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Dispersion Cloud Resource Perception and Scheduling

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Abstract: More and more cloud resources are present dispersion characteristics when the cloud-unit dynamic change. It is an important issue that find and schedule the resources for user's requirements accurately and quickly in cloud computing technology. In this paper, we study the problem about perception and scheduling of the dispersion cloud resources and put forward the solution. The main contribution include: (1) Building a cloud system architecture based on Mobile Agent paradigm. (2) Designing perception and scheduling model based on user preferences and utility functions. (3) Giving the dispersion cloud resources available assessment algorithm based on multi-dimensional cloud model and a scheduling algorithm based on the ideal of Skyline. The innovation in this study lie in constructing a cloud system based MA and giving a perception and scheduling model and an algorithm to be suitable for dispersion cloud resources. The new model and algorithm is verified by a set of experiments in our cloud platform. Compared with the existing methods the response-time of 90% requests can be reduced, the cost of VM is lowed, especially in the over workload states.

Key words: Dispersion cloud resource, perception, scheduling, mobile agent

INTRODUCTION

Cloud computing is a service model which scattered cloud unit converged into a huge shared resources pool using distributed computing techniques and virtual resource management technology through network to provide services for users in dynamic, on-demand and measurable way. The massive resources present the dispersed state and characteristics of big data in the shared resource pool when scattered cloud units change dynamically (China Academy of Telecommunication Reaearch of MIT, 2012). The personalized resources of users' demands are often dispersed in the resource pool. So perception and scheduling these resources became a more challenging job. Researchers have begun to study this problem. For example, A resource scheduling algorithm based on energy-aware and Qos-aware to reduce energy consumption but improve resource utilization and users' satisfaction (Lee *et al*., 2013; Huang *et al*., 2013; Mezmaz *et al*., 2011). A scheduling model for efficiency and profit maximization (Nguyen *et al*., 2013; Goudarzi and Pedram, 2011). A scheduling algorithm for optimizing system throughput (Lucas-Simarro *et al*., 2013). A model to minimizing total execution time (Nguyen *et al*., 2013). A scheduling method based on reliability-aware and trust-aware (Dastjerdi and Buyya, 2012; Sanchez Guerrero *et al*., 2012). A multi-objectives scheduling method (Hadji and Zeghlache, 2012; Prodan *et al*., 2011) and so on.

From the above, the researches on perception and scheduling of cloud resources have received some achievements. However, a lot of essential issues have not been addressed. First of all, massive cloud value-resources have dispersion features but the cloud resources in hybrid cloud environment lack of better portability and interoperability. Therefore, it is a challenging job to perceive and schedule users' personalized requirements. Secondly, there is not yet a mature system used for evaluating the availability of cloud resources, which lead to the problem is that it is difficult to cope with the dynamic uncertainty of the workload in the cloud platform. Thirdly, the existing scheduling method cannot meet the cloud computing service-oriented features.

Dispersion cloud resource availability assessment is not easy, because it chances with dynamic uncertainty. Furthermore, the qualitative concept needs to be converted into quantitative concept. Exactly, cloud model is an uncertainty transformation model that converts qualitative concepts to quantitative values. It is proposed by Li and Du (2005) which is based on probability theory and fuzzy set theory and considers the relevance of the randomness and fuzziness. It has been applied in many fields (Zhao *et al*., 2011; Zhang *et al*., 2007). Dispersion cloud resources with the characteristics of big data that candidate resources increases exponentially, value sparse and distribution of dispersion, resulting in resource selection computation time is too long and real bad.

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Skyline queries (Borzsonyi *et al*., 2001) have gained a lot of attention for multi criteria decision making in large-scale datasets. Skyline query formulation is well suited for capturing intuitive user preferences using dominance. In recent years, it has attracted more and more attention from researchers and has applied in a lot of fields (Cui *et al*., 2009; Pan *et al*., 2010). Therefore, computing the availability of dispersion cloud resources by using the cloud model to safeguard the reliability of resources selection and then remove the redundant candidate resource by Skyline computation in order to reduce the resource selection time, finally select optimal combination of resource from the Skyline resources under the constraints globally.

