

Received February 4, 2020, accepted February 9, 2020, date of publication February 13, 2020, date of current version February 25, 2020.

Digital Object Identifier 10.1109/ACCESS.2020.2973648

Energy Saving Technology of 5G Base Station Based on Internet of Things Collaborative Control

KUO-CHI CHANG¹, KAI-CHUN CHU², HSIAO-CHUAN WANG³,
YUH-CHUNG LIN¹, AND JENG-SHYANG PAN⁴

¹Fujian Provincial Key Laboratory of Big Data Mining and Applications, Fujian University of Technology, Fuzhou 350117, China

²School of Management, Fujian University of Technology, Fuzhou 350117, China

³Institute of Environmental Engineering, National Taiwan University, Taipei 10617, Taiwan

⁴College of Computer Science and Engineering, Shandong University of Science and Technology, Shandong 266590, China

Corresponding author: Kai-Chun Chu (kaykagy@gmail.com)

ABSTRACT For time and space constraints, 5G base stations will have more serious energy consumption problems in some time periods, so it needs corresponding sleep strategies to reduce energy consumption. Based on the analysis of 5G super dense base station network structure, through the analysis of current situation and user demand, a cluster sleep method based on genetic algorithm is constructed under the support of genetic algorithm, which can realize the dynamic matching of energy consumption in time domain and space, and the low load base station enters the sleep state. In order to verify the performance of the algorithm, the simulation network structure is built on the MATLAB platform, and the advantages of the algorithm in this study are obtained through comparative analysis, and the relevant test parameters are set for the technical performance analysis of this study. The research shows that the method proposed in this paper has a certain energy-saving effect, can meet the energy efficiency requirements of 5G ultra dense base station, and in the ultra dense base station group, the complexity can also meet the system operation requirements, which has a certain degree of practicality, and can provide reference for the follow-up related research.

INDEX TERMS Internet of Things, collaborative network control, 5G base station, energy consumption, energy conservation.

I. INTRODUCTION

With the continuous development of mobile communication technology, people's access to information and speed continue to improve, in the context of 5G network gradually popularized, a large number of base stations are in full swing. Compared with 4G network, 5G network requires higher number and density of base stations, so the resource consumption caused by the capacity of communication system should be fully considered in the process of mobile base station layout. The traditional macro cellular network architecture can not meet the energy consumption demand of the dense 5G base station, so we need to improve the traditional macro cellular network structure and propose a new network structure scheme. UDN technology is a heterogeneous network structure which is different from the traditional macro cellular network. This network structure has the characteristics of dense layout, high frequency reuse rate, and can effectively improve the network capacity. It is the basic network structure commonly used in 5G network at present.

The associate editor coordinating the review of this manuscript and approving it for publication was Wei Wei¹.

The layout of this small cellular network structure will lead to higher density of communication base stations. In order to improve the quality of network communication service, it is necessary to further reduce the energy consumption in network operation and realize green communication.

Based on the demand of green communication under the background of 5G growing popularity, this study analyzes the sleep algorithm of base station, explores the energy-saving technology of 5G base station, combines the Internet of things technology, collects network data with the support of sensors, and constructs a centralized dynamic sleep method based on genetic algorithm to realize the system network cluster management of high-density and large-scale base station groups, effectively reduce the energy loss of centralized base station group and improve the system stability. It is found that the current research of some experts and scholars on 5g papers mainly focuses on its networking mode and operation process stability, while the research on energy-saving process is mostly one-sided.

In this study, the algorithm is improved and innovated on the traditional algorithm, the main research work includes the following: (1) this study abandons the traditional base station

distributed network sleep mode, and adopts the centralized sleep algorithm to consider all the combination modes of base stations, so as to find the best sleep scheme, and improve the energy-saving effect of the system and the operation stability of the system; (2) the genetic algorithm is applied to the selection and calculation of dormancy scheme, so as to effectively improve the calculation efficiency of the system, and the cluster mode of collaborative control is proposed, so as to calculate the energy-saving mode of each cluster by combining the genetic algorithm; (3) in the base station clustering, the dynamic clustering algorithm based on the cooperation degree can avoid that the traditional algorithm can not adapt to the actual system channel time-varying, and further improve the system stability.

In conclusion, this study proposes a centralized dynamic sleep strategy based on a series of algorithms for the problem of high complexity of centralized sleep algorithm. With the support of the Internet of things data collection system, the dynamic analysis of base station sleep is carried out to obtain the best network sleep strategy in the shortest time, so as to effectively reduce network energy consumption and achieve the expected purpose of base station energy saving.

II. RELATED WORK

This research is based on the research of many experts and scholars. Through reading many literatures, we can understand the current situation of the research. At present, green wireless communication technology has received extensive attention from the communication industry, and scholars in various countries have studied communication energy-saving technology from multiple perspectives, including network structure innovation, system mode new channel protocol improvement, etc. Through these analysis, we can promote the development of green energy-saving technology, and derive many theories and technical methods. Academic circles have carried out research through some international projects, such as European Telecom design project [1], French mobile communication network structure optimization project [2], UK research on its original network structure and put forward corresponding green energy-saving radio project [3], etc. At present, the international standardization organization has listed the green communication in the corresponding standards, which provides reference for the subsequent communication network construction.

Traditional mobile communication network resource allocation mainly focuses on the effective allocation of network resources. The research parameters include spectrum efficiency, output signal strength, interference items, etc. The reasonable allocation of these projects can effectively improve the efficiency of network operation, but this research method is only applicable to 4G and its previous network structure. The large amount of resource waste caused by 5G intensive base station group needs to be optimized by the corresponding green energy-saving technology. The energy-saving strategy based on wireless resource management is a common energy-saving technology in the current

communication system. This technology not only needs to deal with the integration of various heterogeneous networks, but also needs to make full use of various network protocol information, and provide demand guarantee for the system at different terminals.

According to the mobile communication network structure, the load analysis is carried out [4], and the corresponding base station group model is constructed. Combined with the simulation, the in-depth study of the base station dormancy scheme is carried out, and the corresponding optimization strategy is proposed, and finally an effective optimization scheme is obtained to achieve the expected goal of green energy saving [5]. In view of the high energy consumption of the base station, a random sleep scheme is proposed. The minimum energy consumption of the base station is set as the constraint condition, and the sleep probability of the base station is calculated and analyzed [6]. Based on the previous research of sleep strategy, the parameter of network coverage is added to design the model for performance simulation. The simulation results show that the actual energy consumption is reduced by 30%, but the dynamic load change is not realized.

Reference [7] put forward to take the distance sense as a reference parameter, design the corresponding energy-saving sleep scheme, design the simulation experiment to analyze the energy consumption of the base station. From the research results, although it has some energy-saving effect, it still does not realize the dynamic change of the load [8]. Based on the research of mobile communication base station dormancy technology, choose the double-layer heterogeneous network as the basic network structure, and take the distance between the small base station and the macro base station as the decision condition, and implement the base station dormancy in the order of the distance from the macro base station from the near to the far. This method has certain effect, but it can not effectively identify the distance between the base station and the macro base station, so this method is not easy to promote [9]. According to the analysis of mobile communication network load, a simulation model based on load sensing is proposed, which takes the base station load as the basis of system identification. If the base station load is lower than the set value, it will be shut down to realize the base station sleep. Chaudhary *et al.* [10] combined with the mobile characteristics of mobile networks, and also use the load as the threshold value for load monitoring. When the load is lower than the threshold value, it will enter the sleep state, and when the load gradually increases, it will gradually open, so that the system can serve multiple mobile terminal users.

