit.edu.cn, xuzhu@ieee.org, jiangyufei@hit.edu.cn, zuoyan@stu.hit.edu.cn, hszwei@liverpool.ac.uk, tongwang@hit.edu.cn

***Abstract*—Combining non-orthogonal multiple access (NOMA) with coordination techniques among base stations (BSs) is a promising solution to enhance spectral efficiency and alleviate inter-cell interference of cell-edge users in 5th generation (5G) networks. In this paper, we consider a multi-cell NOMA network with coordinated BSs in the downlink, and investigate its user coordination mode selection and resource allocation to achieve a green system. A fuzzy logic (FL) based multi-criterion scheme is proposed for user coordination mode selection. It is more robust against shadowing and fading than the previous selection schemes that classify coordinated and non-coordinated users by a single criterion. Also, the FL ranking list is fed into subcarrier allocation, leading to significant reduction in searching complexity of subcarrier allocation. A dramatic performance enhancement is achieved over the previous schemes based on single-criterion, in terms of transmission power and energy efficiency.**

I. Introduction

Non-orthogonal multiple access (NOMA) [1] [2], which makes use of superior spectral efficiency by sharing the same frequency among multiple users simultaneously, has drawn considerable attention of academics and industry. Different from resource allocation strategies in orthogonal frequency division multiple (OFDM) networks [3], NOMA allocates resources by exploiting power-domain multiplexing and successive interference cancellation (SIC) techniques to allow receivers to decode and demodulate the superposition coded signals [4] [5].

The users located at edge of cells suffer from low capacity, and require more transmission power to achieve targeted data rates, at the price of high power consumption. In multi-cell networks, coordination techniques can be utilized by base stations (BSs) to jointly transmit messages to the cell-edge users. It has been proven in [6] [7] that a network with coordinated BSs can benefit from the distributed space diversity, in which multiple distributed BSs transmit signals to corresponding cell-edge users at the same time. In [7], Beylerian and Ohtsuki have proposed a coordinated NOMA scheme by introducing NOMA into coordinated BSs. It is shown that coordinated NOMA provides better performance than NOMA in non-coordinated BSs or orthogonal multiple users in coordinated BSs.

The performance of OFDM systems is heavily affected by resource allocation in terms of subcarrier (SC) and power allocation [8] [9]. In order to achieve green communication with minimum transmitted power, it is essential to determine user and coordination selection for coordinated NOMA systems [10]. At present, two single-criterion user coordination selection methods are widely used: distance based approach [9] [11] and channel gain based approach [10] [12]. In [9], an energy-efficient (EE) oriented single channel power allocation scheme for downlink coordinated NOMA networks has been proposed and the coordinated users can be selected in terms of distance. However, these approaches above are not efficient, if users suffer severe fading and shadowing. In such case, the affected users should be considered in coordinated rather than non-coordinated mode by approaches above, even if the user is close to the serving BS. As stated in [13], fuzzy logic (FL) has been applied for wireless communication areas due to its flexibility and cost-effectivity. Therefore, instead of using a single criterion, it is beneficial to employ FL based multi-criterion strategy for user and coordination mode selection.

Motivated by the above open issues, we consider a downlink multi-cell NOMA network with coordinated BSs and study the user selection, coordination mode selection and resource allocation problems under quality-of-service (QoS) requirement. The contributions of this paper are summarized as follows. First, instead of classifying users by a single criterion, such as distance and channel gain as in [9] [10], we consider a multi-criterion user coordination mode selection using FL, in terms of distance, channel gain and reference signal received power (RSRP). The proposed FL based multi-criterion selection is more robust against fading and shadowing, and enhances the effectiveness of user coordination mode selection. In addition, based on the existing FL user ranking list, a low-complexity and efficient subcarrier allocation algorithm is proposed, which requires no user ranking in subcarrier assignment process compared with the subcarrier allocation approach in [4]. Second, different from the single subchannel power allocation scheme in [9], we consider the multi-subcarrier case and provide an FL based one-step solution to coordination mode selection and user ranking for resource allocation. To the best of our knowledge, this is the first work to study the issues of user coordination mode selection, multiple subcarriers assignment and power

