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An Aware Technique of Energy-Aware for Task Consolidation in Cloud Computing

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Abstract

Task consolidation can be considered as a strategy to maximize the availability of cloud computing resources, which includes many benefits, including: a. better use of resources; b. resource maintenance in a rational way; c. customization of the IT service (IT), d. Reliable Services, e. QoS (Quality of Service) and etc. However, maximizing the rates of use and utilization of tasks does not mean efficient use of energy. Many studies show that energy consumption and the use of resources in the cloud paradigm are largely interdependent and relevant together. Some studies have attempted to reduce the resource utilization rate in the cloud paradigm to reduce energy consumption, while others have tried to create a balance between resource utilization rates and energy consumption. In this paper, a task consolidation technique with ability of energy-aware task consolidation (ETC) will be presented that its aims is to optimize energy consumption in the virtual cluster placed on the data center. Many cloud systems have shown that 70% of CPU usage is spent on managing task consolidation among virtual clusters. Simulation results show that the ETC technique can significantly reduce energy consumption from managing task consolidation for cloud systems. Using this technique, it is possible to achieve a 17% improvement in energy consumption, compared to a recent study, aimed at maximizing the rate of resource use.

Keywords: Efficient of energy, Energy-Aware, Task Consolidation, Cloud Computing.

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1. Introduction

Cloud computing has been widespread with the advent of complete technologies such as network devices, software applications, and hardware capabilities that can be used for such complex and mass systems. In the cloud paradigm, resources can be distributed in different parts that their scale can range from multiple servers to a data center. Cloud computing requires efficient methods for managing existing machines in order to integrate and use optimally from various sources with different scales [1]. In this way, recent research has focused on how to efficiently use resources and reduce energy consumption.

In this paper, a new technique based on virtual clusters that are used to optimize energy consumption is presented for task consolidation. Both the cost of using the processor and the network transmission are considered in the cloud paradigm for task migration. Considering machines with an idle state or even with a very low workload, energy consumption in this paradigm is still considerable. In contrast, machines that are in high overhead or in high utilization rates may lead to inefficiencies in energy use. According to these observations, the main idea behind the proposed technique is to define an ideal application level (also known as threshold) on virtual machines. When the CPU usage rate in virtual machines is lower than the predefined threshold, the workload within a cluster should be balanced. If the processor usage rate in virtual machines is more than the threshold, then the task should be performed on more suitable resources. In order to distribute tasks to other machines or clusters, the additional energy consumption for task consolidation must be taken into account. If several sources are located inside a data center and are ready to receive tasks, the source that has the least cost (including transfer and task execution) is selected to perform the task consolidation process. In order to evaluate the effectiveness of the proposed method, in the experiments we performed, we analyzed the effect of different workloads and cluster size on the performance of the task consolidation. Experimental results show that our strategy can improve energy consumption. We present the rest of this article to the following format:

In the second section, we will have a brief look at the history and the relevant activities. In the third section, we will take a preliminary look at the cloud computing model and research architecture.

We will propose a method of task consolidation for energy optimization in the fourth section. The results of simulation and performance analysis will be presented in the fifth section. Finally, in Section VI of this paper, general conclusions will be presented.

2. History

Developers of the energy-conscious task consolidation, for each component in the merged systems need information about the energy consumption of each component in the merged systems, so that they can create better strategies for assigning tasks in the cloud computing paradigm; therefore, we introduce energy consumption in network and machine's components and task consolidation methods in this section.

