Service Selection Algorithm Based on Constraint for Cloud Workflow System

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***Abstract*—It is possible to utilize cloud computing to address the problems of resource extendibility and flexibility for managing large scale workflow applications. Therefore, the investigation of workflow systems based on cloud computing, namely cloud workflow systems is a timely issue and worthwhile for increasing efforts. The technology and application of workflow in cloud computing environment also becomes a research focus.**

The paper firstly proposes a brief introduction to the cloud workflow system. Next, based on cloud architecture, the paper presents the architecture of cloud workflow system. Then, as the key content of the paper, considering the service selection strategy based on constraint, the paper presents a new service selection algorithm–SSAC. The simulation results show that SSAC algorithm further decreases the total execution cost and total execution time in comparison with other algorithms.

***Index Terms*—cloud workflow system; service selection strategy based on constraint; SSAC**

I. INTRODUCTION

The workflow system originated from office automation which occurred in 1970s in order to support the office automatic system for accomplishing some simple business tasks[1]. In recent years, the workflow system has became more adjusted to the process automation of those large scale business and applications of science. It is many workflow systems that have been deployed on high-performance network computing infrastructures such as cluster, P2P and grid computing [2, 3, 4]. The main driving power of using workflow system is the increasing demand of large scale workflow applications which are popular in both e-commerce and e-science application areas. There are so many representative examples included in it such as the instance intensive securities exchange process in a futures market, the ticket booking process in a airfield agency and the data and computation intensive seti@home (search for extraterrestrial intelligence at home) process in BOINC. These large scale workflow applications normally require the support of powerful high performance computing infrastructures such as super computer, parallel computer, P2P and grid computing.

So as to meet the high-performance requirements of resource, expensive computing infrastructures including such as supercomputers, high-performance clusters and high speed Internet access are purchased, installed and maintained by system administrators. Nevertheless, the problems of resource extendibility and flexibility still exist in the classical computing paradigm. Since in a polyphase way most of the resources are independent and organized, resource extendibility is always very low. As a result of such a problem, it incurs much more cost to recruit external resources to address resource insufficiency during the prime time. And at the same time, since in current computing paradigms, the workflow

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systems have to maintain their own computing resources other than deliver them to other parties where resource flexibility is very poor. Therefore, most of the computing resources during off-prime time are primarily idle, and then results in the low return on investment and a giant waste of energy consumption [5, 6].

In the last decade, cloud computing has came out into view as the latest distributed computing paradigm and attracts increasing interests of researchers in the area of Distributed and Parallel Computing [7], Service Oriented Computing [8] and Software Engineering [9]. Since proposed by Ian Foster[10] and shared by many researchers and practitioners, compared to classical computing paradigms, cloud computing can provide "a pool of abstracted, virtualized, dynamically-scalable, managed computing power, storage, platforms, and services are delivered on demand to external customers over the Internet"[11]. As a consequence, cloud computing can provide much more scalable resources which fully meet the system requirements. In the meantime, cloud computing adopts market-oriented business model in which system users are charged according to the usage of cloud services such as computing, storage and network services like traditional utilities in everyday life [12]. Obviously, it is possible to utilize cloud computing to address the problems of resource extendibility and flexibility for managing large scale workflow systems. Thus, the investigation of workflow systems based on cloud computing which is named by cloud workflow systems is a well-timed issue and worthwhile for increasing efforts.

In this paper, we present a summary design of Service Selection Algorithm Based on Constraint for Cloud Workflow System. We start by discussing architecture of cloud workflow system, compared to traditional cloud architecture. Next, We present a study on the service selection strategy based on constraint. Finally, we presents the algorithm SSAC. Simulative experiments show its performance improvement compared to other algorithm. Part Ⅲ and Part Ⅳ is the paper key content.

II. Cloud Workflow System Architecture

A. Cloud Architecture

With respect to cloud software architecture, there is not a unanimous concept as for now. However, compared to the classical five-layer architecture of the grid, Ian Foster presented a representative four-layer architecture for cloud computing which has been accepted by many researchers and practitioners (see Figure 1) [10].

