A Parallel Task Scheduling Optimization Algorithm Based on Clonal Operator in Green Cloud Computing

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Abstract —Computing resources in cloud computing with heterogeneous, dynamic, non-balancing and other features, how to allocate resources to fully improve resource utilization and reduce task execution time and energy consumption optimization is the key problem to be faced in cloud computing. According to the basic characteristics of task scheduling in cloud computing environment, this paper proposes an energy consumption optimization model for task scheduling, and proposes a green clonal scheduling optimization algorithm by taking advantage of the clonal operator of immune algorithm. Experimental results show that the proposed algorithm can not only effectively reduce the execution time and energy consumption, and can achieve resource load balancing, thus effectively improve the resource utilization and scheduling efficiency.

Index Terms—Green cloud computing, clonal operator, task scheduling, computing resources, energy consumption optimization

I. Introduction

Green computing is an emerging technology, which reduces the energy consumption and computing resources pollution using intelligent optimization algorithm and advanced computing technology. Cloud computing is an emerging computing model, which is based on virtualization technology, in response to user requests through the network, and dynamic resource allocation based on user demand [1]. Because cloud computing resources are heterogeneous, dynamic, and non balanced, so how to rational allocation resources, improve the utilization rate of resources, reduce the task execution time and energy consumption of data center, has become one of the key problems in the research of green cloud computing [2]. Now storage scale continues to expand in the data center, high energy consumption has become a major bottleneck restricting the rapid development of large data. Green cloud computing can effectively improve the utilization rate of the cloud computing infrastructure, and minimize energy consumption [3].

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Cloud computing is a new business model of information technology [4]. Cloud computing abstracts IT resources and services from the underlying architecture [5]. Computing resources, storage resources and network source all integrated into a pool of virtualized resources, under the multi user and elasticity of the environment through the IP network to provide highly scalable on-demand services.

It is well known that Artificial Immune System (AIS) is a highly parallel adaptive system that can effectively identify and eliminate dissent (pathogens, bacteria, etc.), and can adaptively identify and exclude foreign antigen enters the body [6]. It has many features about information processing mechanisms and function trait, such as antigen recognition, memory, antibody inhibition and promotion. The Clonal Selection Algorithm (CSA) is used by the natural immune system to define the basic features of an immune response to an antigenic stimulus [7]. The AIS is a new intelligent method for simulating the natural immune system. AIS have enormous potential to supply novel methods for solving complex problems and are becoming another research hot point in the artificial intelligent techniques after neural network and evolutionary computation [8], [9]. In recent years, the theories and applications of artificial immune algorithm has gained a lot of attention and has become an important issue in intelligent computing. We summarize the CSA for the optimization problem as follows: The problem itself is considered as the antigen, the avidity between antibody and antigen are similar to the definition of the objective function and restrictive condition, the possible solution, match between solution and the fitting function [10]. Immune algorithm is suitable for transplantation to cloud computing platform as its adaptive and distributed.

Green communication is the green concept to the entire communications industry chain, specifically refers to the energy conservation, reduce environmental pollution! The waste of resources and harm to human health and the environment of new generation communication concept is a comprehensive application of multiple disciplines [11]. The main purposes of this paper include the following two aspects: (1) to allocate resources to fully improve resource utilization in green cloud computing; (2) to reduce task execution time and reduce energy consumption. According to the basic characteristics of the

task scheduling in cloud computing environment, this paper proposes an energy consumption optimization model of resources, and use the clone operator of immune algorithm, put forward a Green Clonal Scheduling Optimization Algorithm (GCSOA). Experimental results show that our algorithm can not only effectively reduce the completion time of task scheduling and energy consumption, and can achieve resource load balancing, thus effectively improve the resource utilization and scheduling efficiency.