Farther more, cloud computing is a service-oriented, so the user's demand preference is a very important factor. However, the user preference is a qualitative concept, it must be quantified, this process is difficult, because preference is a fuzzy concept and it is difficult to give a preference degree of each indicator from the perspective of quantitative for the majority of user. Sometimes, There may be some inconsistency, such as, A is important than B, B is important than C but C is important than A. This inconsistency should not exist theoretically but in practically it may exist. Analytical Hierarchy Process (Saaty, 2008) provided a fuzzy weights determine method that can solve this problem.

MA is a program based on mobile code which is able to perceive the environment and respond quickly and intelligent migration in the different network (Badawy *et al*., 2010). MA system encapsulates the low-level network protocols and just to make relevant amendments to the MA system rather than make amendments to the details application of MA when the network protocol is upgraded (Cao and Da, 2012). Therefore cross-platform interoperability can be achieved if entire MA systems follow interoperable standards.

Based on the above analysis, section 2 proposes cloud system architecture based on Mobile Agent (MA) paradigm to improve the portability and interoperability in heterogeneous cloud platforms. Section 3 presents dispersion cloud resources perception and the scheduling model and introduces a dispersion cloud resource optimization algorithm based on multi-dimensional cloud model and Skyline method. Section 4 make the experiment to verity the correctness and validity of the method and model.

ARCHITECTURE OF CLOUD SYSTEM BASED ON MA

The dispersion cloud resource is deployed intelligently in physical clusters in the cloud computing domain. The resources that the user requested may also be distributed in the form of "sparse value" in multiple cloud computing domains. In order to rapidly find the most appropriate computing resources in mass value sparse resources to meet users' needs, a dispersion cloud system based on MA is designed in this study. The distributed topology is shown in Fig. 1. Cloud Service

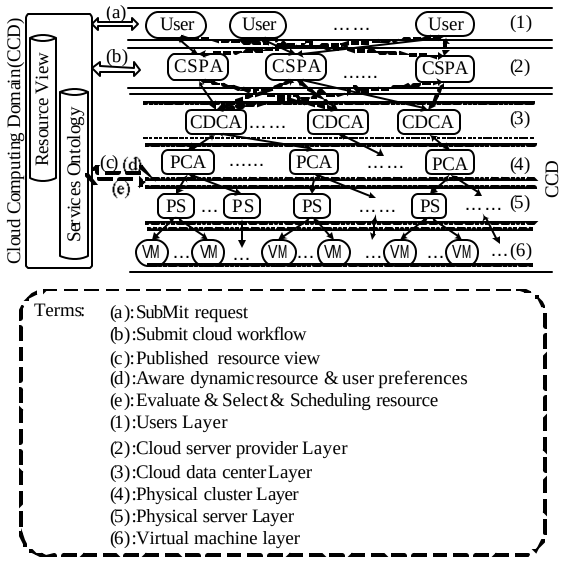

Fig. 1: Distributed topology of dispersion cloud system based on MA

Providers Agent (CSPA) is located in SaaS layer. Virtual Machine (VM), Physical Server (PS), Physical Cluster Agent (PCA) and Cloud Data Center Agent (CDCA) are located in cloud computing domain and connect to the Internet. Service ontology contains a variety of MA behavior and knowledge libraries, user's preferences, services and a lot of atomic requests. The resources view contains the functions, location and capacity characteristics of each cloud computing domain and a kind of dynamic list which is representing the available capacity, load capacity, processing power and data location and available network bandwidth of each server in the cloud units.

This architecture uses agent-based intelligent processing: The PCA real-time perceive the available capacity, load capacity, processing power of the physical server and VM, data location and available network bandwidth in this domain and build the local resources view of cloud computing domain. PCA also evaluates and selects the superior resources in cluster, then allocates, coordinates and synchronizes PS and VM. It provides a common background and rules to achieve common goals. The CDCA is responsible for integrating local resources into global resource view and evaluating and selecting the internal resources and performing the dispersion cloud resources perception and scheduling model in the cloud computing domain. SPA is responsible for selecting cloud computing domain according to users' requests and constraints.

