Weighted Sum Rate Maximization for NOMA-Based UAV Networks

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Abstract. The unmanned aerial vehicle (UAV) based aerial base station (BS) has emerged as a feasible solution to the high traffic demands of the future wireless networks. It is essential that UAV can integrat with non-orthogonal multiple access (NOMA) to support the massive connection service. In this paper, we study the problem of weighted sum rate maximization in the downlink for NOMA-based UAV networks. This is a non-convex optimization problem, which is intractable to be directly solved using the convex optimization method. To deal with the problem, we propose an efficient iterative algorithm via variable substitution and relaxation methods, then construct the framework of alternating optimization to solve the problem joint placement and power allocation optimization. The simulation results show that the proposed algorithm performs better than other schemes.

Keywords: Unmanned aerial vehicle · Non-orthogonal multiple access · Power allocation · Placement optimization · Weighted sum rate

1 Introduction

To satisfy the communication service requirements of 5G networks, non-orthogonal multiple access (NOMA) is proposed to support large-scale access capability and highly efficient spectrum utilization in [1]. The unmanned aerial vehicle (UAV) has swift and flexible with good channel conditions in [2]. Therefore, the UAV as a base station (BS) can achieve better communication performance. The communication network of UAV is being studied to meet the ubiquitous services that are not provided to ground users in crowded or remote areas. The authors in [3] proposed a coverage plan for multiple UAVs to maximize the average capacity of multiple UAVs, while ensuring that the UAV can

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cover the ground users on a large scale. In [4], the author considered multi-UAV wireless network and focused on improving energy efficiency through subchannel assignment and power allocation. Specifically, a NOMA scheme for the power domain of energy-efficient UAV base stations was studied to make better use of limited spectrum resources in [5,6]. Since 5G network will be ultra-dense and heavy-loaded [1], the design of admission control is essential to deal with the infeasibility [7] , and to determine the set of users whose quality-of-service (QoS) requirements can be protected at the same time. The work [8,9] studied how to use NOMA to pair users into each sub-channel, and then maximize the sum rate of the networks. In [10], the scheme for communication with ground users was investigated by trajectory optimization. [11] considered the one-dimensional trajectory optimization of UAVs to maximize energy transmission, where the distribution of users is a linear topology.

So far, for the sake of maximizing the sum rate of users, some works has been done on the placement and power allocation of UAV networks. In [12], jointly optimization of the placement and power allocation of the UAV is a non-convex problem. Firstly, the UAV is deployed at the user's geometric center location, and then the power allocation optimization of UAV is based on Karush-Kuhn-Tucker (KKT) conditions [13]. However,the geometric center locations is suboptimal and the fairness among users is not considered in [12]. Based on this as a motivation, we consider to investigate the weighted sum rate maximization problem for NOMA-based UAV networks. Due to the non-convexity of joint optimization of position and power allocation, it is difficult to solve directly with existing algorithms. We utilize an alternative optimization method to solve the problem of maximizing weighted sum rate. Simulation results show that the proposed algorithm outperform the scheme in In [12].

The remainder of this paper is organized as follows. Section 2 presents the system model of the UAV networks, and formulates the downlink weighted sum rate maximization. Section 3 considers the method of variable substitution and presents the optimal solution to the relaxed problem. In this section, an alternative optimization algorithm is proposed to yield a near-optimal solution to the decoupled problem. Section 4 provides numerical results to validate the effectiveness of our proposed designs. Finally, Section 5 concludes this paper.

2 System Model and Problem Formulation

2.1 System Model

We consider a single antenna UAV in a downlink communication network system. The UAV is deployed at the height of H and sends information to multiple single-antenna users simultaneously. The number of ground users is K. The horizontal position of UAV and ground user i is expressed as (X, Y) and (x_i, y_i), $i = 1, ..., K$, respectively. For simplicity, we assume that the path loss satisfies line-of-sight (LoS) from a single antenna UAV to ground user. UAV sends broadcast information to K users on the ground. Without loss of generality assumption at the same time, the channels are sorted as

$$|h_K|^2 \geq ... \geq |h_k|^2 \geq ... \geq |h_1|^2 \geq 0. \tag{1}$$

$$P_t{}^{[k]} = P_{\text{total}} a_k, a_k \geq 0. \tag{2}$$

where $P_t{}^{[k]}$ are allocated power for the k-th user, P_{total} is the maximum transmit power of the UAV, and a_k is the allocated power coefficient of the k-th user, h_k represents the channel gain from the UAV to the k-th user. The power allocation coefficient of UAV needs to satisfy the following relationship.

