Energy consumption optimization method of cloud computing platform based on customer satisfaction

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Received 1 March 2014, www.cmnt.lv

Abstract

With the global climatic change and the increasing dependence on energy, energy efficiency becomes one of the main obstacles entering the new era of green cloud computing. As a new high-end computation, green computing attracts extensive attention of people, which has great influence on the development of cloud computing. The paper analyzes factors satisfaction degree of cloud computing customers on cloud computing service, and proposes the fuzzy subjection function evaluating customer satisfaction. Based on the function, the objective is to maximize customer satisfaction and minimize cloud computing energy consumption, cloud-computing scheduling optimization model based on customer satisfaction is established, and customer value evaluation is the basis of selecting the weight coefficient of satisfactory function in the model. As cloud-computing scheduling optimization model based on customer satisfaction is multi-target optimization model, the paper optimizes objective functions in the model, uses linear weighting method to convert multi-target functions of the model into Single-objective functions, and applies improved genetic algorithm to solve the model. Finally the paper takes the examples to verify the effectiveness of the model and the algorithm.

Keywords: customer satisfaction, green cloud, control strategy, task scheduling, energy consumption

1 Introduction

Cloud computing is a large scale distributed computing paradigm using business goal as the main source motive force. It uses abstraction, transparency and automation to deploy key techniques including broadband network in real time, which realizes interconnection and interoperability through network. With the form of unified service, it uses multiple terminals, multiple platforms and multiple networks to provide software platform and infrastructures for the user with any from at any time anywhere. According to the requirements, it rapidly deploys efficient and safe non-trivial service. The objective is to provide efficient, flexible and cheap service for the users. In order to meet the requirements caused by wide application of internet, efficient solutions are provided and attract spread attentions of government, industries, enterprises, research organizations and colleges and universities.

Green has been widely applied to describe things. It has the feature of environmental friendliness such as low carbon and energy-saving, energy efficiency, health and economy and sustainability. Green computing means that computing resources are used with the economic and high-efficient form in the life cycle from design, manufacturing, transportation, application, maintenance, recycle and reuse. The main objective is to maintain balance of interests between the earth and profit [1,2]. Green cloud computing realizes sustainable development of cloud computing and reduces the influence of cloud system on environment. Essentially, cloud computing is an efficient mode realizing green computing. For example, virtualization technology is used to realize effective integration of resources, which improves utilization ratio of resources. The dormant technique effectively saves energy. Green computing not only realizes improving utilization ratio of computing resources, but also realizes minimization of energy consumption [2-8].

In order to realize green cloud computing and realize sustainable development of cloud computing, the energy consumption in cloud computing environment needs to be optimized. The existing energy-consumption optimization management techniques of distributed and parallel computing system include resource hibernation, dynamic voltage scaling and virtualization. Resource hibernation is used to r educe idle energy consumption. There are three types of energy consumption management strategies based on the technique, timeout strategy, forecasting strategy and randomized policy. The disadvantage is as follows. When it takes long time to start up the computer, it makes the system performance reduce. In 2005, Wu Qi [9] in China University of Electronic Science made researches. The researches indicate that the service request of computer system has self-similarity, which makes the optimal energy-consumption management strategy based on resource hibernation is timeout strategy. And when idle time duration obeys the distribution of Pareto, under the condition of trimmed mean, the robust of Pareto distribution shape parameters effectively estimates the algorithm. The adaptive technique based on window size effectively estimates DPM control algorithm. In 2009, for embedded multi-processor system, Lee, in Singapore National University, proposed two heuristic task scheduling algorithms of energy consumption perception, EGMS and EGMSIV. The algorithms consider task scheduling order and voltage adjust-

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ment for task scheduling, and use energy consumption gradient as evaluation indexes of task scheduling [10].

