Dynamic APs Grouping Scheme Base on Energy Efficiency in UUDN

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Abstract. Ultra dense Network (UDN) is considered as a promising technology for 5G. With dense access points (APs), one user can be served by several APs cooperatively. Hence, how to choose APs and group them is a big challenge. In this paper, a dynamic APs grouping scheme is proposed for the downlink of User-centric UDN (UUDN). This scheme takes terrain and network topology into consideration to divide the APs into several available candidate sets (ACSs). The APs can be chosen from the ACS as the group member for UE's APs group (APG). Once the service requirement changes or user moves, the group should be changed accordingly. The optimal objective is maximum energy efficiency under the constraints of transmission power and user's data rate requirements. This scheme solves the problem of AP selection and power allocation. It is modeled as a discrete mixed combinational optimization problem, and a quantum-behaved particle swarm optimization (QPSO) algorithm is adopted to solve it efficiently. In addition, simulation results have also proved the effectiveness and flexibility of the proposed scheme.

Keywords: UDN · User-centric · Dynamic APs grouping · Energy efficiency

1 Introduction

With the rapid development of wireless technologies, the research of the fifth generation mobile communication (5G) for the future mobile communication started to emerge. 5G has several distinct characteristics, such as high rate, high capacity, and low delay. Since Ultra Dense Network (UDN) is considered as a promising technology for 5G, each user can be served by more than one access points (AP) [1]. Therefore, how to serve users with multiple APs cooperatively is a big challenge.

The previous works mainly research cooperation in cellular systems to improve the performance of cell edge users. The authors in [2] proposed an adaptive mode switch scheme and power allocation method to achieve a joint optimization for performance of edge users and center users. Nevertheless, the considered distributed framework would result in large signaling overhead. In order to reduce power consumption and data overhead in downlink coordinated multipoint (CoMP) transmission, the authors in [3, 4] proposed a cooperative set selection method. A semi-dynamic cooperative cluster selection scheme was proposed in [3] and the authors in [4] confined the number of APs.

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Some cooperative distributed radio resource management algorithms for time synchronization, carrier selection, and power control were discussed in [5]. The authors in [6] proposed a joint planning methodology. Although the simulation showed its advantage, the scenario and AP type still could be improved. Energy efficiency was an important factor which has to be considered [7]. Energy saving with small cell on/off was proposed in [8]. The proposed method considered four clusters to simplify calculation. While the cluster was fixed, this would result to limitation. The authors in [9] proposed a radio access network coordination framework toward 5G network. Its coordination procedure employed the concept of cluster, but cluster partition was vague which would result to congestion and cost. In the UDN, the authors in [10] proposed a APs cooperation method with dynamical clustering in super dense Cloud-RAN. This approach put forth a downlink cellular model. In order to analyze the performance of the proposed approach, a deterministic rectangular grid model was used to compare with it, which is based on stochastic geometry. This approach mainly considered the SIR, and the result was relevant to the size of the cluster. The concept of device-centric is proposed in [11]. It introduced virtualized device-centric radio access architecture for 5G, its advantage was to meet the stringent quality of service (QoS) requirements of users. Some researchers also proposed a concept of user-centric for UDN (UUDN), they noted that AP's group (APG) would be a challenge.

In this paper, we aim at the problem of how to serve users with multiple APs cooperatively in UUDN. A dynamic APs grouping scheme for downlink is proposed. Grouping procedure can be concluded as initiating, creating group and recreating process dynamically. Initiating adopts a concept of available candidate sets (ACSs). When UE accesses to the network, the local control unit can choose the APs from the ACS to create a group. By dynamically recreating group when the requirement of the UE changed, this process can guarantee UE's real time data rate demand. Grouping criterion is to maximize the energy efficiency. It subjects to the constraints of transmission power for different AP types and user's data rate requirements. This is a discrete mixed combinational optimization problem, and the sub-optimal solution can be obtained by adopting a quantum-behaved particle swarm optimization (QPSO) algorithm [12]. Simulation results show the performance of the proposed scheme.