The main contributions of this paper include: (1) A brief review about the advantages and disadvantages of various existing task scheduling algorithms in cloud computing were presented. (2) An effective optimization model of energy consumption is proposed. (3) A green clonal scheduling optimization algorithm by taking advantage of the clonal operator of immune algorithm is proposed.

The rest of this paper is organized as follows. Section 2 discusses related works, followed by the optimization model of energy consumption design in Section 3. The clone operator and GCSOA algorithm for task scheduling is discussed in Section 4. Section 5 shows the simulation experimental results, and Section 6 concludes the paper with summary and future research directions.

II. Related Works

Cloud computing enables multiple users to share IT devices by virtual resource pool mode, can significantly improve the utilization of IT equipment, and reduces the power consumption of data centers, so it has become an important force in the development trend of the green data center [12]. How to build a green data center in cloud computing era has become the common focus of attention of the industry.

Kaya *et al*. proposed a heuristic algorithm for independent task scheduling based on file sharing, but this method does not fully consider the characteristics of cloud computing systems are heterogeneous and dynamic [13]. Zheng *et al*. proposed an as early as possible scheduling algorithm (ASAP), which may lead to too much focus on control step of the early [14]. William J. *et al*. proposed a Dual Fitness Genetic Algorithm (DFGA), which can find the task at a given time range [15].

Through the existing green computing technology improvement to the cloud system architecture, this paper designs a green infrastructure cloud system, which can realize energy saving and consumption reduction in the system of Internet and cloud data center [16]. Fig. 1 shows the system structure of green cloud computing.

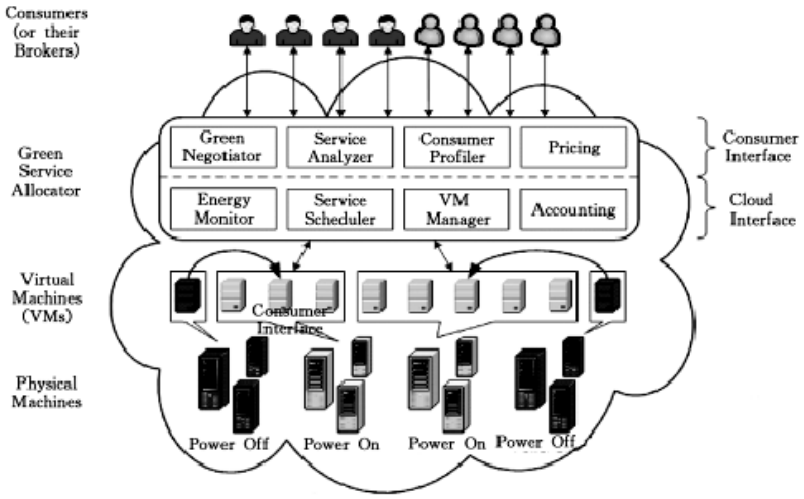

Fig. 1. The system structure of green cloud computing

Aiming at the inefficient problem of task scheduling algorithm in cloud computing environment, Shen Lijun *et al*. used artificial immune principle to realize the global optimization of task scheduling, and proposed a task scheduling algorithm based on immune evolutionary algorithm [17]. The proposed algorithm embedded particle swarm optimization algorithm as the operator into the immune evolutionary algorithm, to avoid falling into local optimum, thus it can effectively improve the convergence effect, reduce the cost of the task scheduling time. Dr. Zhang *et al*. proposed a guaranteed packet and polymorphic ant colony algorithm of cloud service quality, which is based on the completion time of the update of the average completion time [18].

Wang Wenfeng *et al*. proposed a task scheduling strategy based on genetic algorithm in cloud computing [19], the goal is to assign the task to the resource node to complete the task time at least, make full use of the resources, and the resource node in the idle state dynamic adjustment of the task allocation. In [20] proposed an energy-saving scheduling algorithm based on the cloud environment, which used the neural network predictor of energy-saving dispatching.

III. Optimization Model of Energy Consumption

Due to computational applications and data growth speed, reduce the energy consumption of the cloud data center is a challenging and complex problem [21], [22].

