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Energy Consumption Optimization Technique for Micro Base Stations in MIMO-OFDM System

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Abstract. *In order to solve high energy consumption caused by massive micro base stations deployed in multi-cells, a joint beamforming and power allocation optimization algorithm is proposed in Multiple-Input Multiple-Output orthogonal frequency-division multiplexing (MIMO-OFDM) system. By obtaining the optimal beamforming factor and introducing the target user distance control factor, every user get the best power allocation to improve the recognition degree of micro base stations to the target user, and reduce the energy consumption of micro base stations. Furthermore, suitable micro base stations grouping threshold for this paper is proposed, and system energy efficiency would be further improved through micro base stations grouping strategy optimized based on the Artificial fish swarm algorithm (AFSA). Joint optimization algorithm accurately give beam gain, reduce the influence of interfering users, and allocate more power to the target user by satisfying the multi-criteria beamforming. Specifically, compared with other beamformings, when the maximum transmitting power of micro base stations is 15 W, joint optimization algorithm improved system energy efficiency by 9.37% and 9.24%. Compared with other micro base stations grouping strategies, the AFSA optimization improved system energy efficiency by 17.2% and 31.35% with faster convergence performance. Result show that allocating more power to the target users through beamforming and rational micro base stations grouping strategy, which can reduce system energy consumption effectively and improve system energy efficiency.*

Keywords: Micro base stations, MIMO-OFDM system, Energy consumption optimization, Beamforming; Power allocation, AFSA

1. **Introduction.** The last decade has seen an explosion of digital information techniques, Mobile Internet and Internet of Thing are diversified, more and more terminals are joining the interconnecting information space of Man-Man or Man-Machine, including smart handheld devices, smart node sensors, AR/VR headsets and remotely operated intelligent Unmanned Aerial Vehicle (VAC)[1, 2, 3]. According to Cisco's VNI research report [4, 5], the continued adoption of more powerful mobile devices and machine-to-machine connectivity, as well as faster adaptive modulation of network coverage, which are major factors driving significant growth in mobile traffic. Faced with such a large-scale new generation of Internet of Things devices and massive communication traffic needs, the novel base station performance is placed high hopes [6].

At present, the networking mode of base station is based on macro base stations and micro base stations as a supplement [7, 8]. Before 3G, communication services were mainly aimed for calls or messages rather than Internet data. From 4G beginning, the development trend of micro base station is rapid because of data needs caused by massive devices [9, 10, 11]. Also, macro base stations generally located in the towers and other high places, which often affected by buildings, trees, the signal coverage effect is uneven [12]. As the signal frequency increases, mobile 4G or future signals penetration ability would be weaker, and the signal attenuation after passing through the building, which resulting in a large number of weak coverage areas, even blind spots. These places either no signal, or poor signal quality [13, 14]. With the advantages of small size, flexible location and flexible deployment, micro base stations play an important role in network coverage, also are the first choice for expansion and deep coverage, which can well solve signal and capacity needs of local hot spots and blind spots questions [15, 16, 17].

The three visions of 5G are massive connectivity, ultra-low latency, and enhanced bandwidth [18, 19]. MIMO-OFDM is one of the main technologies to realize the vision of 5G, which brings high spectrum utilization, good anti-multipath interference ability, and can effectively increase the channel capacity of communication system [20, 21]. Deploying MIMO-OFDM system into current base station architectures, especially micro base station, can effectively solve the problem of indoor data congestion [22]. If mobile communication network develops according to the current traditional base station architecture, more base stations need to be built to provide communication services. Base stations will be in a continuously open state to ensure the coverage and service quality of the network, which not only causes a waste of resources but also brings high energy consumption[23]. Therefore, how to reduce system energy consumption while expanding system capacity is a hot research topic of green communication.

The rests of this paper are organized as follows. Section 2 shows signal system model. Section 3 presents joint beamforming and power allocation algorithm. Section 4 proposes grouping strategy. Section 5 shows experimental results and analysis and section 6 concludes this paper.

1.1. **Related Work.** Aiming at the problem of micro base stations energy consumption management in MIMO-OFDM system, many scholars have proposed energy consumption optimization algorithms about joint beamforming and power allocation. By adjusting the weighting coefficients of micro base station antenna arrays, beamforming could generate directional beam, which leading the signal gain in target direction is higher than interference direction. On this basis, power allocation can be carried out to realize rational utilization of energy consumption and improve energy efficiency [24]. Therefore, joint beamforming and power allocation is a critical study to solve above problems.

A highly robust adaptive beamforming algorithm in [25] constructed projection matrix to estimate the steering vector of desired signal and interference signals further signal power by estimating signal to ratio (SNR) of desired signal, which could get better output signal to interference and noise ratio (SINR). Reference [26] proposed a kind of robust adaptive beamforming algorithm based on the combination of steering vector optimization and covariance matrix reconstruction, the assumed steering vector is optimized to make it approximate to the actual steering vector, then the complex weights are obtained by related calculation and realizes beamforming, effectively suppresses interference and improves output SINR. A hybrid beamforming architecture was proposed in [27], it can reduce costs and power in massive antenna arrays, and design beamformer for each scenario. Reference [28] transformed the resource allocation problem of maximizing energy efficiency on the downlink into a convex optimization problem, which was solved by an iterative algorithm. In [29], the optimization problem of battery correlation and power allocation was formulated, which can be efficiently solved via a constrained concave convex procedure-based algorithm. Reference [30] researched the overall energy efficiency of large-scale wireless MIMO system and described the expandable model of energy consumption.