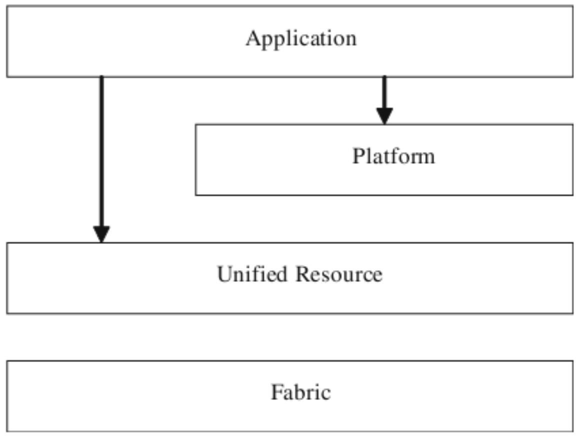

Figure 1. Cloud software architecture.

At the bottom layer of the architecture, the fabric layer is consisted of all kinds of raw hardware resources, such as CPU units, large memory space and high speed network interface. Just like grid computing, most of resources are heterogenous at this layer.

The unified resource layer is consisted of all kinds of heterogeneous resources which are usually in the form of virtualized resources. The physical machines have been abstracted usually by virtualization tools in this layer so that they can be exposed to upper player and those end users as integrated resources.

The platform layer is consisted of a set of resource management tools and middleware services in which is on the top of the unified resources. This layer could provide a development or deployment platform.

And last, at the top layer of the architecture, the application layer is consisted of all kinds of the user applications which can be any kind of applications.

B. Cloud Workflow System Architecture

Compared to the cloud software architecture of Ian Foster, we will propose a general architecture of the cloud workflow system. Obviously, the architecture of the cloud workflow system should be consistent to the general cloud software architecture. Thus, the general cloud workflow architecture can be a part mapping of Ian Foster's four-layer architecture (see Figure 2).

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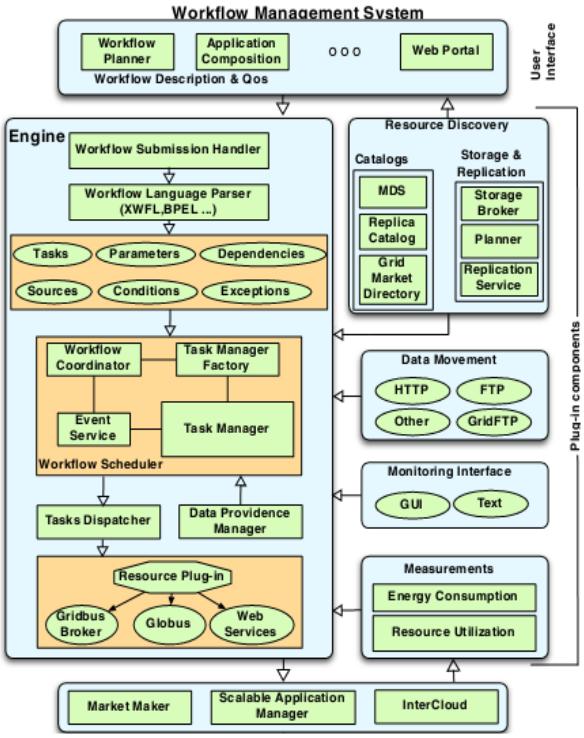

Figure 2. Architecture of Cloud Workflow Management System

The cloud workflow management system is consisted of components that are responsible for handling tasks, relevant data and resources which takes into account the QoS requirements of users[13]. From the figure above, this architecture is consisted of three parts: the user interface layer, the core layer and the plug-ins layer. The user interface is the end users access which allows those end users to work with workflow composition, workflow execution planning, submission and monitoring. Therefore, the end users can define the properties of tasks and link them together which are based on their data dependencies.