Cloud computing use of the scalability and flexibility of virtualization technology, improve resource utilization, and simplify the resource and service management and maintenance [23], [24]. At the same time, the use of information and automation technology encapsulate the resource for service delivery to the user, reduces the data center operational costs [25].

Definition 1 if t_i represents the i task that random arrival cloud computing system, then the cloud computing task set is $T=\{t_1,t_2,...,t_i,...,t_n\}$.

Definition 2 If the average number of arrival of task t_i in unit time is expressed as a_i, w_i represents the work load of task t_i, then t_i denotes as two-tuples $t_i=\{a_i,w_i\}$.

Definition 3 If T represents the set of tasks in cloud computing system, R represents the set of resources in cloud computing system, then cloud computing denotes as two-tuples $CC=(R,T)$, $R=\{r_1,r_2,...,r_j,...,r_m\}$.

Definition 4 According to the amount of computation of tasks and the computing capacity of resources, the task execution time of task t_i on resource r_j is given as

$$ETC(i,j)=\frac{w_i}{c_j} \tag{1}$$

In which, w_i denotes the work load of task t_i, c_j denotes the computing capacity of resources r_j.

Definition 5 assumes that $v_{i,j}$ is a voltage supply value, $f_{i,j}$ is a corresponding working frequency, and $CT(i,j)$ is the estimated completion time of task T_j on resource r_i, then the energy utilized for completing task T_j on resource r_i when the supply strategy is s^i can be defined as follows:

$$E_{ijl}=\gamma\times f_{i,j}\times {v_{i,j}}^2\times CT(i,j) \tag{2}$$

where γ is a intrinsic properties for a given resource.

Definition 6 In the cloud computing task scheduling, the total execution time of independent tasks assigned to computing resources can be defined as follows:

$$t(m,n)=\sum_{i=1}^{m}\sum_{j=1}^{n}ETC(i,j)\times\theta(i,j) \tag{3}$$

In which, $\theta(i,j)$ is the mapping functions for task t_i and resource r_j. When the task t_i is scheduled to execute on the resource r_j, $\theta(i,j)=1$;Otherwise, $\theta(i,j)=0$.

IV. Clone Operator and GCSOA Algorithm

Since human society appears in nature, man invented a lot of techniques, methods and tools by simulating the structure, function and behavior of organism in nature, which used to solve practical problems in social life. Many of adaptive optimization phenomena constantly give revelation in nature: organisms and natural ecosystems through their evolution in humans seem to make a lot of highly complex optimization problem has been the perfect solution. In the biological sciences field, people have been carried out extensive and in-depth study on the evolutionary, genetic and immune and other natural phenomena.

The clonal selection algorithm is used by the natural immune system to define the basic features of an immune response to an antigenic stimulus [21]. We summarize the CSA for the optimization problem as follows: The problem itself is considered as the antigen, the avidity between antibody and antigen are similar to the definition of the objective function and restrictive condition, the possible solution, match between solution and the fitting function. The selection operator of GCSOA is described as follows:

Algorithm 1: Selection operator
Input: selection probability P_s Output: Some high affinity antibody Begin Step 1: Let $k_2=INT(P_s\times Size)$, $INT(*)$ is the integral function. Step2: According to the affinity values in descending order for antibody group $A(k)$, And directly choose the affinity that ranked in the front of k_2 to keep to the next generation. End

The implementation steps of GCSOA are described as follows:

Algorithm 2: green clonal scheduling optimization algorithm selection operator
Input: population size $Size$,selection probability P_s, mutation probability P_m, maximum generation G_m Output: The optimal task scheduling scheme Begin Step 1. Randomly generated initial antibody population $A(0)=\{a_1,a_2,...,a_i,...,a_{Size}\}$, $k=0$. Step 2. Calculate the affinity value of initial population $aff(a_i)$, $i=1,2,...,Size$. Step 3. Perform clone operation from the population $A(k)$. Step 4. Perform mutation operation from the population $A(k)$. Step 5. Perform selection operation from the population $A(k)$. Step 6. let $k=k+1$.If $k\le G_m$,then go to Step 2; Otherwise, algorithm is end. End