$$\sum_{k=1}^{K} a_k = 1. \tag{3}$$

We assume that the channel model from UAV to the ground user k is given by the following path loss model [12]

$$L^{[k]}{}_{Los} = 20\log_{10}(4\pi f_c d_k/c) + \eta_{Los}, k = 1, 2, ..., K. \tag{4}$$

where f_c is the carrier frequency, and d_k is the distance between the UAV and the k-th user, i.e.

$$d_k = \sqrt{H^2 + (X - x_k)^2 + (Y - y_k)^2}. \tag{5}$$

According to the above formula (4) and (5), the received power of the ground k-th user can be obtained as

$$P_r{}^{[k]} = 10\log_{10} P_t{}^{[k]} - L_{Los}{}^{[k]}. \tag{6}$$

The power $P_t{}^{[k]}$ is transmitted from the UAV to k-th user, and the received power $P_r{}^{[k]}$ of k-th user can be known. Therefore, the channel power gain expression of the UAV to the k-th user can be given as follows.

$$|h_k|^2 = \frac{\beta}{d_k^2}. \tag{7}$$

$$\beta = (\frac{c}{4\pi f_c})^2 \frac{1}{(\eta_{Los})_{dB}} \tag{8}$$

where β denotes the channels power gain at a reference distance of d=1m, i.e. The UAV use NOMA protocol to broadcast the information to all the ground users. The transmit signal at UAV is given by $s = \sum_{j=1}^{K} s_j$, where s_j is transmission information from UAV to user j such that $E|s_j|^2 = P_t^{[j]} = P_{total} a_j$. The information received by ground k-th user can be given by

$$y_k = h_k s_k + h_k \sum\nolimits_{j=1, j\neq k}^{K} s_j + n_k. \tag{9}$$

where n_k represents the additive zero-mean Gaussian noise with variance σ^2. According to the successive interference cancellation (SIC) technology of NOMA, the signal-to-interference-plus-noise-ratio (SINR) of the ground k-th user can be obtained as

$$\mathrm{SINR_k} = \frac{P_{total}|h_k|^2 a_k}{P_{total}|h_k|^2 \sum\limits_{j=k+1}^{K} a_j + \sigma^2}. \tag{10}$$

where we have defined $\sum\limits_{j=K+1}^{K} a_j = 0$ to simplify the SINR expression or user K when k equals K. Therefore, the achievable rate for k-th user is given by

$$R_k = \log(1 + \frac{P_{total}|h_k|^2 a_k}{P_{total}|h_k|^2 \sum\limits_{j=k+1}^{K} a_j + \sigma^2}). \tag{11}$$

2.2 Problem Formulation

Given the total power of the UAV, in order to consider the fairness [14] of the information received by the ground users, our goal is to maximize the weighted sum rate of the ground users [15]. We need to optimize the placement and power allocation of UAV jointly [16]. Therefore, the weighted sum rate maximization problem can be written as the following problem.

$$\begin{aligned}
&(\mathrm{P1}): \underset{a_k,X,Y}{\text{maximize}} \sum_{k=1}^{K} w_k \log(1 + \frac{P_{total}|h_k|^2 a_k}{P_{total}|h_k|^2 \sum\limits_{j=k+1}^{K} a_j + \sigma^2}) \\
&\quad \text{s.t.}\ \ C1: \sum_{k=1}^{K} a_k = 1, a_k \geq 0, \\
&\quad\quad\quad C2: (X - x_{k+1})^2 + (Y - y_{k+1})^2 \\
&\quad\quad\quad\quad \leq (X - x_k)^2 + (Y - y_k)^2, \\
&\quad\quad\quad\quad k = 1, ..., K-1, \\
&\quad\quad\quad C3: \log\left(1 + \frac{P_{total}|h_k|^2 a_k}{P_{total}|h_k|^2 \sum\limits_{j=k+1}^{K} a_j + \sigma^2}\right) \geq r_k^{\min}, k = 1, ..., K, \\
&\quad\quad\quad C4: \min\{x_i\} \leq X \leq \max\{x_i\}, 1 \leq i \leq K, \\
&\quad\quad\quad C5: \min\{y_j\} \leq Y \leq \max\{y_j\}, 1 \leq j \leq K.
\end{aligned} \tag{12}$$