Reference [11] select the heterogeneous network architecture to study the sleep system, design the base station group corresponding to the threshold, and carry out the system research with the service load as the sleep combination, and study the heterogeneous network macro base station and small base station, and analyze the best sleep combination scheme from the orthogonal spectrum of macro base station and small base station [12]. Based on the research of

the structure of heterogeneous cellular network, this paper constructs the method of base station dormancy based on heterogeneous cellular network. The system mainly accesses the algorithm model according to the resource pairing. The small base station in this system uses the load threshold to sleep, while the macro base station in the base station uses the low load mode to sleep.

Tian *et al.* [13] analyzed the architecture of the mobile communication network, selected the separation architecture, analyzed the random sleep of the small base station based on the architecture, and analyzed the channel when the base station slept, that is to say, the spectrum is released by the small base station. With the help of the small base station, the macro base station can effectively use these spectrum, so as to help more base stations to sleep. Reference [7] researches on the mobile vehicle network, add the sleep algorithm to the network, so as to realize the real-time update of the vehicle position of the base station.

The design of cooperative communication between mobile communication base stations can effectively reduce the system energy consumption and realize the cooperation between the same layer. In this state, there are two main states, the sleep state and the active state. The base station is generally in one of these two states. When a base station is in the sleep mode, it can transfer to the adjacent base station in the mode, and interfere with other communication users within the sleep range of the base station. In addition, cooperation research can also be carried out through the base stations between different layers. In this way, the central base station mainly helps users within the coverage of the surrounding dormant base stations by expanding [14].

The statistics of the base station energy reduction model are shown in Table 1.

There are also some experts and scholars who realize the base station sleep by combining new energy with base station, so as to effectively reduce the energy consumption of base station. In the research of base station, the random characteristics of base station load and the random characteristics of green energy saving of base station need to be considered. In order to maximize the stability of the system, the above two points need to be combined. When the base station is dormant, we need to consider some control strategies of the base station dormancy mode, and also need to study some other control modes of the base station dormancy, including the control of various signals of the base station.

III. SYSTEM MODEL

Compared with 4G network, 5G network requires higher number and density of base stations, so the resource consumption caused by the capacity of communication system should be fully considered in the process of mobile base station layout. Mobile cellular network is an important carrier of data transmission in mobile communication [15]. There is obvious tidal effect in the process of data transmission, which directly leads to low energy utilization. Therefore, when the traffic load of the base station is low, if it works with the

TABLE 1. 5g base station energy consumption reduction model statistics.

Model	Advantages	Disadvantage
Network Structure Load Optimization	Reduce energy consumption to a certain extent	Unrealized load dynamics
Macro base station model	Reduce energy consumption to a certain extent	Unrealized load dynamics
Load-aware model	Dynamic reduction of model energy consumption	Difficulties in large-scale implementation
Business load model	Dynamic reduction of model energy consumption	Difficulties in large-scale implementation

maximum power, it will lead to serious waste of resources, thus, the base station with low load can be directly selected to enter the sleep state, so as to reduce the unnecessary energy loss in the network system.

In the process of energy-saving technology analysis of 5G base station, this study directly from the perspective of user access, combined with the analysis of user communication quality and network energy efficiency, combined with genetic algorithm to build 5G base station energy-saving technology based on Internet of things collaborative control, and reasonably explain the relevant issues, and reasonably sleep the base station [16].

A. SYSTEM NETWORK MODEL

Compared with 4G network, 5G network requires higher number and density of base stations, so the resource consumption caused by the capacity of communication system should be fully considered in the process of mobile base station layout. The traditional macro cellular network architecture can not meet the energy consumption demand of the dense 5G base station, so we need to improve the traditional macro cellular network structure and propose a new network structure scheme. UDN technology is a heterogeneous network structure which is different from the traditional macro cellular network. This network structure has the characteristics of dense layout, high frequency reuse rate, and can effectively improve the network capacity. It is the basic network structure commonly used in 5G network at present. The layout of this small cellular network structure will lead to higher density of communication base stations. In order to improve the quality of network communication service, it is necessary to further reduce the energy consumption in network operation and realize green communication.

Affected by the wavelength, the density of 5G base station is far higher than 4G network(Fig.1). It is set that there are M service base stations in the base station, and they are expressed as $M = \{1, 2, \dots, M\}$, where BS_m is the base station [17].

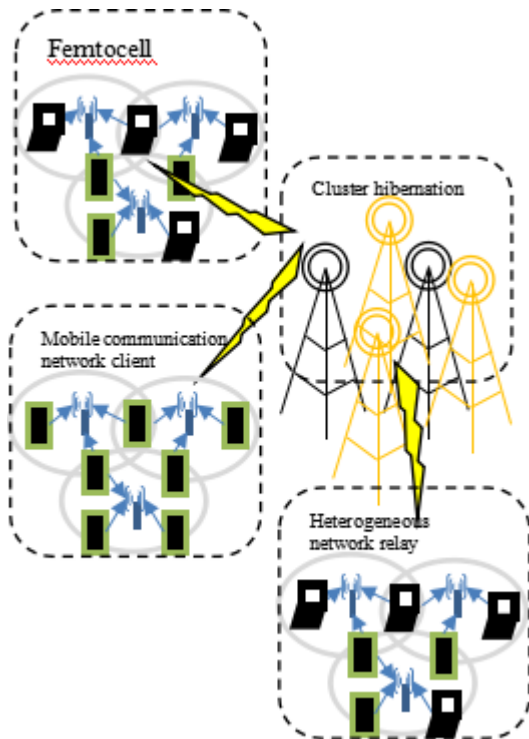


FIGURE 1. Ultra dense small cellular network.

Suppose that there are N users in the network, and they are respectively expressed as $N = \{1, 2, \dots, N\}$, Where UN_n is the user whose number is n , the real-time switch state of the matrix base station is represented by the matrix $S = [s_m]_{l \times M}$, the value of 1 indicates the active state, and the value of 0 indicates the dormant state.

1) NETWORK LOAD

The network complexity in the system indicates the number of users of the network load at a certain time, and there is a positive correlation between the number of users and the network load [18]. Therefore, the network load can be represented by the number of users, and the relationship between the number of users of a certain day and the time can be represented as a histogram, from which it can be seen that the network load is in a dynamic change, among them, 0-8 points is the low period of network load, and the network load over 8 points shows a jump increase, and continues to 0 point, which is closely related to people’s work and rest time(Fig.2) [19]. The statistical results are shown in Figure 2.

2) FLOW MODEL

In order to improve the effective deployment of follow-up skills, it is necessary to analyze the model, establish the attribute parameters corresponding to the model, and the

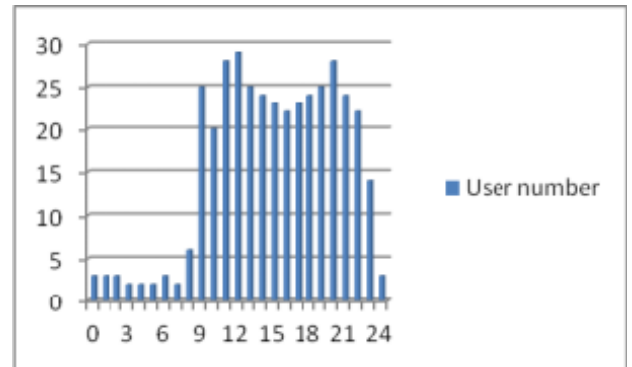


FIGURE 2. Average number of users arriving.

traffic model mainly corresponds to the spatial customer distribution relationship. The user distribution in this study conforms to the characteristics of random distribution (Fig.3) [20]. In this study, experimental analysis was performed through matlab, and the results are shown in Figure 3. Figure 3 (a) shows Random distribution, Figure 3 (b) shows Uniform distribution, Figure 3 (c) shows Uniform distribution.