V. Simulation Experiments and Results Analysis

In order to test the performance of the GCSOA algorithm, this paper builds a data center using CloudSim simulation platform. The simulation is set on the

CloudSim by extending cloud computing platform. In order to make it easier to test the algorithms, CloudSim has been adopted in this work as an effective cloud computing simulation platform. The parameters used in experiment are set as follows: $Size$ =100, G_m =500, P_s =0.8, P_m =0.25.

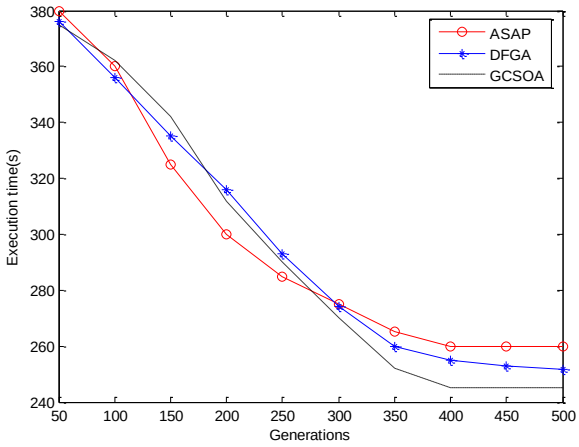

Fig. 2. Comparison of the execution time for the three task scheduling algorithms (n=1000)

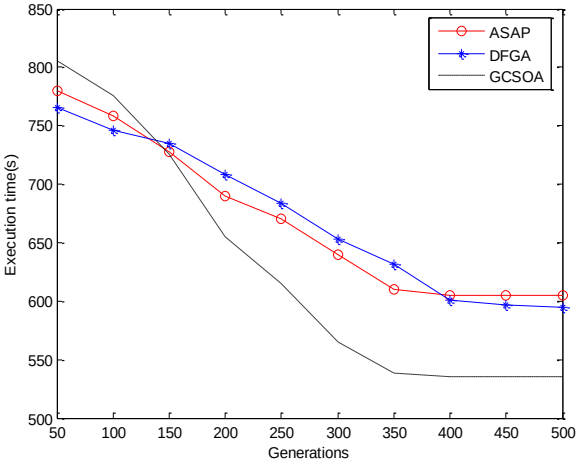

Fig. 3. Comparison of the execution time for the three task scheduling algorithms (n=2000)

The test includes three aspects: the first experiment mainly from the point of view of the task completion time, the second experiment mainly from the point of view of the optimal solutions, and the second kinds of experiments mainly from the angle of comparison of energy consumption optimization. Fig. 2-Fig. 3 show that when the number of tasks in the system is respectively, $n=1000, n=2000$, the comparison for task completion time of three task scheduling algorithms. Fig. 4-Fig. 5 show that when the number of tasks in the system is respectively $n=1000, n=2000$, the comparison of optimal solutions for the three task scheduling algorithms. Fig. 6-Fig. 7 show that when the number of tasks in the system is respectively $n=1000, n=2000$, the comparison for energy consumption optimization in different utilization threshold. Fig. 8-Fig. 9 show that when the number of tasks in the system is respective, $n=1000$, $n=2000$, the comparison for energy consumption optimization in the different scheduling cycles.

It is clearly evident from the Fig. 2-Fig. 3 that: in the early stage of evolution, the GCSOA algorithm's advantage is not obvious, the execution time of GCSOA algorithm are only ASAP's and DFGA's 96.1% and 95.3% in the later evolution, respectively. This is mainly because the clone operator of GCSOA led to feasible solution space to expand in the early stage of evolution, thereby reducing the search speed. With the proportion of excellent antibody in the population has expanded gradually, the GCSOA algorithm can find the optimal solution in a shorter period of time in the later stage of evolution.