Joint beamforming and power allocation can further solve the energy efficiency problem. In [31], the energy-saving problem was modeled as a joint beamforming and power allocation optimization problem, then a two-stage scheme based on dual of uplink-downlink and standard interference mapping theory was given to solve this problem, which can make convergence rate faster and energy consumption lower. In [32], the resource allocation problem involving beamforming and power allocation was described as a non-convex optimization problem. The Zero-forcing beamforming algorithm and the differences of two convex functions projected are used to optimize the problem. Simulation shows that the proposed algorithm effectively improves the energy efficiency for MIMO system.

In addition, due to the increase of energy consumption caused by mutual interference between micro base stations, the computational complexity of corresponding resource allocation also increases. Considering users with different service needs, [33] proposed a cluster-based resource management with Quality of Service (QOS) guarantees, which effectively improves network throughput, system energy efficiency and computing convergence time. Reference [34] proposed an allocation algorithm based on energy efficiency maximization, jointly optimize system energy efficiency in terms of base station clustering, user grouping, resource block allocation and power allocation. Reference [35] proposed a deployment method of micro base stations for ultra-dense heterogeneous cellular networks based on constrained dolphin swarm algorithm, which can balance energy efficiency and electromagnetic radiation and satisfy QoS.

1.2. **Motivation and contribution.** Compared with joint optimization algorithm, beamforming or power allocation just considers the single aspect of performance improvement. To best our knowledge, there are few studies on the energy consumption reduction caused by micro base stations grouping, which motivates the research of this paper.The main motivations and contributions of this paper are shown below:

1) Proposed a joint beamforming and power allocation optimization algorithm. In the beamforming stage, the Minimum Variance Distortionless Response (MVDR) criterion and SINR criterion are used to estimate the Direction of Arrival (DOA). The optimum beamforming factor expression of the target user direction is derived. By constructing the objective function to maximize system capacity, introducing the target user distance control factor, combining the optimal beamforming value, and using the Lagrange multiplier method to obtain the optimal power allocation value for each user.

2) Proposed micro base stations grouping strategy. According to the real-time power obtained by joint optimization algorithm, the threshold of micro base stations is determined, and two types of cooperative and conventional grouping modes are proposed to meet different communication needs. By using the improved artificial fish swarm optimization algorithm, the power interference values among the micro base stations are mapped to the path information, and the optimal micro base stations grouping strategy is obtained through joint optimization of four ecological behaviors of the fish swarm.

2. **Signal Model.** Consider the downlink of a multi-cell MIMO system with L-cells where Q micro base stations and K single-antenna users distributed randomly in each cell. There is a remote antenna array at every micro base station equipped with M antennas.The set of serviceable users under the micro-base station Q_i can be represented as $U_{i,j}$. The steering vector $a_{i,j}$ from micro base station to users is introduced, which could reduce the signal interference between adjacent micro base stations. Assumed block channel fading, the received signal at users from multi-cell micro base stations can be expressed as:

$$y_{i,j} = w_{i,j}a_{i.j}h_{i,j}s_{i,j} + \sum_{l\neq i}^{Q} w_{l,j}a_{l,j}h_{l,j}s_{l,j} + \nu_{i,j} \tag{1}$$

where $w_{i,j}$ denote the beamforming vector, $s_{i,j}$ are the transmitted signals from Q to $U_{i,j}$, the second item expressed as interference between micro base stations in the same cell, $v_{i,j}$ is the additive gaussian white noise(AWGN).

3. Joint Beamforming and Power Allocation Optimization Algorithm.

3.1. Beamforming based on multiple criteria.

A uniform linear array with M matrix elements is obtained by sampling with the small-spacing array technique as shown in Figure 1, the space between matrix elements is d.

