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A Novel Benefit-Tree Based Dynamic clustering algorithm of CoMP in Dense Network

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Abstract. We focus here on the Energy Efficiency (EE), and propose an improved dynamic clustering algorithm that is incorporated into Coordinated MultiPoint (CoMP) with sleeping mode. Thanks to the frame structure of Benefit-tree employed in dynamic clustering of CoMP, the proposed algorithm can significantly improve the EE by choosing the most energy efficient competitive clustering strategy. At the same time, it can save energy by sleeping the underutilized base stations in the cellular network. In the performance simulation for EE, the proposed algorithm provides 10% higher in EE than the existing algorithm.

1. INTRODUCTION

The spectrum in wireless communication is limited in nature, which leads to a evolution of technique for the coming demands. For example, Energy efficient radio resource management and new physical layer techniques introduced in Daquan's paper[1] have been widely researched. According to a specific analysis of the total energy consumption in typical cellular network, the statistical results show that more than 80% energy consumption came from Base Stations (BS), while 60% came from the hardware employed by each BS such as air conditioner as well as signal processing units. In order to achieve higher energy saving offered by reducing the energy consumption of BSs in mobile network, BS sleeping technology comes into researchers' focus. A centralized and decentralized energy saving algorithm that adjusts the working modes of BSs dynamically according to the traffic are presented by Jie[2] . Nevertheless, a trade-off between the energy saving and the outage probability has to be considered. Specifically, Saker [3] introduced a dynamic and semi-static sleep mode mechanisms where a number of resources in system can be shut down for some traffic sce-narios. From another perspective, three different strategies for energy saving are discussed in [4], relying on small cell driven, core network driven, and user equipment driven approaches. Due to a low-power sensor at-tached to the BS, BSs can be switched off in idle conditions astutely. A distributed learning algorithm [5] is proposed using which base stations can choose their optimal transmission strategies autonomously.

However, the techniques introduced above pay attention to energy saving excessively, which result in the lack of some other part of system performance, such as the outage probability, data rate and so

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on. Due to the BS being shut down by low traffic, users served by them will have an effect on the outage of the whole net-work and achieve a low rate. To solve this problem, a novel technology named coordinated multi point trans-mission has been proposed[6]. However, this new technology increases energy consumption due to addtional backhaul and signal processing, which leads to a trade-off between gains in cell throughput and the energy consumption. To analyze the comparision of different CoMP approaches, a new iterative algorithm[7] based on two types of CoMP schemes, such as Joint Processing(JP) and Coordinate beamforming) is proposed un-der the system model introduced. In the meantime, [8] raised a heuristic algorithm to support the on-off opti-mal control of LTE-A cooperative eNodeBs, especially when and which eNodeB will be changed into sleep mode and which one need to be waken up. To achieve the maximisation sum rate of selected mobile stations, a novel dynamic greedy algorithm is proposed by Papadogiannis[9] for the formation of the clusters of coopera-ting BSs. In addition, to save the energy as well as keeping a perfect downlink performace, Huibin developed a multi-step Q-learning of the RL algorithm[10] to optimize the base station sleeping strategy in CoMP com-munications. At the request of reducing the consumption of energy as well as classifying the techniques for energy-efficient dynamic provisioning in wireless access networks, [11] introduced a taxonomy to point out all relevant design aspects. The structure of the taxonomy consists of five branches, such as metrics, type of the algorithm and so on. In order to reduce the energy consumption while maintaining the cellular network quality, the performance of several methods that improve the energy efficiency of wireless networks have been studied [12].

When some cells are switched off, radio coverage and service provisioning are supplied by the cells that remain active by CoMP. So as to guarantee that service is available over the whole area and achieving a higher EE, we pay more attention to optimize the clustering for CoMP. By sleeping some low traffic BSs, then serving the users under the coverage of the sleeping BSs by their neighboring BS through CoMP, a new scheme was proposed[13]. The simulation result shows that this novel technique could be more energy efficient than the traditional one. Based on the research above, another algorithm was presented[14], which employs a static clustering of cooperating on a par with turning off some underutilized BSs in the scenario of light traffic period. Compared to no CoMP and no sleeping mode method, this algorithm can allow the cellular network to achieve a higher EE. However, this approach is only available during the off-peak period. A benefit-tree dynamic clustering algorithm was proposed[15]. However, this algorithm only take data rate into consideration, which ignored the power consumption of whole system. Another novel algorithm using dynamic clustering called SMDC was presented[16]. The algorithm can be adapted to non-uniform user distribution and high traffic scenario. After simulation, the result showed that SMDC algorithm got a higher EE. But there is a limitation in the iteration of the SMDC algorithm. The limitation was caused by choosing the cluster with the highest EE and presented by each sleeping BS, which resulted in a problem that other BSs in the formed cluster have no right to choose the cluster fitting for them optimally. Thus, the problem described above results in a loss of the EE in the consideration of the whole system finally.