B. SYSTEM ENERGY CONSUMPTION MODEL

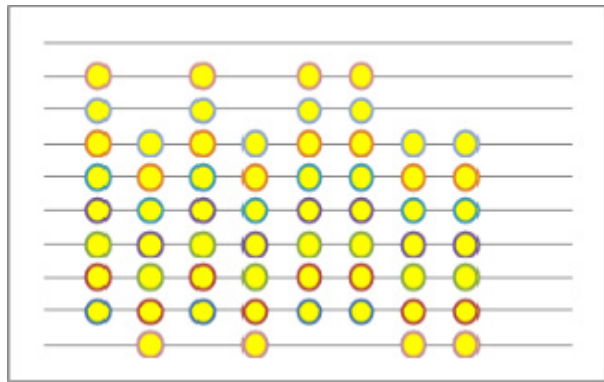
There are two main forms of base station energy consumption: dynamic energy consumption and static energy consumption. Static energy consumption is mainly basic power consumption without load. Dynamic energy consumption has a functional relationship with base station load, which can be expressed as:

$$P_{BS_m} = \begin{cases} P_0 + \Delta m \cdot P_m^T, & \text{active mod } e \\ P_{sleep}, & \text{sleep mod } e \end{cases} \quad (1)$$

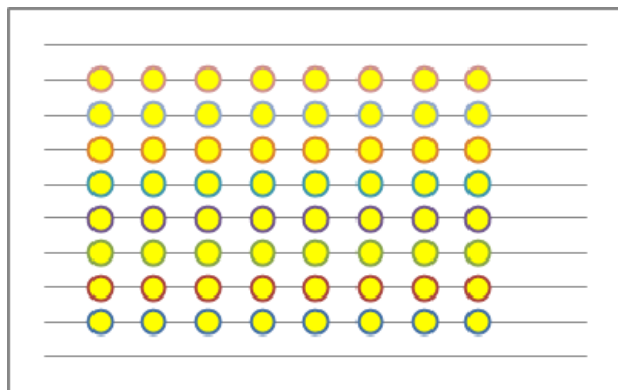
P_0 – SBS represents the basic circuit power consumption in the active state; Δm – represents the load related proportional coefficient; P_m^T – SBS represents the transmission power; P_{sleep} – represents the power consumption when SBS is in the sleep state. There are two main ways to calculate the energy efficiency of cellular network, one is to calculate the energy consumption per unit area, unit W/m^2 . this method focuses on calculating the total energy consumption when calculating the energy consumption [21]. The other is to calculate the energy consumption per unit bit, unit $bit/s.W$, simplification to bit/J . This calculation method mainly calculates the comparison value between data transmission rate and energy consumption, so it is more comprehensive, including not only total energy consumption, but also data transmission rate. In this study, energy consumption per unit bit is used as energy efficiency calculation of cellular network, and the calculation formula is as follows [22]:

$$EE = \frac{C_t}{P_t} \quad (2)$$

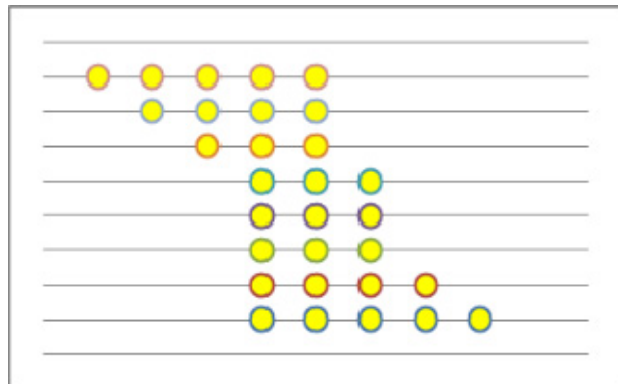
In the above formula, C_t – represents the total capacity of the target network; P_t – represents the total energy consumption of the target network system.



(a) Random distribution



(b) Uniform distribution



(c) Cluster distribution

FIGURE 3. Different flow models.

Combined with the network architecture model of this study, the statistical formula of network energy efficiency EE_{net} can be shown in (3).

$$EE_{net} = \frac{\sum_{i=1}^{N_s} C_i^S}{\sum_{i=1}^{N_s} P_i^S} \quad (3)$$

In the above formula, N_s – represents the number of base stations in the target network; C_i^S – represents the throughput of the i -th small base station; P_i^S – represents the power consumption of the i -th small base station.

C. SYSTEM ACCESS MODEL

1) ESTABLISH PAIRING MODEL TO REALIZE PAIRING CONNECTION BETWEEN USERS AND BASE STATIONS

Due to the dense 5G base stations, the distance between the base stations is small, and there is a serious phenomenon of repeated coverage among the coverage areas of each base station. Therefore, users face a variety of choices in the repeated coverage area. In order to improve the user experience, it is necessary to build a reasonable pairing between users and the base station. The relevant variables of the algorithm are as follows:

$USR(u, s_{ki})$ – indicates whether user u has sent a request to base station s_{ki} within the coverage, 1 indicates that the request has been made, 0 indicates that the request has not been made, $UFree(u)$ – indicates that the user access status, 1 indicates that the request has been connected or the user has not sent a request to the base station, 0 indicates that the user request has not passed, $PT(u)$ – SINR connection reference table, and N_{max} – indicates the maximum number of users connected to the base station.

2) ESTABLISH THE SLEEP ALGORITHM MODEL OF BASE STATION

In order to establish the base station sleep algorithm model, the propagation loss between the base station and the user is set as pl , which can be expressed as follows:

$$pl_{m,n} = \varepsilon \log_{10}(d_{m,n}) + c_d \quad (4)$$

In the above formula, $d_{m,n}$ – represents the distance between base station BS_m and user UE_n ; c_d – represents the distance independent coefficient factor; ε – represents the attenuation coefficient of signal propagation.

In order to establish the connection model between UE and BS, the connection matrix of UE and BS can be expressed as $X = (x_{n,m})_{N \times M}$, $x_{n,m} = \{0, 1\}$, when UE_n is connected to BS_m , $x_{n,m} = 1$, and otherwise $x_{n,m} = 0$.

The node degrees of BS_m and UE_n can be expressed as $\sum_{n=1}^N x_{m,n}$ and $\sum_{m=1}^M x_{m,n}$ respectively. Suppose $P = (P_{m,n})_{M \times N}$. $P_{m,n}$ represents the transmission power sent by BS_m to UE_n . Assuming that the noise power is σ^2 , the SNR between BS_m and UE_n can be expressed as formula (5)

$$\gamma_{m,n} = \frac{pl_{m,n} p_{m,n}}{\sum_{k=1, k \neq m}^M pl_{k,n} p_{k,n} + \sigma^2} \quad (5)$$

In the above formula, $pl_{m,n} p_{m,n}$ – represents the power received by the user from the base station; $\sum_{k=1, k \neq m}^M pl_{k,n} p_{k,n}$ – represents the interference generated by other base stations to the user. Suppose that when $\gamma_{m,n}$ is greater than a threshold \wedge_{th} , UE_n connects to BJ BS_m . The total power consumption

of the system can be expressed as formula (6).

$$P_{cost} = \sum_{m=1}^M \left[s_m \left(P_0 + \Delta m \cdot P_m^T \right) + (1 - s_m) P_{sleep} \right] \quad (6)$$

So the transmission rate of BS_m to UE_n is [23]:

$$R_{m,n} = B_{m,n} \cdot \log_2 (I + \gamma_{m,n}) \quad (7)$$

As formula (8), the ratio of total capacity and total energy consumption is:

$$\eta_{EE} = \frac{\sum_{m=1}^M s_m + \sum_{n=1}^N x_{m,n} R_{m,n}}{\sum_{m=1}^M \left[s_m \left(P_0 + \Delta m \cdot P_m^T \right) + (1 - s_m) P_{sleep} \right]} \quad (8)$$

