An Adaptive Cloud Resource Management Scheme of Cloud Broker with a Broker Profit Model

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Abstract

Cloud Broker, presented between user and cloud service provider(CSP) makes an optimal decision in a smart way instead of user with payment for many objectives such as processing of scientific applications in cloud computing. To maximize its profit, the one of the key issues is to reduce the resource leasing cost from CSP, making use of the payment plans of CSP: reserved VM (RVM) which reserve the instance in advance for long-time in a discount price. Making a VM pool with RVM in advanced by predicting the amount of user request in the future, the cloud broker can reduce the resource usage cost and increase the profit. In this paper, to manage the VM pool in this way, we propose the cost adaptive resource allocation with the pricing model for the cloud broker.

1. Introduction

Heavy applications which are often compute-intensive and data-intensive require the huge amount of computing and storage resource to execute. With the appearance of cloud computing, users can take the service of cloud which provides computing and storage resource based on pay-per-usage base to execute their own heavy applications[1]. However, it is difficult for user to decide which and how much cloud service should be leased in order to use the appropriate cloud resource while guaranteeing the certain performance of the applications. Furthermore, there are many different cloud services from different cloud providers and they have different policies for cloud service and charge. In this situation, users will make non-optimal decision based on limited information about cloud services and waste the execution time and cost owing to the inefficient decision. Therefore, third party, called as cloud broker, presented between user and Cloud Service Provider(CSP) is defined to make an optimal decision in a smart way instead of user.

In the cloud broker, it is the key issue to reduce the resource leasing cost from CSP in order to maximize the profit, making use of the payment plans of CSP: reserved VM (RVM) which reserve the instance in advance for long-time in a discount price. Making a VM pool with RVM in advanced by predicting the amount of requests in the future, the cloud broker can reduce the resource usage cost and increase the profit by allocating the available RVM in the VM pool instead of OVM In this paper, to manage the VM pool in this way, we propose the cost adaptive resource allocation with the pricing model for the cloud broker.

2. A Cost Adaptive Cloud Broker Model

The object of cloud broker is to maximize a profit while satisfying user's SLA as a wholesaler between users and cloud resource providers. Users only pay the cloud broker for their application processing with their own SLA. In our model, the cloud broker focuses on scientific applications.

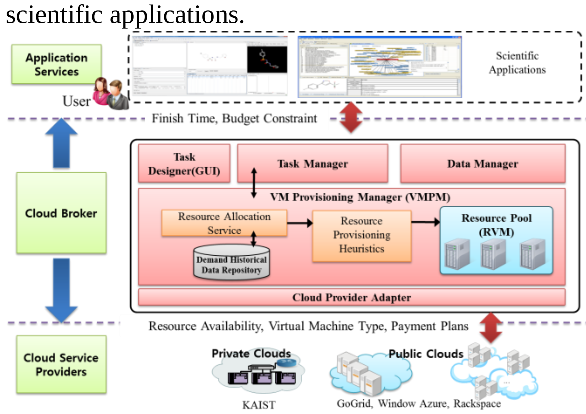

Fig. 1. An Example of Cloud Broker with Cost Adaptive Management

The scientific application is composed of the set of tasks. Each task is allocated to their appropriate VM instances and executed in order of their starting time based on SLA constraints such as deadline *D*. Each task has different performance on different types of VM instances. The scientific application can be represented as a tuple $A(T, D)$ where T is the finite set of tasks $t_i(i \in \{1,2,\dots,n\}, n = number\ of\ tasks)$. We assume that we can estimate the completion time of each task of A, then we can obtain the optimal resource management policy in the cloud broker for multiple scientific application requests which satisfies the following objective function.

$$Maximize\ Pr[\mu] = \sum_{i \in I} c_{sale}(\mu) \cdot \bar{r}(A_i) - c_{expend} \sum_{i \in I} r(A_i)$$
$$Subject\ to\ ECT[A_i] \leq D_i, \forall i \quad (ECT[A_i] = max_{\forall t_{i,j} \in A_i}\{eft[t_{i,j}]\}) \tag{1}$$

Where $Pr[\mu]$ is a profit function of the cloud broker and μ is a strategy for determining a sales price of cloud broker service c_{sale}. c_{expend} $(c_{sale} \geq c_{expend})$ is an expenditure for processing scientific application. $\bar{r}$ is an expected resource requirement for the scientific application request A_i and r is an actual resource requirement based on the cloud broker's VM pool for the request. ECT is an estimated completion time of the request and eft is an estimated finishing time of individual task. $t_{i,j}$ is a j^{th} task of A_i.