The remainder of this paper is organized as follows. Section 2 describes the system model. Section 3 shows the access scheme in detail. Problem formulation and the solution are provided in Sect. 4. Section 5 shows the simulation results and discussions. The conclusion and future work are given in Sect. 6.

2 System Model

2.1 UUDN System Architecture

In the UUDN scenario, we uniformly name low power nodes as APs. The nodes include Micro, Pico, Femto, Relay and so on. User Equipment (UE) itself also can act as APs in UUDN. UUDN is a User-Centric system which focuses on the experience and requirements of UE [13]. There are some core features of UUDN as following:

(1) Intelligent network: The network can intelligently and dynamically detect UE, and record user's requirement and radio link environment.
(2) Transparent network: For UE, the network changes with the UE's mobility, but UE will not realize the handover process.
(3) Dynamical network: By focusing on UE experience, it can provide service adaptively, jointly and cooperatively.

The system architecture is shown as Fig. 1. It is a control plane and user plane detached structure. This architecture can reduce the signaling overhead and switch AP's status into active or sleep mode in a concentrated control manner.

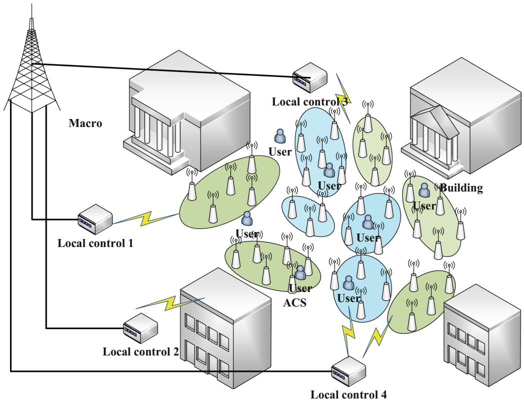

Fig. 1. The architecture of UUDN

2.2 Channel Model

In this paper, multiple APs serve to each UE cooperatively in downlink multiple-input multiple-output (MIMO) system. AP and UE are equipped with transmitting antennas and receiving antennas, respectively. The received signal is described as:

$$y = \mathbf{H}x + \mathbf{n} \tag{1}$$

where x denotes N_t-dimensional transmitted signal vector, H is $N_r \times N_t$ channel matrix, y and n indicates N_r-dimensional received signal vector and noise vector.

We suppose that the rank of H is denoted by $R = rank(\mathbf{H})$. Based on singular value decomposition (SVD) theorem, channel matrix H can be decomposed as:

$$\mathbf{H} = \mathbf{U}\begin{bmatrix} \mathbf{D} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} \end{bmatrix}\mathbf{V}^H \tag{2}$$

where U is a $N_r \times N_R$ unitary matrix, D is a diagonal matrix whose diagonal values are the singular values of H. D is a $N_R \times N_R$ matrix and is described as $\mathbf{D} = diag(\lambda_1, \lambda_2, \cdots \lambda_R)$. V indicates $N_R \times N_t$ unitary matrix, and superscript H is conjugate transpose.

Through formula derivation, we can transform a MIMO channel into R parallel single-input single-output (SISO) channels. It can decrease or eliminate interference among channels. Moreover, the channel gain of each SISO channel is $\lambda_i(i = 1, 2, \cdots, R)$.

3 Dynamic APs Grouping Scheme

In hotspot area where a large number of APs are distributed, how to serve users with multiple APs cooperatively is a big challenge. We propose a method to group APs dynamically to provide accessing service to UE. In the proposed scheme, APs are not limited to Pico, Relay and Femto. All the usable APs are called ACSs and divided into groups. APs can increase or decrease dynamically in the existing groups. With the UE requirement changed, group always dynamically changes accordingly. As APs are ultra-dense deployed, we employ dynamic ACS partition in advance. This way can help us to simplify the problem and save energy consumption. The way of ACS partition will take network topology and terrain into consideration and the ACSs do not overlap. Then APs grouping for a user depends on the user's data rate requirement. When the traffic data is low, the APs of group can switch their status into sleep mode to save energy.