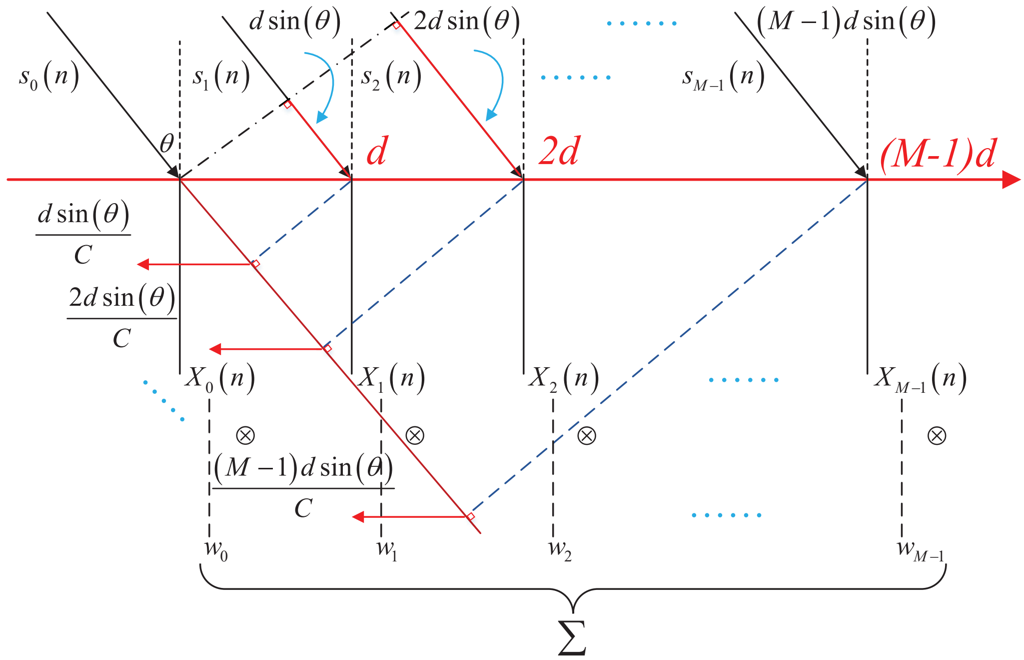

Figure 1. Uniform linear array

There are a set of uplink feedback signals $s_i(n)$ are transmitted into the array from radio frequency link of micro base stations, deviating from normal θ, $i \in \{1, M-1\}$. The space difference of signals between two matrix elements is $d\sin(\theta)$, and latency δ_t defined as:

$$\delta_t = \frac{d\sin(\theta)}{C} \tag{2}$$

where C is Lightspeed. Assumed transmission signal frequency is f_0, due to the different spatial position between matrix elements, phase difference relation of signals can be written as:

$$\begin{aligned} 2\pi f_0 \Delta T &= 2\pi f_0 \left[\delta_t(0), \delta_t(1), \cdots, \delta_t(M-1)\right] \\ &= 2\pi f_0 \left[0, \tfrac{d\sin(\theta)}{C}, \cdots, \tfrac{(M-1)d\sin(\theta)}{C}\right] \end{aligned} \tag{3}$$

Beamforming improves target recognition mainly through interference cancellation. In this paper, DOA estimation based on multiple criteria in beamforming is analyzed.

3.1.1. *Multi-objective beamforming based on MVDR criterion.* At a certain moment, transmitter of micro base stations receives the output signal of array as:

$$x(n) = \left[x_0(n), \cdots, x_i(n), \cdots, x_{M-1}(n)\right]^{\mathrm{T}} \tag{4}$$

Where $x_i(n) = a_i(\theta)s_i(n)$, $a_i(\theta)$ is the steering vector, which is used to preserve furthest $s_i(n)$.

Therefore, the output signal of transmitter of micro base stations after beamforming can be given as:

$$X(n) = W^H x(n) \tag{5}$$

where W is beamforming matrix from micro base stations to users.

Separate the signal of target user from $x(n)$, and the signal of nontarget user denoted $z(n)$, (5) is rewritten as:

$$X(n) = W^H a(\theta) s(n) + W^H z(n) \tag{6}$$

According to the minimum mean square error (MMSE) definition:

$$\min(E[X^H(n)X(n)]) = \min(W^H R_{xx}(n) W) \tag{7}$$

where $R_{xx}(n)$ is the autocorrelation function of $x(n)$.

With Lagrange multiplier, the objective function as follows:

$$L(W, \lambda) = W^H R_{xx} W + \lambda \left(W^H A(\theta) - F\right) \tag{8}$$

where λ is the Lagrange multiplier factor. The optimal beamforming vector can be obtained by calculating the gradient of (8):

$$W_{MVDR} = \frac{R_{xx}^{-1} A(\theta)}{A^H(\theta)(R_{xx}^{-1})^H A(\theta)} \tag{9}$$

3.1.2. *Multi-objective beamforming based on maximum SINR criterion.* According to SINR definition:

$$SINR = 10\lg\left(\frac{X}{V + Jam}\right) \tag{10}$$

Where Jam is the power of interference signal.

The objective function related to SINR performance as:

$$J_{SINR} = \frac{W^H R_{xx} W}{W^H (R_{NN} + R_{N'N'}) W} \tag{11}$$

Where $R_{N'N'}$ is the autocorrelation function of in interference signals.

To maximize the objective function, the eigenmatrix equation of (11) can be used to solve the optimal beamforming vector:

$$\begin{cases} \xi = (R_{NN} + R_{N'N'})^{-1} R_{xx} \\ W_{SINR} = eig(\xi) \end{cases} \tag{12}$$

where $eig\,()$ is the function of solving the eigenmatrix in MATLAB.

3.2. **Power allocation.** After obtaining the optimal beamforming vector w in the previous stage, make it an important parameter in the power allocation stage, update the initial power to the optimal power required by user's expected service.

Power is allocated to any users in a cell. In order to eliminate interference signals in the direction of target user, the distance control factor of target users is introduced in this paper, and the Shannon formula is extended. The maximum system capacity can be expressed as:

$$\begin{aligned} &\max_{P_1,\cdots,P_N} C_{sum} = \max \sum_{n=1}^{U_{i,j}} \log_2(1 + \tfrac{d'_n P_n |h_n|^2}{\delta_n^2}) \\ &\text{s.t.}\varphi 1 : P_n \geq 0,\ \sum_{n=1}^{U_{i,j}} P_n = P_{total} \end{aligned} \tag{13}$$

In Equation (13), the aim of objective function is maximizing rate of all users on subcarriers in a cell. $\varphi 1$ is expressed as each user has initial pre-allocated power, and the total power denoted as P_{total}. The target user distance control factor d'_n and noise power δ_n^2 as:

$$d'_n = 1 - \frac{D_n}{L} \tag{14}$$

$$\delta_n^2 = N_0 \times B_{noise} \tag{15}$$

where D_n is distance from micro base station to the target user, L is the maximum coverage radius of micro base station, N_0 is noise unilateral power density spectrum, B_{noise} is noise bandwidth.