Most of the energy used in IT equipment, including the Internet in the United States, is lost at idle time of this equipment. Gunaratne et al. [2] have proposed an energy management method to reduce their useless use. Chanclou et al. [3] also compared and evaluated optical point-to-point and point-to-multipoint access strategies. They presented their own evolutionary view of broadband optical access networks, and point to some aspects of it to simulate the development process of the network in a network environment in future. A network-based model [4] is presented to estimate energy consumption in core networks, metro networks and access networks that constitute the three main sections of the standard Internet-based service. Baliga et al. [5] also presented an energy consumption model for the network to analyze the use of wireless access networks and optical networks such as passive optical network (PON), fiber to the node network (FTTN), point-to-point optical systems (PtP) and the World Wide Web for WiMAX. The results show that PON and PtP networks can be considered as the best networks in terms of energy consumption. Tucker et al. [6] proposed a model for estimating energy consumption in IP networks. Fiber to the node hybrid network is not recommended for high energy consumption. Lang and Gladysch compared the energy consumption of the FTTH network based on passive optical networks (PONs), active optical network (AON) and point-to-point (PtP) networks.

The results show that PON based FTTH networks have better efficiency in energy consumption. Vasić and Kostić [7] tried to reduce energy consumption by increasing the percentage of putting internet links in sleep. In the same vein, they presented a method known as "Energy-Aware Traffic engineering" (EATe) to improve researches that does not take into account energy measurements. The EATe method successfully places links in sleep mode and manages traffic load changes while maintaining traffic congestion. Alizai et al. [8] presented a list of hardware and software components that affect energy consumption. In this list, the processor is one of the most important components of energy consumption. Lien et al. [9] have been collecting the data on power consumption and processor usage rates, and obtained a relationship in a model. They devised a virtual instrumentation software module to measure energy consumption in the Stroming media servers immediately. Users can use this design without requiring any additional hardware to estimate the correct energy consumption. A scalable multi-server architecture (SMS) [10] is provided to manage the resource in a server center in order to achieve better performance and more efficient energy consumption on the server.

Linear and exponential power models are also available to estimate energy consumption in different network conditions. SMS architecture has led to an improvement of 16.9% of energy consumption in test results. It is difficult to reach maximum power for large scale computing systems because the energy consumption varies depending on the computing activity. Fan et al. [11] studied the energy consumption of thousands of servers (at the cluster level) and even saw significant gaps in power and energy in optimized applications for these servers. They pointed out that maximum efficiency and the range of activity should be considered for energy efficiency. Rivoire et al. [12] compared five high-power models in systems on a laptop and a server, and the results show that the models based on processor performance and operating system are the correct models. Meisner et al. [13] proposed a two-state energy conservation method called "PowerNap" to simplify the complexity of system power. Using an energy-supplying method called "Redundant Array of Inexpensive Load to Share"(RAILS), they improved their energy consumption by 74 percent. Beri et al. [1] have studied energy saving research in order to manage integrated systems. They detected several effects that may occur when implementing energy-saving strategies for cloud computing environments.

Energy consumption in physical machines can be measured by modern server hardware. Although the power of virtual machines cannot be measured directly by hardware. Kansal et al. [14] have proposed a tool called "Julemeter" to solve this problem. There are several coefficients in their suggested formula that take a different amount at any time; therefore, these coefficients must be adjusted based on the threshold they define. Nathuji et al. [15] presented a method called Virtual Power for managing power to support virtual machines (VMs) and virtualized resources. Their experimental evaluations showed an improvement of 34% in energy consumption. Torres et al. [16] proposed a consolidation strategy for a data center that merged memory compression techniques and different requests. Using a workload scenario as a sample and a real workload, they evaluated their proposed strategy. Srikantaiah et al. [17] studied cross-correlation between reducing efficiency, energy consumption, processor usage and disk usage ratios. They converted the consolidation problem into a bin packaging problem and achieved a suitable server with better performance and lower energy consumption per request. This problem is about locating virtual machines. That is, how can we allocate virtual machines to hosts so that its cost is minimized? Song et al. [18] presented an applied analytical model for Internet-oriented servers to determine the high boundary of physical server consolidation for service quality and estimate its power and application. Their experiments showed an improvement in the energy consumption rate and CPU usage (without any loss of efficiency). Lee and Zomaya [19] presented two task consolidation hierarchies cautious to energy consumption, under the MaxUtil and ECTC titles to reduce energy consumption without losing efficiency in cloud environments that have homogeneous resources in terms of capacity and computational capability.