where w_k is weighted factor for user k to express the fairness among users for rate allocation. where C1 is the maximum transmit power constraint for the UAV and the non-negative constraint transmit power for the $k-th$ user, C2 is channel gain order for users such that user k can decoding all the user j such that $k > j$, C3 represents the minimum transmission rate requirement from the UAV to the k-th user, C4 and C5 represent the level of the UAV flight regional restrictions. It is observed from the problem formulation that the objective function is not convex with respect to the joint variables of power allocation coefficient a_k, $k = 1, ..., K$ and UAV's coordinate (X, Y). Therefore, problem (P1) is a non-convex optimization problem. Next, we will solve problem (P1) by decoupling the variable of UAV's coordination and user's power allocation with block coordinate descent (BCD) algorithm.

3 Joint Transmit Power and Placement Optimization

First, we introduce auxiliary variables $R_k = \log(1 + \frac{P_{total}|h_k|^2 a_k}{P_{total}|h_k|^2 \sum_{j=k+1}^{K} a_j + \sigma^2})$, $k = 1, \cdots, K$ to problem (P1), the weighted sum rate problem (P1) is equivalent to the following problem.

$$
\begin{aligned}
(\text{P2}) : & \underset{a_k, X, Y, R_k}{\text{maximize}} \sum_{k=1}^{K} w_k R_k \\
\text{s.t.} \quad & C1 : \sum_{k=1}^{K} a_k = 1, a_k \geq 0, \\
& C2 : (X - x_{k+1})^2 + (Y - y_{k+1})^2 \\
& \quad \leq (X - x_k)^2 + (Y - y_k)^2, \\
& \quad k = 1, \cdots, K-1, \\
& C3 : \log\left(1 + \frac{P_{total}|h_k|^2 a_k}{P_{total}|h_k|^2 \sum_{j=k+1}^{K} a_j + \sigma^2}\right) \geq r_k^{\min}, k = 1, ..., K, \\
& C4 : \log\left(1 + \frac{P_{total}|h_k|^2 a_k}{P_{total}|h_k|^2 \sum_{j=k+1}^{K} a_j + \sigma^2}\right) \geq R_k, k = 1, ..., K, \\
& C5 : \min\{x_i\} \leq X \leq \max\{x_i\}, 1 \leq i \leq K, \\
& C6 : \min\{y_j\} \leq Y \leq \max\{y_j\}, 1 \leq j \leq K.
\end{aligned}
\tag{13}
$$

where we have rewritten the equality constraints $R_k = \log(1 + \frac{P_{total}|h_k|^2 a_k}{P_{total}|h_k|^2 \sum_{j=k+1}^{K} a_j + \sigma^2}), k = 1, \cdots, K$ by inequality constraints $\log(1 + \frac{P_{total}|h_k|^2 a_k}{P_{total}|h_k|^2 \sum_{j=k+1}^{K} a_j + \sigma^2}) \geq R_k, k = 1, \cdots, K$ in C4 for (P2) because the objective function in (P2) is a monotonically increasing function with R_k. Therefore, the optimal solution to (P2) will satisfy the equality constraints $R_k = \log(1 + \frac{P_{total}|h_k|^2 a_k}{P_{total}|h_k|^2 \sum_{j=k+1}^{K} a_j + \sigma^2}), k = 1, \cdots, K$. Thus, problem (P2) has the same optimal solution with problem (P1).

Even the object function of (P2) is linear function, problem (P2) is still a non-convex optimization problem due to non-convex constraints C3 and C4. Next, we utilize variable substitution and relaxation method to handle the non-convex constraints. We further decompose problem (P2) into two subproblems by optimizing the placement and power allocation of the UAV separately.