CSP provides the several types of cloud resource service such as small, medium, large. Each type of VM are charged for usage in proportion to their capacity with Billing Time Unit (BTU) which is the base time unit to charge for resource usage time, usually one-hour(i.e. Partial-BTU resource usage time is rounded up to one BTU). A VM type is represented as $VT_i = \{VT_{c_i}, VT_{m_i}, VT_{s_i}\}$, $i \in \{1,2,\ldots,K\}$: *number of VCPU (#)* VT_{c_i} *,memory size (GBs)* VT_{m_i}*, storage space (GBs)* VT_{s_i}. CSP provides payment plans: reserved VM (RVM) plans [2]. In RVM plan, VM instance is leased for long BTU (e.g., monthly or yearly) with low price.

In this our model, the cloud broker is described in Fig 1. The cloud broker receives the scientific application request through task designer in Graphic user interface. Task manager schedules the resource plan on each task of the requested application and executes all tasks with VM Provisioning Management Scheme (VMPM). VMPM provides the VM instance from CSP for the task manager.

In this situation, the cloud broker can maintain the certain number of RVMs in its own VM pool through VMPM. To do this, the key issue is to decide how many and how long RVMs should be leased in VM pool. To resolve this issue, we propose the cost adaptive resource allocation scheme described in detail in section 3. Before explaining this scheme, the proper price of service sales c_{sale} in Eq. (1) should be decided to maximize the profit of the cloud broker. We use the exponential cost function model which is reasonable to users. The cost for i-type VM instance is between the maximum cost C_i^{max} and C_i^{min} and determined depending on the number of available RVMs at each period.

Exponential cost function The current price is increased exponentially when the number of available RVMs is decreased until the price reaches to the maximum cost as follows,

$$C_{exp,i}(R_i(\tau)) = \begin{cases} C_i^{min} & R_i(\tau) = N_i(\tau) \\ C_i^{max} \cdot exp\left\{\frac{1}{N_i(\tau)} ln\left\{\frac{C_i^{min}}{C_i^{max}}\right\} R_i(\tau)\right\} & 0 < R_i(\tau) < N_i \\ C_i^{max} & R_i(\tau) = 0 \end{cases} \tag{2}$$

$R_i(\tau)$ is the number of i-type available RVM instances in VM pool at time τ. $N_i(\tau)$ is the number of i-type leased RVM instances in VM pool from cloud resource provider at time τ.

3. A Cost Adaptive Cloud Resource Allocation Scheme, VMPM

The cost adaptive cloud resource allocation scheme provided by VMPM is shown in Algorithm 1. This scheme determines the proper amount of leasing RVMs from CSP for reducing the cost in the heuristic way. Basically, the scheme works in the period of time interval T. The amount of provisioned RVMs is dependent on the density of the arrival requests and each resource usage duration. The historical data of all the executed tasks including their allocated VM types during the previous time interval T' is inputted for this scheme. We assume that the request pattern in the current time interval T will be same with the one in T'. Eventually, we can derive the proper amount of i-type RVM, N_i for T by using this scheme.

From line 01 to 05 in Algorithm 1, we first do clustering each task in A according to their allocated VM instance type VT_i. Consequently, all the tasks in A are classified into several clusters Cl_{VT_i}. From line 06 to 18, for each cluster Cl_{VT_i}, we make groups g_m which have a batch of non-overlapped tasks. Firstly, after the tasks of Cl_{VT_i} are sorted in order of their starting time, each task of Cl_{VT_i} is checked in order and picked into g_m if its start time st is later than the finish time ft of last task in the group g_m. This procedure is repeated until we cannot find the available task in Cl_{VT_i} more. From line 19 to 24, by using group completion time of g_m, $gct(g_m)$ and allocated VM instance type of g_m, $VT(g_m)$, we obtain a RVM leasing time $RVM_{VT(g_m),gct(g_m)}$ represented as the BTU by finding the BTU size closest to the $gct(g_m)$.