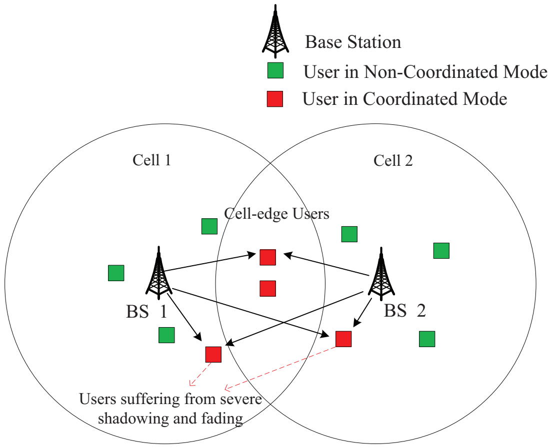

Fig. 1. System model of coordinated NOMA systems.

allocation in downlink coordinated NOMA networks, which is more practical and efficient. By transforming the non-convex power allocation problem into a convex form, a closed-form expression of optimal power allocation is derived. Simulation results show that the proposed multi-criterion method provides significantly higher EE performance than the previous single-criterion approaches in [9] and [10], while contributing to a green coordinated NOMA network with less transmission power consumption.

II. System Model and Problem Formulation

A. System Model

We consider a downlink multi-cell NOMA network with B BSs and K users. Each BS transmits signals to its serving users through N SCs. As depicted in Fig.1, for some users in the edge of cells, they may suffer from severe inter-cell interference; on the other hand, due to the effect of fading and shadowing, some users may also have poor channel conditions even if they are not located in the cell edges. In order to improve performance, these users are selected to work in coordinated mode and served by a set of coordinated BSs. The user's coordinated mode can be selected by a single criterion (*e.g.* distance or channel gain), or the FL based multi-criterion method proposed in this paper. Let K_C and K_N denote the number of coordinated and non-coordinated users, respectively.

The channel between an arbitrary user and BS is modeled as Rayleigh fading. According to NOMA principle [2], multiple users can share the same SC. Considering the set of users served by the b-th BS $(b = 1, ..., B)$ on SC n $(n = 1, ..., N)$ is denoted as $S_{n,b}$, then the symbol $m_{b,n}$ transmitted on this SC can be given by

$$m_{b,n} = \sum_{i \in S_{n,b}} \sqrt{p_{i,n}} D_{i,n}, \tag{1}$$

where $p_{i,n}$ and $D_{i,n}$ are the transmitted power and the data symbol with unit energy of user i on SC n, respectively. Therefore, the received signal at the k-th user over SC n can be written as

$$y_{k,n} = \sum_{b \in B_k} h_{b,k,n} m_{b,n} + \sum_{\tilde{b} \in \{B/B_k\}} h_{\tilde{b},k,n} m_{\tilde{b},n} + z_{k,n}, \tag{2}$$

where $h_{b,k,n}$ is the channel state information (CSI) from the b-th BS to the k-th user on SC n, which can be affected by path loss and shadowing. B_k stands for the set of coordinated BSs serving for user k. Let $z_{k,n} \sim \mathbb{C}N(0, N_0)$ be the additional white complex Gaussian noise, with mean 0 and variance N_0.

At the receiver, SIC process is conducted to decode and separate the received signals. Let us define $H_{b,k,n} = |h_{b,k,n}|^2$. Then after SIC, the received signal-to-interference-plus-noise ratio (SINR) for user k on SC n can be obtained as

$$\gamma_{k,n} = \frac{p_{k,n} \sum\limits_{b \in B_k} H_{b,k,n}}{N_0 + I_{k,n} + \varphi_{k,n}}, \tag{3}$$

where $\varphi_{k,n}$ and $I_{k,n}$ stand for the inter-cell and intra-cell interference gains, respectively.