To obtain the value of the optimal allocated power, the objective function with Lagrange multiplier as follows:

$$L\left(P_n, \lambda_i\right) = \max C_{sum} + \lambda_i \left(P_{total} - \sum_{n=1}^{U_{i,j}} P_n \right) \tag{16}$$

Calculate the gradient for P_n, and set it as μ_i:

$$\mu_i = \lambda_i \ln 2 = \frac{d'_n H_n}{(1 + d'_n P_n H_n)} \tag{17}$$

then, P_n can be expressed as:

$$P_n = \frac{1}{\mu_i} - \frac{1}{d'_n H_n} \tag{18}$$

where $H_n = |h_n|^2 / \delta_n^2$ is the power allocation factor, and h_n is assigned by the optimal beamforming vector.

Consider all users, sum (17):

$$\sum_{n=1}^{U_{i,j}} P_n = \sum_{n=1}^{U_{i,j}} (\frac{1}{\mu_i} - \frac{1}{d'_n} \cdot \frac{1}{H_n}) \tag{19}$$

where $1/\mu_i = \beta$ is expressed as micro base station power limits. Now, P_{total} can be rewritten as:

$$P_{total} = U_{i,j}\beta_i - \sum_{n=1}^{U_{i,j}} \frac{1}{d'_n H_n} \tag{20}$$

Combine (17), P_n can be deduced as:

$$P_n = \frac{1}{U_{i,j}}(P_{total} + \sum_{n=1}^{U_{i,j}} \frac{1}{d'_n H_n}) - \frac{1}{d'_n H_n} \tag{21}$$

Therefore, when a certain P_{total} is given to micro base station, the pre-allocation power of every subcarrier users are calculated as (20).

After above stage, the number of interference users k in the direction θ of target user and their expected optimal power P_n^θ are known. Now, a suitable power allocation method for this paper as:

(1) Initial iterations, compared P_n^θ and the target user power $P_n^{\theta *}$;

(2) If $P_n^\theta < P_n^{\theta *}$, allocate power to interference users;

(3) Otherwise, set the power of interference users less than $P_n^{\theta *}$. The purpose of allocation is to weaken the signals causes strong interference to target users, and maximize the minimum power required by each user's expected service, so as to reduce energy consumption.

4. **Grouping Strategy.**

After optimization of joint beamforming and power allocation algorithm, each users in the direction of target user have been allocated rational power. However, a large number of micro base stations also have power interference. In order to further improve the system energy efficiency, this paper proposes a micro base stations grouping strategy based on AFSA. The real-time power allocation information obtained through joint optimization algorithm, searching the grouping threshold with minimum total power interference and the power weighting factor after grouping, which could realize efficient power utilization of micro base stations.

4.1. **Determination of micro base stations grouping threshold.**

The power obtained in beamforming and power allocation stage reflects the real-time requirements of users. Therefore, the grouping threshold is calculated by the real-time power of users P_n. According to the proportion of each target user on channel in beamforming phase, calculate pre-transmitted power of every micro base stations P_{on} as follows:

$$P_{on} = \sum_{j=1}^{U_{i,j}} P_n \cdot \frac{h_j}{\sum_{j=1}^{U_{i,j}} h_j} \tag{22}$$

where h_j is the subcarrier gain factor from micro base stations to target user.

This paper considers multi-cell multi-users communication system, the real-time pre-transmitted power of each micro base stations can be ranked from high to low, the pre-transmitted power matrix $P_{on}[]^+$ as:

$$P_{on}^+[] = (P_{on,Q_1}, \cdots, P_{on,Q_i}, \cdots, P_{on,Q_n}) \tag{23}$$

the grouping threshold will be selected in $P_{on}[]^+$, and all micro base stations are classified as collaborative and conventional in this paper, as shown in Figure 2.

Collaborative micro base stations are used to deal with complex communication requests from large users, their power set as $(1+\varepsilon)P_{on}$; conventional micro base stations are responsible for daily communication requests of small and medium-scale users, their power

