



# A Base Station Sleep Management Scheme Based on Simulated Annealing Algorithm

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**Abstract.** With the advent of 5G, the energy consumption of communication industry also increases, among which the base station (BS) energy consumption accounts for 43% of the total energy consumption of mobile communication. In order to reduce the communication energy consumption, the BS sleep technology can make the BS with low load enter the sleep state, realize the energy saving and create the green communication. In this paper, the simulated annealing (SA) algorithm is used to determine the BS closing mode. The switching situation can effectively reduce the energy consumption, which has practical significance and conforms to the expectation. The simulation results show that the sleep strategy can reduce the energy consumption, and the optimization of the algorithm can get a better solution and a simpler traversal process.

**Keywords:** 5G · Energy consumption · Simulated annealing algorithm

## 1 Introduction

In the 5G era, the requirements of users are getting more and more, the throughput and the rate is higher and higher, and the energy consumption of the communication industry is also increasing. With the rapid development of the information industry, users' requirement for cellular networks is increasing, and the BS account for 43% of the total energy consumption of mobile communications [1]. In order to meet the requirements of green communication and reduce the communication energy consumption, the research finds that the BS sleep technology can reduce the BS energy consumption by 10% and 60%, and it has great potential in reducing the system energy consumption and operating cost [2].

Chen et al. proposed a heterogeneous campus network protocol with orthogonal frequency division multiple access (OFDMA) [3], which allows a femtocell to completely close its wireless communication-related components without involving effective calls. Ashraf et al. discussed three different sleep strategies [4], namely micro BS control, core network control and user device control. Deployment of sleep strategy control in different locations has its own advantages and disadvantages. Cho et al. proposed a BS sleep mechanism to set the minimum separation distance between the BS [5]. However, for the 5G dense heterogeneous network, it is difficult to set the minimum separation

distance between base stations. Cai et al. proposed an operation scheme based on the joint location and the user density to achieve the approximate optimality in the polynomial time [6]. In 5G dense heterogeneous network, the use of centralized algorithm may bring very high computational complexity, while distributed algorithm may lead to the bad Qos when some nodes are closed and cannot be perceived. Therefore, it is very important to select the appropriate algorithm for the intensive heterogeneous network.

## 2 BS Sleep Strategy

The design of the base station switching mechanism is very complicated. The problems we are faced with are the sleeping period and the number of sleeping BS. If too many BS are closed by the wrong threshold estimation in the mechanism, the available resources in the network will be greatly reduced, resulting in the shortage of bandwidth resources and longer waiting time of users, which cannot meet the communication needs of users. In addition, if too many BS are closed, the distance between each service BS will be greatly increased, and all users cannot be guaranteed to be within the service BS area. As a result, the coverage performance of the network will be deteriorated, and the data transmission efficiency of users and system spectrum efficiency will be reduced correspondingly due to the increase of link delay.

This paper propose an adaptive BS management scheme based on energy balance, and a better BS sleep strategy is solved by using a centralized sleep algorithm in heterogeneous cellular network scenarios. In this paper, the simulated annealing (SA) algorithm was applied to the dormancy strategy, through to the BS and the connection between the users to solve the problem of abstraction and modeling, in view of the BS closed cover blind area and network terminal problem, and frequent closed questions, the BS is put forward in the heterogeneous network management scheme based on energy balance. It is a good way to improve the network energy consumption situation by using the simulated annealing algorithm.

The SA algorithm was proposed by Professor Kirkpatrick in 1982, inspired by the solid annealing process in thermodynamics. The SA algorithm is based on the Monte Carlo iterative solution strategy, with the global search function, good adaptability and robustness. In general, the initial high temperature is set first. In the process of gradual temperature decline, the probability jump can be used to jump out of the local optimal solution and approach the global optimal solution [7].

According to the Boltzmann ordering principle, the annealing process follows the law of thermodynamics, and the spontaneous change of the state of the system is always in the direction of the reduction of free energy. When the free energy reaches the minimum, the system reaches the equilibrium state. If  $E$  is the micro state energy of the system, the probability that the system is in state  $I$  is:

$$P_i = A \exp\left(-\frac{E_i}{kT}\right) \tag{1}$$

From  $\sum_i P_i = 1$ , that is  $\{T, \emptyset, \dots, \emptyset\}$ . Let  $Z = A \sum_i \exp\left(-\frac{E_i}{kT}\right)$ , we get  $A = \frac{1}{Z}$ . The Eq. (1) can be obtained:

$$P_i = \frac{1}{Z} \exp\left(-\frac{E_i}{kT}\right) \tag{2}$$

Where,  $K$  is Boltzmann constant,  $T$  is absolute temperature, and  $\exp(-\frac{E_i}{kT})$  is Boltzmann factor.