The final number of active base stations of energy efficiency $f_1 = \eta_{EE}$ of the system is $f_2 = S \cdot E$, besides, $E = [1, 1, \dots, 1]_{N \times 1}$. Based on the above analysis, the following models can be established according to the actual situation [24]:

$$\begin{aligned} & \text{MAX } [f_1] \quad (9) \\ & \text{s.t.} = \begin{cases} C1: s_m, x_{m,n} \in \{0, 1\}, \quad \forall m, n \\ C2: \sum_{m=1}^M x_{m,n} \leq 1, \quad \forall n \\ C3: \sum_{n=1}^N x_{m,n} \leq M_m^{\max}, \quad \forall m \\ C4: x_{m,n} \leq s_m, \quad \forall m, n \\ C5: s_m p_{l_{m,n}} p_{m,n} \geq x_{m,n} \wedge_{th} \left(\sum_{k=1, k \neq m}^M p_{l_{k,n}} p_{k,n} + \sigma^2 \right) \\ C6: \sum_{m=1}^M \sum_{n=1}^N x_{m,n} \geq (1 - \tau) N \end{cases} \quad (10) \end{aligned}$$

In the above formula, M_m^{\max} – represents the maximum value of the maximum connectable users of the m-th base station. τ – represents the probability of users not being served. C1 – indicates the switch state of base station and the connection state of base station BS_m and user UE_n ; C2 – indicates that a UE can only be serviced by one BS at most; C3 – indicates that the maximum number of UE that a limited base station can be connected to; C4 – indicates that any UE_n can be connected to and serviced by BS only when BS is active; C5 – $\gamma_{m,n} \geq \wedge_{th}$ is deformed; C6 – ensures that the interruption probability of UE is less than τ .

Through the above, the energy-saving problem of the base station can be transformed into a multi-objective optimization problem with multiple parameters of [C1 – C6]. the minimum active state is the optimal energy-saving state. Therefore, it is necessary to optimize the active state of the base station in multiple states, and find the minimum active state from multiple states.

IV. CENTRALIZED SLEEP STRATEGY BASED ON GENETIC ALGORITHM

A. SLEEP ALGORITHM MODEL

In order to achieve the energy-saving effect, it is necessary to find the best combination from multiple base station sleep

combinations when the base station is in normal operation. Based on this study, from the perspective of nonlinear constraints, combined with genetic algorithm to build a multi-objective solution model, to explore the optimal sleeping combination of 5G base station group.

1) CHROMOSOME DESIGN OF GENETIC ALGORITHM

Suppose there are N base stations in total, and the corresponding states of each base station are GK_i , then there are n corresponding states. If the positions of these base stations and the corresponding state sequence function gene are taken as a chromosome, and they are real coded, and the chromosome length is set to N, then the information structure they contain can be expressed as follows:

$$Gene = [(s_1, G_1), (s_2, G_2), \dots, (s_i, G_i), \dots, (s_N, G_N)] \quad (11)$$

In the above formula, s_i – represents the position of the ith base station; G_i – represents the corresponding state of the ith base station; $Gene$ – represents the chromosome; N – represents the chromosome length.

2) FITNESS FUNCTION

Different chromosomes in the population contain a base station dormancy strategy, and the advantages and disadvantages of the strategy are mainly reflected by its functions. Therefore, it is necessary to analyze the system access model to get different base station dormancy combinations. In this process, the role of two genetic algorithms is to find the largest dormancy combination sequence of base station energy efficiency f_i , which can be expressed as

$$\max (f_i) \quad (12)$$

In the process of solving sequence combination optimization, sleep analysis is mainly carried out from the perspective of user and base station connection. Before the analysis, it is necessary to analyze the fitness function and over limit fitness function from the perspective of threshold adaptation.

Threshold fitness function. This function mainly judges the base station dormancy condition by setting the threshold value, that is, to ensure that the signal interference between users does not affect the user experience, it is necessary to avoid the threshold sequence appearing in the process of population evolution, so the threshold fitness function can be expressed as:

$$\begin{aligned} K_v &= \sum_{i=1}^n K_i \\ K_i &= \begin{cases} \wedge_{th} - \gamma_{m,n}, & \gamma_{m,n} \leq \wedge_{th} \\ 0, & \gamma_{m,n} > \wedge_{th} \end{cases} \quad (13) \end{aligned}$$

In the above formula, K_i – indicates whether the SINR of each user and the base station is greater than the threshold value; \wedge_{th} – indicates the threshold value of the connection between the user and the base station; $\gamma_{m,n}$ – indicates the

signal to interference noise ratio of the connection between the user and the base station; n – indicates the number of users; K_v – indicates the threshold fitness value.

Over limit fitness function. Overrun means that the number of base station users cannot exceed the load limit of the base station, so as to ensure the stable operation of the base station. The calculation formula is as follows:

$$K_t = \sum_{i=1}^n K_j$$

$$K_j = \begin{cases} b_{num} - M_n^{\max}, & b_{num} \geq M_n^{\max} \\ 0, & b_{num} \leq M_n^{\max} \end{cases} \quad (14)$$

In the above formula, K_j – indicates whether the number of users connected by the base station exceeds the upper limit; b_{num} – indicates the number of users connected by the base station; M_n^{\max} – indicates the upper limit of the number of users connected by the base station; K_t – indicates the over limit fitness value.

According to the above analysis, the constraints can be taken as the constraints of building the model, so that the sleep policy model can be expressed as:

$$\max obj = f_1 - (\alpha \cdot K_v + \beta \cdot K_j)$$

$$s.t. \begin{cases} \sum_{m=1}^M x_{m,n} \leq 1, & \forall n \\ s_m, x_{m,n} \in \{0, 1\}, & \forall m, n \end{cases} \quad (15)$$

In the above formula, the penalty coefficient of objective function α – is about threshold constraint, and that of objective function β – is about overrun constraint. Through the above analysis, the algorithm model of this study is constructed, and then the algorithm flow is analyzed.

B. ALGORITHM FLOW

Combined with the above algorithm analysis, genetic algorithm is used to optimize the base station sleep strategy, the algorithm flow(Fig.4), and the detailed process is described as follows:

Step 1: initialize the genetic algorithm. Initialization parameters include population size m , maximum genetic algebra, generation gap $gg4p$, individual precision value, individual crossover probability, mutation probability, etc;

Step 2: the constraints are established by combining UE and BS, and the corresponding access model is built on this basis;

Step 3: the chromosome information in the algorithm is encoded by real coding, in which the gene chromosome is the position and state of the base station;

Step 4: calculate the fitness of the function, get the fitness function through the objective function, carry in the numerical value for iterative calculation, and finally get the fitness corresponding to the threshold;

Step 5: judge the iteration process by terminating the iteration function. If the conditions are met, output the best result and enter step 7. If the conditions are not met, enter step 6.