The components of the core layer are responsible for managing the execution of the workflows. They promote the translation of descriptions of high level workflow which are defined at the user-interface using XML to the tasks and the data objects[14]. Thus, these objects are used only by the workflow execution subsystem.

The Plug-ins support the executions of workflow on a different environment and platform. This part is the most import part in the architecture. From the figure above, this part is consisted of five parts: engine, resource discovery, data movement, monitoring interface and measurements. At this layer, the system has plug-ins aiming to query task and data characteristics, transfer data to the resources of system, monitor the execution status of the tasks and the systems and measure consumption of the energy.

At the bottom layer of the architecture, the resources are and include Clusters, Grids and Clouds. The workflow management system has plug-in components for interacting with distinct resource management systems propose at the front end of distributed resources. [15].

III. SERVICE SELECTION STRATEGY BASED ON CONSTRAINT

With the development of the cloud and related technology, more and more persons and enterprises start to implement their business process by using some resources, which belong to other organizations. Owning to its complexness, the traditional approach that user still need to essentially compose detailed workflow descriptions by hand can't satisfy the requirements the cloud application in reality. So cloud workflow, which based on the traditional workflow technology, is put forward amid to automating the business process in cloud environment. Considering the advantage such as loose coupling, quick response and etc, which can be achieved by adopting Service-Oriented Computing paradigm, we utilize the service to refer to the activity in workflow and take the service selection problem as our main research content.

A. *Non-Functional Property of Service*

In many researches' opinion, software non-functional property is often called the service quality. In view of content from the scope, the quality of service can be divided into two kinds: broad sense and narrow sense. Service quality of narrow sense is mainly referred to the software performance, such as the execution time, reliability, etc. It is a software implementation process which is showed some of the characteristics which is often related to specific operating environment .While Service quality of broad sense contains a very wide range of content, that is, in addition to software performance, which still includes software provider information, software version, operation environmental restrictions on conditions etc. And it includes function outside attributes related to all other and service related properties. In the rest of the paper, we will adopt Service quality of broad sense and regard the same meaning as non-functional property.

B. *Concept of NFP Constraint*

Service choice, is essentially a matching search process between service demand description given by users and service characteristics description given by provider. Thus, service choice will mainly involves three aspects: service requirement description, service characteristic description and matching search process

Service requirement description meets the user's standard is in the selection process of candidate service. And it is directly provide by the users. In order to improve the accuracy of service choice, the description of service requires usually clear and overall. Only clear description can effectively reduce the candidate set and eliminate services which do not comply with the requirements. Only overall description can accurately react the user's demand and improve the selection accuracy.

Service characteristic description is those object in the process of service choice evaluation which is provided by the service providers. From non-technical perspective, the most important requirement to service characteristics

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describe is objective. Objective not only requires the service providers offer characteristics of service according to the facts, but also requires this description which can comprehensively represent all aspects of performance and can not deliberately hide some important information such as change of the service performance caused by some special operation environment.

Matching search process is the main part to realize service choice. The core content of process is a specific matching algorithm, whose complexity depends on the difference between service requirement description and service characteristics description. This difference can be expressed in many ways, such as description grammar, semantic, content, granularity and so on. To guarantee Precision Ration and Recall Ration, for the same sample space, the greater the difference is, the more difficult we Realize it, and vice versa.

Definition 1: provider

Set $P=\{p_1,p_2,\ldots,p_n\}$.P is a group of finite, non-empty provider set. One of the providers can be expressed as a triple :p_i=(I, qf, s). Thereinto,

--I is a set of all operation interfaces which are implemented by provider. And through this part we can describe the function property of the providers .

--qf is the description of the characteristics of Non-Functional Property.

--s is a concrete services Implementation. And it can be expressed as a URI.

Definition 2: requester

Set $R=\{r_1,r_2,\ldots,r_n\}$. R is a group of finite, non-empty requester set. One of the requesters can be expressed as a 2-tuple: r_i=(I, qr). Thereinto,

--I is a set of all operation interfaces which are implemented by requester. And through this part we can describe the users' request of service functional property.