For the users selected to be in coordinated mode, the inter-cell interference gain is $\varphi_{k,n} = 0$. Assume that the coordinated BSs have known the channel gain of users and the messages sent to user k by B_k are with the same transmit power [9]. Then the intra-cell interference gain for user k is

$$I_{k,n} = \sum_{b \in B_k} H_{b,k,n} \sum_{i \in \{S_{n,b,k}\}} p_{i,n}, \tag{4}$$

where $S_{n,b,k} = \left\{ \tilde{k} | H_{b,\tilde{k},n} > H_{b,k,n}, \tilde{k} \in S_{n,b} \right\}$.

On the other hand, for the users in non-coordinated mode, the number of serving BS B_k is one. Then, the interference gains of intra-cell $I_{k,n}$ and inter-cell $\varphi_{k,n}$ are expressed as

$$I_{k,n} = H_{B_k,k,n} \sum_{i \in \{\tilde{S}_{n,B_k,k}\}} p_{i,n}, \tag{5}$$

$$\varphi_{k,n} = \sum_{b \in \{B \setminus B_k\}} H_{b,k,n} \sum_{j \in \{S_{n,b}\}} p_{j,n}, \tag{6}$$

where $\tilde{S}_{n,B_k,k} = \left\{ \tilde{k} | H_{B_k,\tilde{k},n} > H_{B_k,k,n}, \tilde{k} \in \{S_{n,B_k} \setminus U_{n,B_k}\} \right\}$, U_{n,B_k} denotes the set of coordinated users on SC n served by B_k and other coordinated BSs. As a result, the achievable data rate to user k on SC n is given by

$$R_{k,n} = C_k \log_2(1 + \tilde{\gamma}_{k,n}) + (1 - C_k) \log_2(1 + \gamma_{k,n}), \tag{7}$$

where $C_k \in \{0, 1\}, C_k = 1$ indicates that user k is in coordinated mode, $\tilde{\gamma}_{k,n}$ and $\gamma_{k,n}$ denote the SINR of user k in coordinated and non-coordinated modes, respectively.

B. Problem Formulation

In this subsection, we dedicate to minimizing the total transmission power under certain QoS requirements. Denote $x_{k,n} \in \{0, 1\}$, in which $x_{k,n} = 1$ indicates that SC n is allocated to user k. Let $\mathbf{X} = [x_{k,n}]_{K \times N}$ and $\mathbf{P} = [p_{k,n}]_{K \times N}$ be the subcarrier assignment and power allocation matrices, respectively. Therefore, according to [2], the resource allocation problem for the downlink coordinated NOMA network can be formulated as

$$\begin{aligned} \min_{\mathbf{P},\mathbf{X}} \; & \sum_{b=1}^{B}\sum_{n=1}^{N}\left(\sum_{k\in S_{n,b}} x_{k,n}p_{n,k}\right) \\ \text{subject to} \;\; & C1: x_{k,n}\in\{0,1\}; \\ & C2: C_k\in\{0,1\}; \\ & C3: \sum_{k\in S_{n,b}} x_{k,n} = L; \\ & C4: R_{k,n}\geq R_{\min}; \\ & C5: p_{n,k}\geq 0; \end{aligned} \tag{8}$$

where $C3$ constrains the maximum number of allocated users on the same SC and $R_{\min}$ denotes the minimum rate requirement. Note that L makes a trade-off between performance and complexity. In this paper, in order to keep low complexity at the receiver and restrict the error propagation, we consider the simple situation where merely two users can be multiplexed on the same SC in each BS [5].

III. Problem Transformation and Algorithms Design

Due to the non-convex constraint of the users' rates in $C4$ and the binary integer assignment variables, the considered resource allocation problem in (8) is difficult to solve, and it is very challenging to obtain the global optimal resource allocation solution in polynomial time. To strike an attractive balance between the performance and complexity, a low-complexity solution is desirable. Hence, similar to [4], we divide (8) into several subproblems in this section to obtain a low-complexity and efficient solution.