In this article, we introduced a novel benefit-tree based algorithm combined BS sleeping with dynamic clustering of CoMP (SMDC-BT) together to achieve higher EE. By sorting and choosing the appropriate trees, the algorithm improves the opportunity for other BSs in the formed cluster presented by each sleeping BS to choosing their favorite cluster directly. Compared to the existing SMDC, the proposed algorithm makes the cellular system to become more energy efficient, which can be showed by the simulation results.

The remainder of this paper is presented as follows. In Section , we introduce the system model briefly and formulate the problem in detail. In Section ¢, while describing the gaps brought by existing approach, we propose a novel algorithm called SMDC-BT by utilizing different clustering architecture. In Section £, some simulation parameters and numerical results that compared the performance of the proposed algorithm to the existing SMDC is presented. Finally, we give a conclusion of this paper in Section .

2. SYSTEM MODEL AND PROBLEM FORMULATION

2.1. System Model

We model a cellular network as a setup of S cells and U users. There is a Base Station(BS) in the center of each cell, which covers a radius of R. Thus, the distance between two adjacent BSs is $D = \sqrt{3}R$. Each BS is equipped with one antenna as well as the user served by them respectively. To simplify the considered model, we assume that the frequency reuse factor of the whole system is one. In the paper[17], a power model for typical BSs as deployed today has been derived. To calculate the energy needed by each BS appropriately, we extend the mode to a linear form

$$P_{BS} = a \cdot P_{tx} + b \cdot P_{sp} + c \cdot P_{bh} \tag{1}$$

where P_{BS} , P_{tx} , P_{sp} and P_{bh} denote the total consumed power , the radiated power, the signal processing power, and the power consumed for backhauling. The several coefficients a, b , c is quantized for the respective power consumption type of each BS, such as amplifier, cooling, or other component dissipations. CoMP techniques are used for increasing the sum and cell edge throughputs significantly in the cellular system[6]. However, they introduce a certain amount of additional power overhead into the system, such as the signal processing power P_{sp} and backhauling power P_{bh} . In the paper[6], the signal processing increased due to CoMP has been modeled as a quadratic function of the CoMP cooperating set degree K :

$$P_{sp} = p_{sp} \cdot (0.87 + 0.1 \cdot K + 0.03 \cdot K^2) \tag{2}$$

Backhauling power consumption P_{bh} for each BS using CoMP modeled as

$$P_{bh} = \frac{C_{bh}}{100Mbits/sec} \cdot 50W \tag{3}$$

where C_{bh} , the additional backhaul data capacity needed, is expressed as

$$C_{bh} = \frac{K \cdot (2K)pq}{T_s} bits/sec \tag{4}$$

where p and q denote the additional pilot density and channel status information(CSI) signal due to CoMP, respectively, and $T_s = 66.7\mu s$. For BSs that are not using CoMP in the downlink P_{bh} can be ignored. when we consider the signal to interference plus noise ratio(SINR) achieved by each user in traditional mode, it can be calculated as

$$SINR = \frac{P_{serving}}{\sum_{i=1}^{N} P_i + P_{noise}} \tag{5}$$

where $P_{serving}$ is the received power from the serving BS, P_i stands for the received power from the i th interfering BS and N is the number of interfering co-channel BSs. However, due to the received power from the BSs inside the CoMP transmission set are treated as useful signal, the SINR achieved by each user in a cellular system using downlink CoMP can be shown as

$$SINR_{comp} = \frac{\sum_{i \in c i=1}^{M} P_i + P_{serving}}{\sum_{i \notin c i=1}^{N} P_i + P_{noise}} \tag{6}$$

where c represents as the cooperative transmission set, M stands for the number of BSs in c without the serving BS, and N is the number of interfering co-channel BSs. In our system, a total of U uses are populated in the network uniformly and the achievable downlink data rate R_k for each user k can be formulated as

$$R_k = W \cdot \log_2(1 + SINR_{comp}) \tag{7}$$

In the above, W denotes the bandwidth assigned to the user k which is set to $5MHz$. The EE is a significant metric in the green wireless communication. In [18] , the author discusses the EE in different aspects according to the demand of EE in details. The different system can employ different EE metric. In the article, we adopt the metric of system EE, which can be defined as the data rate achieved by the energy consumption per unit. The EE of the whole system in terms of $bit/Joule$ can be denoted by

$$EE_t = \frac{R_t}{P_t} \tag{8}$$

where, R_t is the total data rate can be achieved of the system, which can be described as

$$R_t = \sum_{k=1}^{U} R_k \tag{9}$$

and P_t is the total power consumed of the system, which is the sum of power caused by each BS.

$$P_t = \sum_{l=1}^{L} \sum_{i=1}^{c_l} P_{BS}^{i} \tag{10}$$

where, L denotes the number of clusters and c_l is the number of active BS in the $l-th$ cluster.