The inner loop of SA algorithm adopts Metropolis criterion, that is to accept the new state with probability. When the temperature is  $T$ , the new state  $j$  is generated from the current state  $i$ . The energy of the two is  $E_i$  and  $E_j$  respectively. If  $E_j < E_i$ , the new state  $j$  will be accepted as the current state. Otherwise, if the probability  $P_i = \exp(-\frac{E_j - E_i}{kT})$  is greater than the random number in the interval  $[0, 1]$ , the new state  $j$  will be accepted as the current state. If the above conditions are not true,  $i$  will be retained as the current state.

### 3 BS Sleep Scheme Based on SA Algorithm

In this paper, a model of random distribution of base stations is adopted to simulate the actual situation. Matern-like Point Progress (MLPP) improves the Poisson point distribution model [8]. It is mainly that when the distance between two points is less than a given value, one of the points is removed according to certain rules and the Poisson point distribution process is diluted.

(1) The first step is to generate a Poisson point process with a probability density of  $\lambda_P$ . In the finite set  $A \subset R^2$  ( $A$  is the area of some range within the region), the number of points follows Poisson's distribution, and the mean is  $\lambda|A|$ .

$$P(\theta(A) = n) = \exp(-\lambda|A|) \frac{(\lambda|A|)^n}{n!} \quad (3)$$

$\theta(A)$  is the number of midpoints in  $A$ . Meanwhile, for two disjoint finite sets in the region  $A \subset R^2$  and  $B \subset R^2$ , the number of points in  $A$  and  $B$  is not correlated, so the Poisson point process is only correlated to  $\lambda$ .

(2) For any point  $x \in \theta(A)$  in  $\theta(A)$ , add a tag ( $m_x \in U[0, 1]$ ) to each point that is independent of each other.

(3) For each point in the circle  $B(x, R)$ , if the mark of  $x \in \theta(A)$  is the smallest, the point is retained and the rest points are deleted.  $U[0, 1]$  is the uniform distribution between 0 and 1.  $R$  is the dilution radius that is the given minimum distance, and the point selection process can be expressed by Formula (4).

$$\psi = \{x : x \in \theta(A), m_x \leq m_y, \forall y \in B(x, R) \cap \theta(A)\} \quad (4)$$

In the Formula (4),  $\psi$  represents the last remaining points in the circle  $B(x, R)$  which are selected to be retained. According to this method, a reservation can be selected from the points in the close distance, and the distribution model formed by the points left after the steps above is the distribution process model of Matern-like points.

In the actual BS deployment, the microcell has the low power consumption, the small coverage and the strong randomness. Therefore, in this scheme, Poisson point distribution is directly adopted for micro BS and Matern-like point distribution is adopted for macro BS. The simulated area of 5 km is shown in Fig. 1.

The specific steps of the scheme are:

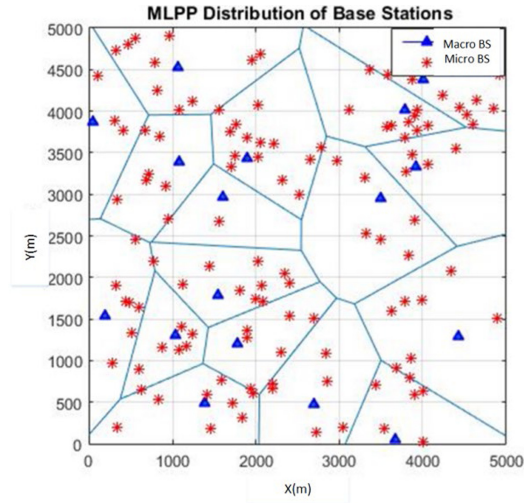


Fig. 1. Heterogeneous cellular network based on MLPP

- (1) Initialization: according to the complexity of the problem, set the initial temperature  $T$ , initial solution state  $S$ , and the number of internal iteration  $L$ .
- (2) perform steps (3) to (6) for  $k = 1, 2, \dots, L$ .
- (3) A disturbance is generated in the original state to find the value of the current optimization function.
- (4) Calculate the increment  $\Delta T = C(S_1) - C(S)$ ,  $C(S)$  is the evaluation function.
- (5) If  $\Delta T < 0$ ,  $S_1$  is accepted as the current latest solution. If  $\Delta T > 0$ ,  $S_1$  is accepted as the new current solution with probability  $\exp(-\Delta T/T)$ .
- (6) If the termination condition is satisfied, the current solution is output as the optimal solution.
- (7) Set the network topology according to the optimal solution, close the the zero-load BS.

## 4 Simulation Analysis

In a two-layer heterogeneous network, there are three sectors in a macro BS, and two micro BS are deployed in each sector. The distance from the micro BS to the macro BS is three-quarters of the coverage radius of the macro BS. Assume that the coverage radius of the macro BS is 500 m and that of the micro BS is 100 m. Users within the coverage area of the micro BS have priority access to the micro BS, while other users have access to the macro BS. The BS sleep algorithm is the SA. When the BS with low load is closed, the users in its cell are reconnected to the nearest macro BS, and the micro BS can only connect the users within its coverage area.