PERCEPTION AND SCHEDULING MODEL OF DIFFUSION CLOUD RESOURES

It is a very challenging work to seek resources to meet users' requirements and allocate them reasonably in dispersion cloud environment. This study design the perception and scheduling model of dispersion cloud resource is shown in Fig. 2. The process of model as following: Firstly, perceive the dynamic change of resource in the cloud data center and build resources view, perceive the resources request and user preferences, design the utility function of the resources scheduling. Then evaluate resource according to the indicators and search optimal resources using search engine. These works are finished by MA.

In Fig. 2, the process of the model is input->select of the best resource->scheduling->run the application. Input is mainly composed of the user's preference, resource request and the resource view. Resource request is a set of description list for the request resources which includes resource name, resource type, the number of requests and the constraint conditions. These request resources can be proposed by the terminal user, cloud service providers, servers, virtual machine and so on. User's preference is the tendency degree of the importance of each indicator of certain resources. Resource view is the real-time reflection of the dynamic resources in the cloud data center which can be gained from the virtualization layer and core monitoring service. It mainly includes usable capacity, load capacity, processing power, data location and available network bandwidth etc.

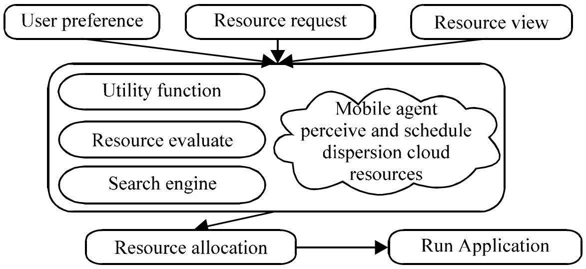

Fig. 2: Perception and scheduling model of dispersion cloud resource

Design of utility function: In order to maximizing the resource utilization of the cloud data center and charge most appropriate fees from the users to meet the SLAs, cloud service providers usually preset different kinds of virtual machine instances used for user scheduling. To facilitate the analysis, we divided the VM into three different types according to the computing power and processing capabilities, which are thin type, standard type and fat type. Furthermore, in order to make the workload with the same demand type allocated to the same virtual cluster in a maximization serialization way, reduce the cost of message delivery between virtual clusters and the tasks in different demand classes assigned to different virtual clusters, which will make the parallelization of the largest and can promote a virtual resource maximum utilization. Therefore, we introduce the concept of demand class which is a series of sessions with the same type and can be executed parallel. Suppose there are D demand classes, each demand class subscript denoted d. The related symbols are described as Table 1.

The objective of scheduling can be regarded as select a VM allocation strategy makes the completion time and the cost of virtual machine in completion all demand classes D can be as smaller as possible, is to minimize the maximum execution time in all demand classes D.

The total remain execution time of D in all virtual clusters I is calculated as Eq. 1:

Table 1: Related symbols explanation

Symbol	Meaning
VC_i	Virtual cluster No. N
$\delta_{ti}^{(d)}, \delta_{si}^{(d)}, \delta_{fi}^{(d)}, \delta_i^{(d)}$	All types VM required by demand d inVC_i, $\delta_i^{(d)} = \sum_{k=t,s,f} \delta_{ki}^{(d)}$
$\theta_i^{(d)}$	Amount of demand d in VC_i
$\eta_i^{(d)}$	Expected execution time of demand d in VC_i
$\mu_{ti}, \mu_{si}, \mu_{fi}, \mu_i$	All types VM required by VC_i
$\sigma_t^{(d)}, \sigma_s^{(d)}, \sigma_f^{(d)}$	Cost of thin, standard and fat VM required by demand d in Vc_i

$$F_1\left(\delta_i^{(d)}\right) = \max_{d\in[1,D]} \max_{i\in[1,I]}\left(\theta_i^{(d)} \times \eta_i^{(d)}\right) \Big/ \delta_i^{(d)} \tag{1}$$