Mezmaz and others proposed a hybrid scheduling method based on the heredity method for cloud computing systems, which aimed at minimizing the finish time and reducing energy consumption by a method based on DVS [11]. Bradley and others proposed the computing method for minimum energy consumption, which predicted future load by historical data, with availability guaranteed, to adjust energy consumption[12]. Simiri dynamically adjustted the number of CPU in the collection, so that the sleeping mode would be adopted when the utilization rate was low. Thus, the energy consumption was reduced [13]. Zhong Wei and others proposed a multi-objective optimazation method of adaptive adjustment of virtual cluster in cloud computing, and a framework of the adaptive adjustment is also provided [14]. Cao jie and others proposed a sub-deadline distribution approach to satisfy the deadline requirements of parallel tasks deadline.to achieve the goal of saving energy in the environment of the computing resources supply voltage to be dynamically adjusted. They propose two energy-efficient scheduling algorithms--energy first scheduling algorithm (Ssef) and energy genetic scheduling algorithm (Egsa) to satisfy sub-deadline. Repeated experiments show that the two energy-efficient scheduling strategies can reduce the energy consumption considerably while meeting deadline constraints [15].

Cloud computing expresses the features and advantages with the form of service, which is the way realizing the values. Cloud computing service quality is the general effect that the users use cloud computing service. Service quality determines the satisfactory degree of the users on cloud computing service. Combined with the user and provider, from the perspective of user requirements, user perception and provider service, Li Chunlan and Deng Zhonghua analyzed cloud computing service quality, and formulated service grade protocol to ensure that the user confirm the performance level and quality level of the cloud computing service before application. Which not only is good for the users to form rational expectation on service quality, but also ensures perception on cloud computing service quality and improves satisfaction degree and loyalty of users [16].

While considering using virtualization technology to design scheduling strategy, the existing research results only minimizes the overhead of energy consumption under the premise of meeting the requirements of application request resources, and ignores the satisfaction of customers on cloud computing service. The modeling of traditional researches is very single, and the research results focus on designing energy-efficient optimization algorithm to solve cloud-computing resource scheduling problem. The paper combines modern customer-oriented management concept and optimization model to research and explore cloud-computing scheduling optimization scheme based on customer satisfaction. The paper proposes the fuzzy subjection function to evaluate customer satisfaction, based on which the paper uses maximizing customer satisfaction and minimizing energy consumption as the objective to establish the optimization model of cloud-computing resource scheduling problem, and selects customer value evaluation as the basis of selecting satisfaction function weight coefficient of the model, which not only is good for enterprises to rationally distribute cloud computing resources, but also improves the loyalty of cloud-computing customers and increases the profit of cloud computing enterprises [17]. By optimizing objective functions of the model, the paper uses linear weighting method to combine multiple objecttive functions of the model into single objective function, and uses genetic algorithm to solve the model. Finally the paper verifies the effectiveness of the model and algorithm by using examples. Your goal is to simulate the usual appearance of papers in a Journal of the Academy Publisher. We are requesting that you follow these guidelines as closely as possible.

2 Related work

2.1 CUSTOMER SATISFACTION

Since the 1950s, customer satisfaction has been used in academia as an academic concept. Since the 1970s, the importance of customer satisfaction has attracted the attention of academia and practice [18]. The paper defines customer satisfaction as the feeling of cloud computing customer for satisfied requirements. Customer satisfaction is established on the basis of cloud computing customer experiencing cloud-computing service. According to the expectation, the customer makes emotional reactions on cloud computing service by combining time, environment and region, which is the direct or indirect interactive result of multiple invariables including customer perception, customer expectation and customer recognition.

Customer satisfaction means the satisfaction of the customers who has purchased the service on the service. It is the function of the expectation before purchase and the quality after purchase, as follows [19].