--qr is described as all constraint of non-functional property to users.

According to the definition above, the process of service selection can be expressed as:

To a workflow wf ,$\forall r\in R(wf)$ and $\forall p\in P$, Services selection process can be described as the way to finding set P_1: $P_1\subset P$, $\forall p\in P$ there is Match_Fun(r,p)=true and Match_NFP(qf,qr)=true. Thereinto, Match_Fun() is a functional property matching function and NFP() is a non-functional property.

As to Match_Fun(), it can be implemented by comprison to interface between p and r. At present a lot of researches on service discovery are based on this , including all kinds of matching algorithms from the view of semantic or grammar. As to NFP(),there are two input parameters qf and qr, each of which seperately represents description of non-functional property for providers and requesters. Only after solving the concrete form, each representing semantic and function evaluation standard of these two input parameters, it will be possible to design a corresponding algorithm to realize the function which must be completed.

C. Model of Non-Functional Property

In order to establish a public description model for Non-Functional Property, we can provide a platform between the users demands and providers. It not only makes providers fully expressed the performance of the services, but also can describe users' own personalized demand, so as to realize the matching comparison of services.

According to descriptions above, we build a Model of non-functional property(see Figure 3).Each non-functional property consist of two parts: NFP Entity and Entity Relationship.

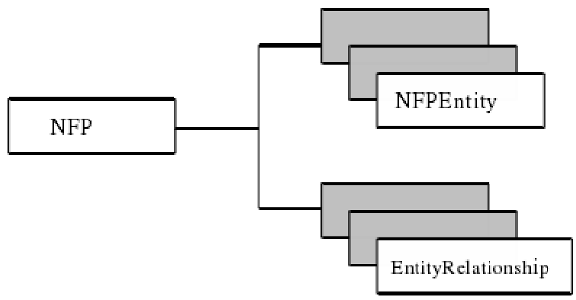

Figure 3. Structure of Non-Functional Property

Thereinto, NFP Entity presents some constraints of a specific subitem under non-functional property. Each description of NFP Entity consists of only one NFP Entity.

Entity Relationship presents relationships between each internal Property of a single service. Each expression of Entity Relationship consists of two or more than two non-functional properties.

In order to enhance the ability and flexibility of non-functional property, we increase Entity Relationship in the service of non-functional property. As stated above, the service of each NFP subitem are not simply isolated exist, but influenced each other. In order to meet the needs of more users, to the same function of the service, providers often provide combination of different non-functional properties to meet different users. Thus it is objective for various NFP subitems to be mutually influenced each other.

Definition 3: NFP Model

To a service s, whose non-functional property $q\in Q$. And Q is a descriptions of NFP set, which can be expressed as a triple: q(s)=(Entities, Relationship, Onto) . Thereinto,

-- Entities are a set of all descriptions of each NFP. Entities=$\varnothing$ or $\{entity_1, entity_2, \ldots, entity_n\}$. $entity_i$ is the expression of NFP. When Entities is a null set, it means that users do not describe a single NFP.

-- Relationship is a set of relation of each NFP . Relationship =$\varnothing$ or $\{rlt_1, rlt_2, \ldots, rlt_n\}$. When Relationship is a null set, it means that users do not describe the relation of NFP.

-- Onto is a ontology set adopted by the expression. If only described from the point of view of grammar, it is a null value.

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Specific, for each subitem description of NFP, the paper will divided it into five parts(see Figure 4).

