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Highlights

In this paper, we propose a task scheduling algorithm considering game theory designed for energy management in cloud computing. Specifically, this paper has three main contributions to the energy management of cloud computing.

First of all, game theory is widely used in management science, but few researchers have applied this method to the calculation of cloud computation theory. In the system based on big data management, the game theory can better coordinate the distribution of task and the distribution of energy. In short, the use of game theory is the most innovative point of this paper.

Based on the balanced scheduling algorithm of the reliability, the task scheduling model for computing nodes by establishing mathematical model is proposed. Because the cloud computing system has a big computation amount, the algorithm needs to be relatively simple in the premise of ensuring effective. This paper has made efforts in this field and has achieved some good results.

In addition, experimental verification in this paper is divided into two parts. First of all, we consider the experiment on the value of objective function in equilibrium state. The second group of experiments is a system with many computing nodes in balanced calculation ability. This test method is very scientific, and it is worth promoting.

In a word, task scheduling algorithm considering game theory is designed for big data in cloud computing. And experiments show that the algorithm can improve the energy management in cloud computing..

A Task Scheduling Algorithm Considering Game Theory Designed for Energy Management in Cloud Computing

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Abstract

With the increasing popularity of cloud computing products, task scheduling problem has become a hot research topic in this field. The task scheduling problem of cloud computing system is more complex than the traditional distributed system. Based on the analysis of cloud computing in related literature, we established a simplified model for task scheduling system in cloud computing.Different from the previous research of cloud computing task scheduling algorithm, the simplified model in this paper is based on game theory as a mathematical tool. Based on game theory, the task scheduling algorithm considering the reliability of the balanced task is proposed. Based on the balanced scheduling algorithm, the task scheduling model for computing nodes is proposed. In the cooperative game model, game strategy is used for the task in the calculation of rate allocation strategy on the node. Through analysis of experimental results, it is shown that the proposed algorithm has better optimization effect.

Keywords:
Task scheduling, Game theory, Cloud computing, Optimization

1. Introduction

Cloud computing is used to provide the calculation platform for Internet users as a large-scale distributed dynamic group. The cloud computing is

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usually in ultra large scale and high scalability. To be more specific, cloud computing can be linked with a large number of idle resources and constitute a large scale resource pool[1]. And then this size can be dynamically adjusted according to the application and demand, which can make full use of the various resources in the cloud computing system to provide services for users and applications [2, 3].

Through virtualization technology, cloud computing makes a variety of underlying devices as cloud, and users can be anywhere to address the cloud using any terminal access for application services[4].Users only need to submit application requests to the cloud, and they do not care about how the application is operated in the cloud through the underlying devices, because the virtualization technology makes the underlying device layer is transparent to the users[5, 6]. Virtualization technology also reduces the dependence of the devices in the cloud computing system, which provides the possibility of high scalability[7, 8].

In addition, distributed computing and high reliability is useful for cloud computing. There are distributed data centers in cloud computing systems[9]. For applications running in the cloud, whether it is in computational requirements or storage needs, it will often involve a number of computing resources. These computing resources are geographically isolated. This kind of distributed characteristic makes the network hacker and the network virus attacks to lose the goal, and has guaranteed the data recovery basis[10, 11]. In a words, cloud computing has greatly enhanced the cloud computing system security and the reliability[12, 13].

In recent years, many achievements have been made in the research of the task scheduling problem. In these studies, scholars have used different research ideas, different mathematical tools, different optimization objectives, and have achieved good results[14, 15]. Cloud computing is not designed for a particular application, the same cloud platform can run different applications at the same time.The large-scale cloud computing node in the system is built on the basis of cheap server[16, 17]. Cloud computing virtualization technology and automation management makes the cloud node can freely join and exit operation, reduce the cost of data center management[18, 19].

Task scheduling problem is a difficult problem in the research field on cloud computing[20, 21]. According to the characteristics of cloud computing the task should be assigned to different resource nodes corresponding to perform appropriate strategies, in order to achieve a better result[20, 22, 23].The process of task scheduling is equivalent to the traditional computer operat-