Introduce auxiliary variables $u_k, k = 1, \cdots, K$ to problem (P2), such that u_k satisfies the following equation.

$$\frac{P_{total}|h_k|^2 a_k}{P_{total}|h_k|^2 \sum\limits_{j=k+1}^{K} a_j + \sigma^2} = \mathrm{e}^{u_k}, k = 1, \cdots, K. \tag{14}$$

Substitute (14) into problem (P2), and use the monotonicity of the original problem (P2) with respect to R_k and $R_k = \log(1 + \mathrm{e}^{\mathrm{u_k}})$. Then we can relax equation (14) into

$$\frac{P_{total}|h_k|^2 a_k}{P_{total}|h_k|^2 \sum\limits_{j=k+1}^{K} a_j + \sigma^2} \geq \mathrm{e}^{u_k}, k = 1, \cdots, K. \tag{15}$$

As $R_k = \log(1+\mathrm{e}^{\mathrm{u_k}})$ can be viewed as an increasing function of u_k, and problem (P2) can be recast as the following equivalent problem

$$\begin{aligned}
&(\text{P3}) : \underset{a_k, X, Y, R_k, u_k}{\text{maximize}} \sum_{k=1}^{K} w_k R_k \\
&\text{s.t.} \quad C1 : \sum_{k=1}^{K} a_k = 1, a_k \geq 0, \\
&\qquad C2 : (X - x_{k+1})^2 + (Y - y_{k+1})^2 \\
&\qquad\quad \leq (X - x_k)^2 + (Y - y_k)^2, \\
&\qquad\quad k = 1, ..., K - 1, \\
&\qquad C3 : \log\left(1 + \mathrm{e}^{u_k}\right) \geq r_k^{\min}, k = 1, ..., K, \\
&\qquad C4 : \log\left(1 + \mathrm{e}^{u_k}\right) \geq R_k, k = 1, ..., K, \\
&\qquad C5 : \frac{P_{total}|h_k|^2 a_k}{P_{total}|h_k|^2 \sum\limits_{j=k+1}^{K} a_j + \sigma^2} \geq \mathrm{e}^{u_k}, \\
&\qquad C6 : \min\{x_i\} \leq X \leq \max\{x_i\}, 1 \leq i \leq K, \\
&\qquad C7 : \min\{y_j\} \leq Y \leq \max\{y_j\}, 1 \leq j \leq K.
\end{aligned} \tag{16}$$

Next,we introduce a new variable substitution s_k, such that $e^{s_k} = P_{total} a_k, k = 1, ..., K$, is brought into the constraints C1 and C5. Based on the above expressions, problem (P3) is equivalent to

$$
\begin{aligned}
(\text{P4}):\ & \underset{X,Y,R_k,u_k,s_k}{\text{maximize}} \sum_{k=1}^{K} w_k R_k \\
\text{s.t.}\quad & C1: \sum_{k=1}^{K} \mathrm{e}^{s_k} \le P_{total}, \\
& C2: (X - x_{k+1})^2 + (Y - y_{k+1})^2 \\
& \quad \le (X - x_k)^2 + (Y - y_k)^2, \\
& \quad k = 1, ..., K-1, \\
& C3: \log\left(1 + \mathrm{e}^{u_k}\right) \ge r_k^{\min}, k = 1, ..., K, \\
& C4: \log\left(1 + \mathrm{e}^{u_k}\right) \ge R_k, k = 1, ..., K, \\
& C5: \frac{\mathrm{e}^{s_k} |h_k|^2}{|h_k|^2 \sum\limits_{j=k+1}^{K} \mathrm{e}^{s_j} + \sigma^2} \ge \mathrm{e}^{u_k}, k = 1, ..., K \\
& C6: \min\{x_i\} \le X \le \max\{x_i\}, 1 \le i \le K, \\
& C7: \min\{y_j\} \le Y \le \max\{y_j\}, 1 \le j \le K.
\end{aligned} \tag{17}
$$

So far, constraints C4 and C5 are still non-convex. Next, we will convert the non-convex constraints C4-C5 into a form of convex constraints. For the constraint C3, the left-hand side is convex, and the right-hand side is constant. Constraint C3 can be rewritten as

$$
\begin{aligned}
& 1 + \mathrm{e}^{u_k} \ge \mathrm{e}^{r_k^{\min}}, \\
& u_k \ge \log\left(\mathrm{e}^{r_k^{\min}} - 1\right), k = 1, \cdots, K.
\end{aligned} \tag{18}
$$