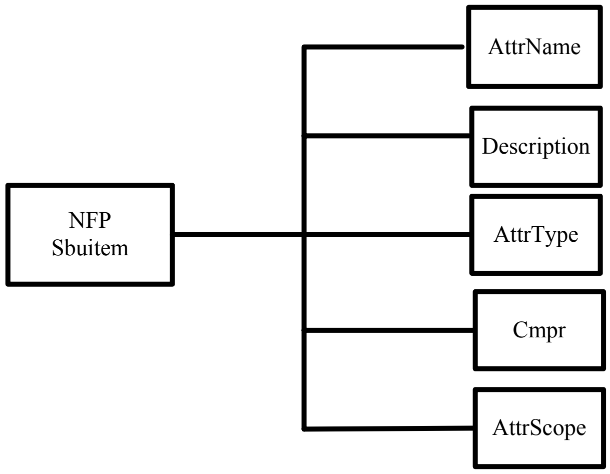

Figure 4. Model of NFP Subitem

Using formalized method, it can be defined as:

To ∀ entity ∈Entities, entity can be expressed as a quintuple (AttrName, Description, AttrType, Cmpr, AttrScope)

AttrName is the name of NFP Subitem, including reliability, execution cost, execution time, etc. And its value is usually string.

Description is the text description of NFP Subitem. Its main function is to provide a visual description for convenient understanding

AttrType is the value type of NFP Subitem. The value types of NFP can be divided into numeric and non numerice. The numeric data mean that the property values can be carried on by quantification analysis, that is,which can be expressed by specific number such as Reliability, Throughput, time, etc. The property of non numeric data can only be carried by qualitative analysis, that is, which can not be expressed by specific number.

Cmpr is comparison operator between value of the property and AttrScope. It limited value scope of items with AttrScope. To numeric data, Cmpr are some common mathematical operator such as "=","<",">". To non numeric data, Cmpr are Set operators and some ways of user-defined .

AttrScope is the value area of the property. To non numeric data, AttrScope is a set of enumeration types . To numeric data, AttrScope is the expression of const data.

D. Users' Constraint of Service NFP

In the service template, the users not only define the required service function properties, but also define the constraint conditions of the function attributes, we will describe the constraint conditions according to the structure of NFP showed in figure 3.

In cloud workflow, the constraints of NFP can be divided into two types: the constraint of a single service and the constraint of more services. The constraint of a single service means that the users gives all kinds of limited conditions according to each NFP in process when making abstract workflow. The conditions include providers, security level and throughput.etc. This kind of conditions usually constraint individual service by an explicit way. The system a will bind to specific services according to the service selection strategy. The constraint of more services have a close relation with the business services which do not exist in isolation. An NFP service often affects the choice of other NFP services.

In addition, the basic model is set for the description of individual service, while the user's constraint condition is aimed at a candidate service set meeting the conditions. In the set, from the point of view of a single property, two completely opposite value services may also meet the requirements of the users. Thus such a single service description is difficult to reasonably describe the user's constraints. So, we must use the model to express the common characteristics of service candidate sets.

Based on the analysis of the constraint conditions in the face of the users, we expand NFP Model(Definition 3) as follow.

Definition 4: SQR

To ∀ r ∈R, the constraint of a single service can be expressed as SQR(r)={sqr_1, sqr_2,…, sqr_n}, each sqr_i={sqc_i, type}. Thereinto,

--sqc_i,⊂ Entities, sqc_i⊂Relationship. If sqc_i=={$entity_{i1}$, $entity_{i2}$…, $entity_{in}$},then each AttrName value of the $entity_{ij}$ should be equal. If sqc_i=={rlt_{i1}, rlt_{i2}…, rlt_{in}}, then each AttrName value of the rlt_{ij} should be equal in number and value.

--∀ sqr_i ∈SQR(r), if i≠j, then two AttrNames in sqr_i and sqr_j are not completely equivalent.

--type∈{obliged, recommend}, If the type equals "obliged", then the constraint means obliged type. If the type equals "recommend", then the constraint means non-obliged type. Thereinto, recommend∈{max min,average,…}

From the definition above, we can see that if we restrict a certain value scope of the service NFP in the service templates, then all the constrain conditions can be expressed only by a piece of sqr_i. And if we restrict the some certain value scopes of the service NFP in the service templates, then all the constrain conditions can be expressed only by a piece of rlt_i. That is, we can connect all constraints of the same properties into one constraint. By this means, the set is expressed by the models.