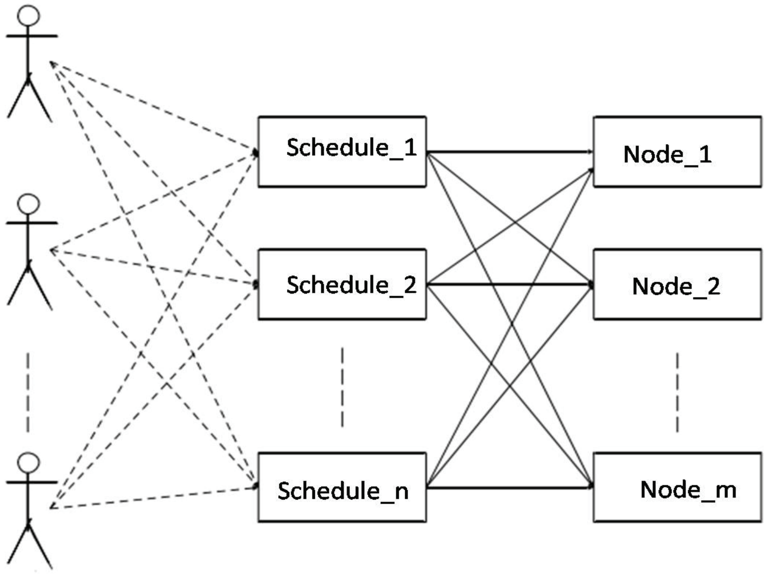

Figure 1: Simplified Task Scheduling System Model in Cloud Computing

ing system scheduling. According to a certain order , it executes distributed processors for execution and processing to minimize the consumption of data communication. In the computer operating system, there are three kinds of processes, which are ready, running and blocking[24, 25].And we can switch between these three states. The process of scheduling is to make the operating system sharing the resources and avoiding the competition. Therefore, a good scheduling algorithm will be effective and reasonable in process, effectively improve the utilization rate of resources[16, 26].

Then, we will introduce the cloud computing task scheduling system model. After simplification, we can get the model as shown in Fig.1. In the task scheduling system, the task scheduling process consists of the following parts. The scheduler analyze the application to receive and identify the types, the results of the analysis will be written into the application configuration file. In addition, the scheduler will decompose applications. There may be dependencies between the execution sequence and data communication[27, 28]. The research of this paper is aimed at the independent task scheduler. And scheduler will read resource description file and select the appropriate resources according to the needs of users [29, 30].

The game theory is a branch of applied mathematics. It mainly studies how to make strategic decisions. At present, game theory is widely used in the research of cross discipline. Game theory is used to quantify the interaction between incentive structures, and to study the interaction between different player in strategic interdependence. Game theory considers the forecast behavior and the actual behavior of the participants in the process, and studies their optimization strategies [31, 32].

Neumann John published an paper that makes the game theory has become an independent field. His first idea is based on the fixed point theorem from Brouwer, and fixed point theorem was mapped to concave-convex set, which has become the standard method of game theory and mathematical economics[33, 34]. Later, in 1944, Theory of Games and Economic Behavior was published, the book laid the foundation for the solution of zero-sum game. Since then, the research on game theory has been focused on the cooperative game theory.

In 1950s, game theory has made a lot of achievements, including the core concept of the game theory, the extended game, repeated games and so on. In addition, the game theory was applied to the field of philosophy and politics for the first time[35, 36]. By 1970s, the application of game theory has been extended to biology, and game theory has become a part of economics.

Now, game theory has become an important tool in many fields, which is widely used. As long as there are more than one individual who can independently choose their own behavior in a system, the game theory can provide a very good framework for the analysis of interaction between these decisions.

According to different classification criteria, game theory can be divided into different types. In the research of this paper, we use the cooperative game theory and sequential game theory, and we will introduce the two kinds of game theory.

Cooperative game theory achieves a relatively good result through the use of a cooperative approach to the overall game framework. To make the game participants cooperate, all the game parties must negotiate with each other to reach a consensus. Through the conclusion, we can draw the following definition and theory of cooperative game, which also is the theoretical basis of the task scheduling algorithm based on game theory in cloud computing.

As for sequential game theory, the game players choose their own game strategy based on time. It is a typical type of dynamic game. In a sequential game, there must be a strict game environment based on sequence of game strategy, the participants give choices in accordance with the order.

In the sequential game process, including the structure of a number of successive different games, each game that we say, the stage of the game. At each stage of the game, players need to think about how their current actions will influence future actions, including opponents and their actions, therefore, participants need to calculate the future consequences of the foundation, to decide how to make their own strategy in the stage game. This is a general feature of sequential games[37, 38, 39]. In sequential game, the participants have the first advantage of action, namely, the game, the first to make s-trategic choices and take action of the participants can occupy a favorable position, get more benefits. In the research of sequential game, we usually use the game tree to solve the sequential game. Game tree is a graphical method for representing and analyzing sequential game. Through the game tree, we can see clearly that all the participants can take all possible actions and give all the possible results of the game.

In this paper, we put forward the task scheduling algorithm based on game theory. According to the characteristics of cloud computing, it can be known that the configuration of nodes in a cloud computing system is controllable. Therefore, each assumed cloud computing system in computing nodes are able to perform the task division.

2. Background and motivation

Compared with the existing scheduling algorithms, balanced scheduling algorithm based on reliability makes use of game theory as different mathematical tool. Considering the reliability analysis of task scheduling model and computing nodes, we can establish mathematical model for steady state task to provide capacity[40, 41]. In the algorithm, we find the utility function by calculating the steady state node's ability, then establish a cooperative game model on cloud computing task scheduling problem. In this way, bargaining solution structure can be given, and we can propose a task scheduling algorithm in next Section.

At present, the cost of a task is usually larger in the cloud computing system, and the user's requirements are with many factors , such as reliability, cost, execution time, etc. In this paper, we mainly consider the execution time of the task. Because cloud computing system and the geographic coverage may be larger,so we can ignore the internal cost of processing[42, 43].