The cost of VM in completion demand class D is represented by Eq. 2:

$$F_2(\delta_i^{(d)}) = \sum_{d=1}^{D} \sum_{k=t,s,f} \sigma_k \times \ln \prod_{i=1}^{I} \delta_{ki}^{(d)} \tag{2}$$

The objective of scheduling is represented by Eq. 3:

$$\begin{cases} \min\limits_{\delta_i^{(c)}} F_1\left(\delta_i^{(d)}\right) \min\limits_{\delta_i^{(c)}} F_2\left(\delta_i^{(d)}\right) \\ \text{s.t.} \sum_{d=1}^{D} \delta_{ki}^{(d)} \le \mu_{ki}, k = t, s, f \end{cases} \tag{3}$$

Therefore, utility objective function of the scheduling problem also can be represented by Eq. 4 and $\eta_i^{(d)}$ are uncertain parameters need to be calculated in advance, $\sigma_{ki}^{(d)}$ are variable parameters:

$$\begin{cases} \min\limits_{\theta_i^{(d)}\in\Omega} \lambda_1 \times F_1\left(\delta_i^{(d)}\right) + \lambda_2 \times F_2\left(\delta_i^{(d)}\right) \\ \text{s.t.} \sum_{d=1}^{D} \delta_{ki}^{(d)} \le \mu_{ki}, k = t, s, f \end{cases} \tag{4}$$

Resource evaluation: Due to the uncertain dynamic factors of the dispersion cloud resources in running process, the cloud resource is instability. In this study, Multi-dimensional cloud model (Li and Du, 2005) is used to evaluate the availability of the dispersion cloud resources.

Definition 1 n-dimensional cloud model: Let n-dimensional quantitative domain U = $\{x_{1I}, x_{2I}, \ldots, x_{ni}\}$, element $(x_{1I}, x_{2I}, \ldots, x_{ni}) \in U$ is a random realization of qualitative concept Q_i, the certainty degree $\mu_i \in [0, 1]$ of $(x_{1I}, x_{2I}, \ldots, x_{ni})$ about Q_i is a stable random number. Mapping from quantitative domain U = $\{x_{1I}, x_{2I}, \ldots, x_{ni}\}$ to certainty degree $\mu i \in [0, 1]$ is called n-dimensional cloud. Denoted by Q_i $(x_{1I}, x_{2I}, \ldots, x_{ni})$, each $(x_{1I}, x_{2I}, \ldots, x_{ni}, \mu_i)$ is called an n-dimensional cloud drops, also namely μ_i: $U \to [0, 1]$, $\forall$ $(x_{1I}, x_{2I}, \ldots, x_{ni}) \in U$, $(x_{1I}, x_{2I}, \ldots, x_{ni}) \to \mu_i$ $(x_{1I}, x_{2I}, \ldots, x_{ni})$, n-dimensional model is the model of the overall characteristics of the concept is described by 3n digital features $(Ex_1, En_1, He_1, \ldots, Ex_n, En_n, He_n)$, which Ex_1, En_1, He_1, i = 1, 2, ...n represent expected value, entropy, hyper entropy.

In this study, we use algorithm 1 to evaluate the availability of dispersion cloud resources. Ex_k is mathematical expectation of x_k which represents the resources performance, En_k and He_k represent the determine degree of the resources and the variable degree of the state respectively. According to setting the decision threshold α, β of En_k and He_k in n-dimensional cloud model, excluding the candidate resources with greater degree of uncertainty in the indicator of x_k, Ex, En, He represent the comprehensive expected value, entropy and hyper entropy considering all the indicators.

Algorithm 1: Availability evaluation algorithm of dispersion cloud resources

Input: The value of indictor attributes of a particular cloud resource, namely n-dimensional cloud droplets $(x_{1I}, x_{2I}, \ldots, x_{ni}, \mu_i)$, the decision threshold α, β

Output: Ex_k, En_k, He_k of the resource considering a single indictor and Ex, En, He of the resource considering all indicators.