Definition 5: MQR

To the process wf, the constraints of multiple services can be expressed as MQR(wf)={mqr_1, mqr_2,…, mqr_n}, each mqr_i={mqc_i, type}. Thereinto,

-- mqc_i ∈MSRelationship, MSRelationship={ $msrlt_1$, $msrlt_2$,…, $msrlt_n$ }

--∀ mqc_i, mqc_j∈MSRelationship, if i≠j, then two AttrNames in mqc_i and mqc_j are not completely equivalent.

--type∈{obliged, recommend}, If the type equals "obliged", then the constraint means obliged type. If the type equals "recommend", then the constraint means non-obliged type. Thereinto, recommend∈{max min,average,…}

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Defining $msrlt_i$ by reference definition of RLT above. We just annotate the name of the service from all properties. In order to narrate concisely, we no longer give a concrete form. In the meantime, we define that each mqr_i will involves in two or more different service templates in the process..

IV. Matching Algorithm Based On Constraint

In this part, we will discuss how to construct the function Match_NFP( ),that is, how to find the candidate service matching the user's request according to the service templates above and the descriptions of each candidate services NFP. Through the analysis of NFP requirements of the service templates, we realize that qr is consist of two parts: SQR(r) the constraint of a single service and MQR(wf), the constraints of multiple services. Thus, according to the characteristic, we will implement it by two-level matching.

The meaning of two-level matching is that firstly, we handle the candidate service sets according to SQR(r), and then eliminate all the services not conforming to the requirements. Thus we get the sets preliminary meeting the requirements. Secondly, we further handle the candidate services sets according to MQR(wf),and finally get the services meeting the requirements. An advantage adopting two-level matching is that it can effectively reduce the computational complexity of the matching algorithm. This is because that the process of MQR (wf) is relatively complicated and the computational complexity greatly depends on the size of the candidate service sets. While in the first step, we can greatly reduce the size of candidate services according to SQR(r).Meanwhile, all constraint relationships are divided into "obliged" and "non-obliged". So we will handle those "obliged" constraints first.

A. Description of The Algorithm

In order to implement the matching algorithm of service selection, We Formulate the corresponding processing priority level according to the different constraint types. That is, "obliged" and SQR>"obliged", MQR>"non-obliged",MQR>"non-obliged" and SQR. Obviously, in the selection of service process, the constraints of "obliged" type must be satisfied. If none of the candidate services could correspond to all constraints of "obliged" type, it return failure choice information. At the same time because of effect on the complexity of MOR composed of the constraint processing services resulting from the size of the candidate services, it is a important way to reduce the complexity of the whole algorithm that handling SQR first. To the constraints of "non-obliged" type, we adopt strategy of "First whole, then local" and give priority to the constraints of MQR.

According to this principle, we present Service Selection Algorithm Based on Constraint for Cloud Workflow System (SSACF for CWF). The algorithm generally describes the implementing steps and details of relevant functions.

The procedures of the proposed SSAC are detailed as follows.

Known conditions:

Service template set: R={SQR(r_1), SQR(r_2),…, SQR(r_n)}

Constraint of MQR: MQR(wf)

Procedural model:wf

Candidate Set: P={{qf_{11}, qf_{12},…, qf_{1i}},{qf_{21}, qf_{22},…, qf_{2j}},…, {qf_{n1}, qf_{n2},…, qf_{nk}}

Execute and return:

Service candidate set P_Result

Algorithm detail:

```
1.initialize P_Result, set each set corresponding to
  presult_i is a null set
2. for (I=1,I<=n, I++)
3. {
4.     for(j=1,j<=count(p_i),j++)
4.     {
6.         p_ij=ApplyRlue(qf_ij, condition)
7.         If  IsSatisfy(SQR(r_i),p_ij)=true)
8.             presult_i=Add(presult_i, p_ij)
9.     }
10         if (presult_i=∅) exit, and return the first
                      service failure information
11 }
12 P_Result=Plan(MQR(wf), P_Result)
13 P_Result=Procal_Compare(P_Resul,wf)
14 P_Result= Optimize(MQR(wf), P_Result)
15 P_Result= Optimize(SQR(r), P_Result)
```