The ACS partition is shown as Fig. 2. In previous work, the number of APs is limited in one ACS. One aspect is that too much APs will result in large signaling overhead, and another one is computational complexity [4]. So in this paper, we design an upper limit for the number of APs in one group.

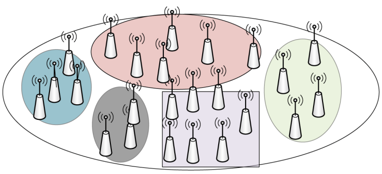

Fig. 2. ACSs partition

The APs in the group will be adjusted by the change of UE's requirements or channel link conditions. Figures 3 and 4 are shown to explain the procedure of dynamic grouping.

Figure 3 shows the situation when UE enters, local control unit will activate all of the APs. After the calculation according to the optimal objective, several APs will be chosen to create a group, while others will be tuned to sleep mode. Once UE's requirement has changed, its group will be changed as Fig. 4 shows. The proposed scheme can be concluded as three steps:

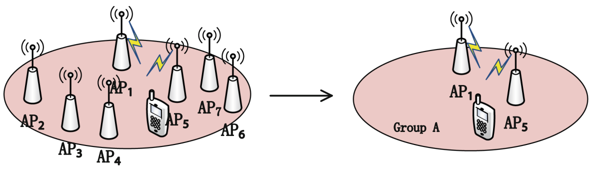

Fig. 3. Dynamic grouping according to UE's requirement

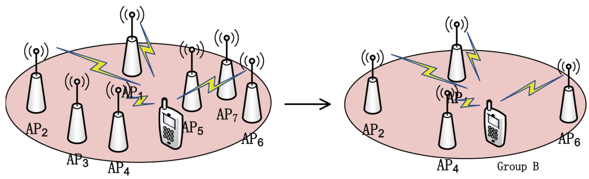

Fig. 4. Grouping changes when UE's requirement changes

Step 1. By combining the network topology and terrain, the dense APs are divided into several ACSs. In one ACS, there are three kinds of Aps: Relay, Pico and Femto. The number and types of APs are unfixed and random.
Step 2. When the UE requires accessing an ACS, local control unit activates APs belonging to the ACS. According to the UE's requirement, the AP group is setup.
Step 3. As UE's requirement and channel link condition may be changed; existing group would not fulfill UE's demand. For this situation, the proposed scheme can change the group with UE's requirement accordingly. Grouping criterion is to maximize energy efficiency under the constraint of UE's requirement and power limit.

4 Problem Formulation and Optimal Solution

In this section, an optimization problem about dynamic APs grouping in UUDN is formulated firstly. Then the solutions are given by adopting QPSO algorithm.

4.1 Problem Formulation

In one ACS, APs will be selected to create a group depending on UE's data rate requirement. When the requirement has changed, the APs in the group can change accordingly. The number of APs in the group will increase or decrease, and then the member's resource will be reallocated. We suppose that perfect channel state information (CSI) is known at the transmitter by dedicated backhaul links and feedback channels, and regardless of the latency. Therefore, the instantaneous channel gain can be available. In addition, a binary variable is used to represent the power allocation, indicating whether the i-th AP is chosen to provide service or not.