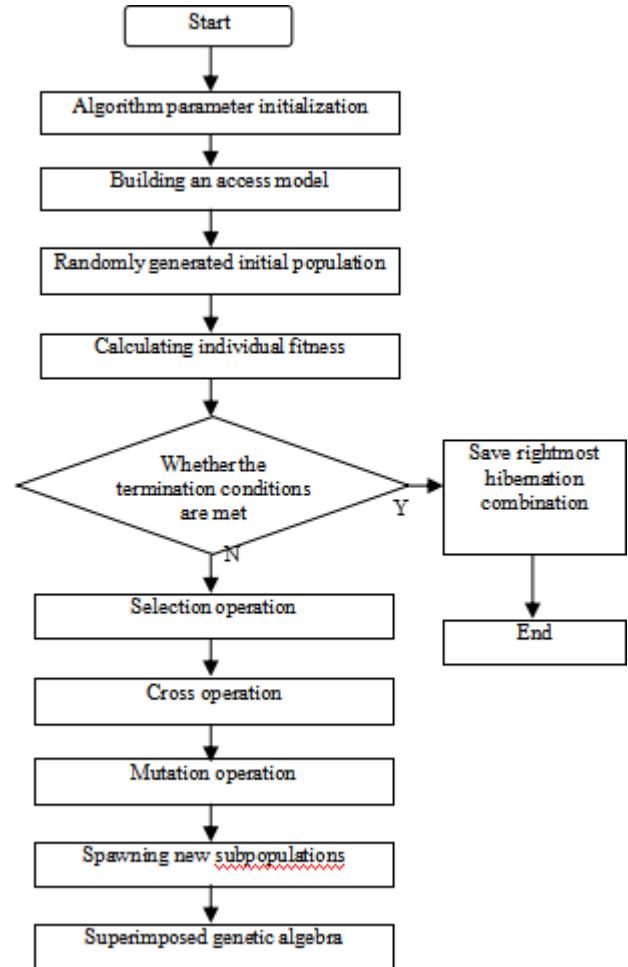


FIGURE 4. Flow chart of obtaining the best sleep combination in energy saving scheme.

Step 6: operator operation is carried out for genetic algorithm. The number of iterations is accumulated by 1 each time. The operator types are gene selection, cross recombination and gene mutation. New population is obtained through operator operation, and then enter step 4.

Step 7: calculate the best sleep combination of the base station and output the result.

C. CLUSTERING TIME SEGMENT DIVISION

Share the time of the day. Set s handover triggered nodes in the day, and the base station load is different at different SP times, so the number of clusters corresponding to them is different. If the corresponding time nodes will re cluster the network structure, frequent clustering will affect the stability of the system. Therefore, according to the SP load in the United States and its load development trend, this study designs a threshold search scheme for the target optimization, and divides the whole day period under the condition of the threshold. The time period is expressed as TD_i , and SP network is used to cluster the clustering algorithm at the beginning of the time period. When clustering, it is mainly based on the following conditions:

(1) For each SP in TD_i , the load difference between its load and other SP in TD_i must be less than the load threshold G , $G = \varphi Load_{max}$, where $Load_{max}$ is the load value when the network is fully loaded, and φ is the decimal between $[0 \sim 1]$, indicating the proportion of G to the full load.

(2) For SP of TD_i , it must be ensured that all SP_i must be continuous. For example, SP_1 and SP_3 cannot be divided into the same TD_i , while SP_1, SP_2 and SP_3 can be divided into the same TD_i .

The time period of a day is divided into regions. It is set that the daily load changes develop in the order shown in the figure(Fig.5). Then between 1 and 5 points, the load lifting speed is slow, so the difference between SP_1 and SP_5 is basically small, and the threshold value is not exceeded, so it can be classified as a TD. It can be clearly expressed as TD1. Similarly, TD2 in Figure 5 can be obtained respectively. The rise speed of TD2 is fast, so it is not suitable to use this load to calculate TD1.

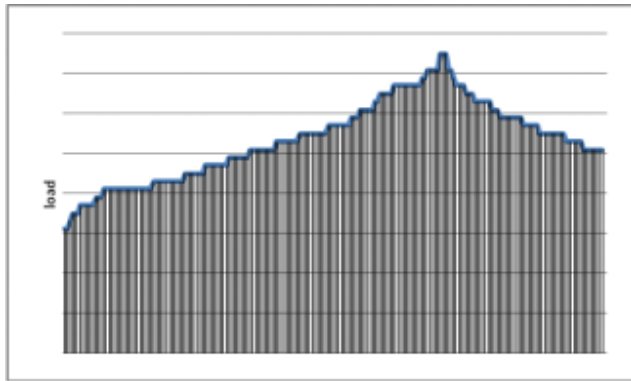


FIGURE 5. Clustering time segment division.

In the actual decision-making, selecting different G will lead to different results, and the more clustering results will lead to further increase in energy consumption, it will lead to less supply of adjacent base stations, and will cause the base stations can not sleep, so it is necessary to select the appropriate threshold g for energy balance effect.

If a base station in the same cluster is defined as an adjacent base station, a model can be established for energy consumption and complexity balancing:

$$\min C = \alpha \cdot A + \beta \cdot B \tag{16}$$

The constraint condition is formula (8) [C1 – C6]. The optimization target is the energy consumption and complex balance of the base station. In the above formula, α and β are numbers in the range of $[0, 1]$, and they are the weights of energy consumption and complexity respectively, besides, $\alpha + \beta = 1$, in this study, both values are 0.5. If A is the normalized energy consumption of the whole network, there is the following formula:

$$\min A = \frac{P_{\cos t}}{\max P_{\cos t}} \tag{17}$$

In the above formula, $P_{\cos t}$ – represents the energy consumption of current threshold G ; $\max P_{\cos t}$ – represents the maximum energy consumption of all thresholds. If B is set as complexity, the following formula exists:

$$\min B = \frac{\text{Complexity}}{\max \text{Complexity}} = \frac{\sum_{i=1}^a N_i \cdot M_i \cdot k_i}{\max \sum_{i=1}^a N_i \cdot M_i \cdot k_i} \tag{18}$$

a – number of clusters of small base stations N_i – number of selected population in genetic algorithm M_i – number of base stations in the i -th cluster k_i – number of iterations completed by the i -th cluster Complexity – complexity generated by the current threshold G ; $\max \text{Complexity}$ – maximum complexity.

The minimum C obtained by formula (16) is the optimal threshold value. In the subsequent calculation, there are certain differences in the optimal threshold value, which can be calculated by the above methods.

D. BASE STATION CLUSTERING ALGORITHM

In this study, a dynamic clustering model of interest tree is designed, which is controlled by the parameters of cooperative factors. From the perspective of network structure, the clustering problem is directly transformed into the problem of interest tree generation. The cooperation factor can be defined as the degree of willingness of two base stations to cooperate with each other, which can be described as: If there are two base stations a and B , and the cooperation factor of them is expressed as $SF(a, b)$, then the dry ratio benefit caused to a by the cooperation of two base stations a and B can be expressed as:

$$SF(A, B) = \frac{SINR_A^{coop(A,B)}}{SINR_A^{no-coop}} \tag{19}$$

In the above formula, $SINR_A^{coop(A,B)}$ – represents the drying ratio caused by the cooperation of base stations A and B to A ; The drying ratio to a caused by the cooperation between the base stations $SINR_A^{no-coop}$ – A and B when they do not cooperate.

It can be seen from formula (19) that for base station A , the larger the $SINR_A^{coop(A,B)}$ value is, the larger the $SF(A, B)$ value is, the greater the SINR gain brought to A by the cooperation between A and B , and the greater the probability of cooperation between them. Similarly, formula (20) represents the received SINR gain of the cooperation of two base stations.

$$SF(B, A) = \frac{SINR_B^{coop(B,A)}}{SINR_B^{no-coop}} \tag{20}$$

In the formula, $SINR_B^{coop(B,A)}$ – the signal to interference ratio received by base station B when base station A and B cooperate; $SINR_B^{no-coop}$ – the signal to interference ratio received by base station B when both of them do not cooperate.

Through the above analysis, we can see that there is a certain directionality in the cooperation between different base stations, $SF(A, B) \neq SF(B, A)$, so that the problem of base station cooperation is transformed into a two-way selection problem.

There are N 5G base stations in the system, and the clustering result is expressed as $Clu = \{clu_1, clu_2, \dots\}$, where $|clu|$ represents the number of clusters, for example, b_i^k is the k-th base station in cluster i. The Clu_i -user set is expressed as $u_i = \{u_i^1, u_i^2, \dots\}$, and the base station cooperation is used to eliminate the possible interference(Fig.6).