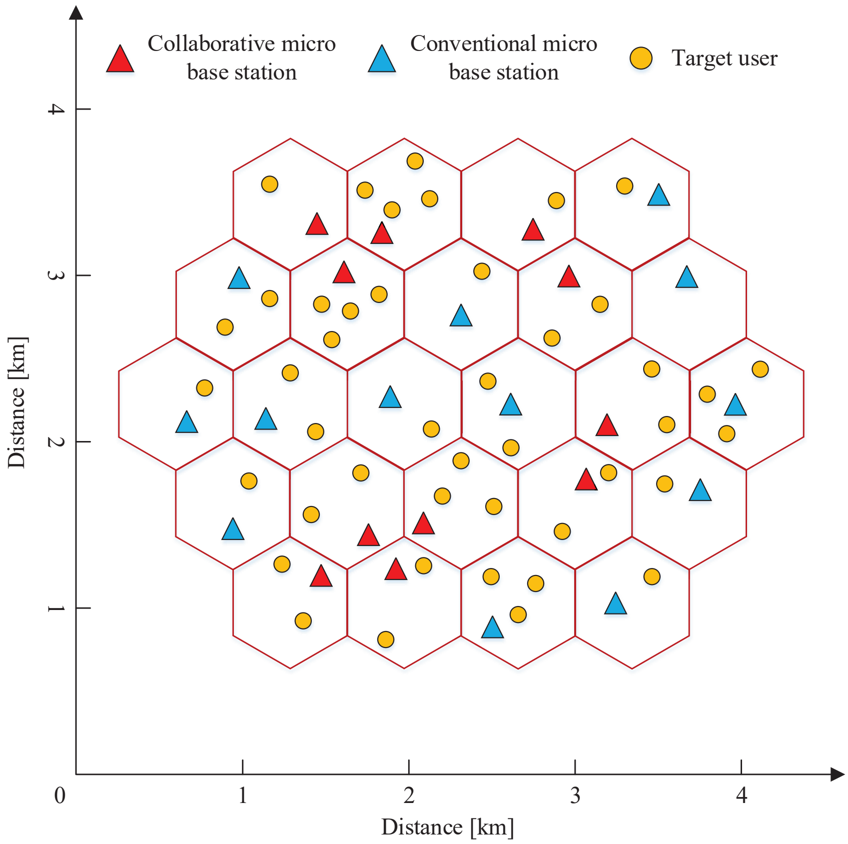

FIGURE 2. Grouping micro base stations

set as $(1-\varepsilon)P_{on}$, $\varepsilon \in (0, 0.5]$ represents the power weighting factor after grouping. As it takes a long time to find the grouping threshold and power weighting factor due to massive deployment of micro base stations, AFSA is adopted in this paper to optimize the computational complexity and improve the grouping efficiency.

4.2. **Micro base stations grouping strategy based on AFSA optimization.** Assumed there is a communication path from each target base station in a cell to other target base stations and nontarget base stations in other cells. Micro base station regards the power interference as path distance in downlink, and the power interference factor between target micro base station Q_α in the i-th cell and nontarget base stations in the j-th cell is expressed as:

$$\varpi_{<i,j>,<Q_\alpha,Q_\beta>} = \frac{P_{<j,Q_\beta>,i}\beta^2_{<j,Q_\beta>,i}}{P_{<i,Q_\alpha>,i}\beta^2_{<i,Q_\alpha>,i}} + \frac{P_{<i,Q_\alpha>,j}\beta^2_{<i,Q_\alpha>,j}}{P_{<j,Q_\beta>,j}\beta^2_{<j,Q_\beta>,j}} \tag{24}$$

where $(P_{on}\varpi)^{1+\varepsilon}$ or $(P_{on}\varpi)^{1-\varepsilon}$ is the power of two kinds of micro base stations after interference.

AFSA is used to optimize the grouping strategy of micro base stations according to the different pre-transmit power, and all micro stations are traversed to find a path that minimizes power interference in the area. X is shoal state, also expressed as the pre-transmit power value and the grouping weight factor of micro base stations. *step* expressed the pre-transmit power of micro base stations and the update step of the grouping factor, $Visual$ expressed the fish's visual of searching. When each fish is faced with multiple paths selection, target renewal and selection are carried out according to four ecological behaviors of fish. The condition of position renewal is the new fitness value greater than the original fitness value, namely the fish moves in the direction of higher food concentration, the specific express-ion as follows:

1) Position updating through foraging behavior:

$$\begin{cases} X_{j,Q_\beta}(t) = X_{i,Q_\alpha}(t) + (2rand(length(X_{i,Q_\alpha}(t)), 1) - 1) \times visual \\ X_{i,Q_\alpha}(t+1) = X_{i,Q_\alpha}(t) + \frac{X_{i,Q_\alpha}(t) - X_{j,Q_\beta}(t)}{\|X_{i,Q_\alpha}(t) - X_{j,Q_\beta}(t)\|} \times step \times rand() \end{cases} \quad (25)$$

2) Position updating through clustering behavior:

$$X_{i,Q_\alpha}(t+1) = X_{i,Q_\alpha}(t) + \frac{X_{i,c}(t) - X_{i,Q_\alpha}(t)}{\|X_{i,c}(t) - X_{i,Q_\alpha}(t)\|} \times step \times rand() \quad (26)$$

3) Position updating through rear-end collision behavior:

$$X_{i,Q_\alpha}(t+1) = X_{i,Q_\alpha}(t) + \frac{X_{i,vbest}(t) - X_{i,Q_\alpha}(t)}{\|X_{i,vbest}(t) - X_{i,Q_\alpha}(t)\|} \times step \times rand() \quad (27)$$

4) Position updating through random behavior:

$$X_{i,Q_\alpha}(t+1) = X_{i,Q_\alpha}(t) + (2P_{<i,Q_\alpha><j,Q_\beta>}(length(X_{i,Q_\alpha}(t)), 1) - 1) \times visual \quad (28)$$

where $P_{<i,Q_\alpha><j,Q_\beta>}$ is the probability of random behavior selection, probability expression as follows:

$$P_{<i,Q_\alpha><j,Q_\beta>} = \frac{f_{<i,Q_\alpha><j,Q_\beta>}(P'_{on}, \varepsilon)(\text{visual}_{<i,Q_\alpha><j,Q_\beta>})^\beta}{\sum\limits_{\eta \neq tabuL, \sigma \neq tabuQ} f_{<i,Q_\alpha><j,Q_\beta>}(P'_{on}, \varepsilon)(\text{visual}_{<i,Q_\alpha><j,Q_\beta>})^\beta} \quad (29)$$

where $f^s_{<i,q>,<j,g>}(P'_{on}, \varepsilon)$ is the concentration of food along the path from micro base station Q_α in i-cell to micro base station Q_β in j-cell; $(\text{visual}_{<i,q>,<j,g>})^\beta$ is range of visual field, which resolution is related to the power interference β between the two micro base stations. The fish moves all paths, and makes random behavior selection when it meets the non-swam areas and micro base stations, otherwise it does not choose.