Steps:

1. Calculate sample mean:

$$\bar{X}_k = \frac{1}{n} \sum_{t=1}^{n} x_{kt}$$

stage sample center distance:

$$\frac{1}{n} \sum_{t=1}^{n} \left| x_{kt} - \bar{X}_k \right|$$

and sample variance:

$$T_k^2 = \frac{1}{n-1} \sum_{t=1}^{n} \left(x_{kt} - \bar{X}_k \right)^2$$

according to x_{kt}

2. Calculate the estimated value of:

$$Ex_k : \hat{Ex}_k = \bar{X}_k$$

3. Calculate the estimated value of:

$$En_k : \hat{En}_k = \frac{\sqrt{\pi/2}}{N} \sum_{t=1}^{N} \left| x_{kt} - \bar{X}_k \right|$$

4. Calculate the estimated value of:

$$He_k : \hat{He}_k = \sqrt{T_k^2 - \hat{En}_k}$$

5. Use the integrated cloud algorithm of the virtual cloud theory to calculate Ex, En, He as show in Eq. 5, wherein w_i is the weights, it is calculated by the user preferences:

$$\begin{cases} Ex = \left(\sum_{i=1}^{n} w_i \times Ex_i\right) \Big/ \left(\sum_{i=1}^{n} w_i\right), i = 1, 2 \cdots n \\ En = \left(\sum_{i=1}^{n} (w_i)^2 \times En_i\right) \Big/ \left(\sum_{i=1}^{n} (w_i)^2\right), i = 1, 2 \cdots n \\ He = \left(\sum_{i=1}^{n} (w_i)^2 \times He_i\right) \Big/ \left(\sum_{i=1}^{n} (w_i)^2\right), i = 1, 2 \cdots n \end{cases} \quad (5)$$

USER PREFERENCE MODELING AND RETRIEVAL

Definition 2 user preference: User preference reflects the tendency of a class of users about the indicators that implement by weight distribution. A class of users is assigned to the same demand class in this study. Let $w_1, w_2, \ldots, w_r$ as a set of weighting values, w_i is tendencies of user u about indicator i:

$$0 \le w_i \le 1, \sum_{i=1}^{r} w_i = 1$$

For most users, preference is a fuzzy concept and it is difficult to give a preference degree of each indicator from the perspective of quantitative. In this study we adopt AHP (Saaty, 2008) to determine the weights. This method needs to construct a indicator comparison matrix, the elements in the matrix corresponding to the results of pairwise comparisons between each indicator, $R = (r_{1I}, r_{2I}, \ldots, r_{nI})$, i = 1, 2, ..., n.
where, r_{ij} is the importance of indicator i relative to indicator J, matrix R is called comparison matrix. If the elements of matrix R satisfy the constraints $r_{ij} = 1$, $r_{ij} = 1$, $r_{ij} = 1/r_{ij}$, $r_{ij} = r_{jk}/r_{jk}$, then matrix R has complete onsistency. $r_{ij} = 1$ means the importance of indicator i to their own, $r_{ij} = 1/r_{ij}$ means the importance is symmetrical of indicator i and j, $r_{ij} = r_{jk}/r_{jk}$ means the importance of indicator i and j independent of the other indicators. Saaty (2008) suggests that using 9 levels to represent the relativity. As shown in Table 2.

Theorem 1 Let the largest eigenvalue of matrix R is $\lambda_{max}>n$, n is the number of indicators and only if R has complete consistency then $\lambda_{max} = n$ (Wind and Saaty, 1980).

Define a consistency indicator to measure the degree of consistency, let $\eta = (\lambda_{max}-n) / (n-1)$. Set up a random consistency indicator ξ as reference of consistency indicator, show as Table 3. If N<3, then matrix R needs to be complete consistency. If $\eta/\xi<0.10$, then R has a acceptable consistency. Otherwise, it needs to adjust matrix R. When comparison matrix R has a complete consistency or a acceptable consistency, the eigenvector corresponding to the largest eigenvalue of matrix R is normalized as a weight vector.