3. Introductions

In order to facilitate the presentation of the proposed technique, we first define the research models and express them in a transparent way, and then provide the symbols and technical terms used in the model. In continue, we present an abstract cloud computing model in Figure 1. A cloud system consists of several clusters that each of them uses a limited number of virtual machines. Without losing the generality of the subject, the virtual machine can be considered as a primary unit for the execution of tasks. The percentage of processor usage is used to judge whether the virtual machine has enough resources to handle a task. It is assumed that the network bandwidth is reliable between clusters, and in various links, its speed varies from 100 Mb to 1 GB per second. Given that the resources in each cluster change dynamically, a cluster uses its own strategy for tasks consolidation to minimize energy consumption. In general, a cluster can ask for support from other clusters and consolidate tasks on appropriate resources. Each cluster has a work queue that has information on all tasks, including the task identifier (t_i), the time entry for task $\boldsymbol{t_j}$ to the system (T_{aj}), the task processing time (t_j) ($T(p,j)$), the size of the task data $\boldsymbol{t_j}$ (DS_j). System status information, such as the CPU usage rate on virtual machines, can be obtained through cloud monitoring systems.

An optimal energy consumption model is presented in [9], which explains that the relationship between CPU usage and energy consumption is not linearly increased. According to this study, energy consumption in a virtual machine can be divided into six levels, one level related to idle status, and 5 levels related to the processor usage rate in the execution state, as shown in Figure 2.

Based on the observations given in Fig. 2, energy consumption in a virtual machine V_i and at time T can be defined as:

$$E_t(V_i) = \begin{cases} \alpha \text{ watts/s, if idle} \\ \beta+\alpha \text{ watts/s, if } 0\% < \text{CPU utilization} \leq 50\% \\ 2\beta+\alpha \text{ watts/s, if } 50\% < \text{CPU utilization} \leq 70\% \\ 3\beta+\alpha \text{ watts/s, if } 70\% < \text{CPU utilization} \leq 80\% \\ 4\beta+\alpha \text{ watts/s, if } 80\% < \text{CPU utilization} \leq 90\% \\ 5\beta+\alpha \text{ watts/s, if } 90\% < \text{CPU utilization} \leq 100\% \end{cases} \quad (1)$$

According to the above definition, the total energy consumption V_i in the time interval t_0 ~ t_m can be formulated as follows:

$$E_{0,m}(V_i) = \sum_{t=0}^{m} E_t(V_i) \quad (2)$$

In a virtual cluster, VC_k consisting of n virtual machines, the VC energy consumption over the time interval t_0 ~ t_m can be represented as follows:

$$E_{0,m}(VC_k) = \sum_{i=0}^{n} E_{0,m}(V_i) \quad (3)$$

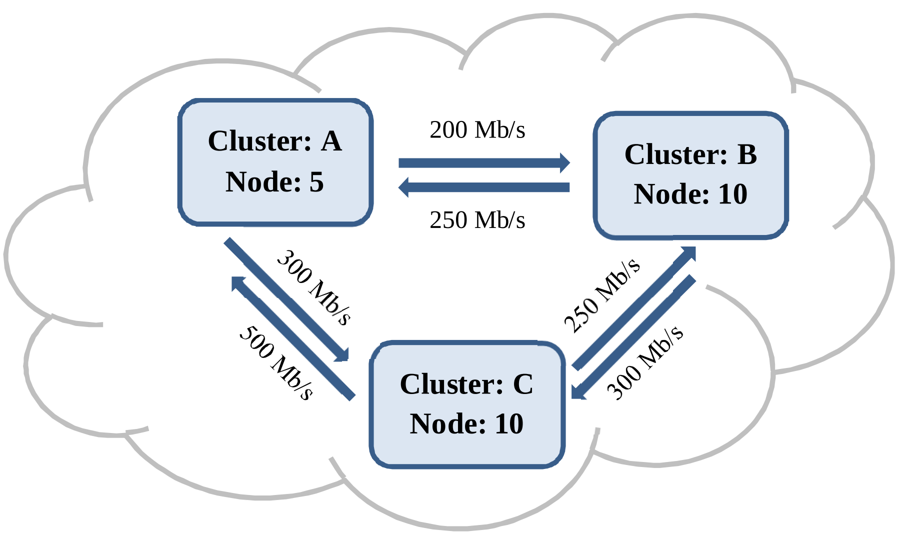

Figure 1. A cloud system that consists of several virtual clusters

CPU Usage Rate

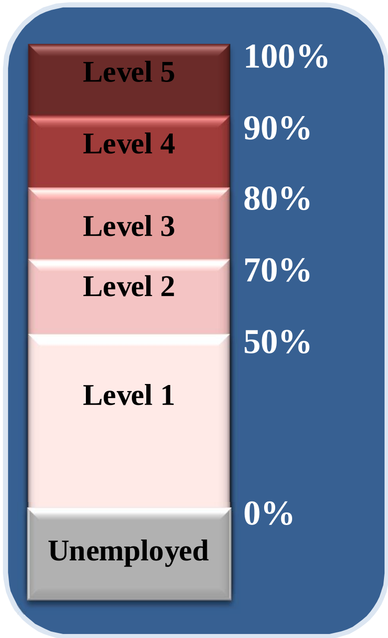

Figure 2. Energy consumption level proportion to CPU usage

Similar to the energy efficiency of the overall system, tasks can be consolidated on other sources that are located in different clusters. Given that task migration can be accompanied by a lot of overhead, there is a balance between energy efficiency and energy consolidation and the cost of migrating tasks to other resources. According to the study presented in [5, 4, 9], the cloud infrastructure network can be considered as a passive optical network, either a FTTN network or point-to-point optical systems. The energy used to access the network and the data conversation in the network is 2β watts per hour, and the access ratio varies between 100 Mbps and 1 GBs per second, based on equation 1.

4. Suggested technique

Figure 2 shows that the power of β watts per second is needed to run tasks, even when the CPU usage rate is between 0 and 50% (as compared to the idle status). If the CPU usage rate is between 50% and 70%, then it's clear that higher rates require more energy and this reflects an undesirable use of energy. For example, when a virtual machine has a processor with the rate of 50%, it consumes as much as $\alpha + \beta$ watts of energy. If $\alpha = \beta$, this means that each β energy can play a role in the processor usage rate of 25% (while the CPU usage rate is below 50%). When a virtual machine has a processor at a rate of 70%, it consumes 3β watts per second of energy, indicating that every β watts of energy have a 23.3% share in processor usage. For application rates of 80%, 90% and 100%, the efficiency is 20% for β w/h, 18% for β w/h and 16.6% for β w/h, respectively. In order to better use of cloud resources and reduce energy consumption effectively, 70% of the usage rate can be considered as an ideal goal in such a configuration. It should be noted that the principle of 70% can be considered as a customizable method depending on different cloud systems. In order to simplify the presentation, we describe our proposed algorithm based on the principle of 70%.

The main idea behind our proposed ETC consolidation method was to consolidate the tasks and, at the same time, set the processor's CPU usage rate below 70% (if possible) for each V_i.

In a cloud system that consists of multiple virtual clusters (*VC*s) (in this example, three virtual clusters under the titles A, B, C, displayed as VC_A, VC_B, VC_C), the task consolidate strategy inside a virtual machine can be described as follows.

- Scheduler for VC_A tries to distribute the task tj onto its virtual machine, however, if each of them is compatible with the principle of 70%. If more than one virtual machine can be approached, the best match strategy is used.
- If there is no V_I that is compatible with the 70% principle, VC_A sends the source support request for *VC*s (for example, VC_B or VC_C).
- If both VC_B and VC_C can provide virtual machines that are compatible with the principle of 70%, then a virtual cluster that uses less energy to transfer and execute the task is selected.
- If no source (virtual machine) is compatible with other *VC*s with the principle of 70%, t_j is assigned to V_i, which has less energy consumption in VC_A.