Therefore, C3 are convex constraints because they can be rewritten as $u_k \ge \log\left(\mathrm{e}^{r_k^{\min}} - 1\right), k = 1, \cdots, K$. For constrain C4, it can be transformed as the following form by relaxtion.

$$
\begin{aligned}
& \log(1 + e^{u_k}) \ge \log(e^{u_k}) \ge R_k, k = 1, \cdots, K, \\
& u_k \ge R_k.
\end{aligned} \tag{19}
$$

Make the constraint C5 id equivalant to the following mathematical transformation.

$$
\begin{aligned}
& \frac{\mathrm{e}^{s_k} \frac{\beta}{H^2 + (X - x_k)^2 + (Y - y_k)^2}}{\frac{\beta}{H^2 + (X - x_k)^2 + (Y - y_k)^2} \sum\limits_{j=k+1}^{K} \mathrm{e}^{s_j} + \sigma^2} \ge \mathrm{e}^{u_k} \Leftrightarrow \\
& \frac{\mathrm{e}^{u_k} \left(\frac{\beta}{H^2 + (X - x_k)^2 + (Y - y_k)^2} \sum\limits_{j=k+1}^{K} \mathrm{e}^{s_j} + \sigma^2 \right)}{\mathrm{e}^{s_k} \frac{\beta}{H^2 + (X - x_k)^2 + (Y - y_k)^2}} \le 1 \Leftrightarrow
\end{aligned} \tag{20}
$$

Constrain C2 can be transformed into the equivalent linear constraint in (21) by expanding the equations on both sides , and canceling out the quadratic term X^2 and Y^2.

$$
\begin{aligned}
& (X - x_k)^2 + (Y - y_k)^2 \le (X - x_{k+1})^2 + (Y - y_{k+1})^2, \\
& 2Xx_k + 2Yy_k - 2Xx_{k-1} - 2Yy_{k-1} \\
& \le x_k^2 + y_k^2 - x_{k-1}^2 - y_{k-1}^2, \\
& k = 2, \cdots, K.
\end{aligned} \tag{21}
$$

According to a series of treatment of the above problems, the problem (P4) is reformulated as the following problem (P5).

$$
\begin{aligned}
&(\text{P5}): \underset{X,Y,R_k,u_k,s_k}{\text{maximize}} \sum_{k=1}^{K} w_k R_k \\
&\text{s.t.} \quad C1: \sum_{k=1}^{K} \mathrm{e}^{s_k} \le P_{total}, \\
&\qquad C2: 2Xx_k + 2Yy_k - 2Xx_{k-1} - 2Yy_{k-1} \\
&\qquad\quad \le x_k^2 + y_k^2 - x_{k-1}^2 - y_{k-1}^2, \\
&\qquad\quad k = 2, \cdots, K, \\
&\qquad C3: u_k \ge \log\left(\mathrm{e}^{r_k^{\min}} - 1\right), k = 1, ..., K, \\
&\qquad C4: u_k \ge R_k, k = 1, ..., K, \\
&\qquad C5: \frac{\mathrm{e}^{u_k}\left(\sum_{j=k+1}^{K} \mathrm{e}^{s_j} + \sigma^2 \frac{H^2 + (X-x_k)^2 + (Y-y_k)^2}{\beta}\right)}{\mathrm{e}^{s_k}} \le 1, k = 1, ..., K, \\
&\qquad C6: \min\{x_i\} \le X \le \max\{x_i\}, 1 \le i \le K, \\
&\qquad C7: \min\{y_j\} \le Y \le \max\{y_j\}, 1 \le j \le K.
\end{aligned} \tag{22}
$$

Next, we will give a joint placement and power allocation optimization algorithm to problem (P5).