In the cloud computing task scheduling system model, there are l users, n schedulers and m computing nodes for performing the task. The users are producers in requesting task, and each user submits tasks independently to the scheduler, the average request rate of user k is β_k, and it satisfies Poisson distribution. Then the submitted task from computing nodes are sent to the scheduler to be performed. And the task scheduler assigned tasks to the computing nodes in the system implementation. The average speed of the task scheduler i is λ_i. Computing nodes are task executors, the general task can be calculated by node j, the average rate of computing nodes j is u_j, task execution time can be subject to arbitrary distribution, each calculation points can be regarded as a general M/G/1 queuing system with retry time and server crash.

Let λ_i be the average rate of task scheduler i, which satisfies the constraints: the sum of all the average rates of the task schedulers should be less than the sum of all the average execution rates.

$$\sum_{i=1}^{n} \lambda_i < \sum_{j=1}^{m} u_j \tag{1}$$

In this paper, we can set the arrival rate of average task is ϕ_j, which can meet the constraints:

$$0 \leq \phi_j < u_j \tag{2}$$

$$\sum_{i=1}^{n} \lambda_i = \sum_{j=1}^{m} \phi_j \tag{3}$$

We model the task scheduling problem in cloud computing system as a cooperative game, m computing nodes are regarded as the participants of the game, the task rates $\varphi = \phi_1, \phi_2, ..., \phi_j, ..., \phi_m$ of computing nodes are regarded as the game strategy. As a M/G/1 queuing system with a general retry time and server crash, the computing formula for the calculation in the cloud computing task scheduling system is shown in Equ.4.

$$A_j = 1 - \phi_j \beta_{1j}(1 + u_j \gamma_j) \tag{4}$$

Among them, ϕ_j is the average task arrival rate of the calculating node j , β_{1j} is the mean value of task service time for node j , $u_j^{'}$ is the average speed of failure for node j in busy time,γ_j is the mean value of the retrial time for node j, and A_j meet the constraints:$0 < A_j < 1$.

As reciprocal of the provide ability in stable state on computing node j, D_j can be Calculated for the cooperative game of the utility function. Each of the compute node j has a largest D_j^0.

$$D_j^0 = \frac{1}{1 - \phi_j^{max}\beta_{1j}(1 + u_j\gamma_j)} \tag{5}$$

Among them, ϕ_j^{max} is the maximum rate:$0 \leq \phi_j^{max} < u_j$, $\phi_j < \phi_j^{max}$.

We note that D_j is convex and bounded. The optimal solution can be obtained by the definition of cooperative game.

$$\sum_{j=1}^{m} ln(D_0^j - D_j) = \sum_{j=1}^{m} ln\left[\frac{1}{1 - \phi_j^{max}\beta_{1j}(1 + u_j\gamma_j)} - \frac{1}{1 - \phi_j\beta_{1j}(1 + u_j\gamma_j)}\right] \tag{6}$$

$$\phi_j = \frac{1 + \phi_j^{max}B_j - \sqrt{(1 + \phi_j^{max}B_j)^2 - 4B_j(\phi_j^{max} - \frac{1-\phi_j^{max}B_j}{\alpha})}}{2B_j} \tag{7}$$

Taking the above derivation as the theoretical basis and taking into account the compactness of the results, we can obtain the bargaining solution algorithm as follows.

3. Proposed method

According to the characteristics of cloud computing, it can be known that the configuration of nodes in a cloud computing system is controllable.

In the task scheduling system, there are l users, n schedulers, m computing node, user request can be decomposed into m task by the i_{th} scheduler.The users are producers requesting task, and each user independently submits tasks to the scheduler, the average request rate of user k is β_k , and it satisfies Poisson distribution. Then the submitted task from computing nodes are sent to the scheduler to be performed. And the task scheduler assigned tasks to the computing nodes in the system implementation.

The average rate for the task scheduler i,λ_i , meet:

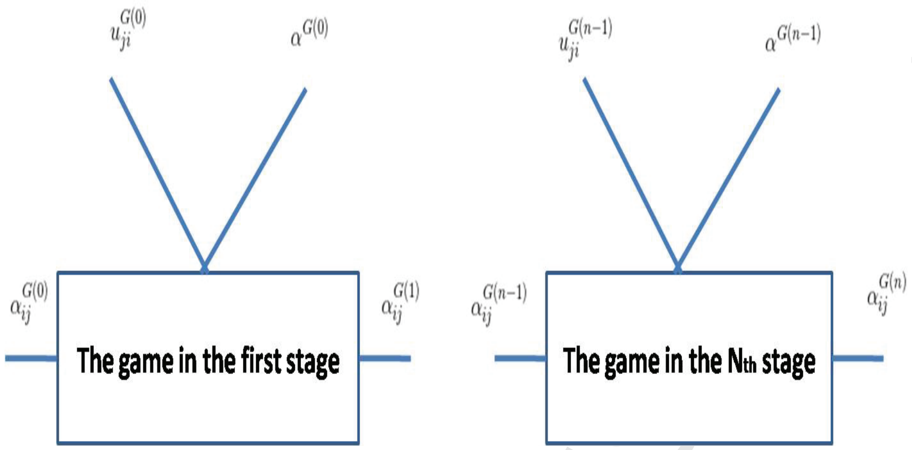

Figure 2: The data flow diagram of sequential game model

$$\sum_{i=1}^{n} \lambda_i < \sum_{j=1}^{m} u_j, \sum_{i=1}^{n} \lambda_i a_{ij} < u_j \tag{8}$$