A. User Coordination Mode Selection Based on Fuzzy Logic

Since cell-edge users usually receive heavy interference. It is significant to determine which users are in coordinated mode or non-coordinated mode. Two kinds of user coordination mode selection methods are mostly mentioned in literatures: distance based methods [9] [11] and channel gain based methods [10] [12]. The user selection methods can be expressed, respectively, as

if $d_k > d_{\text{thd}}$, user k is in coordinated mode,

if $H_k > H_{\text{thd}}$, user k is in coordinated mode,

where d_{thd} and H_{thd} are predetermined thresholds of distance and channel gain, respectively.

Nevertheless, these methods based on a threshold only divide users into coordinated and non-coordinated groups. Note that the main constraint in user coordination mode selection is the limited frequency resources. Given a large number of coordinated users, the majority of frequency resource will be assigned to the coordinated users, which decreases the performance of the non-coordinated users caused by the frequency resource constraint. Hence, the threshold should be adaptively changed when the number of coordinated users is limited; the other effective scheme is to build a ranking based user coordination selection. Based on ranking criterion (*e.g.*, distance or channel gain), users are sorted in order and some top users are chosen as coordinated users.

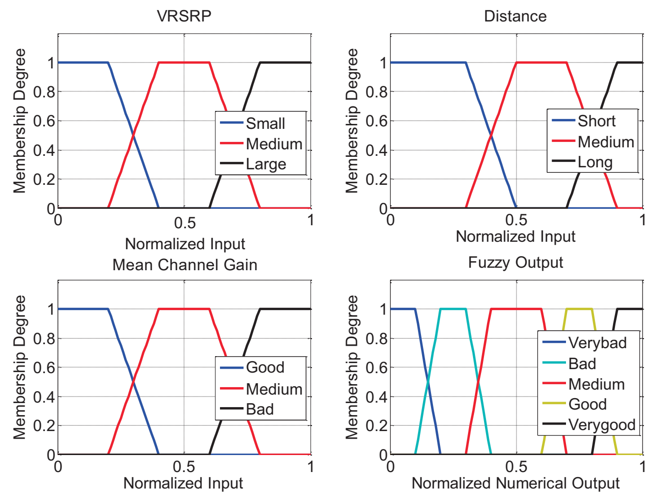

Fig. 2. Inputs and output fuzzy membership function.

As mentioned above, both the distance and channel gain are empirical criteria to sort out coordinated and non-coordinated users. However, due to fading and shadowing, the single-criterion methods cannot provide enough information in consideration of system performance, the coordination mode of users can not be selected appropriately. To overcome their drawbacks, we propose an FL based multi-criterion scheme which considers distance, channel gain and RSRP to perform user coordination mode selection.

1) Fuzzy Inputs: For each user k, there are three inputs in the proposed FL based scheme: the distance d_k, the mean channel gain $\bar{H}_k = \sum_{n=1}^{N} H_{B_k,k,n}/N$ and the standard deviation of reference signal received power (VRSRP):

$$VRSRP_k = E\left[\left(RSRP_k^{B_k} - \overline{RSRP_k}\right)^2\right], \tag{9}$$

where $RSRP_k^{B_k}$ denotes the RSRP of user k from serving BS B_k, and $\overline{RSRP_k}$ is the mean value of RSRPs from user k's potential coordinated cells. User with lower VRSRP is more likely to be chosen in coordinated mode.

2) Fuzzification and Defuzzification Processes: The FL membership functions of inputs and output are presented in Fig. 2 and we choose the Trapezoidal function to generate membership function [13]. As presented in Table I, we formulate 27 FL rules to map inputs to output. Since FL rules are set by AND logic, the membership of FL output set obtained by taking the minimum value of the inputs

$$\mu_o \triangleq \min\left(\mu_X, \mu_Y, \mu_Z\right), \tag{10}$$

where μ_X, μ_Y and μ_Z denote the degree of membership of VRSRP, distance and mean channel gain, respectively. The FL output indicates users' suitability for the coordinated mode in consideration of all three inputs. Then we utilize the weighted average defuzzification method [13] to transform