The optimization problem is to maximize the energy efficiency under the constraints of power and the number of APs in an ACS. The optimization problem can be presented as the following expressions:

$$\max_{\{I_1,I_2,\ldots I_n,P_1,P_2\cdots P_n\}} \frac{C}{P} = \max_{\{I_1,I_2,\ldots I_n,P_1,P_2\cdots P_n\}} \frac{\sum_{i=1}^{n} W \log_2\left(1 + \frac{I_i \lambda_i^2 P_i}{\sigma_n^2 + \sum_{k \neq i} I_k P_k}\right)}{\sum_{i=1}^{n} (I_i P_i + I_i P_{c_i})}$$
$$s.t: \begin{cases} C \geq R \\ 0 \leq P_i \leq P_{i\max}, P_{i\max} \in \{1, 0.5, 0.1\} \\ I_i \in \{0, 1\} \\ P_{c_i} \in \{0.2, 0.01, 0.02\} \\ n = 5 \end{cases} \tag{3}$$

where I_i represents AP's status, W represents the bandwidth, $\sum_{k \neq i} I_k P_k$ is interference among APs, P_i indicates the transmission power of the i-th AP, λ_i is channel gain, n indicates the number of AP, σ_n^2 is Additive White Gaussian Noise (AWGN) which can express as $\sigma_n^2 = n_0 W$ and P_{c_i} indicates the power consumption of link. In the first constraint, R is the requirement of UE and C represents the rate that can be provided by the group. Then $P_{i\max}$ indicates the different power upper limit.

4.2 Optimal Solution

Because the optimization problem is a discrete mixed combinational optimization problem, we intend to employ a heuristic algorithm QPSO to resolve it. In terms of QPSO, we have to transform the constraint into unconstrained form, so the penalty function is introduced in the paper. Then the fitness function includes the optimization objective function and one penalty function. The fitness can be expressed as follows:

$$F = f(I_i, P_i) + \alpha G(I_i, P_i) \tag{4}$$

where the objective function is $f(I_i, P_i)$, α is penalty factor, $G(I_i, P_i)$ represents penalty function and its expression form as follows:

$$G = [\max(0, C - R)]^2 + [\max(0, -P_{i\max})]^2 + [\max(0, P_i - P_{i\max})]^2 + \left(I_i^2, -I_i\right)^2 \tag{5}$$

where $C = \sum_{i=1}^{n} W \log_2\left(1 + \frac{I_i \lambda_i^2 P_i}{\sigma_n^2}\right)$ and $\max(\cdot, \cdot)$ returns the larger number of the two values.

We can define the particle as a vector and each of the vectors is consist of two variables. So it is a two-dimension vector and the expression can be defined as:

$$\mathbf{X}_i = (I_1, \cdots, I_i, P_1, \cdots, P_i) \tag{6}$$

where I_i denotes the status of the i-th AP and its value is 0 or 1. 0 represents that this AP's status is in sleep mode and 1 is active mode, P_i means the power of this AP.

Every particle updates their positions and calculates respective local, global best position and mean best position. Through limitation iterations, we can calculate a sub-optimal solution. It is worth noting that we adopt three types of APs in the group, so we need to judge the AP's type to confirm its upper limit of power to satisfy its penalty function. The procedure of the algorithm can be described as follows:

Step 1. Initialize the particle's position and choose the maximum iteration value.
Step 2. Based on the fitness function (4), calculate a best position as the global best position, a mean best position and update particle's position. It's an iteration process.
Step 3. Calculate each particle's current position by fitness function (4) and then output the current optimal solution.

5 Simulation Results and Discussions

In this section, the proposed scheme was evaluated by simulations. We assume each ACS has 5 APs and the types of APs, including the Pico, Relay and Femto. Simulation has two cases, with the group including three types of AP or only one kind of AP. The user's requirement is 5×10^8 bps and channel gain is assumed to be a random number between 0 and 1. The simulation parameters are shown in Table 1.

Table 1. Parameters of simulation.