5. **Experimental Results and Analysis.** In this section, we present the details regarding the performance evaluation of the proposed algorithm. Multi-cell micro base stations and users communication scenario are considered as: $L = 24$, and the radium of micro base stations is from $50m$ to $150m$. the number of micro base stations and users are random. In omnidirectional beam scanning phase, the maximum transmitted power of micro base stations is set as $15W$. We set different demand rates for each user.

MVDR and SINR criteria are used to detect the contrast effect of beamforming and power allocation effect after beamforming when the target user's direction angle is 21°, 51°, 111°, 131°, 151°, respectively. As shown in Figure 3 and Figure 4, the resolution of the main lobe is different under two criteria, and the suppression effect of the side lobe (interference wave) is different. After using the multi-criterion beamforming technology, the beam gain in the direction of target user is greater than in the direction of users on both sides. It indicates the main lobe peak is obvious when the transmitter of micro base stations performs beamforming and weighting management for target user, and the ability to suppress incoming waves from interference direction is also improved to some extent, which improves the detection ability of micro base stations to target user.

As shown in Figure 5 and Figure 6, the power given by micro base stations to users in the target direction are significantly higher than users in the interference direction, which indicating the influence of interference waves on the target user is greatly avoided when the micro base station allocate power to the target user in the beamforming stage. Under joint beamforming and power allocation algorithm, the maximum power rejection ratio reaches 15.3% and 18.8% respectively, which improves the power utilization rate of the micro base stations to a certain extent, namely reduces energy consumption.

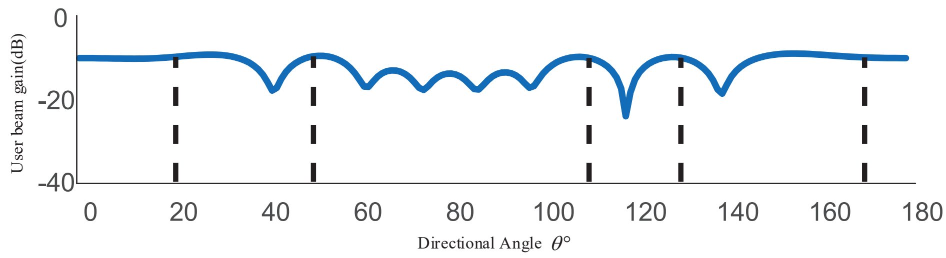

FIGURE 3. Beamforming effect based on MVDR criterion

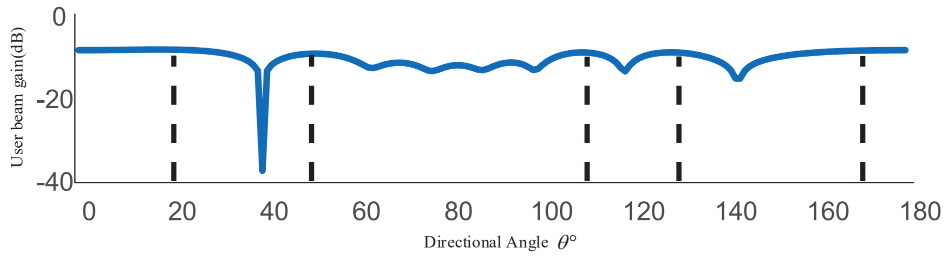

FIGURE 4. Beamforming effect based on SINR criterion

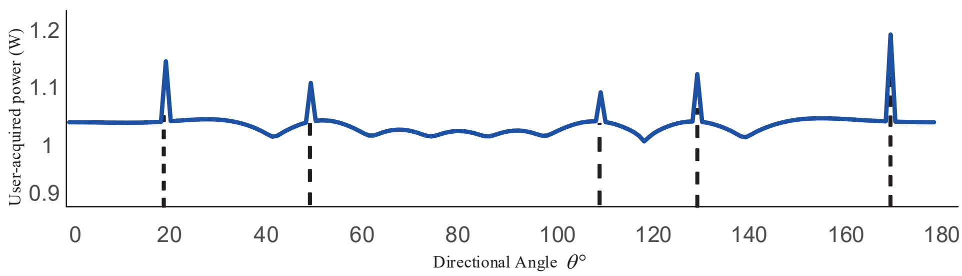

FIGURE 5. Power allocation effect based on MVDR criterion

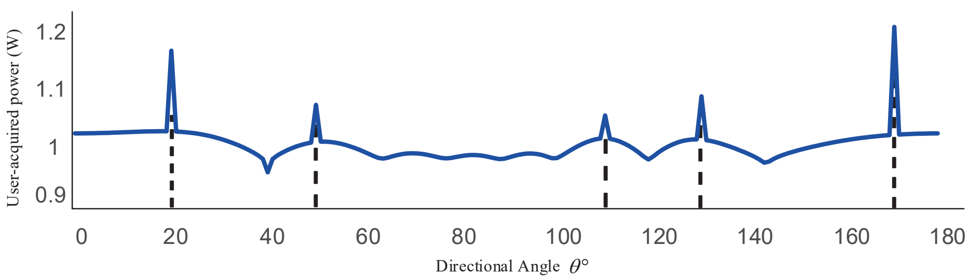

FIGURE 6. Power allocation effect based on SINR criterion

Figuge 7 shows the curves of energy efficiency of micro base stations with change the maximum transmitted power under different beamforming criteria. Due to Zero-Forcing (ZF) algorithm with no consider distinguishing the difference between target and interfering users in the same direction, which forces all user gains to be reduced, so it has the lowest energy efficiency. Compared with ZF algorithm, Zero Forcing Serial Interference Cancellation (ZF-SIC) algorithm improves energy efficiency by detecting target user, however, the order of detecting user in the same direction is serial sorted. Using the steering vector, MVDR and SINR in this work simultaneously allocate power to multiple target user signals, which can further improve energy efficiency. Due to MVDR criterion introduces minimum mean square error and Lagrange multiplier to obtain the optimal beam weighting vector, so energy efficiency performance is better than SINR criterion. When the maximum transmitted power of micro base stations is $15W$, MVDR and SINR criteria increase energy efficiency by 9.37% and 9.24% compared with ZF-SIC algorithm.