2.2. Problem Formulation

Assume that all the BSs take two working mode: active and sleep, where in the latter mode the BSs consume negligible power and the transmission power consumed by active BS is limited to fixed value $P_{tx} = 41dbm$. In order to satisfy certain user data rate of $40Mbit/s$, we formalize the optimization problem as follows:

$$\begin{aligned} &\max EE_t = \frac{R_t}{P_t} \\ &s.t. \quad P_{tx}^{i} = 0, 41dbm, \forall i = 1, \cdots, S. \\ &R_{sleep} \geq 40Mbit/s. \\ &\left|\gamma\right| > 0 \\ &\left|\beta\right| \geq 0 \end{aligned} \tag{11}$$

where γ represents the set of active BSs and β denotes the set of turned off BSs but need to participate in coordination.

3. THE BENEFIT-TREE BASED SMDC ALGORITHM

The SMDC algorithm proposed in [16] utilizes a dynamic clustering method and it achieves a higher EE than the algorithm proposed in [14]. Nevertheless, many problems can be seen observably in the SMDC algo-rithm. Firstly, from the sight of CoMP strategy, the size of clusters in the optimal clustering strategy must be un-fixed, due to the random distraibution of users in the system. However, the size of clusters in SMDC is fixed, which leads to a destruction in achieving the optimal clustering and a limited EE. Secondly, in the clustering for CoMP in the SMDC, the cluster provided by each sleeping BS with highest EE will be chose sequentially. Consequently, a enormous gap in performance will emerge between the cluster formed earlier with the cluster formed later, which reduces the total EE can be obtained in the system. Finally, we point out an uni-directional problem existing in the clustering in SMDC, which only considers the highest data rate achieved by one BS with the neglect of other BS's performance in the same cluster. How-ever, this problem will be overcomed in the proposed algorithm, due to a metric called degree of aspiration to cooperate(DAC). In this section, we will give a detail description of the proposed algorithm. If all the channel information and the traffic requirements is known at the network, A new algorithm can be utilized to solve the formulated problem. Firstly, we implement a traffic-aware BS sleeping strategy to achieve the energy saving. Some BSs work in sleep mode when the traffic load is light enough, otherwise, work in active mode. Then, the CoMP strategy will be come into effect to guarantee the coverage of the sleeping BS without increasing the transmission power of adjacent BSs. We apply the Benefit-Tree based dynamic clustering algorithm finally.

3.1. Traffic-Aware BS Sleeping Strategy

Particularly, we consider dynamically turning off or sleeping certain BSs when the network traffic is low. To determine the type of each station, we must determine its traffic load first. In the paper[16], three types called α, β,γ had been generated according to their traffic load. The first one called α denotes the set of BSs that can activate the sleep mode directly and do not need cooperation, due to no user need to be serviced by this kind of BS. The second type called β includes those BSs can be turn off and need to participate in coordination because of their light traffic. The last type of BSs represents those remaining active BSs with high traffic.

3.2. CoMP Strategy of the Sleeping BS

To guarantee the coverage of the sleeping BSs, a sleeping BSs j in β and a active BS i in γ will be cho-sen together to form as a tree τ_{ij} until $\beta = \emptyset$.

3.3. Benefit-Tree Based Dynamic Clustering Algorithm

Firstly, we introduce two metrics utilized in the proposed algorithm called the Degree of Aspireation to Cooperate(DAC) and the Degree of Benefit(DB) as below: we determine that $DAC(t_m, t_n)$ is the gain achieved by tree t_m in data rate bringing by CoMP with tree t_n , which can be expressed as

$$DAC(t_m, t_n) = \frac{DR_{t_m}^{comp(t_m,t_n)}}{DR_{t_m}^{non_comp}} \tag{12}$$

where, $DR_{t_m}^{comp(t_m,t_n)}$ denotes the data rate achieved by tree t_m by CoMP with tree t_n and $DR_{t_m}^{non_comp}$ represents the data rate achieved by tree t_m without CoMP. According to the equation (12), the higher the $DR_{t_m}^{comp(t_m,t_n)}$, the higher the $DWC(t_m, t_n)$, which stands that tree t_m wants to joint CoMP with tree t_n . In the same way, $DAC(t_n, t_m)$ is the gain achieved by tree t_n in data rate bringing by CoMP with tree t_m, which can be expressed as

$$DAC(t_n, t_m) = \frac{DR_{t_n}^{comp(t_n,t_m)}}{DR_{t_n}^{non_comp}} \tag{13}$$