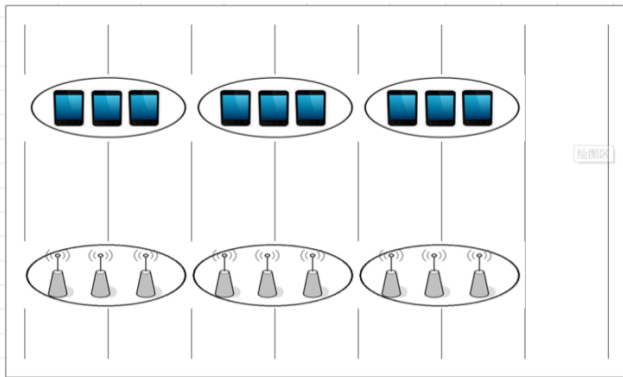


FIGURE 6. Clustering model.

Assuming that the sum rate of the system is R_t , it can be expressed as shown in formula (21).

$$R_t = \sum_{i=1}^N \log_2 (I + SINR_i) \quad (21)$$

If Clu_i does not use the intra cluster anti-interference technology, the receiving dryness ratio of base station i can be expressed as:

$$\begin{aligned} SINR_i^{no-coop} &= \frac{P_u \cdot |l_{ii}|^2}{P_u \cdot \sum_{k \neq i, k \in N} |l_{ki}|^2 + \sigma_n^2} \\ &= \frac{|l_{ii}|^2}{\sum_{k \neq i, k \in N} |l_{ki}|^2 + \sigma_0^2/P_u} \end{aligned} \quad (22)$$

In the above formula, the channel parameter vector between l_{ki} - user K and base station i; $|l_{ki}|^2 = pl_{k,j}$ - is the propagation loss; σ_n^2 - is the noise variance; P_u - is the transmission power of the user;

If user i and user j promote the work through collaborative technology, the mutual interference between them will be eliminated, then the drying ratio can be expressed as:

$$SINR_i^{coop} = \frac{|l_{ii}|^2}{\sum_{k \neq i, k \neq j, k \in N} |l_{ki}|^2 + \sigma_0^2/P_u} \quad (23)$$

Through the above comparative analysis, it is not difficult to find that the base station cooperative control technology

can effectively improve the drying ratio of the reception between the base stations. Therefore, after the cluster is established, the gain can be divided through the cooperative effect to improve the system stability. It is not difficult to see from formula (24) that the gain can be divided by cooperation between base stations, and the system operation efficiency and data transmission efficiency can be effectively improved. Therefore, the clustering algorithm proposed in this study has a certain effect. As shown in Fig. 8, the process of converting a cooperative base station into a weighted connected graph is transformed from (a) to (c)(Fig.7).

$$\begin{aligned} SF(i, j) &= \frac{\sigma_0^2/P_u + \sum_{k \neq i, k \neq j, k=1}^N |l_{ki}|^2 + |l_{ji}|^2}{\sigma_0^2/P_u + \sum_{k \neq i, k \neq j, k=1}^N |l_{ki}|^2} \\ &= 1 + \frac{|l_{ji}|^2}{\sigma_0^2/P_u + \sum_{k \neq i, k \neq j, k=1}^N |l_{ki}|^2} \end{aligned} \quad (24)$$

V. SIMULATION TEST

A. SIMULATION PARAMETERS

Based on MATLAB platform, a super dense 5G base station group based on the Internet of things is constructed in this study. In the test simulation, a simulation area of 2000m * 2000m is constructed. There are 25 base stations arranged in this area, which are evenly distributed, and UE presents a state of on-line distribution at each time. The simulation parameters selected in this paper are shown as following (Tab.2, Tab.3). Tab.2 shows simulation parameters of mobile communication cellular network, tab.3 shows control parameters of genetic algorithm.

TABLE 2. Simulation parameters of mobile communication cellular network.

Parameter item	Set value
Area size	2000m*2000m
Thermal noise	-175dBm/Hz
SINR threshold value	-5dB
SBS bandwidth	20MHz
Outage probability	0.02
Path loss	178.3Bm/Hz
SBS circuit power consumption (active)	47dBm
SBS circuit power consumption (sleep)	43dBm
SBS maximum number of serviceable UE	30

B. SIMULATION RESULTS

In order to prove the effectiveness of this research method, this paper studies the number of active base stations, network energy efficiency, algorithm complexity and outage probability.

Firstly, the dynamic sleep mechanism of the base station is studied, that is, the base station with small load is dynamically

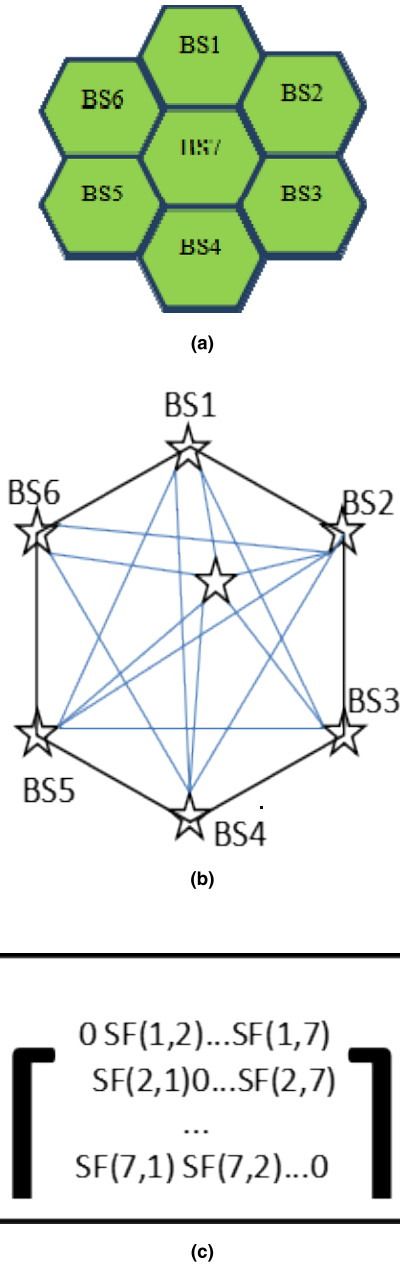


FIGURE 7. Topology transformation flow chart of cooperative base station group (N = 7).

TABLE 3. Control parameters of genetic algorithm.

Control parameters of genetic algorithm	Parameter value
Algebra of the greatest inheritance	47
Crossover probability	90%
Mutation probability	1%
Time penalty coefficient	10000000
Generation gap	0.95
Population size	100
Penalty coefficient of other constraints	10000000

controlled to switch to the sleep state. Combined with the genetic algorithm, the base station dormancy problem can be transformed into a multi-objective optimization problem.

In the experiment, the parameters such as QoS and outage probability of system users are considered comprehensively to solve the optimal dormancy scheme of the system. The number of active base station users and energy efficiency trend calculated by genetic algorithm(Fig.8).

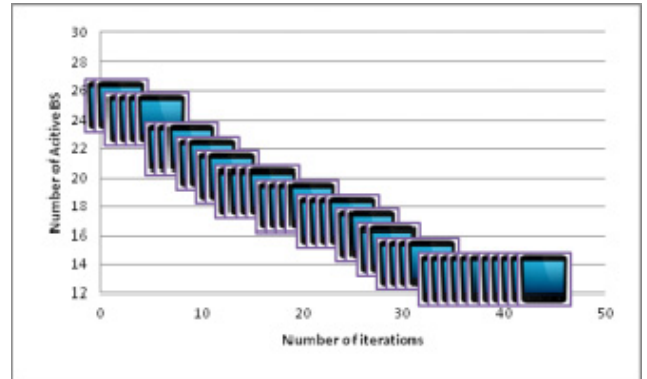


FIGURE 8. Number change of active base stations during genetic algorithm iteration.