Customer satisfaction=f(customer expectation, perceived quality):

1) Expected quality means the evaluation of cloud computing customer on service quality before buying a service. The expectation of customer on quality is influenced by two factors. On one hand, the paper has expectation on cloud computing service quality by comparing the price of cloud computing service, knowing the public praise of cloud computing enterprises in the market and media advertising. The more the customers master positive information, the higher the expectation of the customers.
2) Perceived quality is the actual feeling and perception of cloud computing customer on the quality after purchasing and consuming the service. The customers are not the expert of service, so they judge and evaluate the quality of cloud computing service only by factors reflecting service quality such as reliability, timeliness, convenience and accuracy of service, which is perceived quality.

From the above definition of customer satisfaction, we can see that the expectation of customers on service quality and the service quality they feel are two determining factors influencing cloud-computing customer satisfaction. The customer with great satisfaction is one of the most important sources of enterprises making profit. Customer satisfaction can influence the final sales by a series of delivery function, which influences the income and profit of cloud computing enterprises.

2.2 CUSTOMER SATISFACTION EVALUATION

Accurately reflecting the satisfaction of cloud computing customer and mastering dynamic change of customer requirements need to quantify customer satisfaction, which means to evaluate customer satisfaction. The existing methods evaluating customer satisfaction include exponent method, fuzzy comprehensive evaluation method and function method [20]. The paper selects satisfaction function method to measure customer satisfaction. Satisfaction function method converts each response into satisfaction function, which means converting each response value into the number from 0 to 1 by using specific satisfactory function. 0 means that the customer is completely unsatisfactory with the distributed service, and 1 means that the customer is very satisfactory with the distributed service. The single satisfactory function is:

$$f_i(y_i) = \begin{cases} \left[\dfrac{y_i - l_i}{t_i - l_i}\right]^{\gamma} & l_i \le y_i \le t_i \\ \left[\dfrac{k_i - y_i}{k_i - t_i}\right]^{\lambda} & t_i \le y_i \le k_i \\ 0 & other \end{cases}, \quad (1)$$

where l_i means the minimum, k_i is the maximum, t_i is the optimization value of response i, γ and λ decides the shape of satisfactory function, and $f_i(y_i)$ increases with the increase of the responded satisfaction. The response variable of customer satisfaction function in the paper is influencing factors of customer satisfaction including timeliness, accuracy, safety and response, which can be defined as overall satisfaction function of multi-response system, which can realize the transformation from multiple response variables to single response variable.

2.3 CUSTOMER VALUE

Customer value has two meanings [21,22]. One meaning is the value of enterprises for users, which means the value for the users provided by the enterprises from the perspective of customers. The view considers that customer value is the value which is achieved from the products or service provided by the enterprises. The other meaning is the value of customers for enterprises from the perspective of enterprises. The value of customers for enterprises is the traditional customer value. Customer value includes the existing value and potential value. The existing customer value is the profits created by enterprises, is an important aspect that enterprises perceive value, and determines the existing profitability of enterprises. The potential customer value means the profit of customers for enterprises. It relates to long-term profit of enterprises, and has direct influence on the judgment of enterprises on customer value. And it is an important basis if enterprises continue to invest in the customer relationship. The existing researches about customer value analyze from the perspective of life cycle of customers. Customer life-cycle value can fully respect the value-increasing ability of customers for enterprises in the life cycle, so it can measure the overall value of customers comprehensively.

Under the condition with limited resources, customer value is heterogeneous. According to Pareto’s Law, unilaterally pursuing service satisfaction of all customers may have the situation that too many resources are distributed on value customers and little resources are distributed on high-value customers. So cloud computing service enterprises need to identify customer value to realize optimizing resource allocation and improve customer satisfaction.

Qi Jiayin proposed that there were three indicators describing the present value of customers, gross profit, purchase volume and service cost [23]. The indicators describing potential value of customers include loyalty and credit. According to the actual situation of cloud computing service, the paper establishes customer value evaluation index system consisting of present value and potential value. The present value includes profit, purchase amount of cloud service and service cost, and potential value consists of customer loyalty and customer credit.