The schedulers in cloud computing system share computing nodes,and they are independent with each other, the response time to perform the task is always expected to be shortest. For scheduler i, task decomposition strategy is $a_i = \{a_{i1}, ..., a_{ij}, ..., a_{im}\}$. In the game, each scheduler wants to finish a task in the shortest time, therefore, we take the response time of task execution as the optimal objective function. The response time of a task execution is determined by the processing time of each activity slice. To determine the response time of the task execution, we first need to investigate the processing time of each activity slice. The processing time of each activity divided by two parts:(1) the transmission time for active slice a_{ij} from scheduler i to computing node j . (2)the queuing time and execution time in node j. In this paper, we assume that the average data length is b , e_{ij} is the transmission delay from scheduler i to computing nodes j , and c_{ij} is the transmission rate of line between scheduler i and computing nodes j , so the transmission time can be obtained.

$$L_{ij} = e_{ij} \times a_{ij} + \frac{b \times a_{ij}}{c_{ij}} \tag{9}$$

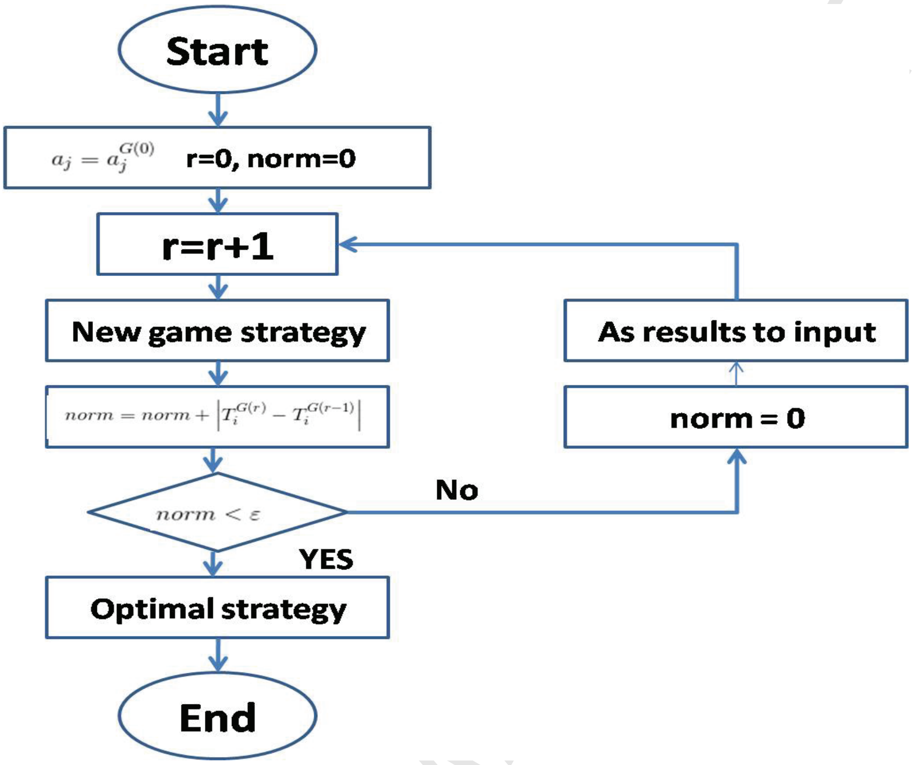

Figure 3: Frameworks of the designed method

$$F_{ij} = \bar{h}_j \times a_{ij} + \frac{a_{ij} \times \bar{h}_j^2 \times \sum_{i=1}^{n} \lambda_i a_{ij}}{1 - \bar{h}_j \times \sum_{i=1}^{n} \lambda_i a_{ij}} \tag{10}$$

On the basis of the optimal strategy of each participant, we can get the balanced task scheduling algorithm based on reliability.First of all, system parameter initialization can be done. Then set up the initial value of ϕ_j^{max} is $\phi_j^{max}(0) = \frac{u_j(0)}{3}$.

In the sequential game, the game participants predict the value of u_{ji} in the next game based on the last game.Constantly adjust their tasks to achieve a balanced state.Let G be a stage game of sequential game, $G(n)$ is the game at n_{th} stage, the activity slice in the stage is $a_{ij}^{G(n)}$, the value of α is denoted by $\alpha^{G(n)}$, and the value of u_{ji} is denoted by$u_{ji}^{G(n)}$. The data flow of sequential game model is shown in Fig.2 and 3.