We give the definition of $DB(t_m, t_n)$ as the aspireation of two trees t_m , t_n those joint CoMP together. When $|t_m| + |t_n| \leq K$ satified, $DB(t_m, t_n)$ can be denotes as

$$DB(t_m, t_n) = \frac{\eta}{2 \cdot |t_m| \cdot |t_n|} \{DAC(t_m, t_n) + DAC(t_n, t_m)\} \tag{14}$$

otherwise, $DB(t_m, t_n) = 0$. Where, η is the factor to control the size of cluster, $|t_m|$ represents the active BSs in tree t_m and $|t_n|$ denotes the active BSs in tree t_n , K is the maximum size of cluster in the system. The Benefit-Tree based SMDC algorithm is been shown in TABLE I.

Table 1: THE PROPOSED ALGORITHM

Algorithm1 :The SMDC-BT Algorithm
Step1 : Specify the maximum size of cluster K .
Step2 : To classify the BSs into three sets α, β, γ , we excute the Traffic-aware BS sleeping Strategy. For allBSs in α, activate their sleep mode directly.
Step3 : A sleeping BSs j in β and a active BS i in γ will be chosen together to form as a tree τ_{ij}, which can be denotes as $\tau_{ij} = \{i, j\} (i \in \gamma, j \in \beta)$. Set $\beta = \beta - j$ and$\gamma = \gamma - i$.
Step4 : If $\beta = \emptyset$, go to step 5, otherwise, go to step 3 instead.
Step5 : All BSs in γ, each BS i proposes a tree alone,which can be expressed as $\pi_i = \{i\} (i \in \gamma)$.
Step6 : Now the system consists of several trees $t = \{\tau, \pi\}$. Choose the biggest $DB(t_m, t_n)$ achieved by t_m, t_n and merge t_m, t_n into a new tree .

4. THE SIMULATION RESULTS

In this section, we present the results of thorough simulations carried out to test the performance and behavior of the proposed algorithms, and compare them to existing SMDC. First, we introduce the simulation parameters. Then, to better emulate practical systems, and to assess the algorithm performance under such constraints, we give the results of a thorough simulation, including data rate, average proportion energy saving and energy efficiency, while complex to evaluate analytically, can be including in a simulation and give a practical view of the results in this paper.

4.1. Simulation Parameters

Some significant simulation parameters are shown in TABLE II.

Table 2: SIMULATION PARAMETERS

Maximum size of a cluster N_{msize}	5
The Number of BS	19
Inter-site distance	$200m$
Pass loss model in dB	128.1+37.6$\log_{10}$(dist)
System bandwidth B	10 MHz
Noise power density	-174dBm
Baseline signal processing power p_{sp}	52W
Transmit power P_{tx}	41dBm
Pilot density p	8/168
CSI signaling q	8
Network Structure	Hexagonal gird with wrap-around

4.2. Numerical Results

In this sub-section, we give the numerical results for the existing algorithm and the Benefit-Tree Based SMDC Algorithm. Our main figure of merit is the EE of the system, summed over all clusters and all cells. In consideration of the quality of the communication, we take the data rate into account firstly. During off-peak time, some active BSs operate in off state due to its low traffic load. The users in the sleeping BSs are served by this BS's adjacent and active BSs through CoMP. However, Due to the interference, the sleeping BS's user's data rate is lower than the users in active BS. At the same time, to satisfy a minimum demand of communication, we need to find the relationship between the maximum of cluster size with the user's average data rate in BS which works in sleeping mode firstly. Fig.1 shows the average data rate of users in the coverage of BS which are switched into sleeping mode. Due to the active BSs in the cluster increasing, then the interference brought by inter BSs changing into useful signal by using CoMP, the average data rate of users in the coverage of sleeping BS increases with the increasing of the cluster maximum size. Nevertheless, the number of active BSs is limited when the system is during low traffic load, because the sleeping mode was worked in this scenario.