TABLE I
COORDINATION SUITABILITY LIST

	Criteria			Coordination Suitability
No.	VRSRP	D	Mean Channel Gain	
1	small	short	bad	medium
2	small	short	medium	bad
3	small	short	good	very bad
4	small	medium	bad	good
5	small	medium	medium	medium
6	small	medium	good	medium
7	small	large	bad	very good
8	small	large	medium	very good
9	small	large	good	good
10	medium	short	bad	medium
11	medium	short	medium	bad
12	medium	short	good	very bad
13	medium	medium	bad	good
14	medium	medium	medium	medium
15	medium	medium	good	bad
16	medium	large	bad	very good
17	medium	large	medium	good
18	medium	large	good	medium
19	large	short	bad	bad
20	large	short	medium	bad
21	large	short	good	very bad
22	large	medium	bad	medium
23	large	medium	medium	bad
24	large	medium	good	very bad
25	large	large	bad	good
26	large	large	medium	medium
27	large	large	good	bad

the aggregated output set μ_o into a crisp number. The crisp number, which ranges from 0 to 1, is

$$\eta = \frac{\sum\left(\mu_o \cdot O_M(\mu_o)\right)}{\sum \mu_o}, \tag{11}$$

where $O_M(\mu_o)$ denotes the middle value of the normalized numerical value of output membership μ_o and the user with larger η has more probability to be chosen in the coordinated mode. Then, we take η as the ranking criterion for user mode selection, and form the FL output ranking list Γ_{FL} by sorting users in descending order based on η. After the FL based user coordination mode selection, we choose the top K_C users in Γ_{FL} as coordinated users.

B. FL Ranking List Based Subcarrier Allocation Algorithm

In this subsection, considering the users with high coordination suitability, we propose a low-complexity subcarrier allocation algorithm based on the existing FL user ranking order Γ_{FL}. As mentioned in Section II, due to the complexity of decoding in SIC, we consider that merely two users can be allocated on the same SC for each BS. Following [5], we assume the number of users served by each BS is $M = 2N$, and the number of coordinated users is $K_C = N$. For each BS, the N coordinated users are taken as weak users for their poor channel conditions while the non-coordinated users are treated as strong users.

We first concentrate on subcarrier allocation for coordinated users. The subcarrier allocation procedures can be briefly described as follows: First, for all coordinated users, we form a $K_C \times N$ candidate list Pr_C based on $\sum\limits_{b\in B_k} H_{(b,k,n)}$. Then, we dedicate to allocating SCs to coordinated users based on the FL ranking list. Notice that if a user has higher coordination suitability, it is more likely to be chosen in coordinated mode. Hence, we consider the users with high coordination suitability and allocate SCs to coordinated users in turn from the top of Γ_{FL}. The detailed procedures are presented in Algorithm 1. Repeat the step above until all N SCs and all K_C coordinated users are allocated.

Algorithm 1 Low-Complexity and Efficient Subcarrier Allocation for Coordinated Users Based on FL Ranking List

Initialization: Given FL ranking list Γ_{FL}, for all K_C coordinated users, sort N SCs for each user in descending order according to $\sum\limits_{b\in B_k} H_{(b,k,n)}$ and put them in a $K_C \times N$ candidate list Pr_C;
while all of N SCs and K_C coordinated users have not been allocated **do**
From the top of the FL user ranking list Γ_{FL}, each user (*e.g.* user k) selects the first SC (*e.g.* SC n) on the k-th row of candidate list Pr_C;
if SC n has not been allocated yet, user k chooses it as the candidate SC;
else if this SC has been allocated to other user, then 1) SC n compares the two users' channel gains, selects the user with higher channel gain and rejects the other user; 2) the rejected user removes SC n from its candidate list;
end if
end while

After the coordinated users have been allocated, we perform the subcarrier allocation for non-coordinated users in each cell separately. Notice that each non-coordinated user is served by its serving BS, let us define the number of non-coordinated users served by each BS as $K_{N_b} = N, b = 1, 2, ..., B$. For the b-th cell, we first form a $K_{N_b} \times N$ candidate list Pr_N for all non-coordinated users in cell b. Then, we allocate SCs to non-coordinated users in turn based on Γ_{FL}, which is similar to Algorithm 1. Repeat the process above until all N SCs are allocated and all K_{N_b} non-coordinated users are selected.