In sequential game,the value of $a_{ij}^{G(n)}$ can be obtained

$$a_{ij}^{G(n)} = \frac{u_{ji}^{G(n-1)}}{\lambda_i} - \frac{\sqrt{h_j^2 u_{ji}^{G(n-1)}}}{\lambda_i h_j \sqrt{\alpha^{G(n-1)+\frac{h_j^2}{h_j}-h_j-e_{ij}-\frac{b}{c_{ij}}}}} \tag{11}$$

The value of $\alpha^{G(n-1)}$ is decided by Equ.12

$$\sum_{j=1}^{d_i} \left[\frac{u_{ji}^{G(n-1)}}{\lambda_i} - \frac{\sqrt{h_j^2 u_{ji}^{G(n-1)}}}{\lambda_i h_j \sqrt{\alpha^{G(n-1)+\frac{h_j^2}{h_j}-h_j-e_{ij}-\frac{b}{c_{ij}}}}} \right] = 1 \tag{12}$$

Based on the calculated optimal scheduler scheduling strategy, achieved the task scheduling process.

(1)Initialization, which makes the initial policy for each participant to $a_i^{G(0)} = \left\{ a_{i1}^{G(0)}, ..., a_{ij}^{G(0)}, ..., a_{im}^{G(0)} \right\} = \left\{ \frac{1}{m}, ..., \frac{1}{m}, ..., \frac{1}{m} \right\}$. At the same time, the definition of the game stage counter is r.

(2)Find the strategies $a_i^{G(r)}$ for the participants i, and obtain the corresponding time $T_i^{G(r)}$. At the same time, to get $norm = norm + \left| T_i^{G(r)} - T_i^{G(r-1)} \right|$, transfer $norm$ for the next participant $i + 1$.

(3)Repeat step 2 until finish calculating the strategy for all participants.

(4) To determine whether the norm meets the requirements, such as meeting the predetermined error, end algorithm, response time optimal scheduling strategy and optimal scheduling strategy of each participant ; if it can not meet the requirements of norm, go to step 2 and continue to implement.

4. Experimental results

In order to prove that the proposed algorithm has a better optimization effect, we select some existing task scheduling algorithms based on non cooperative game and balance task scheduling algorithm for comparison. For the comparison of the experimental results, we labeled the proposed balanced scheduling algorithm based on reliability as RSA algorithm. Then the task scheduling algorithm based on non cooperative game algorithm can be labeled as NSA algorithm and the balancing task scheduling algorithm can be labeled as BSA algorithm.

First of all, we consider the experiment on the value of objective function in equilibrium state. In this experiment, we assume that the cloud computing

Table 1: The task scheduler's relative arrival speed

scheduling	1	2	4	6	7	8	9
TSRAS	0.00349	0.00211	0.00141	0.00065	0.00057	0.000024	0.00013

Table 2: The node's average task processing speed

scheduling	7	10	11	12	13	14	15
NATPS	0.02212	0.03423	0.02509	0.02706	0.01634	0.02212	0.02845

system load coefficient $\rho = 0.6$, the number of schedulers is 10, the number of computing nodes is 15, the task scheduler's relative arrival speed is ω_i, as shown in Table.1. The task scheduler's actual arrival speed λ_i can be caculated by Equ.13.

$$\lambda_i = \omega_i \cdot \rho \cdot \sum_{j=1}^{m} u_j \tag{13}$$

Considering the characteristics of the caculation system, the cloud computing capability of these nodes may be in all balanced, but it may also be in a part of balance.As for these two cases, we carried out two experiments.

The first group of experiments is a system with many computing nodes in high calculation ability. In the system, the node's average task processing speed (computing power) u_j are shown in Table.2.

Based on the above initial conditions, respectively using the reliability algorithm , the non cooperative game algorithm and balanced algorithm to obtain the node's average task processing speed (computing power) u_j, then we can get the objective function which reflects the steady state ability of the system, the experimental results are shown in Table.3.

It can be seen from Table.3, if some nodes have high ability, the task scheduling algorithm proposed in this paper can enable the system to provide higher computational power, so that the reliability algorithm proposed in this paper is more excellent. In this experiment, the reliability algorithm, the non cooperative game algorithm and the equilibrium algorithm are used

Table 3: The result of test1 (some nodes have high ability)

scheduling	RSA	NSA	BSA
1	1.0000	1.0000	1.0091
2	1.0000	1.0000	1.0091
3	1.0000	1.0000	1.0091
4	1.0000	1.0000	1.0091
5	1.0000	1.0000	1.0091
6	1.0000	1.0000	1.0091
7	1.0000	1.0000	1.0091
8	1.0248	1.0336	1.0091
9	1.0248	1.0336	1.0091
10	1.0248	1.0336	1.0091
11	1.0000	1.0336	1.0091
12	1.0000	1.0000	1.0091
13	1.0000	1.0000	1.0091
14	1.0000	1.0000	1.0091
15	1.0000	1.0000	1.0091
$\sum D_j$	15.0744	15.1008	15.1365