In the process of iterating the number of active base stations with genetic algorithm. In the initial state of system operation, 25 base stations are all active, in the iterative process of the algorithm, the number of active base stations decreases after the number of iterations increases, and the number of active base stations remains basically the same from iteration to generation 34, so as to get the optimal solution. Finally, the number of active base stations is 13. At this time, 40% of the base stations enter the sleep state.

The sleep algorithm of base station based on genetic algorithm can make the low load base station in the system enter the sleep state, and the users within the coverage of the base station will unload its load to the adjacent base station after entering the sleep state. At this time, the UE connection state, that is, the base station activity()(Fig.9).

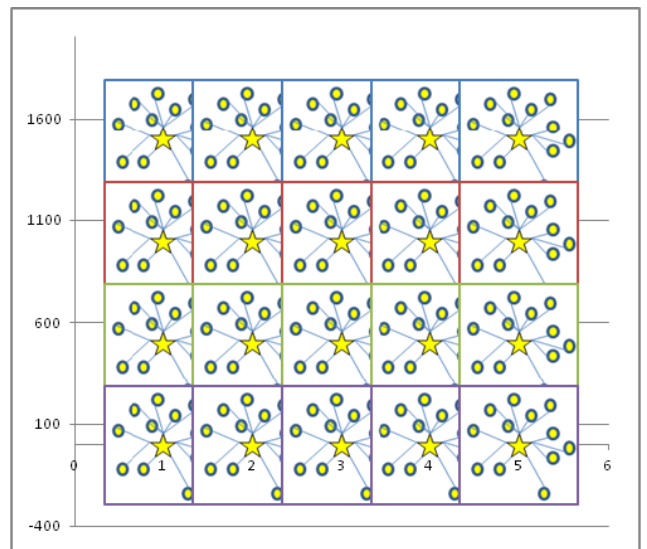


FIGURE 9. Initial connection state of base station.

Before the base station sleep scheme is activated, all the base stations are active. It shows that after the implementation of the centralized sleep scheme based on genetic algorithm, most of the base station switch state and UE connections are in the sleep state(Fig.10). The reduction of the number of sleep base stations will effectively reduce the system energy consumption. The simulation results of this process(Fig.11).

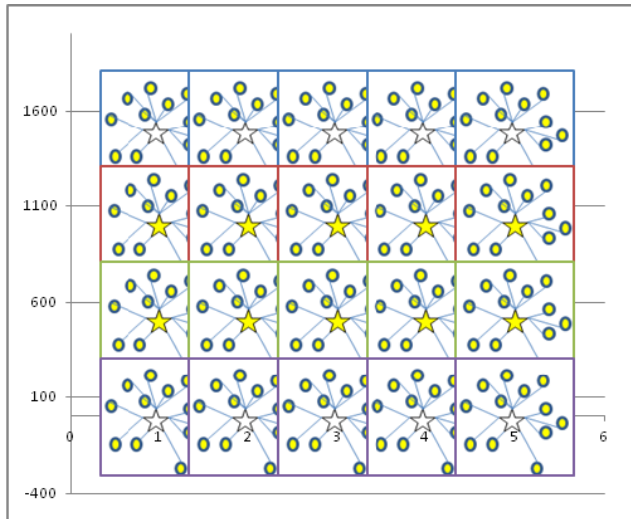


FIGURE 10. Centralized sleep node based on genetic algorithm.

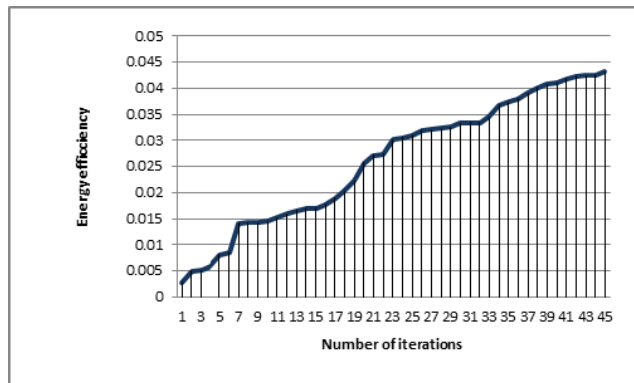


FIGURE 11. Energy efficiency change in the iteration process of genetic algorithm.

With the number of dormant base stations increasing in the iteration, the energy consumption of the system is gradually reduced and the energy efficiency is enhanced. It is not difficult to see from the figure that the system energy efficiency is about 0.02, and the optimal solution can be found after 34 iterations of the system. The system energy efficiency is increased to about 0.027. Therefore, the base station energy-saving technology based on genetic algorithm has a certain effect, which can effectively improve the energy efficiency of the system. Using the same method to study clustering algorithm, we find that clustering algorithm is close to genetic algorithm in energy efficiency improvement, so they have similar effect in the search of sleep strategy. After that, the complexity of genetic algorithm and clustering

algorithm are compared and analyzed, and the results are shown(Fig.12).

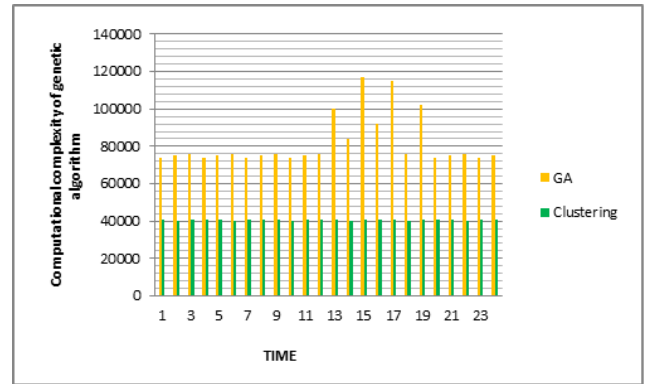


FIGURE 12. Computational complexity of genetic algorithm and clustering at each time.

The complexity comparison between the genetic algorithm and the clustering algorithm at each time is given. From the above analysis, it can be seen that the clustering algorithm has lower complexity than the genetic algorithm, especially when the number of base stations is large, the clustering algorithm has a more obvious advantage in computing complexity, and the legacy algorithm has a strong advantage in the sleep decision of the base station of 5G super dense base station group. Therefore, in the subsequent 5G base station energy-saving technology, we can give full play to the advantages of the fractional algorithm.

VI. CONCLUSION

5G communication network has a large number of base stations, a large density of base stations, and a large fluctuation of users in the time and space domain, so there will be a relatively obvious waste of resources in the low load period. It is necessary to use the base station sleep technology to make the low load base stations enter the sleep state, so as to reduce the system energy consumption and improve the system energy consumption. This paper analyzes the principle and performance of distributed algorithm and centralized algorithm in the base station sleep scheme, and proposes a centralized dynamic cluster sleep strategy based on genetic algorithm.

In this study, the sleep strategy of 5G ultra dense network base station is studied, and build 5G base station energy-saving technology based on Internet of things collaborative control. Through the MATLAB simulation platform, the algorithm is simulated and analyzed, the relevant simulation parameters are set, the simulation data is collected and the statistical chart is drawn. The simulation results show that the proposed 5G base station sleep scheme has a certain energy reduction effect and can effectively improve the system energy efficiency. At the same time, the performance of clustering algorithm and genetic algorithm proposed in this study are analyzed. Both of them can effectively reduce the energy consumption of 5G base station, and clustering algorithm has the advantage of complexity, and more practical.