C. Power Allocation

After subcarrier assignment, the resource allocation problem can be reformulated as

$$\min_{\mathbf{P}\succ\mathbf{0}} \sum_{b=1}^{B}\sum_{n=1}^{N}\left(\sum_{k\in S_{n,b}} p_{k,n}\right) \tag{12}$$

$$\text{subject to } C3: R_{k,n} \geq R_{\min}.$$

Notice that the data rate $R_{k,n}$ in (7) can be rewritten as

$$p_{k,n}\sum_{b\in B_k} H_{(b,k,n)} + \left(N_0 + \sum_{b\in B_k} H_{(b,k,n)} \sum_{i\in\{S_{(n,b,k)}\}} p_{i,n} + \sum_{b\in\{B\setminus B_k\}} H_{(b,k,n)} \sum_{i\in\{S_{n,b}\}} p_{i,n}\right)\left(1 - 2^{R_{\min}}\right) \geq 0, \tag{13}$$

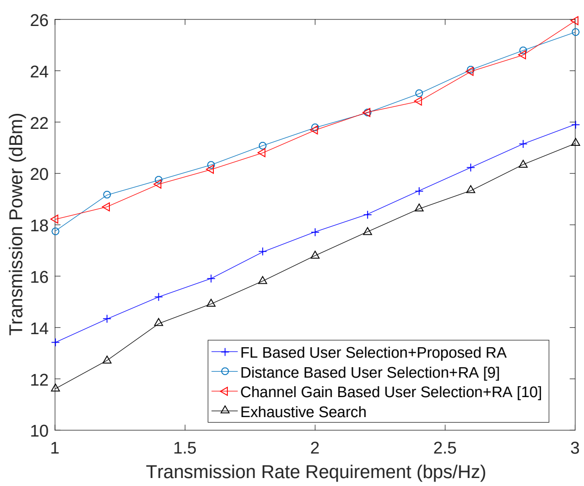

Fig. 3. Transmission power consumption performance for green coordinated NOMA systems under minimum rate requirement ($K = 9$).

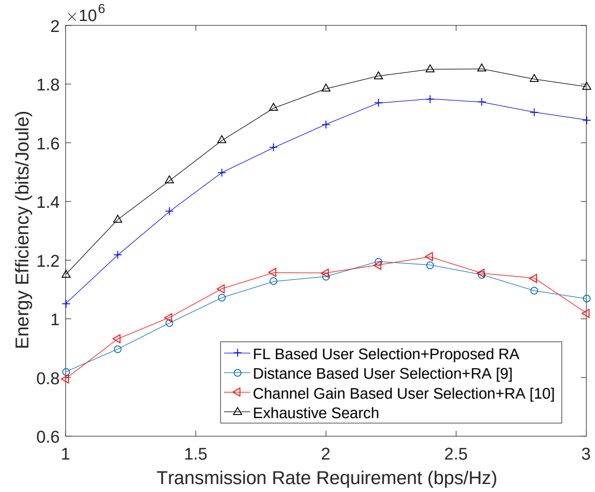

Fig. 4. EE performance for green coordinated NOMA systems under minimum rate requirement ($K = 9$).

which is a linear function with respect to $\mathbf{P_n}$ to be assigned on SC n. Therefore, problem (12) can be further transformed into

$$\min_{\mathbf{P}\succ\mathbf{0}} \sum_{b=1}^{B}\sum_{n=1}^{N}\left(\sum_{k\in S_{n,b}} p_{n,k}\right) \tag{14}$$
$$\text{subject to (13)},$$

which is a convex problem. We then attempt to derive the optimal solution by Karush-Kuhn-Tucker (KKT) conditions.