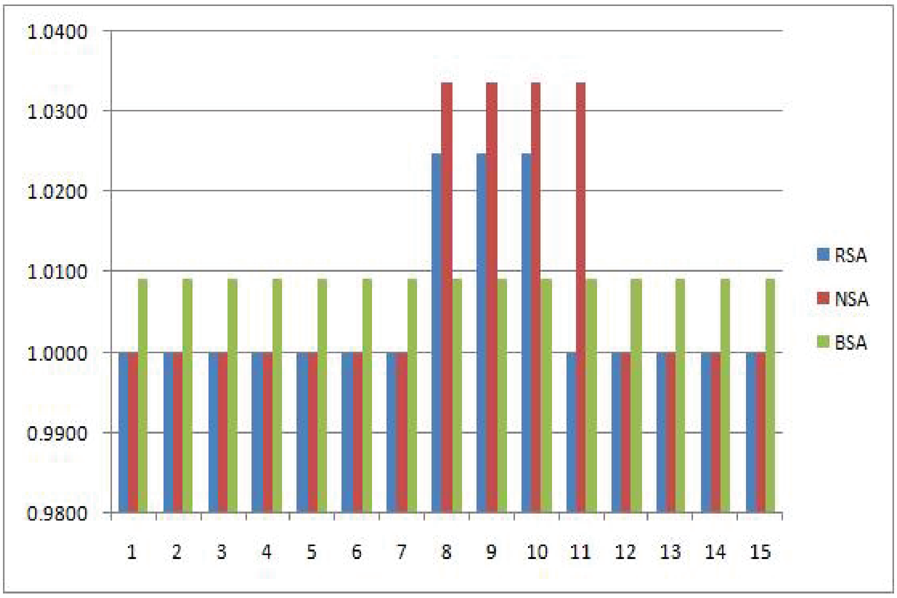

Figure 4: The comparison chart of target value(some nodes have high ability)

to calculate the reciprocal of the ability for each computation node which can be provided in the steady state. It is shown in Fig.4.

The second group of experiments is a system with many computing n-odes in balanced calculation ability. In the system, the node's average task processing speed (computing power) u_j are shown in Table.4. Other experimental data are the same as the first set of experiments.

Based on the above initial conditions, respectively using the reliability algorithm, the non cooperative game algorithm and balanced algorithm to obtain the node's average task processing speed (computing power) u_j, then

Table 4: The average processing speed of tasks of computing nodes (nodes have balancing computing power)

scheduling	1	2	3	5	6	8	10	11	13	15
APSTC	0.031	0.030	0.029	0.031	0.034	0.036	0.035	0.029	0.030	0.031

Table 5: The result of test1 (nodes have balancing computing power)

scheduling	7	10	11
1	1.0127	1.0115	1.0091
2	1.0018	1.0000	1.0091
3	1.0000	1.0000	1.0091
4	1.0000	1.0000	1.0091
5	1.0138	1.0131	1.0091
6	1.0007	1.0000	1.0091
7	1.0007	1.0000	1.0091
8	1.0223	1.0261	1.0091
9	1.0223	1.0261	1.0091
10	1.0326	1.0420	1.0091
11	1.0000	1.0000	1.0091
12	1.0000	1.0000	1.0091
13	1.0062	1.0017	1.0091
14	1.0062	1.0017	1.0091
15	1.0116	1.0099	1.0091
$\sum D_j$	15.1320	15.1364	15.1365

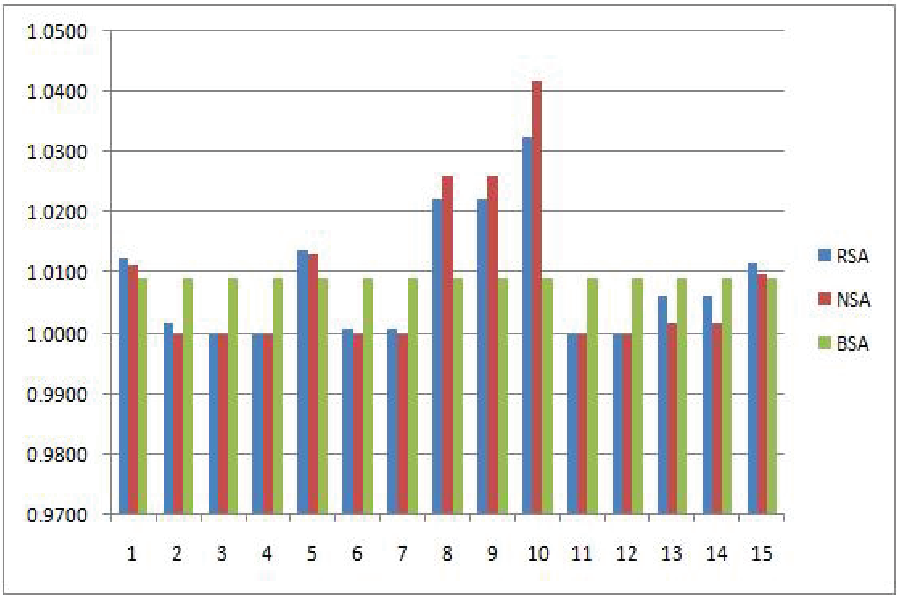

Figure 5: The comparison chart of target value(nodes have balanced computing power)

we can get the objective function which reflects the steady state ability of the system, the experimental results are shown in Table.5.