In this algorithm, we first handle the dynamics of each candidate service. In line 6, the function ApplyRule( ) determines the specific value of service NFP according to the rules and the corresponding external condition. And this function is usually provided by the service providers. In line 7 and line 8,the algorithm judge if candidate services meet compulsive SQR of "obliged" type defined by users and then add the services meeting the requirements to the the corresponding candidate sets. If there is no candidate service which can satisfy the constraint conditions, the algorithm return the first service failure information. In line 12, the algorithm uses the constraints of SQR of "obliged" type to a further filter to the candidate sets. In line 13, the algorithm takes into consideration the compatibility of candidate services. In line 14 and line 15, the algorithm optimizes the candidate services by constraints of "non-obliged" type. Because of the length of the paper, the process of Plan and Optimize is not present in detail.

B. Simulation and Performance Evaluation

For assurance of such characteristics in cloud systems under development, it is required timely, repeatable, and controllable methodologies for evaluation of new cloud applications and policies before actual development of cloud products. Because utilization of real testbeds limits the experiments to the scale of the testbed and makes the reproduction of results an extremely difficult undertaking, simulation may be used[16].

In order to assess the performance of the algorithm, we use CloudSim to simulate and evaluate. Cloudsim is a typical framework aiming to modeling and simulation of Cloud Computing Infrastructures and Services[17]. The toolkit of CloudSim can support both system and behavior

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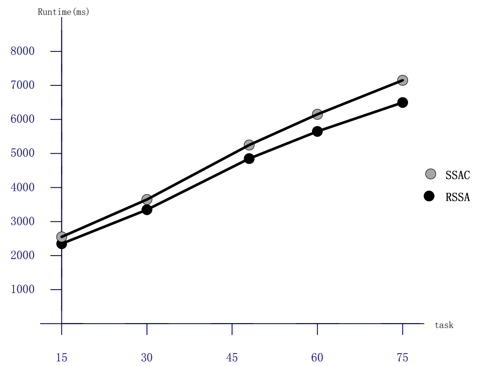
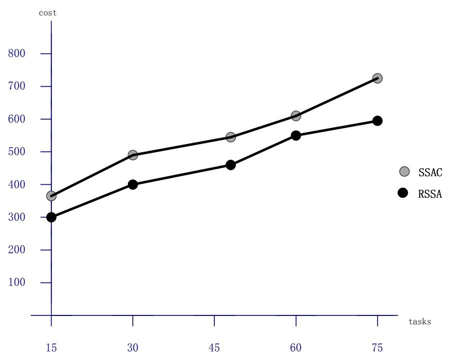
modeling of the components of Cloud system such as data centers, virtual machines and resource provisioning policies. Thus, it can implement common application provisioning techniques which could be extended with ease and limited effort[18]. Generally, it supports modeling and simulation of Cloud computing environments which consists of both single and inter-networked clouds

In the simulation, we compare SSAC to random service selection algorithm in cloudsim(RSSA) in runtime and cost. We separately set up the number of tasks are:15,30,45,60,75 and created eight virtual machines. In comparing to runtime, we respectively operate five different experiment tasks and each task are operate five times. Each experiment result of application is all it's average of the instances.

Figure 5 shows runtime and cost comparison of two different algorithms with different tasks and virtual machines.



a) The comparison of Runtime



b) The comparison of Cost

Figure 5 The comparison of Runtime and Cost

From the figure above, we can draw the conclusion that comparing to RSSA,SAAC has an advantage on runtime and cost. When the number of tasks is small, the advantage is faint. But With the increasing of the number of tasks, the advantage becomes more and more obvious.

V. Conclusion

The technology and application of workflows in cloud computing environment becomes a research focus. In this paper, we have presented the architecture of cloud workflow system. We discussed the characteristic of e service selection strategy based on constraint. Finally, as the focus of this paper, we present SSAC which has an advantage on runtime and cost compared to other algorithm.

Acknowledge

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