During the iteration of dynamic clustering, the number of available BS joining into cluster is declining with the cluster maximum size increasing, which causes the average data rate of users in the coverage of sleeping BS increasing slowly. Compared with SMDC, SMDC-BT can achieve a higher data rate. It is because that SMDC can only choose the BS from the active BSs remanded by last clustering. However, a forest supplies numerous candidate clustering strategies in the SMDC-BT algorithm, which comprehensively considers the better channel condition BSs to join into the same cluster together that serves for the users in the coverage of sleeping BS and finally leads to a higher data rate.

After the discussion above, in order to meet the minimum data rate of 40Mbit/s and achieve higher system EE, we choose the cluster maximum size of 5 for simulation. Fig.2. shows the average proportion of energy saving compared with the traditional whole power consumption without CoMP and sleeping mode.

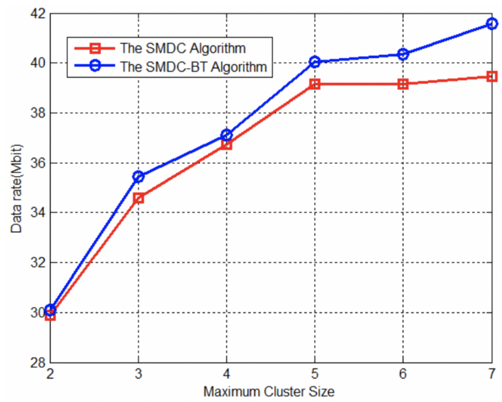

Figure 1: The average data rate of users in the coverage of sleeping BS

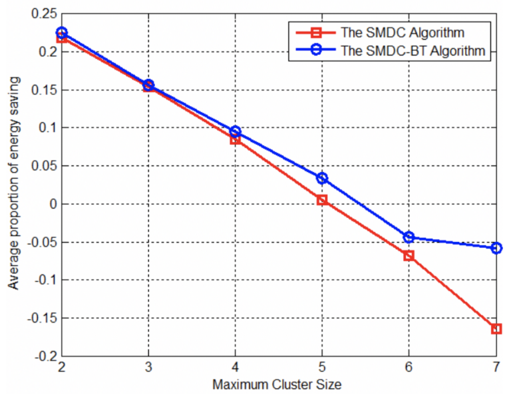

Figure 2: Average proportion of energy saving

With the increasing of cluster maximum size, the proportion of energy saving got by SMDC and SMDC-BT algorithm declines at the same time due to the additional signal processing power and backhauling increasing. However, compared with the traditional SMDC, SMDC-BT gets higher proportion of energy saving due to the really cluster generated smaller, which costs little extra signal processing power. When the cluster maximum size is higher than 5, the two algorithms aren't energy saving so obviously any more due to the high energy consumed by CoMP.

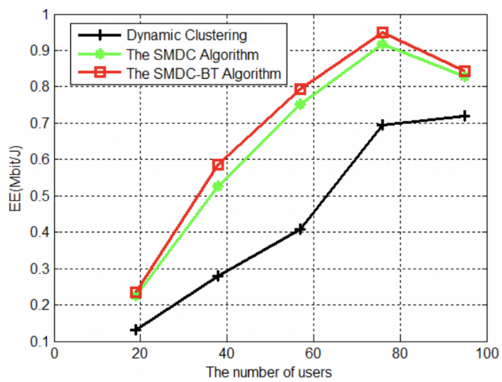

Figure 3: EE with a variable number of users

We compare the two algorithms with a variable number of users in Fig. 3. When the number of users is less than 76, with the increasing of users, the EE increases at the same time due to the increasing of the total data rate got in the network. Significantly, compared to the existing SMDC, SMDC-BT can achieve almost 10% higher in EE. It is because that the existing SMDC is a sequential and unidirectional dynamic clustering algorithm, which loses the opportunity to achieve a higher EE. However, SMDC-BT chooses the strategy which can obtain the highest EE from a forest in parallel.

5. CONCLUSIONS

In this paper, we concentrated on the EE of the cellular system. Specifically, to achieve higher EE, we proposed an benefit-tree based SMDC algorithm, which leads CoMP integrated with sleeping mode to improve the EE of the whole system. The main idea is to find out the most energy efficient clustering strategy through the benefit-tree based architecture. The uniform EE metric is also presented in details. The SMDC-BT algorithm is capable to non-uniform user distribution scenario and peak time. Moreover, The SMDC-BT algorithm can achieve a higher EE and more energy saving when compared to the traditional SMDC algorithm. As for future work, we can focus on how to reduce the complexity of our proposed SMDC-BT algorithm.

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