It can be seen from Table.5, if all the nodes have balanced ability, the task scheduling algorithm proposed in this paper can enable the system to provide higher computational power, so that the reliability algorithm proposed in this paper is more excellent. In this experiment, the reliability algorithm, the non cooperative game algorithm and the equilibrium algorithm are used to calculate the reciprocal of the ability for each computation node which can be provided in the steady state. It is shown in Fig.4.

From the above experiments can be seen, no matter what kind of computing power, the algorithm proposed in this paper can achieve the best optimization. Next, we'll think about factors affecting the scale of cloud computing system.

In the task scheduling of cloud computing, the factors affect cloud computing system contains the scheduler number and computing node. Therefore, changes of system scale includes a scheduler change in number and computing node number. In this experiment, we have done the following two groups of experiments.

Table 6: The average processing speed of tasks for computing nodes

scheduling	1	4	8	11	12	13	14	15
APSTC	0.011	0.022	0.033	0.028	0.034	0.029	0.023	0.031

Table 7: The relative arrival speed of tasks of the scheduler

number	RASTS	number	RASTS	number	RASTS	number	RASTS
1	0.0034	6	0.0006	11	0.003	16	0.0003
2	0.0021	7	0.0005	12	0.002	17	0.001
3	0.0011	8	0.0002	13	0.003	18	0.0035
4	0.0011	9	0.0001	14	0.001	19	0.0063
5	0.011	10	0.0001	15	0.004	20	0.0029

In the first experiment, we consider the effect of the changes in the number of schedulers in system. In this experiment, we assume that the number of schedulers changes from 5 to 20, increased 1 scheduler step by step, system load coefficient is $\rho = 0.6$, the number of computing nodes is 15, the average processing speed of each computing node task (capacity)u_i are shown in Table.6. The relative arrival rates of the 20 task schedulers are shown in Table.7.

Based on the above initial conditions, respectively using the reliability algorithm , the non cooperative game algorithm and balanced algorithm to obtain the node's average task processing speed (computing power) u_j, then we can get the objective function which reflects the steady state ability of the system, the experimental results are shown in Table.8.The comparison of the objective function value in the three algorithms is shown in Fig.4.

In Table.5, we can know that no matter in which algorithm , when the scheduler number increases with tasks number in the system,the objective function in the system will increase; No matter how many schedulers in the system, the objective function value corresponding to the reliability algorithm are the minimum in algorithms. Fig.4 can also shown that the objective function value of the reliability algorithm is the minimum of the three algorithms. And with the increasing number of the schedulers, the reliability

Table 8: The target value when the number of schedulers varies

scheduling number	RSA	NSA	BSA
5	15.0820	15.0830	15.1155
6	15.0880	15.0891	15.1237
7	15.0929	15.0941	15.1306
8	15.0949	15.0962	15.1333
9	15.0959	15.0972	15.1347
10	15.0961	15.0982	15.1361
11	15.1265	15.1290	15.1774
12	15.1469	15.1498	15.2051
13	15.1828	15.1867	15.2537
14	15.1932	15.1973	15.2677
15	15.2385	15.2458	15.3309
16	15.2417	15.2491	15.3351
17	15.2523	15.2600	15.3492
18	15.2895	15.2985	15.3989
19	15.2962	15.3055	15.4078
20	15.3273	15.3380	15.4492

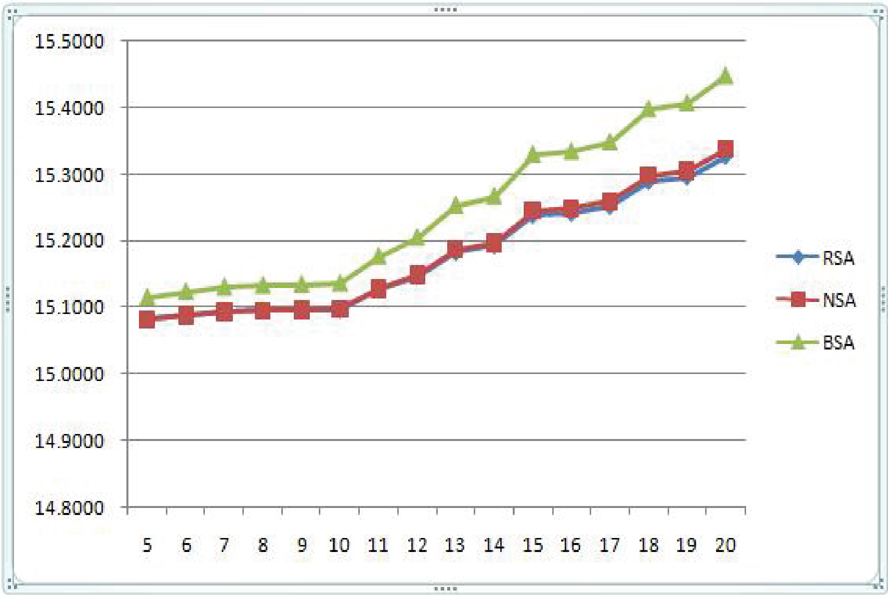

Figure 6: The affect of system scale (the number of schedulers varies)

algorithm is more better than the non cooperative game and equalization algorithm.