2.4 CUSTOMER SATISFACTION MANAGEMENT

Customer satisfaction management of cloud computing integrates customer resources of cloud computing by optimizing business process relating to customer relationship with the help of advanced information technology and management concept, which not only improves customer satisfaction and enhances customer loyalty, but also realizes enterprise profit maximization. Customer satisfaction management of cloud computing is the integration of modern management concept and information technology. It is a management strategy managing customer information resources with the means of information technology. Idea, mechanism, technology and strategy composes basis system of customer satisfaction management of cloud computing. In order to realize the win of cloud computing enterprise and customers, cloud computing enterprises need to persist in customer-oriented service concept, and providing high-quality service for customers and making customers satisfactory is the key to realizing customer maintenance and customer achievement. Customer value is the difference between the total value and total cost of customers. Total customer cost includes all direct and indirect cost relating to profit. Customers are willing to purchase service from providers who can provide the highest customer value. By analyzing and researching customer requirements and preference, customer satisfaction management focuses on breaking through key value factors, and exploring new ways and methods to meet real requirements and potential requirements of customers to realize the leap of customer value. The research proves that satisfactory customers have higher loyalty than the unsatisfactory customers, and satisfactory customers are willing to pay higher price for service and accept more projects of enterprises. Customer satisfaction management not only improves customer satisfaction, but also improves the popularity of cloud computing enterprises in the market. Cloud computing enterprises can establish long-term and good cooperation with customers by quality management for customers. Cloud computing enterprises have great advantage for cloud computing projects improving satisfaction and loyalty.

3 Description of cloud computing scheduling problem based on customer satisfaction

The cloud computing scheduling problems based on customer satisfaction in the paper are as follows. There is a scheduling center with cloud computing resources which can be scheduled by scheduling center, and it serves customers who have constraint for service time. Each customer only has one chance to use virtual machine, a virtual machine can serve multiple customers, and it is scheduled again by scheduling center after completing tasks. The scheduling scheme with minimal energy consumption and maximum customer satisfaction is solved under the premise of meeting constraint conditions.

The cloud computing resource scheduling problems based on customer satisfaction in the paper have two optimization objectives, customer satisfaction minimization and energy consumption minimization. The main factors influencing customer satisfaction include timeliness, accuracy, responsiveness and safety. Customer satisfaction management can improve customer satisfaction greatly. So the paper selects punctuality of cloud computing service as the response of satisfactory function. If the time slot that the customer can accept is $\left[KK_i, LL_i\right]$, the time slot that the customer is completely satisfactory is $\left[K_i, L_i\right]$ and the satisfactory function is $K(t_i)$:

$$K(t_i)=\begin{cases}\left[\dfrac{t_i-KK_i}{K_i-KK_i}\right]^{\gamma} & KK_i<t_i<K_i\\ 1 & K_i\le t_i\le L_i\\ \left[\dfrac{LL_i-t_i}{LL_i-L_i}\right]^{\lambda} & L_i<t_i<LL_i\\ 0 & other\end{cases}. \tag{2}$$

when the customer i is served in the range of the expected service time, the satisfaction degree is 1, or the satisfactory degree reduces with the increase of the difference between service time and expected time. t_i is the beginning time serving customers, KK_i and LL_i is the range of the customers tolerating the beginning time range of service of the customers, and γ, λ are the sensitivity coefficients of customers for time.

4 Modeling of cloud computing scheduling optimization problems based on customer satisfaction

4.1 MODEL ESTABLISHMENT

4.1.1 Hypothesis of problems

There is only a scheduling center, and each virtual machine is scheduled by scheduling center. After completing cloud computing tasks, it receives the scheduling of scheduling center. The requirement of cloud service of the customer is less than the upper limit of the virtual machine. Each virtual machine can provide cloud service for different customers. The service requirements of each customer must be satisfied. The cloud service resource of scheduling center is uncertain. The requirement amount and service time of cloud computing service has been known. Dataflow limitation is not considered.