Parameter	Value
α	1.5
W	30 M
n_0	2×10^{-7} W/Hz
$P_{i\max\_relay}$	30 dbm/1 W
$P_{i\max\_pico}$	27 dbm/0.5 W

Case 1 shows the group with 5 APs. There are three types: relay, pico and femto. Their power upper limits are shown in Table 1, 1 W, 0.5 W and 0.1 W, respectively. Set 1 shows AP power distribution and status, it can be expressed as follows:

$$X_{11} = \{0, 1, 1, 1, 1, 0.91, 0.29, 0.05, 0.06, 0.03\} \tag{7}$$

$$X_{12} = \{1, 1, 1, 0, 1, 0.7, 0.2, 0.03, 0.08, 0.04\} \tag{8}$$

$$X_{13} = \{1, 1, 1, 1, 1, 0.5, 0.11, 0.03, 0.06, 0.02\} \tag{9}$$

$$X_{14} = \{1, 1, 1, 1, 0, 0.3, 0.01, 0.06, 0.04, 0.06\} \quad (10)$$

$$X_{15} = \{1, 1, 1, 1, 0, 0.6, 0.08, 0.01, 0.01, 0.09\} \quad (11)$$

$$X_{16} = \{0, 1, 1, 1, 1, 0.8, 0.3, 0.04, 0.01, 0.07\} \quad (12)$$

The energy efficiency diagram is shown in Fig. 5. In the setting of the simulation scenario, the transmission rate can reach their peak rates for gigabit per second, therefore, in the power allocation, the service rate is far higher than the required rate. It can be seen from the curves in the following figure that the gradual increase of the emission power is a downward trend, which is consistent with the trend of the energy efficiency curve. According to the above six sets of values, the horizontal coordinate value will be limited to the maximum transmission power of the data. Because of the limitation of the AP number and AP type for an ACS, the total emission power of the mechanism will be a limited set, but this does not affect the trend of the curve.

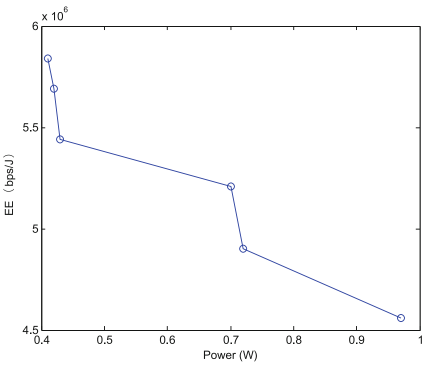

Fig. 5. Hybrid AP energy efficiency

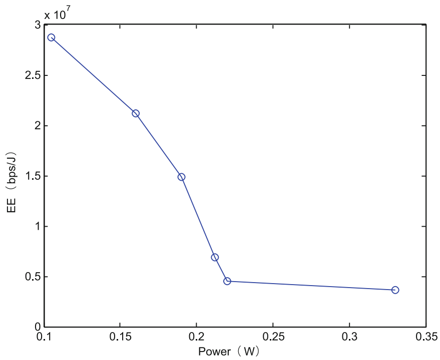

Fig. 6. Single type AP energy efficiency

Case 2 is a single AP type as Femto and the maximum transmission power limit is 0.1 w. In this scenario, the power allocation and the AP are selected as shown below:

$$X_{21} = \{1, 1, 1, 1, 1, 0.07, 0.08, 0.05, 0.02, 0.08\} \quad (13)$$

$$X_{22} = \{1, 0, 1, 1, 1, 0.08, 0.09, 0.03, 0.05, 0.03\} \quad (14)$$

$$X_{23} = \{1, 1, 1, 1, 1, 0.002, 0.07, 0.08, 0.01, 0.05\} \quad (15)$$

$$X_{24} = \{1, 1, 1, 1, 0, 0.03, 0.05, 0.03, 0.05, 0.06\} \quad (16)$$

$$X_{25} = \{1, 1, 1, 1, 1, 0.01, 0.003, 0.02, 0.07, 0.002\} \quad (17)$$

$$X_{26} = \{0, 1, 1, 1, 1, 0.08, 0.07, 0.073, 0.05, 0.03\} \quad (18)$$

As shown in Fig. 6 for case 2, this case and the case 1 can provide the similar user's rate. Meanwhile, the energy efficiency is improved to a maximum of three times of case 1. The main reason for this phenomenon is that the circuit loss of Femto is low. According to the above six sets of values plotted curve chart, the horizontal coordinates are the limited, this is because of the limited number of APs in the group.