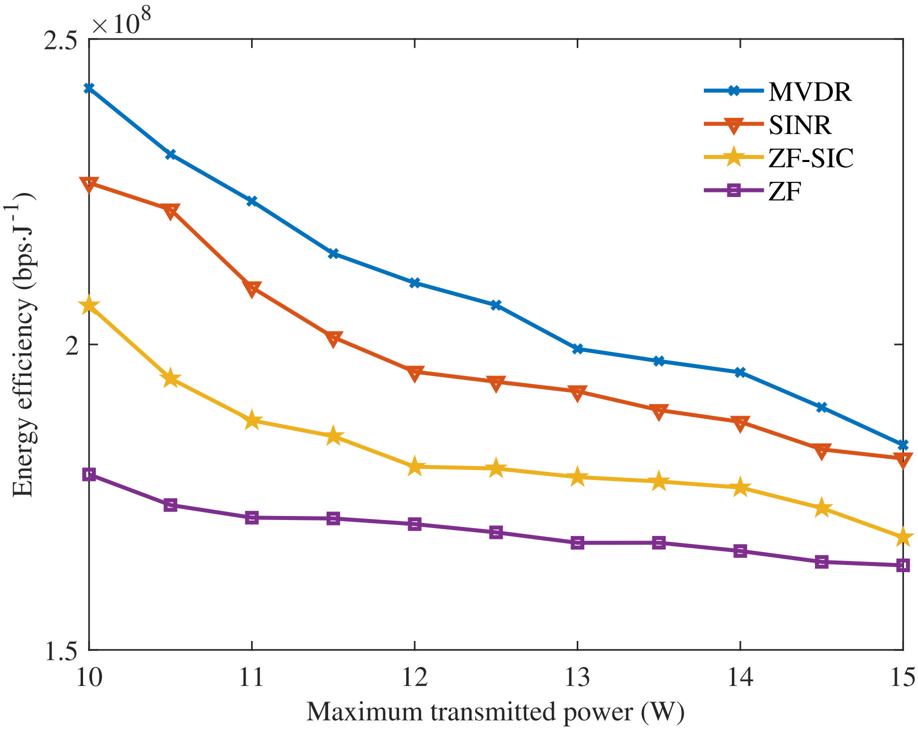

FIGURE 7. Energy efficiency curves of four different beamforming criteria

In order to demonstrate the superiority of AFSA, we compare with three conventional approaches: Quantum Genetic algorithm (QGA), Particle Swarm Optimization (PSO) algorithm and improved PSO. Figure 8 shows Convergence performance of micro base stations grouping strategy optimized by four intelligent searching algorithms. The convergence performance of QGA is poor when dealing with micro base stations grouping, and it converges at the 43rd iteration. PSO and improved PSO are improved by 37.2% and 44.1% respectively compared with QGA. AFSA adopts a number of bionic behaviors that jumping out of the local optimal, such as clustering, rear-end collision and randomization, it converges at the 9th iteration. The convergence performance is improved by 79% compared with QGA, and by 66.7% and 62.5% compared with PSO and improved PSO. It indicated that AFSA can find the optimal micro base stations grouping mode faster.

Figure 9 shows the comparison curves of energy efficiency of four micro base stations grouping strategies. When the number of micro base stations is small, the average allocation algorithm assigns the same number of micro base stations to each cell. Due to it ignores the actual expected service user demand, when the target user interference power