TABLE I. AN STRUCTURAL PSEUDO CODE FOR VM POOL MANAGEMENT SCHEME

INPUT: *historical data including* $A = \{\forall t_{i,j}\}$ *and* $\forall VT(t_{i,j})$ *during previous time interval* T'
OUTPUT : N_i *during current time interval* T

For $VT_i, \forall\, i \in \{1,2,\dots,K\}$.
  For $\forall t \in S$
    $Cl_{VT_i} = Cl_{VT_i} \cup \leftarrow t \in S \; if \; VT(t) = VT_i$
  End for
End for
$m = 0$
For $Cl_{VT_i}\; \forall\, i \in \{1,2,\dots,K\}$.
  sort $tasks$ in Cl_{VT_i} in order of their starting time
  While available $tasks$ exists in Cl_{VT_i} **do**
    For $\forall t' \in Cl_{VT_i}$
      If $st(t') \geq ft(t''), t'' = last\ task$ in g_m
        $g_m = g_m \cup t'$
      End If
    End For
    remove tasks in g_m from Cl_{VT_i}
    $m = m + 1$
  End while
End for
For $\forall g_m$
  $gct(g_m) = ft(g_m) - st(g_m)$
  If $\frac{C(RVM_{VT(g_m),gct(g_m)})}{\sum_{\forall t \in g_m} et(t) \cdot C(OVM_{VT(t)})} < 1$ **then**
  lease $RVM_{VT(g_m),gct(g_m)}$ from cloud resource provider
  End if
End for

We check the following condition to choose whether to lease $RVM_{VT(g_m),gct(g_m)}$ from cloud resource provider or not.

$$\frac{C(RVM_{VT(g_m),gct(g_m)})}{\sum_{\forall t \in g_m} et(t) \cdot C(OVM_{VT(t)})} < 1 \qquad (3)$$

The denominator of Eq. (3) represents the total cost on OVMs for the tasks having execution time et in g_m. The numerator of Eq. (3) represents the cost of RVM for g_m. If Eq. (3) is satisfied, it means that the leasing of RVM is more efficient on cost than the leasing of OVMs for g_m. As the value of Eq. (3) is decreased, the cost efficiency by leasing RVM is increased.

4. Test Environments and Performance Evaluation

To evaluate the performance of the proposed VMPM scheme, we built the test environment with cloud platforms as shown in Fig. 2 with the specific configuration on testbed platform shown in Table 2. We organize the cloud platforms with the configuration of 5 computing nodes on the OpenStack and 4 computing nodes on the CloudStack respectively [3,4] to consider the diversity of resource composition on physical cloud service environment.

We defined relative cost for evaluating the proposing scheme on cost efficiency in private cloud. The definition of relative cost in the i^{th} service contract is described as Eq. (4) when c_u^i is unit time cost and t_u^i *is* resource leasing time.

Unlike the billing contract with hourly policy on real cloud service domain, we assign unit time as a second for OVM and a week for RVM. When the weight vector $\vec{w} = [w_c, w_m]$ is applied for the effectiveness of each element respectively, the unit time cost on resource contract, c_{ur}^i is calculated as Eq. (5). Also, the weight vector for RVM is applied to half of OVM's with the reference of price policies announced on cloud service provider GoGrid (on annual case) [5].

$$RC^i = c_u^i \cdot t_u^i \qquad (4)$$
$$c_{ur}^i = w_c \cdot r_c^i + w_m \cdot r_m^i \qquad (5)$$

For the evaluation, we built a science gateway, which is a solution that is the common interface for solving complicated scientific problems by orchestrating geographically distributed resources, especially for workflow typed scientific applications in this paper. The request from the user is analyzed through workflow engine – act as both application service provider and computing resource demander. Obviously, to process the task, the workflow scheduler demands cloud resources to resource provisioning manager. We adapted a phased workflow scheduling scheme with division policy [6] as scheduler. Also, we orchestrated Next Generation Sequencing (NGS) with Burrows-Wheeler Aligner (BWA) as a scientific application [7]. The NGS is used for the determination of the order on the nucleotide bases in DNA molecules and is used for the analysis of biological phenomena from the relation