4.1.2 Definition of parameters and variables

V – node set;
R – customer node set $R=\{i\}$, $i=0$ is the dispatch center, $i=1,2\cdots n$, n is a node of the customer;
K – virtual machine set;
β_i – satisfactory function weight of customer;
c_1 – migration energy consumption of the virtual machine per unit time;
c_2 – operation energy consumption per virtual machine;
g_i – cloud service demand of customer i;
d_{ij} – required migration time for the virtual machine from i to j;
b_k- cloud service ability of virtual machine k;
T_i – the time of virtual machine serving customer i;
DT_{ji} – scheduling time of virtual machine between different customers;
ST_j – service time of virtual machine for customer;
ρ – the minimum of the set customer satisfaction;
$\left[H_i(\rho, L_i(\rho))\right]$ – service time requirement based on customer satisfaction ρ;

$$x_{ijk}=\begin{cases}1 & Virtual\ machine\ k\ transfers\ from\ i\ to\ j\\ 0 & other\end{cases}, \tag{3}$$

$$y_{ik}=\begin{cases}1 & Customer\ i\ is\ served\ by\ virtual\ machine\ k\\ 0 & other\end{cases}. \tag{4}$$

Mathematical model of cloud computing scheduling based on customer satisfaction is as follows:

$$\max Z_1=\sum_{i\in R}\beta_i F(t_i), \tag{5}$$

$$\min Z_2 = c_1 \sum_{k\in K}\sum_{i\in R}\sum_{j\in R} d_{ij}x_{ijk} + c_2 \sum_{k\in K}\sum_{j\in R} x_{0jk} \quad , \tag{6}$$

$$F_i(t_i) \geq \rho, \forall i \in R \,, \tag{7}$$

$$\sum_{i\in R} g_i y_{ik} \leq b_k, \forall k \in K \,, (8)$$

$$T_i = \sum_{k\in K}\sum_{j\in R} x_{ijk}(t_j + ST_j + DT_{ji}), \forall_i \in R \,, \tag{9}$$

$$\max(T_i, H_i(\rho)) \leq t_i \leq L_i(\rho), \forall i \in R \,, \tag{10}$$

$$\sum_{i\in R} x_{ihk} - \sum_{j\in R} x_{hjk} = 0 \ \ \forall h \in R, \forall k \in K \,, \tag{11}$$

$$\sum_{i\in R} x_{0ik} = \sum_{j\in R} x_{j0k} = 1, \forall k \in K \,. \tag{12}$$

Equations (5) and (6) is the optimization object functions of problems. Equation (5) means maximizing satisfaction of customers, Equation (6) means the minimization of energy consumption, Energy consumption includes migration energy consumption and operation energy consumption. Equation (7) means that customer satisfaction is not loser than the set minimum, which meets the requirement of service time of the customer. Equation (8) means that the load of any virtual machine doesn't allow greater than the limited value. Equation (9) means that virtual machine provides cloud service time expression for customers. Equation (10) means that the virtual machines stop serving. Equations (11) and (12) means the virtual machine must accept the scheduling of the scheduling center after completing tasks.

4.2 DETERMINATION OF WEIGHT COEFFICIENTS OF SATISFACTORY

The model in the paper sets weight coefficients of customer satisfaction function. In fact, if the weight of customer satisfaction function takes the average value of satisfaction degree of all customers, it can make the cost increase because of excessively pursuing satisfaction of all customers. In order to realize optimized allocation of resources and improve profitability of computing enterprises, the paper establishes evaluation system of customer value and uses fuzzy comprehensive evaluation method to quantify customer value, and uses it as the weight of customer satisfaction function. The process is as follows.

Determining evaluation indicators and evaluation objects. According to actual requirements, *n* indicators, *m* evaluation objects, indicator set *U* and evaluation set *V* needs to be determined.