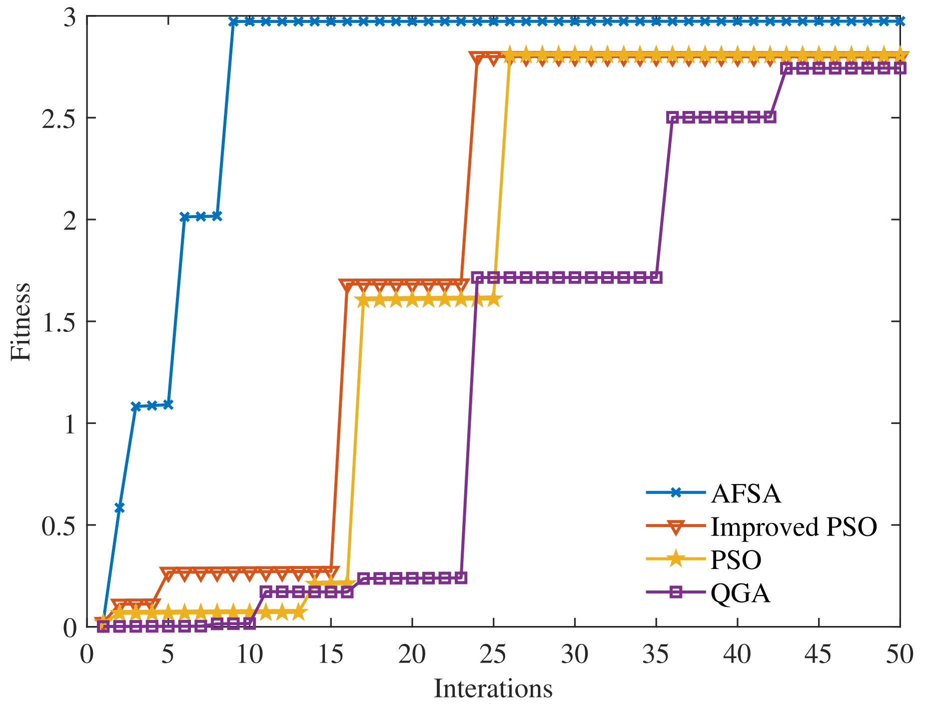

Figure 8. Convergence performance of micro base stations grouping strategy optimized by four intelligent searching algorithms

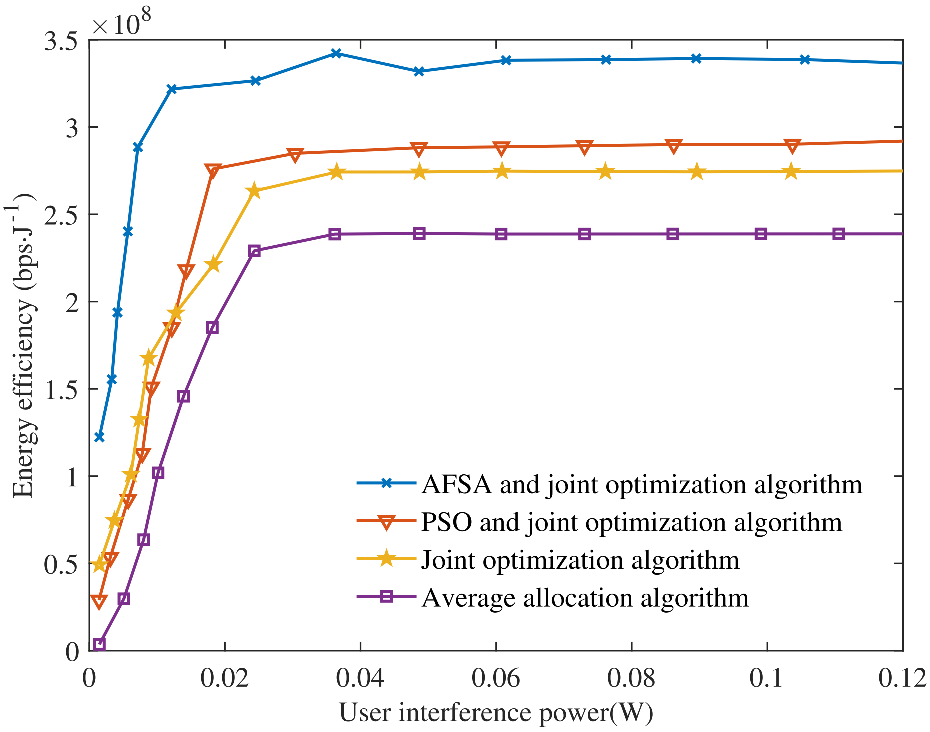

Figure 9. Energy efficiency curves of four micro base stations grouping strategies

is $0.03W$, energy efficiency gets peak. Joint optimization algorithm considers actual desired service requirement of target user and improves energy efficiency compared with the average allocation algorithm. Considering the large number of micro base stations, the grouping strategy combined with intelligent searching algorithm is more effective. When AFSA and joint optimization algorithm are adopted to energy efficiency, it begins to converge when the target user interference power is $0.008W$, and reaches the peak when the target user interference power is $0.036W$. Compared with PSO and joint optimization algorithm, and the average allocation scheme, the improvement is 17.2% and 31.3%, respectively. Since AFSA has the process of searching for the second-best value, with the increase of interference power, energy efficiency decreases slightly between $0.04W$ and $0.06W$. With the robustness of AFSA, energy efficiency shows an overall rising trend and basically tends to be stable in the later stage. Therefore, the proposed algorithm is fully applicable to solve the energy consumption problem of micro base stations.

6. **Conclusions.** This work presents a joint beamforming and power allocation algorithm and grouping strategy for MIMO-OFDM micro base stations. In the beamforming stage, MVDR and SINR criteria are used to obtain the optimal beamforming factor of the target direction Angle, which results in micro base stations can give more beam gain to user in the target direction. Compared with ZF algorithm, which no consider with distinguishing between target user and interfering users, and ZF-SIC algorithm, which can only detect one target user at a time, energy efficiency is effectively improved. Second, introducing the target user distance control factor, the Shannon formula is extended, and the expression of maximizing system capacity is obtained. The Lagrange multiplier is used to obtain the optimal allocation power under the optimal beamforming gain, so that the same power allocation for all users is changed to the power allocation for target user is higher than interference users, thus reducing the energy consumption.

In addition, based on the real-time power obtained by joint optimization algorithm, the threshold of micro base stations is determined, and two kinds of groupings, collaborative and conventional are proposed to meet different communication needs. AFSA is introduced to map the power interference value between each micro base station into the path information, and the optimal micro base stations grouping is obtained through joint optimization algorithm of four ecological behaviors of fish. Simulation results show compared with other grouping strategies, the proposed strategy has faster convergence speed and higher energy efficiency.

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