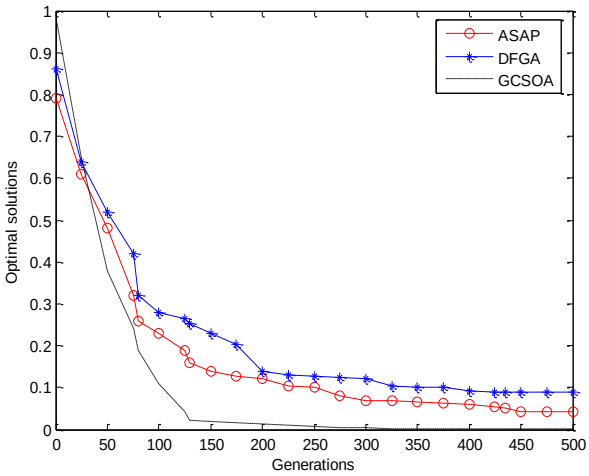

Fig. 4. Comparison of optimal solutions for the three task scheduling algorithms (n=1000)

As shown in Fig. 4 and Fig. 5, the experimental results shows that the whole performance of GCSOA is superior to ASAP and DFGA. The results of simulation indicate that GCSOA can significantly enhance the quality of the solutions obtained, and reduce the time taken to reach the solutions.

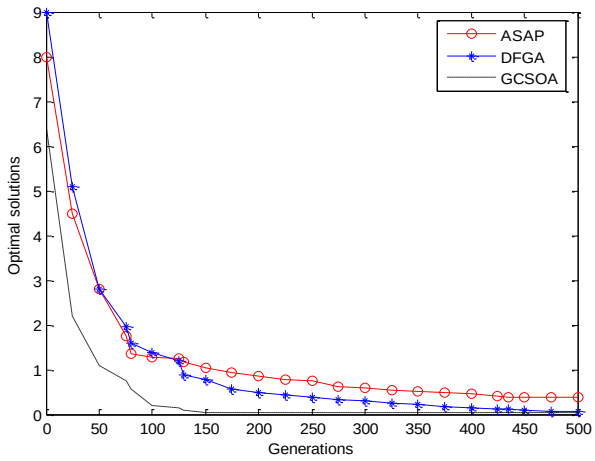

Fig. 5. Comparison of optimal solutions for the three task scheduling algorithms (n=2000)

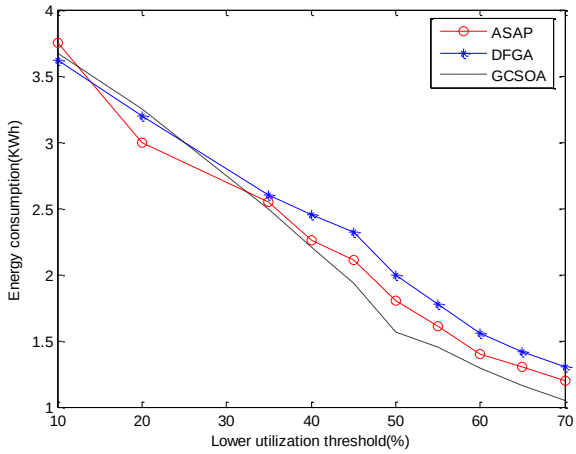

Fig. 6. Comparison of energy consumption for the three task scheduling algorithms in different utilization threshold (n=1000)

