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Virtual machine consolidation enhancement using hybrid regression algorithms

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ABSTRACT

Cloud computing data centers are growing rapidly in both number and capacity to meet the increasing demands for highly-responsive computing and massive storage. Such data centers consume enormous amounts of electrical energy resulting in high operating costs and carbon dioxide emissions. The reason for this extremely high energy consumption is not just the quantity of computing resources and the power inefficiency of hardware, but rather lies in the inefficient usage of these resources. VM consolidation involves live migration of VMs hence the capability of transferring a VM between physical servers with a close to zero down time. It is an effective way to improve the utilization of resources and increase energy efficiency in cloud data centers. VM consolidation consists of host overload/underload detection, VM selection and VM placement. Most of the current VM consolidation approaches apply either heuristic-based techniques, such as static utilization thresholds, decision-making based on statistical analysis of historical data; or simply periodic adaptation of the VM allocation. Most of those algorithms rely on CPU utilization only for host overload detection. In this paper we propose using hybrid factors to enhance VM consolidation. Specifically we developed a multiple regression algorithm that uses CPU utilization, memory utilization and bandwidth utilization for host overload detection. The proposed algorithm, Multiple Regression Host Overload Detection (MRHOD), significantly reduces energy consumption while ensuring a high level of adherence to Service Level Agreements (SLA) since it gives a real indication of host utilization based on three parameters (CPU, Memory, Bandwidth) utilizations instead of one parameter only (CPU utilization). Through simulations we show that our approach reduces power consumption by 6 times compared to single factor algorithms using random workload. Also using PlanetLab workload traces we show that MRHOD improves the ESV metric by about 24% better than other single factor regression algorithms (LR and LRR). Also we developed Hybrid Local Regression Host Overload Detection algorithm (HLRHOD) that is based on local regression using hybrid factors. It outperforms the single factor algorithms.

1. Introduction

Cloud computing can be considered as a computing paradigm with many exciting features like on-demand computing resources, elastic scaling, elimination of up-front capital and operational expenses, and establishing a pay-as-you-go business model for computing and information technology services [1]. Cloud computing data centers consume enormous amounts of electrical energy resulting in high operating costs and carbon dioxide emissions. The reason for high energy consumption is not just the quantity of computing resources and the power inefficiency of hardware, but rather lies in the inefficient usage of these resources. One way to address the energy inefficiency is to leverage the capabilities of the virtualization technology. The reduction in energy consumption can be achieved by switching idle nodes to low-power modes (i.e., sleep, hibernation), thus eliminating the idle power consumption. Moreover, by using live migration the VMs can be dynamically consolidated to the minimal number of physical nodes according to their current resource requirements.

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Most of current researches migrates VMs based on CPU utilization since there is a relationship between the total power consumption by a server and its CPU utilization [2]. Basically their model proposes that power consumption by a server grows linearly with the growth of the CPU utilization. CPU utilization based models are able to provide an accurate prediction for CPU-intensive applications; however they tend to be inaccurate for other types of applications like network, I/O and memory intensive applications [2]. The purpose of this work is:

- Develop Multiple Regression Host Overload Detection algorithm (MRHOD).
- Develop Hybrid Local Regression Host Overload Detection algorithm (HLRHOD).
- Compare different host overload detection algorithms.

The paper is organized as follows: Section 2 explains dynamic virtual machine consolidation. Section 3 presents the virtual machine selection. Section 4 discusses the related work. Section 5 discusses the Multiple Regression Host Overload Detection (MRHOD) algorithm. Section 6 discusses the Hybrid Local Regression Host Overload Detection. Section 7 discusses the evaluation methodology. Section 8 simulation results and analysis. Finally, the conclusion and future work is discussed in Section 9.

2. Dynamic virtual machine consolidation

All Dynamic Virtual Machine (VM) consolidation is a promising approach for reducing energy consumption by dynamically adjusting the number of active machines to match resource demands. To address this problem, most of the current approaches apply Regression based algorithms that is based on estimation of future CPU utilization. The limitation of these approaches is that they lead to sub-optimal results and do not allow the administrator to explicitly set a QoS goal. Comparison between types of Host Overload Detection Algorithms [3] is shown in Table 1.

The static utilization threshold is a simple method since it is based on a fixed CPU utilization threshold but it is unsuitable for dynamic environment. Adaptive utilization based algorithms are suitable for dynamic environment but give poor prediction of host overloading. Regression based algorithms give better predictions of host overloading since they are based on estimation of future CPU utilization but they are complex. Once a host overload is detected, the next step is to select VMs to offload the host to avoid performance degradation. Once a host overload is detected, the next step is to select VMs to offload the host to avoid performance degradation.

3. Virtual machine selection

Once a host overload is detected, the next step is to select VMs to offload the host to avoid performance degradation. After a selection of a VM to migrate, the host is checked again for being overloaded. If it is still considered as being overloaded, the VM selection policy is applied again to select another VM to migrate from the host. This is repeated until the host is considered as being not overloaded. This section presents three policies for VM selection.

3.1. Minimum migration time (MMT)

The Minimum Migration Time policy migrates a VM that requires the minimum time to complete a migration relative to the other VMs allocated to the same host. The migration time is estimated as the amount of RAM utilized by the VM divided by the spare network bandwidth available for the host [6].

3.2. Random choice (RC)

Random choice policy is another simple method to select VMs from overloading hosts. It randomly selects a VM to be migrated from the host according to a uniformly distributed discrete random variable [6]. If it is still overloaded, repeat the step until the host considered being not overloaded.

3.3. Maximum correlation

The idea behind the Maximum Correlation (MC) policy is that the higher the correlation between the resource usages by applications running on an oversubscribed server is the higher the probability of the server overloading will be. According to this idea, we select those VMs to be migrated that have the highest correlation of the CPU utilization with other VMs. To estimate the correlation between CPU utilizations multiple correlation coefficients is applied. It is used in multiple regression analysis to assess the quality of the prediction of the dependent variable. The multiple correlation coefficients correspond to the squared correlation between the predicted and the actual values of the dependent variable [6].

4. Related work

Prior approaches to energy efficient dynamic VM consolidation can be broadly divided into three categories: periodic adaptation of the VM placement (no overload detection), threshold-based heuristics, and decision-making based on statistical analysis of historical data. All categories enjoyed significant attention from the research community, so we focus here only on a certain subset of the most relevant work.

4.1. Periodic adaptation of VM placement

Lots of work has been proposed for energy efficiency and management on cloud data centers. In some approaches, VM consolidation has been formulated as an optimization problem with the objective to find a near optimal solution since an optimization problem is associated with constraints, such as data center capacity and SLA. Farahnakian et al. [8] presented distributed system architecture to perform dynamic VM consolidation to improve

Table 1
Types of host overload detection algorithms.

Type	Static utilization threshold based algorithms	Adaptive utilization based algorithms	Regression based algorithms
Explanation	Based on fixed CPU utilization threshold	Based on statistical analysis of historical data of VM	Based on estimation of future CPU utilization
Pros	Simple	Suitable for dynamic environment (robust)	Better predictions of host overloading
Cons	Unsuitable for dynamic environment	Poor prediction of host overloading	Complex
Examples	THR (Averaging threshold-based algorithm) [4]	MAD (Median Absolute Deviation) [5], IQR (Inter Quartile Range) [6]	LR (Local Regression) [7], LRR (Robust local Regression) [7]

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