Design of search engine: Search engine is mainly used to search the optimal resource set under each evaluation indicator in the dispersion cloud resources. This study quotes Skyline computing (Borzsonyi *et al*., 2001) to remove the redundant candidate resources which is governed by other resources in the massive resources. It reduced the search space of the resource selection. The definition of the Skyline resources and the optimal algorithm of the Skyline are described in Algorithm 2 and 3.

Definition 2 skyline resource: Set a resource class has m candidate resources, denoted by $Qx = \{Qx_{1I}, Qx_{2I}, \ldots, Qx_{km}\}$, each resource has k evaluation indicators x_{ij}, i = 1, ...k, j = 1, ...m, If for $\forall_i \in [1, k]$, $s \ne t$, $x_{is}>x_{it}$ and $\exists_I \in [1, k]$, s, $t \in [1, m]$ $s \ne t$ $x_{is} \neg x_{it}$ then resource Qx_{is} is governed by Qx_{it}, denoted by $Qx_{is}<Qx_{it}$, so $Sky\ Q = \{ Qx_{1I} \in Qx | \neg \exists\ Qx_{1I} \in Qx: Qx_{ij} \prec Qx_{ik}\}$ is called Skyline resource, Where is ≥ means better or equal and > means better.

Algorithm 2: Skyline Resource Select Algorithms (SRSA)

```
    Input: The value of each indicator of the cloud resources namely n-dimensional cloud droplet ($x_{1I}, x_{2I}, \ldots, x_{nI}$)
    Output: Skyline resources
    Step:
    1. Let candidate resources C: = $\phi$, redundant resources R: = $\phi$
    2. Every two resources are divided into a group, no intersection between the group
    3. For resources s and t, if $x_{is}<x_{it}$ then R; =   s. else if $x_{is} = x_{it}$ then until $x_{is}>x_{it}$, then C: = s, R; = t, else if $x_{is}<x_{it}$ then until i = m or $x_{is}<x_{it}$, if i = m then C: = s, R; = t, else R; = s, C: = t.
    4. Candidate resources set is divided according to step 2, then perform step 4.
    5. Until All resources are Skyline resources in candidate resources set.
```

Algorithm 3: Skyline Dispersion Cloud Resources Select Algorithm (SDCRSA)

```
Input: the indicator attribute record values which have been selected by the cloud model.
Output: Skyline dispersion cloud resources
Step:
1. Find Skyline resources within each physical server and submit them to the belonging physical cluster
2. Find Skyline resources within each physics cluster and submit them to the belonging cloud computing domain
3. Find Skyline resources within each cloud computing domain
```

Table 2: Two indicators important classification

Grade (g)	1	2	3	4	5
Meaning	Equal	g∈(1, 3)	Nuances	g∈(3,5)	Obvious
Grade(g)	6	7	8	9	
Meaning	g∈(5, 7)	Significant	g∈(7, 9)	Extreme	

Table 3: Mean of random consistency indicator Cao (2012)

N	1	2	3	4	5	6	7	8	9	10	11	12
ξ	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.14	1.46	1.49	1.52	1.52

EXPERIMENT RESULTS

This experiment has been performed in the cloud platform of Hebei University of Economics and Business. There are 8 servers. The hardware configuration of each server is Dell R710 processor, 32 GB memory and 20TB hard disk storage. The building scheme of physical and virtual cluster is shown in Table 4.

All experiment programs are written in Java. Web server for Apache tomcat 6.0.29, whose function is to perceive request, organize static pages, realize load balance and deploy the servlets of application that associated with transaction. The database server is MySQL which is mainly used to store resource view, table data associated with the application, transaction history, product information and customer information. The virtual machine instances are supplied and scheduled on demand. In the initial case, the Web server and application server both are made of a thin virtual machine. This experimental uses the workload within one hour as shown in Fig. 3.