Let's illustrate the above idea with several examples. In Figure 3, the primary information was displayed for a set of tasks. In order to simplify, it assumes that there are three virtual machines in VC_A. The first scenario outlines a task that is assigned locally in VC_A to virtual machines and is compatible with the principle of 70%. As shown in Figure 4, after assigning five tasks to all virtual machines, t_5 can be assigned to both V_0 and V_1. By employing the best matching strategy, task t_5 is assigned to V_1, since the total processor usage rate is close to 70%.

Data size	Processor usage	Processing time $(T_{p,j})$	Entry Time $T_{a,j}$	Task t_j
150 Mbit	30%	50 Secs	0 Secs	t_0
75 Mbit	30%	20 Secs	10 Secs	t_1
20 Mbit	40%	35 Secs	12 Secs	t_2
150 Mbit	30%	15 Secs	15 Secs	t_3
250 Mbit	60%	30 Secs	20 Secs	t_4
110 Mbit	30%	25 Secs	30 Secs	t_5

Figure 3. A list of tasks

In order to distribute and execute task t_6, since t_6 requires 50% CPU usage, assigning it to each virtual machine in VC_A results the principle of 70%. Approving the principle of 70%, the A cluster requests for resource support from other clusters (for example, VC_B or VC_C). As shown in Figure 5, both VCB and VCC have sources that are compatible with the principle of 70%, and so VCA should decide on a destination cluster that reflects better energy consumption. In order to estimate energy consumption to task consolidation on other sources located in other clusters, CPU computing and network transmission must be considered. In a task t_j emigrated from VCP and consolidated on the V_i virtual machine located on VCQ, the expected energy consumption can be summarized as follows:

$$Cost_{i,j} = \sum_{t=T_{a,j}}^{T_{a,j}+T_{p,j}} E_t(V_i) + \frac{DS_j}{BW_{PQ}} \times 2\beta watt/s \qquad (4)$$

In which, BW_{PQ} and DS_j can be used to determine the bandwidth of VC_P to VC_Q and the size of the task data set t_j (respectively).

Regarding Equation 4, migration of T_6 on VC_B and VC_C consumes $(3\beta + \alpha) * 10 + \frac{201}{250} * (2\beta + \alpha) * 10 + \frac{210}{500} * 2\beta$ watts of energy. It's easy to see that the VC_C consume energy more efficiently. Therefore, the task t6 can be consolidated on the virtual machine contained in the VCC. The processor usage rate from virtual machines in VC_B and VC_C is more than or equal to 70%. Therefore, VC_A will not seek external resources, which can be resulted from overhead increasing. As a result, it tries to assign t_6 to local resources, even though the VM cannot match the principle of 70%.

5. Efficiency evaluation and analysis

In order to evaluate the efficiency of the proposed technique, we implemented the ETC method with the MaxUtil method [19]. The MaxUtil method tries to consolidate tasks on the same number of virtual machines. A virtual cluster uses 5, 10 and 15 virtual machines to display low resources (LR), medium resources (MR) and high resources (HR).

A number of tasks are used to represent different workloads, in which 1000, 2000, and 3000 tasks respectively represent low load (LL), medium load (ML) and high load (HL) respectively. The time of entry of tasks is limited from 0 to 9 seconds.

Therefore, different loads have different task densities. The average processing time, CPU usage, and the size of the task data are 50 seconds, 50%, and 100 MB, respectively. In general, 27 cases are presented in Table 1 in order to evaluate the ETC's efficiency. Each test case is represented as $(\delta_1, \#, \delta_2)$ to represent different combinations of work load and sources of virtual clusters in which, $\delta 1$ can be called workload VC_A, # is size of VC_A (or the number of machines) and $\delta 2$ represents the work load VC_B and VC_C. For example, (L, 5, L) represents a low load in VC_A, in which 5 nodes are in VC_A, and VC_B and VC_C have low load.