The second set of experiments is to calculate the effect caused by changes in the number of nodes. In this experiment, we assume the scheduler number is 15, the load coefficient of the system $\rho = 0.6$, the number of computing nodes in the system varies from 15 to 20.

Based on the above initial conditions, respectively using the reliability algorithm , the non cooperative game algorithm and balanced algorithm to obtain the node's average task processing speed (computing power) u_j, then we can get the objective function which reflects the steady state ability of the system, the experimental results are shown in Table.9. The comparison of the objective function value in the three algorithms is shown in Fig.4.

In Fig.4, the difference in objective function of reliability algorithm and non cooperative game algorithm is not very obvious. Reliability algorithm always makes the system provides high computing capability. With the increase of the computing nodes number, objective function values corresponding to the three kinds of algorithm will increase gradually. By comparing the above two results, no matter how the system scale change, the reliability of

Table 9: The target value when the number of computing nodes varies

node number	RSA	NSA	BSA
15	15.2387	15.2460	15.3312
16	16.2583	16.2671	16.3532
17	17.2782	17.2870	17.3753
18	18.2964	18.3056	18.3974
19	19.3102	19.3198	19.4195
20	15.3255	20.3356	20.4415

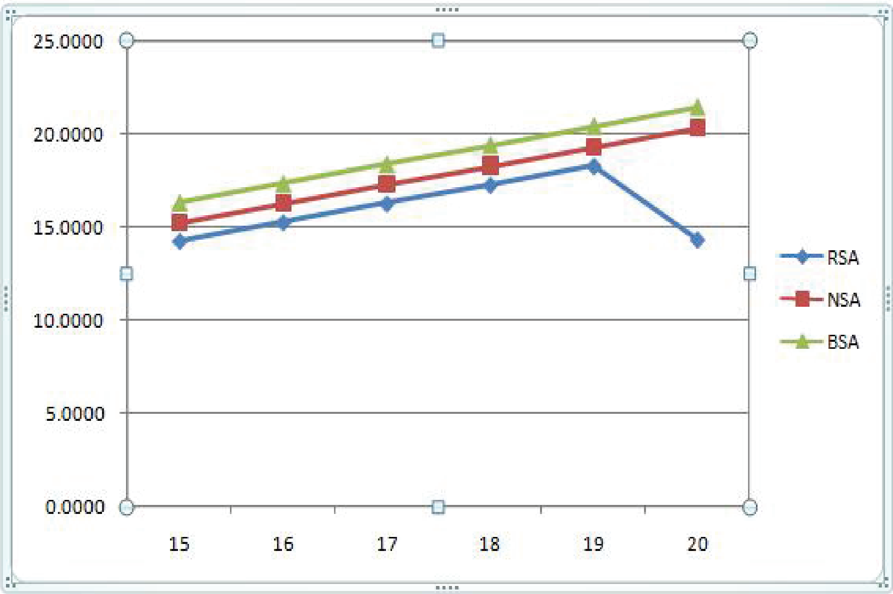

Figure 7: The affect of system scale (the number of computing nodes varies)

the algorithm can make system provides higher computational power. Compared with non cooperative game algorithm and equalization algorithm, it always has a better effect.

5. Conclusion

As the core issue of cloud computing, task scheduling has been widely concerned. For this paper, the main work is focused on the following points.

First, based on the simplified model for task scheduling system and the reliability analysis model for computing nodes, this paper establishes a mathematical model to calculate the stability of nodes. Compared with the existing research work, it is a new research idea. Most of the other optimization is based on the task response time, resource utilization and system throughput. Reliability is also one of the factors that cannot be ignored in the user QoS, so the reliability of the node is studied as the optimization objective.

Second, using the game theory, we establish a cooperative game model for cloud computing task scheduling.At present, most research results are based on the traditional algorithm, such as Max-Min algorithm, genetic algorithm, ant colony algorithm and so on. in this paper, the game theory is applied to the research of task scheduling problem, which can be said to be a new research method.

Third, the task scheduling problem in cloud computing is modeled as a multi-stage sequential game model. Based on the sequential rational assumption, the participants of the game can optimize their own game strategy. Based on the analysis of the Nash equilibrium solution, a task scheduling algorithm based on sequential game is presented. By comparing with the experimental results, the task scheduling algorithm based on sequential game is proved to have better advantage in response time.

The research work of this paper provides a new way for the research of cloud computing task scheduling problem, but there is still a lot of room for improvement. For example, the algorithm proposed in this paper is a hypothesis that ignores the processing cost in the task based on the internal scheduler. In the future, we will consider to add more influence factors into the algorithm, and gradually improve our research work.

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***Biographies (Photograph)**