The experimental results show the response time of cloud platform within one hour as shown in Fig. 4. The figure shows that the response-time of 90% requests can be reduced and the corresponding curve is relatively stable, improving the original case of large-scale fluctuations.

Table 4: Physical/virtual cluster configuration

Name	Explanation
Cluster size	Two Cloud Computing Domains (CCD), two Cloud Data Center (CDC) and each has two Physical Clusters (PC), each PC has two servers in CDC1, one PC has one server and the other one has three servers in CDC2
Cluster architecture	Server has 16-core Dell R710,32GB 24 GB memory and Linux KVN
VM configuration	Virtual CPU, memory, hard disk specifications of standard VM, thin VM, fat VM are 1core/2G/30G, 2core/4G/60G, 4core/8G/120G
VM architecture	Built 14 virtual machines per physical server

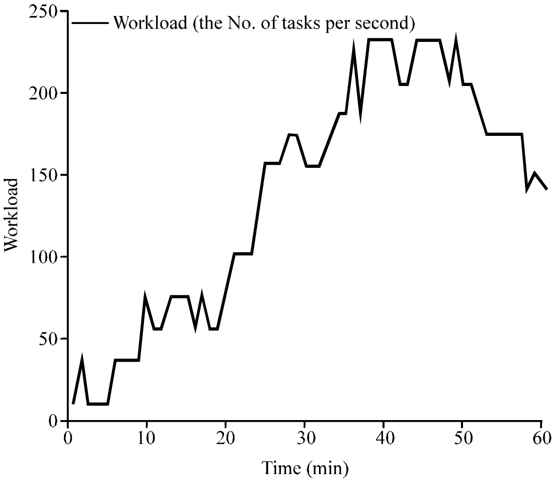

Fig. 3: Workload of cloud platform within one hour

The experimental results show the cost of cloud platform within one hour as shown in Fig. 5. The figure shows that the cost is reduced, especially in the over workload states.

The system throughput to some extent is increased with 128 VM and different tasks show as Fig. 6.

Figure 7 shows that significant increase system throughput with 20K task and different VM.

Figuer 8 shows that the scheduling time of each area are reduced, particularly, when the virtual machine number reached 128, the scheduling time can be lowed two orders of magnitude.