In order to show the feasibility of the proposed mechanism, the fixed power AP hybrid cooperative algorithm is used to compare with the proposed method. The AP type selection and the maximum transmission power are the same as the above values. In this group, all the APs are cooperating to provide service to the user, and the maximum transmission power of AP in the group is 1.8 W. The power setting and energy efficiency of the multiple hybrid APs are shown in the Tables 2 and 3:

Table 2. Multiple APs fixed power allocation type table.

Relay	Pico	Femto	Femto	Femto	EE (10^6)
1	0.5	0.1	0.1	0.1	2.27
0.8	0.4	0.08	0.08	0.08	3.47
0.5	0.25	0.05	0.05	0.05	3.6
0.2	0.1	0.02	0.02	0.02	4.7

Compared with the dynamic energy distribution of this mechanism, dynamic allocation makes energy efficiency improved. According to the UE's rate requirement, the power allocation of each AP can be adjusted dynamically, rather than the overall operation, so that power allocation and AP selection are more flexible. From the comparison of are more flexible. From the comparison of Figs. 6 and 8, the proposed dynamic power allocation can improve the efficiency of at least 1.2 times.

Compared with the dynamic power allocation proposed by this mechanism, the energy efficiency value is also very close to the results obtained by the fixed power allocation value, which proves the reliability of the mechanism. And from Figs. 7 and 8, the allocation strategy adopted by the mechanism has been improved.

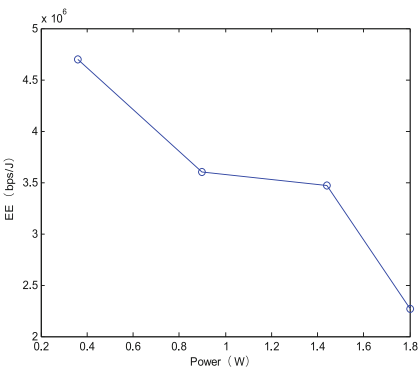

Fig. 7. Fixed power for hypbrid APs

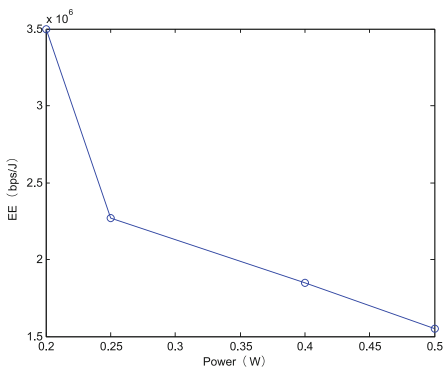

Fig. 8. Fixed power for single type AP

Table 3. Fixed power allocation table for femto

Femto	Femto	Femto	Femto	Femto	EE (10^6)
0.1	0.1	0.1	0.1	0.1	1.55
0.08	0.08	0.08	0.08	0.08	1.85
0.05	0.05	0.05	0.05	0.05	2.27
0.04	0.04	0.04	0.04	0.04	3.50

6 Conclusions

This paper proposes a dynamic APs grouping scheme in UUDN. According to the topology of network and terrain, the dense APs are divided into several ACSs. When UE accesses to the network, the APs of the ACS corresponding to the UE will be activated. Then we adjust the cooperative APs to create a group and switch the inactive APs into sleep mode. When the UE's data rate requirement has changed, the group can dynamically adjust its members accordingly. The adjustment and grouping criterion is to maximize the energy efficiency under the constraints of transmission power and UE's demand. Since this problem is a discrete mixed combinational optimization, we employ QPSO algorithm to solve it. Simulation results demonstrate the proposed scheme can save power consumption and is flexible in use. Future work will consider the scenario that backhaul link routing selection base on the AP's group.

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