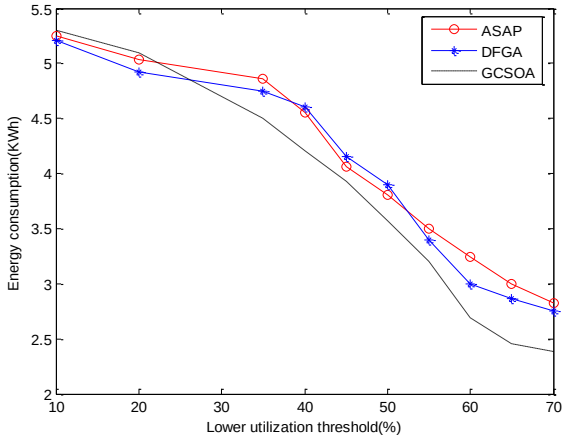

Fig. 7. Comparison of energy consumption for the three task scheduling algorithms in different utilization threshold (n=2000)

From the experimental results in Fig. 6-Fig. 7 are not difficult to see that: with the different utilization threshold gradually increased, the energy consumption of three algorithms in the rapid decrease. In a variety of different utilization threshold condition, the energy consumption of GCSOA algorithm is the least of in the vast majority of cases, the performance of the other two algorithms is the same.

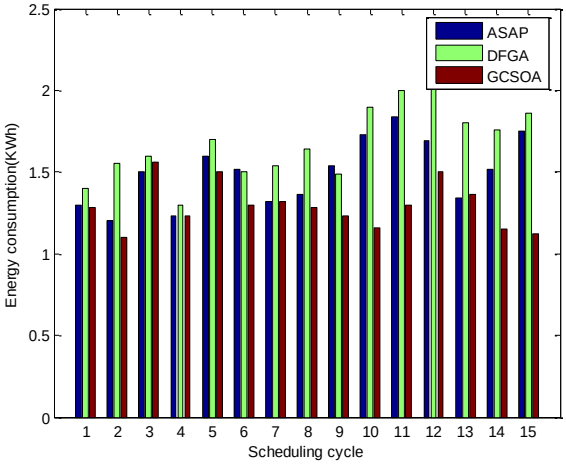

Fig. 8. Comparison of energy consumption for the three task scheduling algorithms in different scheduling cycle (n=1000)

As shown in Fig. 8-Fig. 9, our proposed GCSOA algorithm is the least energy consumption in different scheduling cycle. The performance of the GCSOA algorithm is superior to other two algorithms.

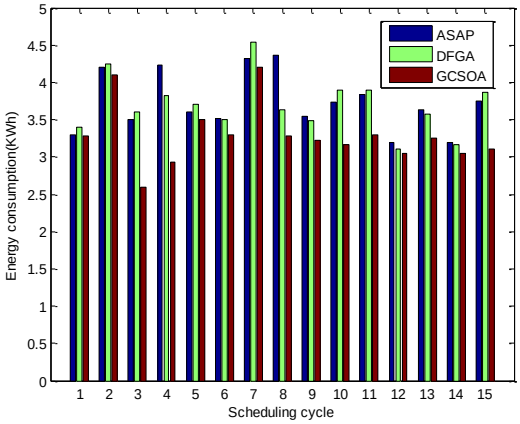

Fig. 9. Comparison of energy consumption for the three task scheduling algorithms in different scheduling cycle (n=2000)

Through a series of experimental results, it is not hard to come to the following conclusions that our proposed GCSOA is able to reduce energy consumption, and obtain higher efficiency, as well as effectively balanced on exploration and exploitation.

VI. Conclusions

Cloud computing is a computing model through an Internet to provide dynamic scalable virtualized resources. According to the basic characteristics of task scheduling in cloud computing environment, this paper designs a optimization model of energy consumption, and puts forward a green cloning scheduling optimization algorithm by using of clonal immune algorithm. Experimental results show that our algorithm can not only effectively reduce the execution time and energy consumption, and can achieve resource load balancing, thus effectively improve the resource utilization and scheduling efficiency. In the future, we will be considered to optimize the energy consumption of data center in cloud computing, and design the dynamic adaptive task scheduling algorithm that is more efficient and reasonable.

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