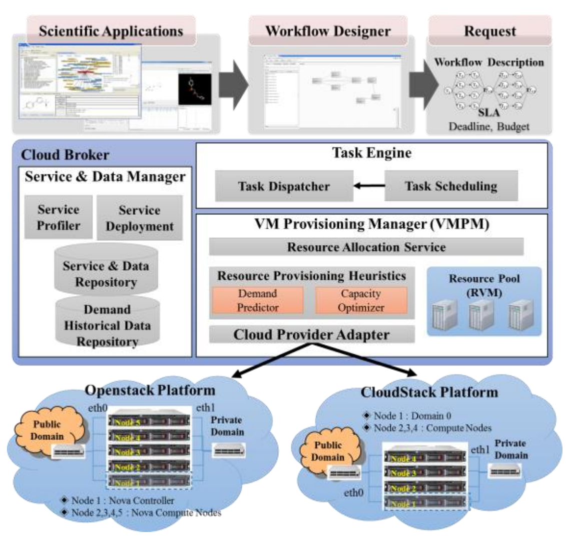

FIG. 2. AN EXPERIMENTAL TESTBED FOR COST ADAPTIVE RESOURCE POOL MANAGEMENT SCHEME

TABLE II. SPECIFIC CONFIGURATIONS ON TESTBED ENVIRONMENT

		OpenStack Platform	CloudStack Platform
Hypervisor		KVM	XEN
H/W Specification		Intel Xeon E5620 2.40GHz, Core 16, MEM 16G, HDD 1T, 5 Node	Intel Core i7-3770 CPU 3.40GHz, Core 8, MEM 16G, HDD 1T, 4 Node
S/W Specification		OS: Ubuntu 14.04	OS: CentOS 6.0
VM Types	**small**	Spec: 1 VCPU, 2 GB MEM, 80GB Disk On-demand VM Unit Time Cost: 2 RC per second Reserved VM Unit Time Cost: 1,209,600 RC per week	
	medium	Spec: 2 VCPU, 4 GB MEM, 80GB Disk On-demand VM Unit Time Cost: 4 RC per second Reserved VM Unit Time Cost: 2,419,200 RC per week	
	large	Spec: 4 VCPU, 8 GB MEM, 80GB Disk On-demand VM Unit Time Cost: 8 RC per second Reserved VM Unit Time Cost: 4,838,400 RC per week	
	c4.small	Spec: 4 VCPU, 1 GB MEM, 80GB Disk Unit Time Cost: 4 RC per second Reserved VM Unit Time Cost: 2,419,200 RC per week	
	m8.small	Spec: 1 VCPU, 8 GB MEM, 80GB Disk Unit Time Cost: 4 RC per second Reserved VM Unit Time Cost: 2,419,200 RC per week	

between genotype and phenotype.

In the experiments, we measured relative cost on VM leasing cost (OVM leasing + RVM leasing) among case without resource pool management, resource pool management schemes with static number of RVM (1, 2 respectively) and proposing VMPM scheme with different average interarrival time of workflow request in exponential distribution and with scale downed 4 weeks of experiments. As shown in Fig. 3, the measured VM leasing cost is represented in log scale for the better comparison. We can figure out the over-provisioning on static pool management for low workload. On the other hand, static pool management shows better performance for high workflow. Also, figure shows different enhancement aspects (e.g. best point, enhencement ratio) on the number of RVM. It means that ability of adaptive RVM leasing management with the variation of workload is essential for cloud resource pool management. In addition, our proposing VMPM scheme shows good adaptivity and cost efficiency for all environment case. With the reference of profit model on cloud service broker in Eq. (1), we can maximize the profit thgough the decline of VM leasing expendature cost, using proposing VMPM scheme.

5. Conclusion

In this paper, to maximize the profit of cloud broker, we propose the cost adaptive resource allocation with the pricing model to manage the Reserved VM pool. Experiment shows the proposed scheme reduce the expenditure of leasing VM instances and increase the profit of cloud broker and also shows the good performance for different enhancement aspects (e.g. best point, enhencement ratio) on the number of RVM compared to the static pool management. In addition, our proposing VMPM scheme shows good adaptivity and cost efficiency for all environment case.

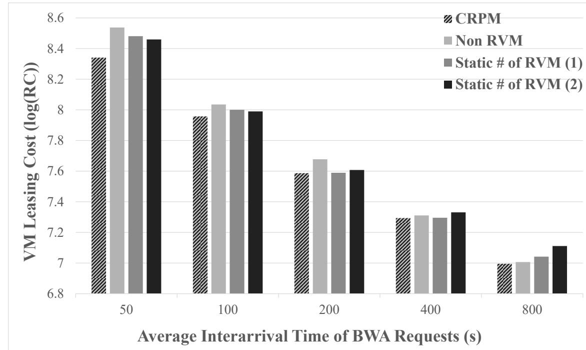

Fig. 3. Performance comparison of cloud resource pool management schemes. VM leasing cost (relative cost) is measured in log scale among proposing cost adaptive cloud resource pool management scheme (VMPM), case without pool management and scheme with static number of RVM pool management (#1, #2), while increasing the average interarrival time in log scale from 50 sec to 800 sec.

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