Since the channel gain in this paper is modeded as Rayleigh block fading, we consider a single subcarrier scenario. As stated above, the coordinated users are served by all coordinated BSs. For each SC, the number of non-coordinated users in all BSs is $K_n = B$. Define the coordinated user on SC n as user j. Then the Lagrange function for SC n can be written as

$$L(\mathbf{P_n},\lambda)=\sum_{b=1}^{B}\left(\sum_{k\in S_{n,b}} p_{n,k}\right)+\sum_{k=1}^{K_n}\lambda_k\left(R_{k,n}-R_{\min}\right), \tag{15}$$

where λ_k, for $k = 1, ..., K_n$, is a non-zero Lagrange multiplier. Denote $\mathbf{P}=[\mathbf{P_1}...\mathbf{P_n}...\mathbf{P_N}]^T$, $\mathbf{P_n}=[(p_{1,n})...(p_{K_n,n})\ (p_{j,n})]^T$, $\mathbf{Q} = [(-aN_0)...(-aN_0)\ \ (-aN_0)]^T$, with $a = 1 - 2^{R_{\min}}$.

Substituting $R_{k,n}$ into (15) and according to the KKT conditions, we have

$$\mathbf{A_n P_n} - \mathbf{Q} = \mathbf{0}, \tag{16}$$

where $\mathbf{A_n}$ is a square matrix.

$$\mathbf{A_n}=\begin{bmatrix} H_{1,1,n} & ... & aH_{b,1,n} & ... & aH_{B,1,n} & a\sum\limits_{i=2}^{B} H_{i,1,n} \\ ... & & & & & \\ aH_{1,K_n,n} & ... & aH_{b,K_n,n} & ... & H_{B,K_n,n} & a\sum\limits_{i=1,i\neq K_n}^{B} H_{i,K_n,n} \\ aH_{1,j,n} & ... & aH_{b,j,n} & ... & aH_{B,j,n} & \sum\limits_{i=1}^{B} H_{i,j,n} \end{bmatrix}$$

The solution of $\mathbf{P_n}$ can be obtained as

$$\mathbf{P_n^*} = [p_{1,n}{}^* \ ... \ p_{K_n,n}{}^* \quad p_{j,n}{}^*]^T = \mathbf{A}_n{}^{-1}\mathbf{Q}. \tag{17}$$

Hence, the closed-form solution to the optimal power allocation is given by

$$\mathbf{P}^* = \left[\mathbf{A_1}^{-1}\mathbf{Q} \ ... \ \mathbf{A_n}^{-1}\mathbf{Q} \ ... \ \mathbf{A_N}^{-1}\mathbf{Q}\right]^T. \tag{18}$$

IV. Numerical Results and Analyses

In this section, numerical results are presented to evaluate the performance of our proposed FL based user coordination mode selection and resource allocation algorithms for green coordinated NOMA systems. The number of BS is 2 and the radius for each cell is set as 500 m. The number of users is K and the subcarrier signal of each user independently suffers from Rayleigh fading ($\mathbb{C}N(0,1)$). The circuit power is set to 20 dBm [1], the noise spectral density is -174 dBm/Hz. In addition, the settings of other parameters are as follows: the subcarrier interval is set to 15 kHz, the shadowing standard deviation is 10 dB, and the path loss model is given as a function of distance d: $PL(d) = 38.4 + 35\log_{10}(d)$ [14].