HL	ML	LL			
MR					
(L,5,H)	(L,5,M)	(L,5,L)	LR(5)	LL	EHL
(L,10,H)	(L,10,M)	(L,10,L)	MR(10)		
(L,15,H)	(L,15,M)	(L,15,L)	HR(15)		
(M,5,H)	(M,5,M)	(M,5,L)	LR(5)	ML	
(M,10,H)	(M. 10,M)	(M,10,L)	MR(10)		
(M,10,H)	(M,15,M)	(M,15,L)	HR(10)		
(H,5,H)	(,5,M)	(H,5,L)	LR(5)	HL	
(H,10,H)	(H,10,M)	(H,10,L)	MR(10)		
(H,15,M)	(H,15,M)	(H,15,L)	HR(15)		

Table 1. cases with different load and resources

As stated in the last section, the virtual machine consumes a watts of energy per seconds and in idle state, and consumes energy between β and 5β watts per second at different levels of processor usage. According to the evaluation [9], α is equal to 7β. Figure 7 shows the results at a time when the workload of neighboring resources (VC_B, VC_C) is low. Figure 7 shows the results, when the workload of neighboring resources (VC_B, VC_C) is low. These conditions have led VC_A to migrate tasks to neighboring clusters to better energy consumption. For example, in the case of (L, 5, L), VC_A has limited resources (e.g., 5), which has led VC_A to send its request for resource support to VC_B and VC_C to reduce energy consumption by using ETC. For cases (L, 10, L) and (L, 15, L), VC_A has an about large resource; VC_A does not need to request neighboring resources, and therefore, ETC and MaxUtil have the same efficiency.

HL	**ML**	**LL**			
MR					
(L,10,H)	(E,5,M)	(E,5,L)	LR(5)		
(E,10,H)	(E,10,M)	(E,10,L)	MR(10)	EHL	VC_A
(E,15,H)	(E,15,M)	(E,15,L)	HR(15)		

Table 2. Cases of VCA with high workload

For many other cases, ETC has a better sufficiency, because the workload of VC_A is relatively higher than the neighboring clusters (VC_A with medium and high load, VC_B and VC_C with low load), and may overload a heavy task consolidation on the neighboring clusters), and this shows the benefits of the ETC strategy.

6. Conclusion

Maximizing profits can be considered as one of the high priorities in cloud computing systems, which in this way, minimizing energy consumption play a critical role. Many studies have shown that energy consumption and resource utilization in the cloud paradigm are very important, and task consolidation can be considered as an effective technique to increase resource utilization rates and, at the same time, reduce energy consumption. In this paper, a resource consolidation technique (ETC) aware of resource was proposed to minimize energy consumption. Considering architecture, many of cloud systems are compatible with the principle of 70% and hence this principle is used to manage task consolidation between virtual clusters. The idle state in virtual machines and network transmission is also assumed to consume sevenfold and double times of the original energy, respectively.

These values can be modified in the ETC method so that they can be used for different cloud systems. The simulated results show that ETC can significantly reduce energy consumption for task consolidation management in cloud systems. It can be achieved by up to 17% improvement compared to the activity performed in [11] and its goal is to maximize the rate usage of resource.

Enterprise capital (EC) is independent components of the organization that creates benefits to the business of the organization [8]. These advantages appear in different roles that have certain and effective effects on the business factors of the organization. Today, Enterprise capital has many types: intellectual capital, social capital, capital [4,13]. Most organizations also have a variety of resources and capitals to achieve organizational goals [11]. Part of these capitals is tangible and quantitative and them role in the business of the organization is direct, clear and certain [1].

The fact that which capital portfolios (both capital and relative) is the most appropriate portfolio of organizational capital, needs to be examined in the dimensions of organizational work paths.

7. Conclusion

Developing a strategy to create an enterprise portfolio helps managers to select from different types of existing enterprise capitals for different parts of them missions.

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