Hierarchical analytical method needs to be used to determine weight distribution vector *A* of evaluation indicators.

Delphi method is used to hire experts to evaluate indicators. The evaluation score in the paper has five levels, 9, 7, 5, 3 and 1, which can get an evaluation matrix *W*.

Compositional operation is made to get comprehensive evaluation results.

After fuzzy comprehensive evaluation, customer value is achieved. The paper uses customer value as weight coefficient of satisfaction function in the model, β. The greater the customer value, the greater the weight coefficient of satisfaction function, which means the customers with greater customer value should rationally allocate cloud service resources to make customer satisfaction great, improve the loyalty of customers and make the enterprises make more profits.

4.3 MODEL SOLUTION

The cloud computing resource scheduling optimization model based on customer satisfaction in the paper includes two objective functions, minimal cloud computing energy consumption and maximal customer satisfaction. The model can be summarized multi-objective model optimization problems making two objectives optimal under constraint conditions. The basic idea of multi-target model optimization method is converting multi-target optimization problem into one or a series of single-target optimization problems, and completing the solution of multi-objective optimization problem by solving one or a series of single-target optimization problems. So the paper uses the method.

The cloud computing scheduling optimization model based on customer satisfaction in the paper directly uses weight coefficient variation method, which needs to make the following conversion:

1) The targets of the established model can't be directly weighted. The paper takes reciprocal value of cloud computing energy consumption, converts it into maximization of the reciprocal value, and simplifies it into single-target optimization.
2) The order of magnitude between two objective functions is not identical. After taking reciprocal value, the cloud computing energy consumption function is less than the customer satisfaction function. If it is added directly, it may weak the effect of multi-objective optimization. For the problem, a conversion factor is added to the reciprocal value of energy consumption to make two objective functions balanced. The converted objective function is:

$$\max S = S_1 + \frac{\mu}{S_2} = \sum_{i\in R} \beta_i F_i(t_i) +$$

$$\mu / \left(c_1 \sum_{k\in K}\sum_{i\notin R}\sum_{J\in R} d_{ij}x_{ijk} + c_2 \sum_{k\in K}\sum_{j\in R} x_{0jk} \right),$$

S is the objective function after conversion, and μ is conversion factor, β expressed the weight coefficient of satisfaction. The revised single-target optimization model converts two optimization objectives of the original model into one, and determine the order of optimization objectives by setting parameters. Customer satisfaction and energy consumption are two objective functions with inconsistent optimization directions. One optimization must make the loss of the other optimization, so the satisfactory solution only can be achieved according to actual requirements.

The cloud computing scheduling optimization model based on customer satisfaction in the paper can be summarized multi-objective optimization problems making multiple objectives achieve optimal under constraint conditions. The basic idea of solving multi-objective optimization is to convert multi-objective optimization problem into single-target optimization problem, and complete the solution of multi-objective optimization by solving single-target optimization problems.

The difference from single-target optimization problem is that [24] the solution of multi-objective optimization problems is not unique, but there is an optimal solution set. The objective of multi-objective optimization algorithm is to find. Traditional optimization methods need more than one operation optimization to achieve the optimal solutions of Pareto. But the optimization process is independent, and the achieved results are not consistent. The traditional optimization methods are limited, the paper uses genetic algorithm to solve cloud computing resource scheduling optimization problems based on customer satisfaction to get cloud computing resource scheduling optimization model, which is an efficient means.

4.4 SCHEDULING STRATEGY

Through fuzzy comprehensive evaluation, the values of 25 customers can be achieved. The result of customer value is used as the value of parameter β in the model. According to the difference of customer value, logistics distribution enterprises implement different scheduling strategies. According to customer value, the customers are divided into three sets, $C=\{C_l,C_n,C_h\}$ When the customer value is greater than 0.05, they are high-value customers, which is included in C_h. The resources are scheduled preferentially, which makes customer satisfaction great and makes them keep the loyalty. When the customer value is greater than 0.035 and is less than 0.05, the customers are included in C_n, which only has scheduling resources which are secondary to high-value customers. After meeting the requirements of C_h, cloud computing resources are scheduled to C_n. The customers with customer value less than 0.035 are low-value customers, which is C_l. When C_h and C_n is null set, cloud computing resources are scheduled to C_l.