3.1 Placement Optimization for the UAV

Based on the analysis of the above formula, we first fix the variables u, R, s in (P5) and update the placement coordinates (X, Y) of UAV by problem (P6). The objective function of problem (P6) is indepent of variable (X, Y), but the constraint set is convex. We can use the convex solver (CVX) to find a feasible UAV position, and update the UAV position.

$$
\begin{aligned}
&(\text{P6}): \underset{X,Y}{\text{maximize}} \sum_{k=1}^{K} w_k R_k \\
&\text{s.t.} \quad C1: 2Xx_k + 2Yy_k - 2Xx_{k-1} - 2Yy_{k-1} \\
&\qquad\quad \le x_k^2 + y_k^2 - x_{k-1}^2 - y_{k-1}^2, \\
&\qquad\quad k = 2, \cdots, K, \\
&\qquad C2: \log\left(\frac{\mathrm{e}^{u_k}\left(\sum_{j=k+1}^{K} \mathrm{e}^{s_j} + \sigma^2 \frac{H^2 + (X-x_k)^2 + (Y-y_k)^2}{\beta}\right)}{\mathrm{e}^{s_k}}\right) \le 0, \\
&\qquad C3: \min\{x_i\} \le X \le \max\{x_i\}, 1 \le i \le K, \\
&\qquad C4: \min\{y_j\} \le Y \le \max\{y_j\}, 1 \le j \le K.
\end{aligned} \tag{23}
$$

Next, after we find the (X, Y), we fix UAV's placement and derive u, s and R in problem (P7). The problem (P7) is a convex optimization problem with respective to u, s, R.

3.2 Transmit Power Optimization for the UAV

The objective function is affine in the following problem (P7), and the left-hand side of the constraint (C4) is convex set with respect to the variables $u_k, R_k, s_k, k = 1, ..., K$ because it satisfies log sum function is convex function.

Therefore, the fixed UAV position coordinates can be solved using the interior point algorithm in convex programing [13] of CVX.

$$\begin{aligned}
&(\text{P7}) : \underset{R_k, s_k, u_k}{\text{maximize}} \sum_{k=1}^{K} w_k R_k \\
&\text{s.t.} \quad C1 : \sum_{k=1}^{K} \mathrm{e}^{s_k} \leq P_{total}, \\
&\qquad C2 : u_k \geq \log\left(\mathrm{e}^{r_k^{\min}} - 1\right), \\
&\qquad C3 : u_k \geq R_k, \\
&\qquad C4 : \log\left(\frac{\mathrm{e}^{u_k}\left(\sum_{j=k+1}^{K} \mathrm{e}^{s_j} + \sigma^2 \frac{H^2+(X-x_k)^2+(Y-y_k)^2}{\beta}\right)}{\mathrm{e}^{s_k}}\right) \leq 0.
\end{aligned} \tag{24}$$

Finally, we constitute an alternate optimization algorithm and obtain solution to problem (P5) as follows.

3.3 Joint Transmit Power and Placement Optimization

The placement and power allocation of the joint optimization UAV is a non-convex problem from the above discussion. It is difficult to find the optimal global solution. Therefore, we decompose the original problem (P1) into two sub-problems (P6) and (P7), and use BCD algorithm to alternately optimize the position and power of the UAV. Then, we can obtain the solution with reasonable accuracy. Based on the above two sub-problems, we propose a joint placement and power allocation optimization (JPPAO) algorithm given in Algorithm 1.

Algorithm 1. Joint placement and power allocation optimization (JPPAO)

Initialization: the UAV's placement (X, Y) , the iteration number $i = 0$, and the tolerance of accuracy ε. (X, Y) is the geometric center of the user. Let Π be the set of all possible permutations of K.

Repeat

Let $\pi \in \Pi$ be the decoding order of the users. Let $\pi(i)$, where $i \in \{1, 2, ..., |K|\}$, be its i-th component. SIC decoding order satisfies $h_{\pi(1)} \leq h_{\pi(2)} \leq, ..., \leq h_{\pi(|K|)}$.

Repeat

Fix the UAV's placement, find the optimal solution u^*, s^*, R^* at the iteration to problem (P7) by standard convex optimization techniques, and let $u^*, s^*, R^* \rightarrow u^{i+1}, s^{i+1}, R^{i+1}$.