The simulated cellular network is shown in Fig. 2. This two heterogeneous cellular network includes 19 macro BS, each of which is surrounded by six micro BS evenly distributed.

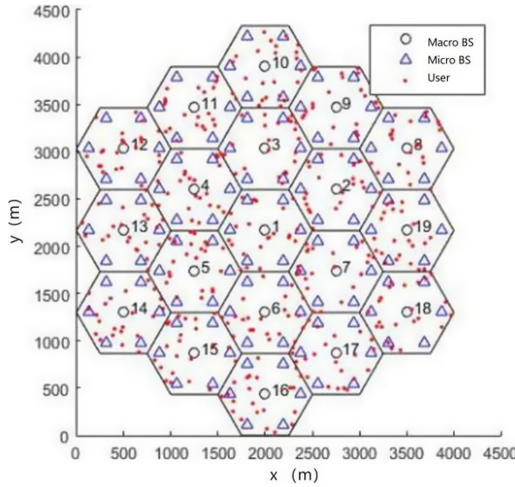


Fig. 2. Simulated two heterogeneous cellular network.

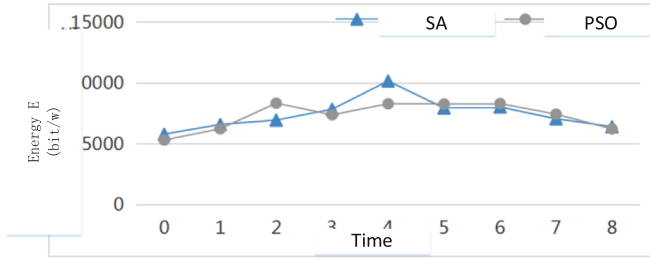
Table 1 shows the energy consumption comparison between the SA algorithm and the typical particle swarm optimization (PSO) algorithm from 0:00 a.m. to 8:00 a.m. it can be seen that the results of the two algorithms are close when the user flow is low, but at 7:00, the energy consumption of the SA algorithm is about 1 kW lower than that of the PSO algorithm. This reason is that random factors are introduced into the search process of the SA algorithm, there is some probability to accept the worse solution in the inner loop, which can make the algorithm jump out of the current optimal solution in the execution process, and find the global optimal solution. As the data in the table shows, the PSO algorithm has good stability, but it will fall into the local optimal solution. The SA algorithm introduces random factors, and can jump out of the current solution at some times to obtain the overall optimal solution.

Table 1. Comparison of energy consumption between SA and PSO (W)

Time	0 a.m	1 a.m	2 a.m	3 a.m	4 a.m	5 a.m	6 a.m	7 a.m	8 a.m
SA	63469	49956	38584	30279	25638	25571	30068	38531	50171
PSO	63077	49934	38168	30551	25845	26014	29991	39408	50258

The energy efficiency is equal to the throughput of the system divided by the total energy consumption. By comparing the energy efficiency of the SA algorithm and the PSO algorithm to verify the green of the algorithm, the energy efficiency comparison between the two algorithms is shown in Fig. 3.

It can be seen from the figure that the energy efficiency of the SA algorithm at 3–4 a.m. is higher than that of the PSO algorithm, and at other time the energy efficiency of the PSO algorithm is slightly higher or close to that of the SA algorithm.



**Fig. 3.** Energy efficiency comparison.

Figure 4 and Fig. 5 respectively count the time consumed to execute the algorithm of the two algorithms and the number of active BS.

In Fig. 4, the SA algorithm takes much less time to solve than the PSO algorithm. It can be seen from the simulation results that the SA algorithm can search for the optimal solution quickly. In Fig. 5, the number of the BS opened with the SA algorithm is less than that of PSO algorithm in most cases. That means the SA algorithm can better closed the BS with light load. From the global perspective, it can close the BS with the low load under the condition of ensuring the communication quality of users, and achieve the purpose of the energy consumption balance. By applying the BS sleep algorithm to the actual scene, achieve the purpose of green communication in the 5G environment.

## 5 Conclusion

This paper focuses on the energy consumption of the BS in the communication system, and use a BS sleep scheme with the SA algorithm, which can quickly solve the large-scale combination optimization problem. With a two-layer heterogeneous cellular network model based on matérn like point distribution process, this scheme is compared with the typical PSO method from energy consumption, energy efficiency, algorithm consumption time etc. The simulation results show that in the case of the similar performance, the SA algorithm can get the global optimal solution, and its energy consumption can be saved 500–1000 watts. Its' algorithm speed is 15% faster than PSO algorithm. Under the condition of ensuring the quality of user communication, the SA algorithm can sleep the low load base station and achieve the green communication in 5G environment.

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