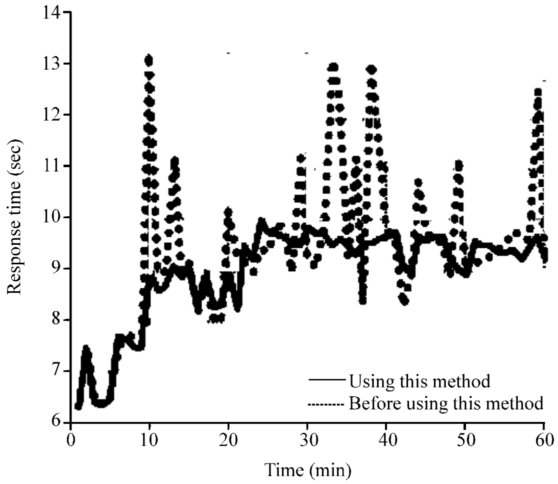

Fig. 4: Response time of dispersion cloud platform

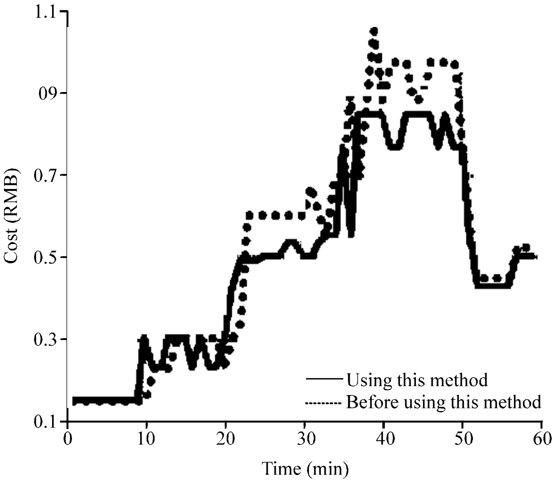

Fig. 5: Service costs of cloud platform

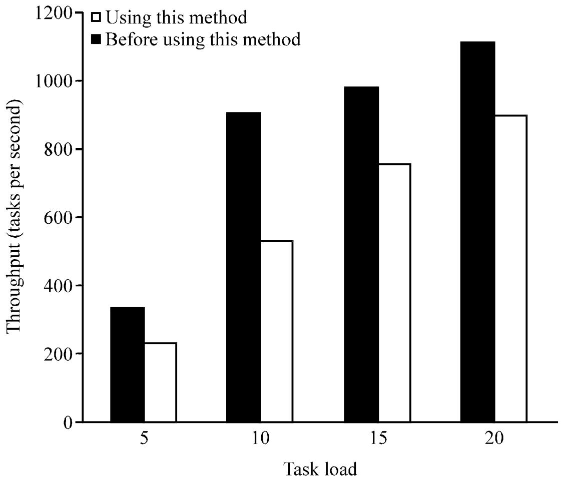

Fig. 6: Throughput with 128 VM and different task

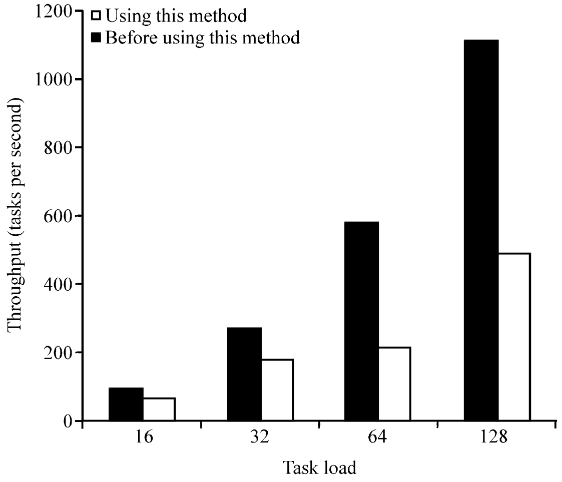

Fig. 7: Throughput with 20K task and different VM

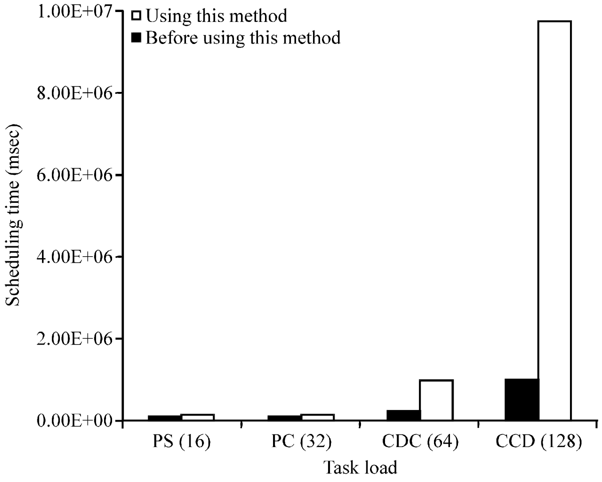

Fig. 8: Scheduled time of dispersion cloud platform

CONCLUSION

In this study, we put forward the concept of dispersion cloud resources and make a study for its perception and scheduling problem. First, we propose the architecture of cloud system based on Mobile Agent paradigm.Then we develop a model for perception and scheduling of dispersion cloud resource, build objective function and propose availability evaluate algorithm for dispersion cloud resources by multi-dimensional cloud model. Further, we quote the idea of Skyline to select the superior resources and give SDCRSA algorithm. Finally, we make the experiment to verity the proposed method in the cloud platforms of Hebei University of Economics and Business. The experiments results verify the correctness and validity of the method and model. Next work, we will optimize the method and the model in scheduling aspects, such as split scheduling interval when the load moves dramatically and merger scheduling interval when the load moves gently.

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