REFERENCES

- [1] M. Chen, Y. Zhang, L. Hu, T. Taleb, and Z. Sheng, "Cloud-based wireless network: Virtualized, reconfigurable, smart wireless network to enable 5G technologies," *Mobile Netw. Appl.*, vol. 20, no. 6, pp. 704–712, Dec. 2015.
- [2] M. R. Palattella, M. Dohler, A. Grieco, G. Rizzo, J. Torsner, T. Engel, and L. Ladid, "Internet of Things in the 5G era: Enablers, architecture, and business models," *IEEE J. Sel. Areas Commun.*, vol. 34, no. 3, pp. 510–527, Mar. 2016.
- [3] M. Peng, Y. Li, Z. Zhao, and C. Wang, "System architecture and key technologies for 5G heterogeneous cloud radio access networks," *IEEE Netw.*, vol. 29, no. 2, pp. 6–14, Mar. 2015.
- [4] T. X. Tran, A. Hajisami, P. Pandey, and D. Pompili, "Collaborative mobile edge computing in 5g networks: New paradigms, scenarios, and challenges," *IEEE Commun. Mag.*, vol. 55, no. 4, pp. 54–61, Apr. 2017.
- [5] X. Chen, L. Pu, L. Gao, W. Wu, and D. Wu, "Exploiting massive D2D collaboration for energy-efficient mobile edge computing," *IEEE Wireless Commun.*, vol. 24, no. 4, pp. 64–71, Aug. 2017.
- [6] G. A. Akpakwu, B. J. Silva, G. P. Hancke, and A. M. Abu-Mahfouz, "A survey on 5G networks for the Internet of Things: Communication technologies and challenges," *IEEE Access*, vol. 6, pp. 3619–3647, 2018.
- [7] H. Zhang, W. Quan, H.-C. Chao, and C. Qiao, "Smart identifier network: A collaborative architecture for the future Internet," *IEEE Netw.*, vol. 30, no. 3, pp. 46–51, May 2016.
- [8] O. I. Asensio and M. A. Delmas "Nonprice incentives and energy conservation," *Proc. Nat. Acad. Sci. USA*, vol. 112, no. 6, pp. E510–E515, 2015.
- [9] M. Furqan, W. Yan, C. Zhang, S. Iqbal, Q. Jan, and Y. Huang, "An energy-efficient collaborative caching scheme for 5G wireless network," *IEEE Access*, vol. 7, pp. 156907–156916, 2019.
- [10] R. Chaudhary, N. Kumar, and S. Zeadally, "Network service chaining in fog and cloud computing for the 5G environment: Data management and security challenges," *IEEE Commun. Mag.*, vol. 55, no. 11, pp. 114–122, Nov. 2017.
- [11] D. P. Van, B. P. Rimal, J. Chen, P. Monti, L. Wosinska, and M. Maier, "Power-saving methods for Internet of Things over converged fiber-wireless access networks," *IEEE Commun. Mag.*, vol. 54, no. 11, pp. 166–175, Nov. 2016.
- [12] F. M. Al-Turjman, M. Imran, and S. T. Bakhsh, "Energy efficiency perspectives of femtocells in Internet of Things: Recent advances and challenges," *IEEE Access*, vol. 5, pp. 26808–26818, 2017.
- [13] Y. Tian, T. Li, S. Fong, L. Song, J. Han, and W. Song, "Smart power management Internet of Things system with 5G and LoRa hybrid wireless networks," in *Proc. 5G-Enabled Internet Things*, 2019, p. 375.
- [14] D. B. Rawat and S. R. Reddy, "Software defined networking architecture, security and energy efficiency: A survey," *IEEE Commun. Surveys Tuts.*, vol. 19, no. 1, pp. 325–346, 1st Quart., 2017.
- [15] C.-H. Chen, M.-Y. Lin, and C.-C. Liu, "Edge computing gateway of the industrial Internet of Things using multiple collaborative microcontrollers," *IEEE Netw.*, vol. 32, no. 1, pp. 24–32, Jan. 2018.
- [16] M. Gigli and S. Koo, "Internet of Things: Services and applications categorization," *Adv. Internet Things*, vol. 1, no. 2, pp. 27–31, 2011.
- [17] Y. Chen, G. Lee, L. Shu, and N. Crespi, "Industrial Internet of Things-based collaborative sensing intelligence: Framework and research challenges," *Sensors*, vol. 16, no. 2, p. 215, Feb. 2016.
- [18] Y. Lu and J. Cecil, "An Internet of Things (IoT)-based collaborative framework for advanced manufacturing," *Int. J. Adv. Manuf. Technol.*, vol. 84, nos. 5–8, pp. 1141–1152, Sep. 2015.
- [19] R. L. G. Cavalcante, S. Stanczak, M. Schubert, A. Eisenblaetter, and U. Tuerke, "Toward energy-efficient 5G wireless communications technologies: Tools for decoupling the scaling of networks from the growth of operating power," *IEEE Signal Process. Mag.*, vol. 31, no. 6, pp. 24–34, Nov. 2014.
- [20] D. Sabella, A. de Domenico, E. Katranaras, M. A. Imran, M. di Girolamo, U. Salim, M. Lalam, K. Samdanis, and A. Maeder, "Energy efficiency benefits of RAN-as-a-service concept for a cloud-based 5G mobile network infrastructure," *IEEE Access*, vol. 2, pp. 1586–1597, 2014.
- [21] S. Buzzi, C.-L. I. T. E. Klein, H. V. Poor, C. Yang, and A. Zappone, "A survey of energy-efficient techniques for 5G networks and challenges ahead," *IEEE J. Sel. Areas Commun.*, vol. 34, no. 4, pp. 697–709, Apr. 2016.
- [22] X. Ge, J. Yang, H. Gharavi, and Y. Sun, "Energy efficiency challenges of 5G small cell networks," *IEEE Commun. Mag.*, vol. 55, no. 5, pp. 184–191, May 2017.
- [23] L. Militano, G. Araniti, M. Condoluci, I. Farris, and A. Iera, "Device-to-device communications for 5G Internet of Things," *EAI Endorsed Trans. Internet Things*, vol. 1, no. 1, Nov. 2015, Art. no. 150598.
- [24] M. Feng, S. Mao, and T. Jiang, "Base station ON-OFF switching in 5G wireless networks: Approaches and challenges," *IEEE Wireless Commun.*, vol. 24, no. 4, pp. 46–54, Aug. 2017.



machine/facility systems, smart industrial safety and health monitoring and management systems, smart lean production management, and edge computing chip design.



KAI-CHUN CHU received the Ph.D. degree from the Department of Business Administration Group of Strategic Management, National Central University, Taoyuan, Taiwan, in 2019. She is currently an Associate Professor with the School of Management, Fujian University of Technology. Her research interests are in wireless networks and smart industrial safety and health monitoring and management systems, and intelligent nursing systems.



HSIAO-CHUAN WANG received the M.S. degree from the Institute of Environmental Engineering, National Taiwan University, Taipei, Taiwan, in 2004. She is currently the Director of the ISD Technology Company. She research interests include intelligent manufacturing, smart environmental engineering technology, and corporate social responsibility (CSR).



YUH-CHUNG LIN received the B.S. degree in computer science and information engineering from National Chiao Tung University, Hsinchu, Taiwan, in 1991, the M.S. degree in computer science from the University of Southern California, Los Angeles, CA, USA, in 1996, and the Ph.D. degree in computer science and information engineering from National Sun Yat-sen University, Kaohsiung, Taiwan, in 2008. He is currently an Associate Professor with the College of Information Science and Engineering, Fujian University of Technology. His research interests are in wireless networks, the IoT applications, and Intelligent control systems.



JENG-SHYANG PAN received the Ph.D. degree in electrical engineering from the University of Edinburgh, U.K., in 1996. He is currently a Professor with the Shandong University of Science and Technology, Harbin Institute of Technology Shenzhen and Fujian University of Technology. His current research interests include soft computing, information security, big data mining, and signal processing.

...