Firstly, in order to compare the performance of our proposed algorithms with exhaustive search method, we set a small number of users as $K = 9$. As can be seen from Fig. 3 and Fig. 4, the performance of our proposed scheme gets close to the exhaustive search when the number of users is small, in terms of transmission power consumption and EE. In addition, the proposed FL based user coordination selection and resource allocation algorithms are substantially better than the traditional single-criterion based schemes. For example, when the minimum rate requirement of all users is $R_{\min} = 1$ bps/Hz, the proposed FL based method transmits 22% less power than that of traditional single-criterion based algorithms, and the FL based algorithms provide 31% higher EE than that of single-criterion based schemes. The gap of EE becomes larger as $R_{\min}$ increases. The reason is that the FL based user coordination selection has considered three

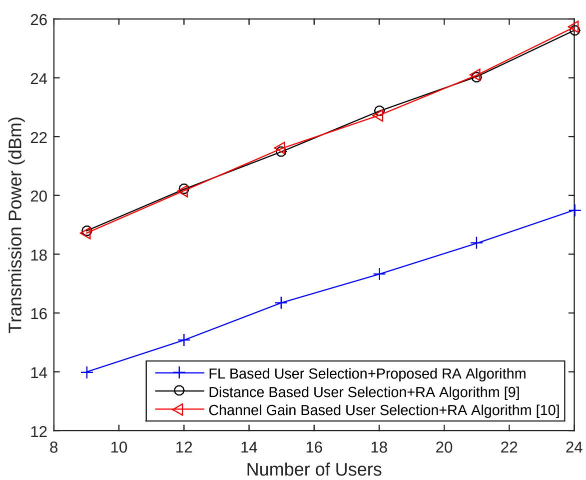

Fig. 5. Impact of the number of users on transmission power consumption performance of the green coordinated NOMA system with $R_{\min} = 1$ bps/Hz.

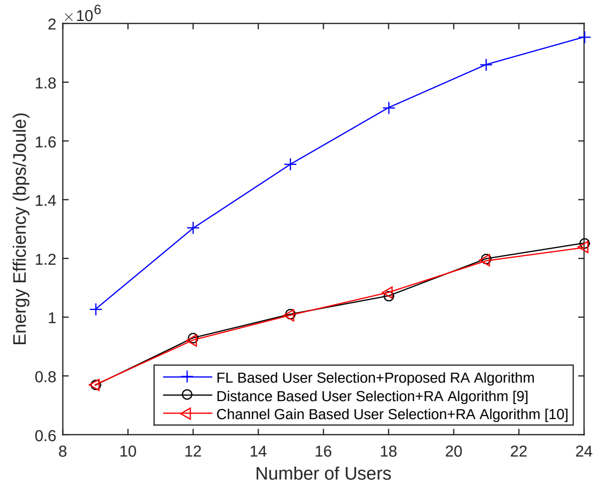

Fig. 6. Impact of the number of users on energy efficiency of the green coordinated NOMA system with $R_{\min} = 1$ bps/Hz.

input parameters including distance, channel gain and VRSRP, which overcomes the drawbacks of the user selection methods based on only a single criterion and improve the network performance.

Then, we compare the transmission power consumption and EE versus the number of users K, with the minimum rate requirement $R_{\min} = 1$ bps/Hz. It can be learned from Fig. 5 and Fig. 6 that the FL based user selection scheme substantially outperforms the single-criterion based methods. When the number of users is 12, the proposed FL based scheme has 25% lower transmission power and 40% EE improvement than the single-criterion based methods.

For the proposed FL based user selection algorithm, according to [13], the complexity is in the order of $9N^2$. Although FL based user selection requires slightly higher complexity than the single-criterion based methods, they have the same complexity order. Moreover, the complexity of the traditional single-criterion based subcarrier allocation algorithms in [4] is in the order of N^3. While the proposed subcarrier allocation algorithm utilizes the existing FL user ranking list and requires no user ranking in the process of subcarrier allocation. Therefore, it has much less complexity than the single-criterion based schemes.

V. Conclusions

In this paper, we have investigated a coordinated NOMA network, and proposed an FL based multi-criterion user coordination mode selection scheme based on distance, channel gain and VRSRP, as well as a low-complexity and effective subcarrier allocation algorithm exploiting the existing FL user ranking list. The FL based scheme achieves transmission power reduction of around 20% and EE enhancement of more than 30% over the single-criterion based user selection schemes [9][10], thus leading to a green coordinated NOMA network.

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