Fix the UAV's u, s, R, find the optimal solution (X^*, Y^*) to problem (P6) at the i-th iteration, and let $(X^*, Y^*) \rightarrow (X^{i+1}, Y^{i+1})$.

$$\{(u, s, R), (X, Y)\}^i \rightarrow \{(u, s, R), (X, Y)\}^{i+1}, and\ i \rightarrow i + 1.$$

Until $\left|R^{i+1} - R^i\right| \leq \varepsilon$

Until traverse all permutations Π

Find the largest weighted sum rate among all permutations.

Output return the optimal solution of placement (X^*, Y^*) and (u^*, s^*, R^*) to problem (P5).

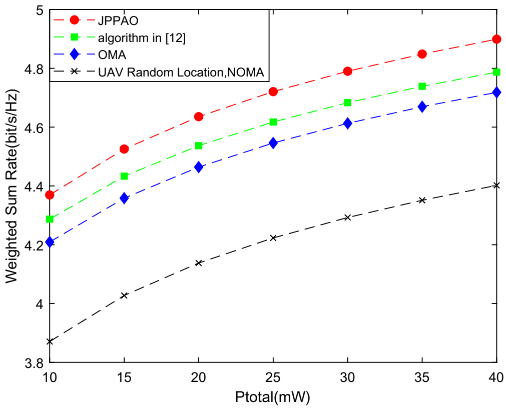

Fig. 1. Weighted sum rate versus maximizing power of UAV

4 Simulation Results and Discussion

In this part, we evaluate the proposed joint placement and power allocation (JPPAO) algorithm performance through simulation results, and users are randomly deployed on the ground. We set K=4, $H = 60\,\text{m}$, $\sigma^2 = -140\ dBm$, $r_k^{\min} = 1\ bit/s/Hz$, $\varepsilon = 10^{-4}$, $\beta = 10^{-3}$, the weight $w_k = 1$, $i = 1, ..., K$.

The average weighted sum rate of the vertical axis of Fig. 1 are obtained by taking multiple network topologies. The sum rate of the network is compared for different values of P_{total} with NOMA and orthogonal multiple access (OMA). In order to maximize the weighted sum rate, in this paper, the JPPAO uses an alternative optimization scheme. The algorithm in [12] first obtains the geometric center position of the UAV, and then uses KKT to obtain the power allocation coefficient. The power allocated by the OMA scheme is P_{total}, and OMA scheme is based on the location of the UAV in [12]. It can be seen that the UAV can achieve better performance after optimizing the location of UAV. Compared with other schemes, the proposed scheme can get better performance by optimizing the placement and power allocation of the UAV alternately. When the P_{total} is 20 mw, the performance of JPPAO is 2.6% better than that of algorithm in [12]. Moreover, we can see that the sum rate increases, as the total transmit power of UAV increases. This is because the UAV has more power to allocate to user to maximize the weighted sum rate of system.

From Fig. 2, it can be seen that as the height of UAV increases, the weighted sum rate of the ground users gradually decreases. This is because as the height of the drone increases, the channel gain from UAv to all the user becomes worse and worse.

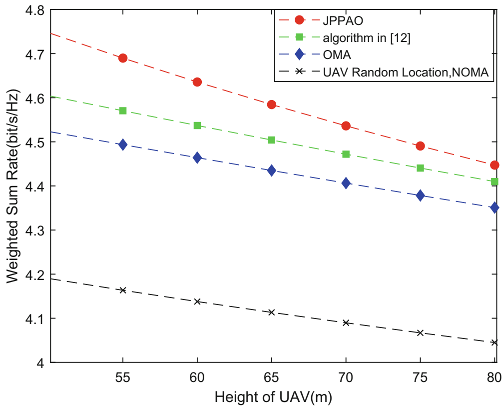

Fig. 2. Weighted sum rate versus height of UAV

5 Conclusion

This paper studies the joint optimization of the UAV's placement and power allocation to maximize the weighted sum rate of the ground users. To solve the non-convex problem, we apply variable substitution and BCD method to the problem, divided into two subproblems. Then, a joint transmit power and placement optimization by convex optimization is developed. In the end, we derive the optimal placement and power allocation of signal UAV for maximizing the weighted sum rate of ground users. The efficiency of the proposed algorithm is vefied by comparison with other benchmark methods.

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