5 Experiment and result analysis

The popular open-source virtual machine management infrastructure software OpenNebula is used in the paper. The front end of OpenNebula is equipped with a physical server of Intel Core i5™ 2.5GHz CPU, 4GB 1600MHz DDR3 RAM, Ubuntu11.10 operation system. The front end of OpenNebula is installed on the physical server to schedule and mange virtual machine. The paper selects 8 physical servers with OpenNebula virtual machine platform and KVM as client-side nodes. The client-side machines are equipped with Ubuntu11.10 operation system. The physical host is used as the root node and dispatcher, and the other client machines are used as the nodes of the secondary layer, and are deployed on virtual machines of the client machines as sub nodes. And the relevant parameters are shown in Table 1.

TABLE 1 Parameter setting

arameter	Meaning	Value
ρ	The lowest service level	0.1
n	Population size	60
p_m	Mutation probability	0.05
G	The maximal iteration times	100
p_c	Crossover probability	0.80

TABLE 2 Customer satisfaction

Number	Customer value parameter	Customer satisfaction
1	0.0317	1.0000
2	0.0318	0.2332
3	0.0586	0.8972
4	0.0465	1.0000
5	0.0379	1.0000
6	0.0374	0.1264
7	0.0382	0.2425
8	0.0478	1.0000
9	0.0461	1.0000
10	0.0358	0.6247
11	0.0377	1.0000
12	0.0318	0.6247
13	0.0306	1.0000
14	0.0320	0.5112
15	0.0376	1.0000
16	0.0413	1.0000
17	0.0361	0.7034
18	0.0438	0.5035
19	0.0519	1.0000
20	0.0230	0.2437
21	0.0548	1.0000
22	0.0410	1.0000
23	0.0561	1.0000
24	0.0404	0.8341
25	0.0382	0.4597

We can see from Table 2 that the satisfaction of customer 3, 19, 21 and 23 with greater customer value is more than 89%. The customer satisfaction with great customer value can increase the overall customer satisfaction. The paper sets the lowest service level for the customers, which effectively prevents the situation of improving overall satisfaction and reducing customer satisfaction (Figure 1 and 2).

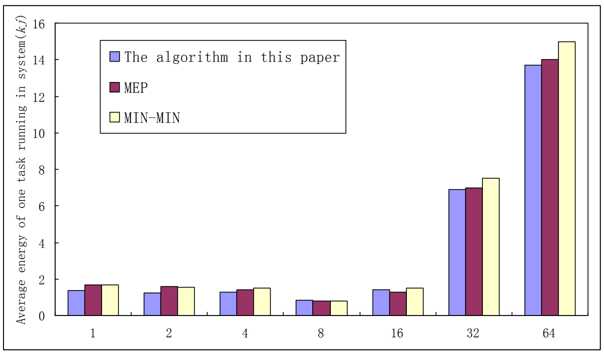

FIGURE 1 Average energy of one task running in system

In order to prove the effectiveness of the algorithm, the algorithm is compared with MIN-MIN algorithm and MEP algorithm. MIN-MIN is dynamic scheduling algorithm for independent tasks [25], and it is widely applied for homogeneous or heterogeneous distributed parallel computing environment, and has good performance. The core idea of MEP algorithm is as follows. When tasks are scheduled, the load of the computer and the service time executing tasks is not considered, and the tasks are scheduled on computers with the minimal execution power. The paper makes comparative analysis on three algorithms for average energy consumption, average power, and average response time and customer satisfaction.

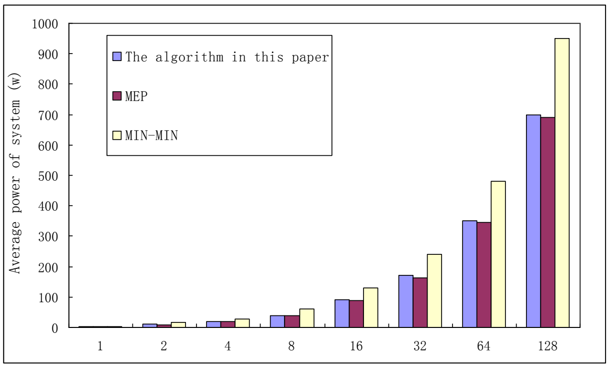

FIGURE 2 Average power of system

For average energy consumption executing tasks, MIN-MIN algorithm is the maximal, and the response time of MIN-MIN is minimal, the reason for which is that MIN-MIN algorithm doesn't consider energy consumption and load balance, but focuses on completion time of tasks. The average power of MEP algorithm is minimal, and the algorithm in the paper is greater than MEP algorithm. The power of MIN-MIN algorithm is the greatest, and is greater than the algorithm in the paper and MEP algorithm, the reason for which is that MEP algorithm only schedules tasks on machines with the minimal execution power, and focuses on optimization of system execution power. So the average power is minimal. The average customer satisfaction of three algorithms is 0.7602, 0.7320 and 0.7128. For customer satisfaction of important customer 3, 19, 21 and 23, the algorithm of the paper is evidently better than the other algorithms, the reason for which is that the algorithm in the paper focuses on service requirement of important customers (Figure 3 and 4).

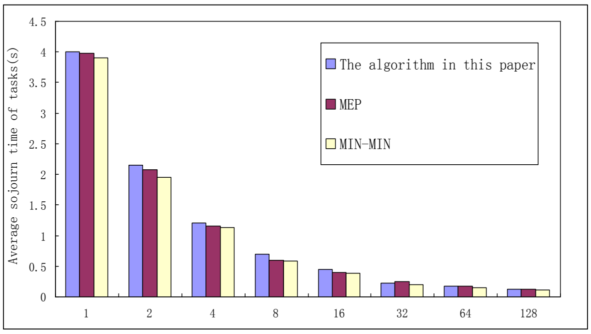

FIGURE 3 Average sojourn time of tasks

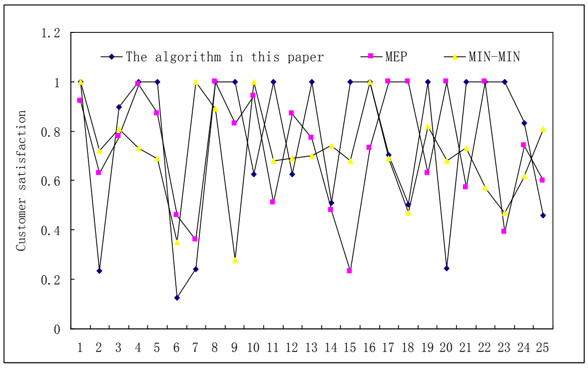

FIGURE 4 CUSTOMER SATISFACTION

6 Conclusion

The paper combines customer management concept and traditional model optimization, proposes solution strategies of cloud computing scheduling optimization problem based on customer satisfaction, and establishes cloud computing scheduling problem optimization model based on customer satisfaction with maximizing customer satisfaction and minimizing energy consumption as the objective. The paper quantifies customer satisfaction and uses it as objective function of solution, which not only avoids the research situation only focusing on algorithm, and solves actual problems, but also is more applicable. Based on keeping the original customers, cloud computing enterprises attract more potential customers by improving customer satisfaction and improving brand and popularity of enterprises, which achieves more profits. The model established in the paper is scientific and applicable, and solution algorithm has great convenience and practical operation.

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